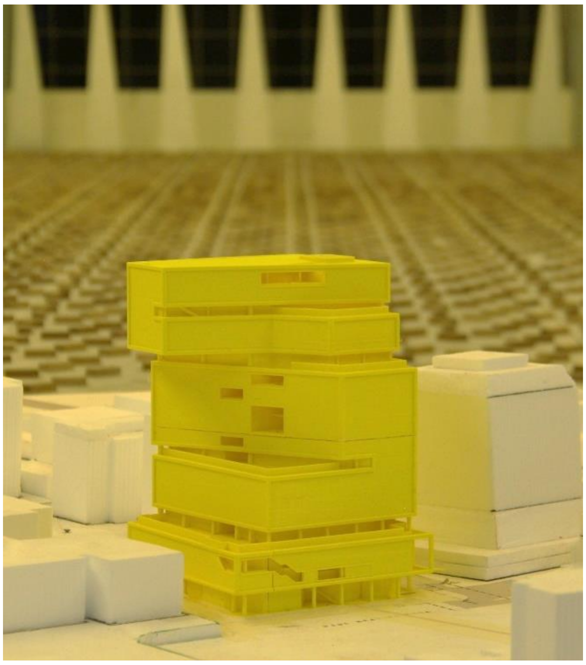
WINDTECH



PEDESTRIAN WIND ENVIRONMENT STUDY

BANKSTOWN CITY CAMPUS DEVELOPMENT, WSU

WE691-01F02(REV0)- WE REPORT

MAY 28, 2019

Prepared for:

Archerfield Partners

Level 5, 139 Macquarie Street

Sydney NSW, 2000

WINDTECH Consultants Pty Ltd
Head Office: 607 Forest Road, Bexley, NSW 2207, Australia
P +61 2 9503 0300 **E** reception@windtechglobal.com **W** www.windtechconsult.com

DOCUMENT CONTROL

Date	Revision History	Issued Revision	Prepared By (initials)	Instructed By (initials)	Reviewed & Authorised by (initials)
May 28, 2019	Initial.	0	NR	SWR	JG

The work presented in this document was carried out in accordance with the Windtech Consultants Quality Assurance System, which is based on International Standard ISO 9001.
This document is issued subject to review and authorisation by the Team Leader noted by the initials printed in the last column above. If no initials appear, this document shall be considered as preliminary or draft only and no reliance shall be placed upon it other than for information to be verified later.
This document is prepared for our Client's particular requirements which are based on a specific brief with limitations as agreed to with the Client. It is not intended for and should not be relied upon by a third party and no responsibility is undertaken to any third party without prior consent provided by Windtech Consultants. The information herein should not be reproduced, presented or reviewed except in full. Prior to passing on to a third party, the Client is to fully inform the third party of the specific brief and limitations associated with the commission.

EXECUTIVE SUMMARY

This report presents the results of a detailed investigation into the wind environment impact of the Bankstown City Campus Development, WSU located at 74 Rickard Road, Bankstown. 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 16 wind directions at 22.5 degree increments. Testing was carried out using a 1:300 detailed scale model of the development. 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 375m.

Peak gust and mean wind speeds were measured 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 wind conditions for the pedestrian footpaths around the site have also been tested to determine the impact of the proposed development. In-principle treatments have been recommended for any area exposed to strong winds.

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

- Retain proposed densely foliating evergreen trees along Appian Way and within Paul Keating Park as indicated in the Landscape Drawing Package (received May 3, 2019).
- Recommended inclusion of a cluster of densely foliating evergreen trees within the north-western corner of Paul Keating Park on the Ground Level.
- Recommended inclusion of an impermeable full height screen along the eastern perimeter of the terrace located on Level 07.
- Recommended inclusion of 2.1m high impermeable perimeter screens around the entire terrace located on Level 13.
- Recommended inclusion of strategic densely foliating evergreen landscaping within the south-west corner of the terrace on Level 13.

- Recommended inclusion of localised mobile screening within the Level 13 terrace.

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 assess 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 16 wind directions at 22.5 degree increments. The wind tunnel was configured to the appropriate boundary layer wind profile for each wind direction. Wind speeds were measured using Dantec hot-wire probe anemometers, 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.

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 effect of nearby buildings and land topography has been accounted for through the use of a proximity model, which represents a radius of 375m 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.

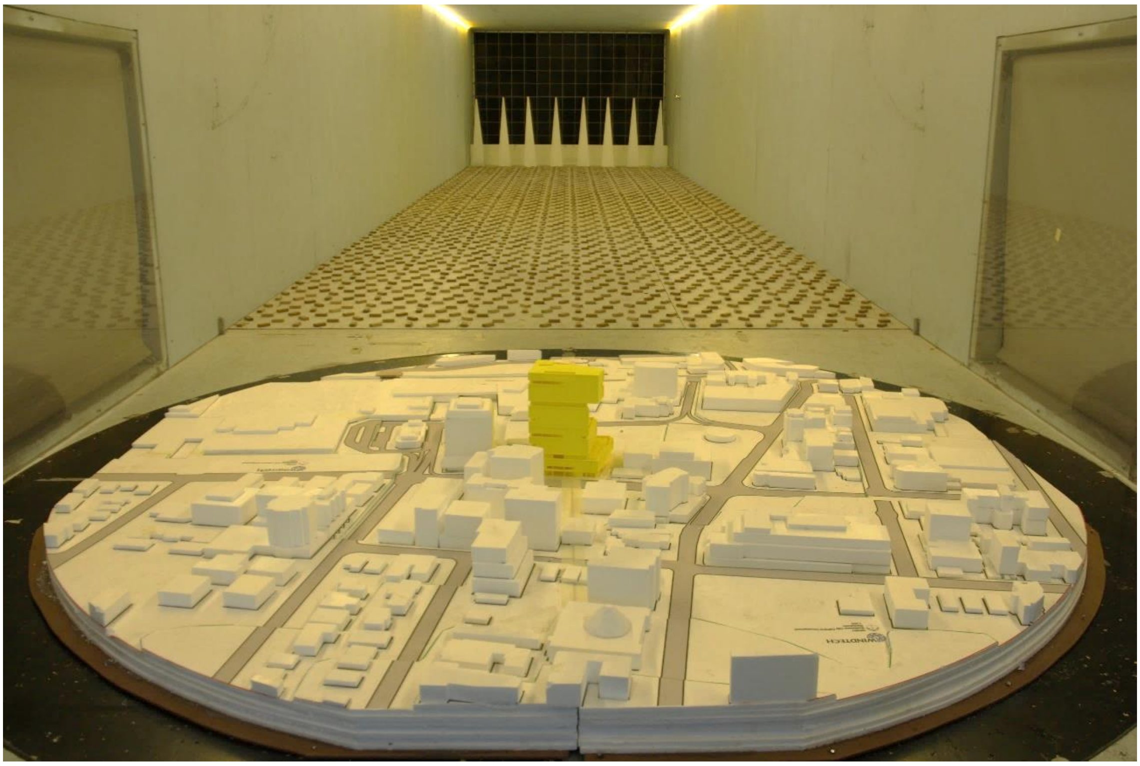


Figure 1a: Photograph of the Wind Tunnel Model (view from the north)

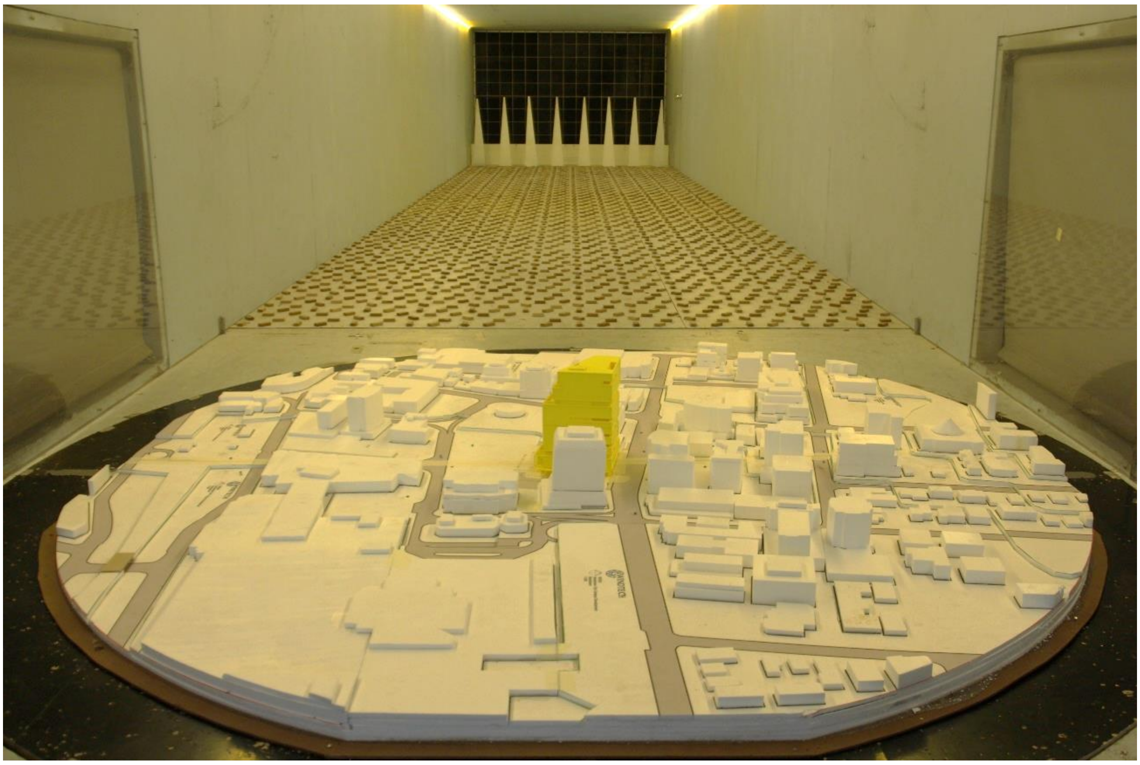


Figure 1b: Photograph of the Wind Tunnel Model (view from the east)

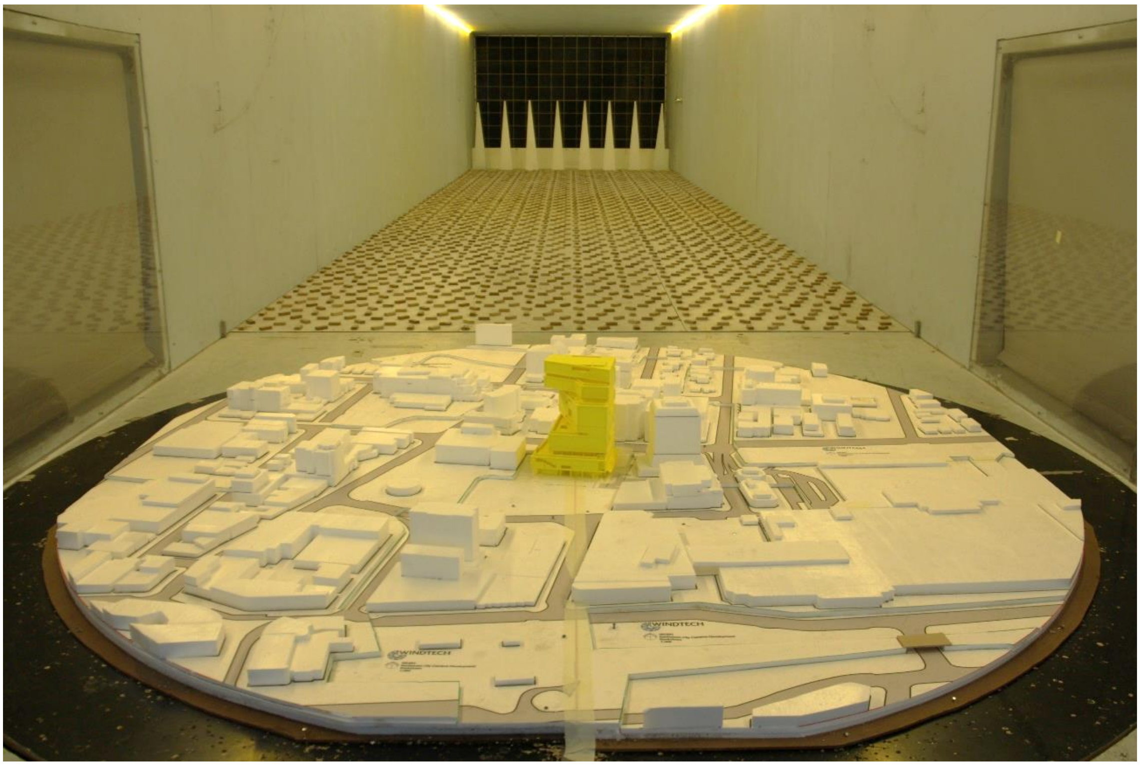


Figure 1c: Photograph of the Wind Tunnel Model (view from the south)

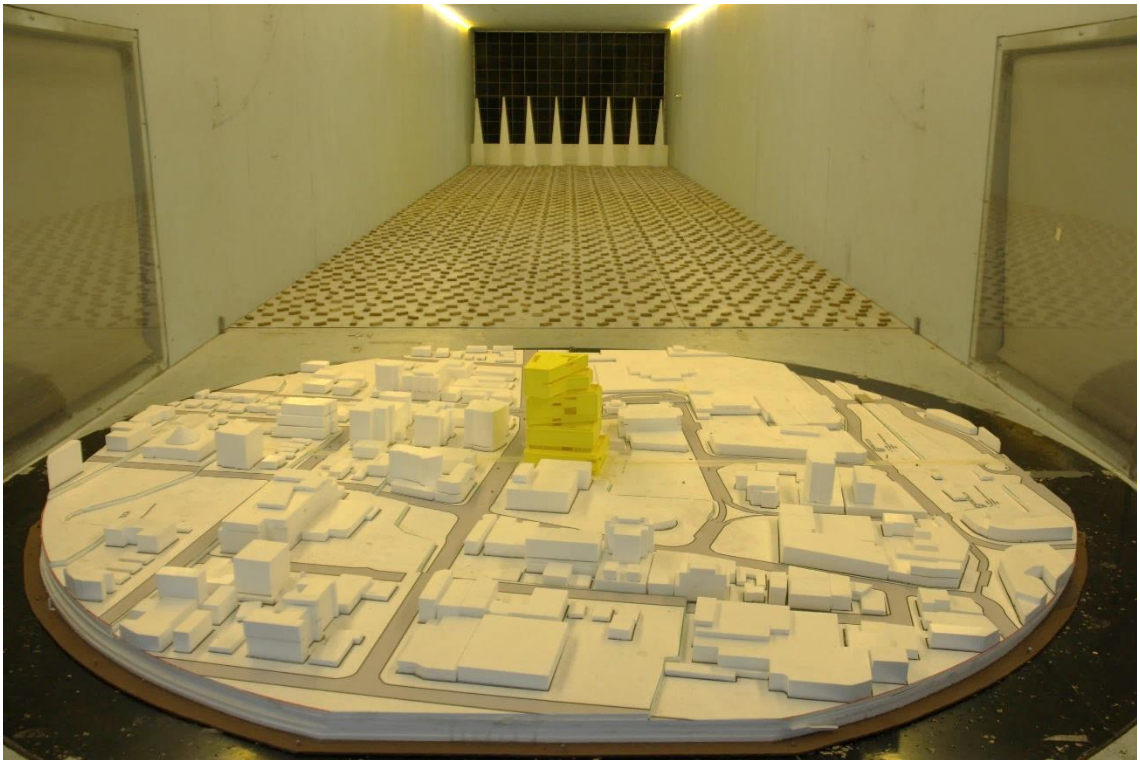


Figure 1d: Photograph of the Wind Tunnel Model (view from the west)

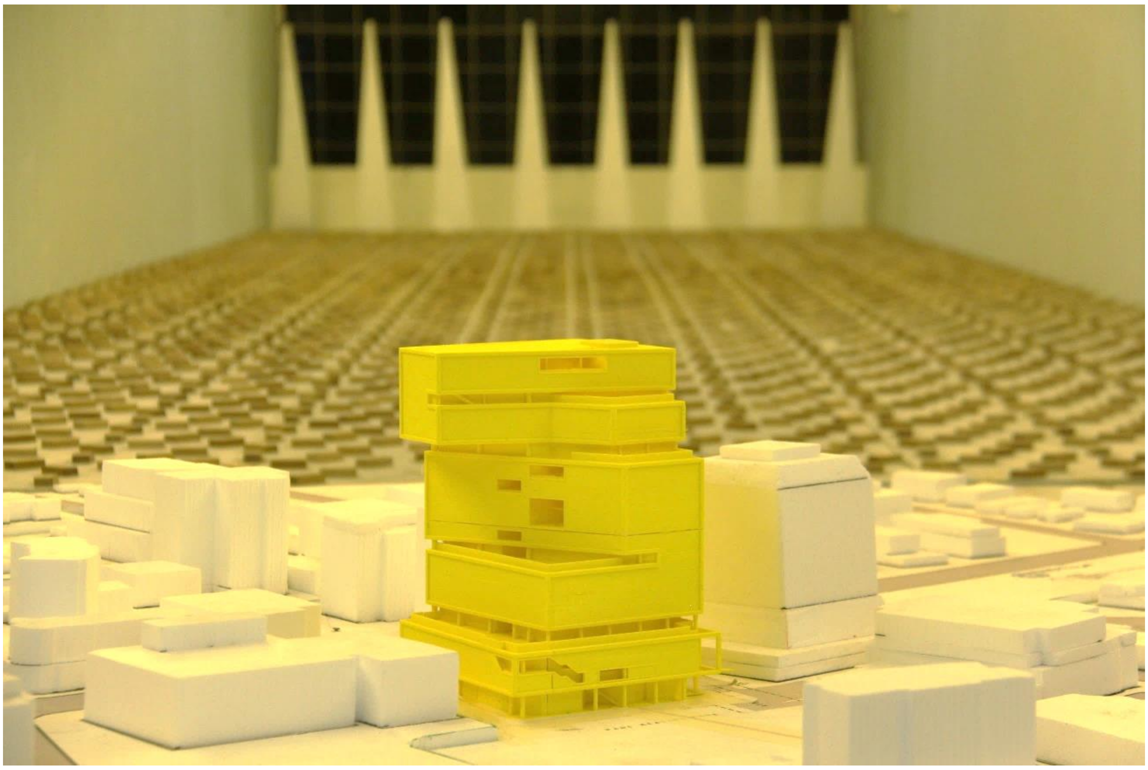


Figure 1e: Photograph of the Wind Tunnel Model (view from the southwest)

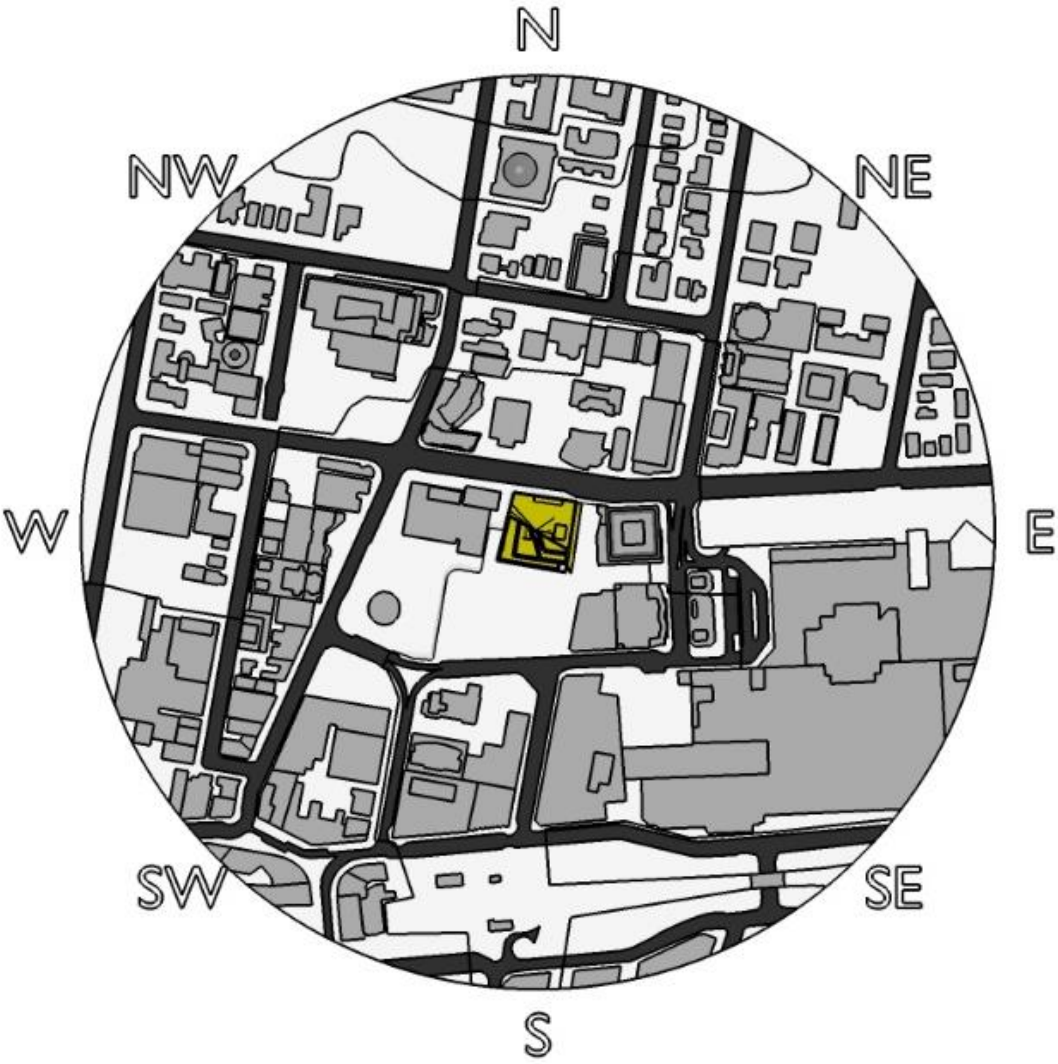


Figure 2: Proximity Model Plan

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 Deaves & 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.

For this study this has been undertaken based on the method given in AS/NZS1170.2:2011, which requires that the upwind terrain roughness for a fetch length of 40 times the tower reference height be analysed for each prevailing wind direction. However, it should be noted that this fetch commences *beyond* a lag distance area, which has a length of 20 times the building reference height (in accordance with AS/NZS1170.2:2011), so the actual fetch of terrain analysed is the area between 20 and 60 times the reference height of the tower away from the site.

An aerial image showing the surrounding terrain is presented in Figure 3 for a range of 2.8km 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 1, referenced to the study reference height (which is approximately half of 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 1: Approaching Boundary Layer Wind Profile Analysis Summary (at the study reference height)

Wind Sector (degrees)	Terrain and Height Multiplier			Turbulence Intensity	Equivalent Terrain Category
	$k_{tr,T=1hr}$ *(hourly)*	$k_{tr,T=10min}$ *(10min)*	$k_{tr,T=3s}$ *(3sec)*	I_v	*(AS/NZS1170.2:2011 naming convention)*
0	0.70	0.74	1.11	0.195	2.7
30	0.60	0.64	1.03	0.249	3.3
60	0.66	0.69	1.08	0.216	3.0
90	0.66	0.69	1.08	0.216	3.0
120	0.66	0.69	1.08	0.216	3.0
150	0.66	0.69	1.08	0.216	3.0
180	0.59	0.63	1.03	0.254	3.3
210	0.66	0.69	1.08	0.216	3.0
240	0.66	0.69	1.08	0.216	3.0
270	0.66	0.69	1.08	0.216	3.0
300	0.66	0.69	1.08	0.216	3.0
330	0.66	0.69	1.08	0.216	3.0

For each of the 16 wind directions tested in this study, the approaching boundary layer wind profiles modelled in the wind tunnel closely matched the profiles listed in Table 1. Plots of the boundary layer wind profiles used for the wind tunnel testing are presented in Appendix D of this report.

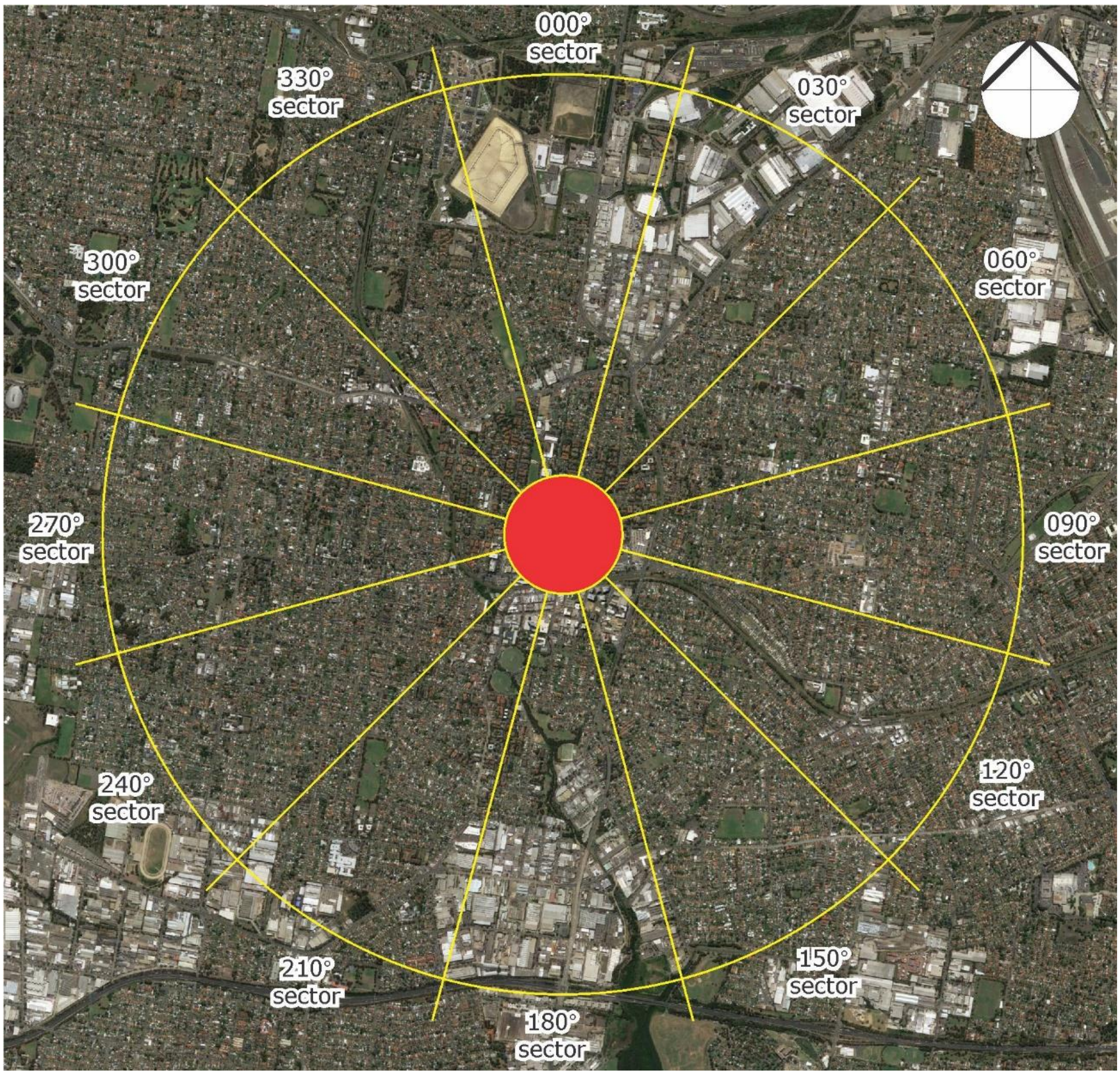


Figure 3: Aerial Image of the Surrounding Terrain
(radius of 2.8km from the edge of the proximity model, which is coloured red)

4 REGIONAL WIND MODEL

The Bankstown region is governed by three principal wind directions, and these can potentially affect the subject development. These winds prevail from the north-east, south-east to south, and west. These wind directions were determined from an analysis undertaken by Windtech Consultants of recorded directional wind speeds obtained at the meteorological station located at Bankstown Airport by the Bureau of Meteorology. The data has been collected from this station from 1993 to 2016 and corrected so that it represents winds over standard open terrain at a height of 10m above ground level. Figure 4 shows a summary of this analysis in the form of a directional plot of the annual and 5% exceedance mean winds for the region. The frequency of occurrence of these winds is also determined and shown in Figure 4.

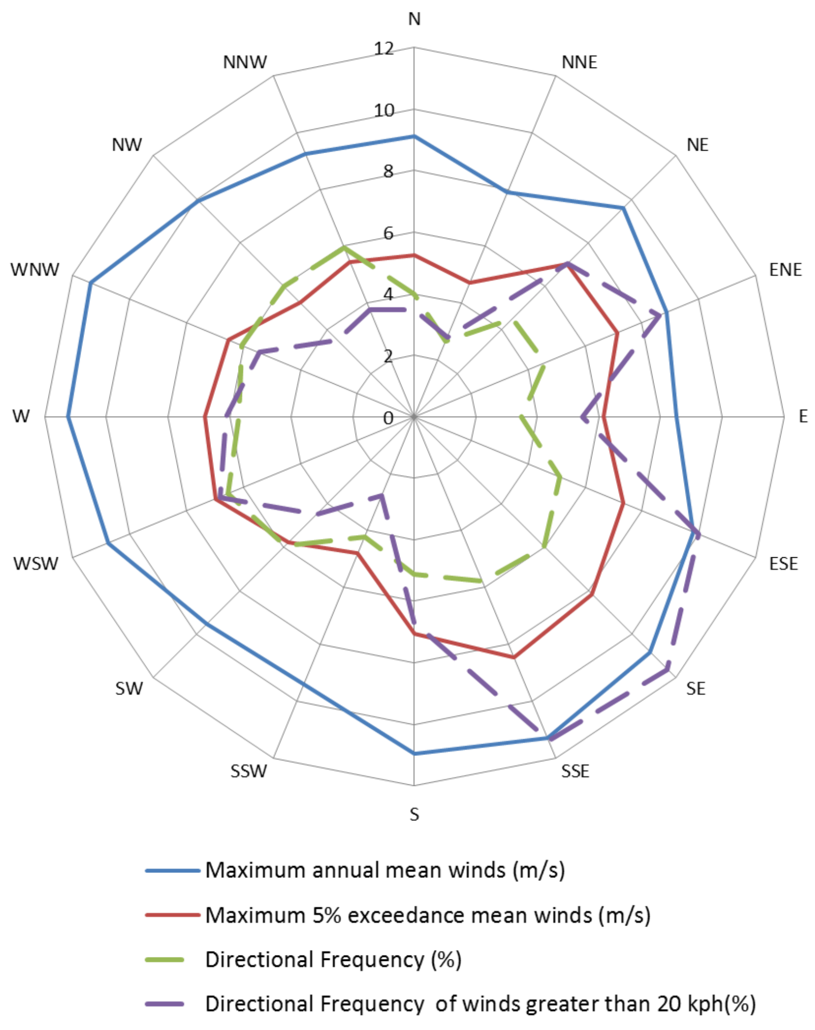


Figure 4: Annual and 5% Exceedance Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Bankstown Region (referenced to 10m above ground in standard open terrain)

5 PEDESTRIAN WIND COMFORT AND SAFETY

The acceptability of wind conditions of an area is determined by comparing the measured wind speeds against an appropriate criterion. 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 Dantec hot-wire probe anemometers, 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 16 wind directions at 22.5 degree increments using a sample rate of 1,024Hz. The full methodology of determining the wind speed measurements at the site from the Dantec Hot-wire probe anemometers 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), 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.

For pedestrian safety, the safety limit criterion of 23m/s applies to 3-second duration annual maximum gust winds for all areas, in accordance with W.H. Melbourne (1978).

For pedestrian comfort, the A.G. Davenport (1972) criteria are used in conjunction with the GEM wind speed using a 5% probability of exceedance. Research by A.W. Rofail (2007) has shown that the A.G. Davenport (1972) criteria, used in conjunction with a GEM wind speed, has proven over time and through field observations to be the most reliable indicator of pedestrian comfort. A more detailed comparison of published criteria has been provided in Appendix A.

The criteria considered in this study are summarised in Tables 2 and 3 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 2: Comfort Criteria (from A.G. Davenport, 1972)

Classification	Description	Maximum 5% Exceedance GEM Wind Speed (m/s)
Long Exposure	Long duration stationary activities such as in outdoor restaurants and theatres, etc.	3.5
Short Exposure	Short duration stationary activities (generally less than 1 hour), including window shopping, waiting areas, etc.	5.5
Comfortable Walking	For pedestrian thoroughfares, private swimming pools, most communal areas, private balconies and terraces, etc.	7.5

Table 3: Safety Criterion (from W.H. Melbourne, 1978)

Classification	Description	Annual Maximum Gust Wind Speed (m/s)
Safety	Safety criterion applies to all trafficable areas.	23

5.3 Layout of Study Points

For this study a total of 50 study point locations were selected for analysis in the wind tunnel. This includes the following:

- 22 study points on Ground Level, along the pedestrian footpaths, development entrances and shared pedestrian areas,
- 22 study points on Level 02-18, located on various terrace and balcony areas of the development, and
- 6 study points on the further surrounding area of the development along the pedestrian footpaths of Rickard Road, Appian Way and within Paul Keating Park.

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 Figures 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.

