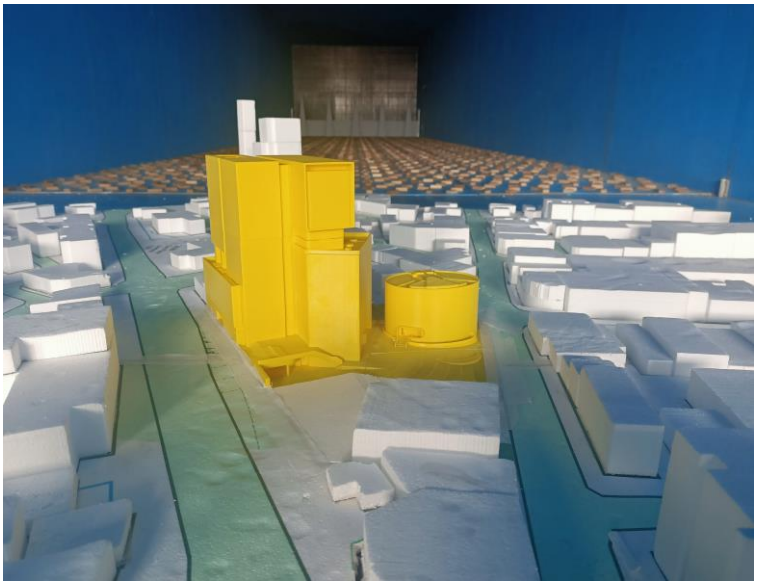

PEDESTRIAN WIND ENVIRONMENT STUDY

CIVIC PLACE, LIVERPOOL

WE999-02F02(REV3)- WE REPORT

SEPTEMBER 24, 2020

Prepared for:

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DOCUMENT CONTROL

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August 14, 2020	Initial.	0	PT	SWR	HK
September 8, 2020	Inclusion of standard text introduction.	1	PT	SWR	HK
September 23, 2020	Update to standard text and in-principle treatments.	2	PT	SWR	HK
September 24, 2020	Update to standard text and comment regarding Public Domain Panel and Plan	3	PT	SWR	HK

EXECUTIVE SUMMARY

This report presents the results of a detailed investigation into the wind environment impact of the Civic Place development, located in Liverpool, NSW. 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.

The following scenarios have been investigated as part of this study:

- Existing Case: the existing development with the existing surrounding buildings.
- Proposed Case: the proposed development with the existing surrounding buildings.
- Future Case: the proposed development with the future surrounding buildings, including Phase B and C of the subject development.

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. 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. The suggested treatments described below are based on an analysis of the results of both the Proposed and Future surrounds cases, and have been devised to mitigate exceedances for both cases, with temporary treatments recommended where appropriate.

- Retention of the proposed densely foliating trees on the eastern side of the site on Ground Level.
- Retention of the proposed densely foliating evergreen trees on the western side of the site on Ground Level.

- Inclusion of additional densely foliating evergreen trees with undergrowth to the western of the Library on Ground Level.
- Inclusion of an additional densely foliating tree along Terminus Street on Ground Level.
- Retention of the 1.2-1.5m planting on the western terrace on Level 01.
- Inclusion of a mitigation strategy such as screening or vegetation at the south-western corner of the terrace on Level 04.
- Retention of the proposed 1.5-2.5m high densely foliating evergreen trees on Level 04.
- Retention of the proposed 1.5-2m high undergrowth on Level 04.
- Inclusion mitigation strategies such as screening or vegetation along the western and eastern perimeters of the terrace on Level 07.
- Retention of the proposed densely foliating evergreen trees on the Level 07 terrace.
- Retention of the proposed undergrowth on the Level 07 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 in the proposed or future scenarios.

The treatment recommendations on Ground Level are subject to endorsement by the Public Domain Panel.

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.

This Pedestrian Wind Environment Study is submitted to Liverpool City Council (Council) on behalf of Built Development Group in support of a Stage 2 Development Application (DA) for Phase A of the Liverpool Civic Place development located at 52 Scott Street, Liverpool.

It follows the approval of a Concept Proposal / Stage 1 DA (DA-585/2019) for the broader Liverpool Civic Place master plan that has determined land uses, building envelopes, public domain and a multi-level common basement across the site. The full Liverpool Civic Place site, subject to the Concept Proposal / Stage 1 DA approval is illustrated at Figure 1, however the scope of this Stage 2 DA is limited to Phase A, as illustrated at Figure 2.
Phase B and Phase C will be subject to future Stage 2 DA(s).

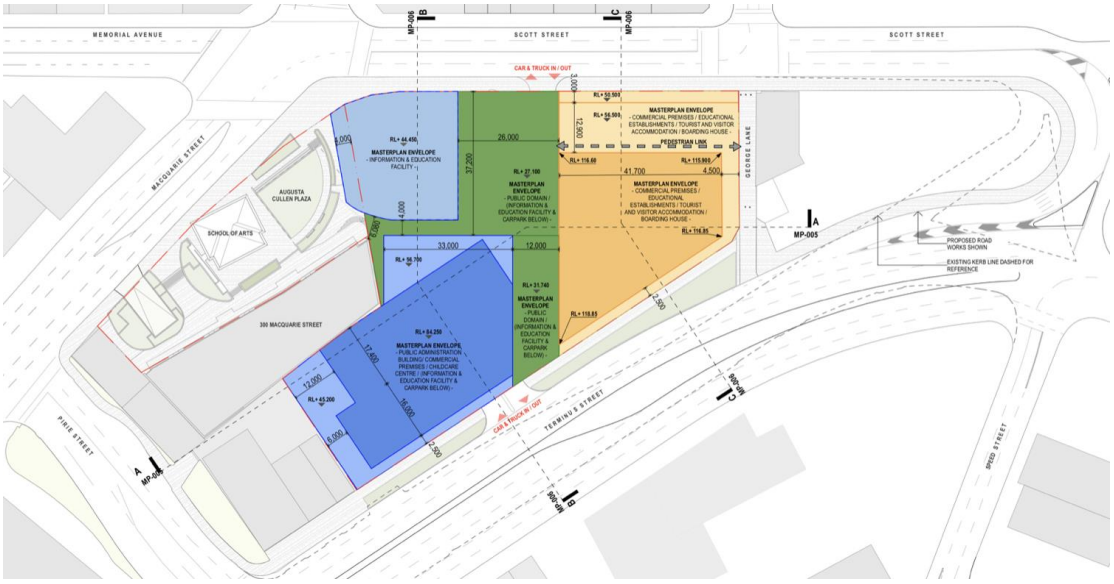

Figure 1: Liverpool Civic Place Master Plan Site

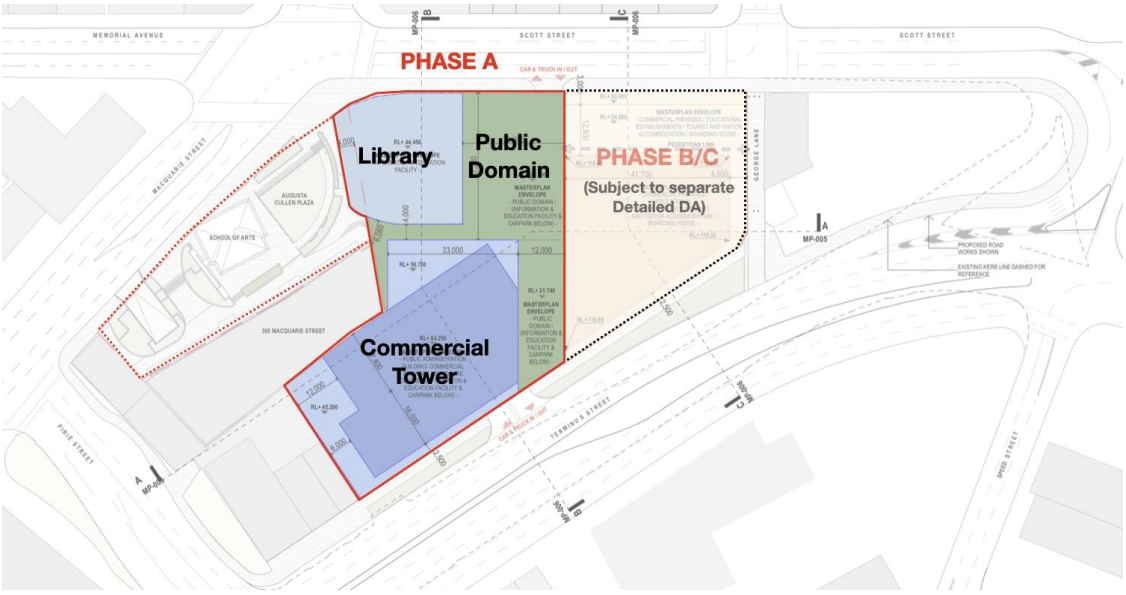

Figure 2: Liverpool Civic Place Master Plan Site

This Stage 2 DA seeks approval for:

- Construction and use of a six (6) storey information and education facility (public library);
- Construction and use of a fourteen (14) storey mixed use building comprising:
  - Eight (8) storeys of public administration building floor space to be occupied by Liverpool City Council;
  - Four (4) storeys of commercial premises (office) floor space;
  - Single storey above ground child care centre on Level 6; and
  - Single storey of rooftop plant.
- Partial construction and use of the overall site's common basement;
- Landscaping and public domain works including:
  - an internal shared road connecting to Scott Street with basement access;
  - a public plaza fronting Scott Street; and
  - an elevated pocket park fronting Terminus Street.
- Extension and augmentation of services and infrastructure as required.

This DA reflects the staged planning approval pathway for the Liverpool Civic Place redevelopment which has included two previously approved DAs, as outlined below:

Concept DA DA-585/2019:

The planning approval pathway for the Liverpool Civic Place development commenced in in 2019, with the submission of a Concept Proposal / Stage 1 DA for the Liverpool Civic Place master plan. On 31 August 2020, the Concept Proposal / Stage 1 DA (DA-585/2019) was approved by the Sydney Western City Planning Panel. The Concept Proposal / Stage 1 DA consent sets out the future development concept of the site, including the approved land uses, building envelopes, an expanse of public domain and a common basement. The Concept Proposal / Stage 1 DA did not approve any physical works.

Early Works DA DA-906/2019:

Development Application DA-906/2019 was approved by the Sydney Western City Planning Panel on 29 June 2020. The development consent relates to demolition of all structures, select tree removal and bulk earthworks including shoring through the use of piles. Early works commenced on site in September 2020 and are scheduled for completion in August 2021.

2 SITE ANALYSIS

Site Location and Context

The site is located at 52 Scott Street, Liverpool within the Liverpool City Council Local Government Area (LGA) as illustrated at Figure 1. The site is located at the southern fringe of the Liverpool CBD. The site is approximately 300m south west of the Liverpool Railway Station and is also in the vicinity of a number of regionally significant land uses and features including Liverpool Hospital, Westfield Liverpool, Western Sydney University Liverpool Campus, the Georges River and Biggie Park public open space as illustrated at Figure 1.

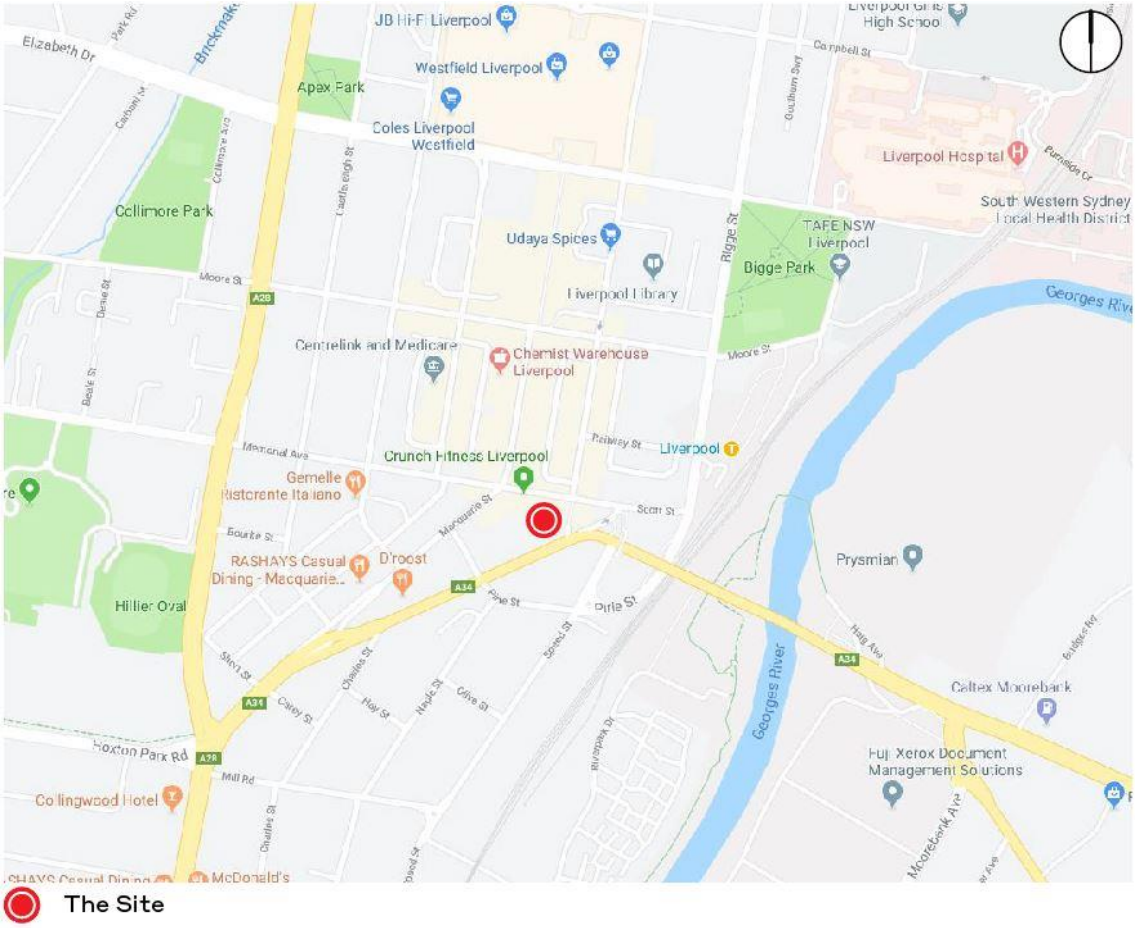

Figure 3: Site Location

3 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 4 and 5. Plans of the proximity models is provided in Figures 6.

The following scenarios have been investigated as part of this study:

- Existing Case: the existing development with the existing surrounding buildings.
- Proposed Case: the proposed development with the existing surrounding buildings.
- Future Case: the proposed development with the future surrounding buildings, including Phase B and C of the subject development.

It should be noted that the buildings included in the Future Case are based on illustrative designs that may be subject to changes at a later date. In this case, it is advised that Windtech be consulted to determine whether additional wind tunnel testing is required, particularly if there are significant design changes to Phases B and/or C of the subject development.

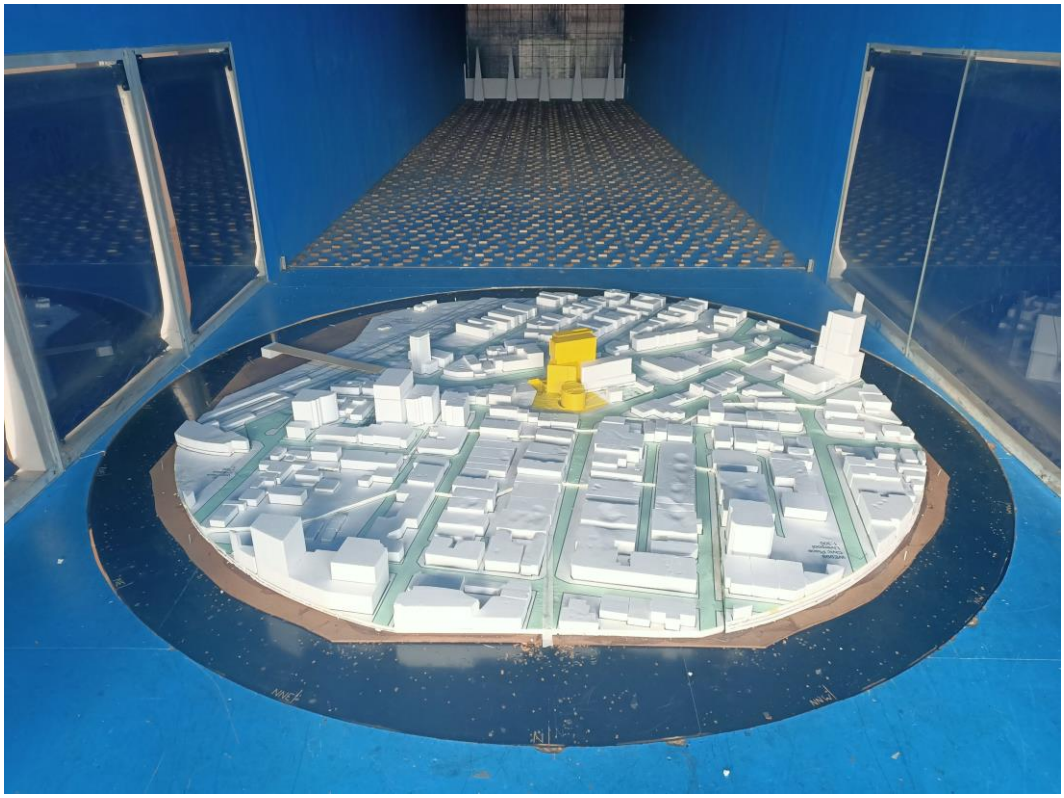

Figure 4a: Photograph of the Wind Tunnel Model – Proposed Case (view from the north)

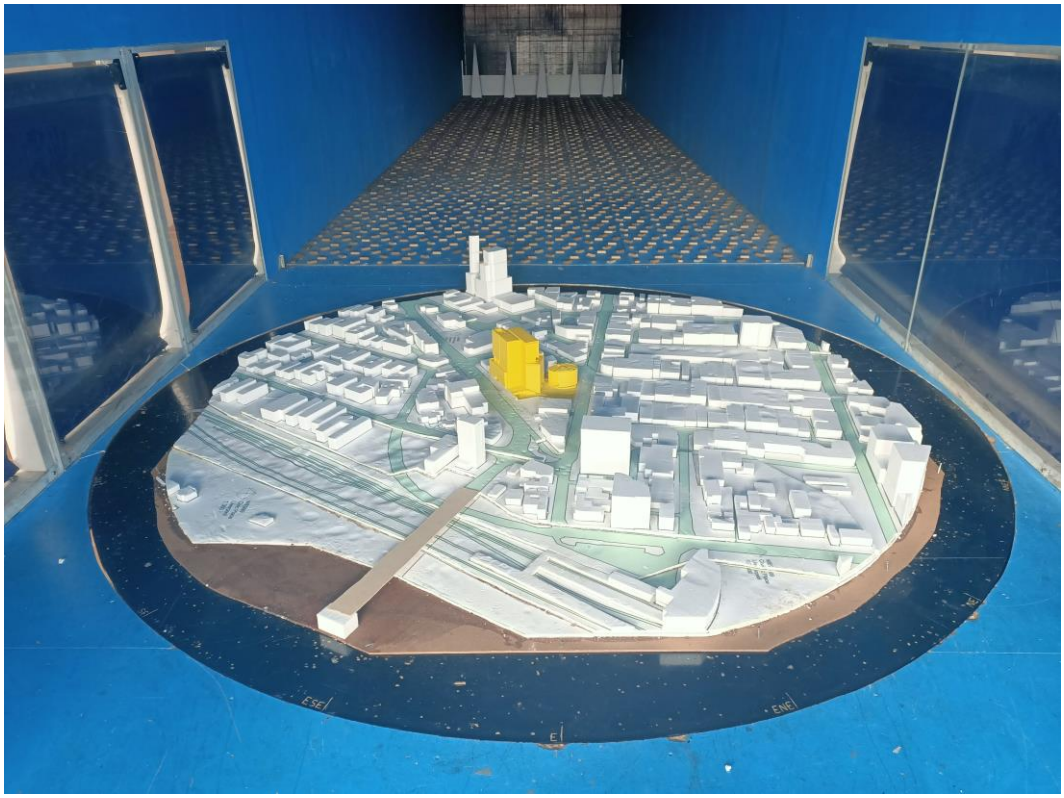

Figure 4b: Photograph of the Wind Tunnel Model – Proposed Case (view from the east)

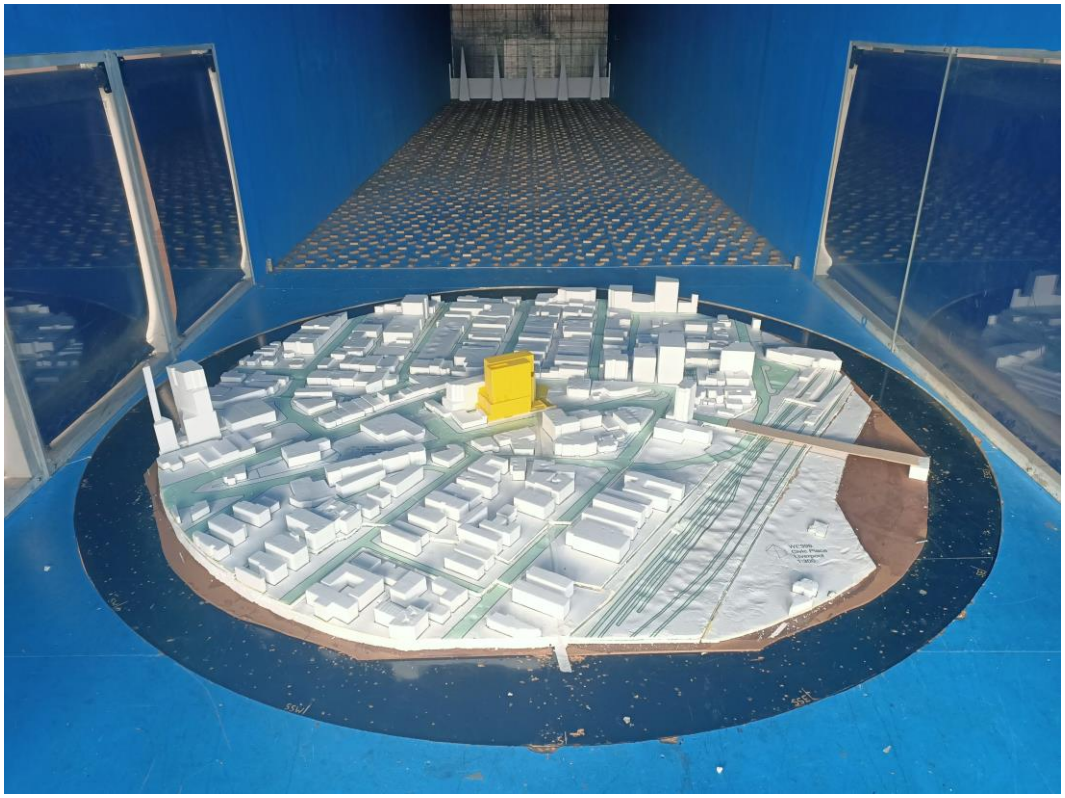

Figure 4c: Photograph of the Wind Tunnel Model – Proposed Case (view from the south)

Figure 4d: Photograph of the Wind Tunnel Model – Proposed Case (view from the west)

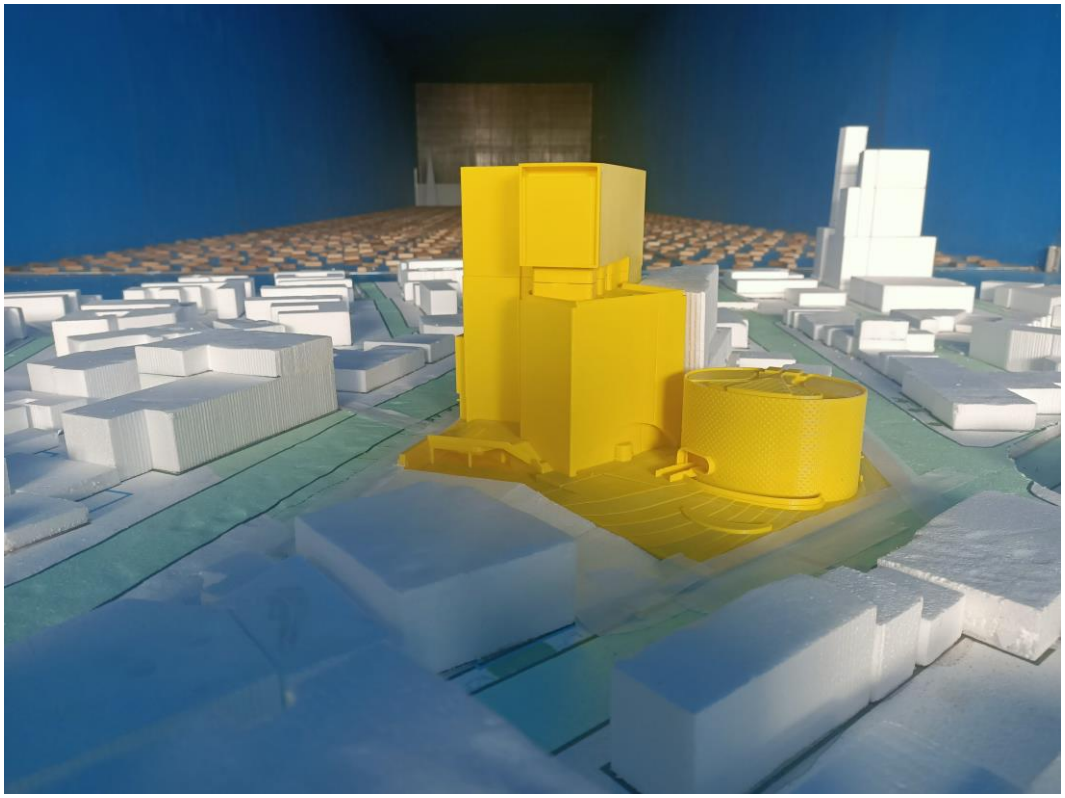

Figure 4e: Photograph of the Wind Tunnel Model – Proposed Case (view from the north-east)

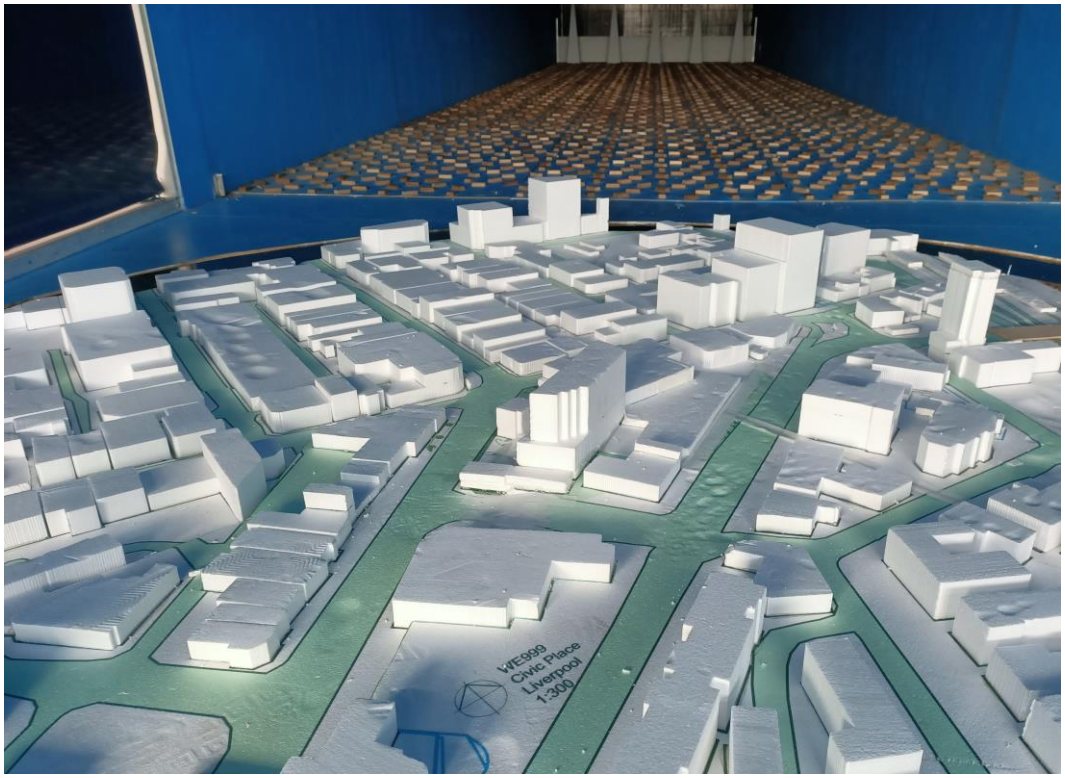

Figure 4f: Photograph of the Wind Tunnel Model – Existing Case (view from the south-west)

Figure 5a: Photograph of the Wind Tunnel Model – Future Case (view from the north)

Figure 5b: Photograph of the Wind Tunnel Model – Future Case (view from the east)

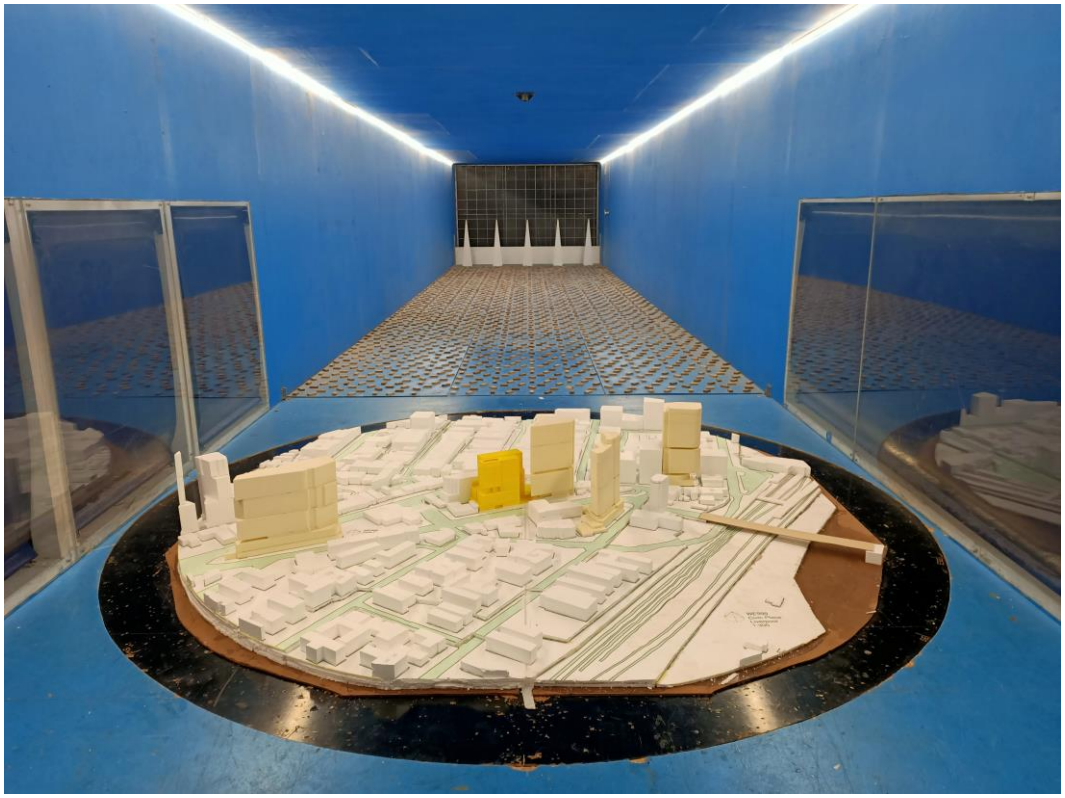

Figure 5c: Photograph of the Wind Tunnel Model – Future Case (view from the south)

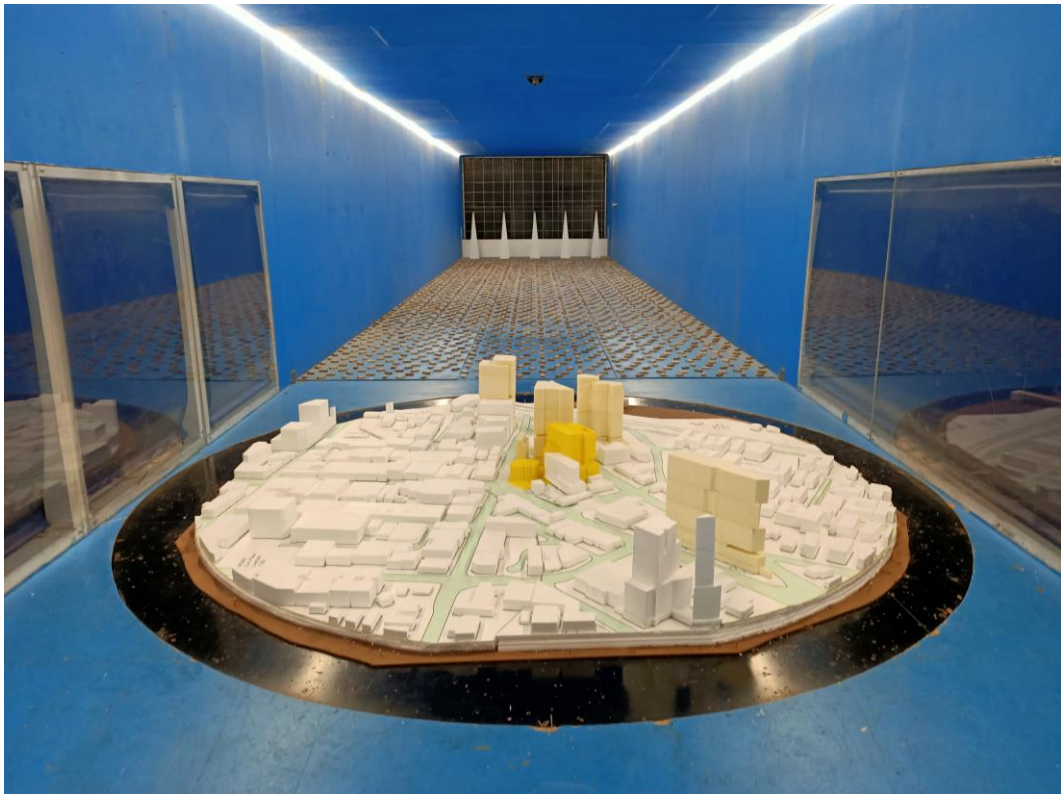

Figure 5d: Photograph of the Wind Tunnel Model – Future Case (view from the west)

Figure 5e: Photograph of the Wind Tunnel Model – Future Case (view from the north-west)

Figure 6a: Proximity Model Plan – Existing Case

Figure 6b: Proximity Model Plan – Proposed Case

Figure 6c: Proximity Model Plan – Future Case

4 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, using a fetch length of 20 to 40 times the study reference height (as per the recommendations of ASCE-7-16 and AS/NZS1170.2:2011). The proximity model accounts for the effect of the near field topographic effects as well as the influence of the local built forms.

An aerial image showing the surrounding terrain is presented in Figure 7 for a range of 3.0km 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 5) 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	0.69	0.73	1.12	0.208	3.0
30	0.68	0.72	1.11	0.211	3.0
60	0.66	0.71	1.10	0.220	3.1
90	0.73	0.76	1.14	0.191	2.8
120	0.66	0.70	1.10	0.223	3.1
150	0.65	0.69	1.09	0.229	3.2
180	0.66	0.71	1.10	0.220	3.1
210	0.69	0.73	1.12	0.208	3.0
240	0.69	0.73	1.12	0.208	3.0
270	0.69	0.73	1.12	0.208	3.0
300	0.69	0.73	1.12	0.208	3.0
330	0.69	0.73	1.12	0.208	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.

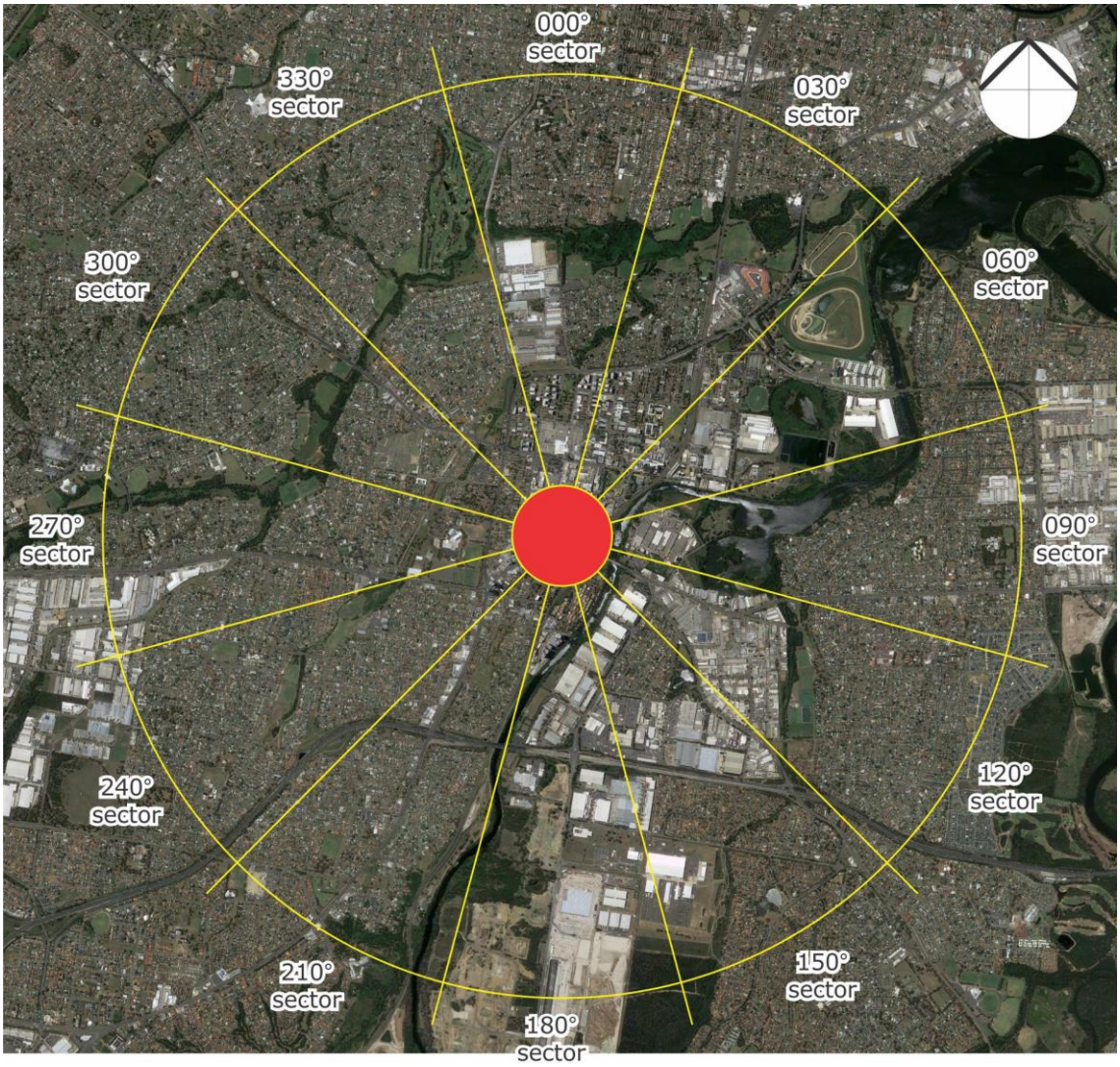

Figure 7: Aerial Image of the Surrounding Terrain
(radius of 3.0km from the edge of the proximity model, which is coloured red)

5 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 Bankstown Airport. Data was collected from 1993 to 2016 and corrected so that it represents winds over standard open terrain at a height of 10m above ground (including correcting for the presence of the nearby buildings to north-east of the anemometer). From this analysis, directional probabilities of exceedance and directional wind speeds for the region are determined. The directional wind speeds are summarised in Table 2. The directional wind speeds and corresponding directional frequencies of occurrence are presented in Figure 8.

The recurrence intervals examined in this study are for exceedances of 5% (per 90 degree sector) for the pedestrian comfort criteria using Gust-Equivalent Mean (GEM) wind speeds, and annual maximum wind speeds (per 22.5 degree sector) for the pedestrian safety criterion. Note that the 5% probability wind speeds presented in Table 2 are only used for the directional plot presented in Figure 8 and are not used for the integration of the probabilities.

Table 2: Directional Wind Speeds (m/s)
(hourly means, referenced to 10m above ground in standard open terrain)

Wind Direction	5% Exceedance	Annual Maximum
N	5.2	9.1
NNE	4.7	7.9
NE	7.0	9.6
ENE	7.1	8.9
E	6.2	8.5
ESE	7.4	9.8
SE	8.2	10.8
SSE	8.5	11.3
S	7.1	11.0
SSW	4.8	9.4
SW	5.8	9.5
WSW	7.0	10.8
W	6.8	11.2
WNW	6.5	11.4
NW	5.2	9.9
NNW	5.4	9.3

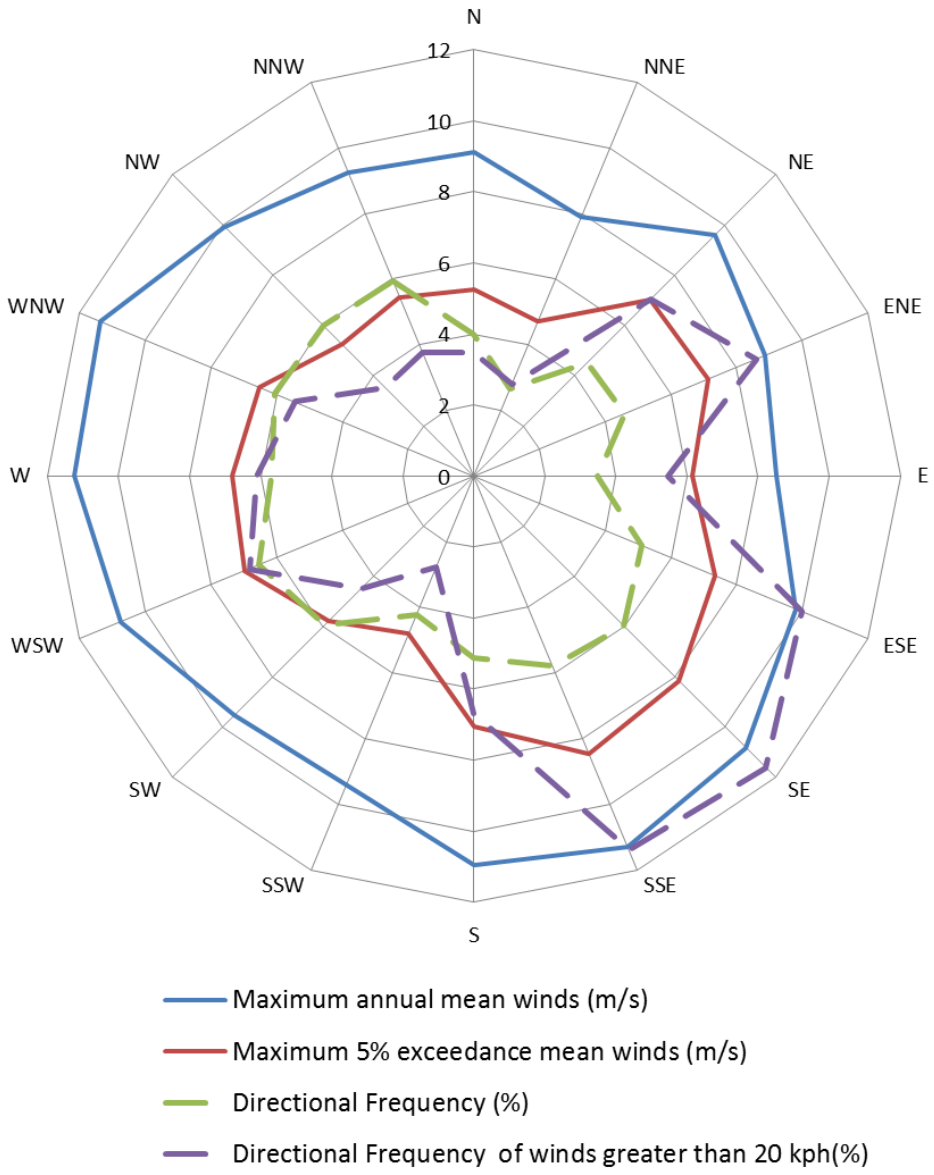

Figure 8: Annual and 5% Exceedance Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Bankstown Airport (referenced to 10m above ground in standard open terrain)

6 PEDESTRIAN WIND COMFORT AND SAFETY

The acceptability of wind conditions of 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.

6.1 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 4), and incorporating the regional wind model (see Section 5), 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.

6.2 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:

$$GEM = max\left(\bar{V}, \frac{\hat{V}}{1.85}\right) \tag{6.1}$$

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 3 and 4 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 3: 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 4: 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

6.3 Layout of Study Points

For this study a total of 46 study point locations were selected for analysis in the wind tunnel. This includes the following:

- 34 study points throughout the Ground Level trafficable areas.
- 2 study points on the Level 01 terrace.
- 6 study points on the Level 04 terrace.
- 4 study points the Level 07 terrace.

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 9 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.

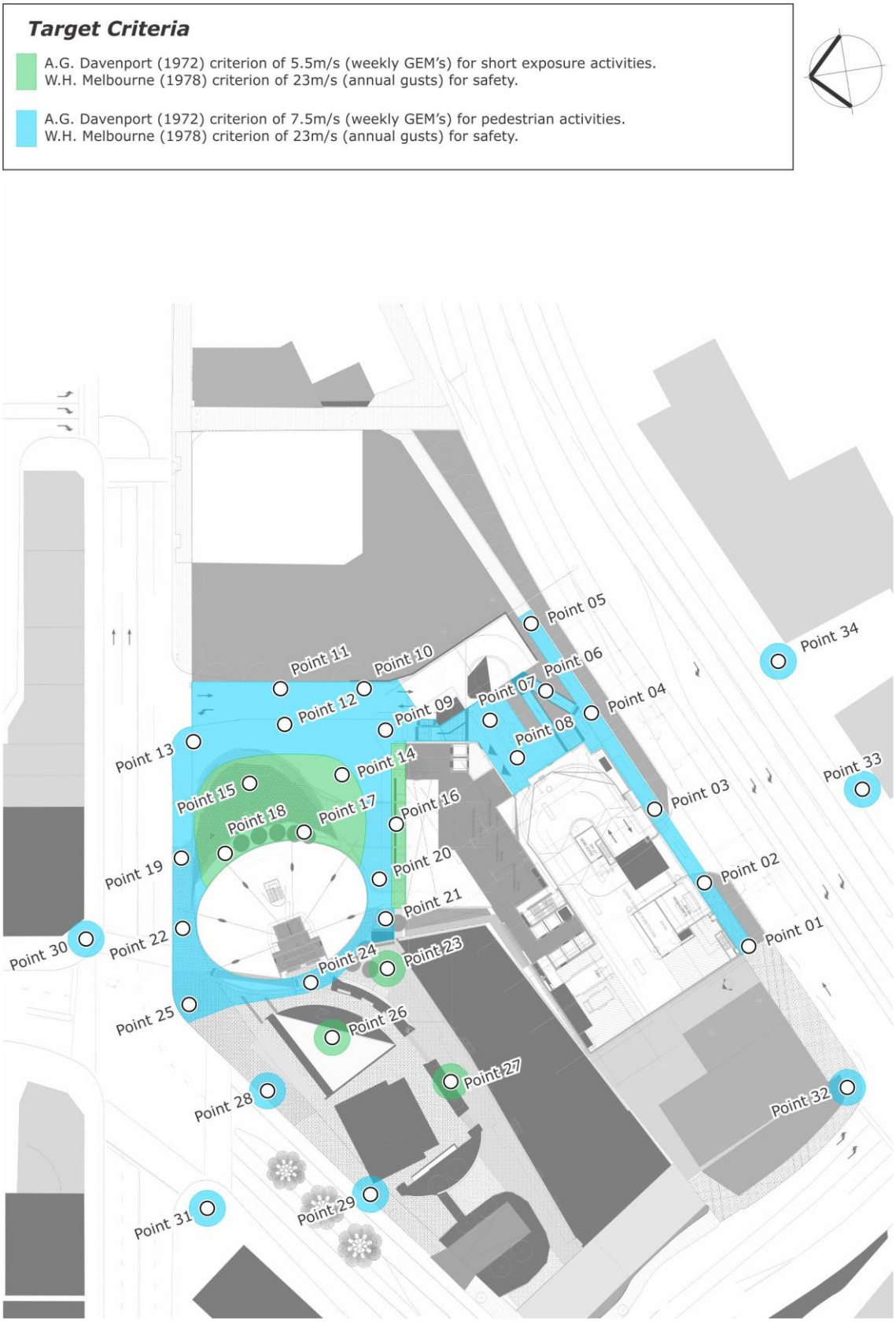

Figure 9a: Study Point Locations and Target Wind Speed Criteria
Ground Level Plan

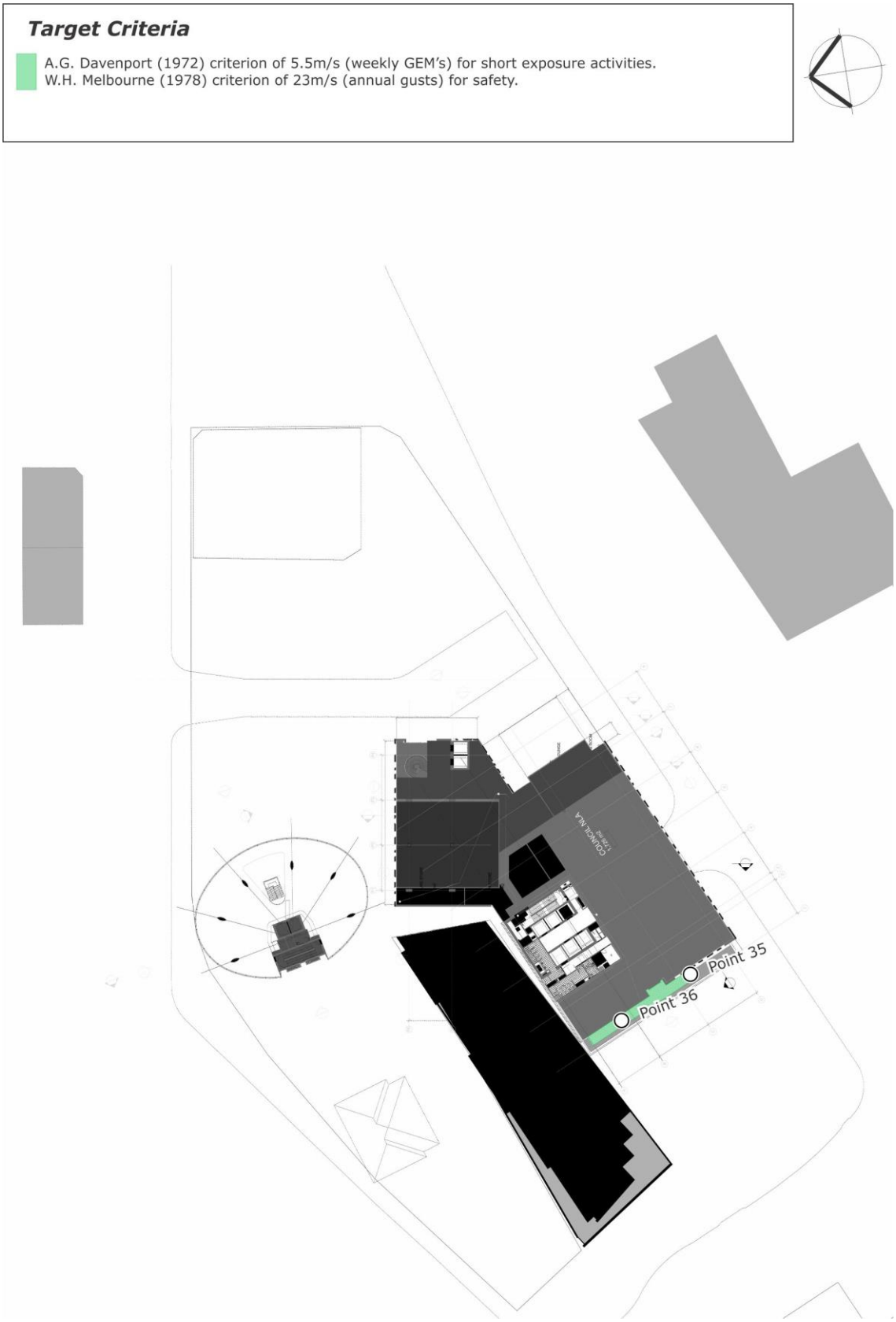

Figure 9b: Study Point Locations and Target Wind Speed Criteria

Level 01 Plan

Figure 9c: Study Point Locations and Target Wind Speed Criteria

Level 04 Plan

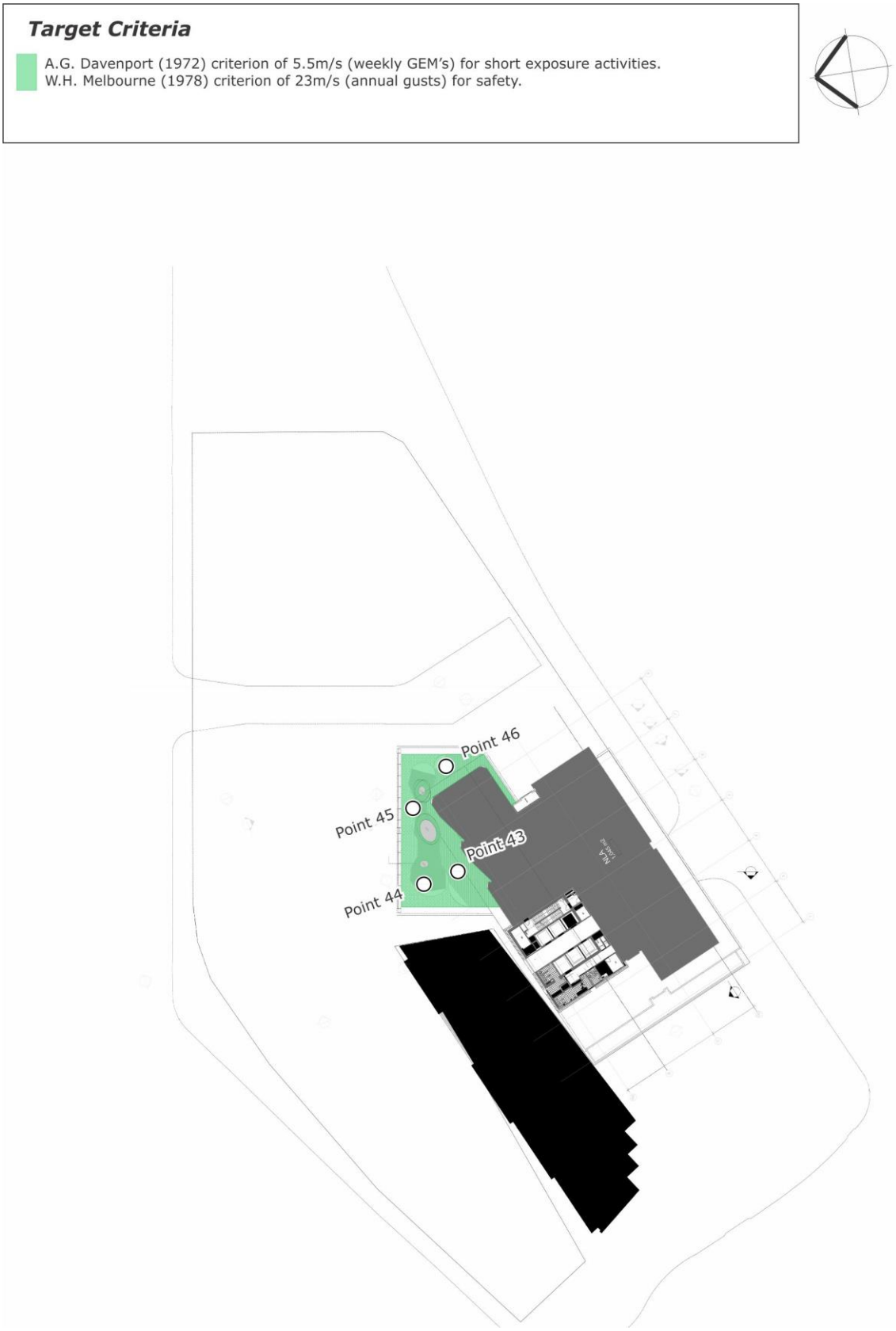

Figure 9d: Study Point Locations and Target Wind Speed Criteria

Level 07 Plan

7 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 5, and shown on marked-up plans in Figures 10 and 11. The wind speed criteria that the wind conditions should achieve are also listed in Table 5 for each study point location, as well as in Figures 9.