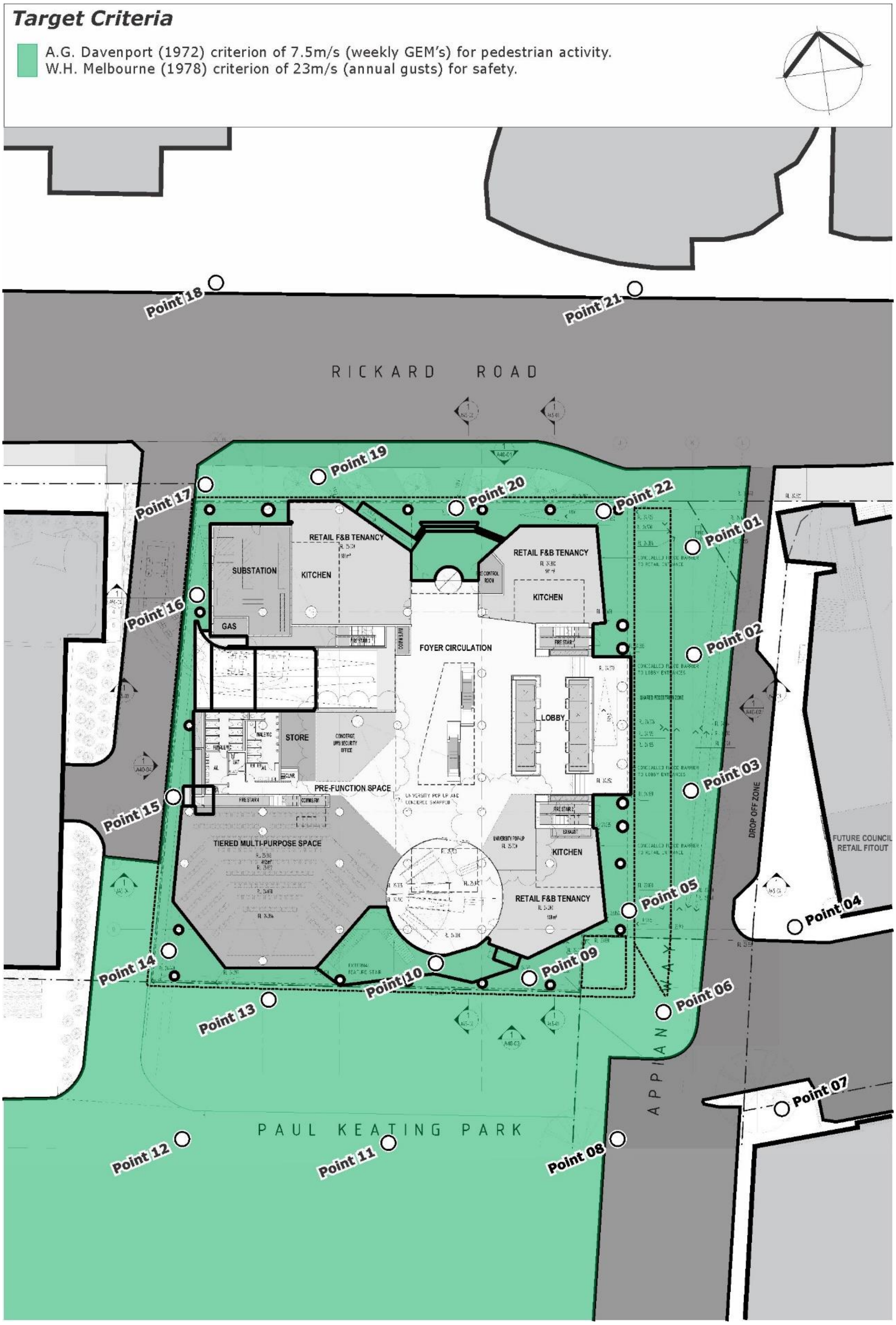


Figure 5a: Study Point Locations and Target Wind Speed Criteria

Ground Level Plan

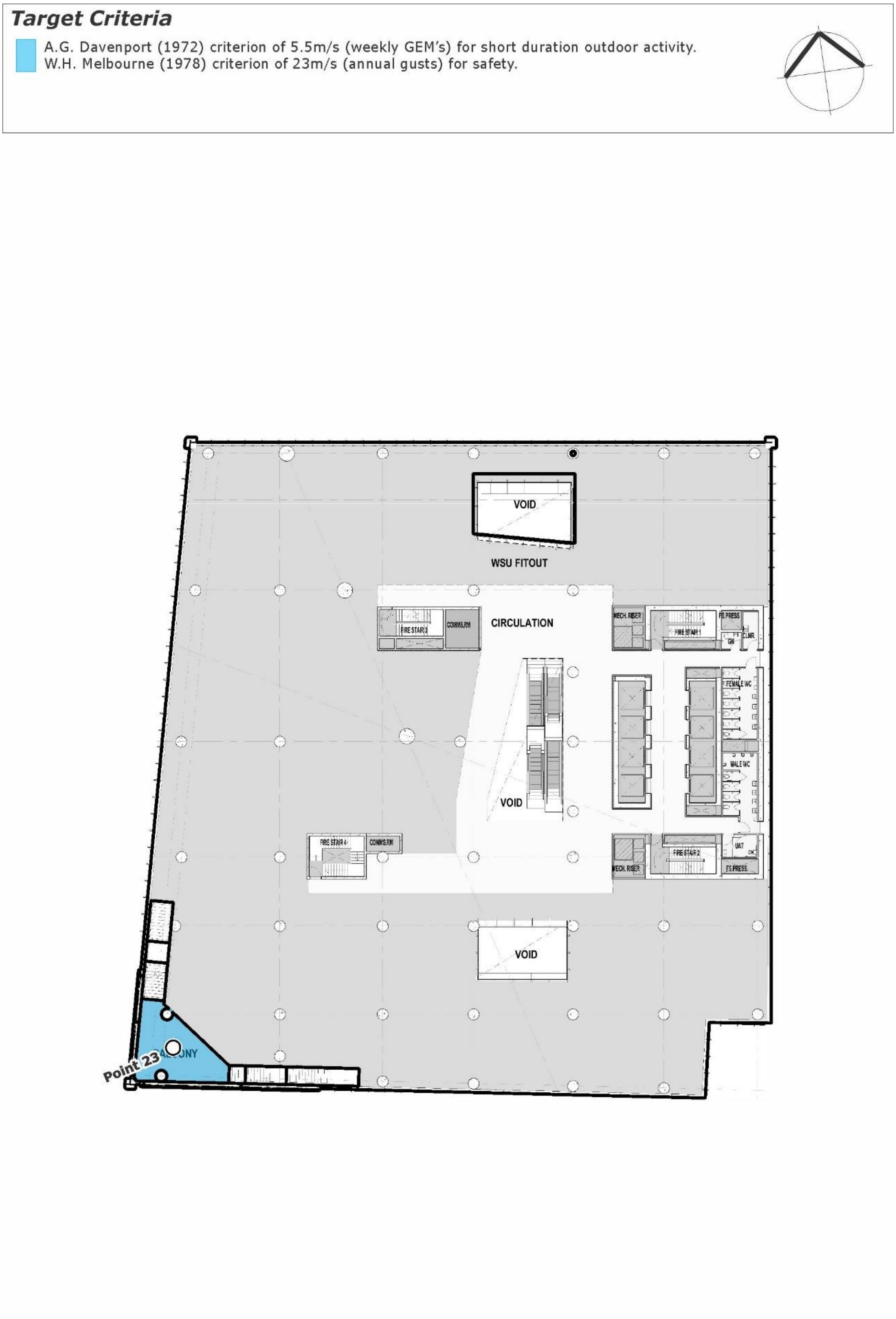


Figure 5b: Study Point Locations and Target Wind Speed Criteria

Level 02 Plan

Target Criteria

A.G. Davenport (1972) criterion of 5.5m/s (weekly GEM's) for short duration outdoor activity.
W.H. Melbourne (1978) criterion of 23m/s (annual gusts) for safety.

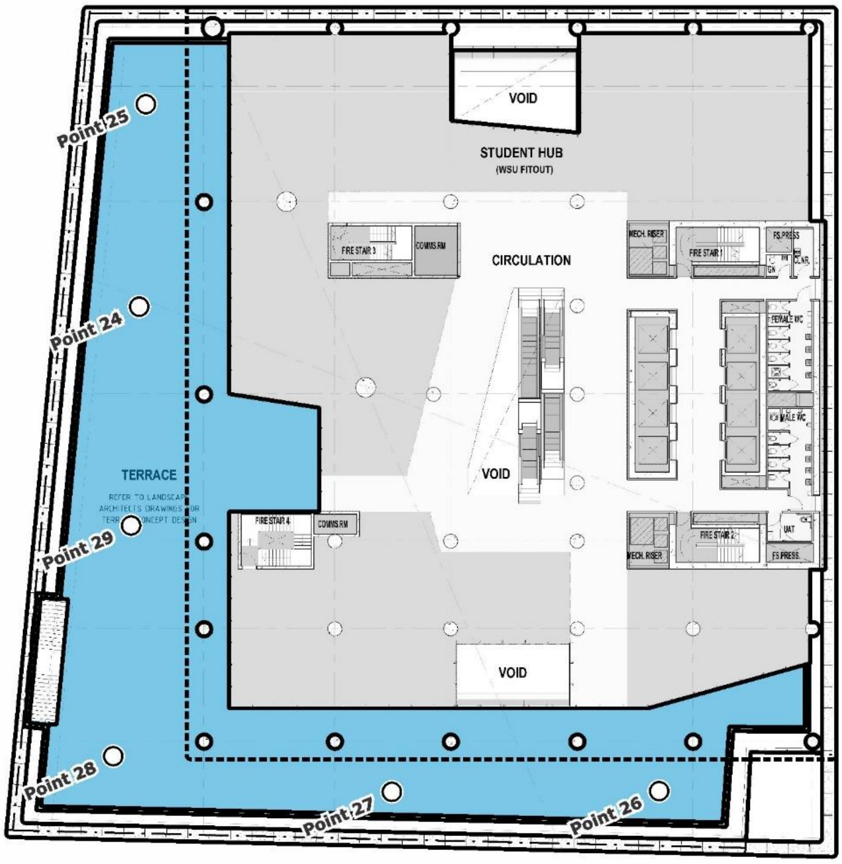


Figure 5c: Study Point Locations and Target Wind Speed Criteria
Level 03 Plan

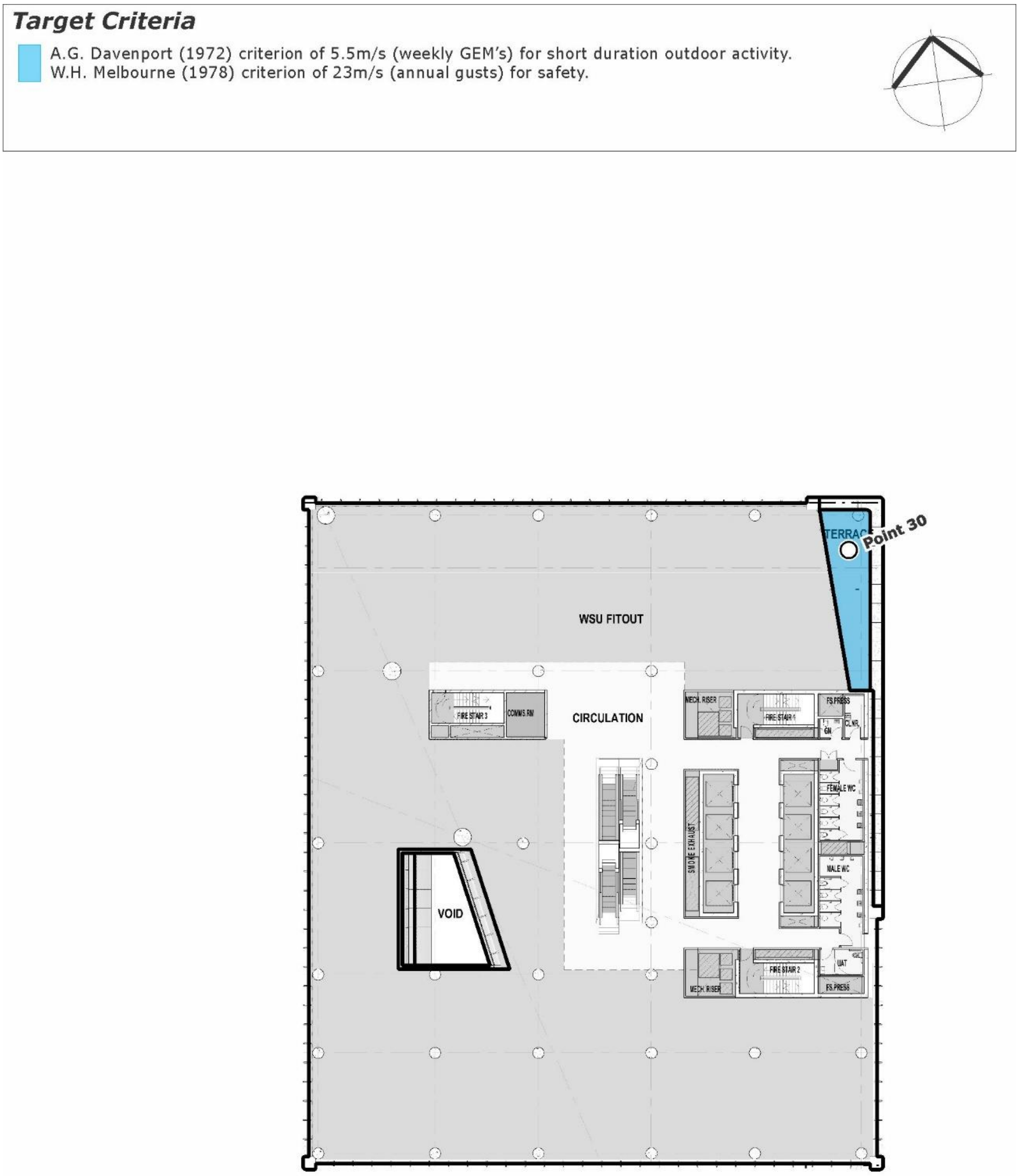


Figure 5d: Study Point Locations and Target Wind Speed Criteria
Level 05 Plan

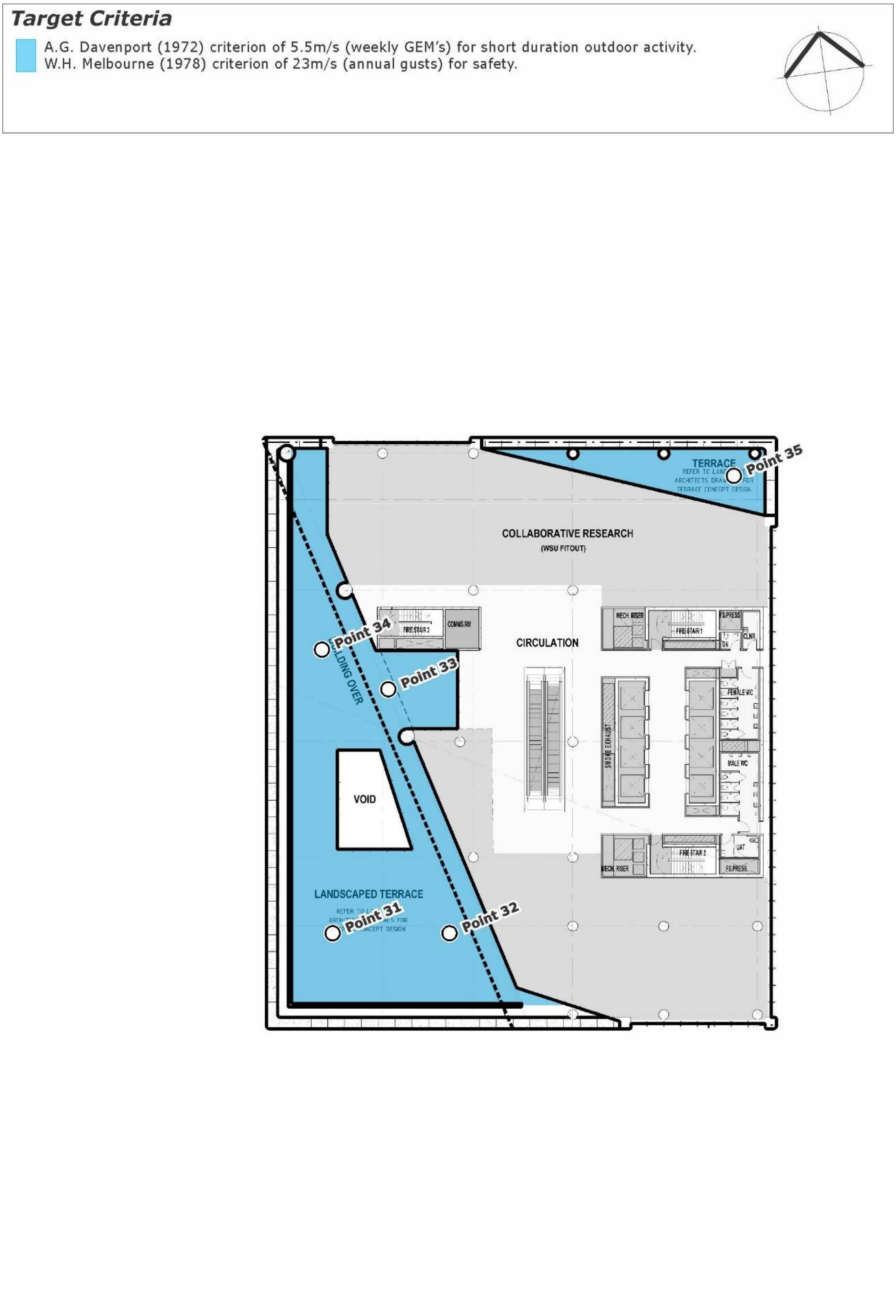


Figure 5e: Study Point Locations and Target Wind Speed Criteria

Level 07 Plan

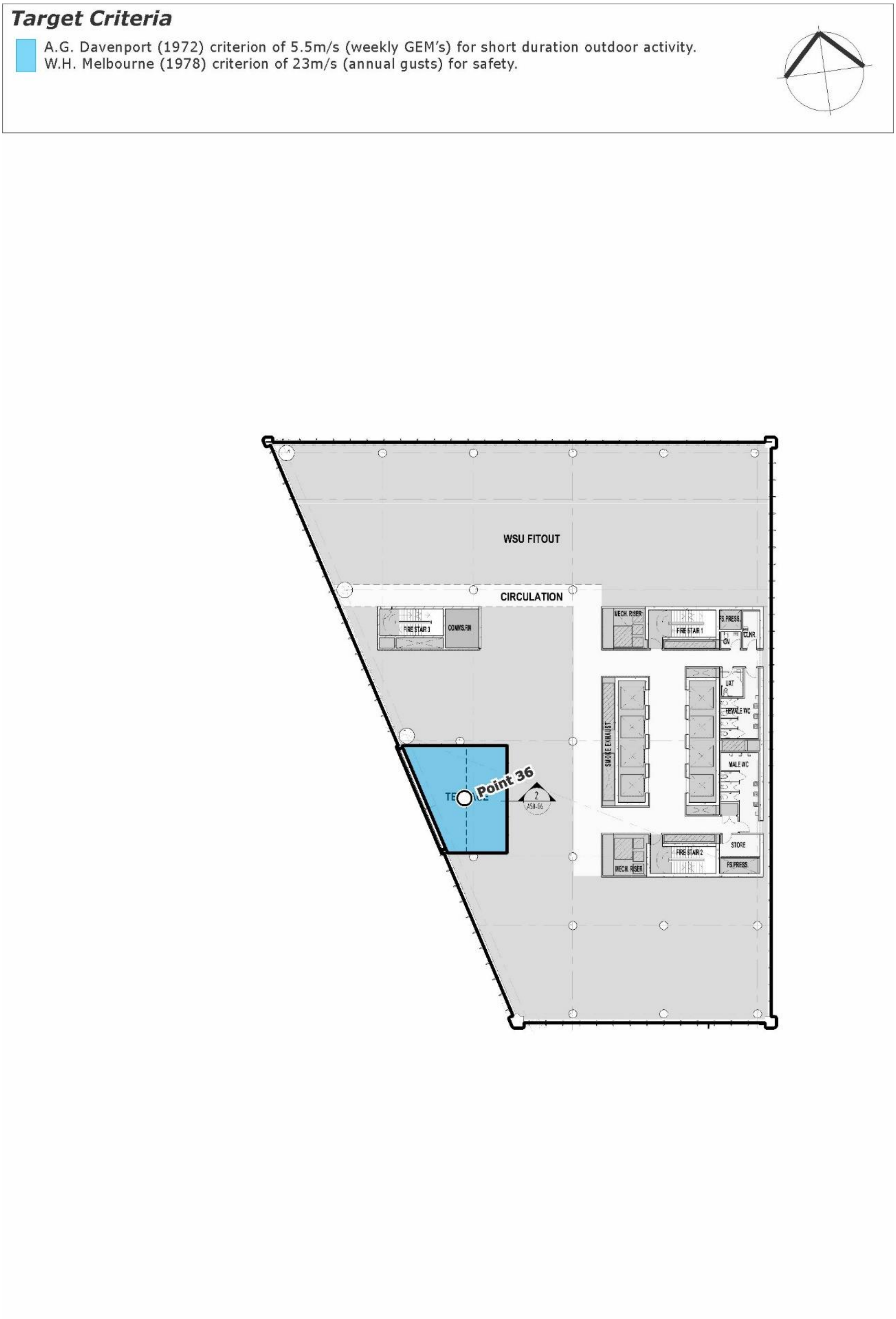


Figure 5f: Study Point Locations and Target Wind Speed Criteria

Level 09 Plan

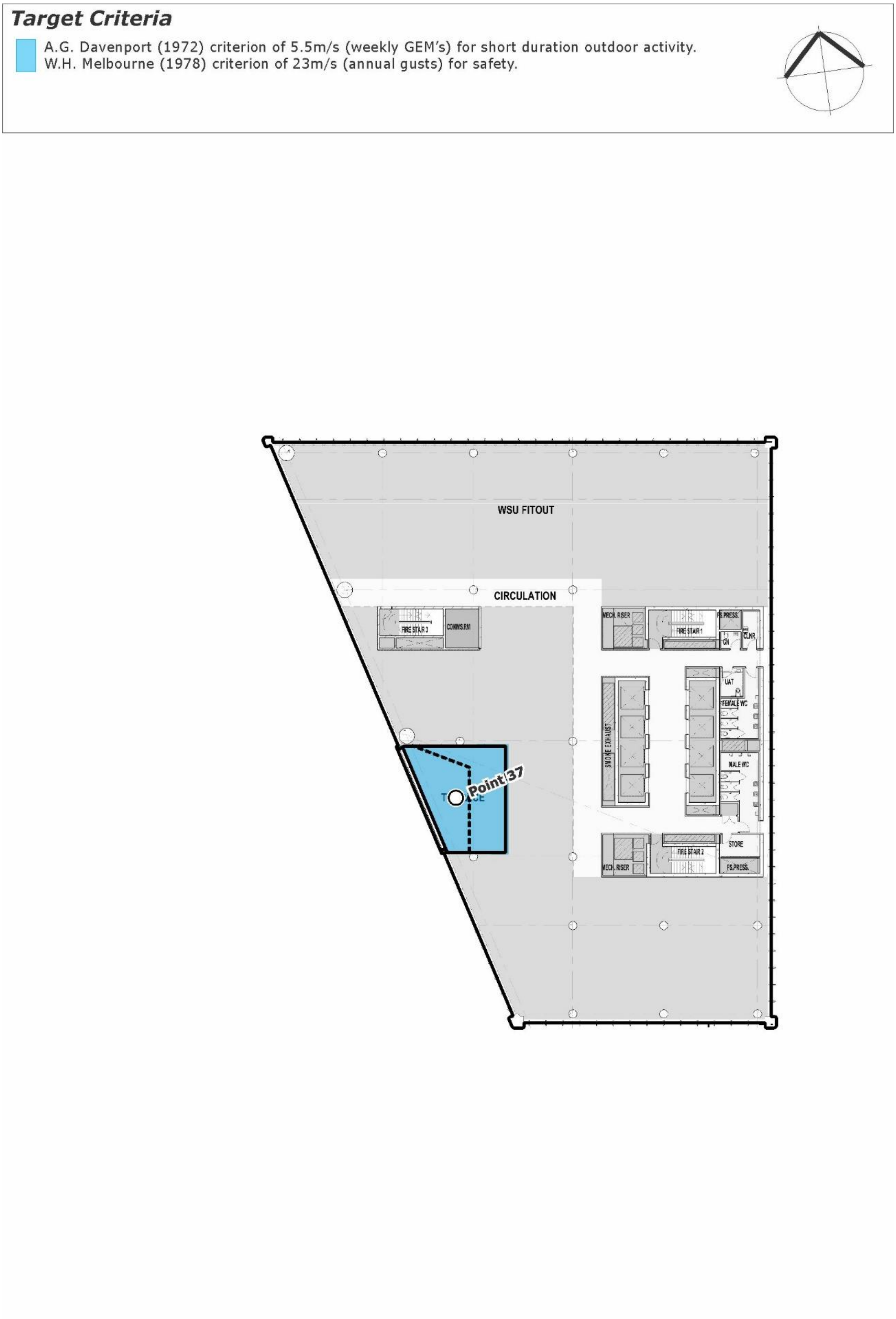


Figure 5g: Study Point Locations and Target Wind Speed Criteria
Level 12 Plan

Target Criteria

A.G. Davenport (1972) criterion of 5.5m/s (weekly GEM's) for short duration outdoor activity.
W.H. Melbourne (1978) criterion of 23m/s (annual gusts) for safety.

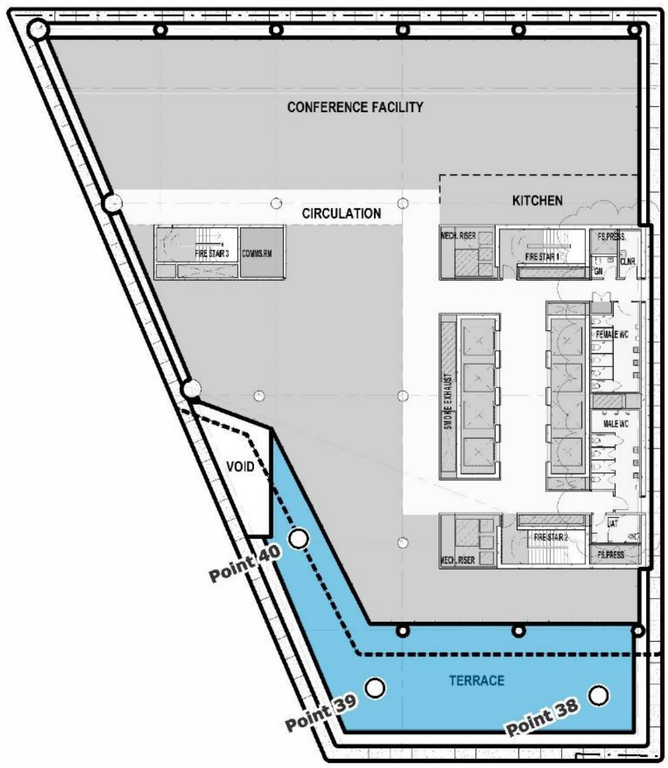


Figure 5h: Study Point Locations and Target Wind Speed Criteria
Level 13 Plan

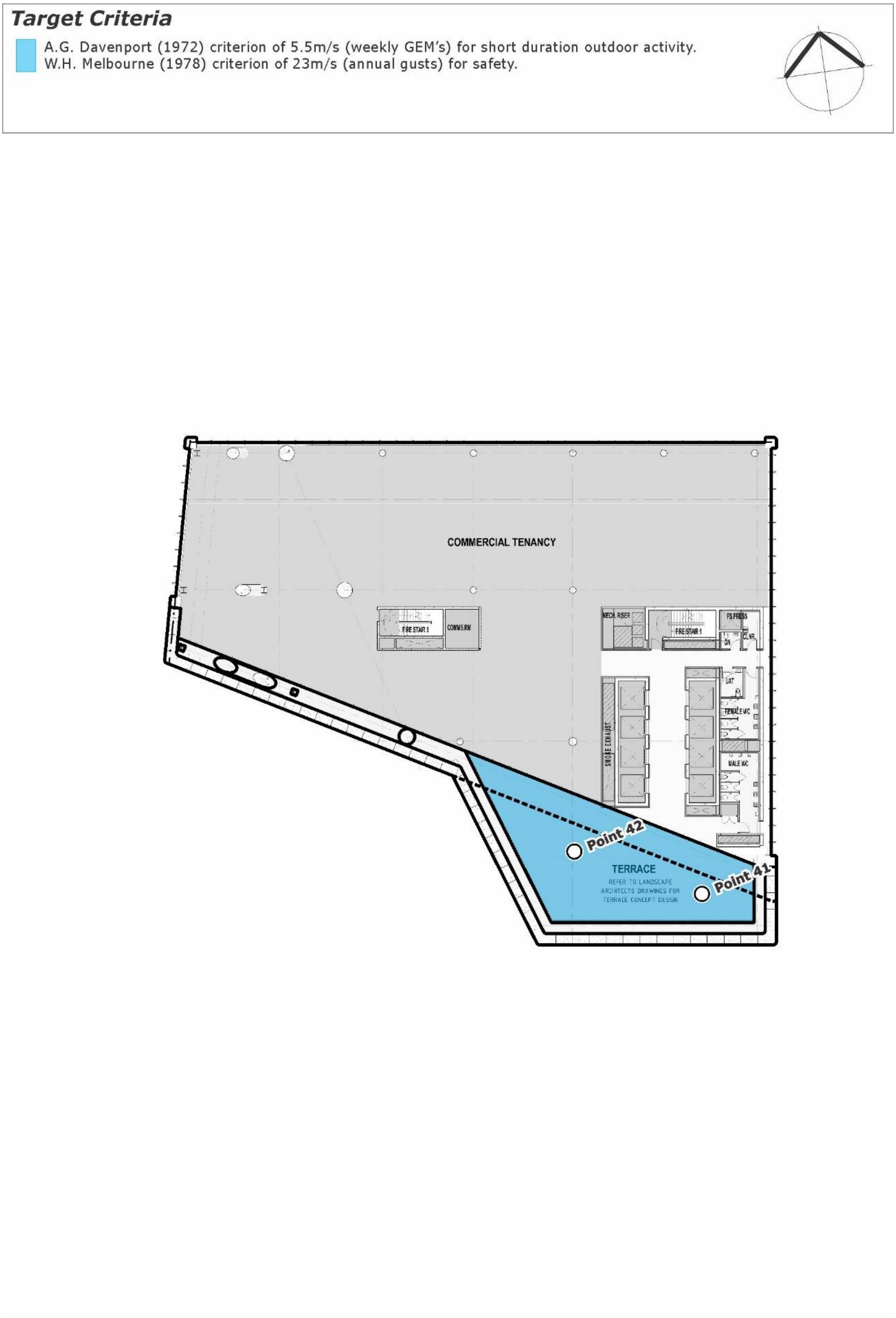


Figure 5i: Study Point Locations and Target Wind Speed Criteria
Level 16 Plan

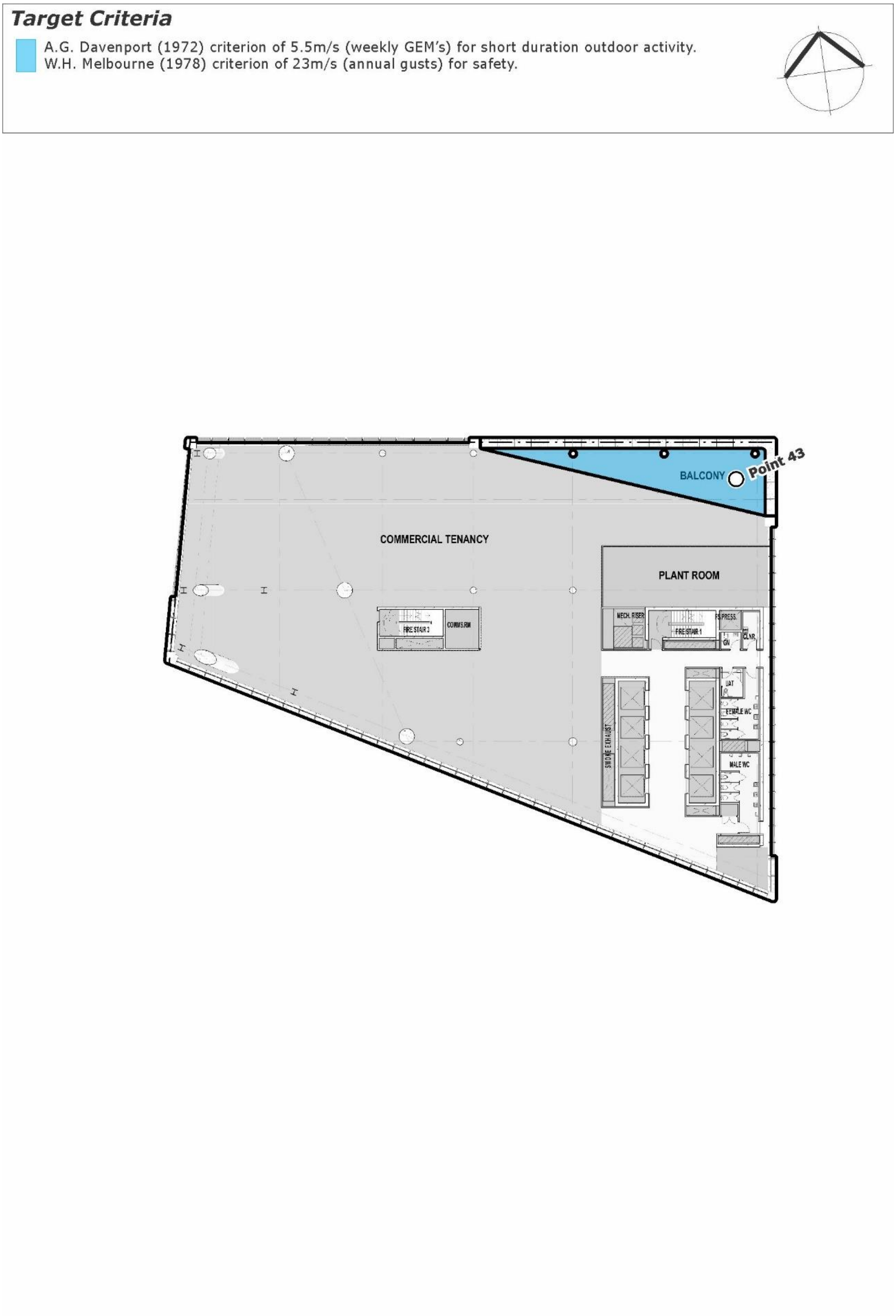


Figure 5j: Study Point Locations and Target Wind Speed Criteria

Level 17 Plan

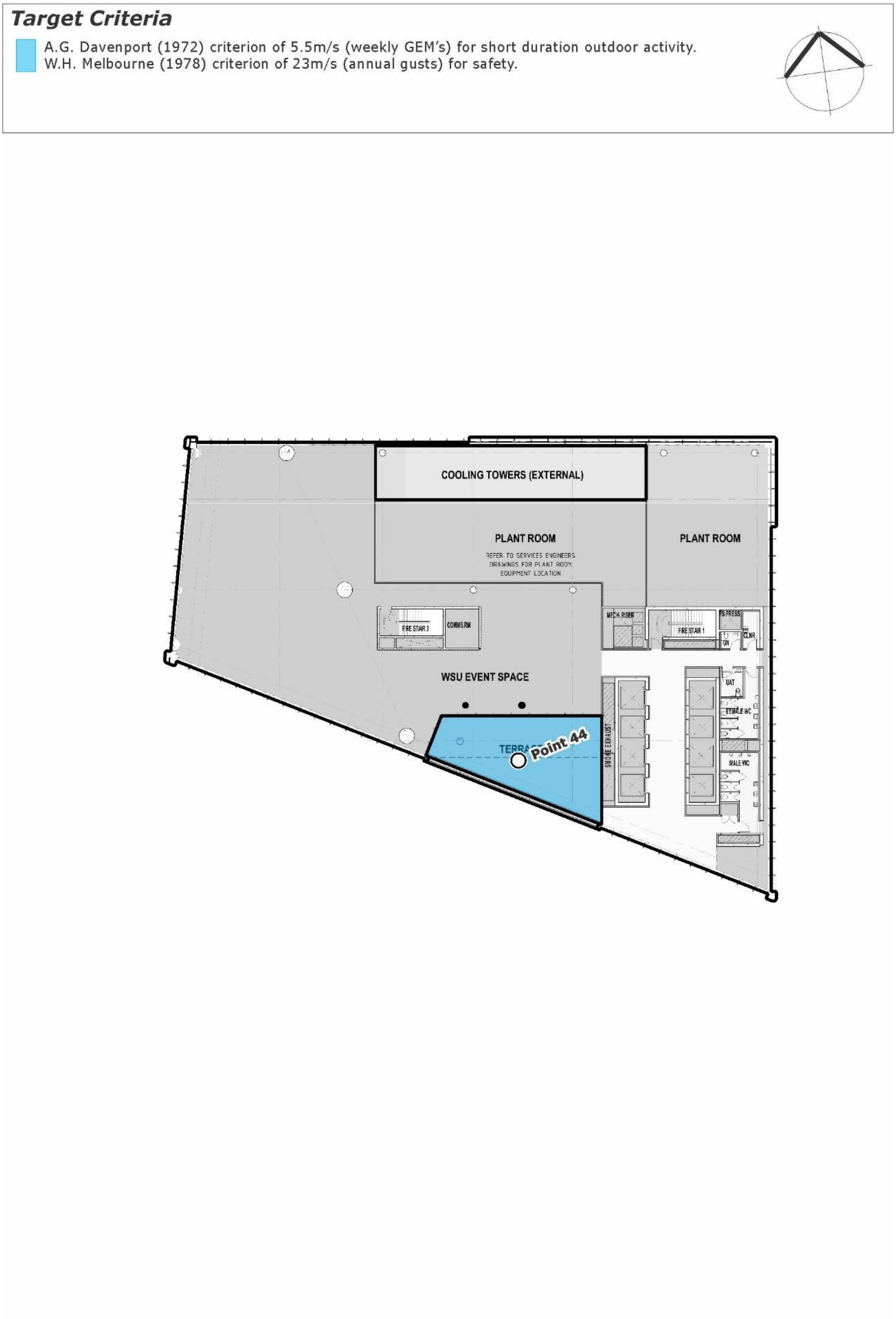


Figure 5k: Study Point Locations and Target Wind Speed Criteria
Level 18 Plan

Target Criteria

A.G. Davenport (1972) criterion of 7.5m/s (weekly GEM's) for pedestrian activity.
W.H. Melbourne (1978) criterion of 23m/s (annual gusts) for safety.