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. The suggested treatments described below are based on an analysis of the results of both the Proposed and Future surrounds cases, and have been devised to mitigate exceedances for both cases, with temporary treatments recommended where appropriate. Wind tunnel testing can be undertaken to verify the efficacy of the strategy.

7.1 Ground Level

- Retention of the proposed densely foliating trees on the eastern side of the site, as shown in Figure 12a.
- Retention of the proposed densely foliating evergreen trees on the western side of the site, as shown in Figure 12a.
- Inclusion of additional densely foliating evergreen trees with undergrowth to the western of the Library, as shown in Figure 12a.
- Inclusion of an additional densely foliating tree along Terminus Street, as shown in Figure 12a.

The above treatment recommendations are subject to endorsement by the Public Domain Panel.

7.2 Level 01

- Retention of the 1.2-1.5m planting on the western terrace, as shown in Figure 12b.

7.3 Level 04

- Inclusion of a mitigation strategy such as screening or vegetation at the south-western corner of the terrace, which can be further developed at a more detailed design stage, as shown in Figure 12c.
- Retention of the proposed 1.5-2.5m high densely foliating evergreen trees, as shown in Figure 12c.
- Retention of the proposed 1.5-2m high undergrowth, as shown in Figure 12c.

7.4 Level 07

- Inclusion of mitigation strategies such as screening or vegetation along the western and eastern perimeters of the terrace, which can be further developed at a more detailed design stage, as shown in Figure 12d.
- Retention of the proposed densely foliating evergreen trees on the terrace, as shown in Figure 12d.
- Retention of the proposed undergrowth on the terrace, as shown in Figure 12d.

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 in the proposed or future scenarios.

Figure 10a: Wind Tunnel Results – Ground Level Plans (Proposed Surrounds Case) (results shown without treatments applied)

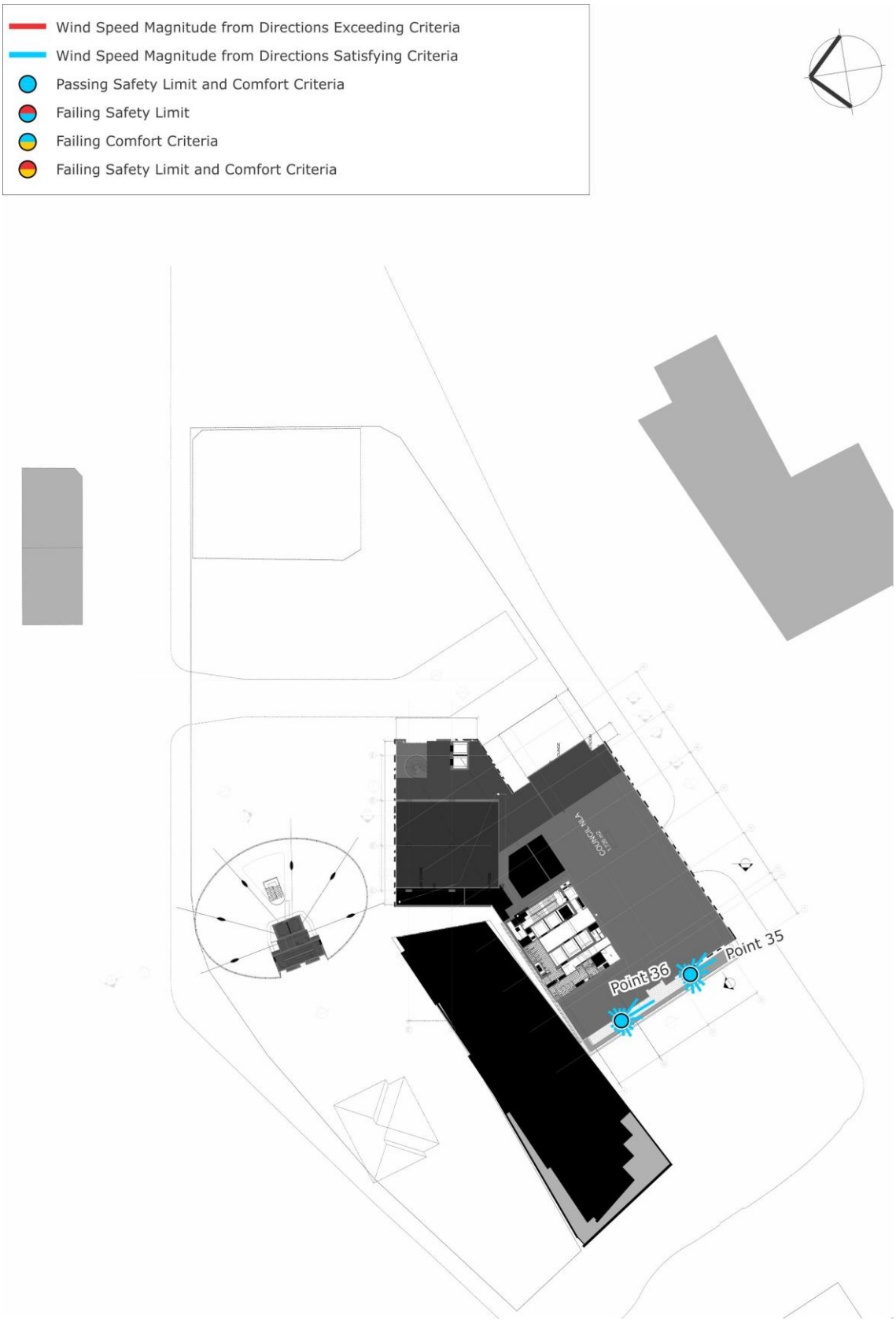

Figure 10b: Wind Tunnel Results – Level 01 Plan (Proposed Surrounds Case)
(results shown without treatments applied)

Figure 10c: Wind Tunnel Results – Level 04 Plan (Proposed Surrounds Case) (results shown without treatments applied)

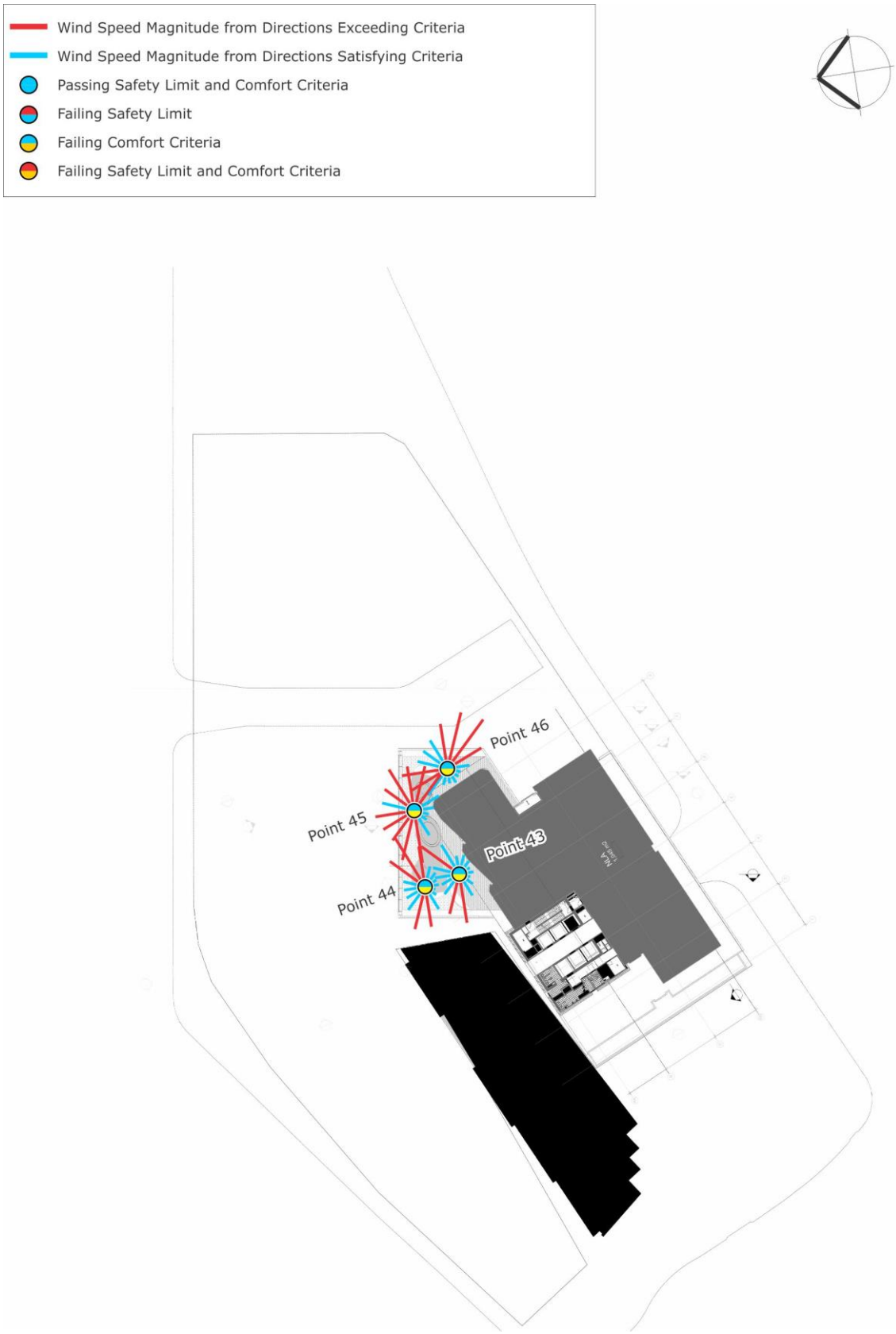

Figure 10d: Wind Tunnel Results – Level 07 Plan (Proposed Surrounds Case)
(results shown without treatments applied)

Figure 11a: Wind Tunnel Results – Ground Level Plans (Future Surrounds Case) (results shown without treatments applied)

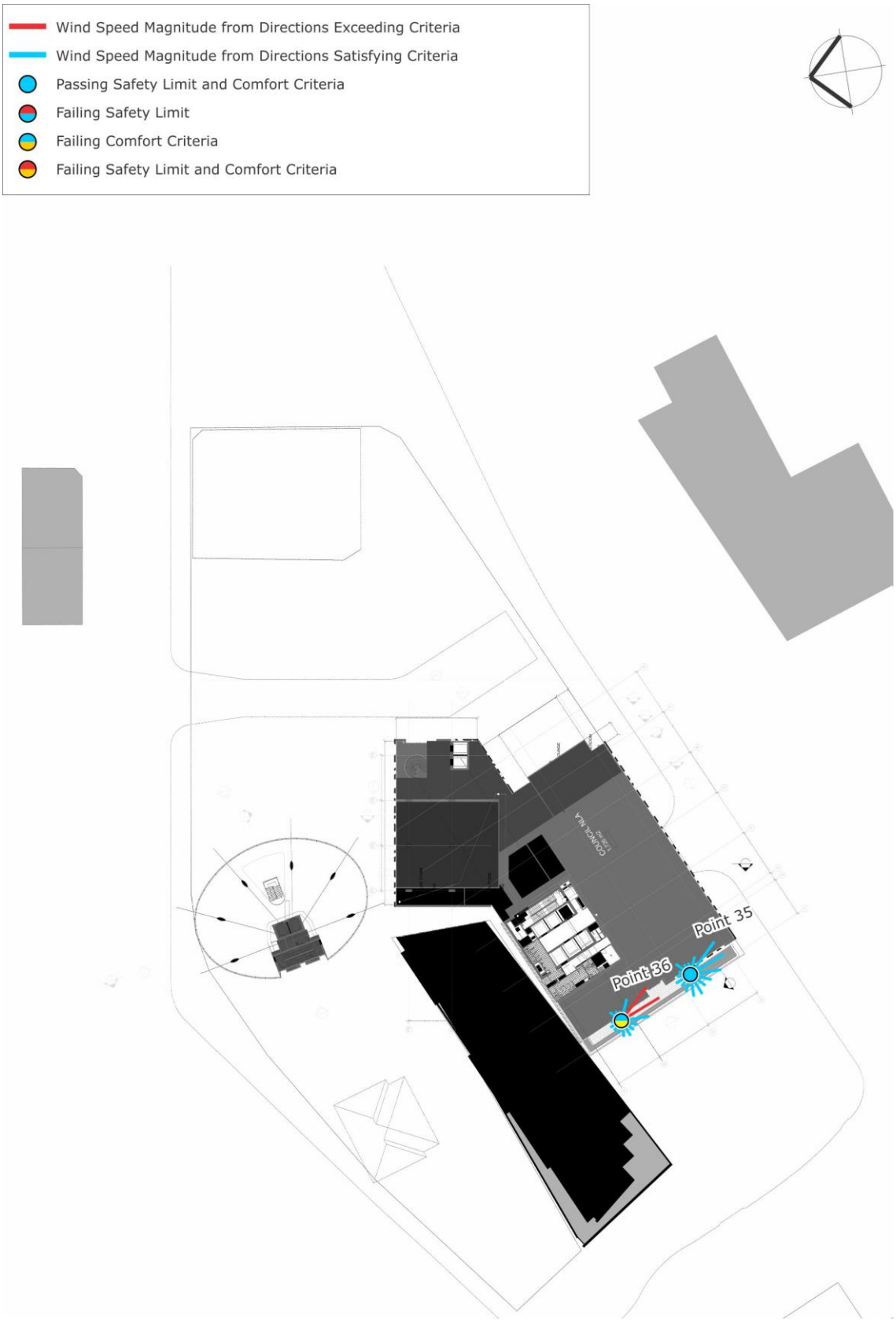

Figure 11b: Wind Tunnel Results – Level 01 Plan (Future Surrounds Case)
(results shown without treatments applied)

Figure 11c: Wind Tunnel Results – Level 04 Plan (Future Surrounds Case)
(results shown without treatments applied)

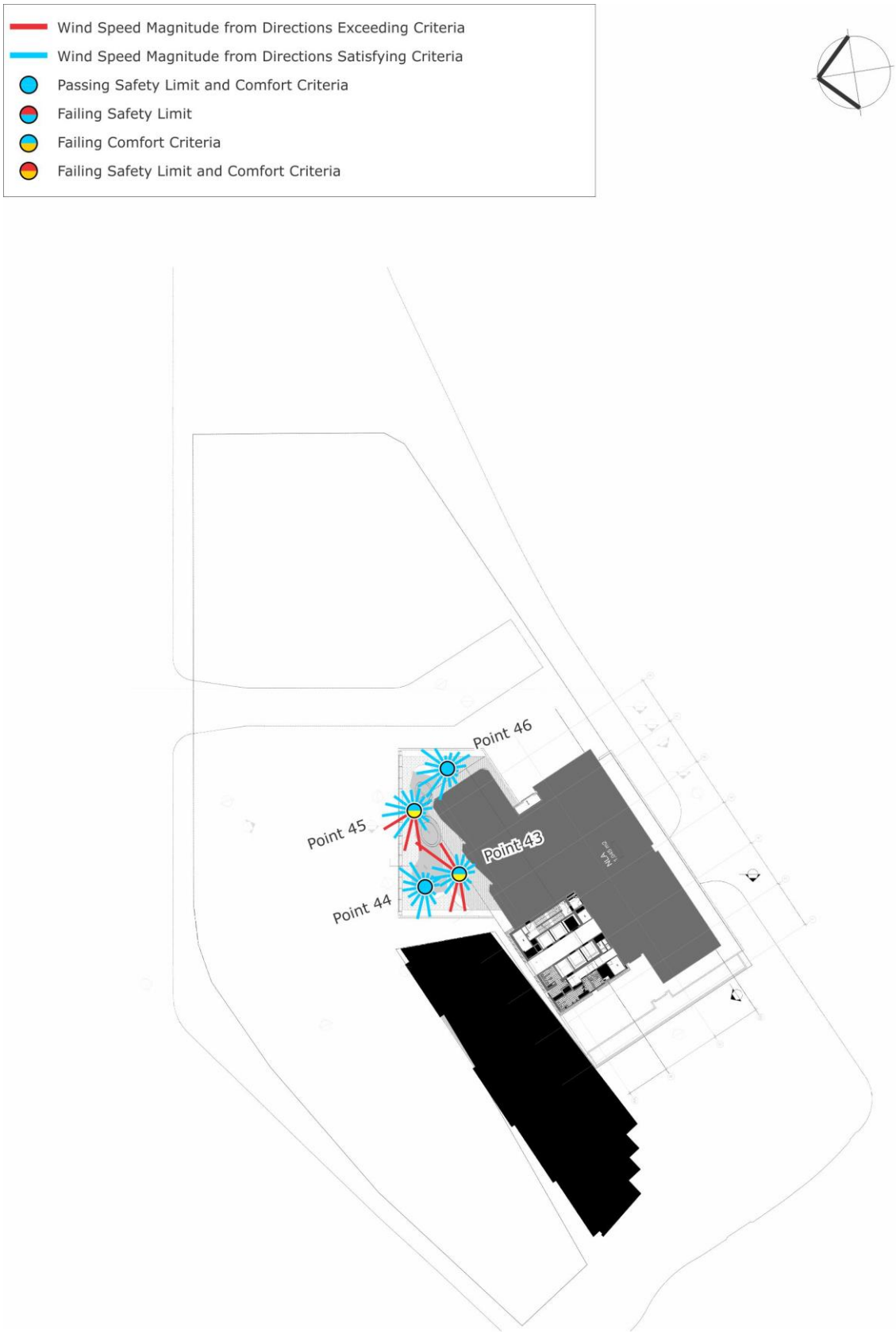

Figure 11d: Wind Tunnel Results – Level 07 Plan (Future Surrounds Case)
(results shown without treatments applied)

Table 5: Wind Tunnel Results Summary – Proposed and Existing Cases

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	6%	Fail	23	18	Pass	Fail	Refer to Figure 12a.
Existing		0%	Pass		13	Pass	Pass	
Point 02	7.5	1%	Pass	23	13	Pass	Pass	
Point 03	7.5	0%	Pass	23	14	Pass	Pass	
Point 04	7.5	5%	Pass	23	19	Pass	Pass	
Existing		1%	Pass		17	Pass	Pass	
Point 05	7.5	8%	Fail	23	20	Pass	Fail	Refer to Figure 12a.
Existing		1%	Pass		16	Pass	Pass	
Point 06	7.5	1%	Pass	23	16	Pass	Pass	
Point 07	7.5	0%	Pass	23	11	Pass	Pass	
Point 08	7.5	0%	Pass	23	15	Pass	Pass	
Point 09	7.5	5%	Pass	23	16	Pass	Pass	
Point 10	7.5	3%	Pass	23	17	Pass	Pass	
Point 11	7.5	1%	Pass	23	16	Pass	Pass	
Point 12	7.5	1%	Pass	23	16	Pass	Pass	
Point 13	7.5	9%	Fail	23	19	Pass	Fail	Refer to Figure 12a.
Existing		1%	Pass		13	Pass	Pass	
Point 14	5.5	13%	Fail	23	17	Pass	Fail	Refer to Figure 12a.
Point 15	5.5	12%	Fail	23	16	Pass	Fail	Refer to Figure 12a.
Point 16	5.5	8%	Fail	23	20	Pass	Fail	Refer to Figure 12a.
Point 17	5.5	0%	Pass	23	9	Pass	Pass	
Point 18	5.5	7%	Fail	23	14	Pass	Fail	Refer to Figure 12a.
Point 19	7.5	5%	Pass	23	17	Pass	Pass	
Point 20	7.5	7%	Fail	23	21	Pass	Fail	Refer to Figure 12a.
Point 21	7.5	11%	Fail	23	20	Pass	Fail	Refer to Figure 12a.
Point 22	7.5	2%	Pass	23	17	Pass	Pass	
Point 23	5.5	1%	Pass	23	11	Pass	Pass	
Point 24	7.5	0%	Pass	23	12	Pass	Pass	
Point 25	7.5	3%	Pass	23	17	Pass	Pass	
Point 26	5.5	2%	Pass	23	13	Pass	Pass	
Point 27	5.5	2%	Pass	23	13	Pass	Pass	
Point 28	7.5	1%	Pass	23	14	Pass	Pass	
Point 29	7.5	0%	Pass	23	14	Pass	Pass	
Point 30	7.5	1%	Pass	23	16	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 31	7.5	0%	Pass	23	14	Pass	Pass	
Point 32	7.5	13%	Fail	23	20	Pass	Fail	Refer to Figure 12a.
Existing		4%	Pass		17	Pass	Pass	
Point 33	7.5	2%	Pass	23	15	Pass	Pass	
Point 34	7.5	3%	Pass	23	16	Pass	Pass	
Point 35	5.5	1%	Pass	23	11	Pass	Pass	
Point 36	5.5	2%	Pass	23	14	Pass	Pass	
Point 37	5.5	2%	Pass	23	14	Pass	Pass	
Point 38	5.5	5%	Pass	23	16	Pass	Pass	
Point 39	5.5	27%	Fail	23	20	Pass	Fail	Refer to Figure 12c.
Point 40	5.5	9%	Fail	23	17	Pass	Fail	Refer to Figure 12c.
Point 41	5.5	5%	Pass	23	14	Pass	Pass	
Point 42	5.5	0%	Pass	23	7	Pass	Pass	
Point 43	5.5	11%	Fail	23	21	Pass	Fail	Refer to Figure 12d.
Point 44	5.5	15%	Fail	23	18	Pass	Fail	Refer to Figure 12d.
Point 45	5.5	25%	Fail	23	22	Pass	Fail	Refer to Figure 12d.
Point 46	5.5	20%	Fail	23	20	Pass	Fail	Refer to Figure 12d.

Note that, for any study points listed in Table 5 with two rows of results data, the second row is for the existing site conditions. The test results shown in Table 5 are without any treatments applied. If treatment is required, the treatment is described in Table 5.

Table 6: Wind Tunnel Results Summary – Future and Existing Case

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	3%	Pass	23	18	Pass	Pass	-
Existing		0%	Pass		13	Pass	Pass	
Point 02	7.5	0%	Pass	23	14	Pass	Pass	
Point 03	7.5	0%	Pass	23	14	Pass	Pass	
Point 04	7.5	6%	Fail	23	22	Pass	Fail	Refer to Figure 12a.
Existing		1%	Pass		17	Pass	Pass	
Point 05	7.5	4%	Pass	23	18	Pass	Pass	
Existing		1%	Pass		16	Pass	Pass	
Point 06	7.5	3%	Pass	23	19	Pass	Pass	
Point 07	7.5	6%	Fail	23	19	Pass	Fail	Refer to Figure 12a.
Point 08	7.5	1%	Pass	23	16	Pass	Pass	
Point 09	7.5	4%	Pass	23	17	Pass	Pass	
Point 10	7.5	3%	Pass	23	17	Pass	Pass	
Point 11	7.5	5%	Pass	23	17	Pass	Pass	
Point 12	7.5	1%	Pass	23	17	Pass	Pass	
Point 13	7.5	3%	Pass	23	18	Pass	Pass	
Existing		1%	Pass		13	Pass	Pass	
Point 14	5.5	2%	Pass	23	14	Pass	Pass	
Point 15	5.5	1%	Pass	23	13	Pass	Pass	
Point 16	5.5	5%	Pass	23	18	Pass	Pass	
Point 17	5.5	0%	Pass	23	10	Pass	Pass	
Point 18	5.5	1%	Pass	23	12	Pass	Pass	
Point 19	7.5	0%	Pass	23	14	Pass	Pass	
Point 20	7.5	4%	Pass	23	19	Pass	Pass	
Point 21	7.5	2%	Pass	23	16	Pass	Pass	
Point 22	7.5	5%	Pass	23	20	Pass	Pass	
Point 23	5.5	0%	Pass	23	9	Pass	Pass	
Point 24	7.5	0%	Pass	23	9	Pass	Pass	
Point 25	7.5	2%	Pass	23	16	Pass	Pass	
Point 26	5.5	1%	Pass	23	13	Pass	Pass	
Point 27	5.5	1%	Pass	23	13	Pass	Pass	
Point 28	7.5	1%	Pass	23	14	Pass	Pass	
Point 29	7.5	1%	Pass	23	15	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 30	7.5	1%	Pass	23	15	Pass	Pass	
Point 31	7.5	0%	Pass	23	11	Pass	Pass	
Point 32	7.5	5%	Pass	23	20	Pass	Pass	
Existing		4%	Pass		17	Pass	Pass	
Point 33	7.5	0%	Pass	23	11	Pass	Pass	
Point 34	7.5	1%	Pass	23	15	Pass	Pass	
Point 35	5.5	5%	Pass	23	16	Pass	Pass	
Point 36	5.5	6%	Fail	23	17	Pass	Fail	Refer to Figure 12b.
Point 37	5.5	1%	Pass	23	11	Pass	Pass	
Point 38	5.5	6%	Fail	23	17	Pass	Fail	Refer to Figure 12c.
Point 39	5.5	25%	Fail	23	23	Pass	Fail	Refer to Figure 12c.
Point 40	5.5	6%	Fail	23	16	Pass	Fail	Refer to Figure 12c.
Point 41	5.5	9%	Fail	23	16	Pass	Fail	Refer to Figure 12c.
Point 42	5.5	7%	Fail	23	15	Pass	Fail	Refer to Figure 12c.
Point 43	5.5	10%	Fail	23	19	Pass	Fail	Refer to Figure 12d.
Point 44	5.5	3%	Pass	23	15	Pass	Pass	
Point 45	5.5	8%	Fail	23	19	Pass	Fail	Refer to Figure 12d.
Point 46	5.5	5%	Pass	23	18	Pass	Pass	

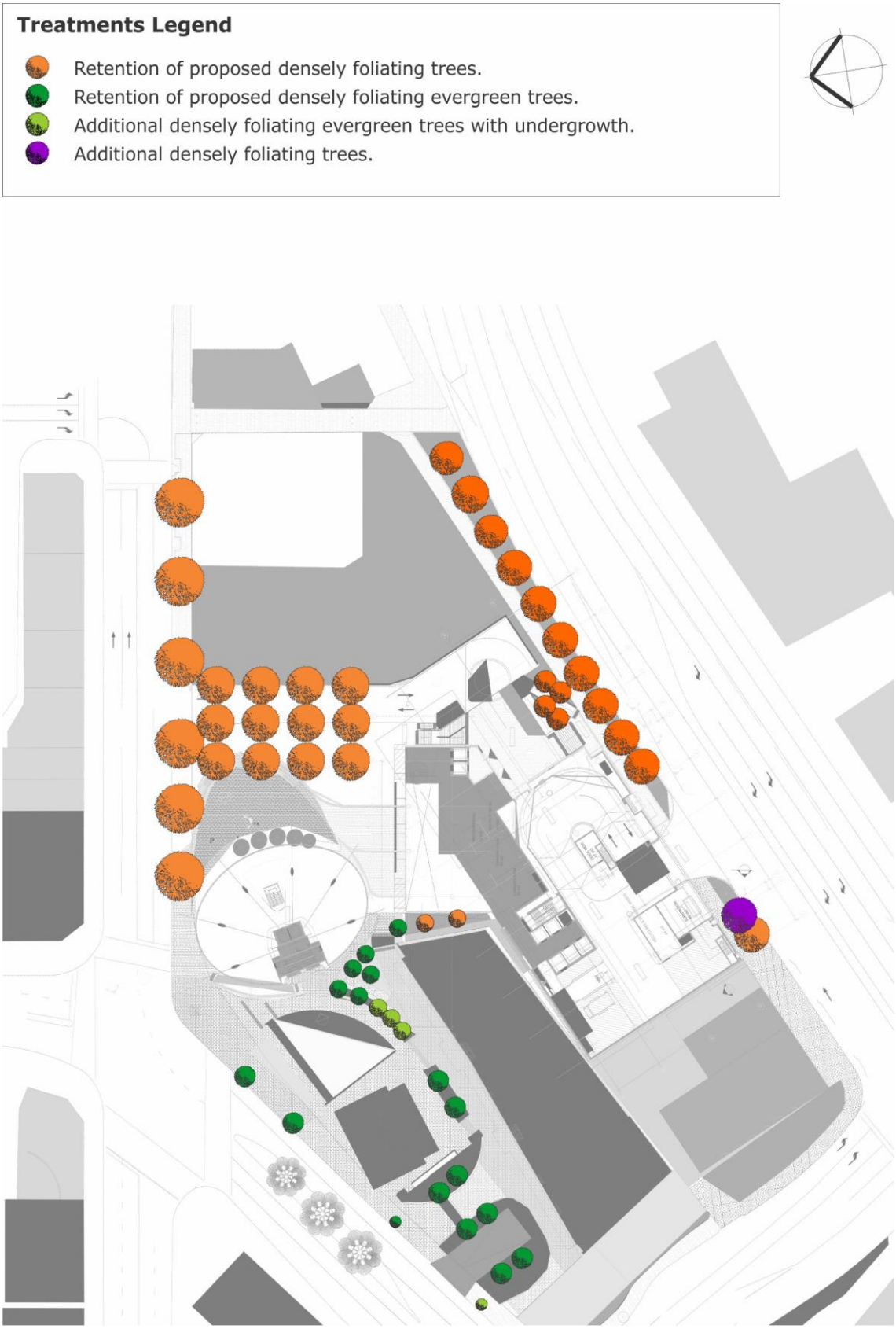

Figure 12a: Suggested Treatments – Ground Level Plan

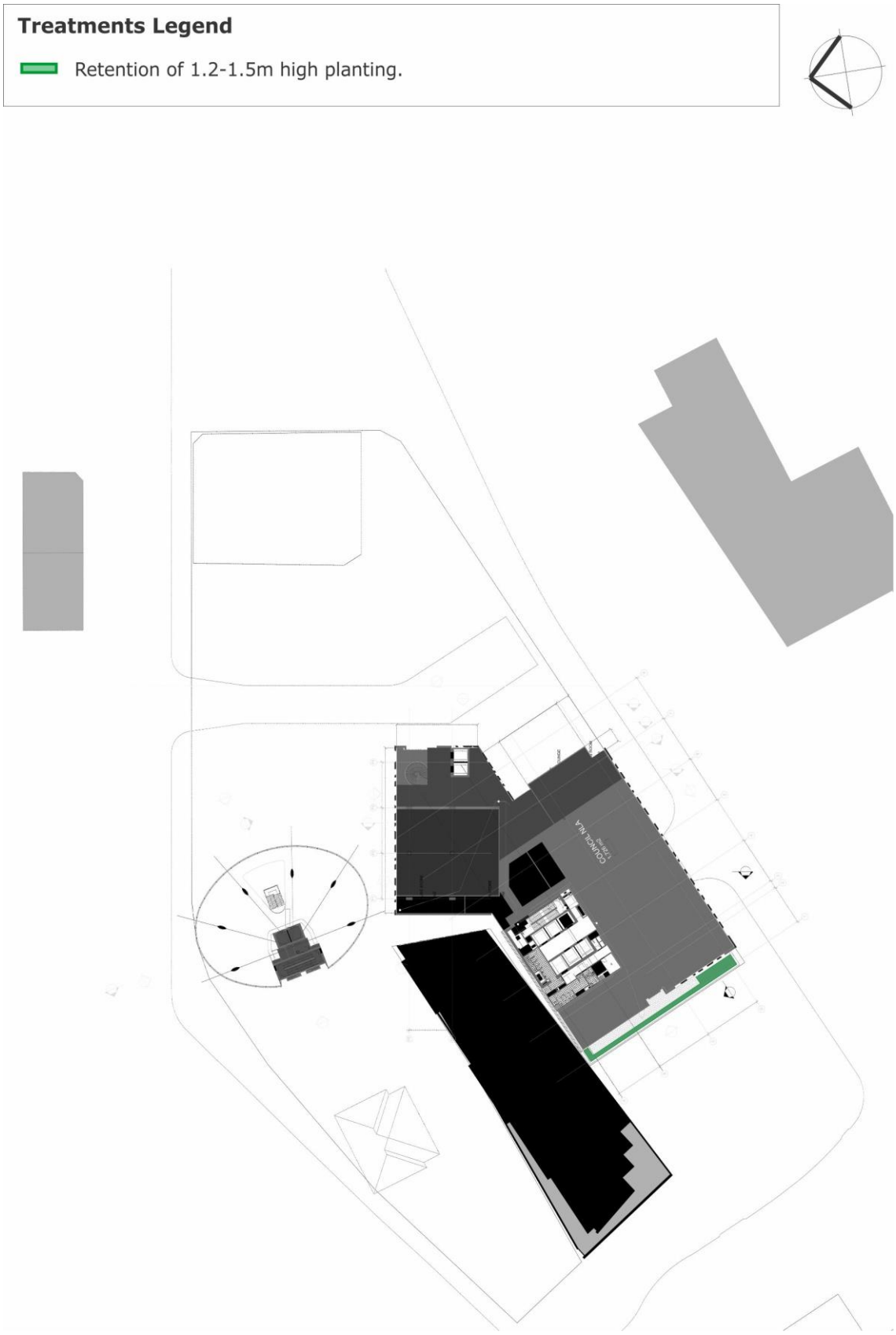

Figure 12b: Suggested Treatments – Level 01

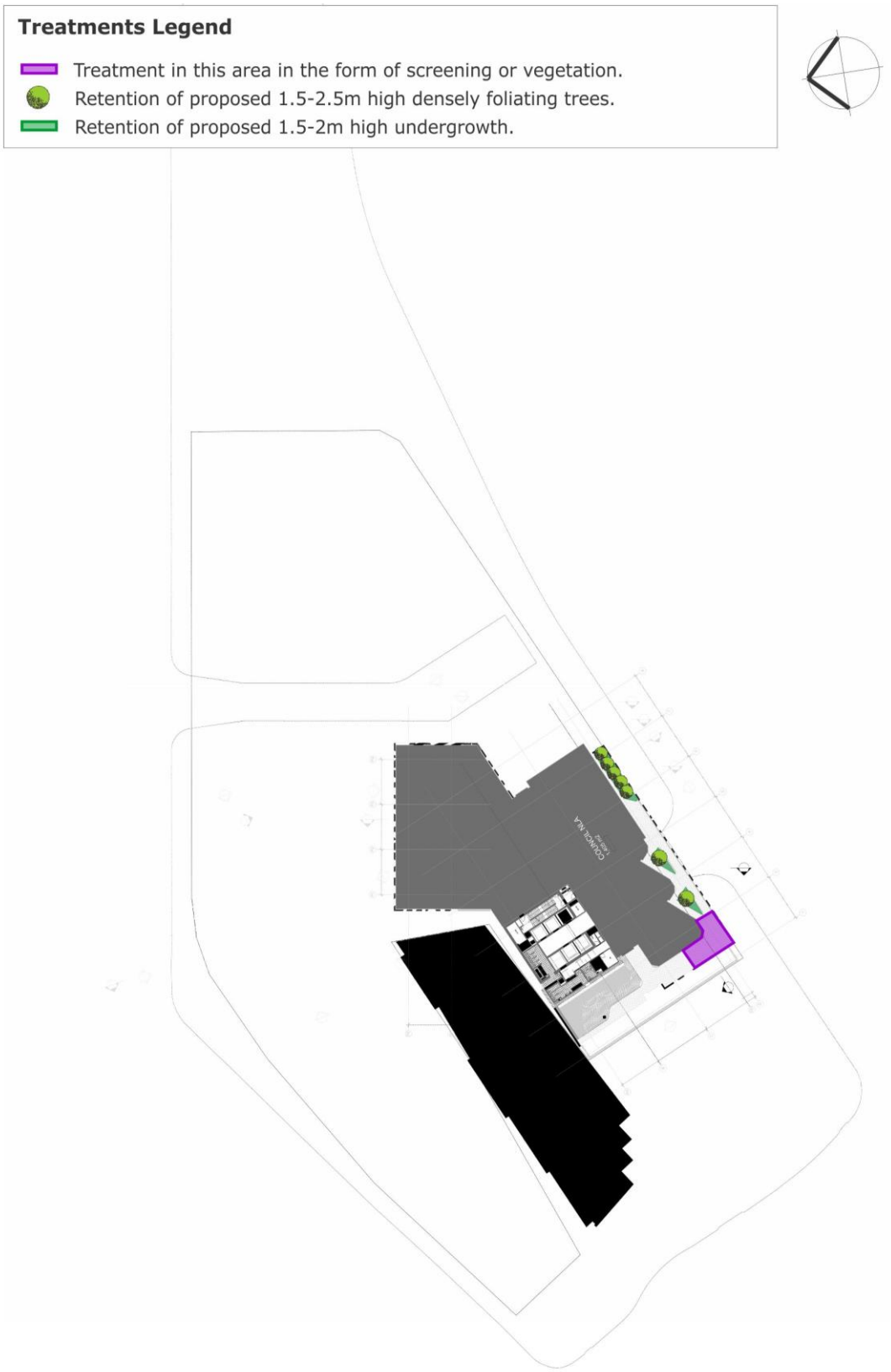

Figure 12c: Suggested Treatments – Level 04

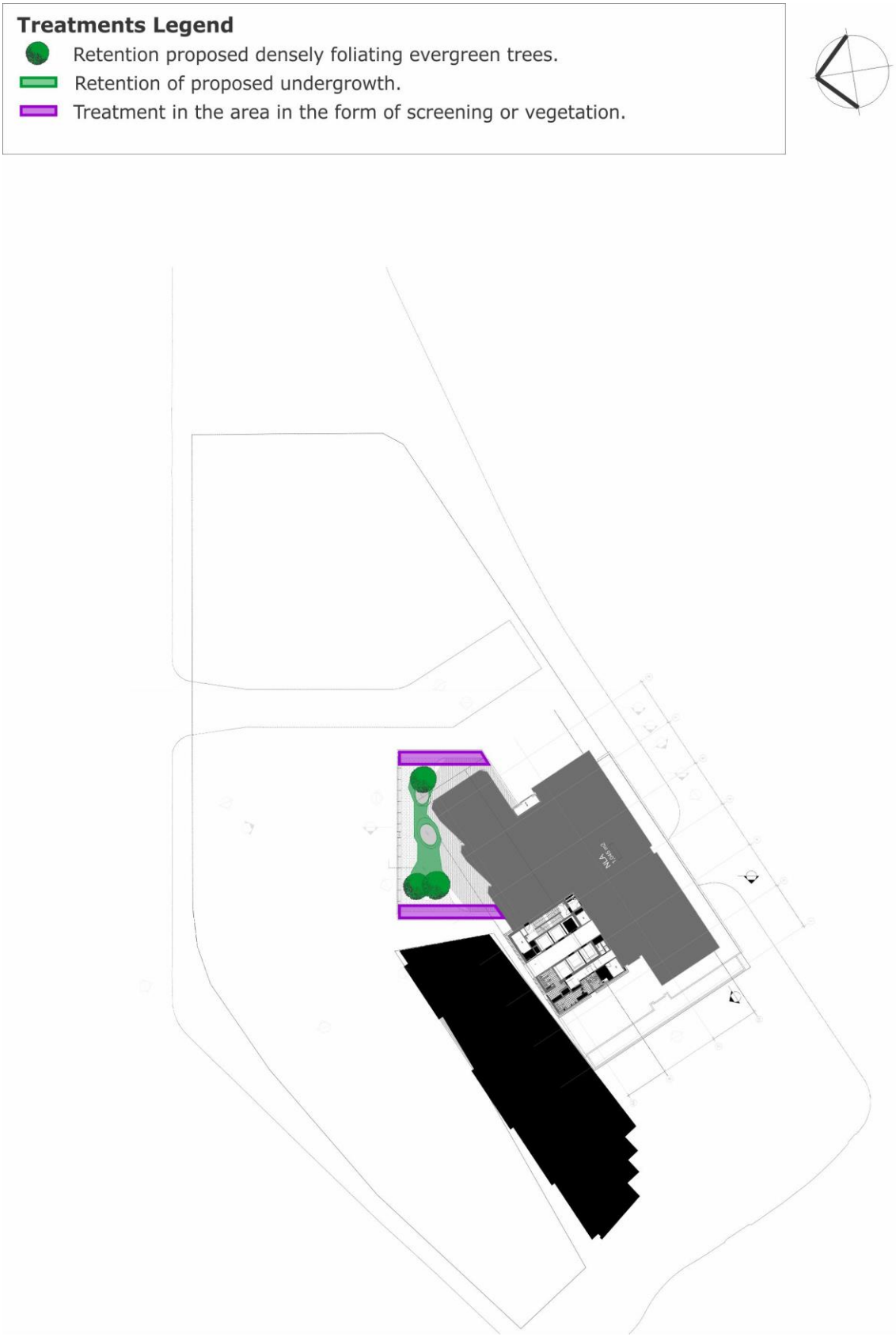

Figure 12d: Suggested Treatments– Level 07

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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.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%.

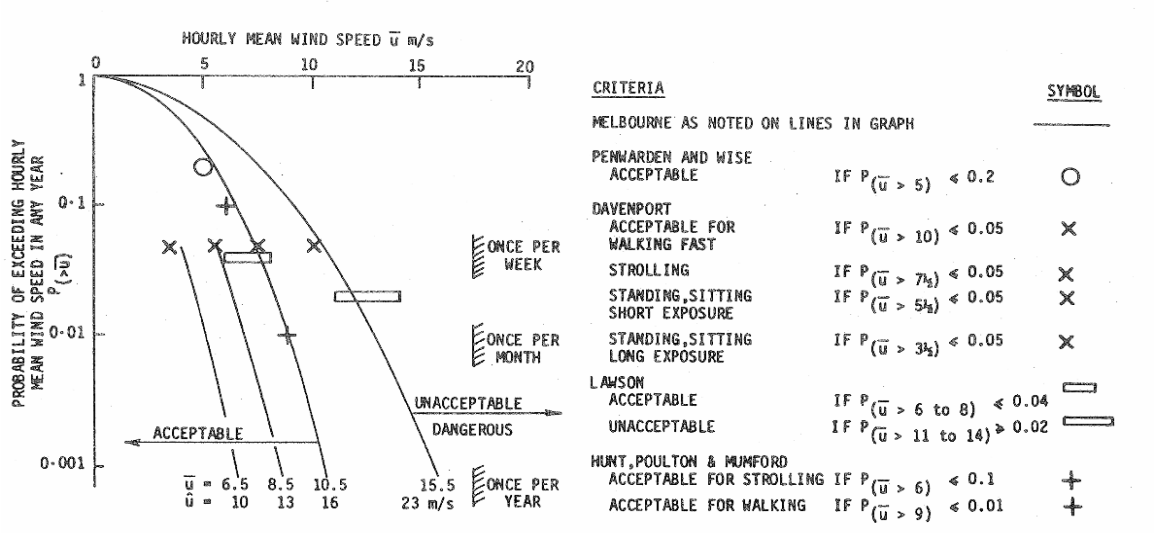

Figure A.1: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (W.H. Melbourne, 1978)

A.3 References relating to Pedestrian Comfort Criteria

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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 5 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 5) and the upwind terrain and height multipliers for the site (detailed in Section 4).

$k_{200m,tr,T=1hr}$ 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 4).

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 $\mathrm{V_{ref,RH}}$ 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.

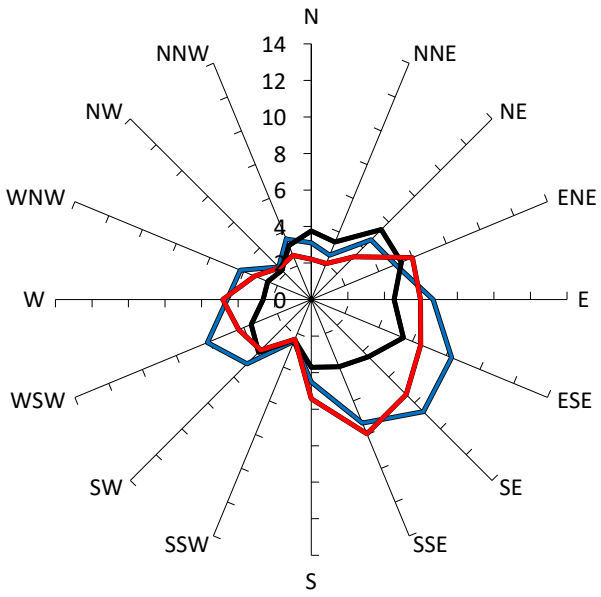
Lawson, T.V., 1980, "Wind Effects on Buildings - Volume 1, Design Applications". Applied Science Publishers Ltd, Ripple Road, Barking, Essex, England.

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

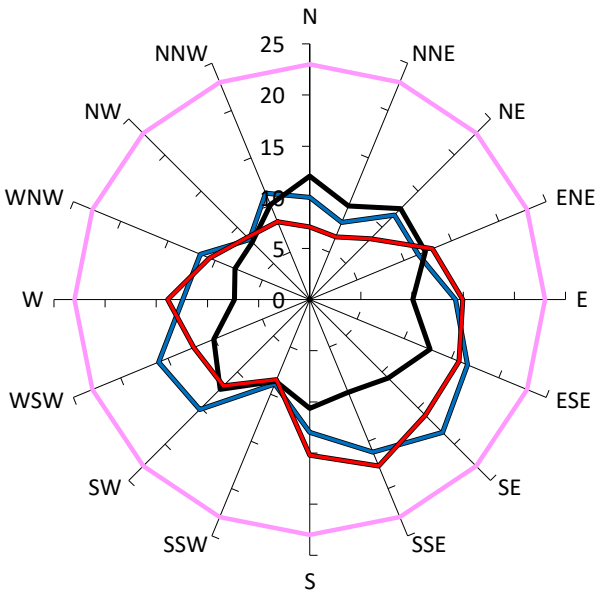
Results for Point 01

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

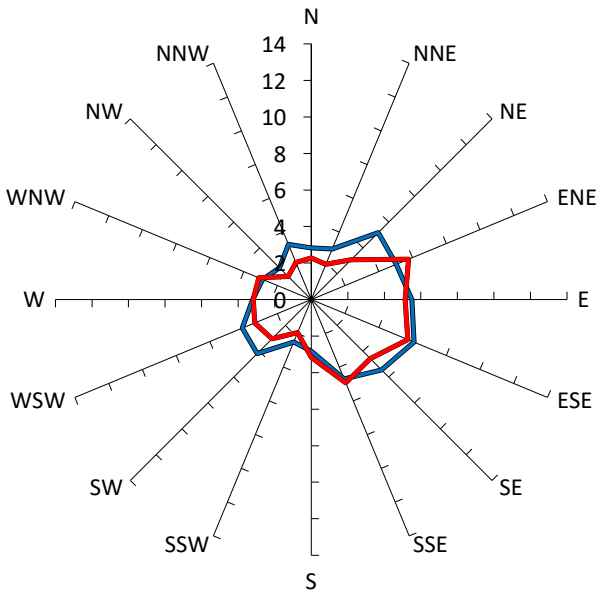


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	6%	18
Existing Case	0%	13
Future Case	3%	18

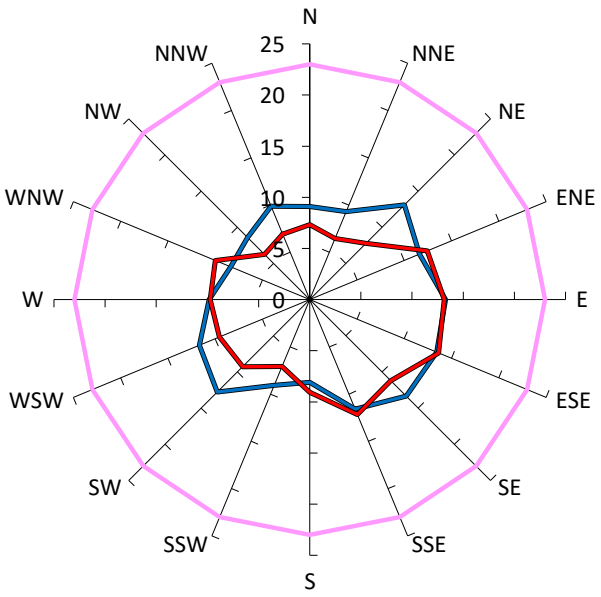
Results for Point 02

Gust Equivalent Mean (m/s)



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

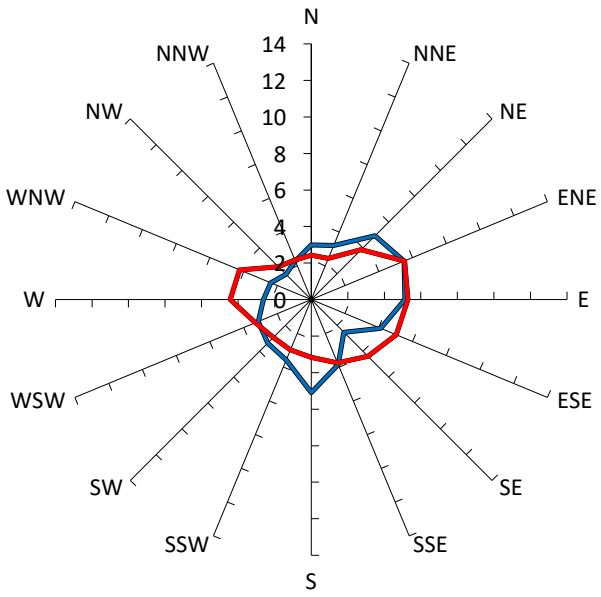
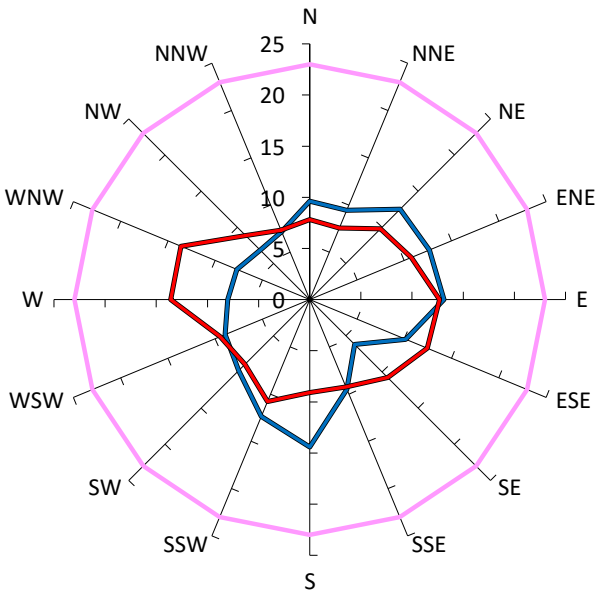
Maximum Gust (m/s)



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
Proposed Case	1%	13
Future Case	0%	14