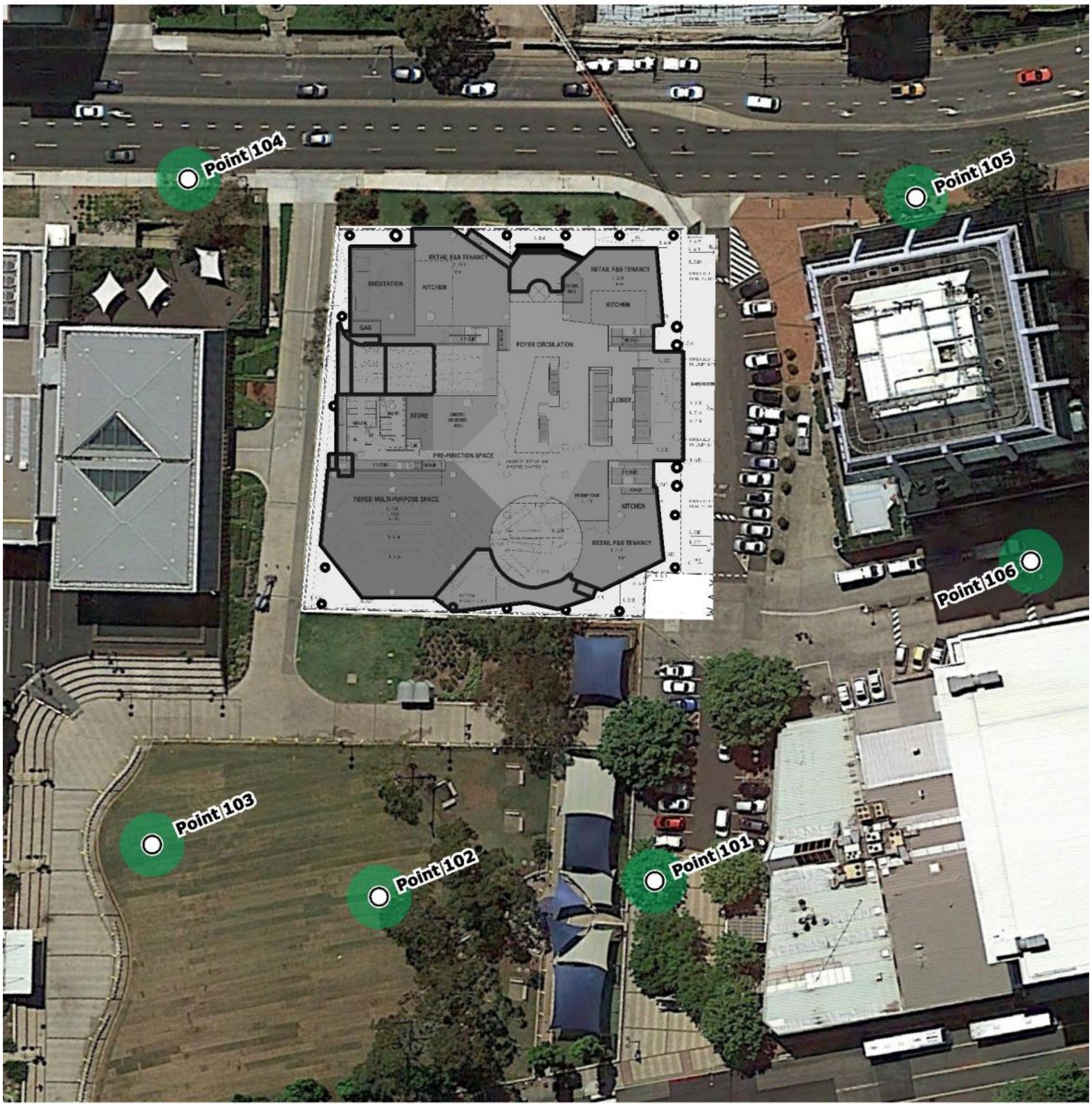


Figure 5l: Study Point Locations and Target Wind Speed Criteria Surrounding Areas

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 Table 4, and shown on marked-up plans in Figures 6. The wind speed criteria that the wind conditions should achieve are also listed in Table 4 for each study point location, as well as in Figures 5. The existing wind conditions for the pedestrian footpaths around the site have also been tested to determine the impact of the proposed development.

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

- Retain proposed densely foliating evergreen trees along Appian Way and Paul Keating Park as indicated in the Landscape Drawing Package (received May 3, 2019), as shown in Figure 7a.
- Recommended inclusion of a cluster of densely foliating evergreen trees within the north-western corner of Paul Keating Park on the Ground Level, as shown in Figure 7a.
- Recommended inclusion of an impermeable full height screen along the eastern perimeter of the terrace located on Level 07, as shown in Figure 7b.
- Recommended inclusion of 2.1m high impermeable perimeter screens around the entire terrace located on Level 13, as shown in Figure 7c.
- Recommended inclusion of strategically located densely foliating evergreen landscaping within the south-west corner of the terrace on Level 13, as shown in Figure 7c.
- Recommended inclusion of localised mobile screening within Level 13 terrace.

It should be noted that for any points that are exceeding the safety limit (Annual Peak) as shown in Table 4, the treatment solutions recommended (in-principle) do not rely solely on planting or vegetation. If an area exceeds the safety limit and the treatment recommendation includes planting or vegetation, it should be noted that this is made in combination with solid element treatment solutions, such that the planting/vegetation assists with the comfort levels and the solid element treatment mitigates the annual peak winds.

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.

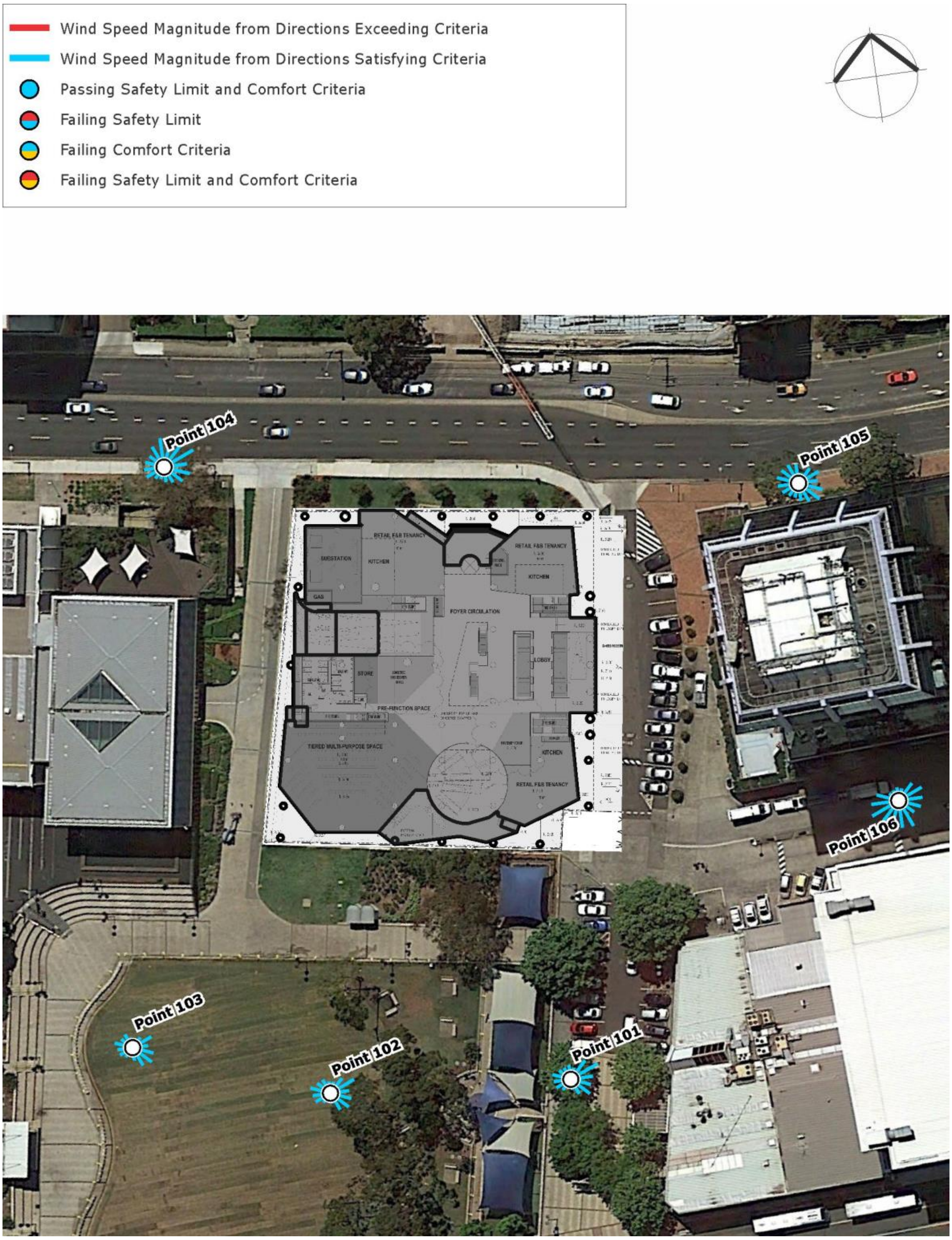


Figure 6a: Wind Tunnel Results – Surrounding Areas (results shown without treatments applied)

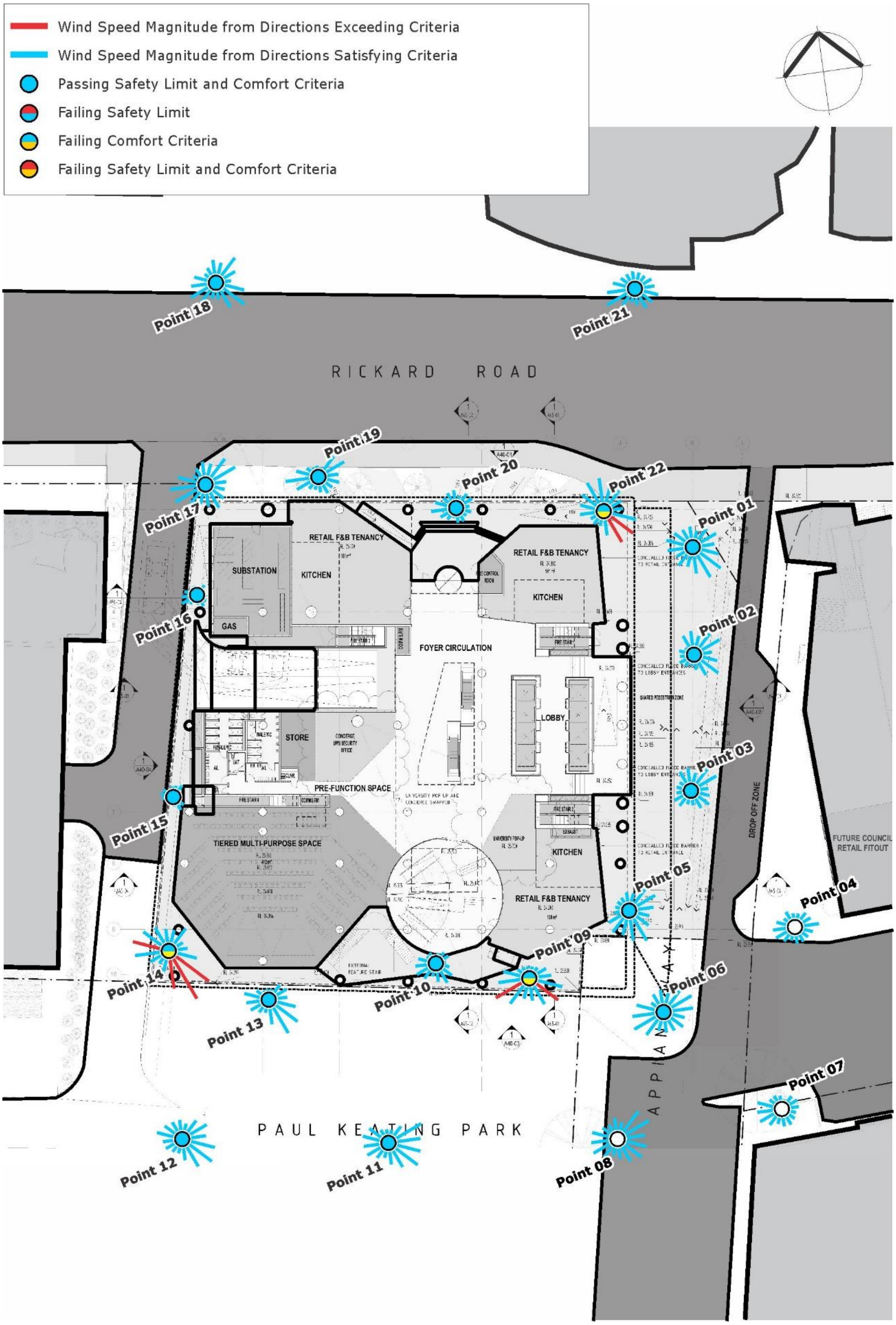


Figure 6b: Wind Tunnel Results – Ground Level Plan
(results shown without treatments applied)

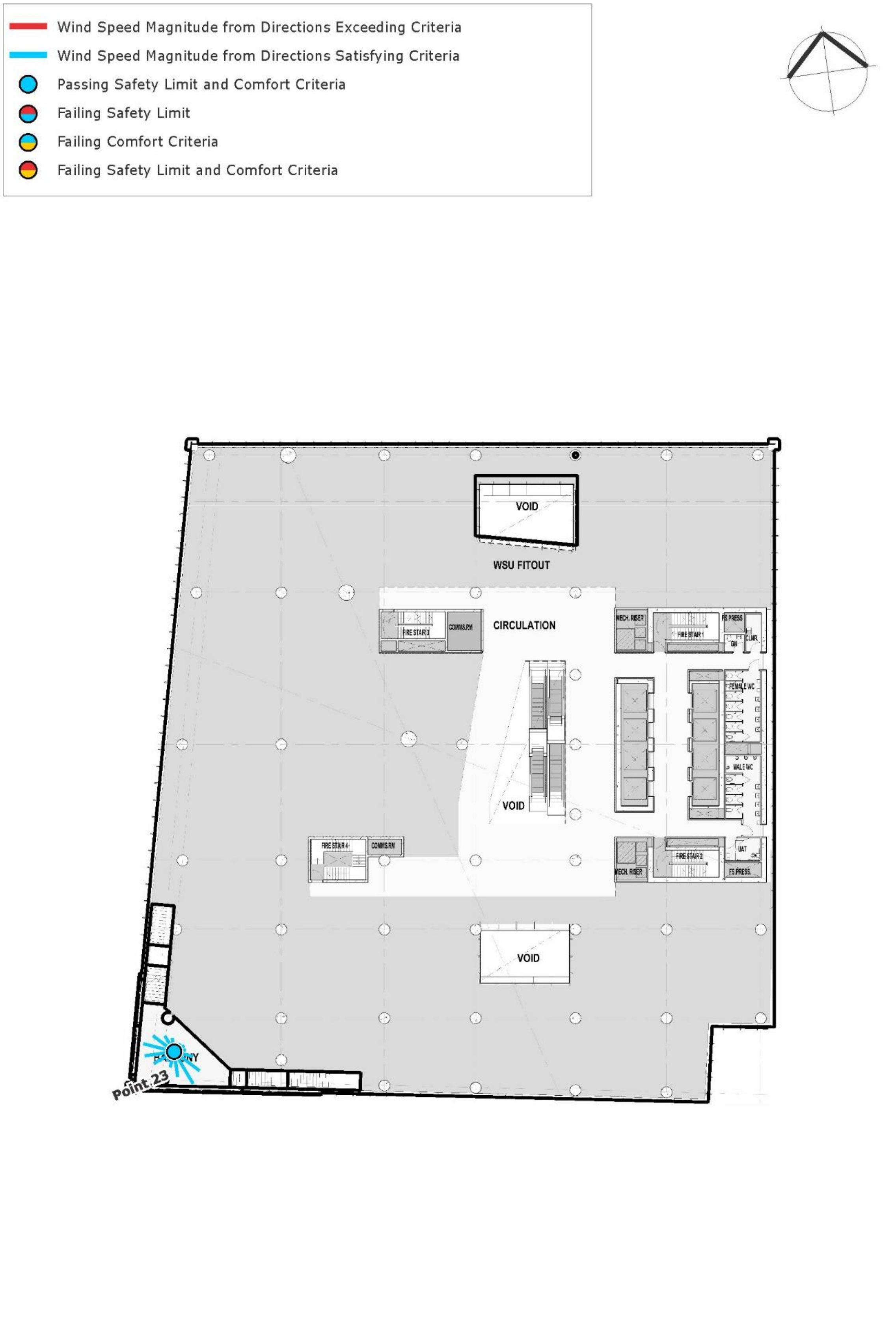


Figure 6c: Wind Tunnel Results – Level 02 Plan
(results shown without treatments applied)

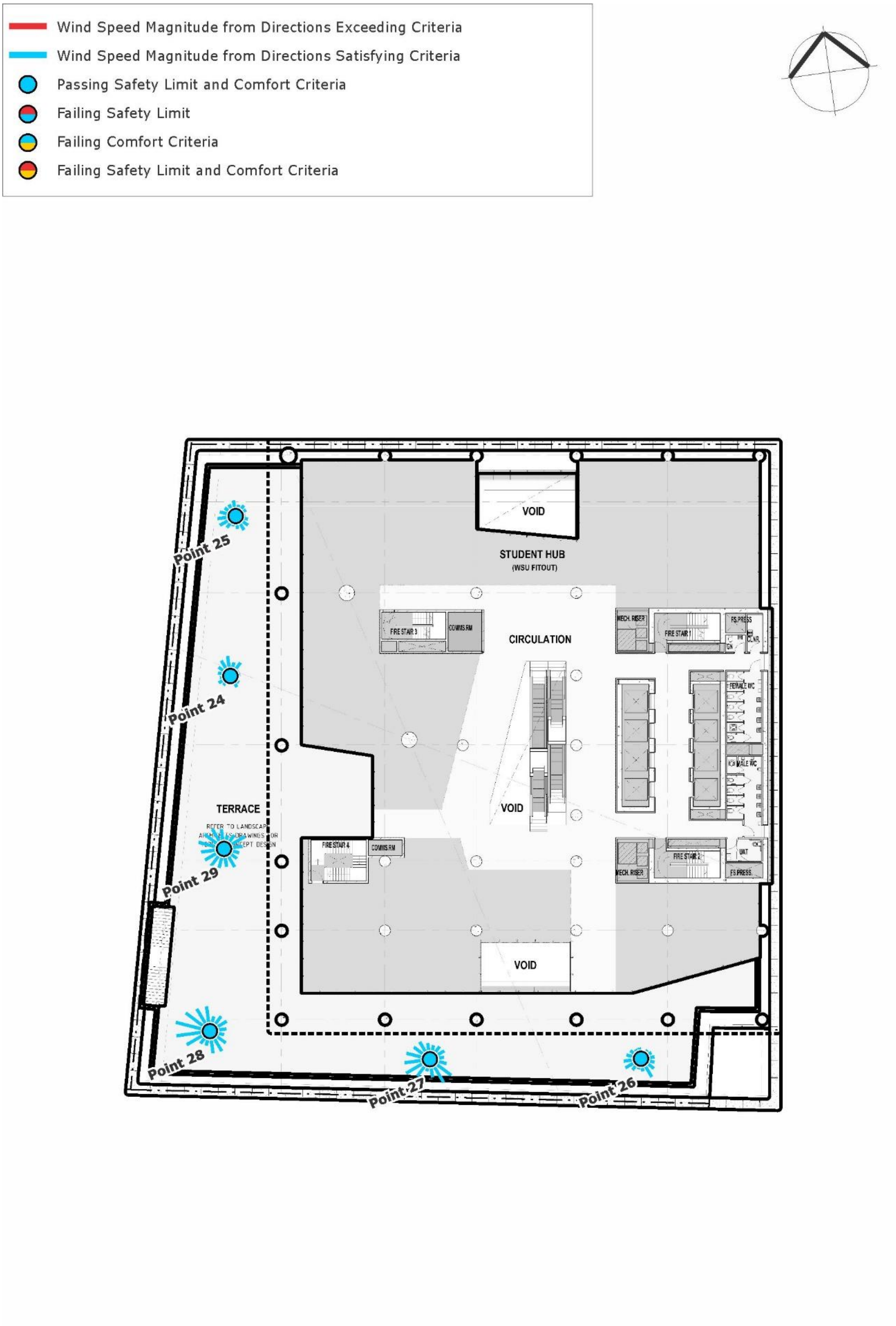


Figure 6d: Wind Tunnel Results – Level 03 Plan (results shown without treatments applied)

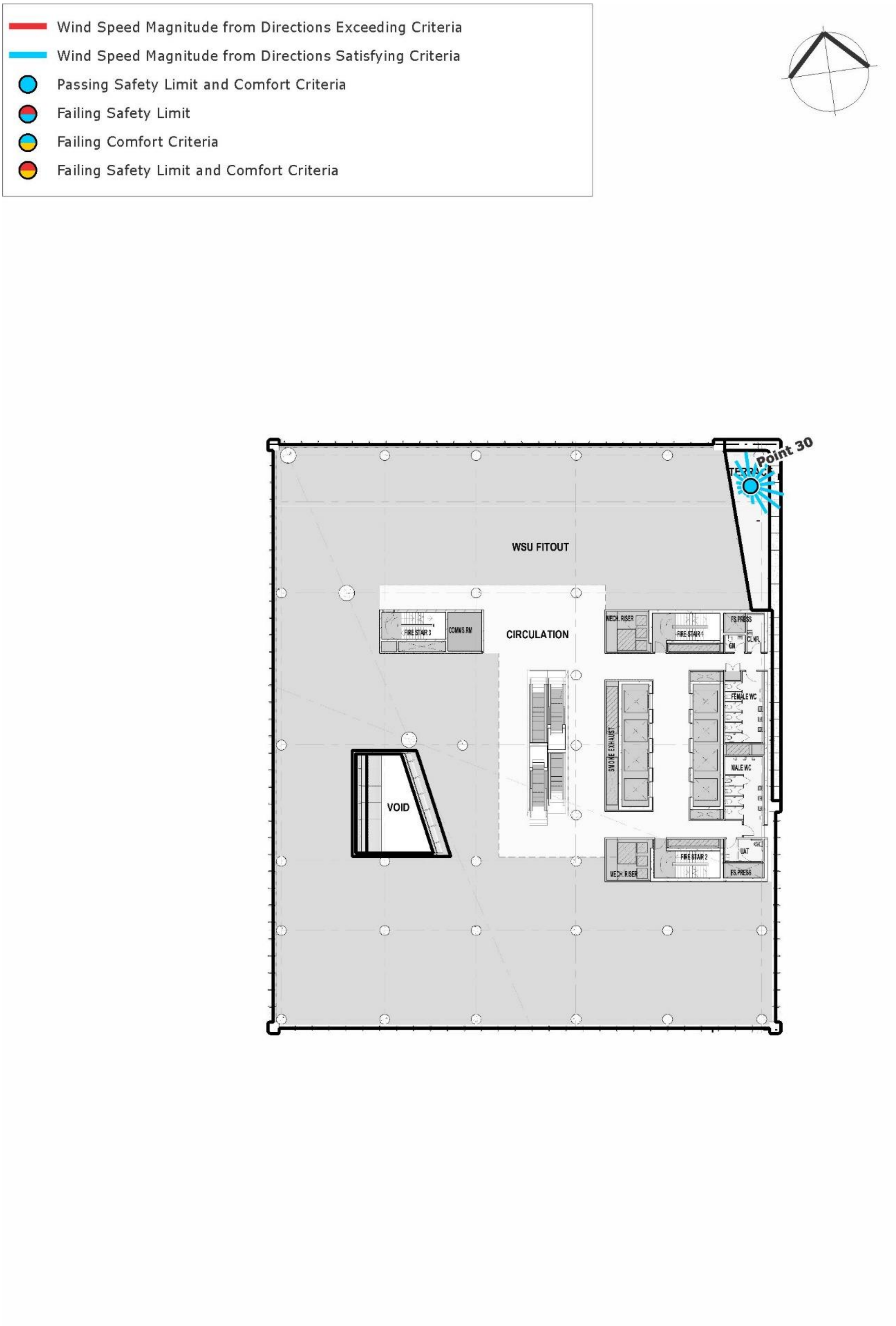


Figure 6e: Wind Tunnel Results – Level 05 Plan
(results shown without treatments applied)

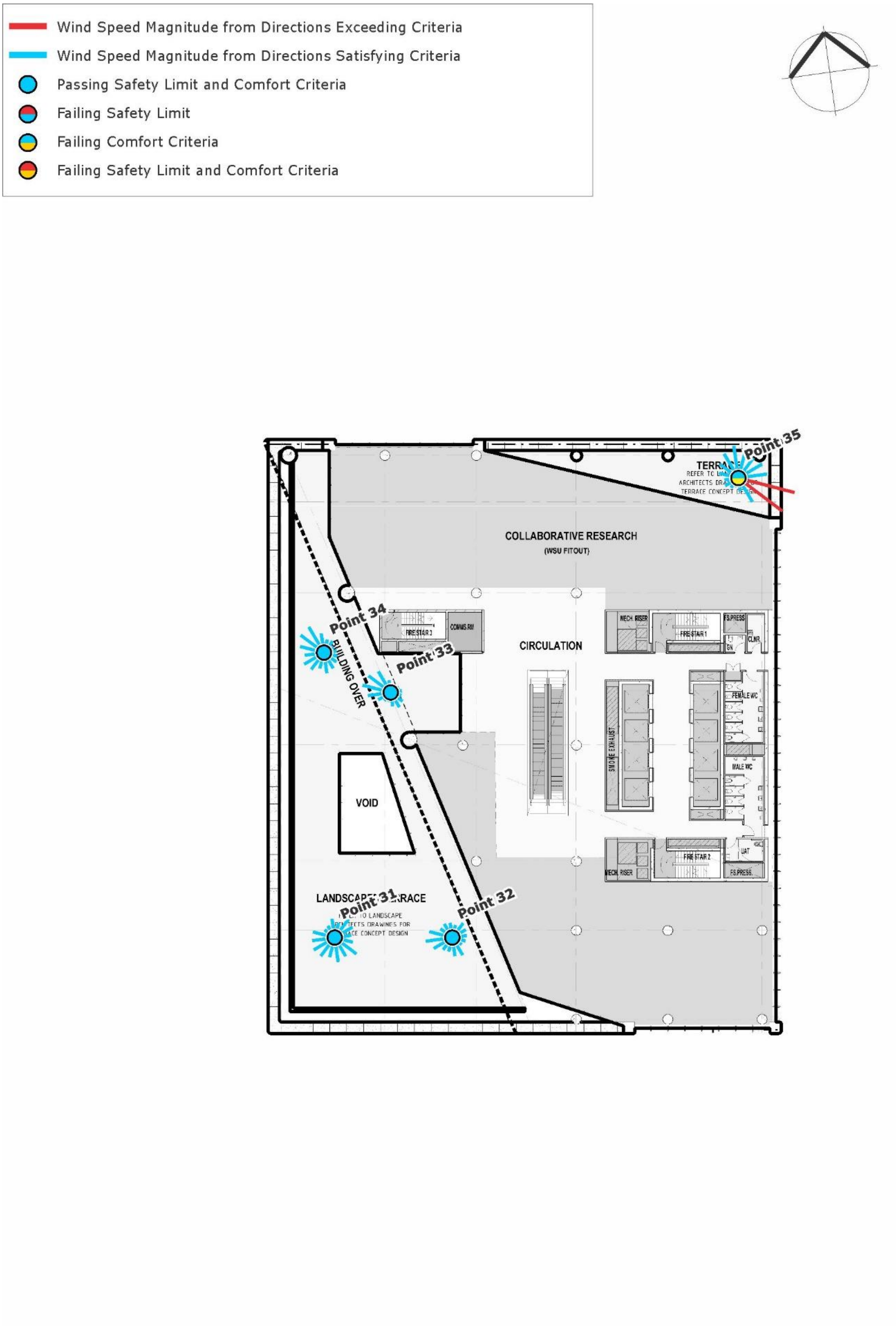


Figure 6f: Wind Tunnel Results – Level 07 Plan
(results shown without treatments applied)