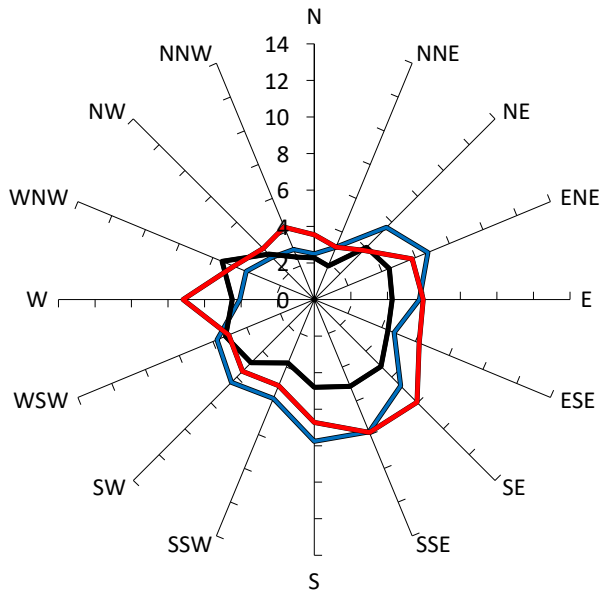
Results for Point 03

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
Proposed Case	0%	14
Future Case	0%	14

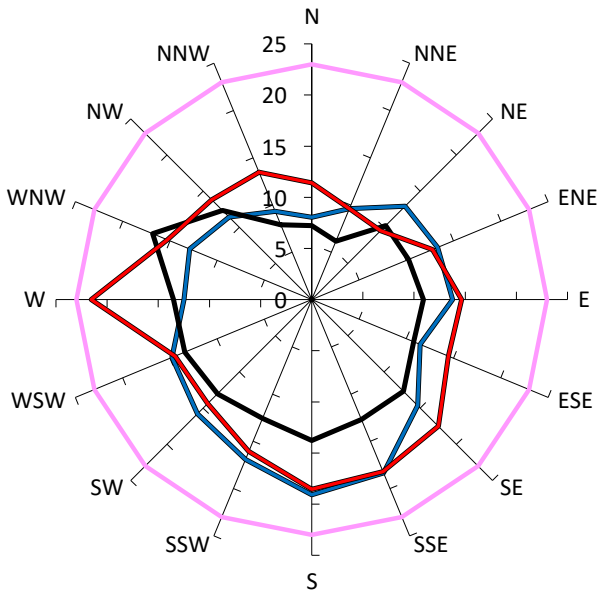
Results for Point 04

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
Proposed Case	5%	19
Existing Case	1%	17
Future Case	6%	22

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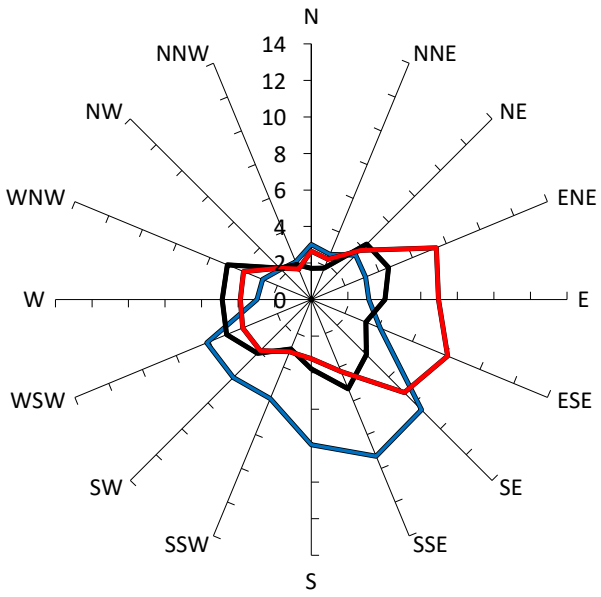
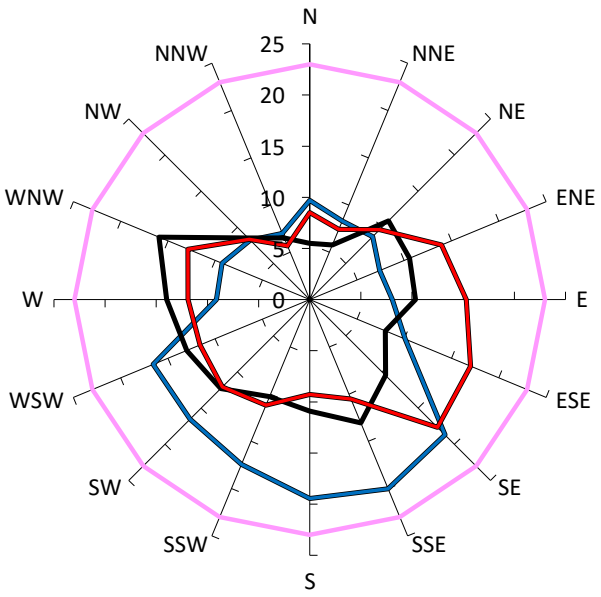
Results for Point 05

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
Proposed Case	8%	20
Existing Case	1%	16
Future Case	4%	18

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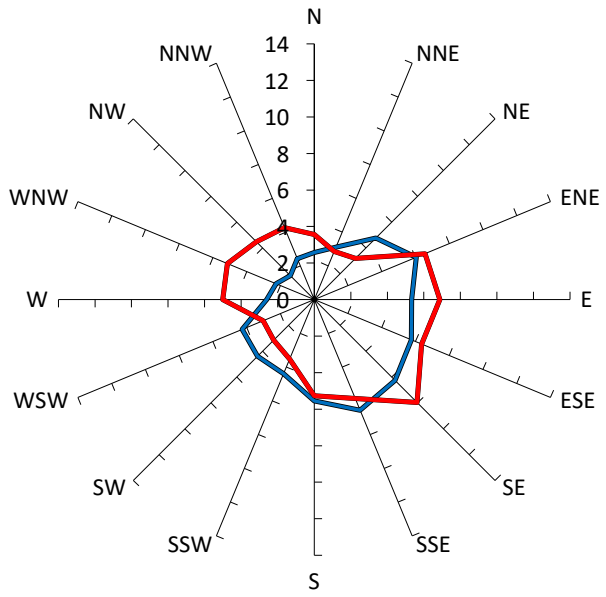
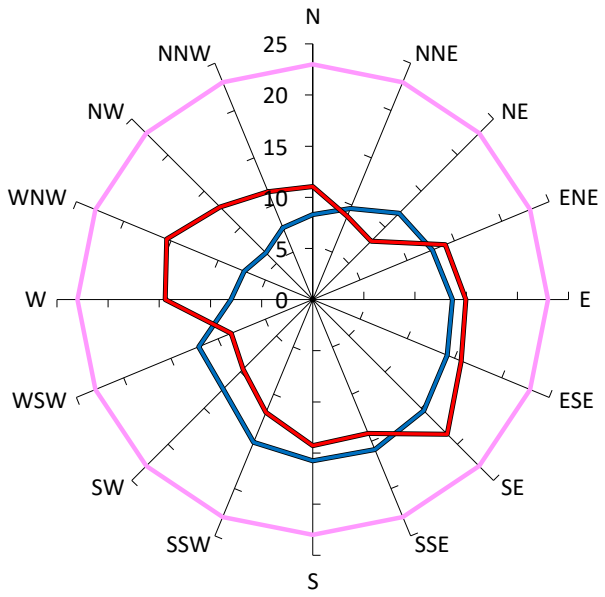
Results for Point 06

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

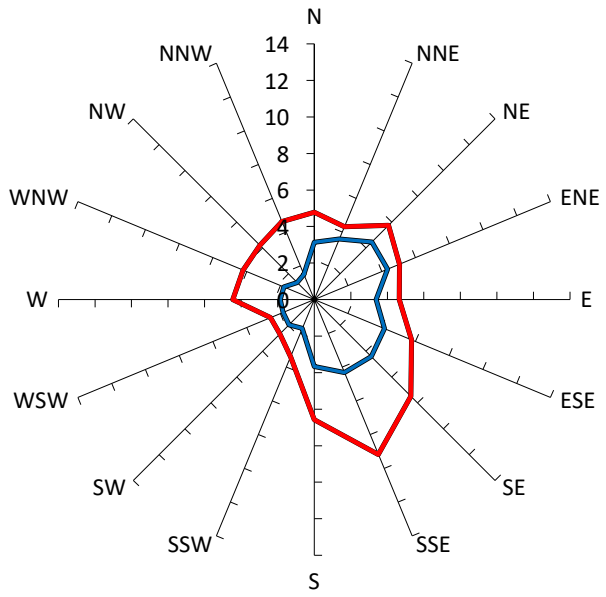


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	1%	16
Future Case	3%	19

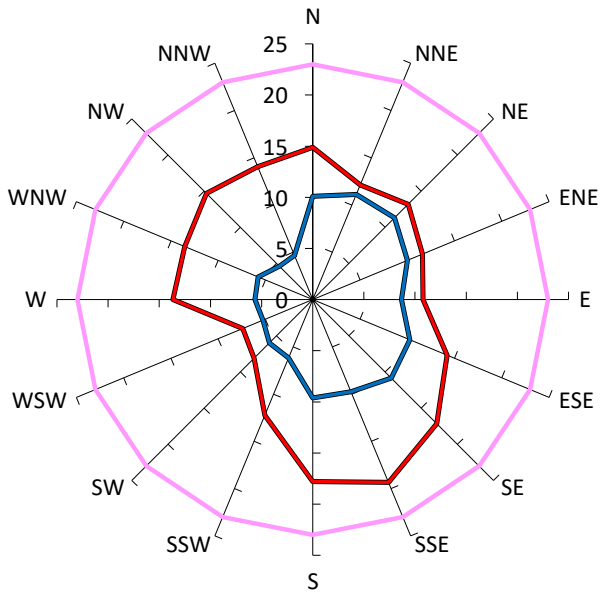
Results for Point 07

Gust Equivalent Mean (m/s)



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

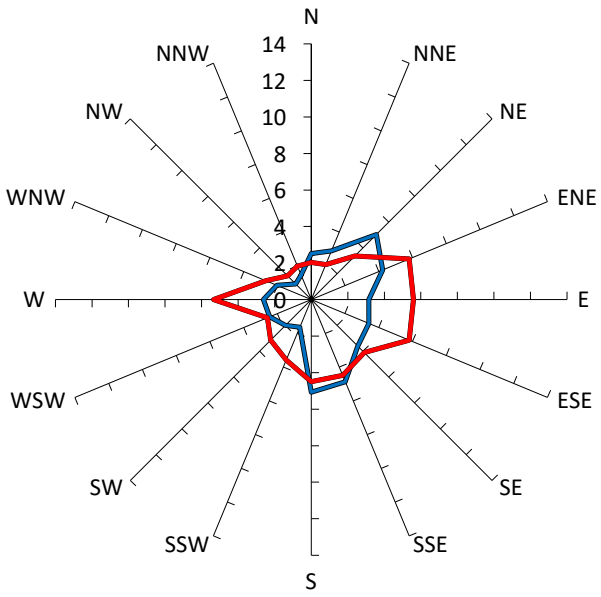
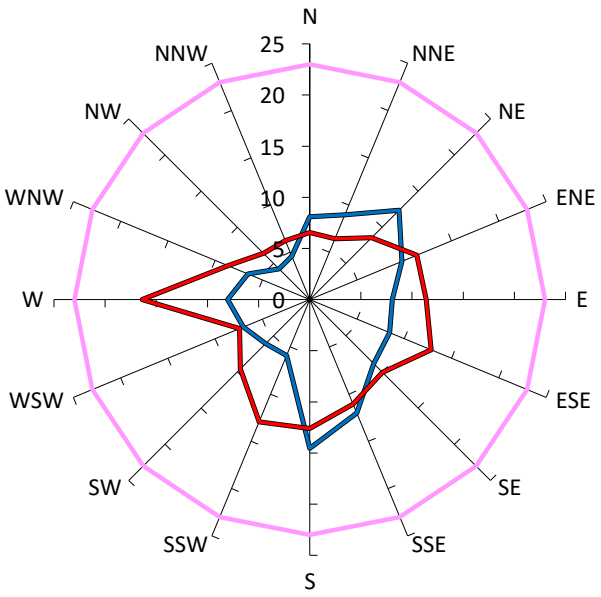
Maximum Gust (m/s)



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
Proposed Case	0%	11
Future Case	6%	19

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
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	0%	15
Future Case	1%	16

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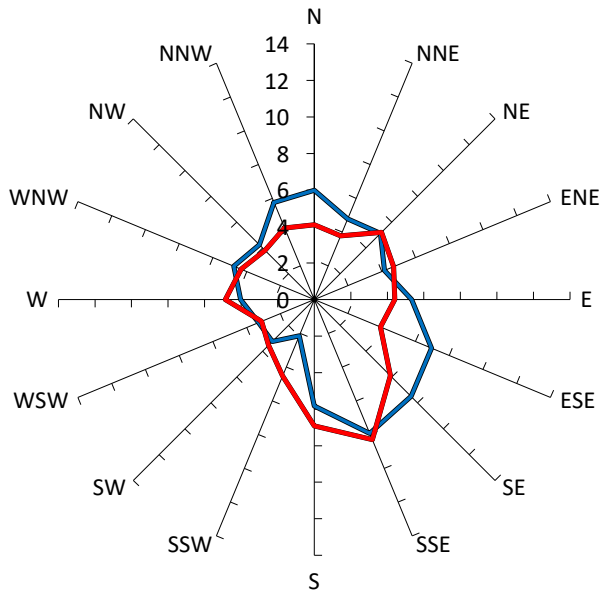
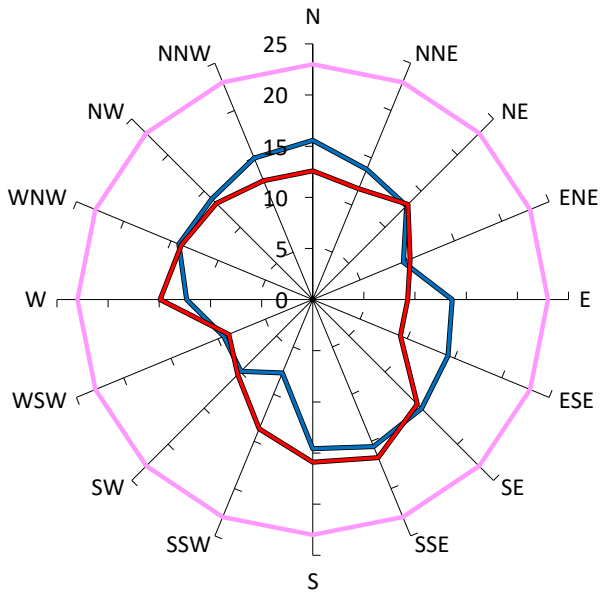
Results for Point 09

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

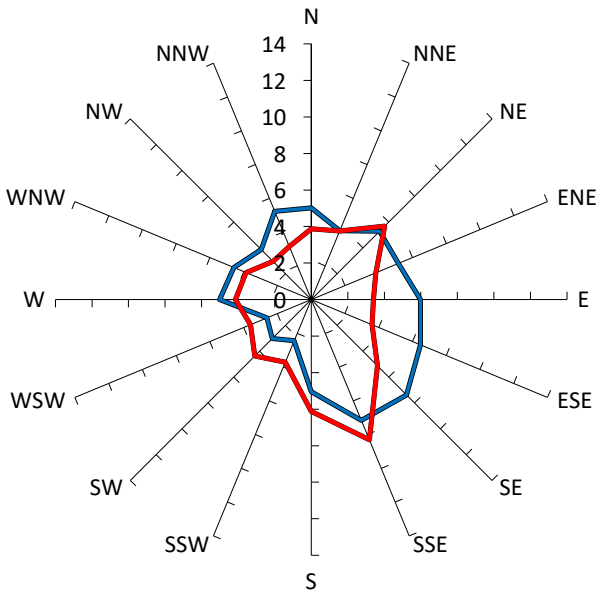


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	5%	16
Future Case	4%	17

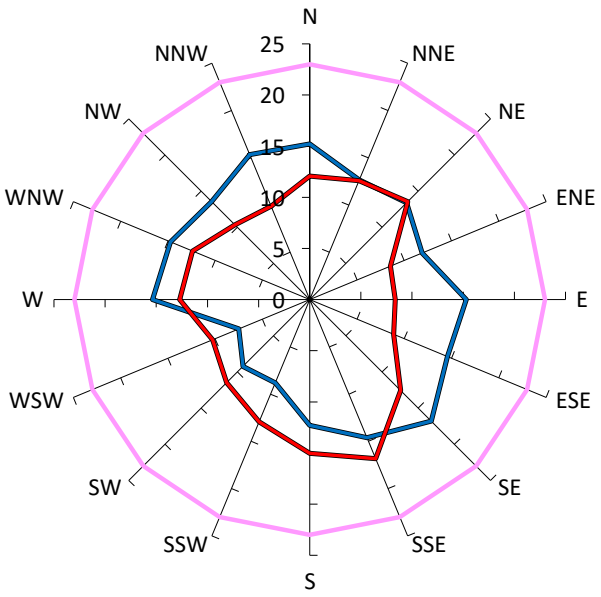
Results for Point 10

Gust Equivalent Mean (m/s)



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

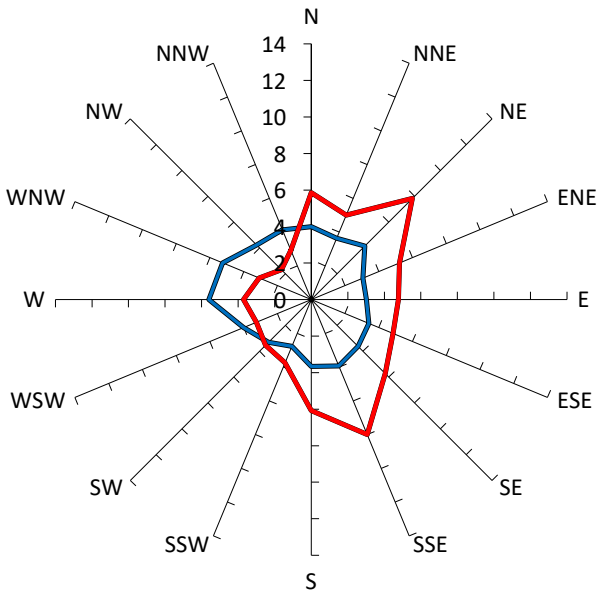
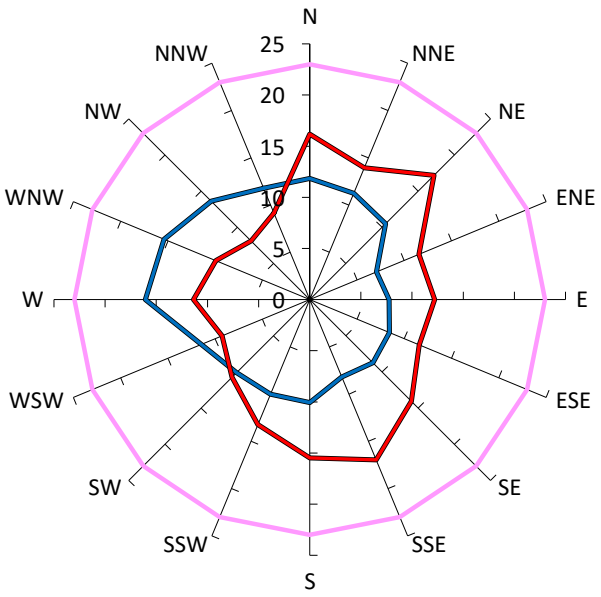
Maximum Gust (m/s)



Safety Limit: 23m/s

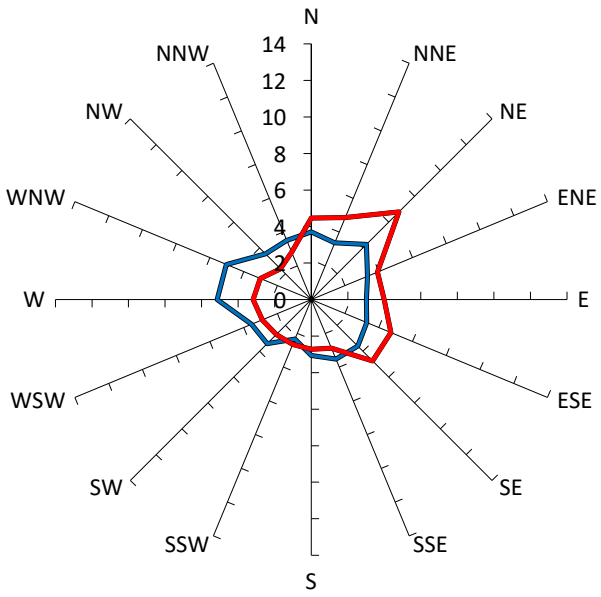
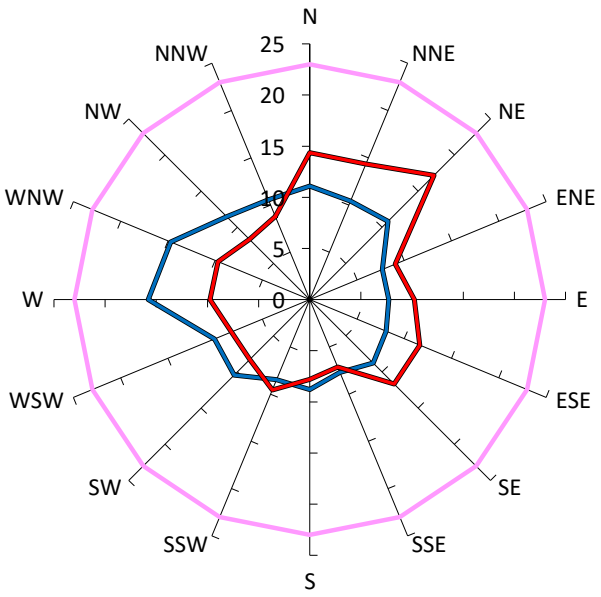
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	3%	17
Future Case	3%	17

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

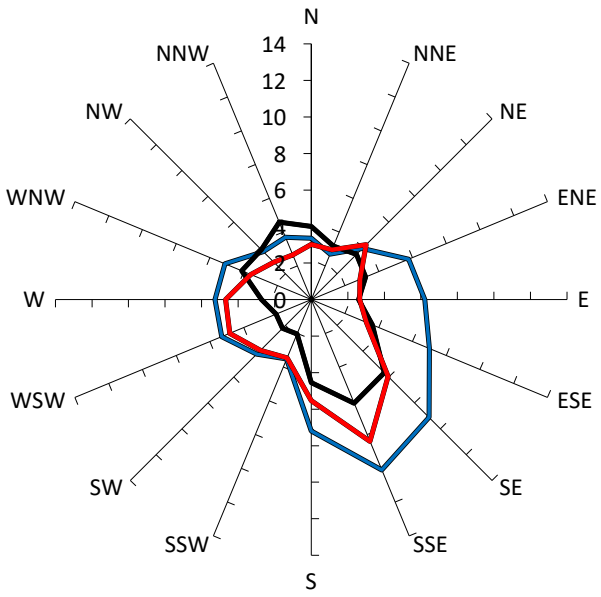
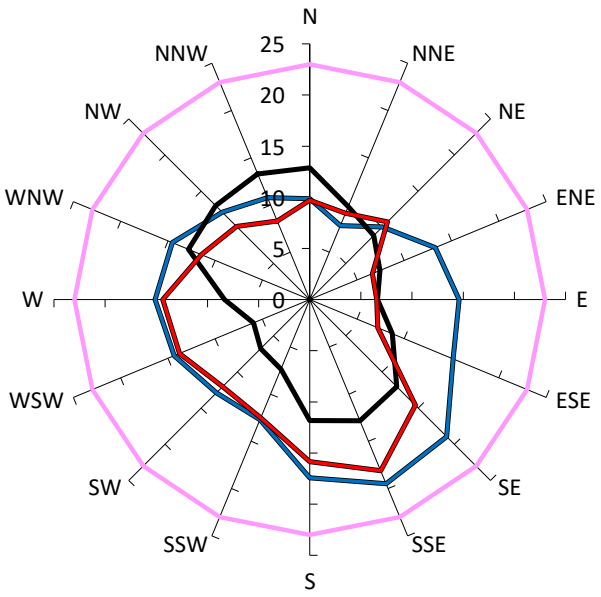
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	1%	16
Future Case	5%	17

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
Proposed Case	1%	16
Future Case	1%	17

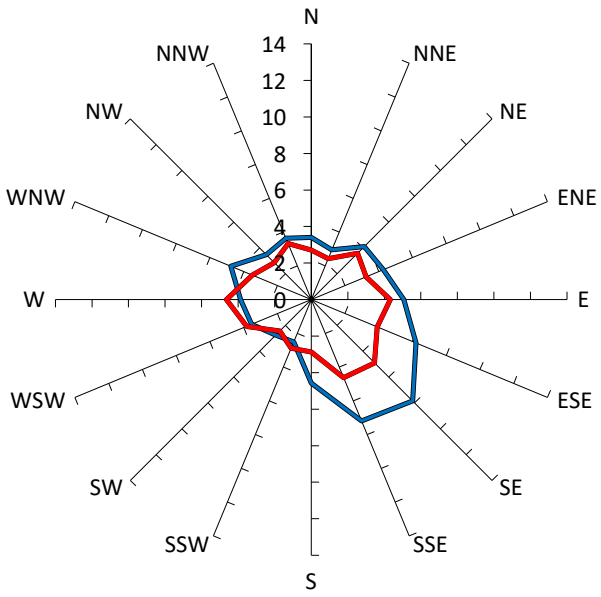
Results for Point 13

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
Proposed Case	9%	19
Existing Case	1%	13
Future Case	3%	18

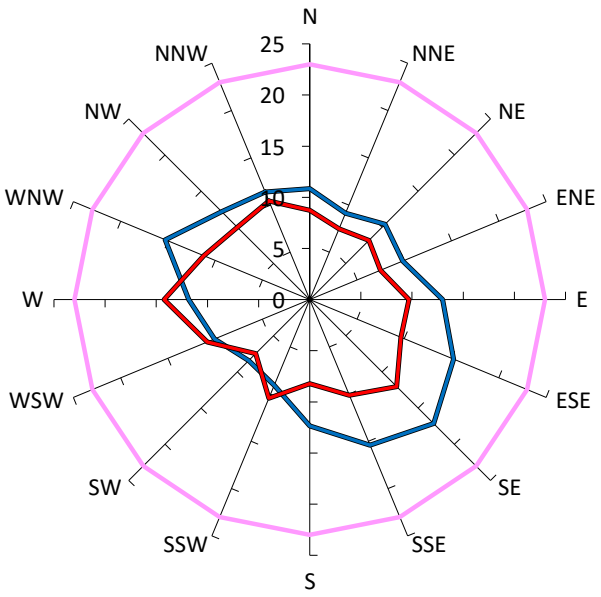
Results for Point 14

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

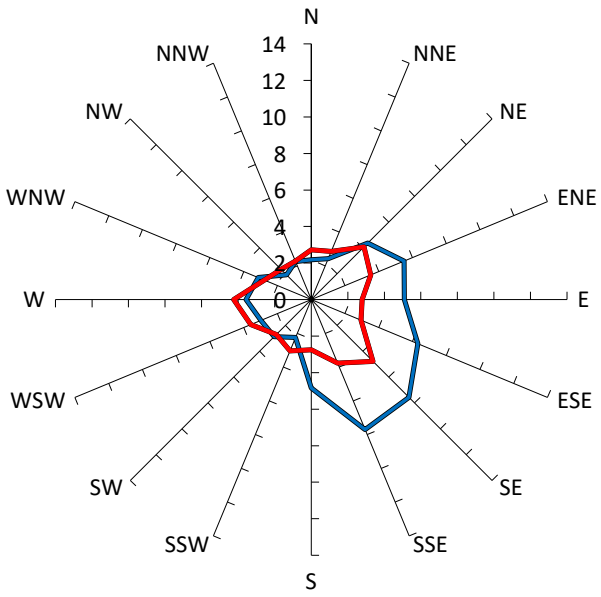


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	13%	17
Future Case	2%	14

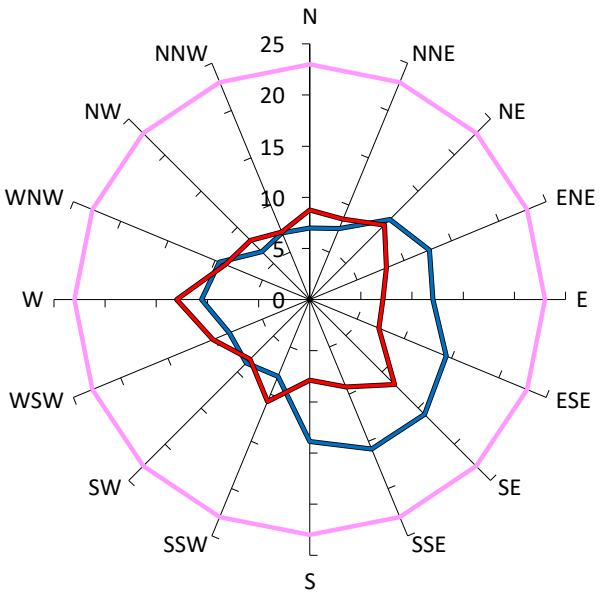
Results for Point 15

Gust Equivalent Mean (m/s)



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

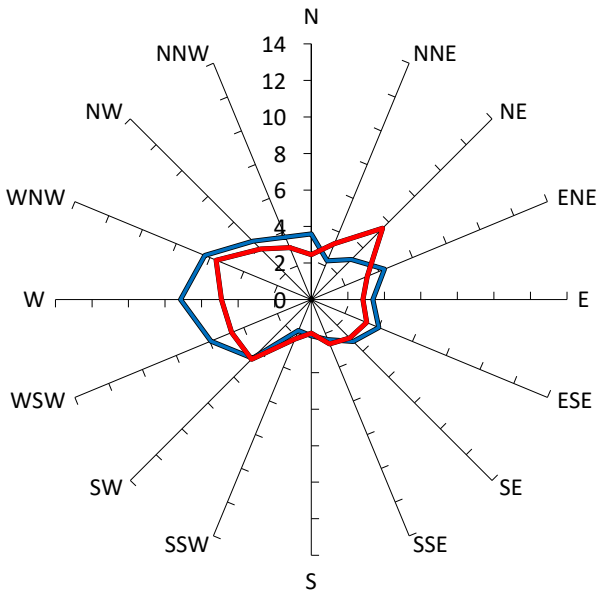
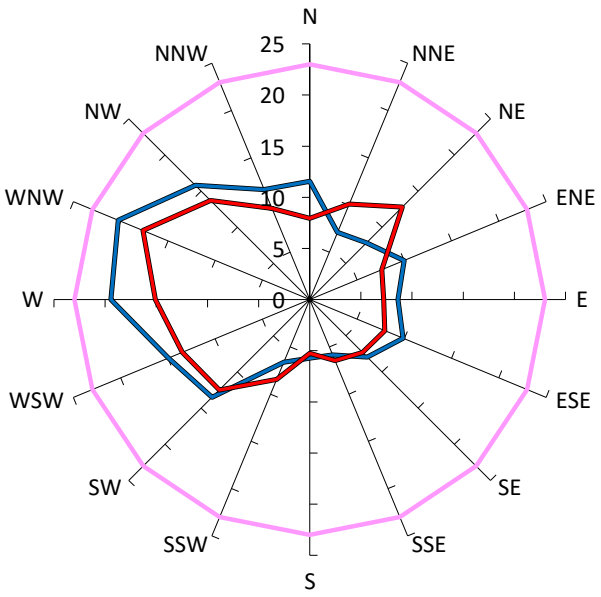
Maximum Gust (m/s)



Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	12%	16
Future Case	1%	13

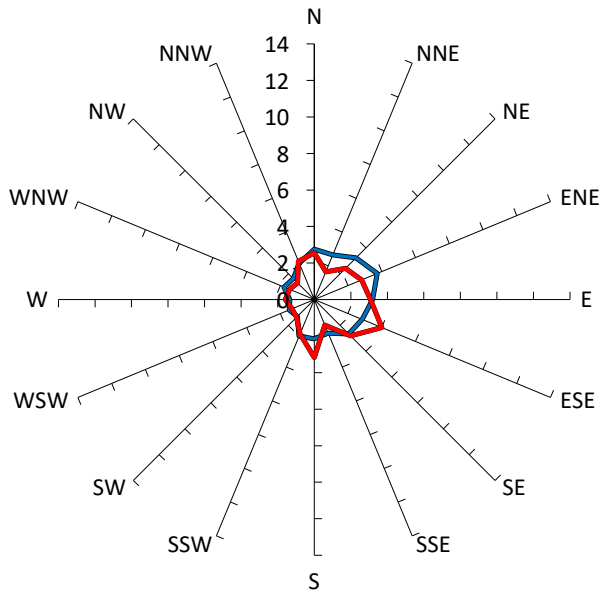
Results for Point 16

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
Proposed Case	8%	20
Future Case	5%	18

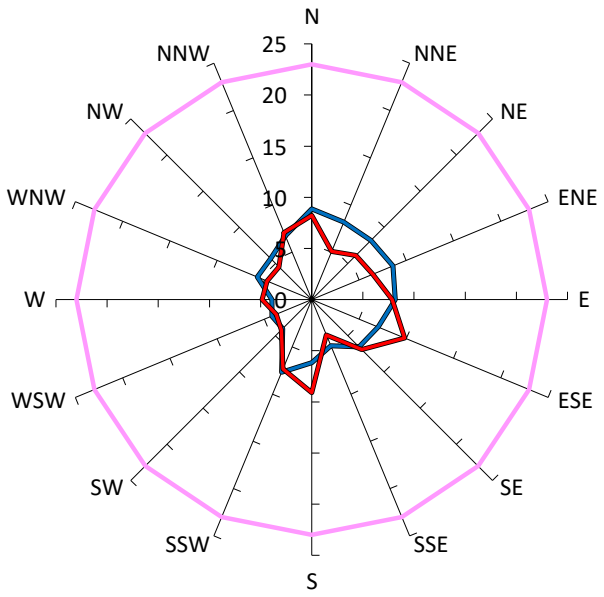
Results for Point 17

Gust Equivalent Mean (m/s)



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

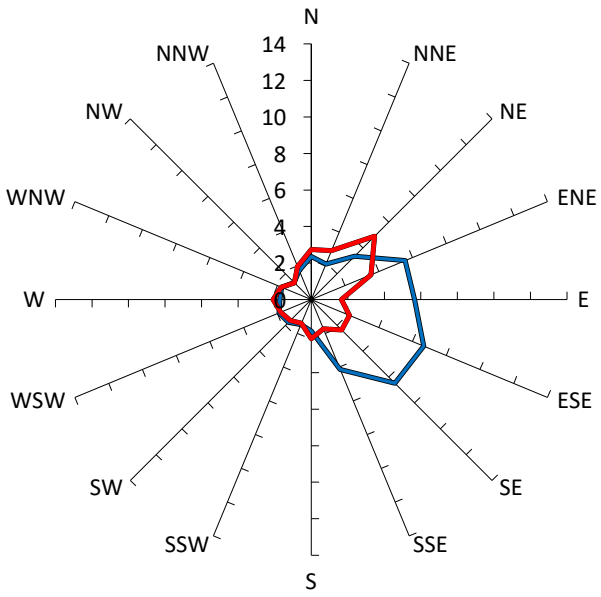
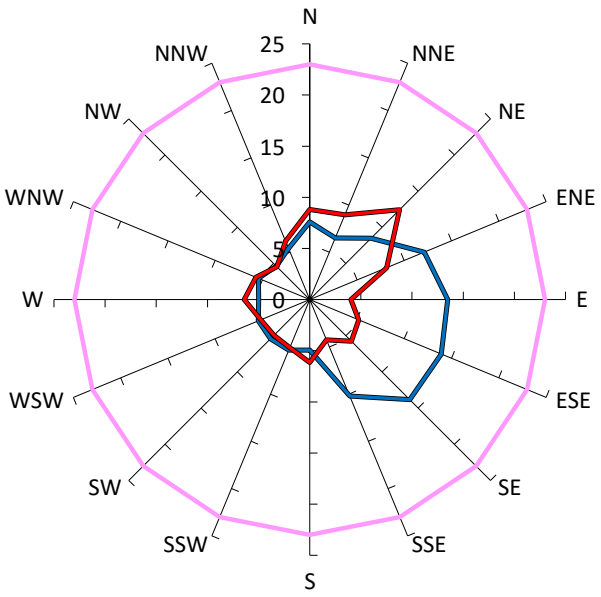
Maximum Gust (m/s)



Safety Limit: 23m/s

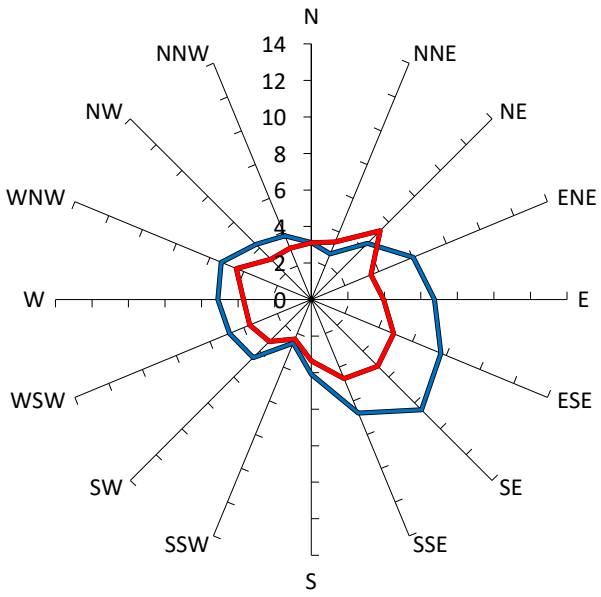
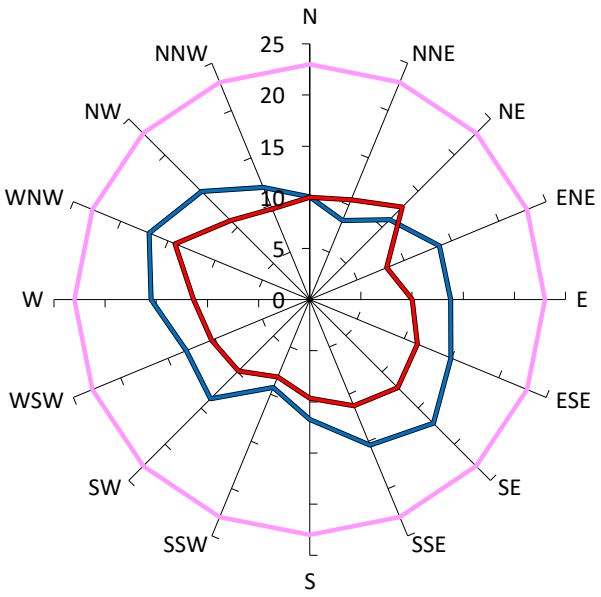
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	0%	9
Future Case	0%	10

Results for Point 18

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
Proposed Case	7%	14
Future Case	1%	12

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
Proposed Case	5%	17
Future Case	0%	14

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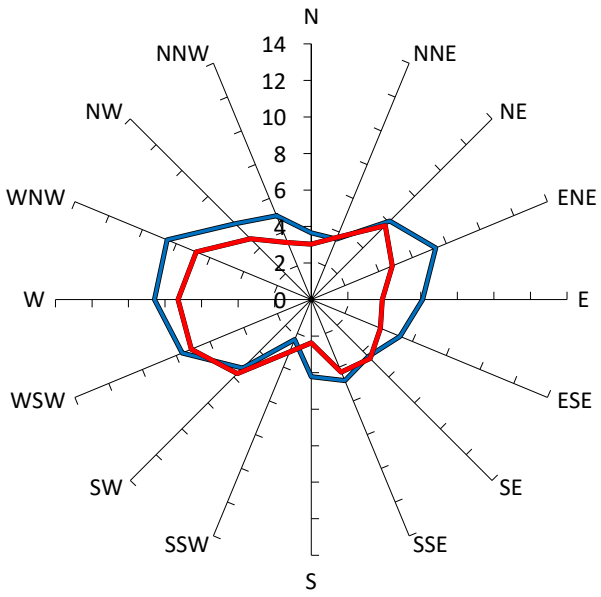
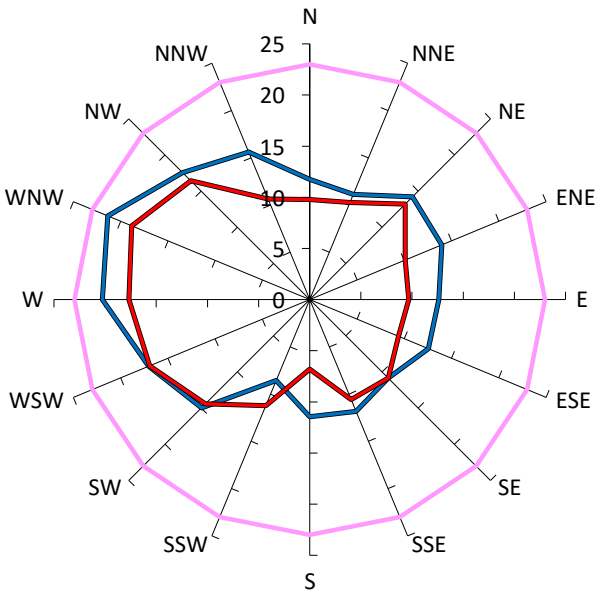
Results for Point 20

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
Proposed Case	7%	21
Future Case	4%	19

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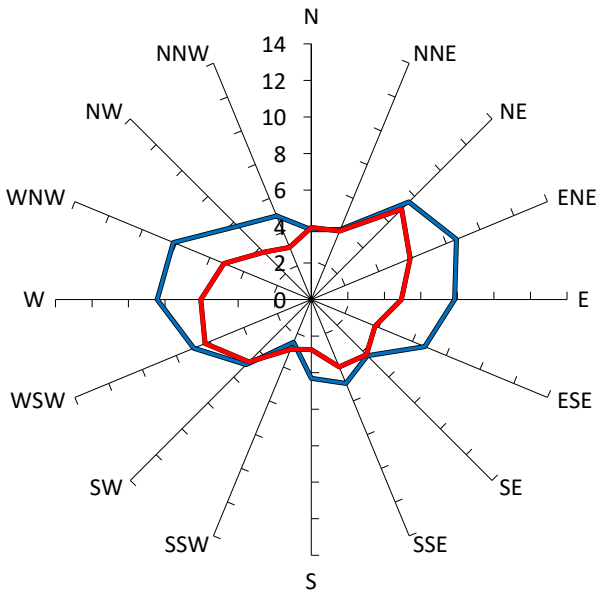
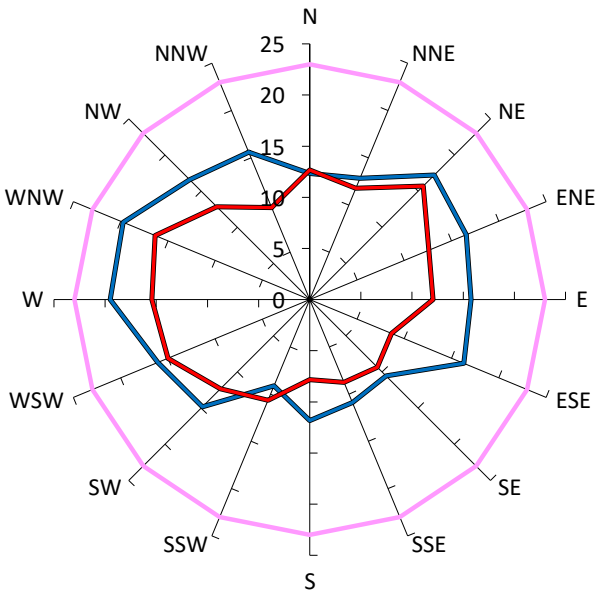
Results for Point 21

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
Proposed Case	11%	20
Future Case	2%	16

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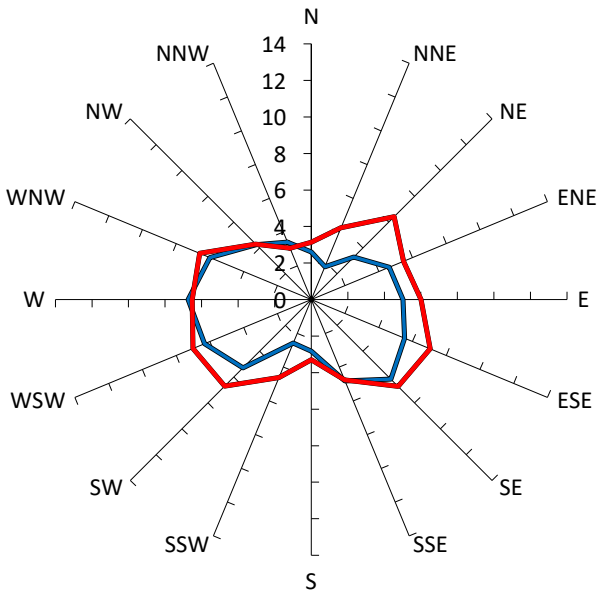
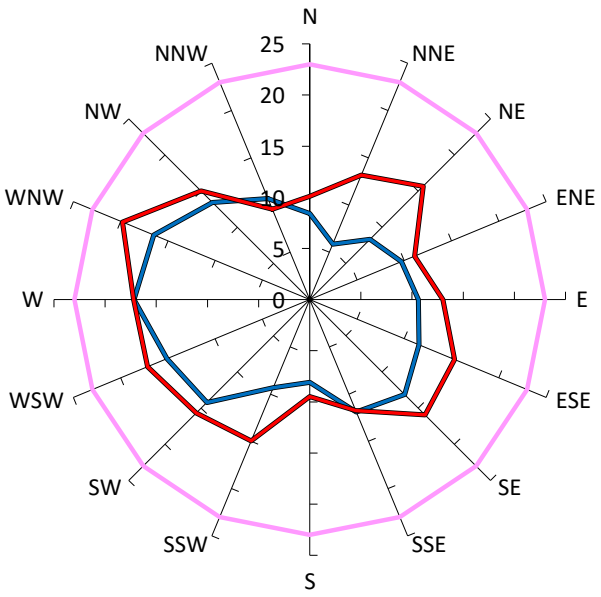
Results for Point 22

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

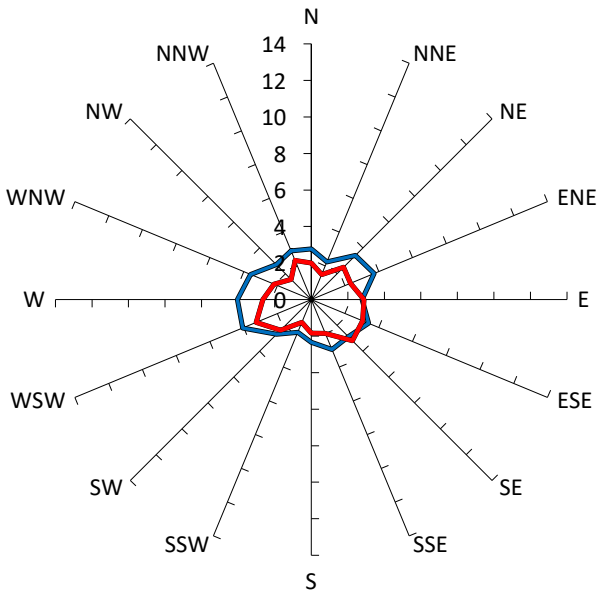


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	2%	17
Future Case	5%	20

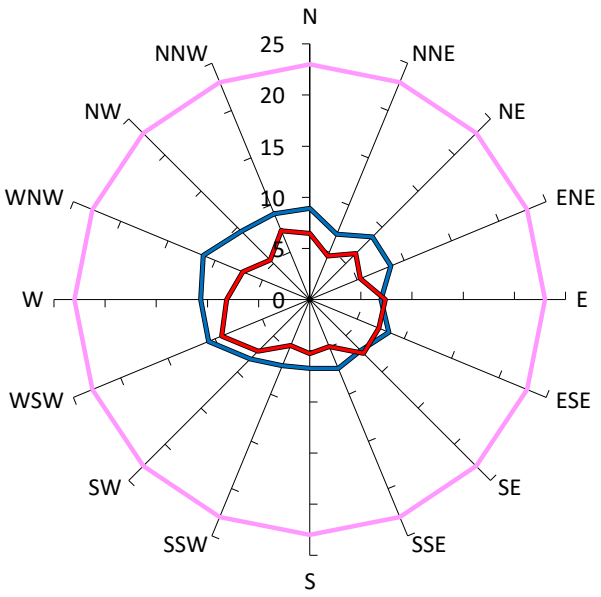
Results for Point 23

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

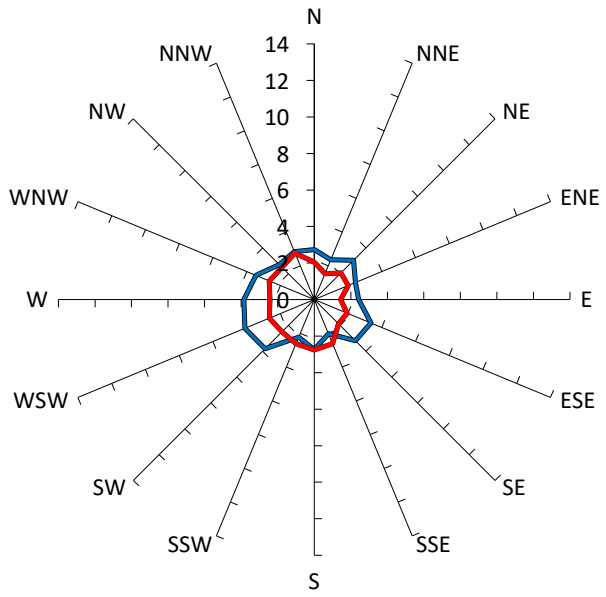


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	1%	11
Future Case	0%	9

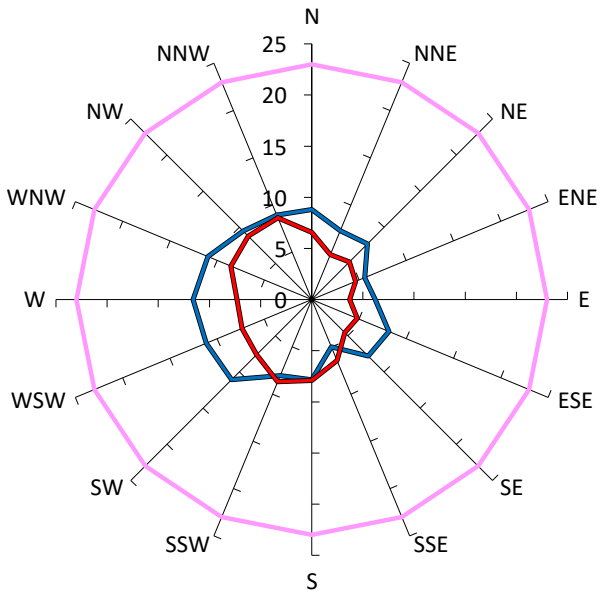
Results for Point 24

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

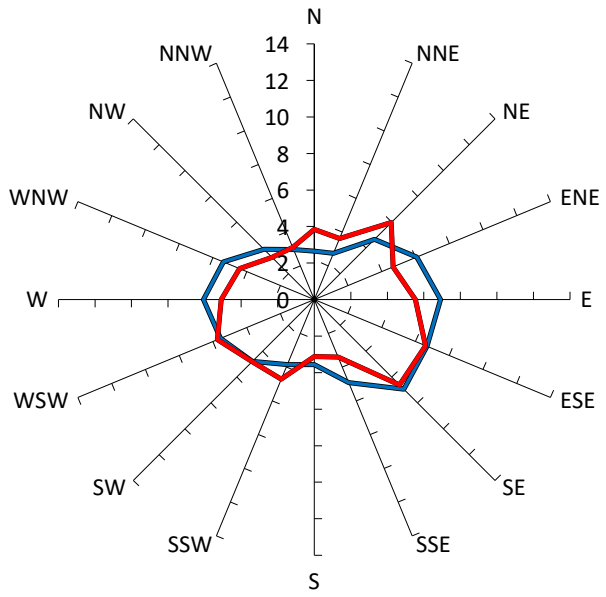


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	0%	12
Future Case	0%	9

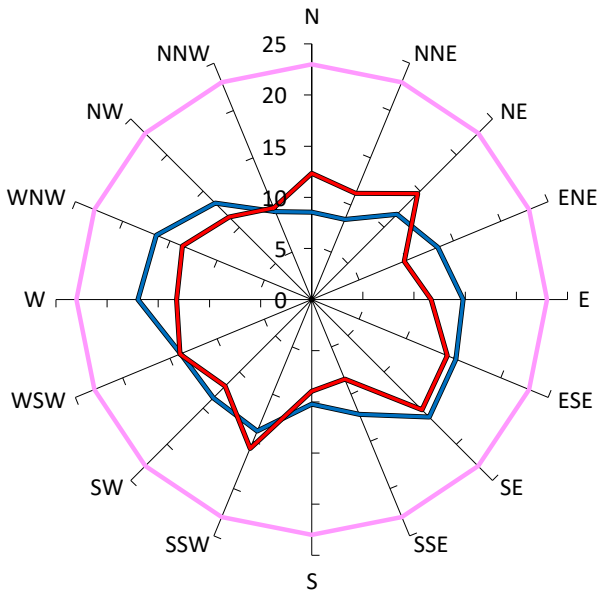
Results for Point 25

Gust Equivalent Mean (m/s)