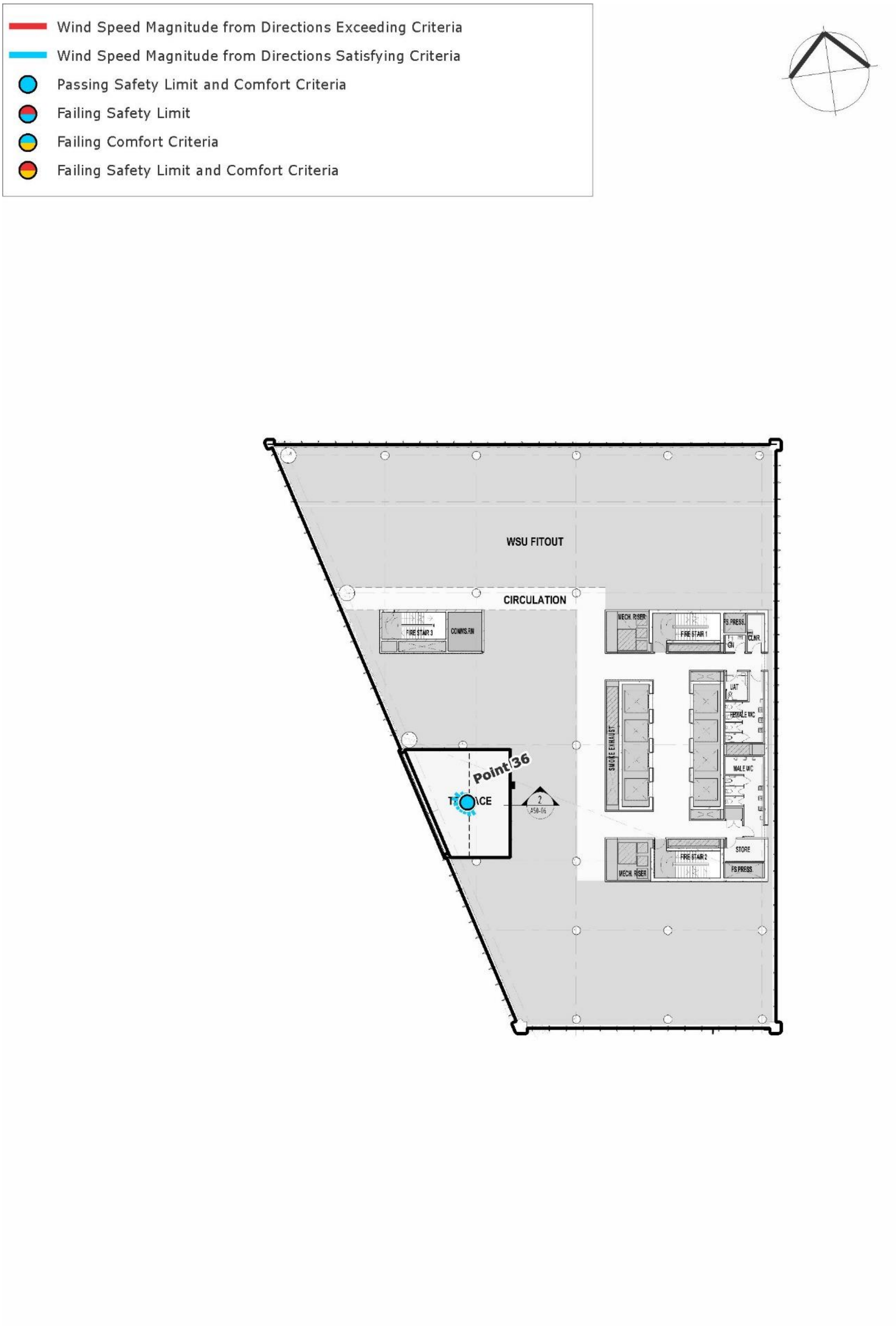


Figure 6g: Wind Tunnel Results – Level 09 Plan
(results shown without treatments applied)

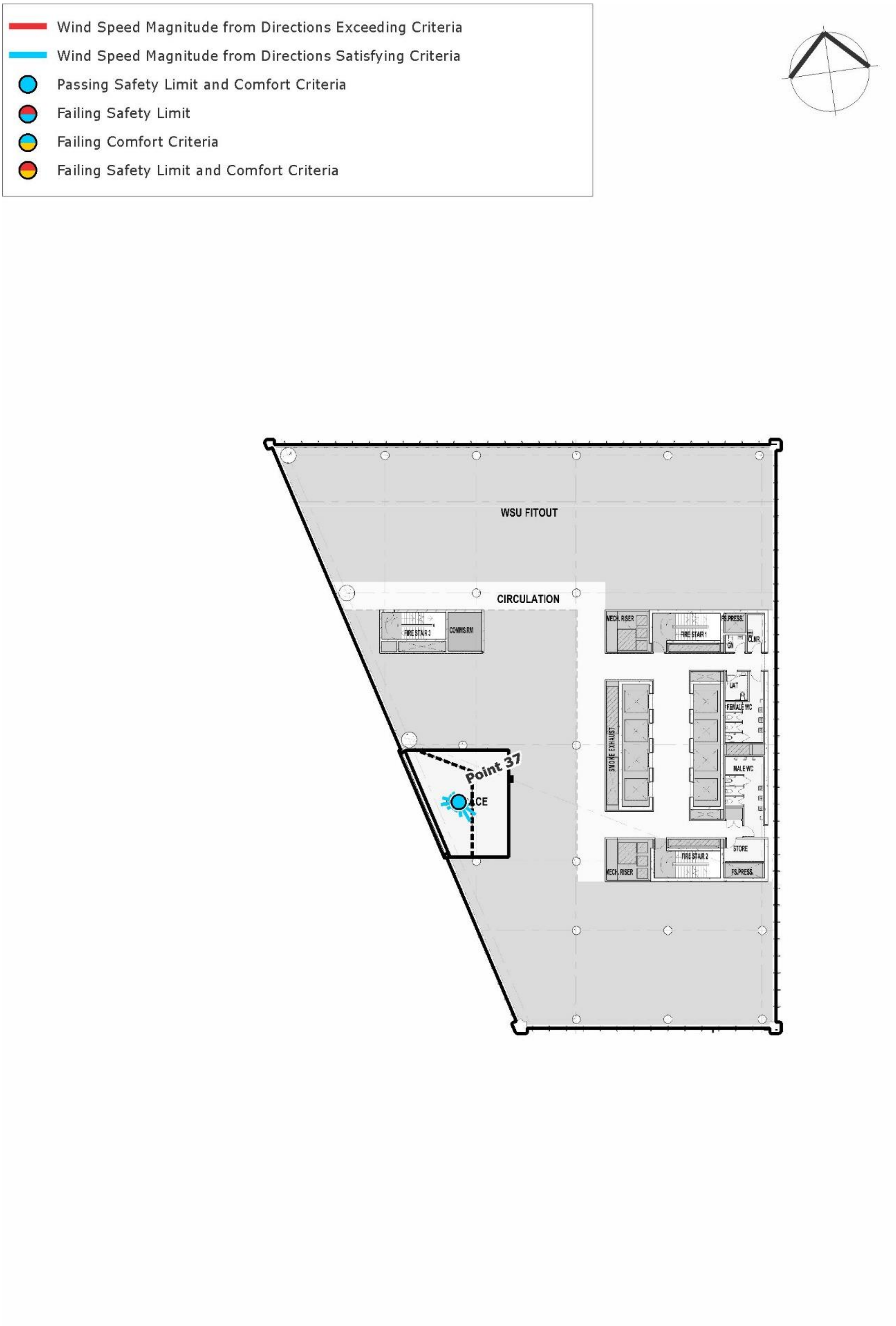


Figure 6h: Wind Tunnel Results – Level 12 Plan
(results shown without treatments applied)

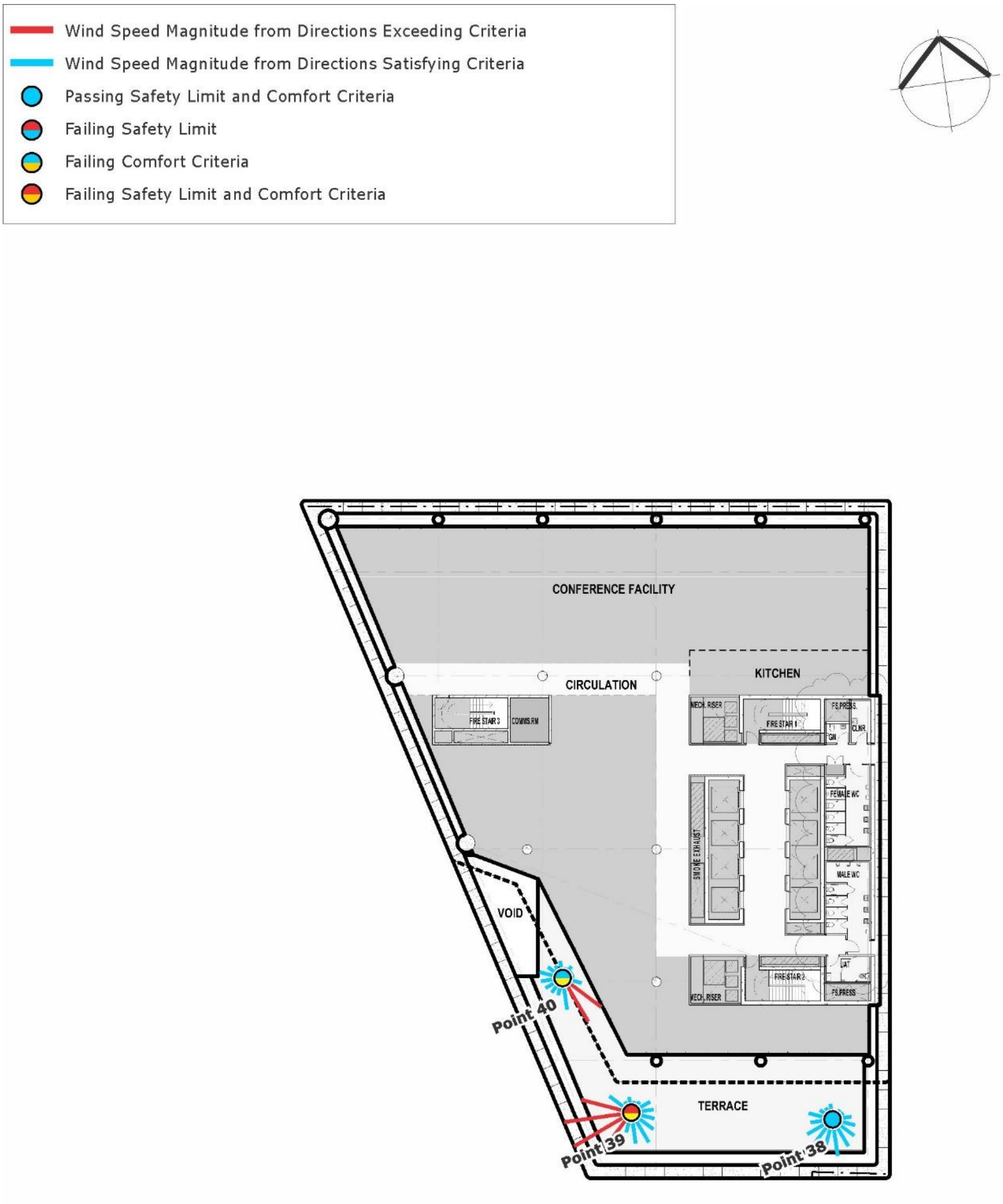


Figure 6i: Wind Tunnel Results – Level 13 Plan
(results shown without treatments applied)

Figure 6j: Wind Tunnel Results – Level 16 Plan (results shown without treatments applied)

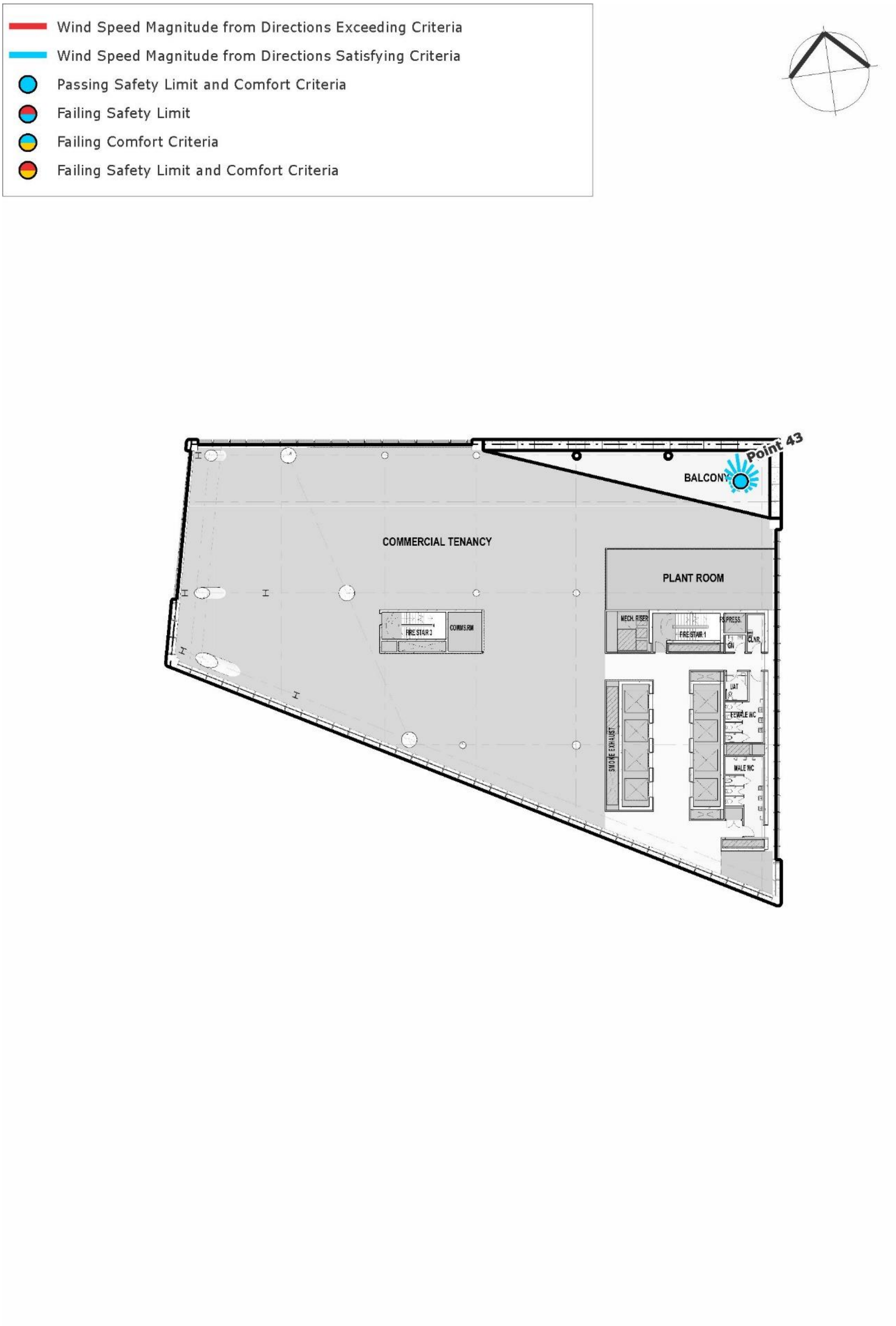


Figure 6k: Wind Tunnel Results – Level 17 Plan
(results shown without treatments applied)

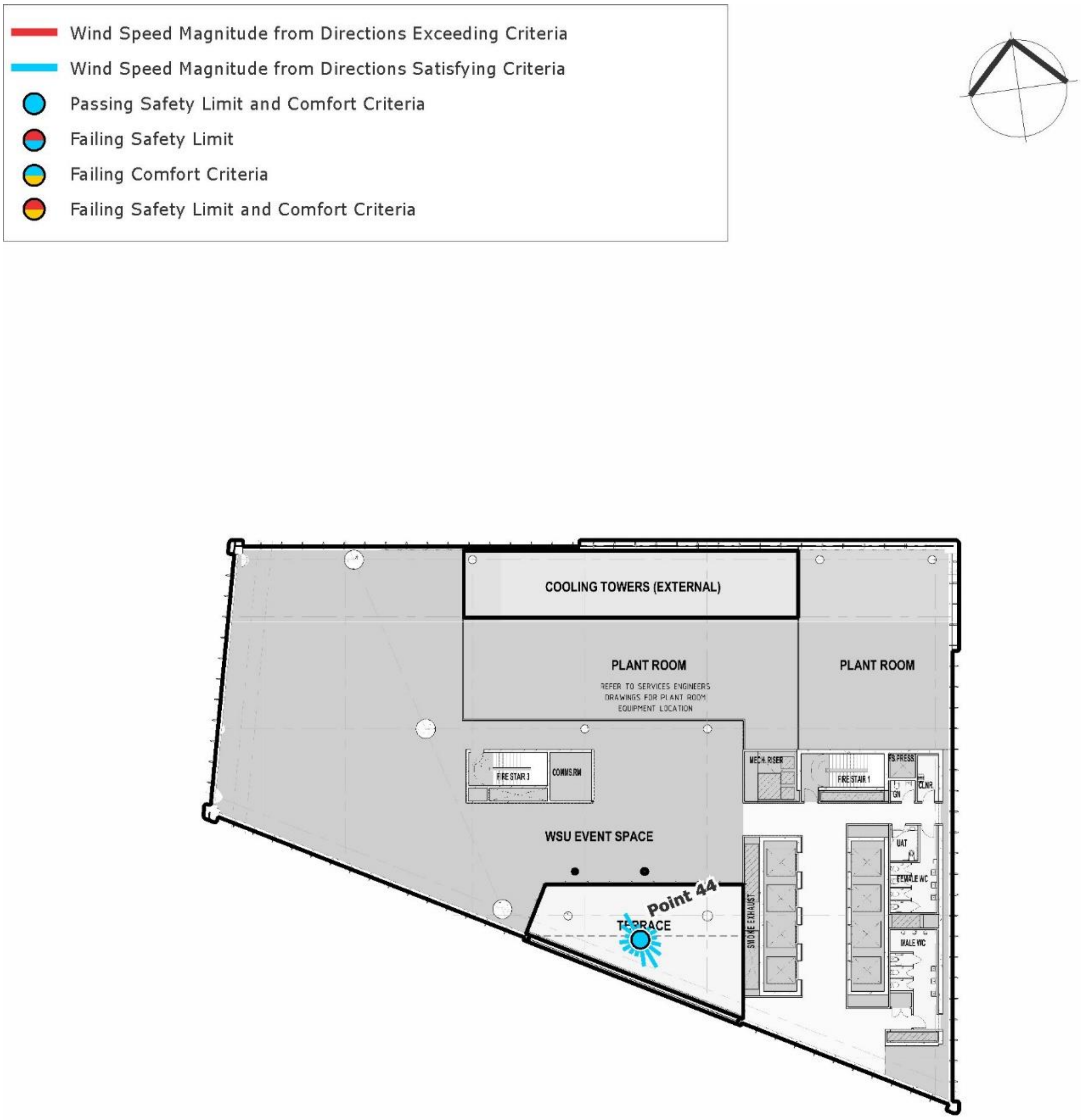


Figure 6l: Wind Tunnel Results – Level 18 Plan
(results shown without treatments applied)

Table 4: Wind Tunnel Results Summary

Study Point	GEM (5% exceedance)			Annual Gust			Final Result	Description of Treatment
	Criterion (m/s)	Results (%)	Grade	Criterion (m/s)	Results (m/s)	Grade		
Point 01	7.5	4%	Pass	23	17	Pass	Pass	
Point 02	7.5	1%	Pass	23	16	Pass	Pass	
Point 03	7.5	1%	Pass	23	15	Pass	Pass	
Point 04	7.5	0%	Pass	23	12	Pass	Pass	
Point 05	7.5	3%	Pass	23	18	Pass	Pass	
Point 06	7.5	4%	Pass	23	17	Pass	Pass	
Point 07	7.5	1%	Pass	23	17	Pass	Pass	
Point 08	7.5	5%	Pass	23	16	Pass	Pass	
Point 09	7.5	6%	Fail	23	21	Pass	Fail	Refer to Figure 7a
Existing		3%	Pass		18	Pass	Pass	
Point 10	7.5	0%	Pass	23	13	Pass	Pass	
Point 11	7.5	5%	Pass	23	19	Pass	Pass	
Point 12	7.5	3%	Pass	23	18	Pass	Pass	
Point 13	7.5	4%	Pass	23	17	Pass	Pass	
Existing		1%	Pass		16	Pass	Pass	
Point 14	7.5	15%	Fail	23	23	Pass	Fail	Refer to Figure 7a
Existing		0%	Pass		14	Pass	Pass	
Point 15	7.5	0%	Pass	23	8	Pass	Pass	
Point 16	7.5	0%	Pass	23	10	Pass	Pass	
Point 17	7.5	5%	Pass	23	20	Pass	Pass	
Point 18	7.5	3%	Pass	23	17	Pass	Pass	
Point 19	7.5	1%	Pass	23	22	Pass	Pass	
Point 20	7.5	0%	Pass	23	16	Pass	Pass	
Point 21	7.5	2%	Pass	23	19	Pass	Pass	
Point 22	7.5	6%	Fail	23	19	Pass	Fail	Refer to Figure 7a
Existing		4%	Pass		18	Pass	Pass	
Point 23	7.5	4%	Pass	23	19	Pass	Pass	
Point 24	7.5	0%	Pass	23	13	Pass	Pass	
Point 25	5.5	0%	Pass	23	8	Pass	Pass	
Point 26	5.5	0%	Pass	23	8	Pass	Pass	
Point 27	5.5	1%	Pass	23	12	Pass	Pass	
Point 28	5.5	4%	Pass	23	16	Pass	Pass	
Point 29	5.5	1%	Pass	23	13	Pass	Pass	
Point 30	5.5	5%	Pass	23	14	Pass	Pass	
Point 31	5.5	1%	Pass	23	11	Pass	Pass	
Point 32	5.5	1%	Pass	23	13	Pass	Pass	
Point 33	5.5	2%	Pass	23	15	Pass	Pass	
Point 34	5.5	2%	Pass	23	14	Pass	Pass	

Study Point	GEM (5% exceedance)			Annual Gust			Final Result	Description of Treatment
	Criterion (m/s)	Results (%)	Grade	Criterion (m/s)	Results (m/s)	Grade		
Point 35	5.5	11%	Fail	23	21	Pass	Fail	Refer to Figure 7b
Point 36	5.5	0%	Pass	23	8	Pass	Pass	
Point 37	5.5	0%	Pass	23	8	Pass	Pass	
Point 38	5.5	2%	Pass	23	14	Pass	Pass	
Point 39	5.5	16%	Fail	23	24	Fail	Fail	Refer to Figure 7c
Point 40	5.5	7%	Fail	23	15	Pass	Fail	Refer to Figure 7c
Point 41	5.5	1%	Pass	23	13	Pass	Pass	
Point 42	5.5	2%	Pass	23	13	Pass	Pass	
Point 43	5.5	1%	Pass	23	11	Pass	Pass	
Point 44	5.5	0%	Pass	23	11	Pass	Pass	
Point 101	7.5	0%	Pass	23	13	Pass	Pass	
Point 102	7.5	0%	Pass	23	12	Pass	Pass	
Point 103	7.5	0%	Pass	23	11	Pass	Pass	
Point 104	7.5	3%	Pass	23	18	Pass	Pass	
Point 105	7.5	0%	Pass	23	14	Pass	Pass	
Point 106	7.5	1%	Pass	23	15	Pass	Pass	

Note that, for any study points listed in Table 4 with two rows of results data, the second row is for the existing site conditions. The test results shown in Table 4 are without any treatments applied. If treatment is required, the treatment is described in Table 4.

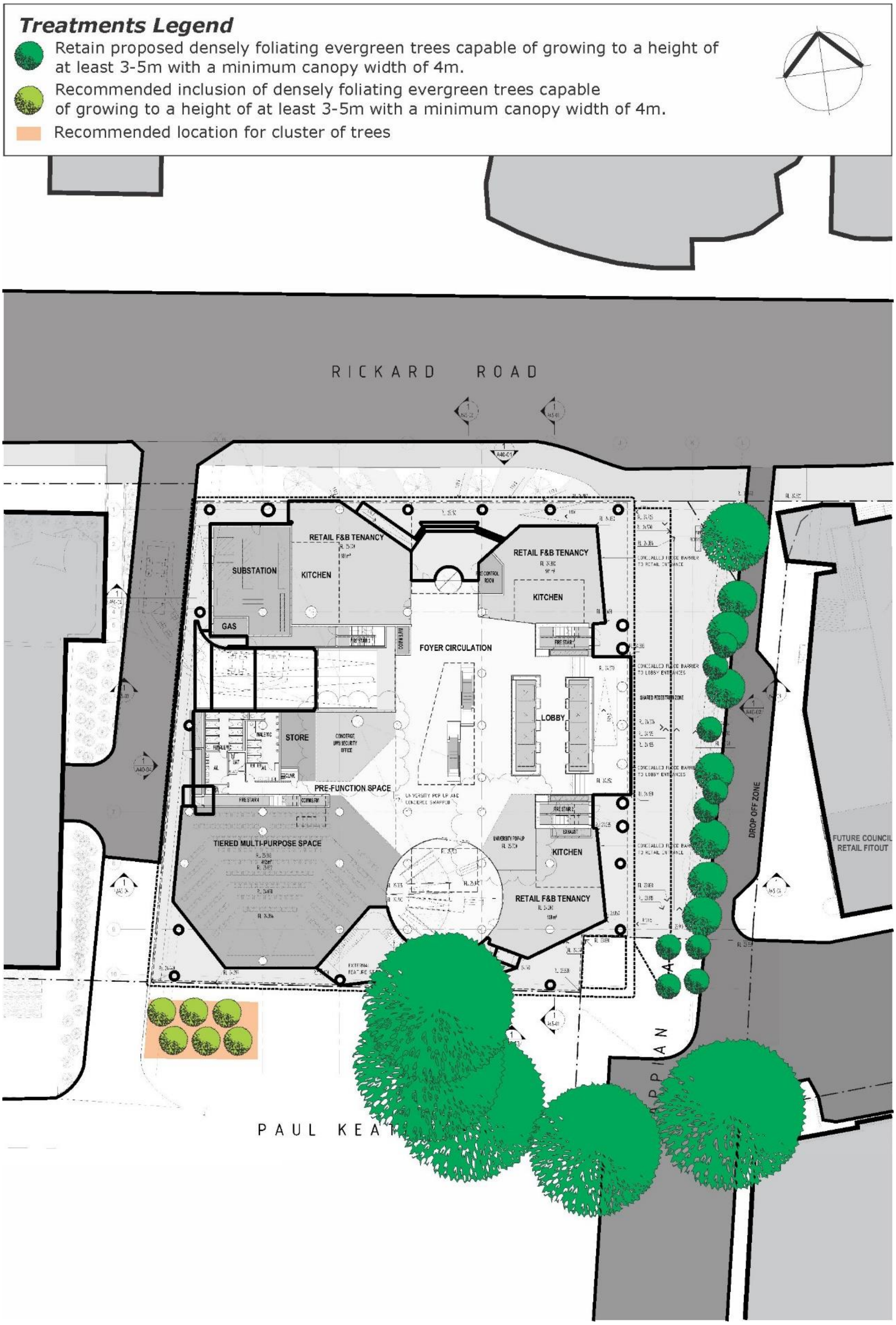


Figure 7a: Suggested Treatments – Ground Level Plan

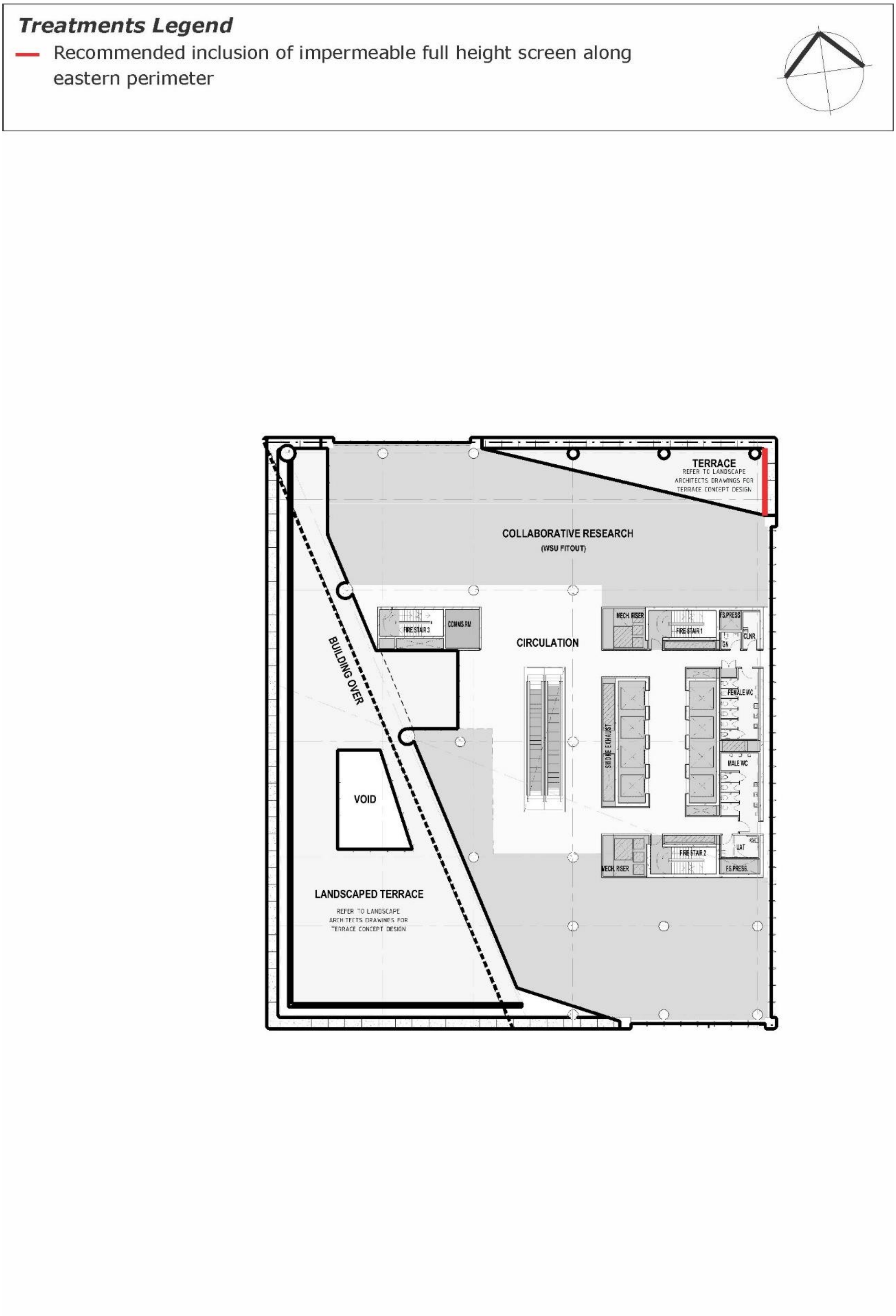


Figure 7b: Wind Tunnel Results – Level 07 Plan

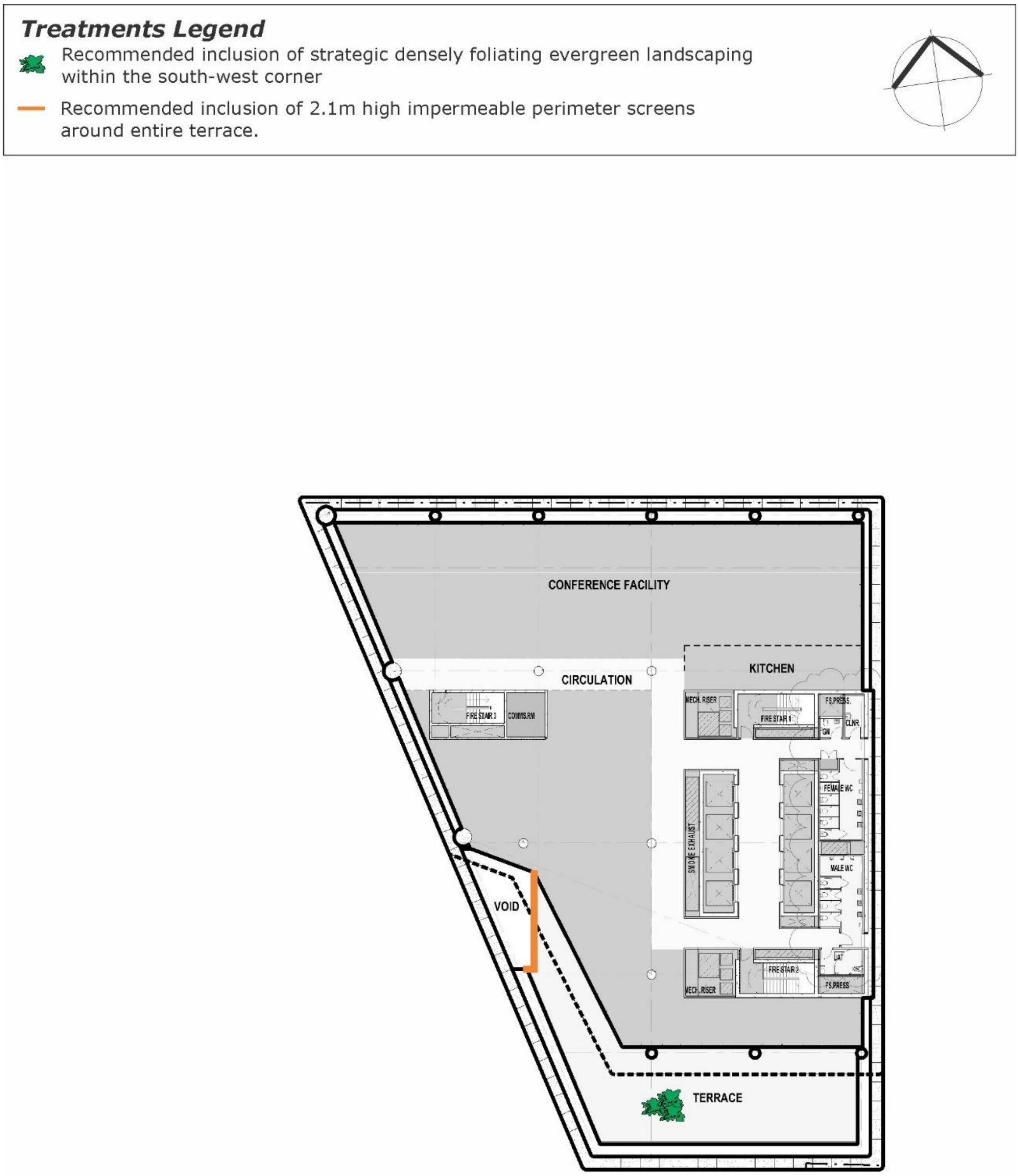


Figure 7c: Wind Tunnel Results – Level 13 Plan

7 REFERENCES

American Society of Civil Engineers (ASCE), 2003, "Outdoor Human Comfort and its Assessment – State of the Art".

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*.

Australasian Wind Engineering Society (AWES), 2014, "Guidelines for Pedestrian Wind Effects Criteria".

Council on Tall Buildings and Urban Habitat (CTBUH), 2013, "Wind tunnel testing of high-rise buildings", CTBUH Technical Guides.

Davenport, A.G., 1972, "An approach to human comfort criteria for environmental conditions". Colloquium on Building Climatology, Stockholm.

Deaves, D.M. and Harris, R.I., 1978, "A mathematical model of the structure of strong winds." Construction Industry and Research Association (U.K), Report 76.