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

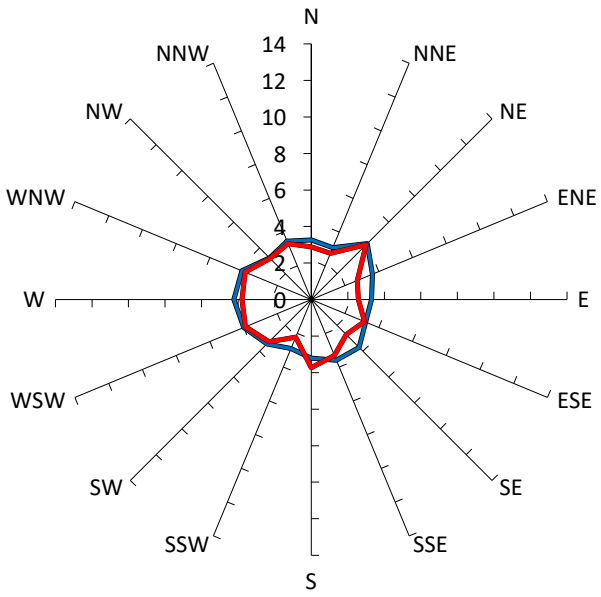
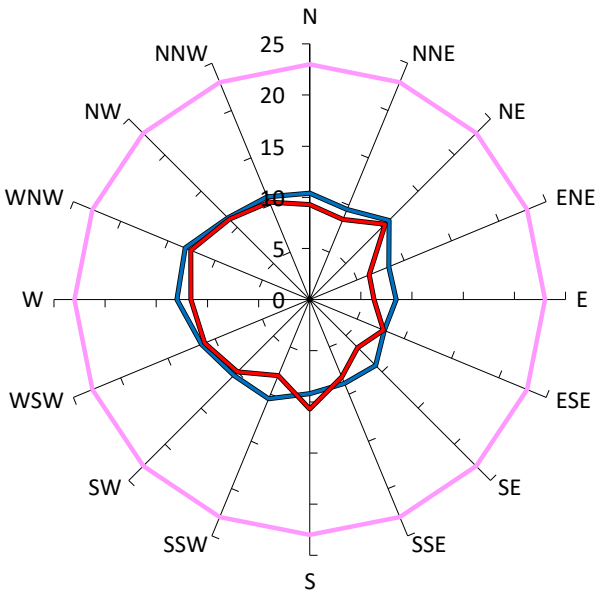
Maximum Gust (m/s)



Safety Limit: 23m/s

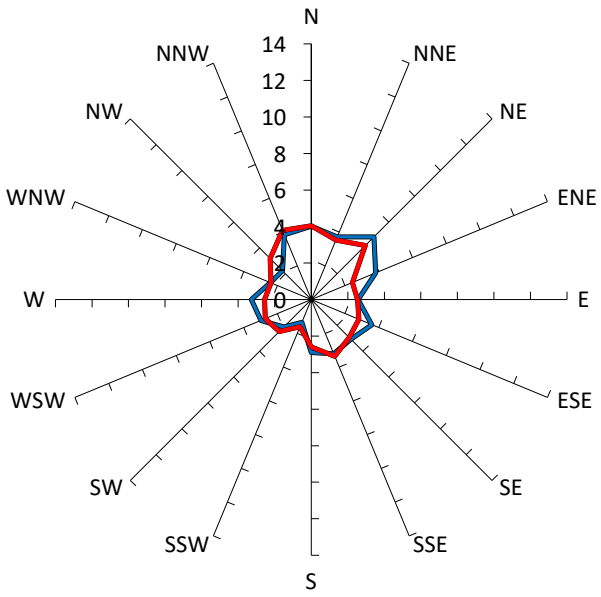
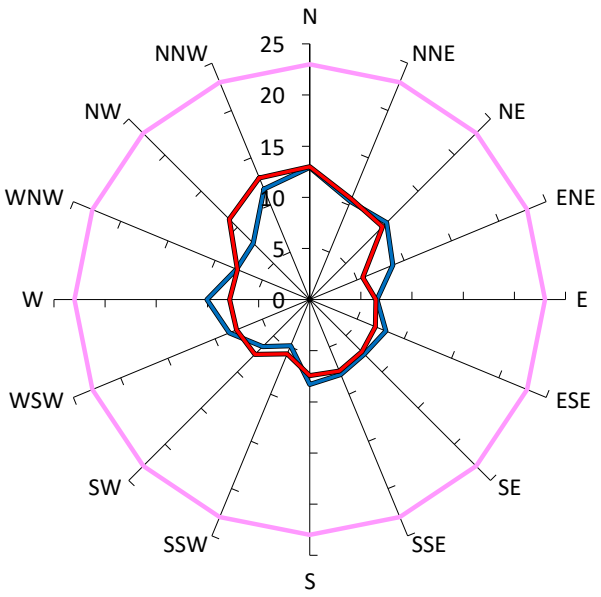
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	3%	17
Future Case	2%	16

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

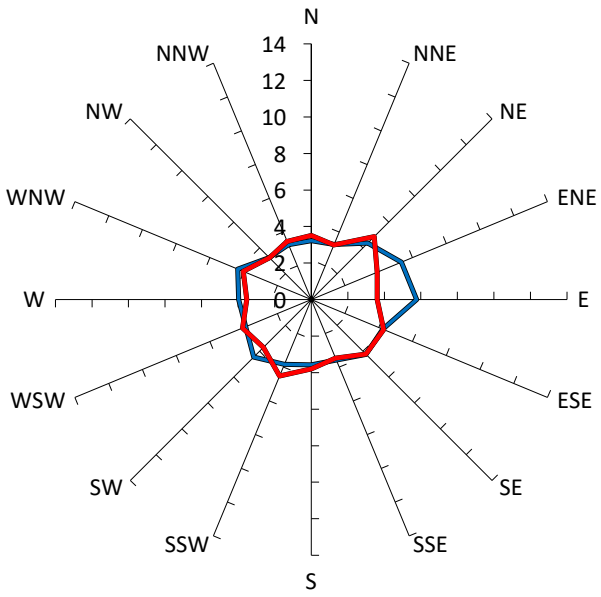
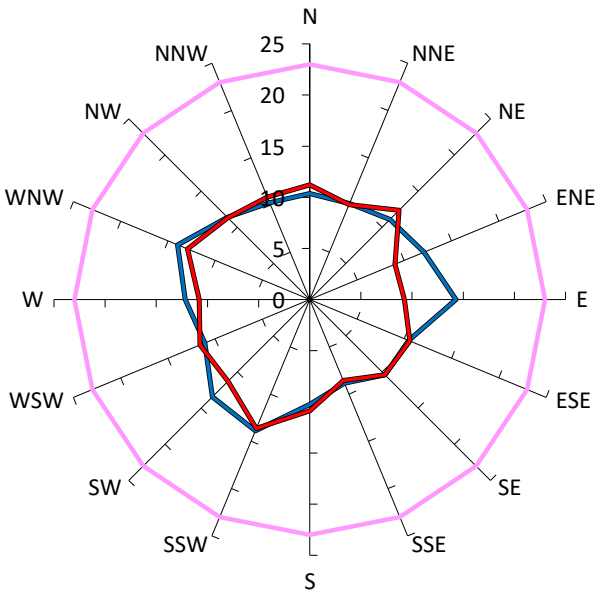
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	2%	13
Future Case	1%	13

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
Proposed Case	2%	13
Future Case	1%	13

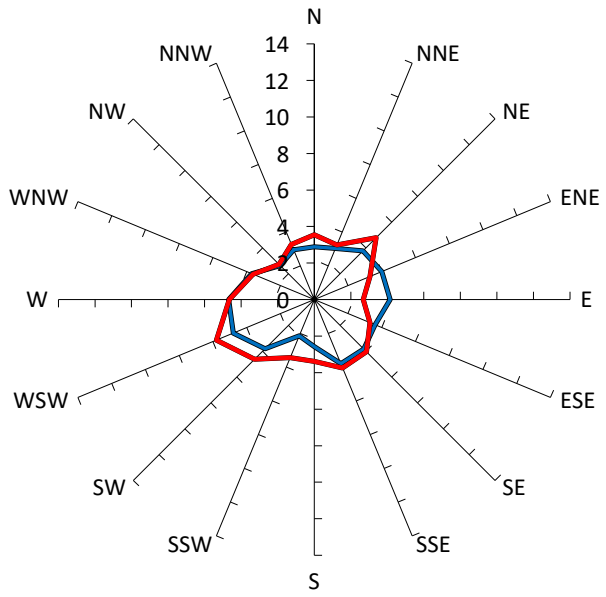
Results for Point 28

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
Proposed Case	1%	14
Future Case	1%	14

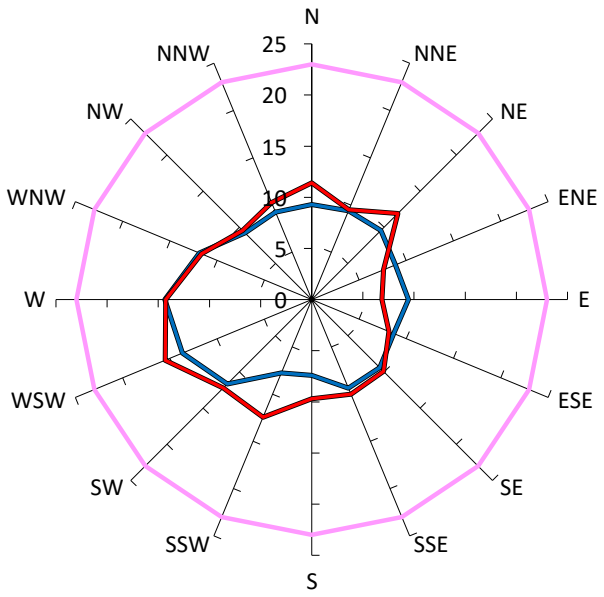
Results for Point 29

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

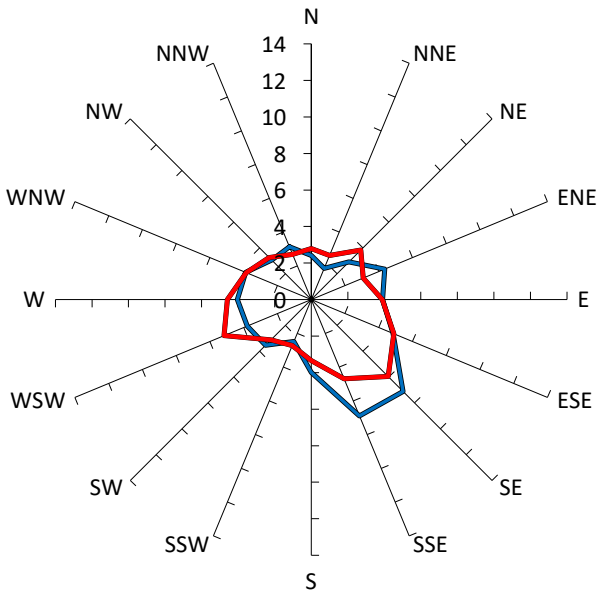


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	0%	14
Future Case	1%	15

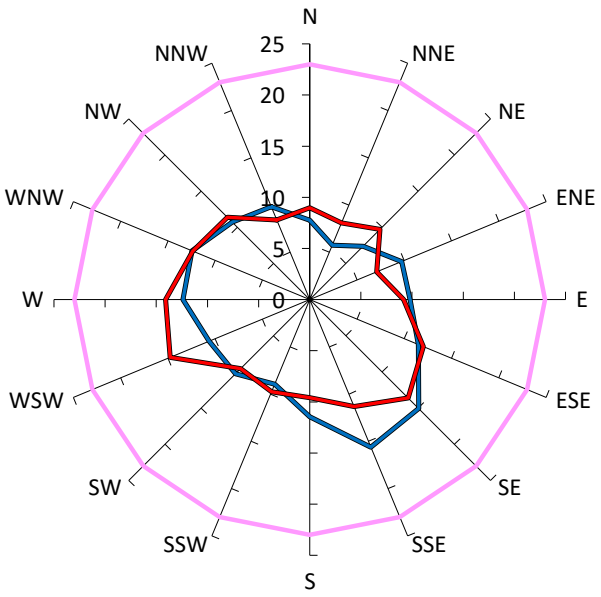
Results for Point 30

Gust Equivalent Mean (m/s)



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

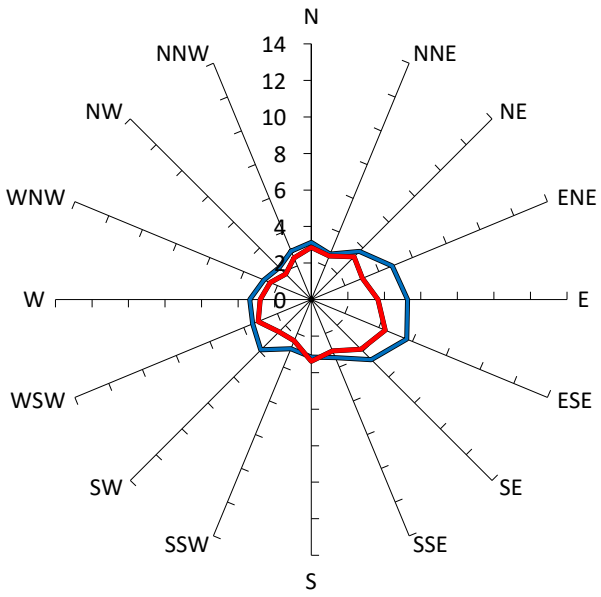
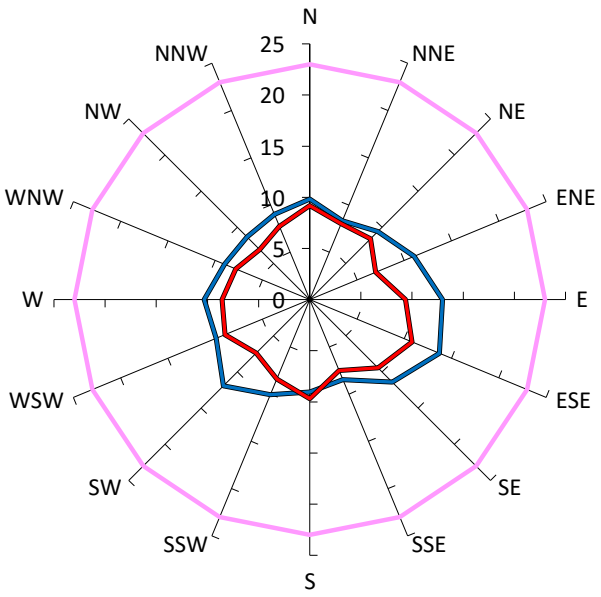
Maximum Gust (m/s)



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
Proposed Case	1%	16
Future Case	1%	15

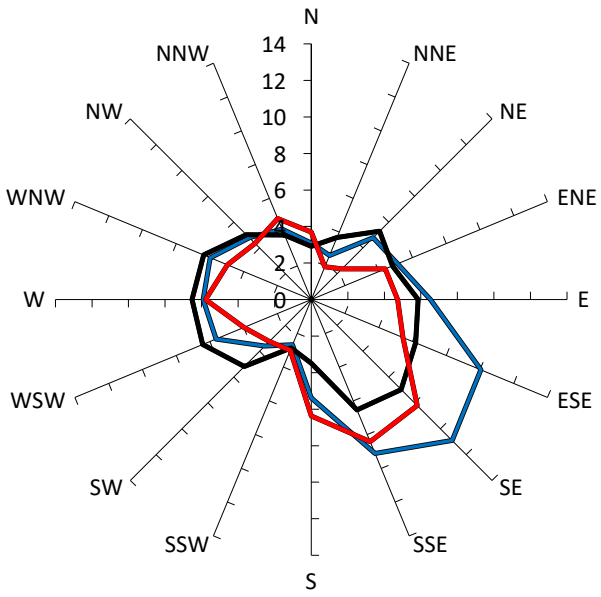
Results for Point 31

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
Proposed Case	0%	14
Future Case	0%	11

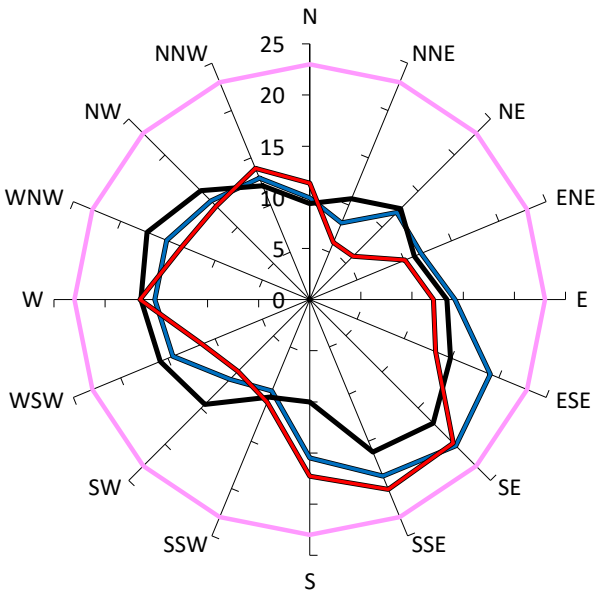
Results for Point 32

Gust Equivalent Mean (m/s)



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

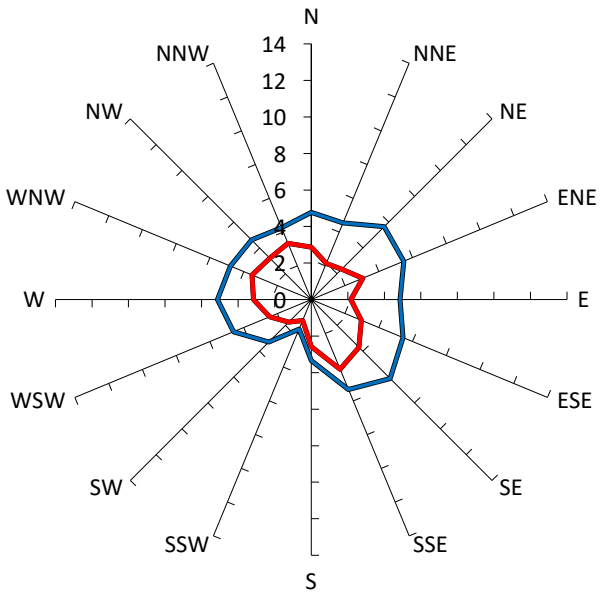
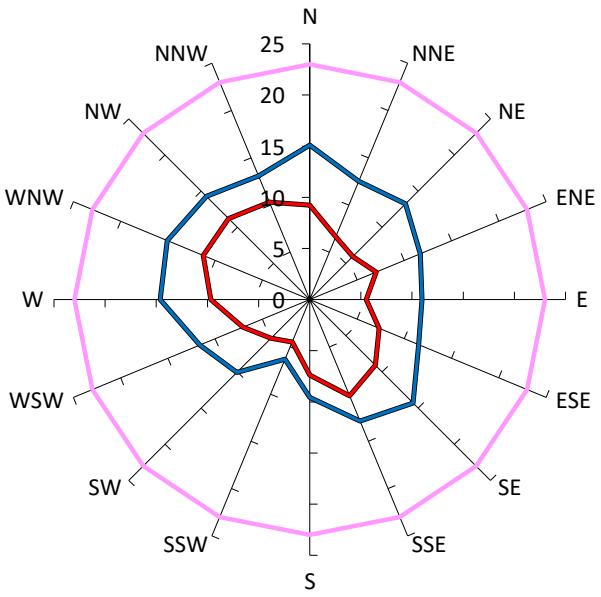
Maximum Gust (m/s)



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
Proposed Case	13%	20
With development "as existing", existing surrounds case.	4%	17
Future Case	5%	20

Results for Point 33

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
Proposed Case	2%	15
Future Case	0%	11

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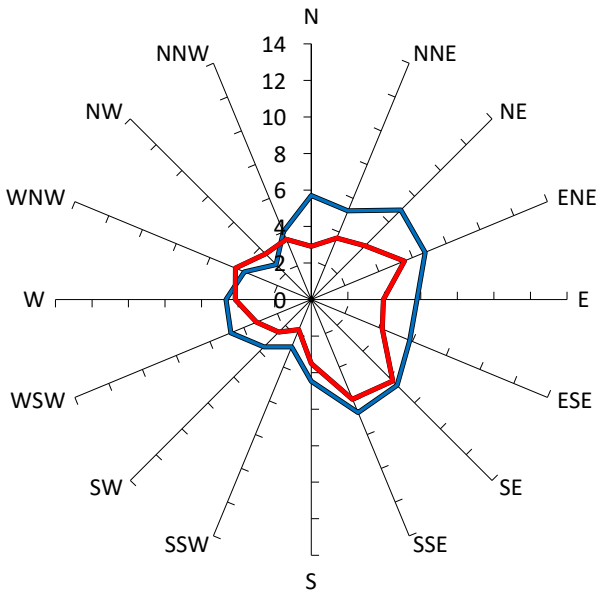
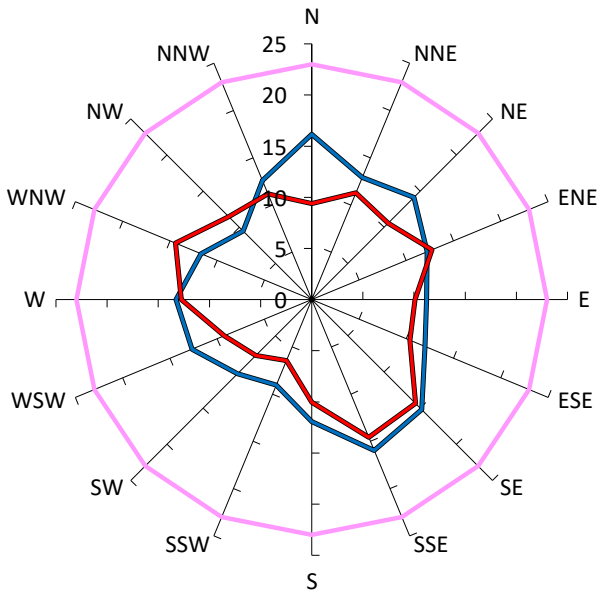
Results for Point 34

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

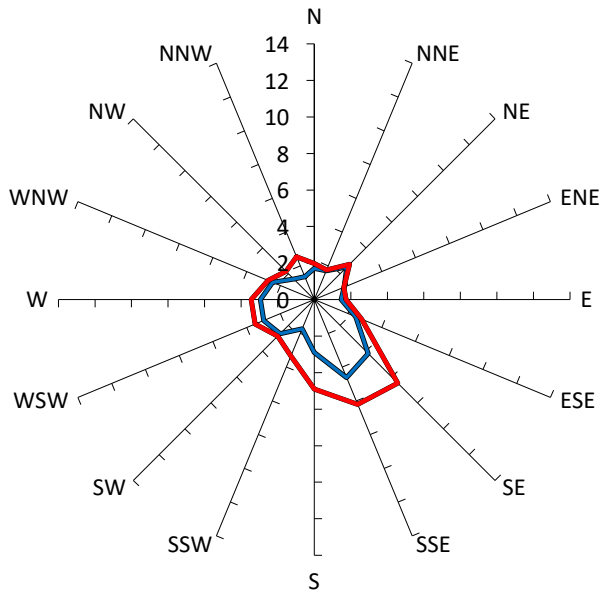


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	3%	16
Future Case	1%	15

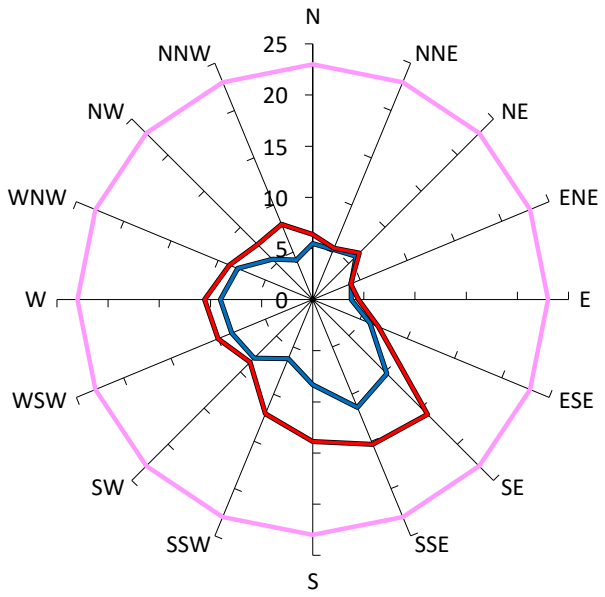
Results for Point 35

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

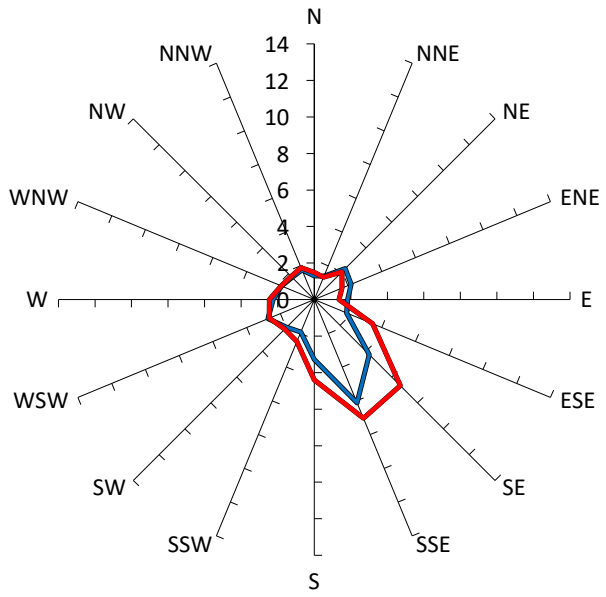


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	1%	11
Future Case	5%	16

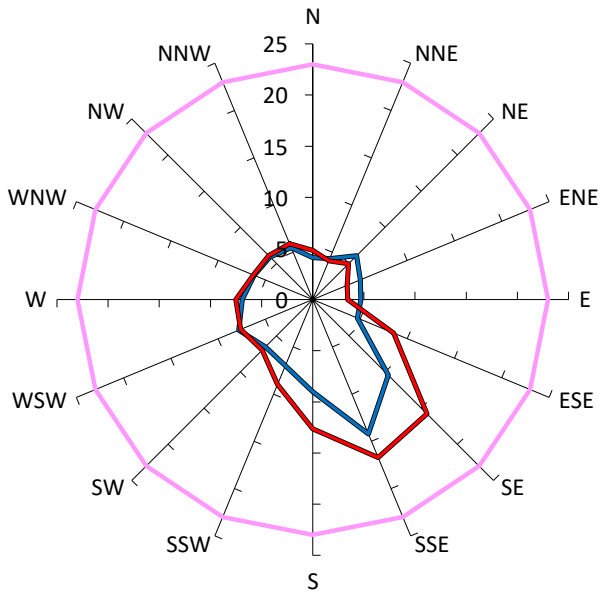
Results for Point 36

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

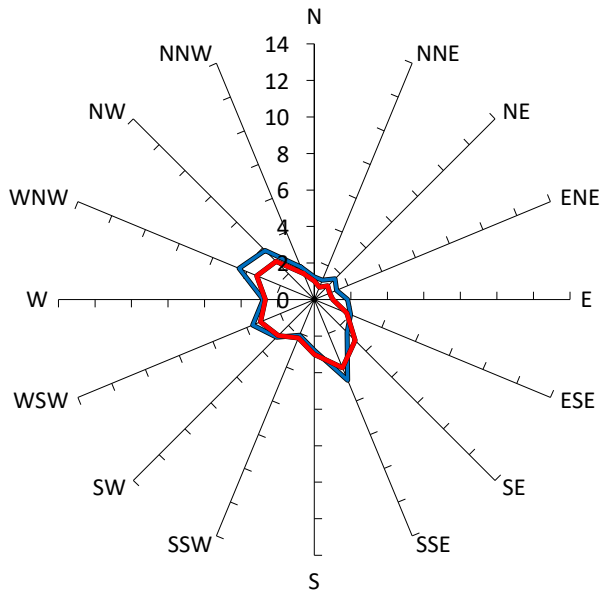


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	2%	14
Future Case	6%	17

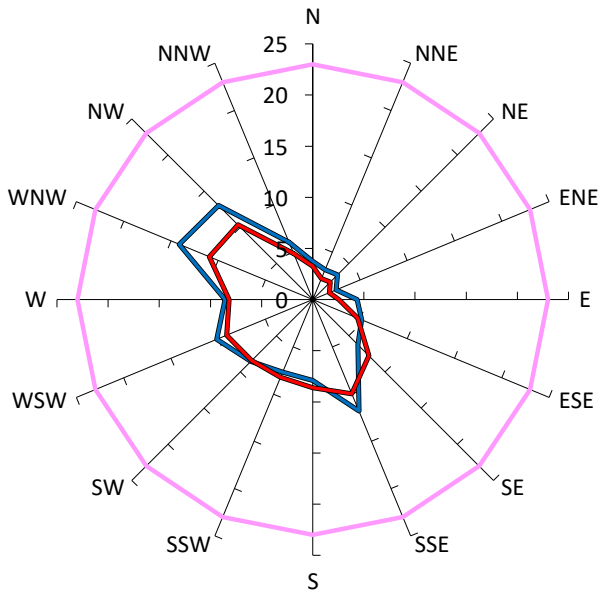
Results for Point 37

Gust Equivalent Mean (m/s)



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

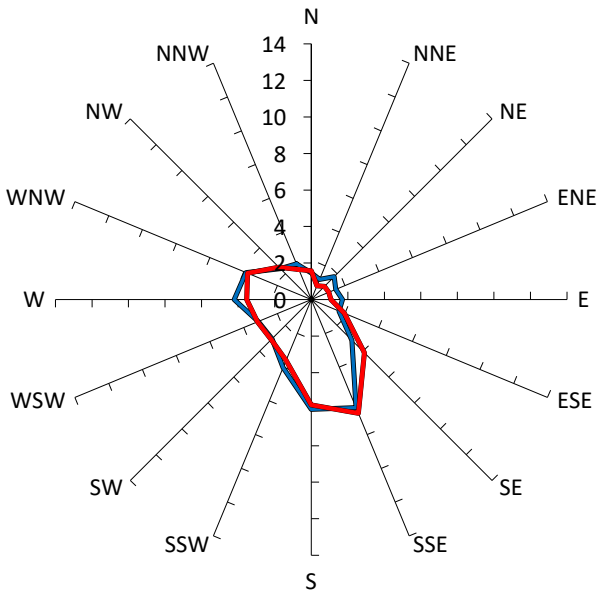
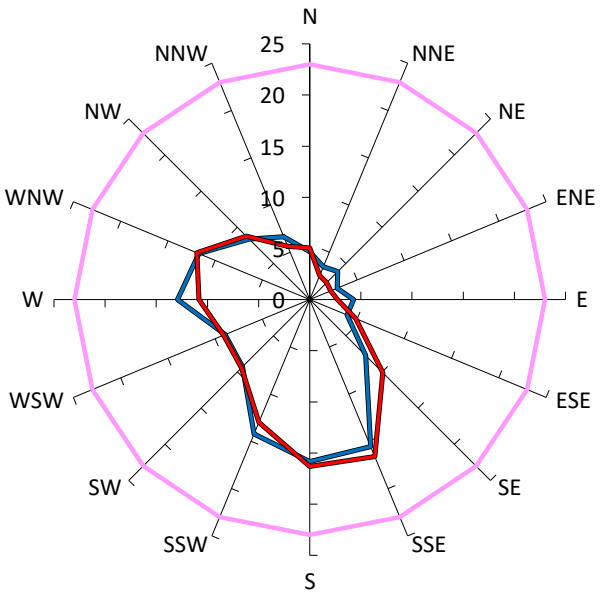
Maximum Gust (m/s)



Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	2%	14
Future Case	1%	11

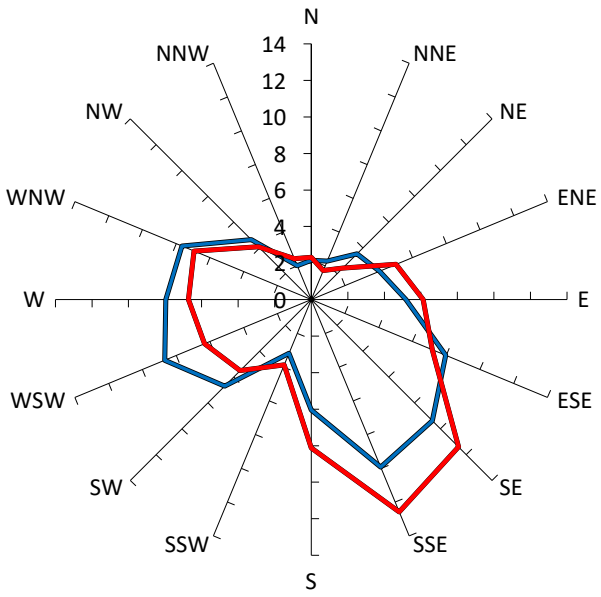
Results for Point 38

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
Proposed Case	5%	16
Future Case	6%	17

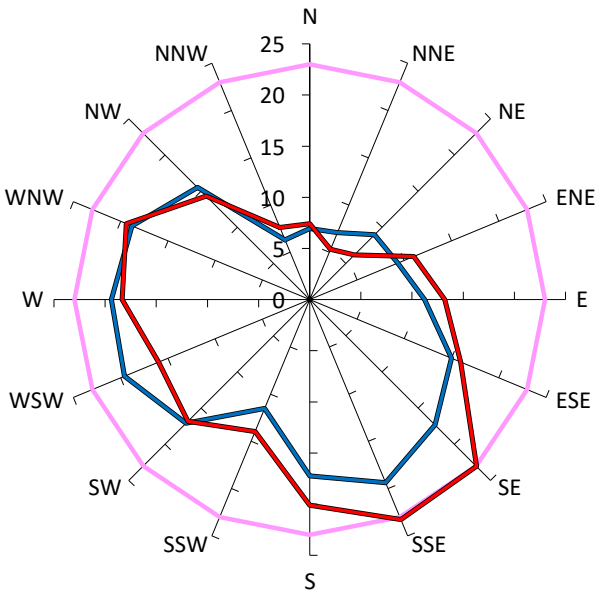
Results for Point 39

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

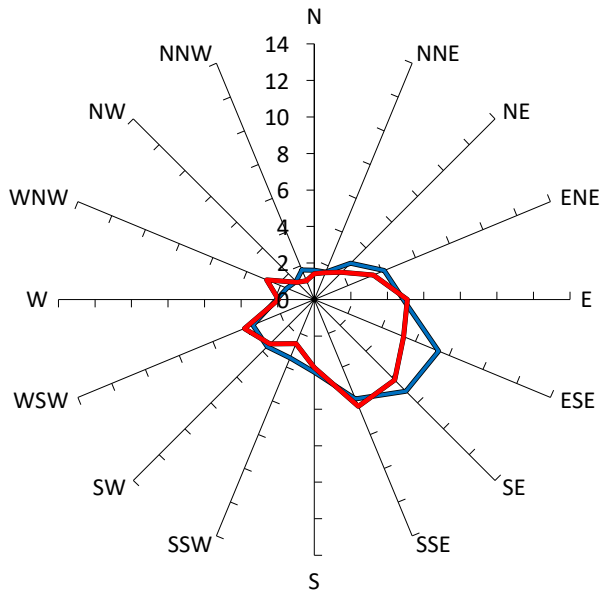


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	27%	20
Future Case	25%	23

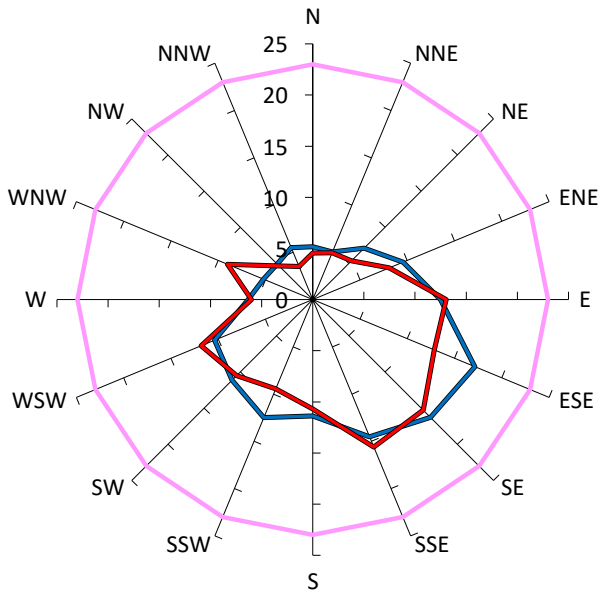
Results for Point 40

Gust Equivalent Mean (m/s)



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

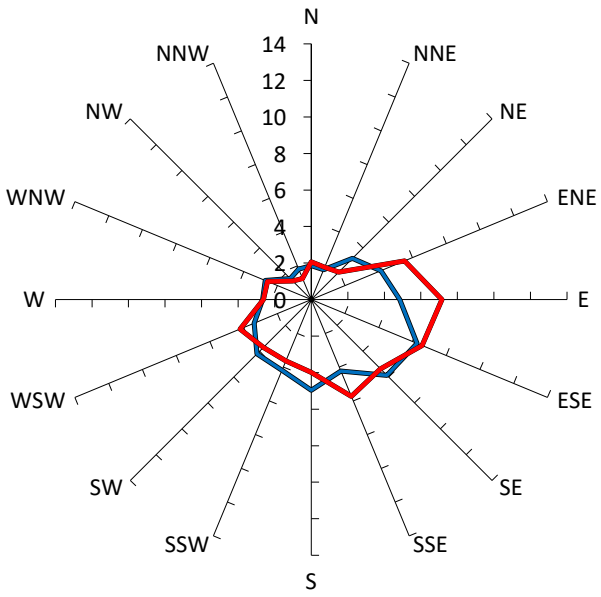
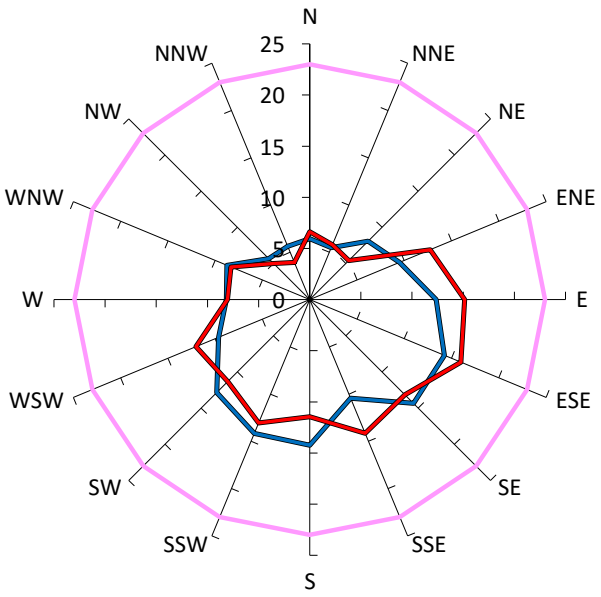
Maximum Gust (m/s)



Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	9%	17
Future Case	6%	16

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
Proposed Case	5%	14
Future Case	9%	16

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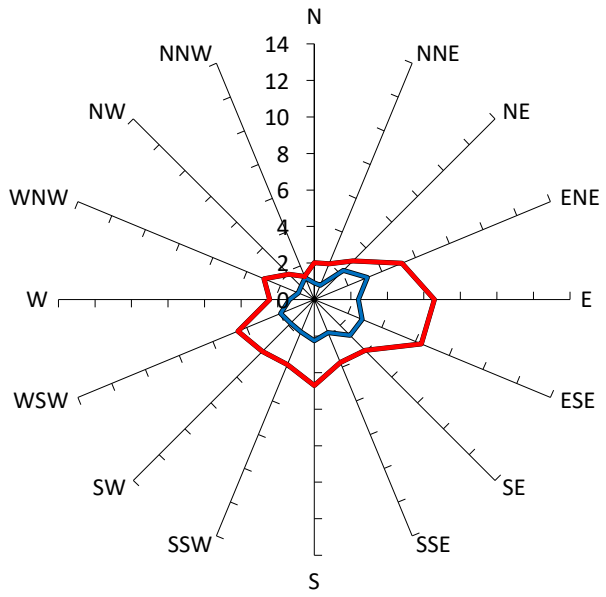
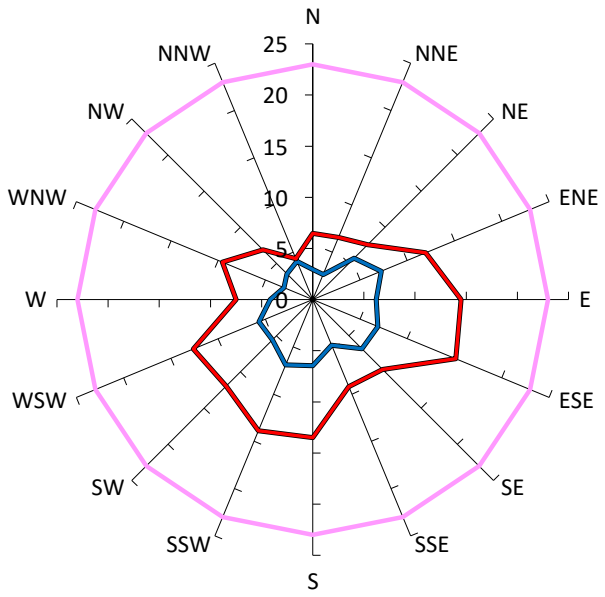
Results for Point 42

Gust Equivalent Mean (m/s)



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

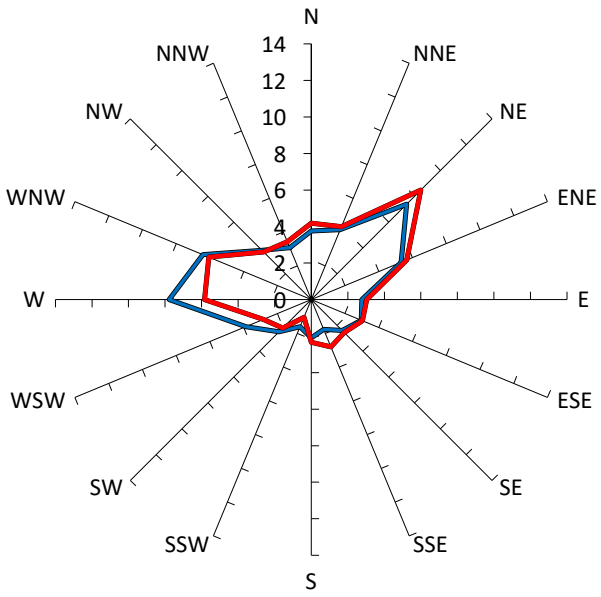
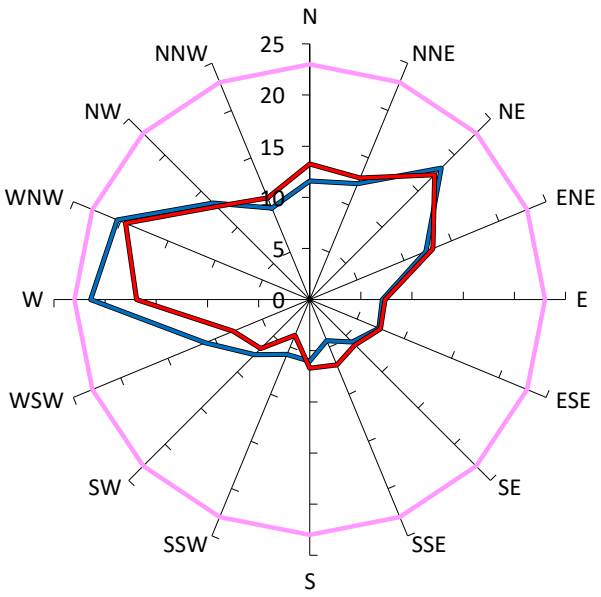
Maximum Gust (m/s)



Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	0%	7
Future Case	7%	15

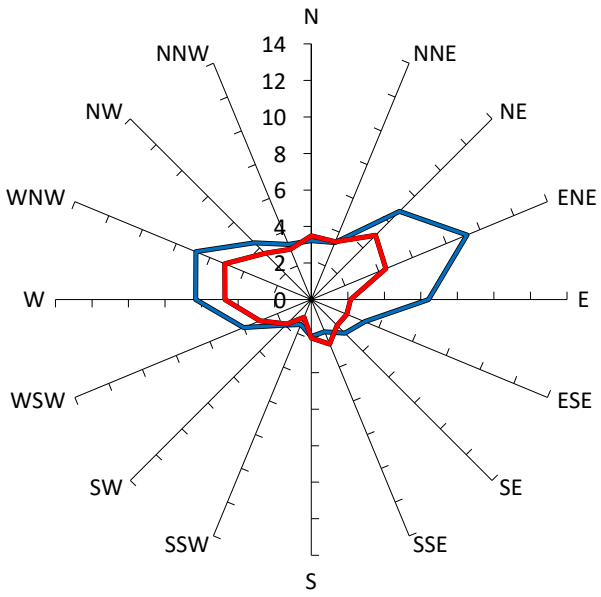
Results for Point 43

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
Proposed Case	11%	21
Future Case	10%	19

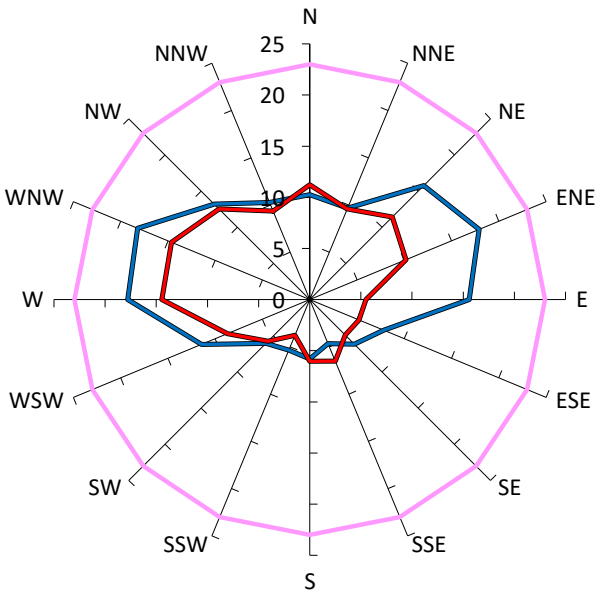
Results for Point 44

Gust Equivalent Mean (m/s)



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

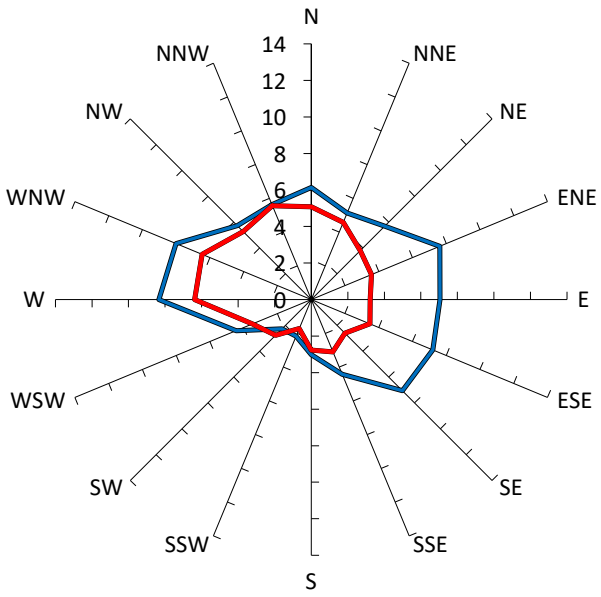
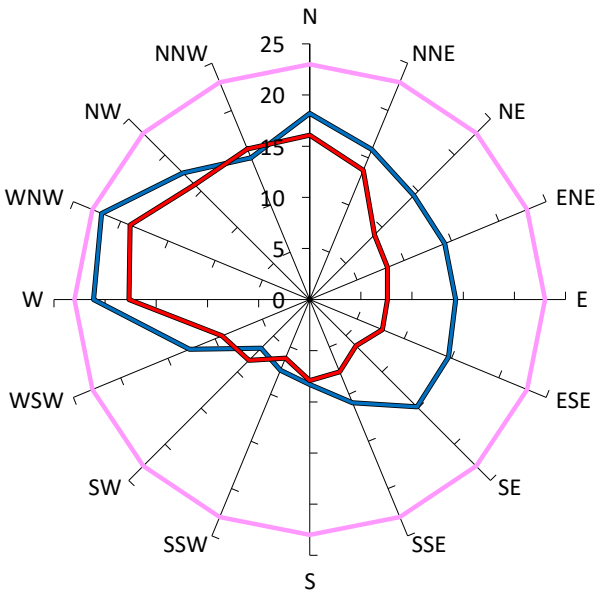
Maximum Gust (m/s)



Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	15%	18
Future Case	3%	15

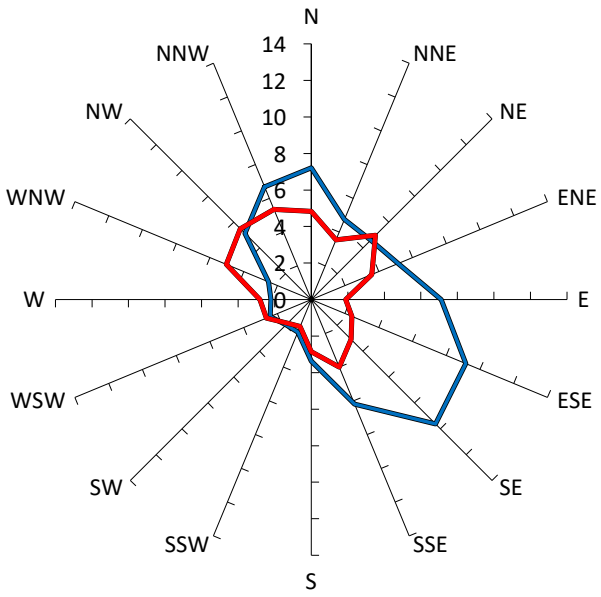
Results for Point 45

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
Proposed Case	25%	22
Future Case	8%	19

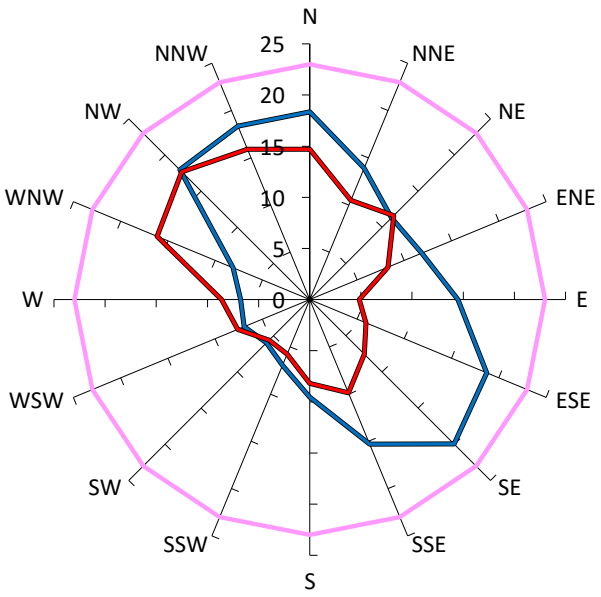
Results for Point 46

Gust Equivalent Mean (m/s)



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

Maximum Gust (m/s)

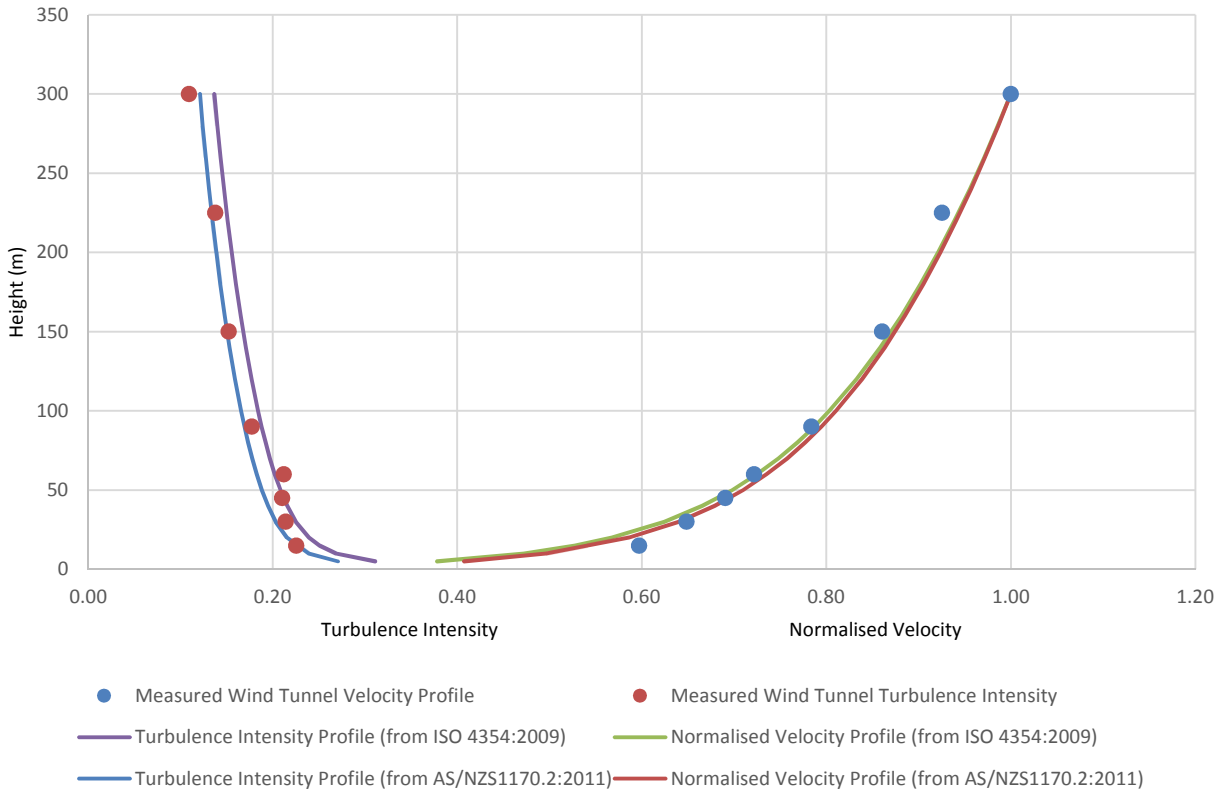


Safety Limit: 23m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).	5%	23
Proposed Case	20%	20
Future Case	5%	18

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



Longitudinal Spectra Density for Suburban/Forest Terrain (0.2m < z0 < 0.3m) (TC3) at a 1:300 Scale