Engineering Science Data Unit, 1982, London, ESDU82026, "Strong Winds in the Atmospheric Boundary Layer, Part 1: Hourly Mean Wind Speeds", with Amendments A to E (issued in 2002).

Engineering Science Data Unit, 1983, London, ESDU83045, "Strong Winds in the Atmospheric Boundary Layer, Part 2: Discrete Gust Speeds", with Amendments A to C (issued in 2002).

Melbourne, W.H., 1978, "Criteria for Environmental Wind Conditions". *Journal of Wind Engineering and Industrial Aerodynamics*, vol. 3, pp241-249.

Rofail, A.W., and Kwok, K.C.S., 1991, "A Reliability Study of Wind Tunnel Results of Cladding Pressures". Proceedings of the 8th International Conference on Wind Engineering, Canada.

Rofail, A.W., 2007, "Comparison of Wind Environment Criteria against Field Observations". 12th International Conference of Wind Engineering, Cairns, Australia.

Standards Australia and Standards New Zealand, AS/NZS 1170.2, 2011, "SAA Wind Loading Standard, Part 2: Wind Actions".

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.1.1 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 - 0.25	
Calm, light air	1	0 25 - 1.55	No noticeable wind
Light breeze	2	1.55 - 3.35	Wind felt on face
Gentle breeze	3	3.35 - 5.45	Hair is disturbed, clothing flaps, newspapers difficult to read
Moderate breeze	4	5.45 - 7.95	Raises dust, dry soil and loose paper, hair disarranged
Fresh breeze	5	7.95 – 10.75	Force of wind felt on body, danger of stumbling
Strong breeze	6	10.75 – 13.85	Umbrellas used with difficulty, hair blown straight, difficult to walk steadily, wind noise on ears unpleasant
Near gale	7	13.85 – 17.15	Inconvenience felt when walking
Gale	8	17.15 - 20.75	Generally impedes progress, difficulty balancing in gusts
Strong gale	9	20.75 – 24.45	People blown over

A.1.2 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.1.3 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.1.4 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	Human 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.2 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%.

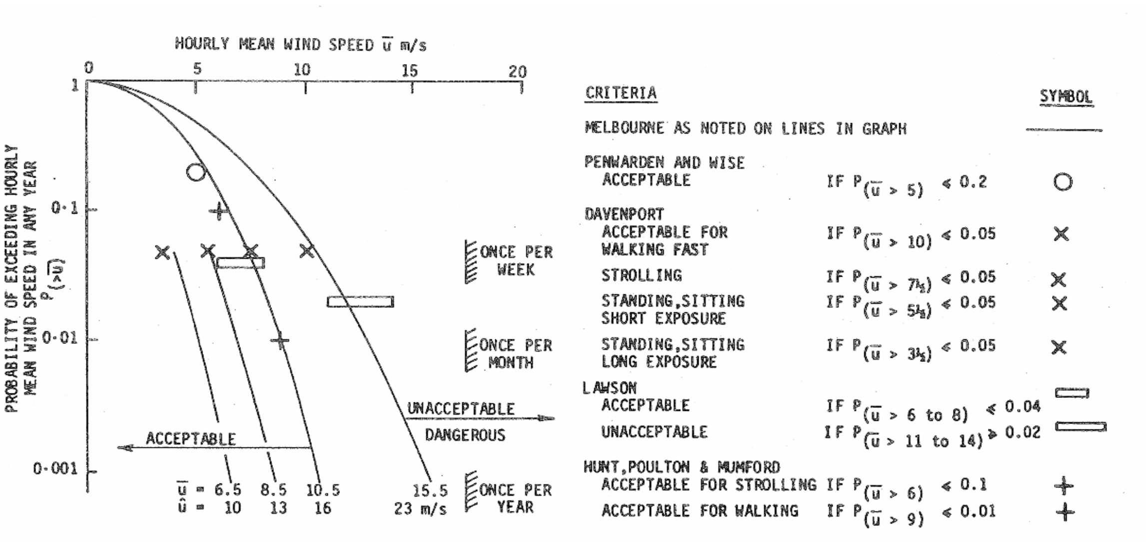


Figure A.1: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (W.H. Melbourne, 1978)

A.3 References relating to Pedestrian Comfort Criteria

Davenport, A.G., 1972, "An approach to human comfort criteria for environmental conditions". Colloquium on Building Climatology, Stockholm.

Davenport, A.G., 1977, "The prediction of risk under wind loading", 2nd International Conference on Structural Safety and Reliability, Munich, Germany, pp511-538.

Lawson, T.V., 1973, "The wind environment of buildings: a logical approach to the establishment of criteria". Bristol University, Department of Aeronautical Engineering.

Lawson, T.V., 1975, "The determination of the wind environment of a building complex before construction". Bristol University, Department of Aeronautical Engineering.

Melbourne, W.H., 1978, "Criteria for Environmental Wind Conditions". Journal of Wind Engineering and Industrial Aerodynamics, vol. 3, pp241-249.

Penwarden, A.D. (1973). "Acceptable Wind Speeds in Towns", Building Science, vol. 8: pp259–267.

Penwarden, A.D., Wise A.F.E., 1975, "Wind Environment Around Buildings". Building Research Establishment Report, London.

Rofail, A.W., 2007, "Comparison of Wind Environment Criteria against Field Observations". 12th International Conference of Wind Engineering, Cairns, Australia.

APPENDIX B DATA ACQUISITION

The wind tunnel testing procedures 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 acquired as coefficients by Dantec hot-wire anemometers 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 Dantec hot-wire probe anemometers at selected critical outdoor locations. The anemometers were positioned at each study location at a full-scale height of approximately 1.5m above ground/slab level. The support of the probe was mounted such that the probe wire was 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 probe wire and in avoiding wall-heating effects.

Wind speed measurements were made in the wind tunnel for 16 wind directions, at 22.5° increments. The output from the hot-wire probes was obtained using a National Instruments 12-bit data acquisition card. The 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.

The mean, gust and standard deviation velocity coefficients were measured 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 coefficient.

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

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

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

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.2.1 Maximum Gust Wind Speeds

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

$$V_{study} = V_{ref,RH} \left(\frac{k_{200m,tr,T=1hr}}{k_{RH,tr,T=1hr}} \right) C_V \qquad \text{B.2}$$

Where:

V_{study} is the full-scale wind speed at the study point location, in m/s.

$V_{ref,RH}$ is the full-scale reference wind speed, measured 3m upstream 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 standard deviation of the wind speed.

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

C_V is the velocity coefficient measurement obtained from the hot-wire anemometer, which is derived from the following relationship:

$$C_V = \frac{C_{V,study}}{C_{V,200m}} \qquad \text{B.3}$$

Where:

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

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

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.2.2 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.3 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*.

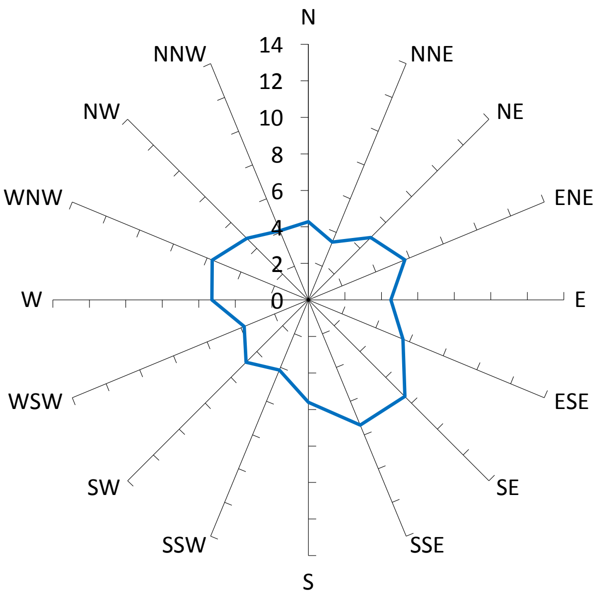
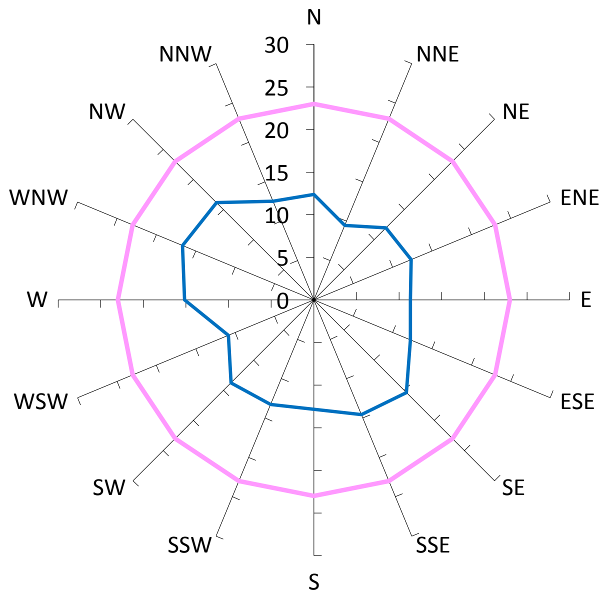
Council on Tall Buildings and Urban Habitat (CTBUH), 2013, “Wind tunnel testing of high-rise buildings”, CTBUH Technical Guides.

Lawson, T.V., 1980, “Wind Effects on Buildings - Volume 1, Design Applications”. Applied Science Publishers Ltd, Ripple Road, Barking, Essex, England.

Standards Australia and Standards New Zealand, AS/NZS 1170.2, 2011, “SAA Wind Loading Standard, Part 2: Wind Actions”.

APPENDIX C DIRECTIONAL PLOTS OF WIND TUNNEL RESULTS

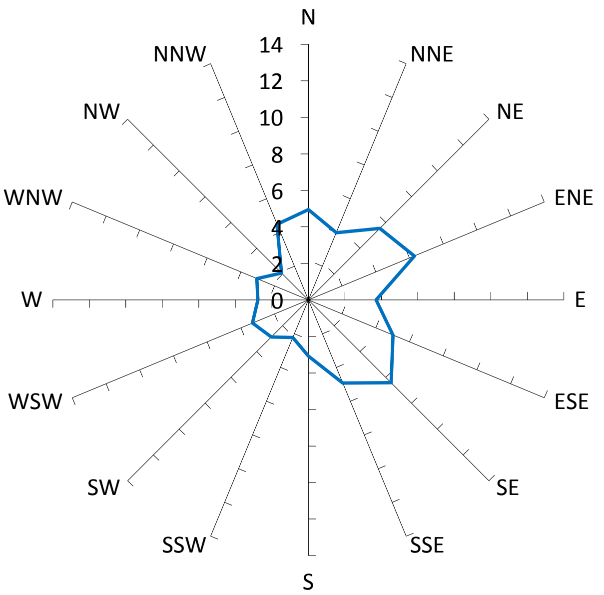
Results for Point 01

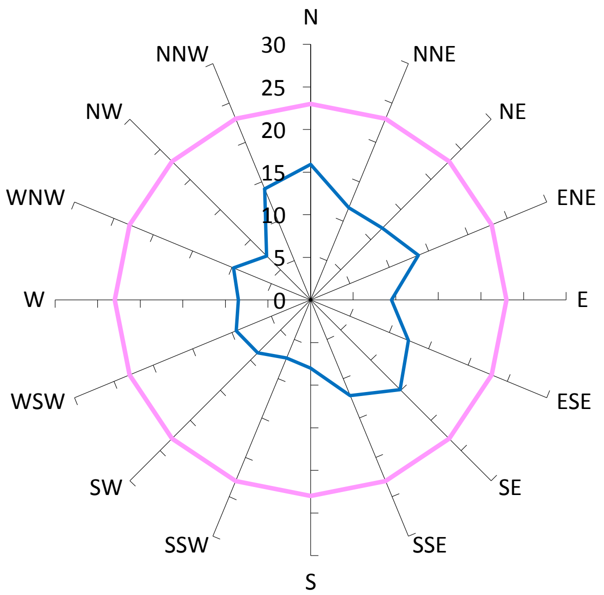
Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	4%	17

Results for Point 02

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)



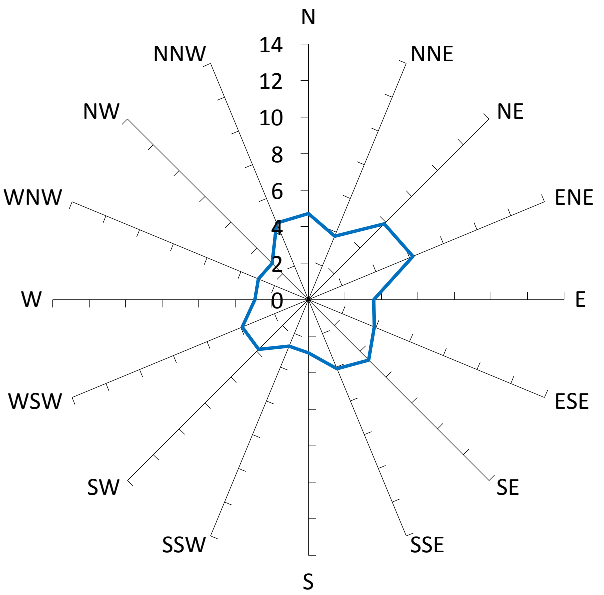


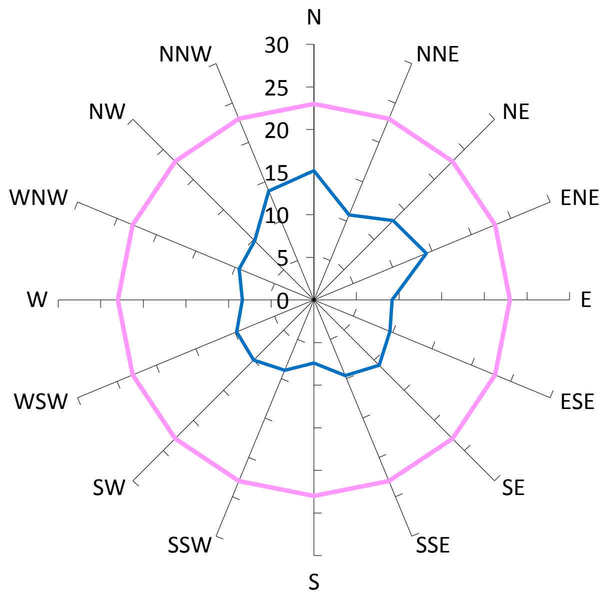
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	1%	16

Results for Point 03

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)



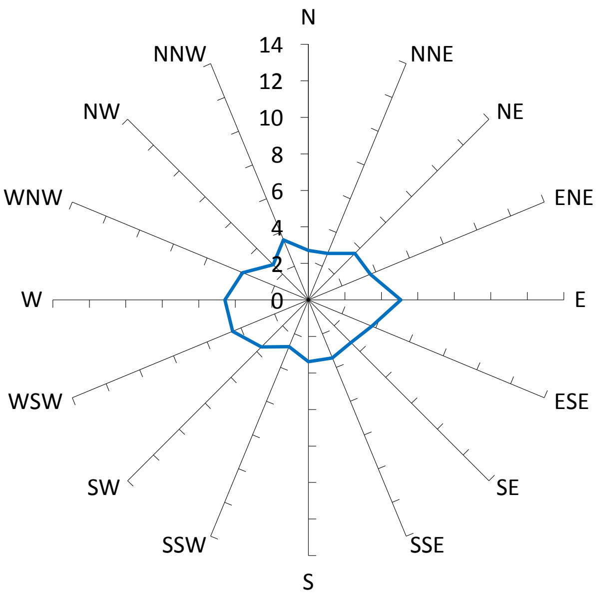


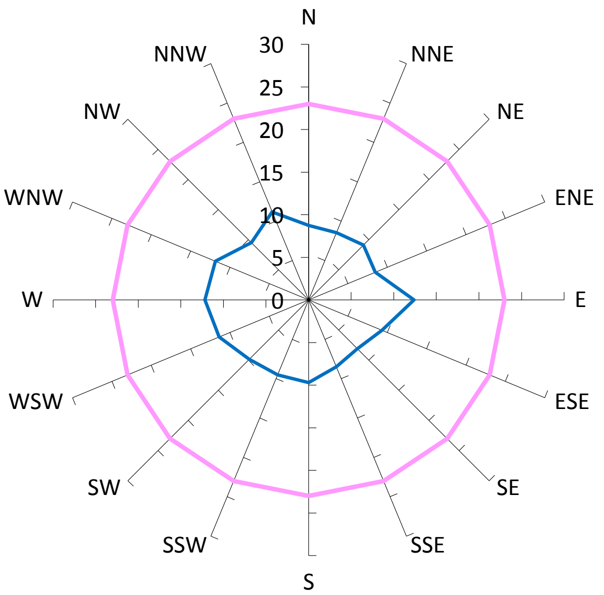
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	1%	15

Results for Point 04

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)

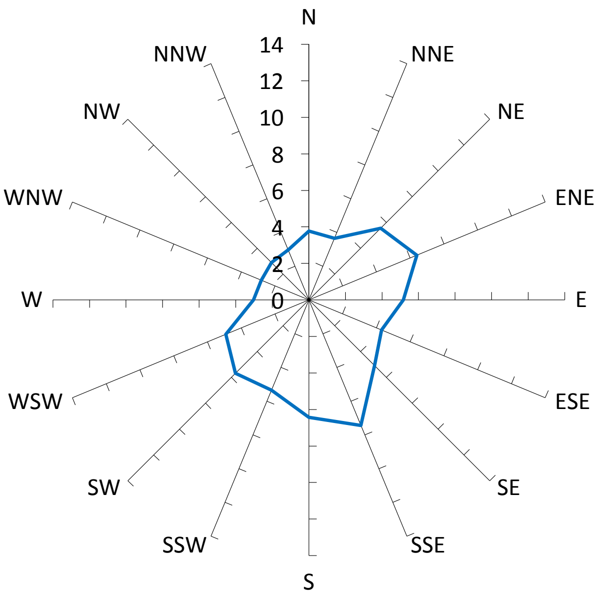
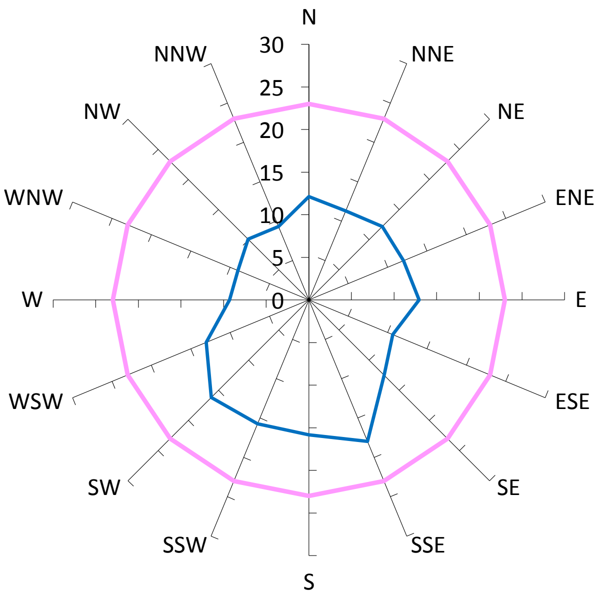




Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	12

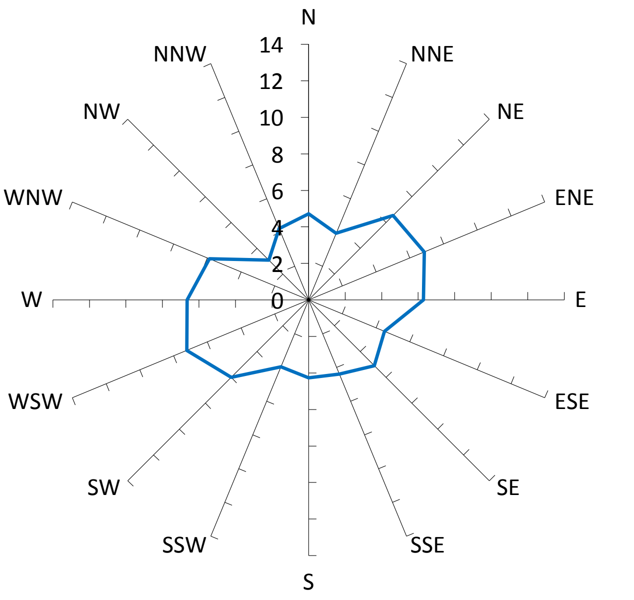
Results for Point 05

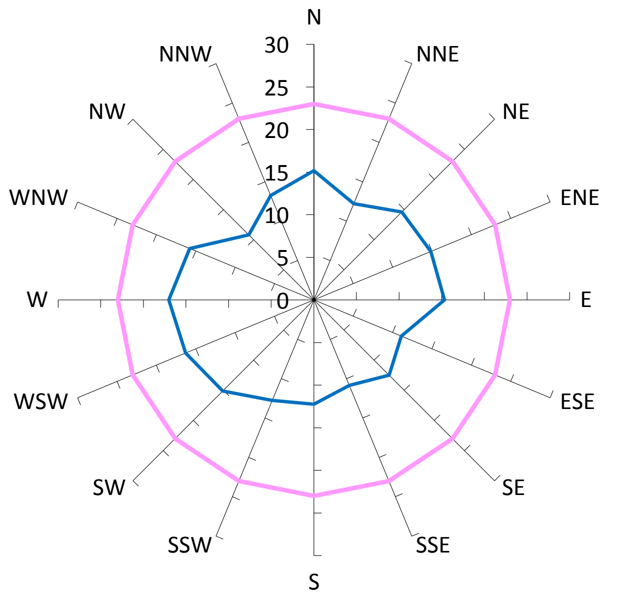
Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	3%	18

Results for Point 06

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)

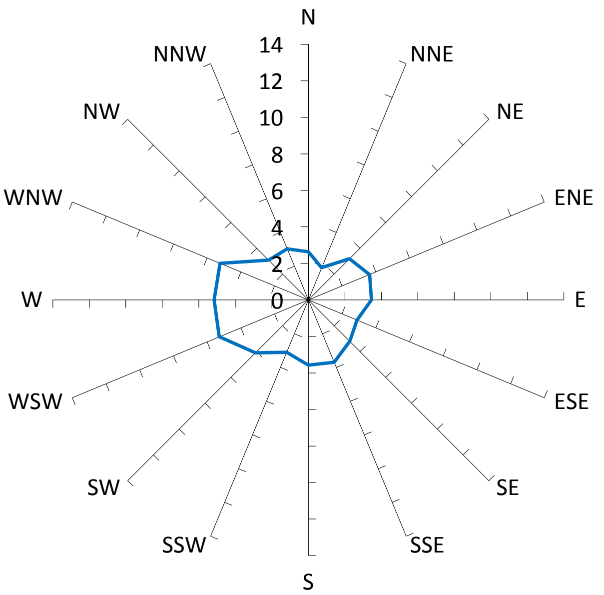
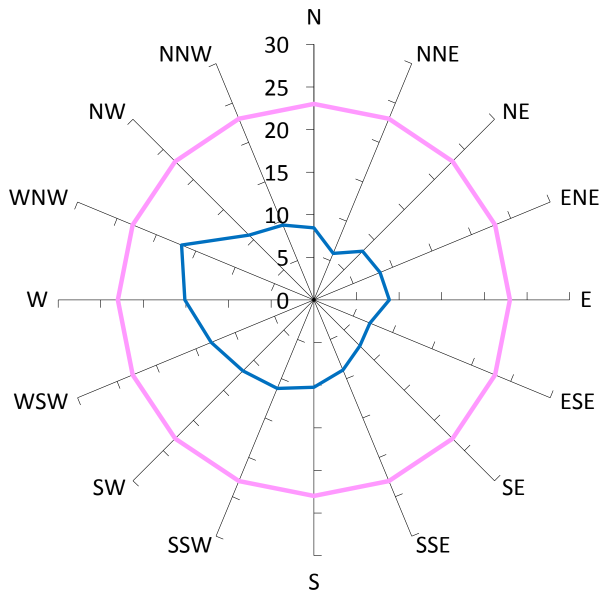




Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

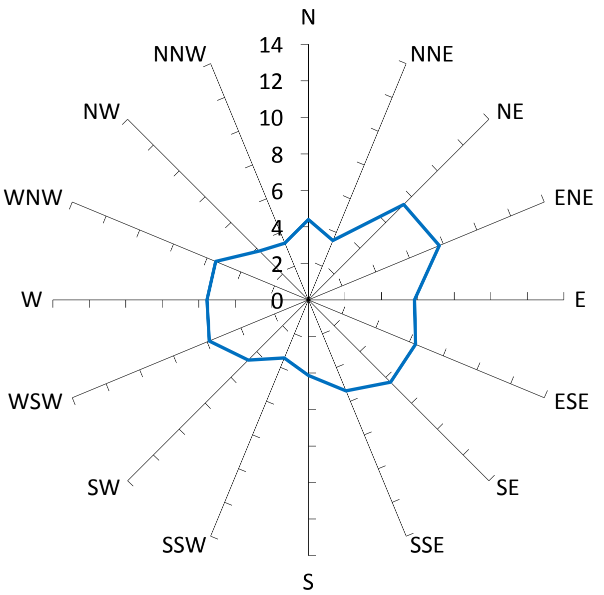
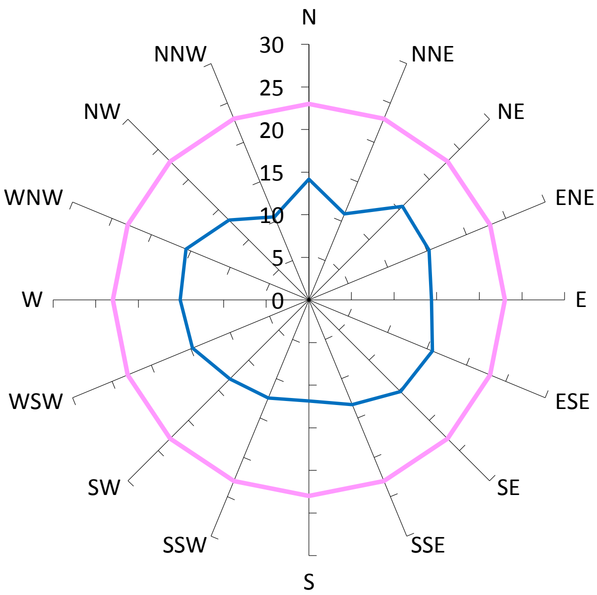
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	4%	17

Results for Point 07

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

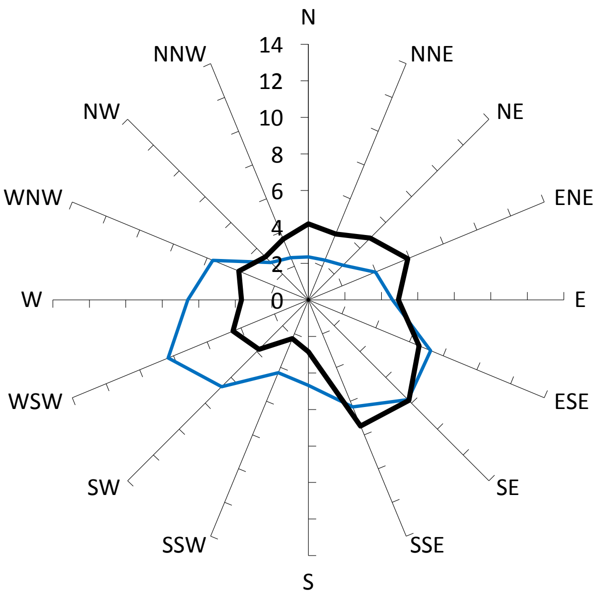
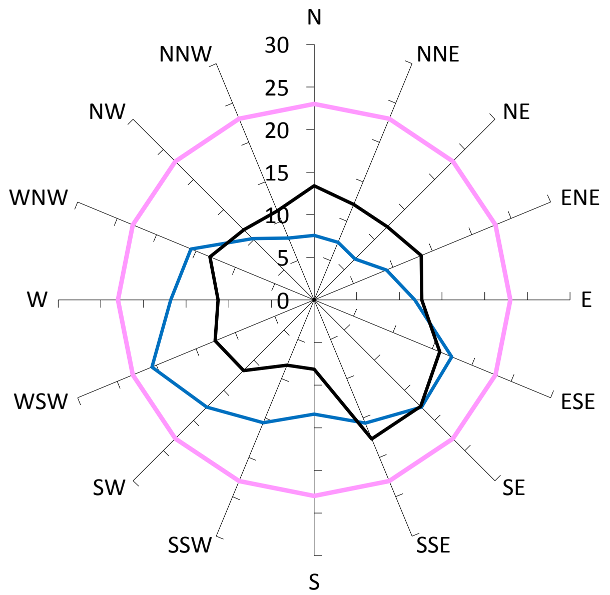
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	1%	17

Results for Point 08

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

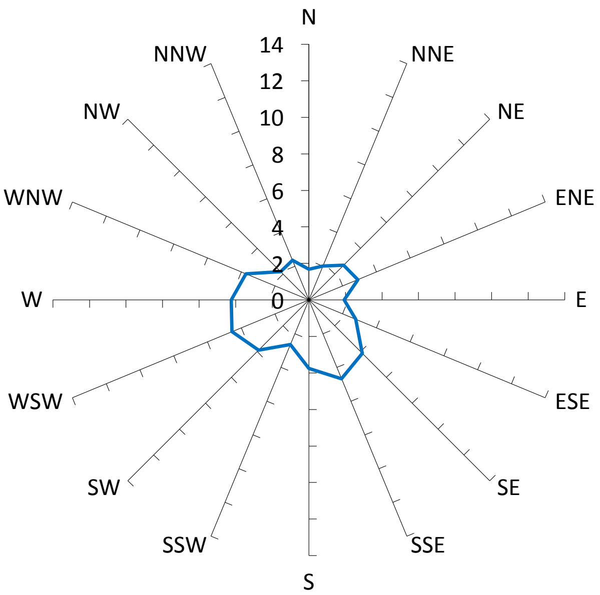
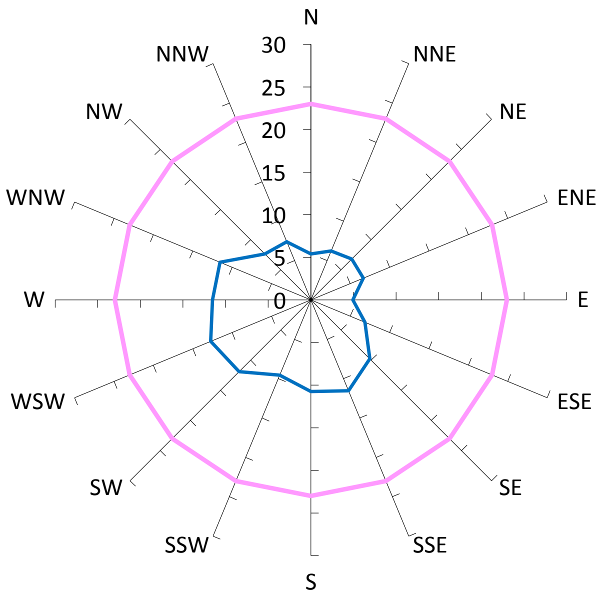
	Description	GEM Prob of Exceed %	Peak Gust m/s
pink line	*Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).*	5%	23
blue line	*With development "as proposed", no vegetation or other treatments.*	5%	16
black line			
red line			
yellow line			
light green line			
green line			
cyan line			
purple line			

Results for Point 09

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	6%	21
Existing site only	3%	18

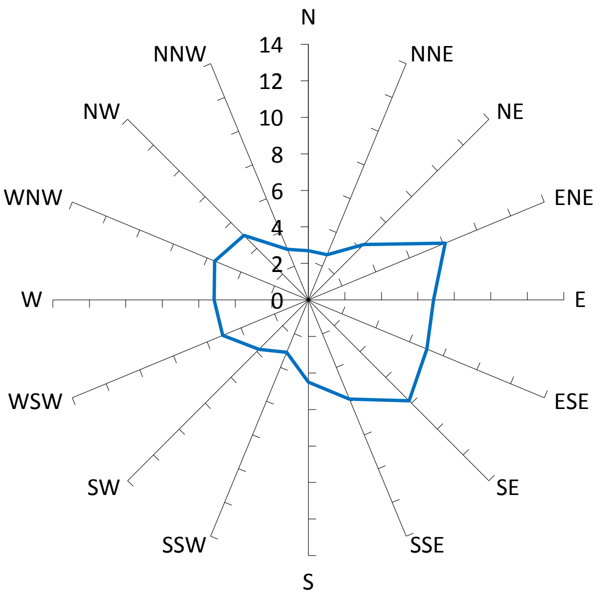
Results for Point 10

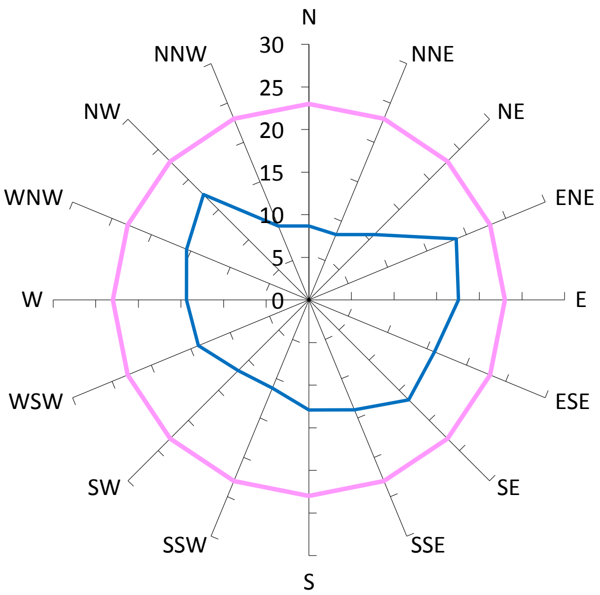
Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	13

Results for Point 11

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)



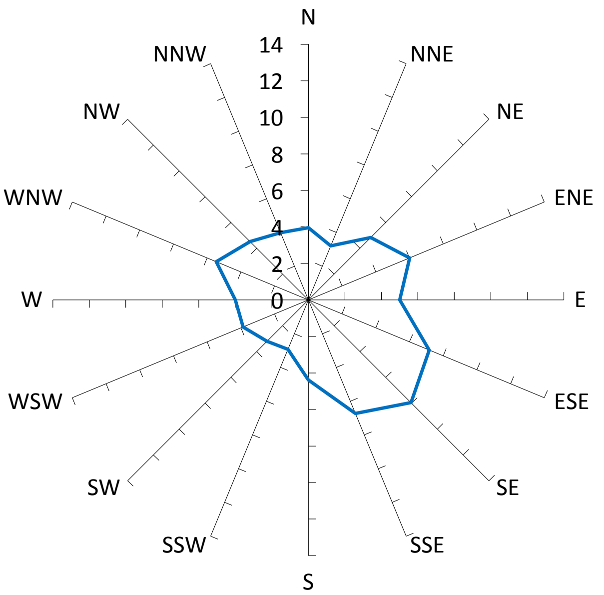


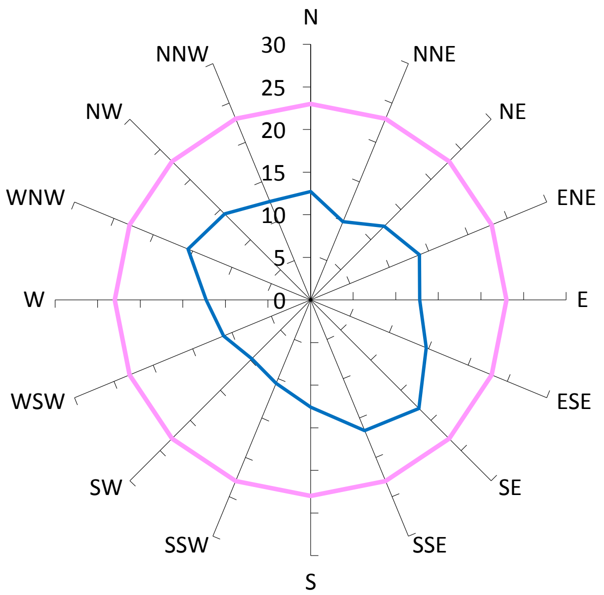
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	5%	19

Results for Point 12

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)

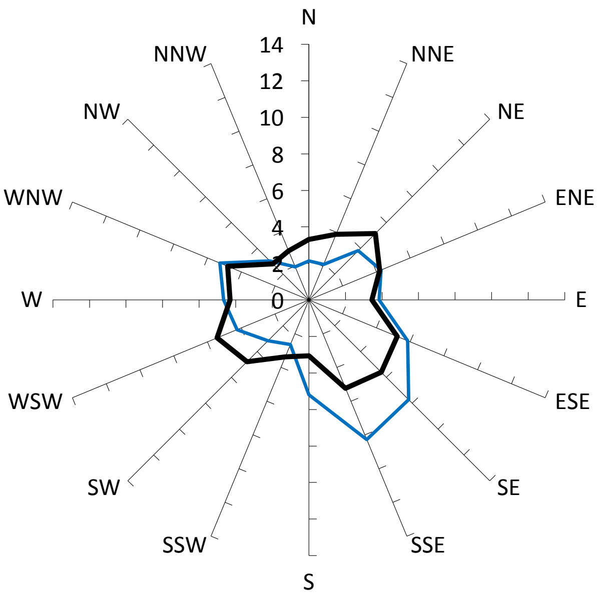
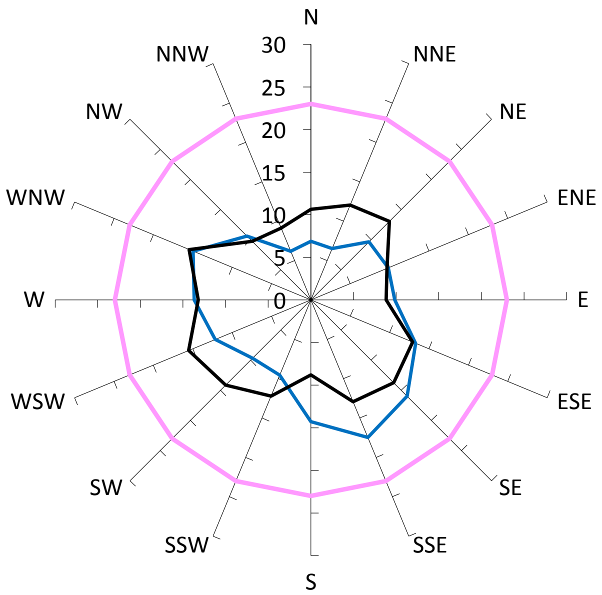




Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	3%	18

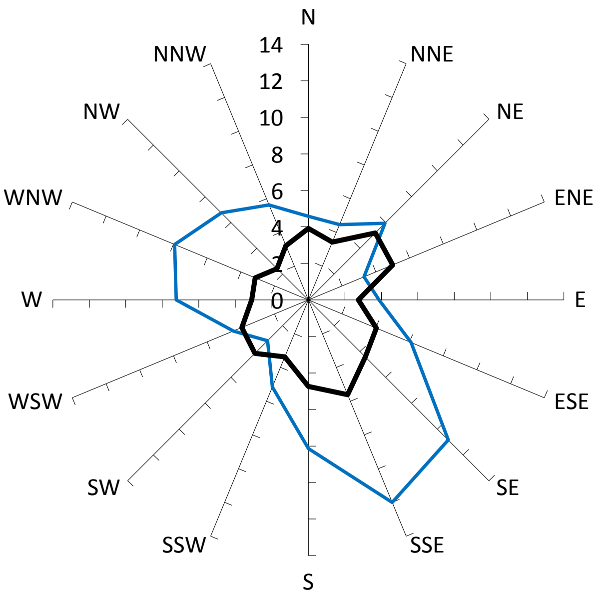
Results for Point 13

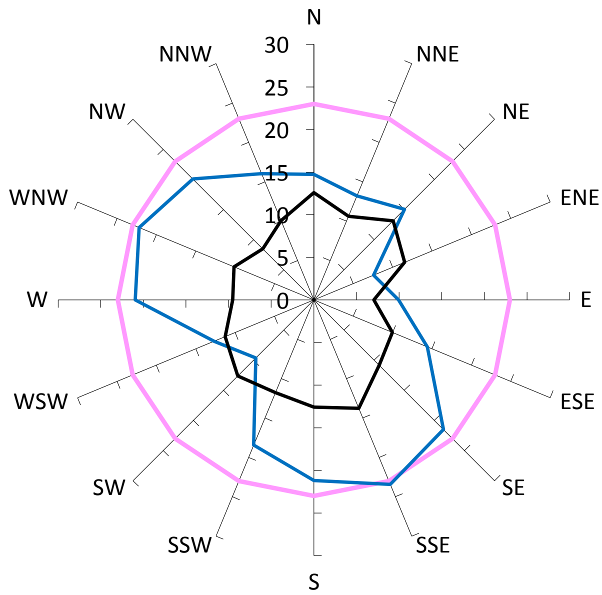
Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	4%	17
Existing site only	1%	16

Results for Point 14

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)



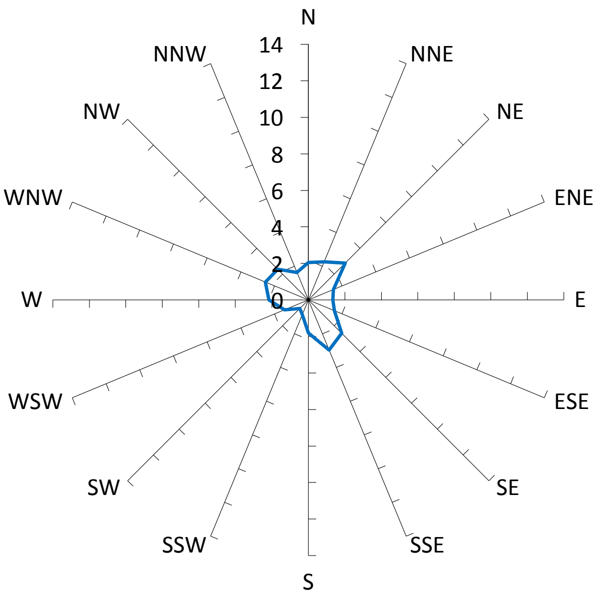


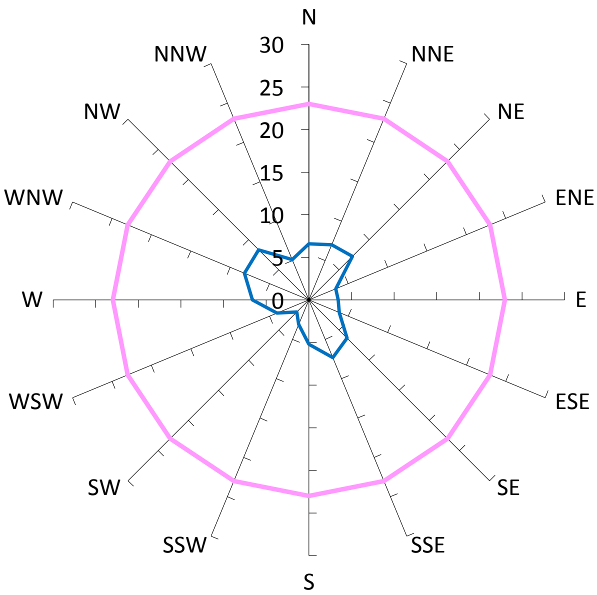
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	15%	23
Existing site only	0%	14

Results for Point 15

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)



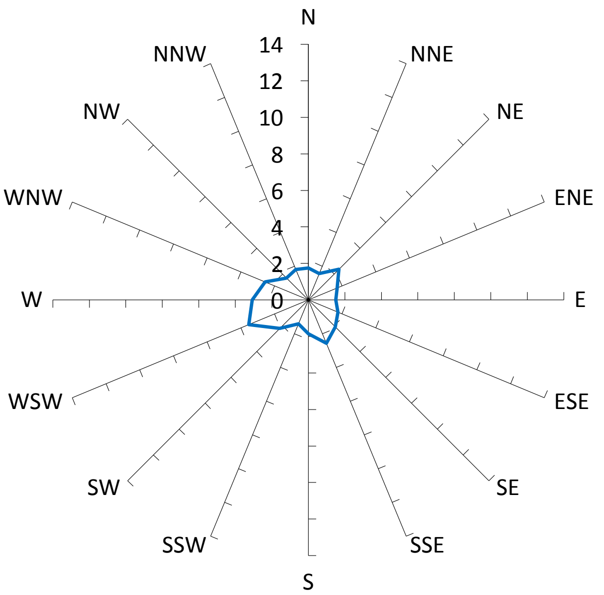


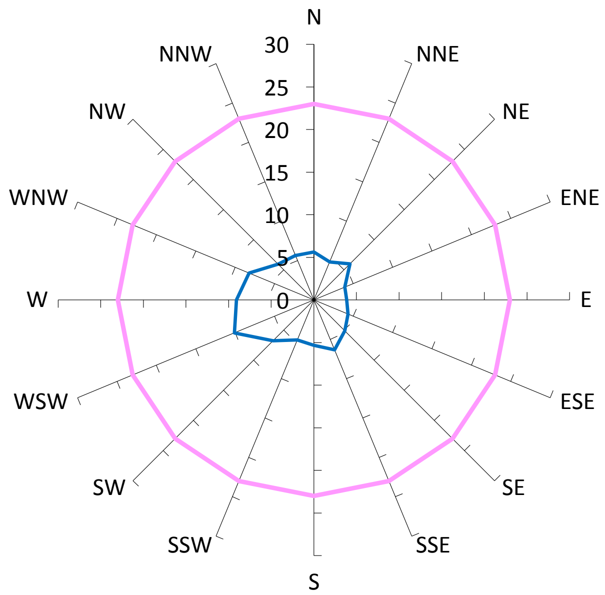
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	8

Results for Point 16

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)

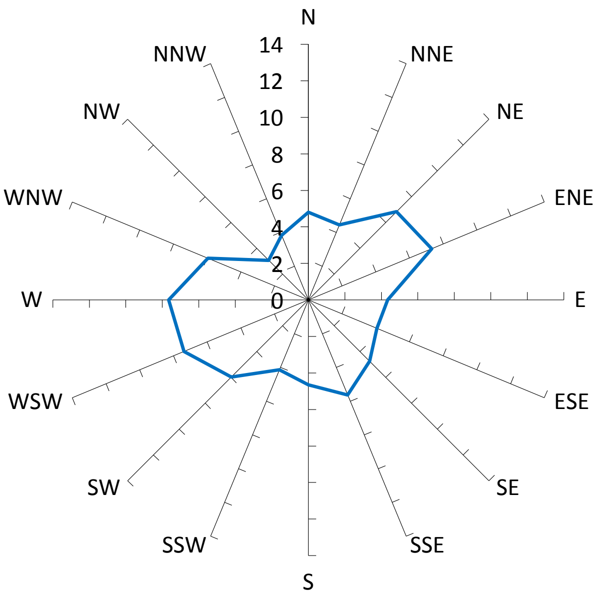
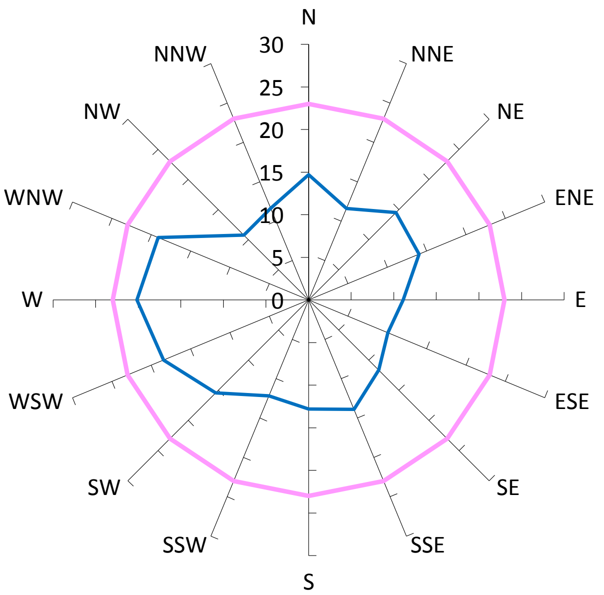




Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	10

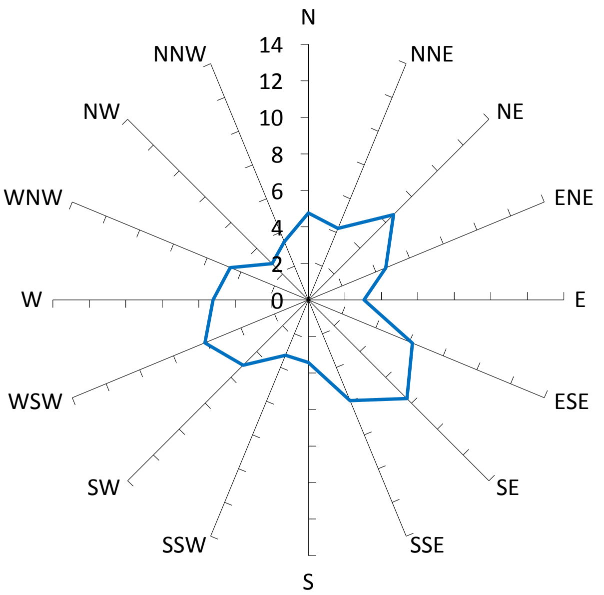
Results for Point 17

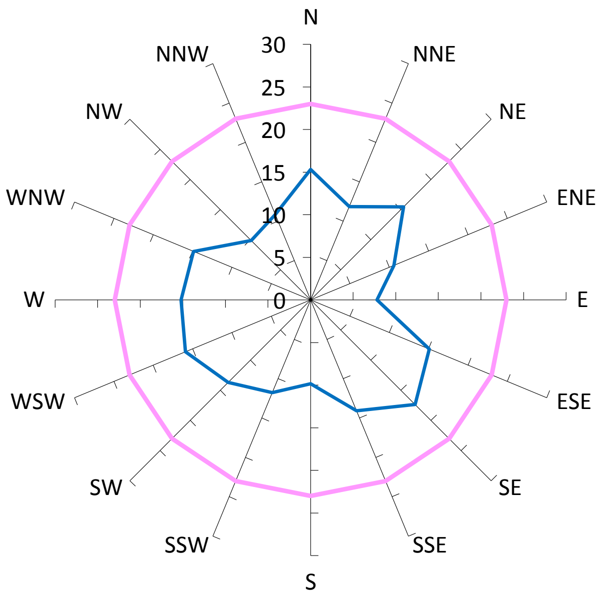
Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	5%	20

Results for Point 18

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)

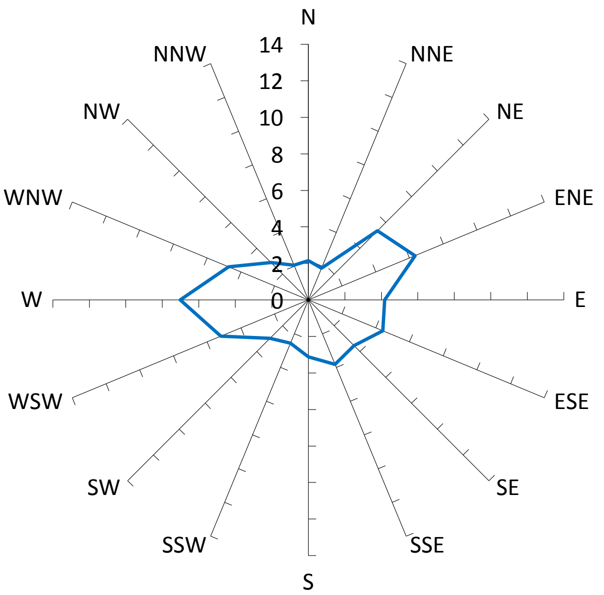
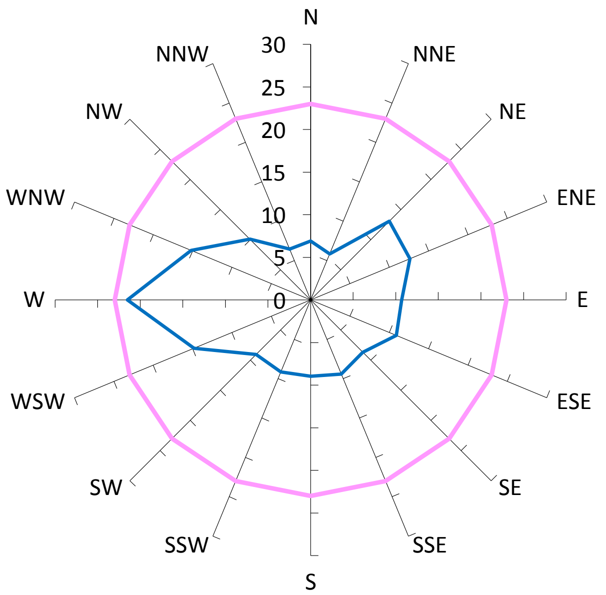




Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

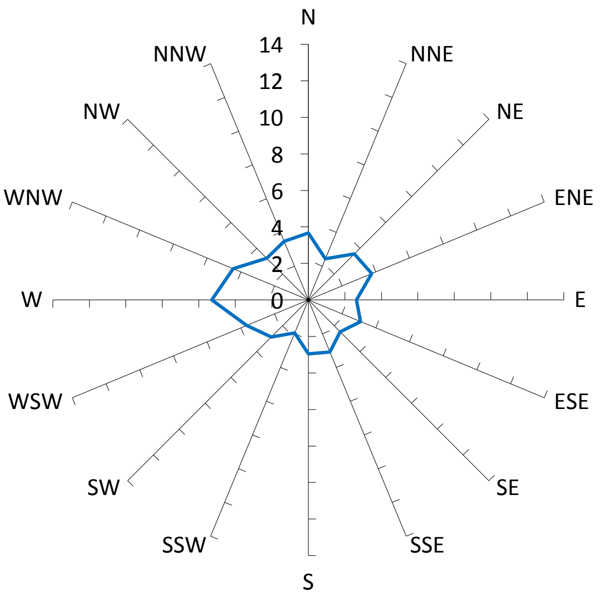
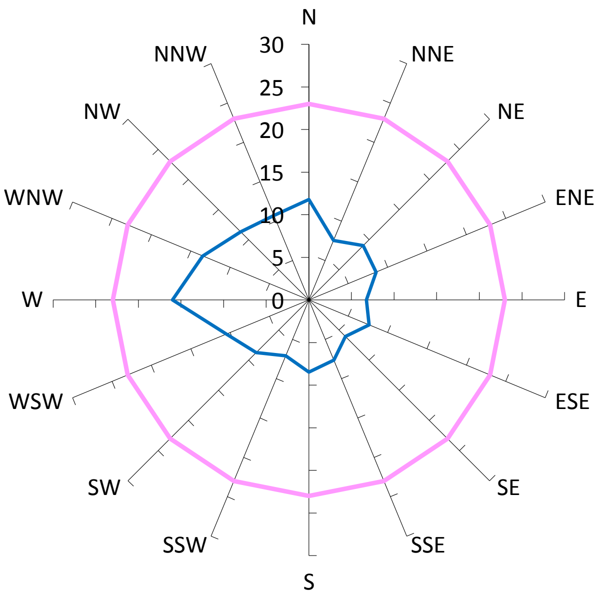
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	3%	17

Results for Point 19

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

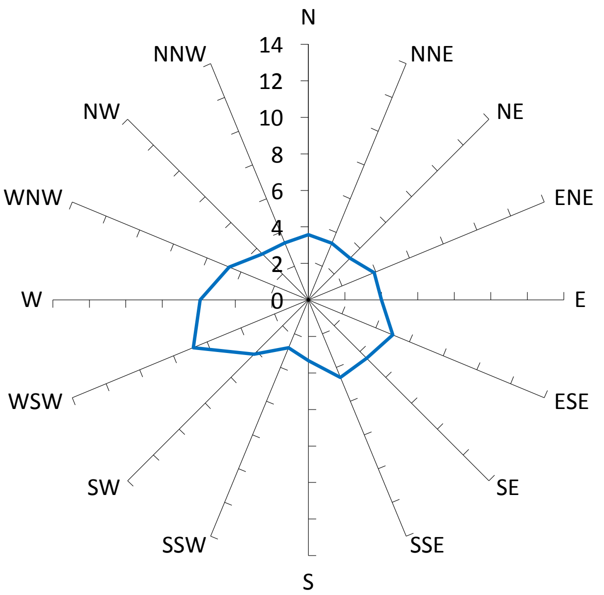
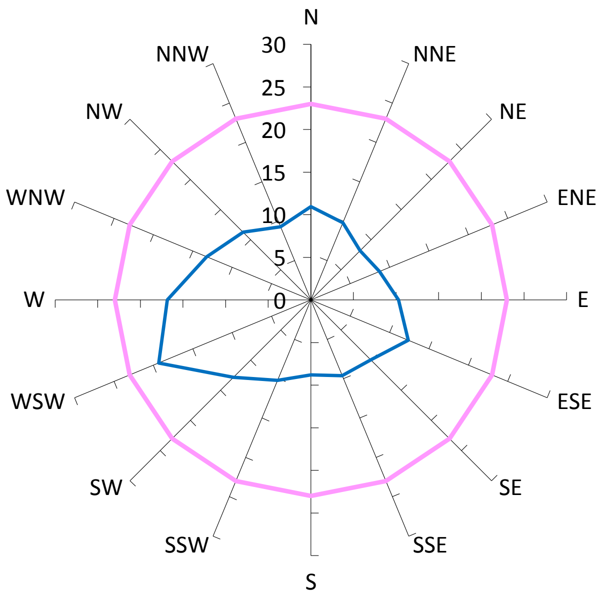
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	1%	22

Results for Point 20

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

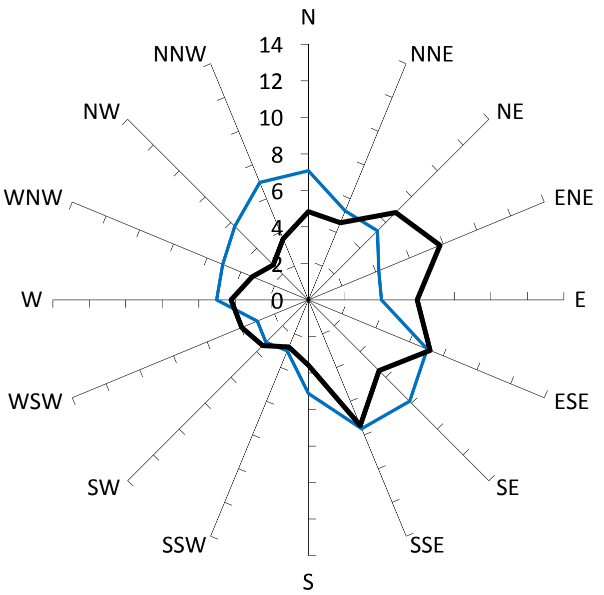
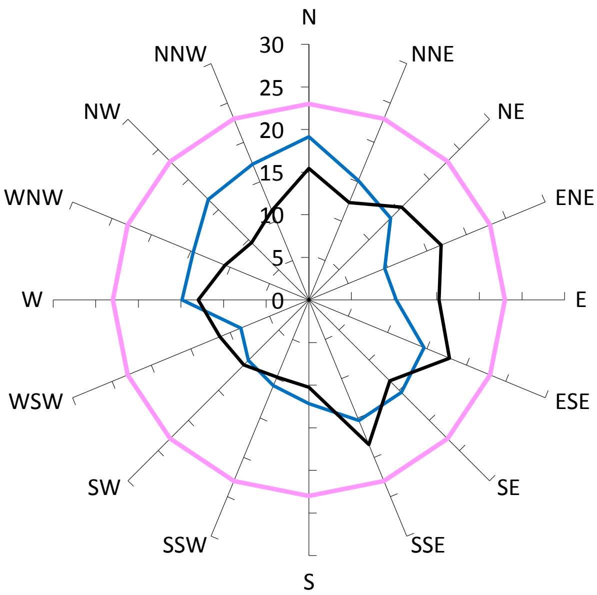
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	16

Results for Point 21

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

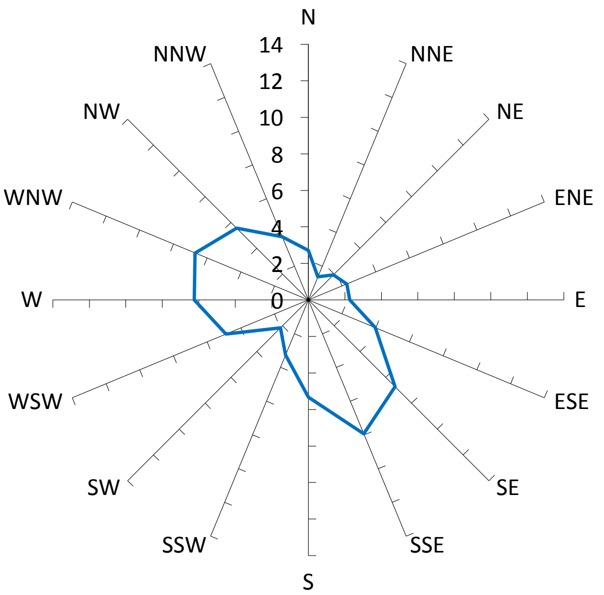
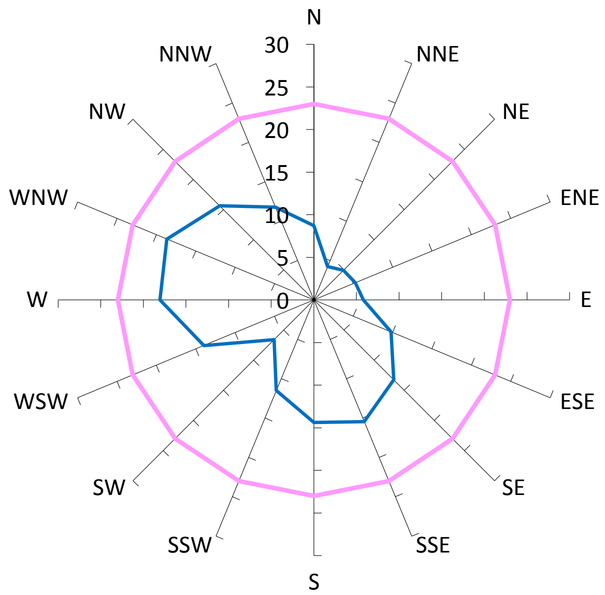
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	2%	19

Results for Point 22

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

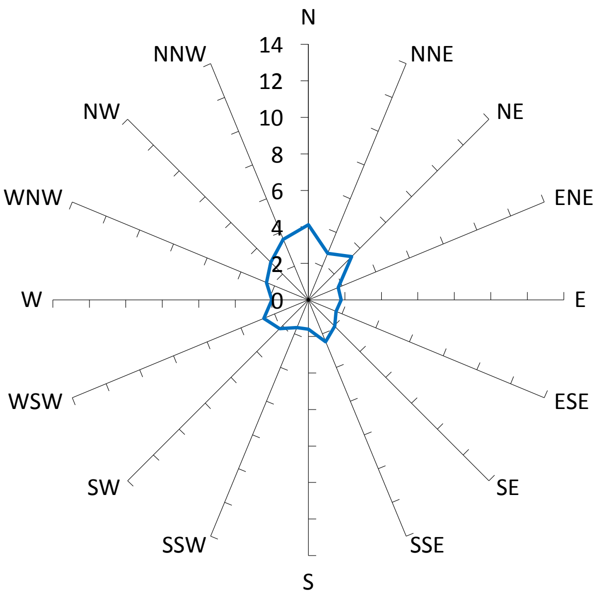
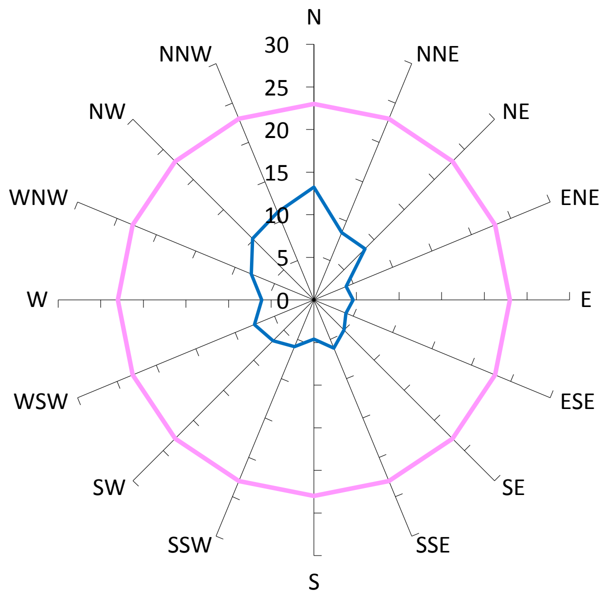
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	6%	19
Existing site only	4%	18

Results for Point 23

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

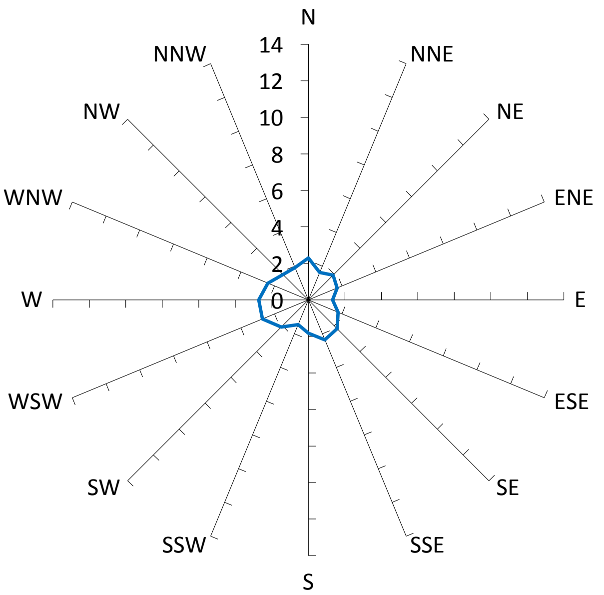
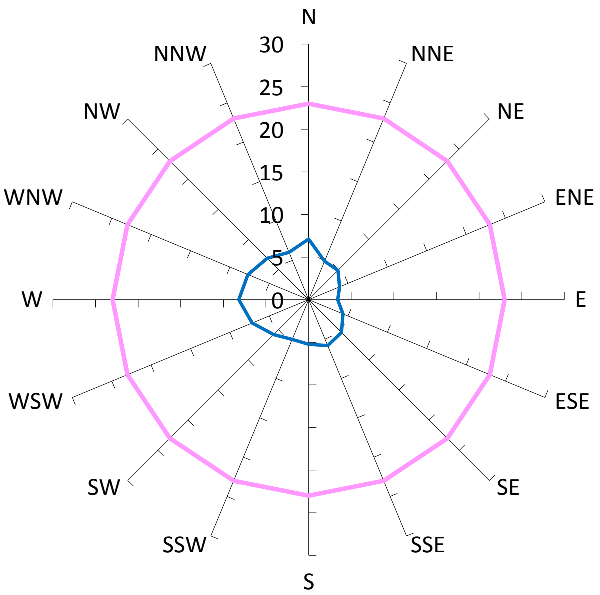
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	4%	19

Results for Point 24

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

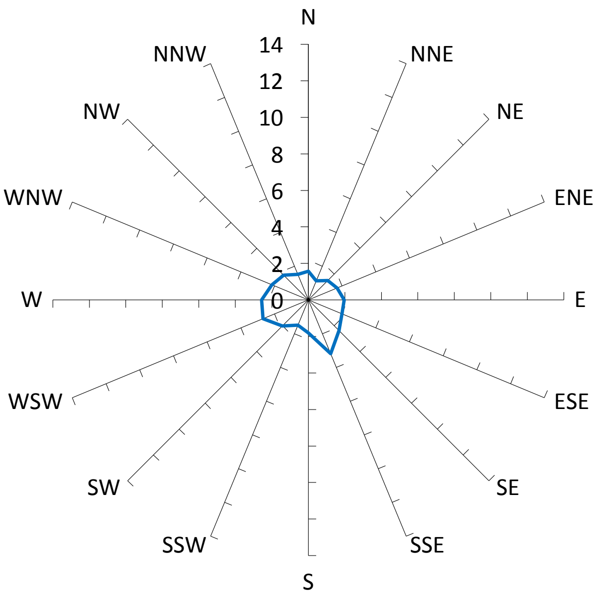
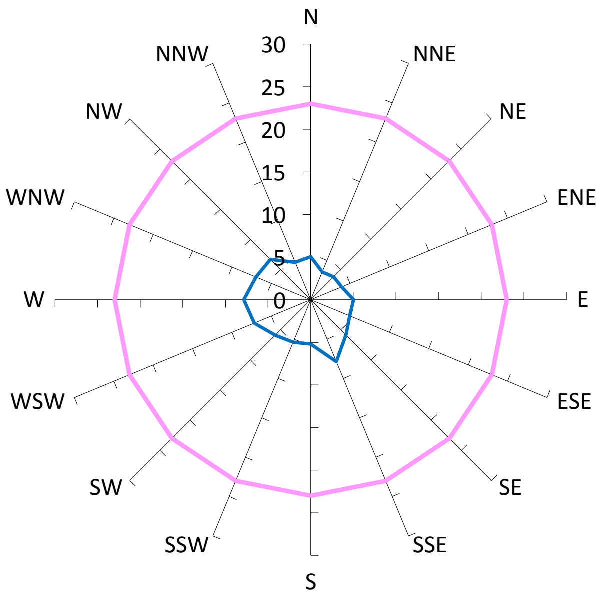
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	13

Results for Point 25

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

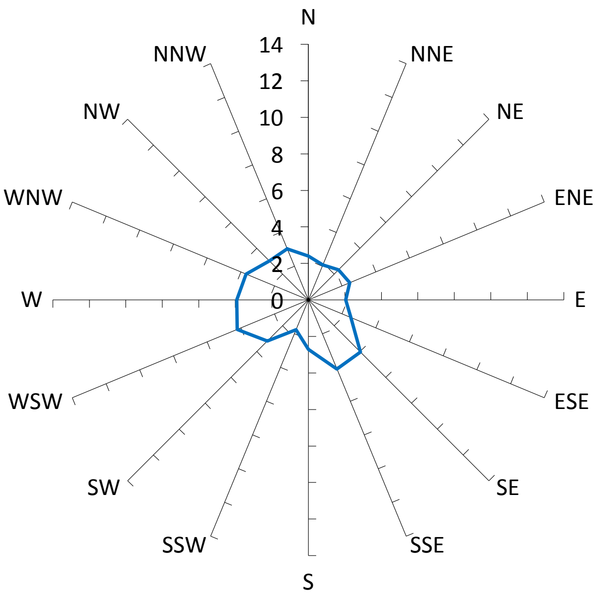
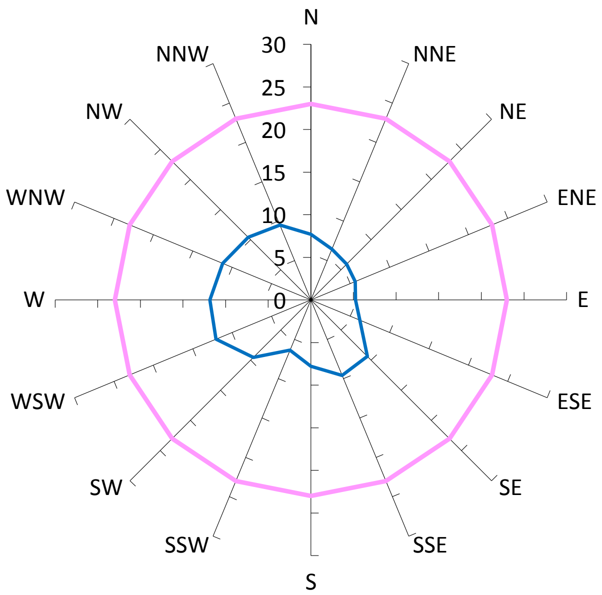
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	8

Results for Point 26

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

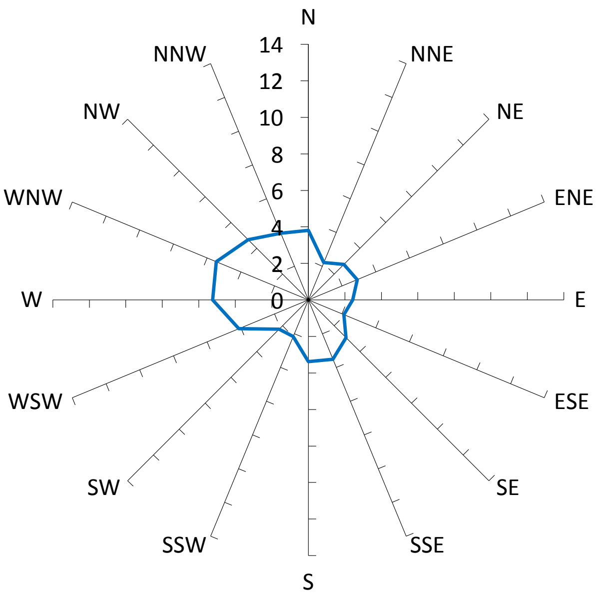
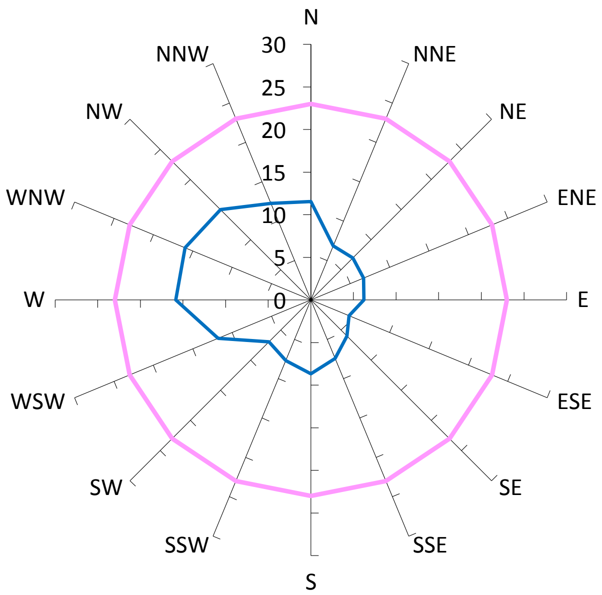
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	8

Results for Point 27

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

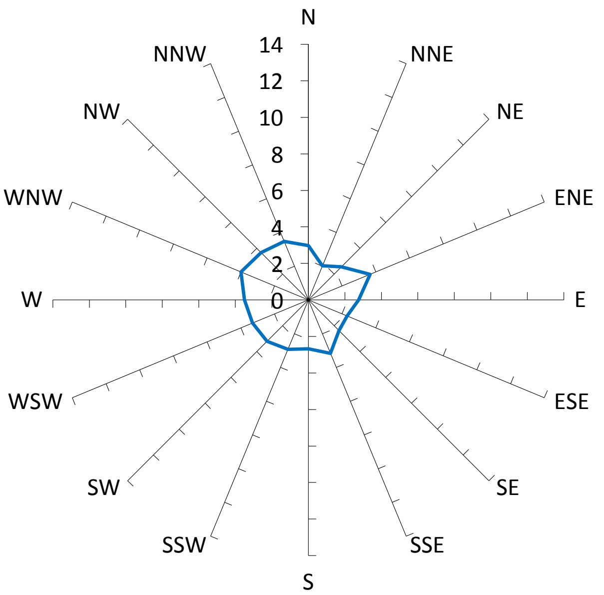
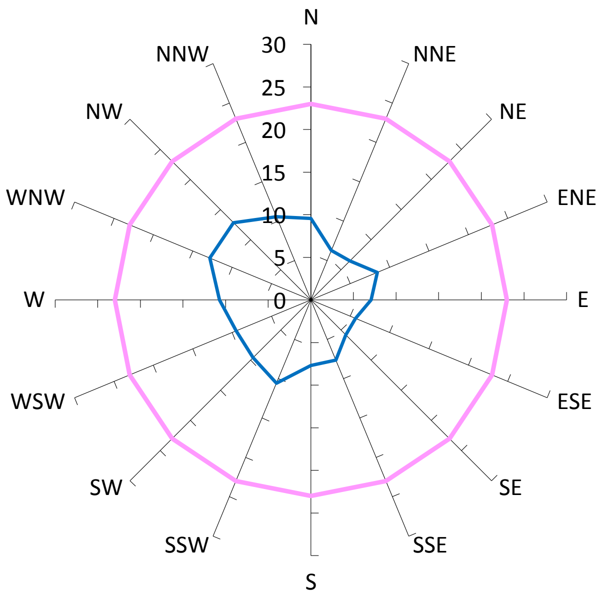
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	1%	12

Results for Point 28

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

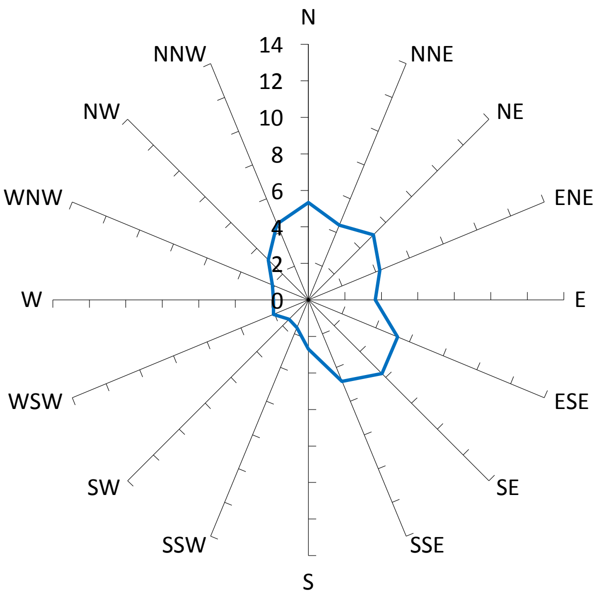
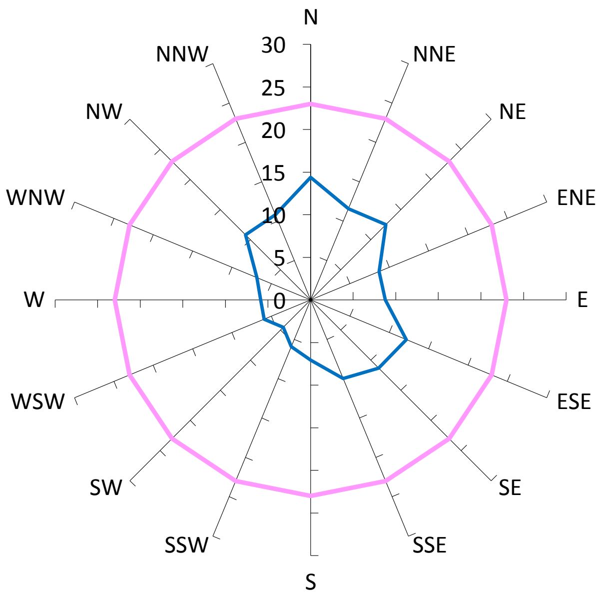
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	4%	16

Results for Point 29

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	1%	13

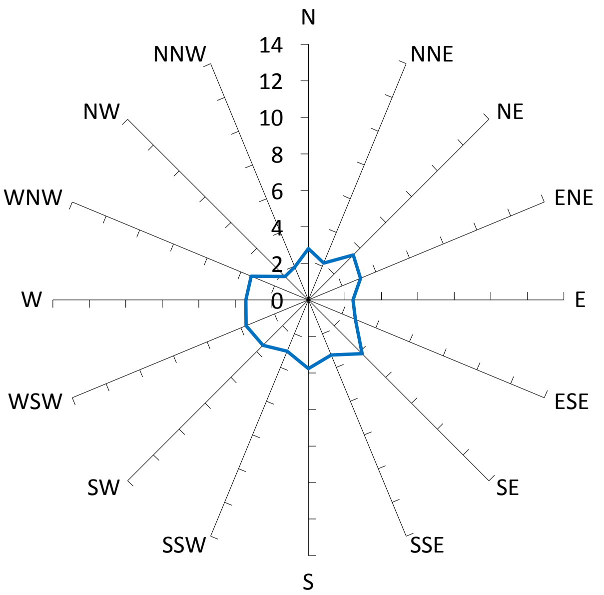
Results for Point 30

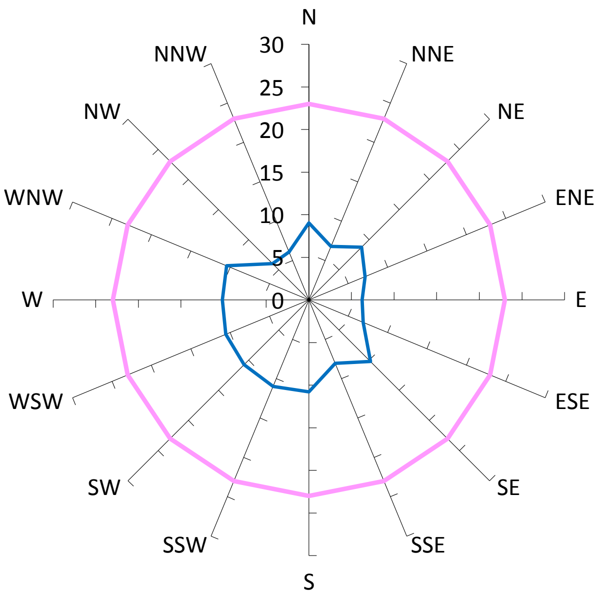
Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	5%	14

Results for Point 31

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)

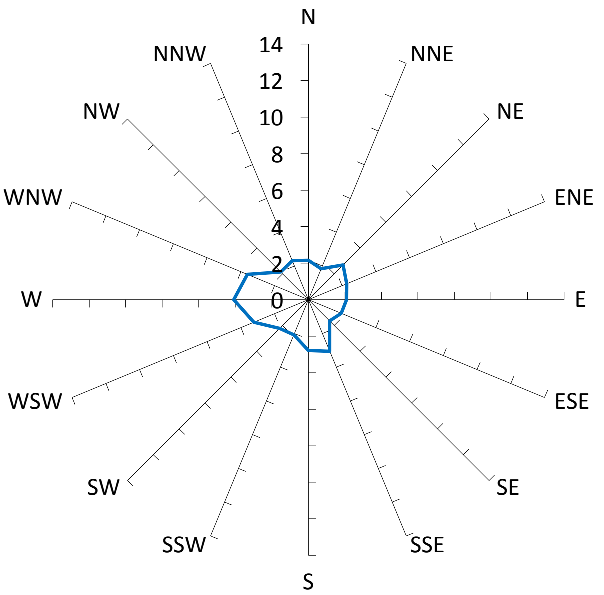
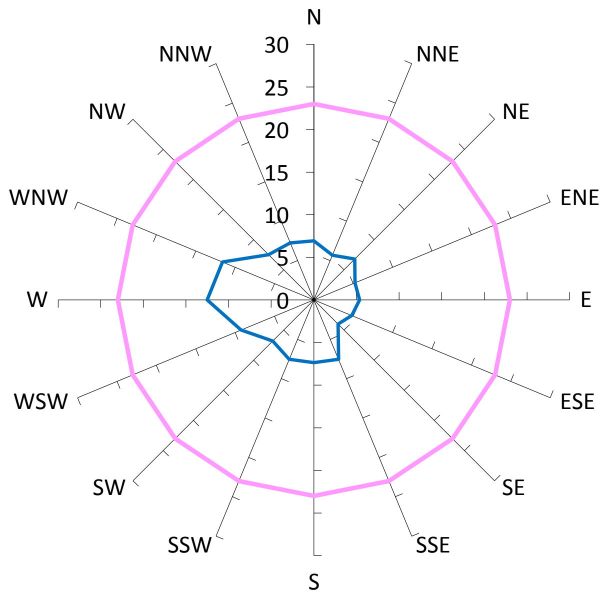




Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

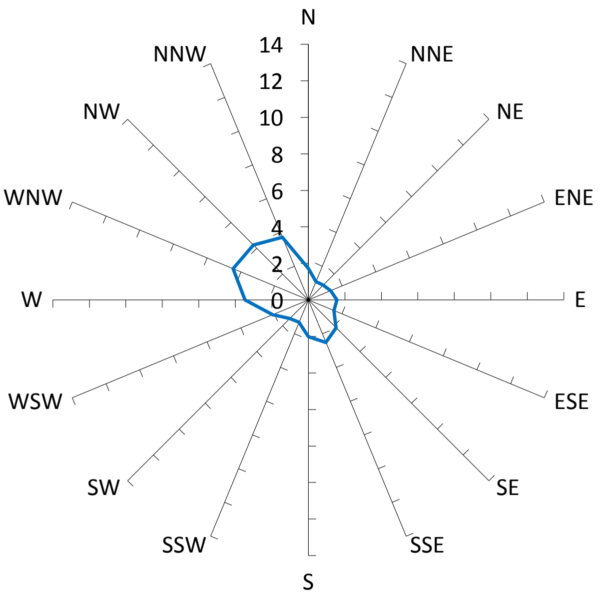
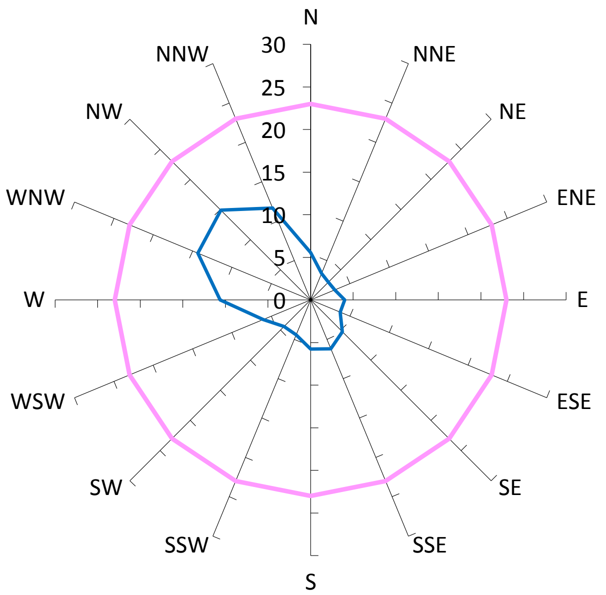
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	1%	11

Results for Point 32

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

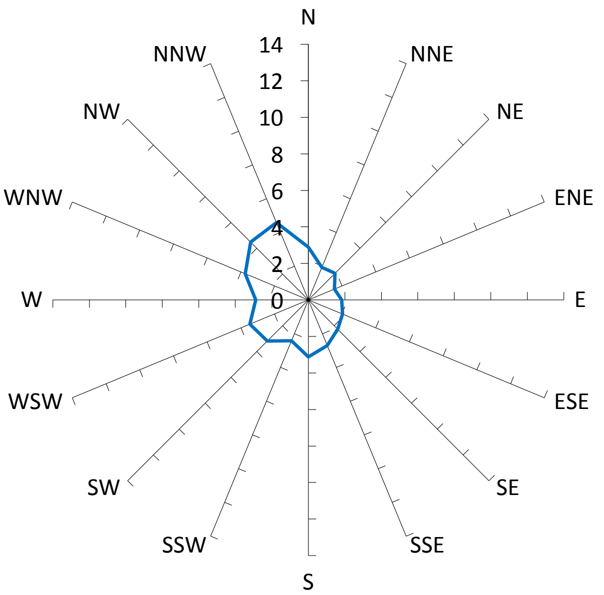
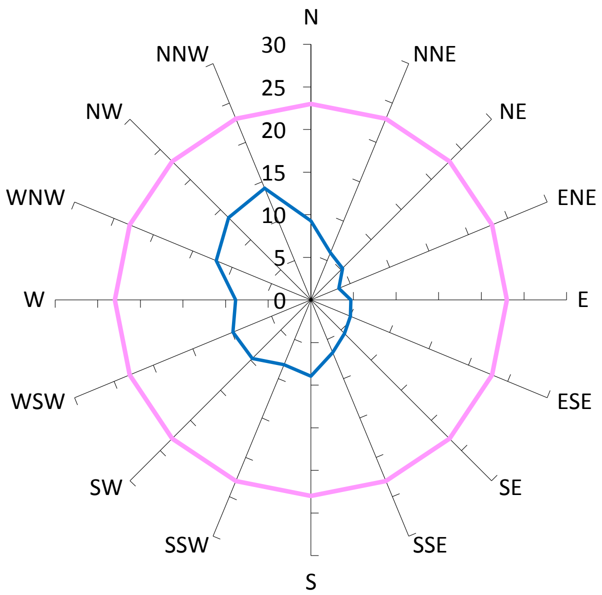
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	1%	13

Results for Point 33

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

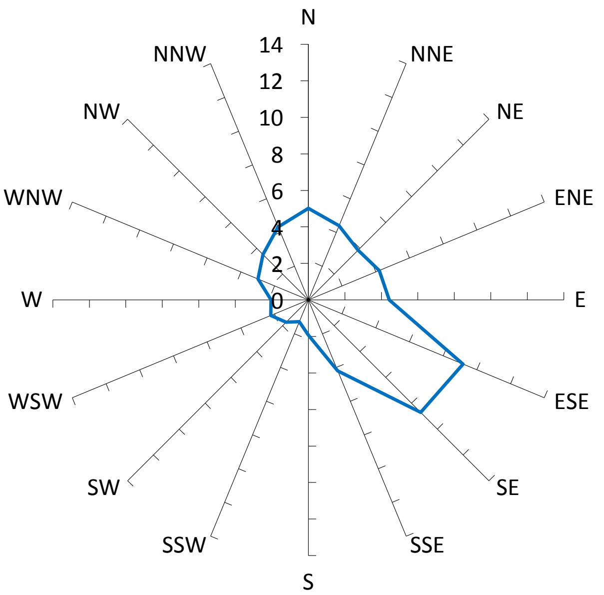
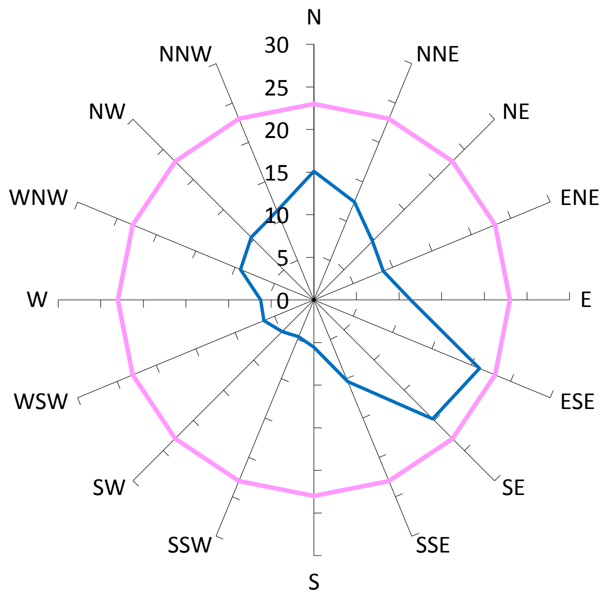
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	2%	15

Results for Point 34

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

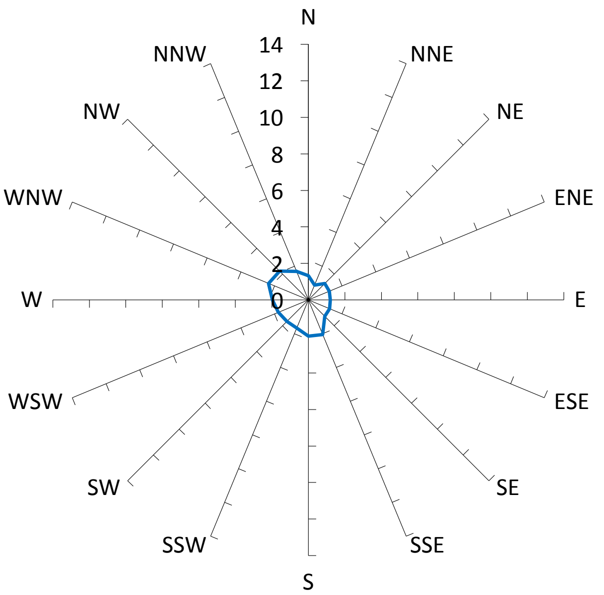
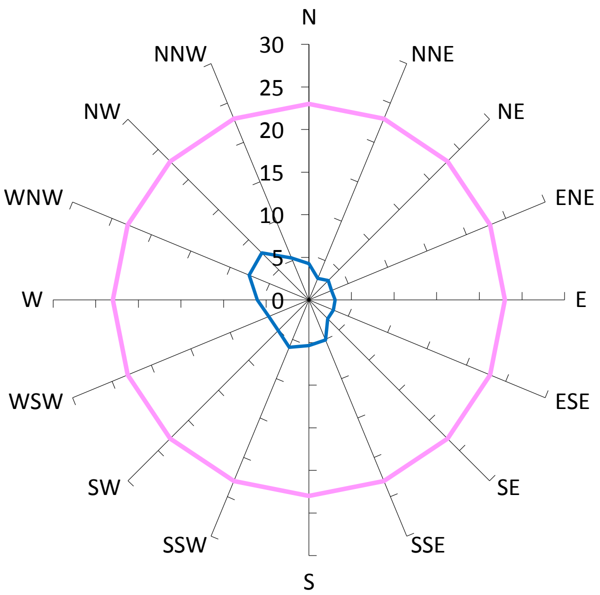
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	2%	14

Results for Point 35

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

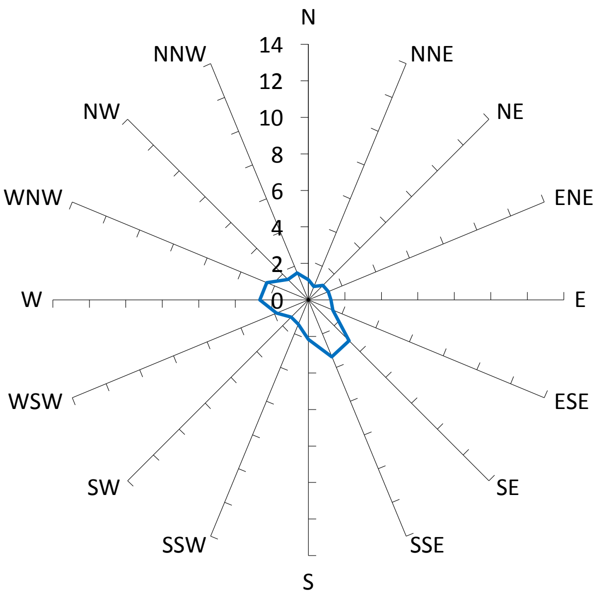
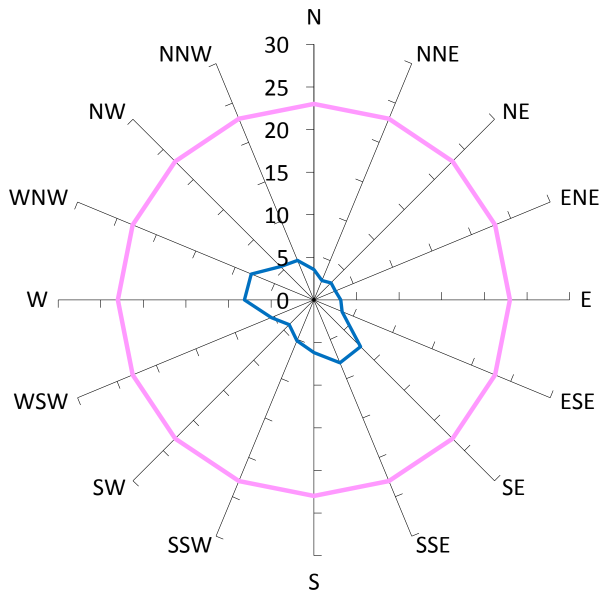
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	11%	21

Results for Point 36

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

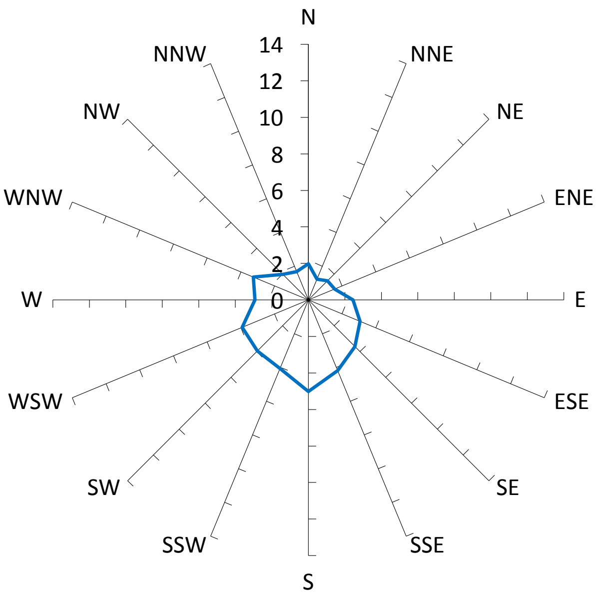
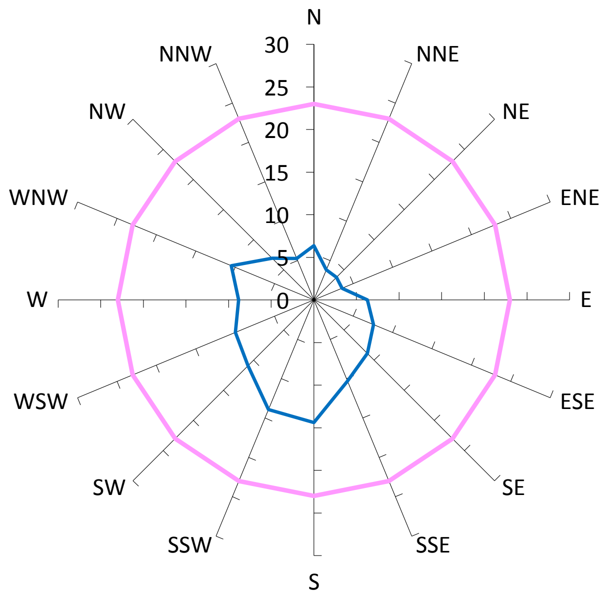
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	8

Results for Point 37

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

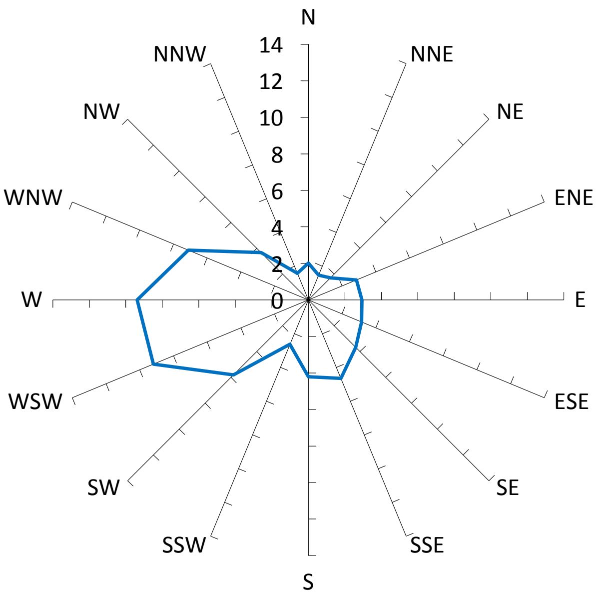
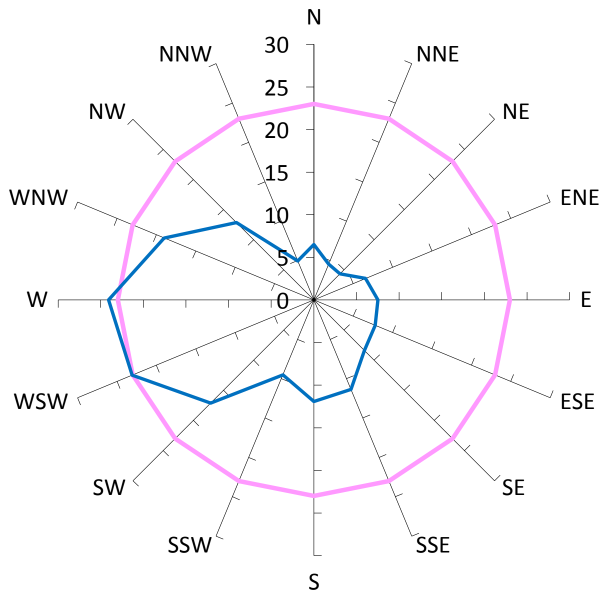
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	8

Results for Point 38

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

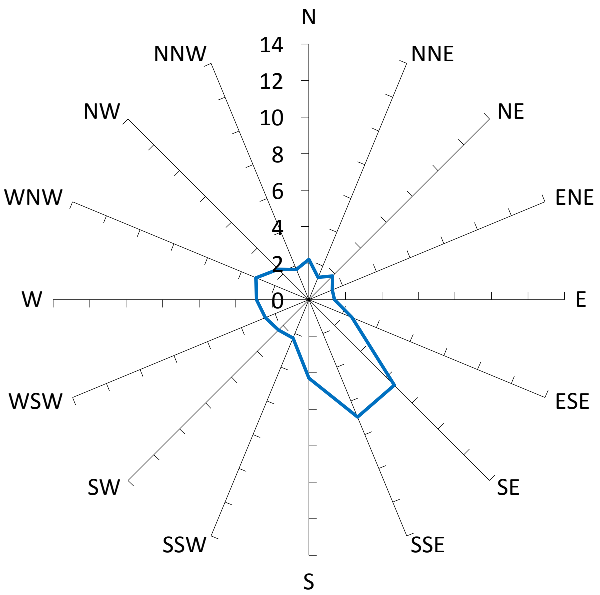
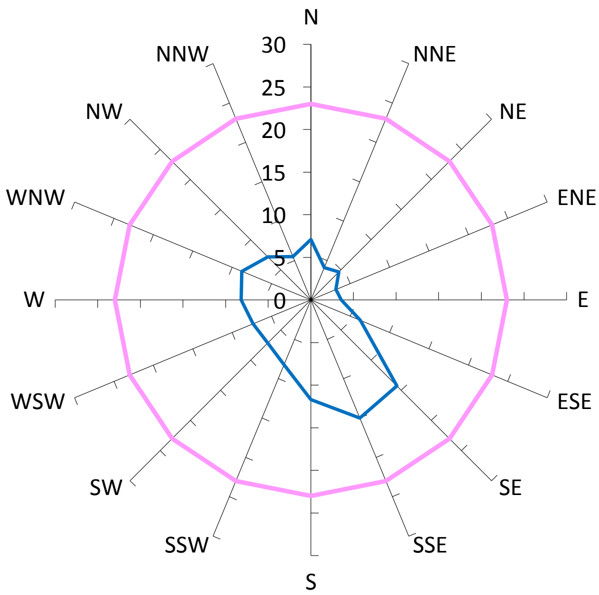
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	2%	14

Results for Point 39

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

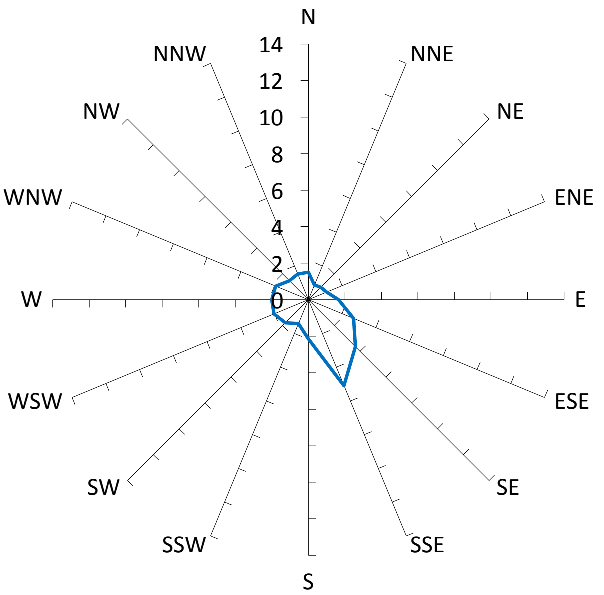
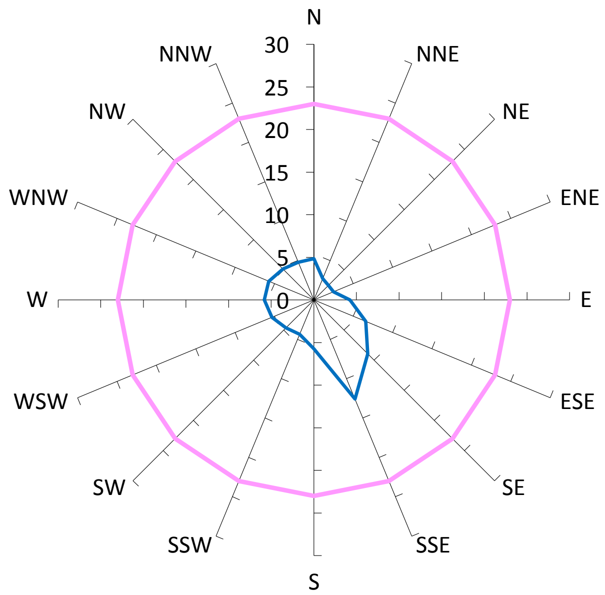
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	16%	24

Results for Point 40

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

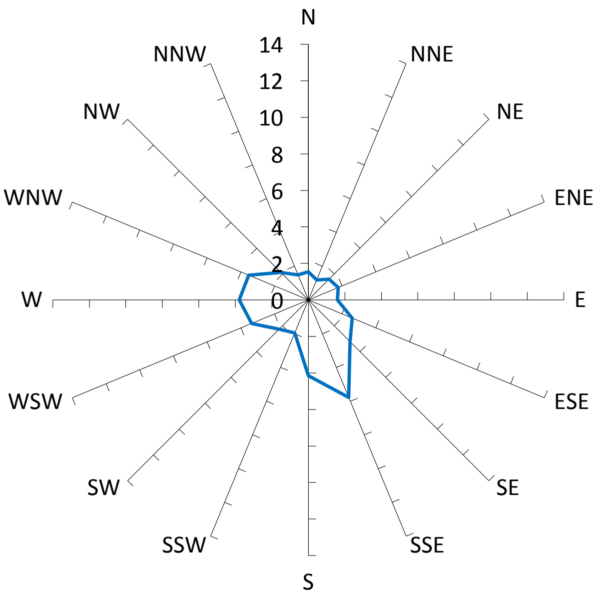
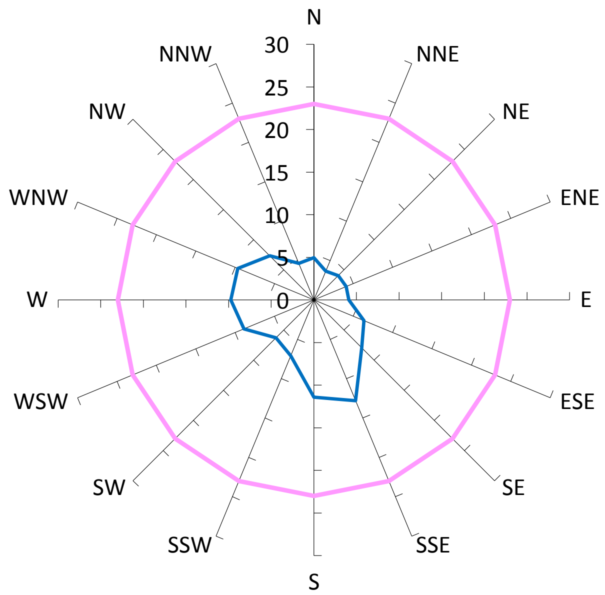
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	7%	15

Results for Point 41

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	1%	13

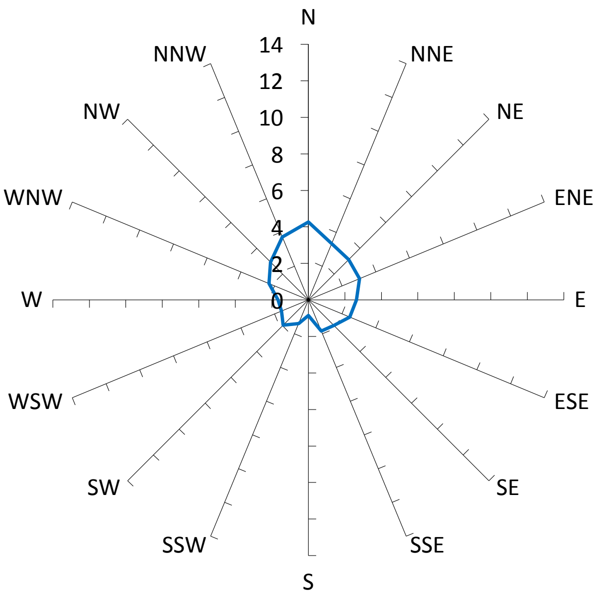
Results for Point 42

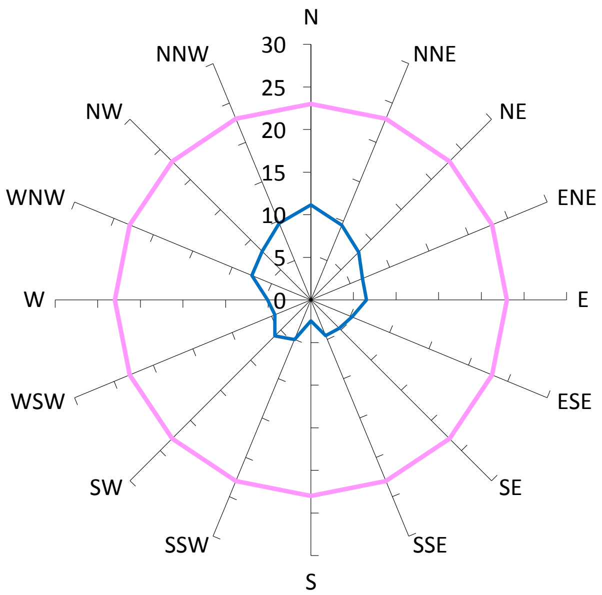
Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	2%	13

Results for Point 43

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)

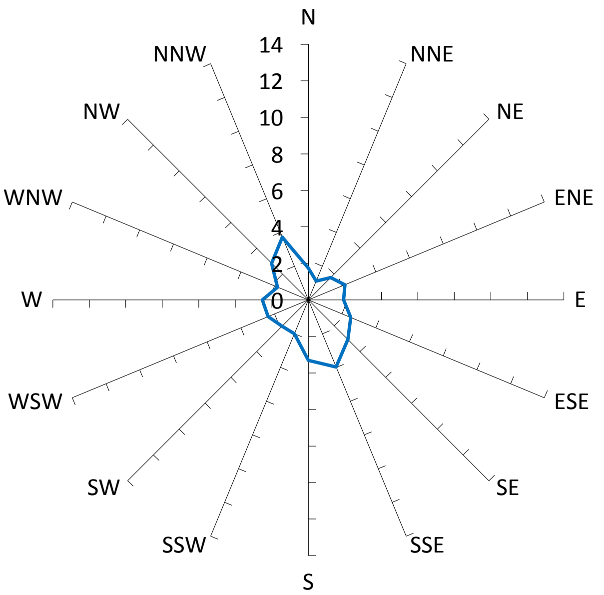
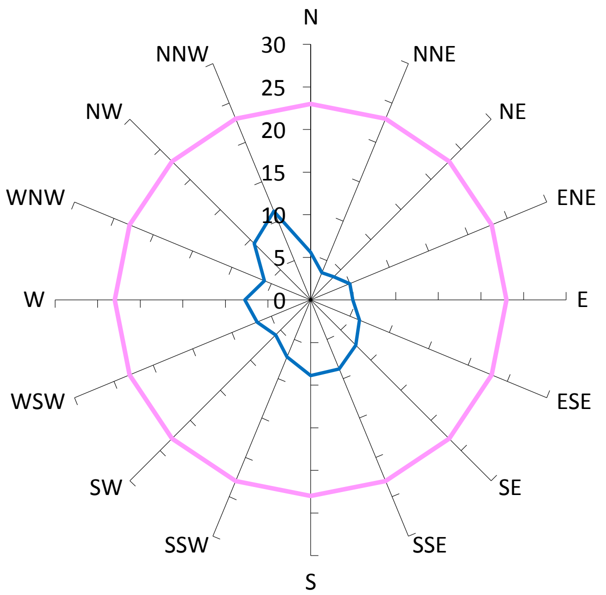




Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

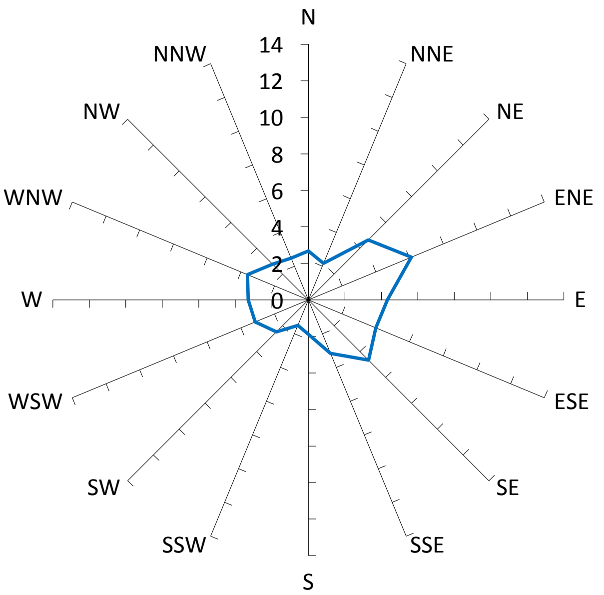
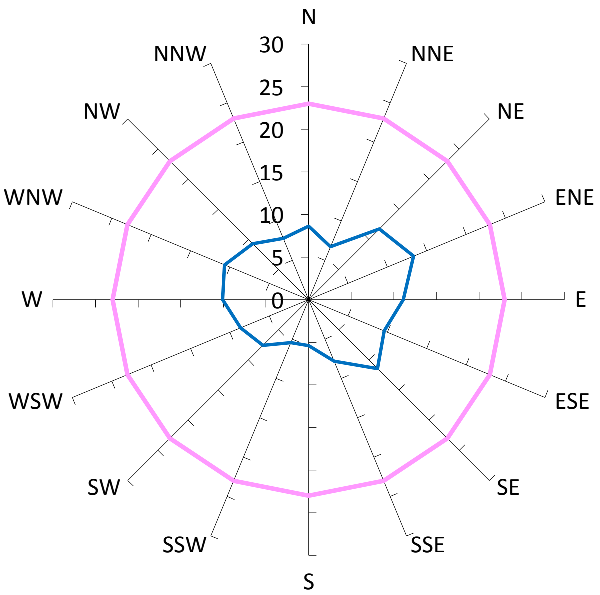
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	1%	11

Results for Point 44

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 5.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

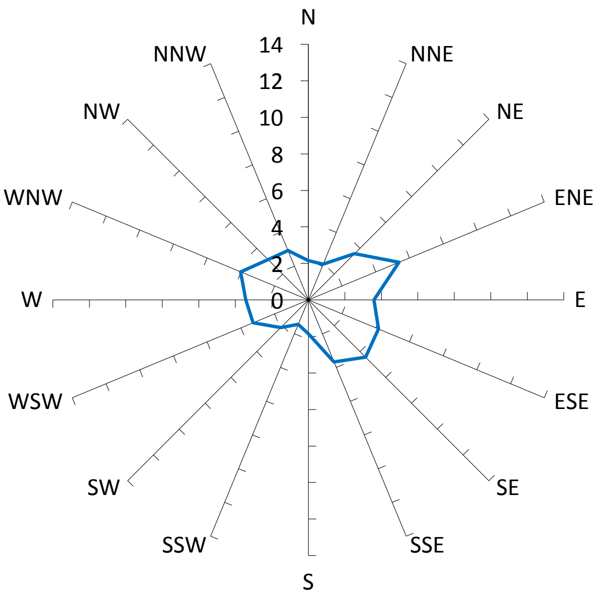
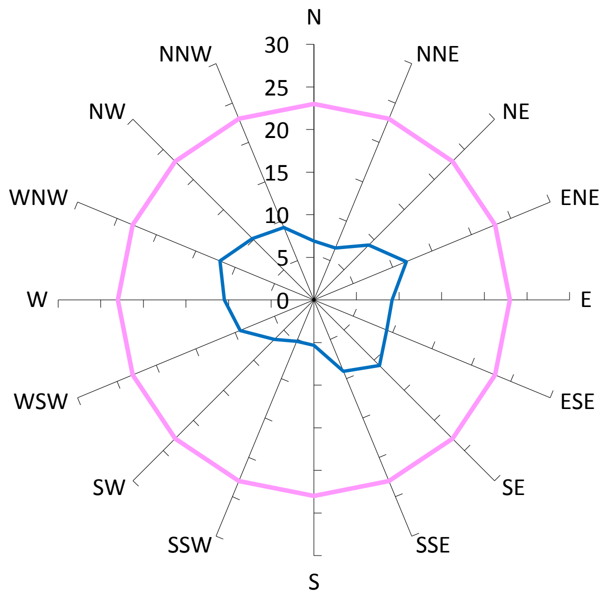
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	11

Results for Point 101

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	13

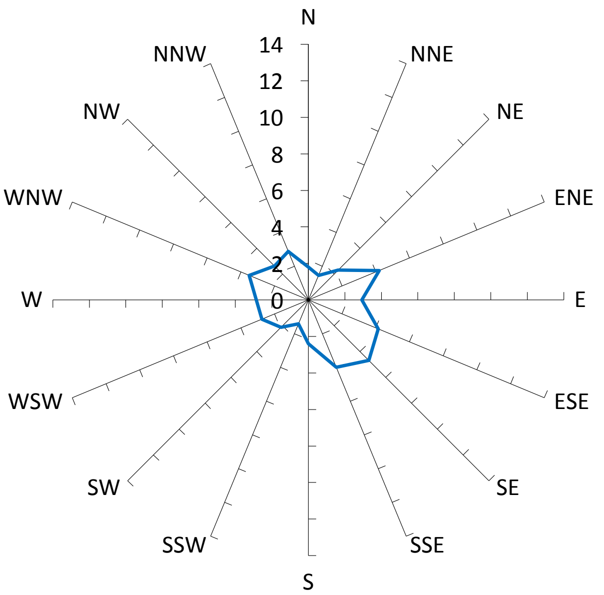
Results for Point 102

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	12

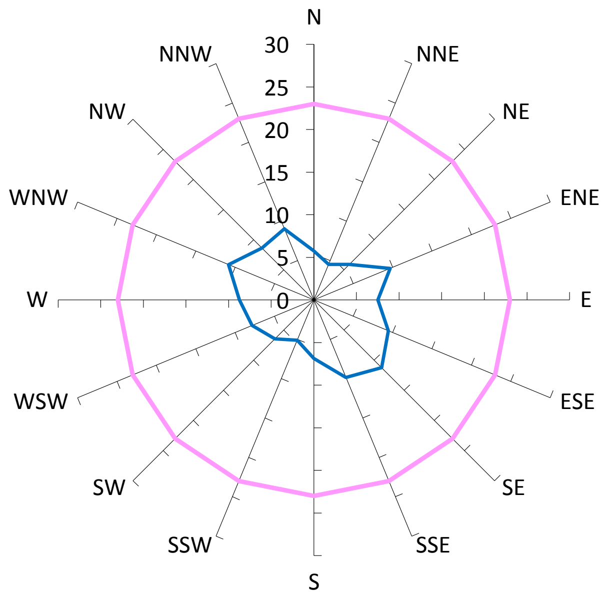
Results for Point 103

Gust Equivalent Mean (m/s)



Comfort Criteria: 7.5m/s with 5% probability of exceedence

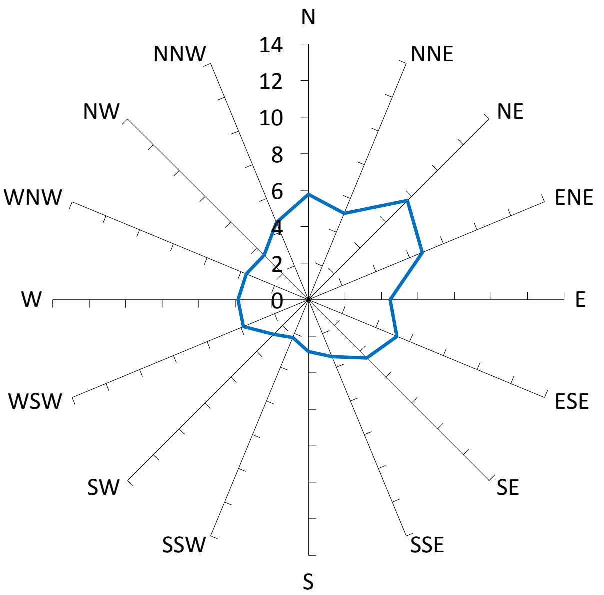
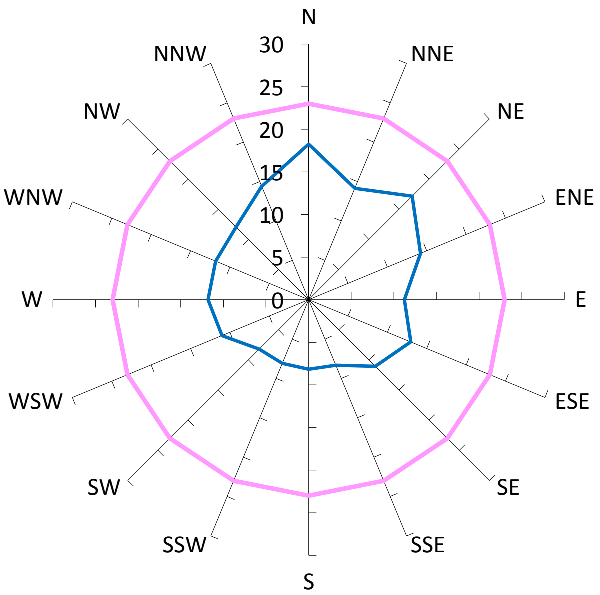
Maximum Gust (m/s)



Safety Limit: 23m/s

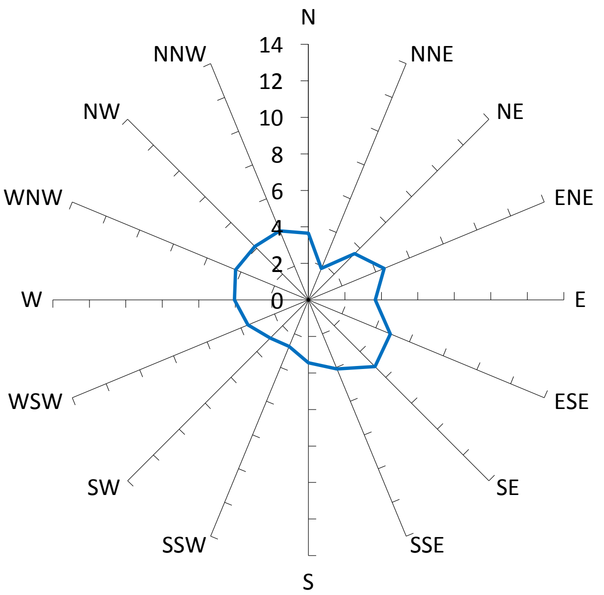
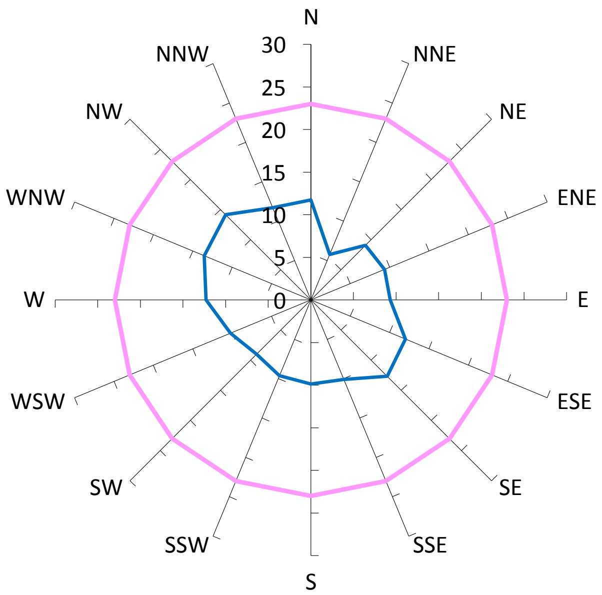
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	11

Results for Point 104

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

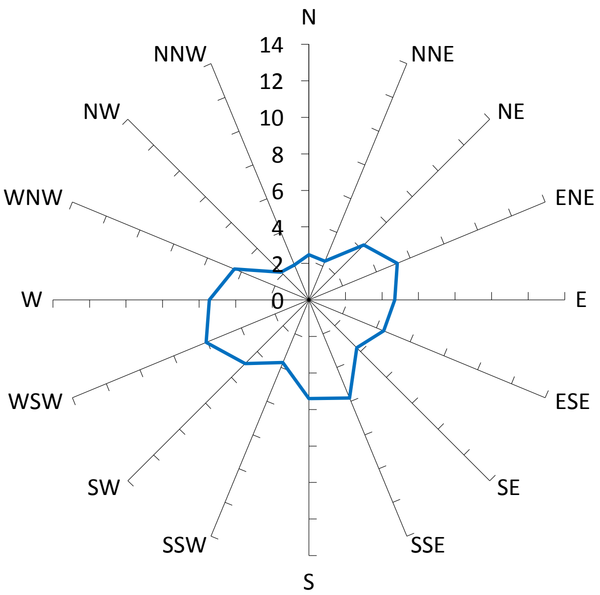
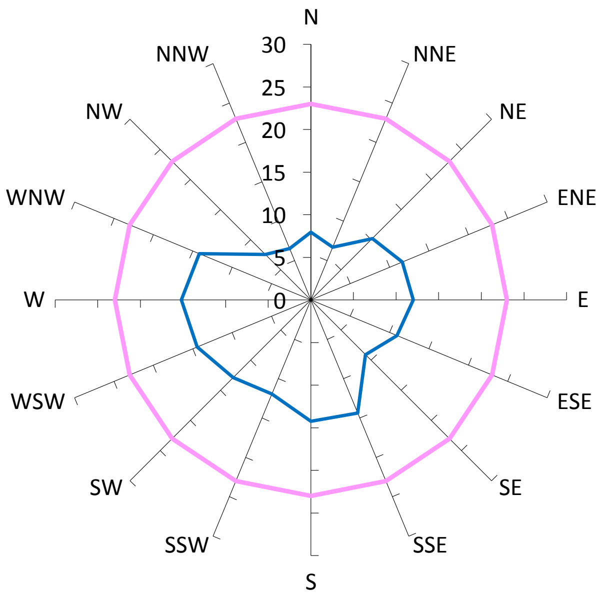
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	3%	18

Results for Point 105

Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

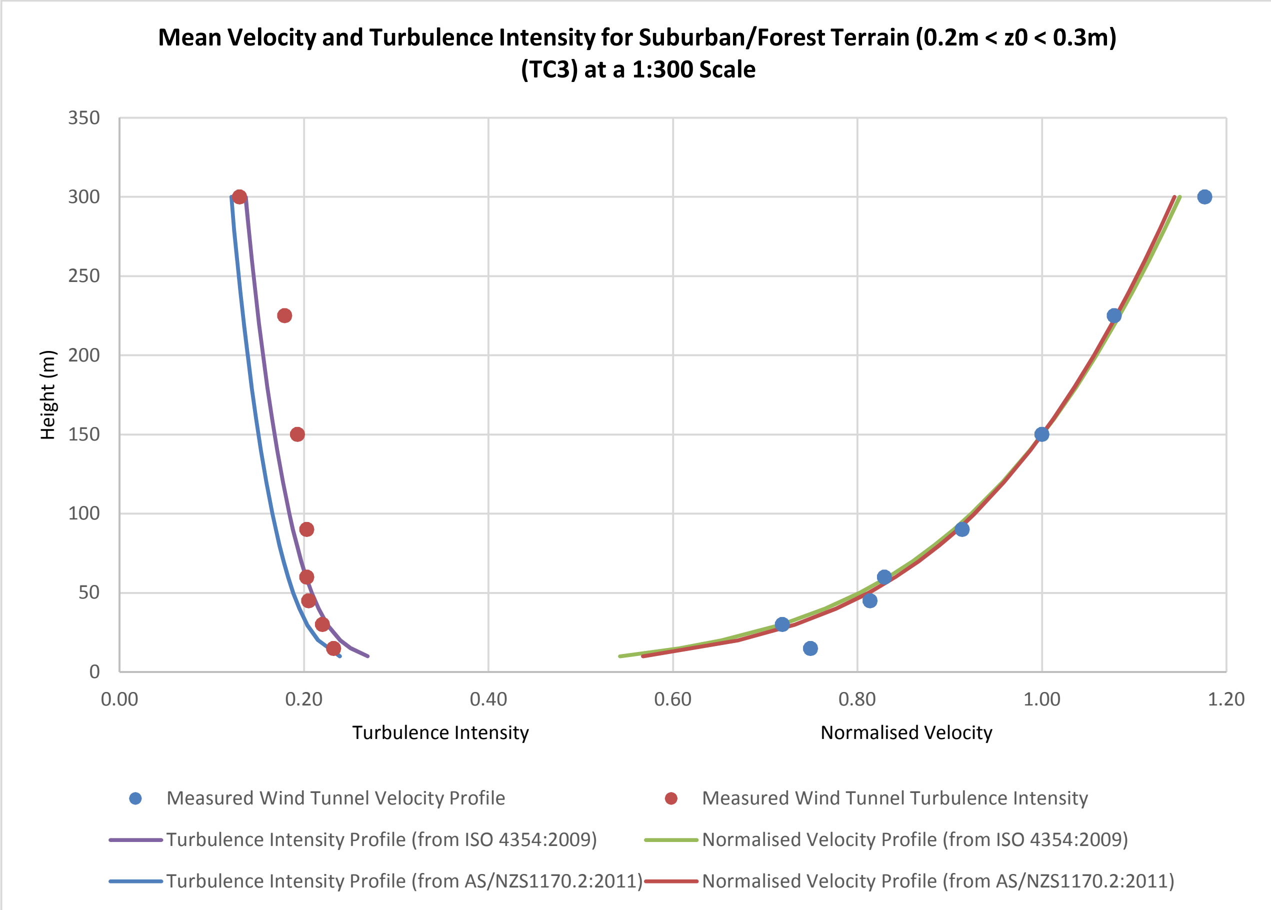
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	0%	14

Results for Point 106

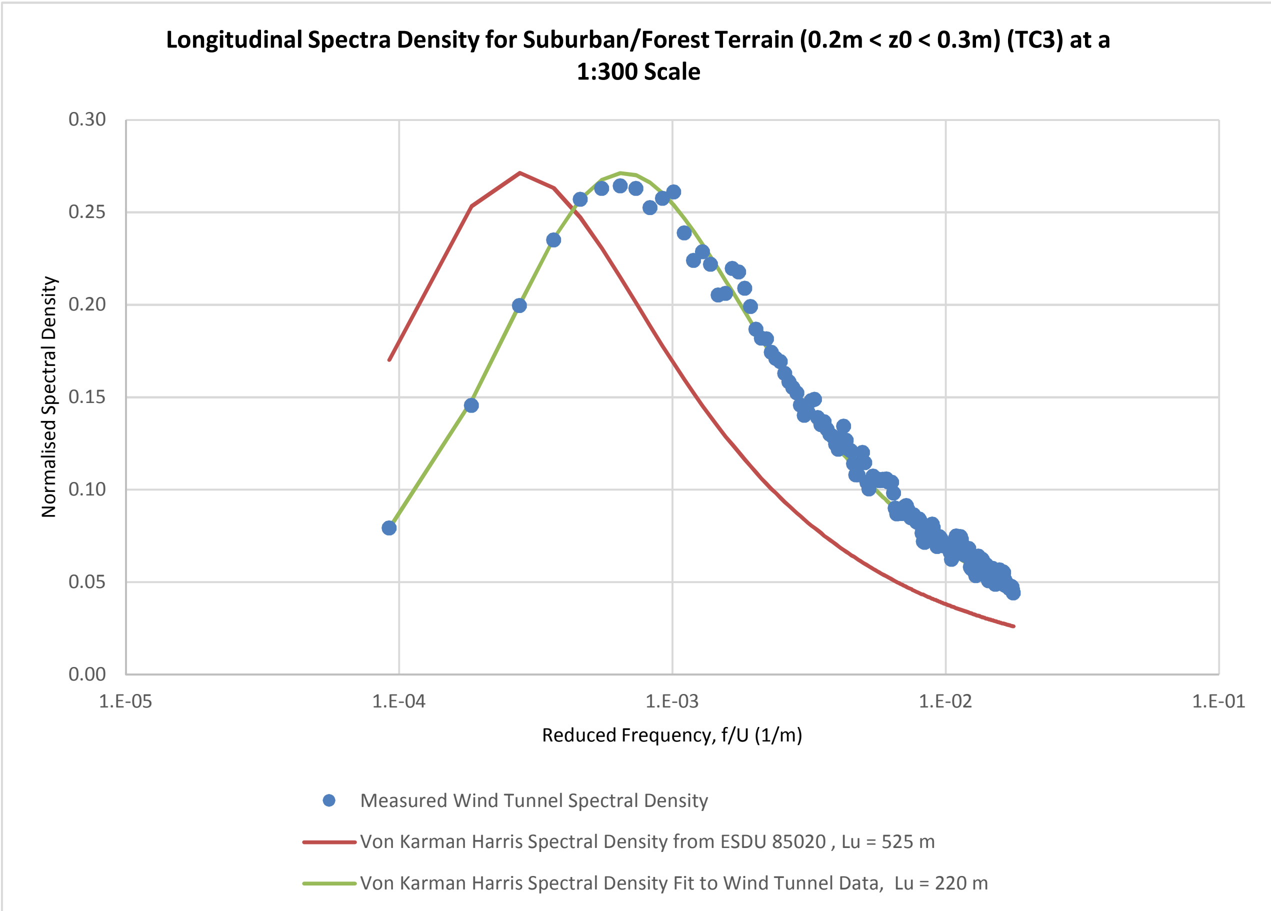
Gust Equivalent Mean (m/s)	Maximum Gust (m/s)
	
Comfort Criteria: 7.5m/s with 5% probability of exceedence	Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
With development "as proposed", no vegetation or other treatments.	1%	15

APPENDIX D VELOCITY AND TURBULENCE INTENSITY PROFILES



Mean Velocity and Turbulence Intensity for Suburban/Forest Terrain (0.2m < z0 < 0.3m) (TC3) at a 1:300 Scale
Height (m)
350
300
250
200
150
100
50
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
Turbulence Intensity
Normalised Velocity
Measured Wind Tunnel Velocity Profile
Measured Wind Tunnel Turbulence Intensity
Turbulence Intensity Profile (from ISO 4354:2009)
Normalised Velocity Profile (from ISO 4354:2009)
Turbulence Intensity Profile (from AS/NZS1170.2:2011)
Normalised Velocity Profile (from AS/NZS1170.2:2011)



Longitudinal Spectra Density for Suburban/Forest Terrain (0.2m < z0 < 0.3m) (TC3) at a 1:300 Scale
Normalised Spectral Density
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1.E-05
1.E-04
1.E-03
1.E-02
1.E-01
Reduced Frequency, f/U (1/m)
Measured Wind Tunnel Spectral Density
Von Karman Harris Spectral Density from ESDU 85020 , Lu = 525 m
Von Karman Harris Spectral Density Fit to Wind Tunnel Data, Lu = 220 m