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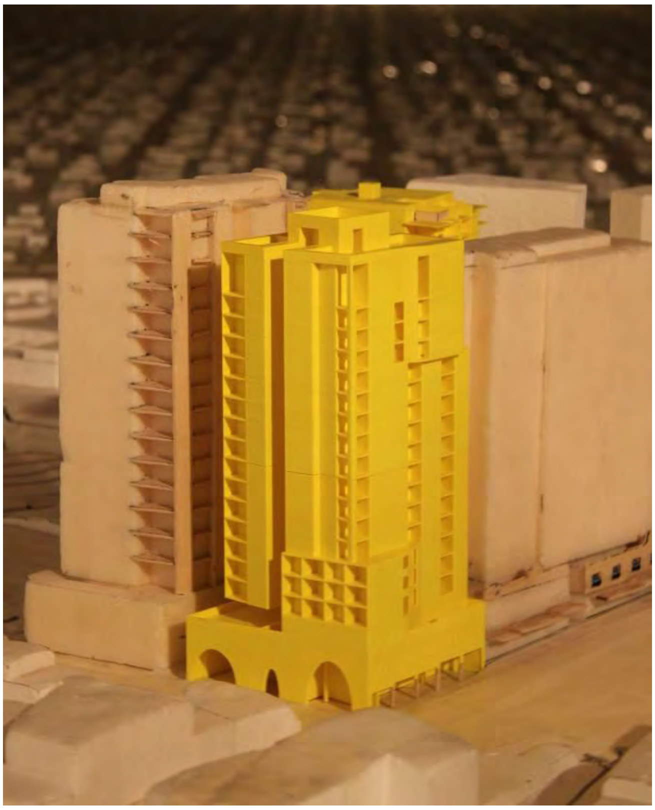

80-88 REGENT STREET, REDFERN

PEDESTRIAN WIND ENVIRONMENT STUDY

WC853-01F02(REV1)- WE REPORT

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Prepared for:

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DOCUMENT CONTROL

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EXECUTIVE SUMMARY

This report presents the results of a detailed investigation into the wind environment impact of the proposed development located at 80-88 Regent Street, Redfern. Testing was performed using Windtech's boundary layer wind tunnel, which has a 2.6m wide working section and has a fetch length of 14m. Measurements were 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.

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. These wind speed measurements are compared with criteria for pedestrian comfort and safety, based on gust wind speeds which are representative of an annual recurrence, and Gust-Equivalent Mean (GEM) wind speeds which are representative of approximately a weekly recurrence.

The model was initially tested in the wind tunnel without the effect of any forms of wind ameliorating devices such as screens, balustrades, awnings, etc, which are not already shown in the architectural drawings. If the results of the study indicate that any area is exposed to strong winds, in-principle treatments have been recommended. These treatments could be in the form of vegetation that is already proposed for the site, and/or additional trees, shrubs, screens, awnings, etc.

The results of the study indicate that wind conditions at ground level along the southern aspect of the development exceed the City of Sydney DCP requirements but are comparable to, and in most cases better than the existing wind conditions. In particular, strong westerly winds are experienced along Marian Street, which is an existing wind effect with a slight improvement with the inclusion of the proposed development. Note that a future development across Marian Street on the Gibbons Street corner is expected to alleviate the impact of these westerly winds.

The south-eastern corner balconies and Level 1 terrace area are exposed to the prevailing southerly winds due to the exposure of the site in this direction. The rooftop area is noted to be exposed to the wind up-washing over the built form. The interaction of the tower with the adjacent Iglu development to the north is noted to exacerbate this effect.

Treatments are required for certain locations to achieve the desired wind speed criteria for pedestrian comfort and safety. The suggested treatments are summarised as follows:

Level 1:

- Include 1.8m tall porous screen along the southern and eastern aspects of the outdoor terrace area as proposed.

- Inclusion of proposed trees along the southern aspect. Trees should be densely foliating, evergreen and capable of growing to a height of 4m to meet with the tower overhang above. Trees should have interlocking canopies where possible.

Levels 5-13:

- Include either a full height impermeable screen or louvres along the southern aspect of the south-eastern corner balcony. The louvres must be oriented so that they baffle the southerly winds.

Levels 14-17:

- Inclusion of either a 2m tall impermeable screen or louvres along the southern aspect of the south-eastern corner balcony. The louvres must be oriented so that they baffle the southerly winds.

Rooftop Terrace:

- Include dense landscaping along the perimeter of the rooftop terrace area. Landscaping should be evergreen and at least 1.8m tall.
- Include either dense landscaping or a 1.8m tall impermeable screen at the centre of the eastern section of the terrace area.

With the inclusion of these recommended treatments to the final design, the results of this study indicate that wind conditions for all outdoor trafficable areas within and around the development will be suitable for their intended uses.

CONTENTS

1 WIND CLIMATE FOR THE SYDNEY REGION

The Sydney region is governed by three principle wind directions, and these can potentially affect the subject development. These winds prevail from the north-east, south and west. A summary of the principal time of occurrence of these winds throughout the year is presented in Table 1 below. This summary is based on a detailed analysis undertaken by Windtech Consultants of recorded directional wind speeds obtained at the meteorological station located at Kingsford Smith Airport by the Bureau of Meteorology (recorded from 1939 to 2008). The data was corrected to represent winds in standard open terrain at a height of 10m above ground. From this analysis, directional plots of the 10-minute mean winds for the Sydney region is also determined (as shown in Figure 1), which are representative of approximately the weekly and annual recurrences. The frequency of occurrence of these winds is also shown in Figure 1.

As shown in Figure 1, the southerly winds are by far the most frequent wind for the Sydney region, and are also the strongest. As indicated in Table 1, the westerly winds occur most frequently during the winter season for the Sydney region, and although they are typically not as strong as the southerly winds, they are usually a cold wind since they occur during the winter and hence can be a cause for discomfort for outdoor areas. North-easterly winds occur most frequently during the warmer months of the year for the Sydney region, and hence are usually welcomed within outdoor areas since they are typically not as strong as the southerly or westerly winds.

Table 1: Principle Time of Occurrence of Winds for Sydney

Month	Wind Direction		
	North-Easterly	Southerly	Westerly
January	X	X	
February	X	X	
March	X	X	
April		X	X
May			X
June			X
July			X
August			X
September		X	X
October	X	X	
November	X	X	
December	X	X	

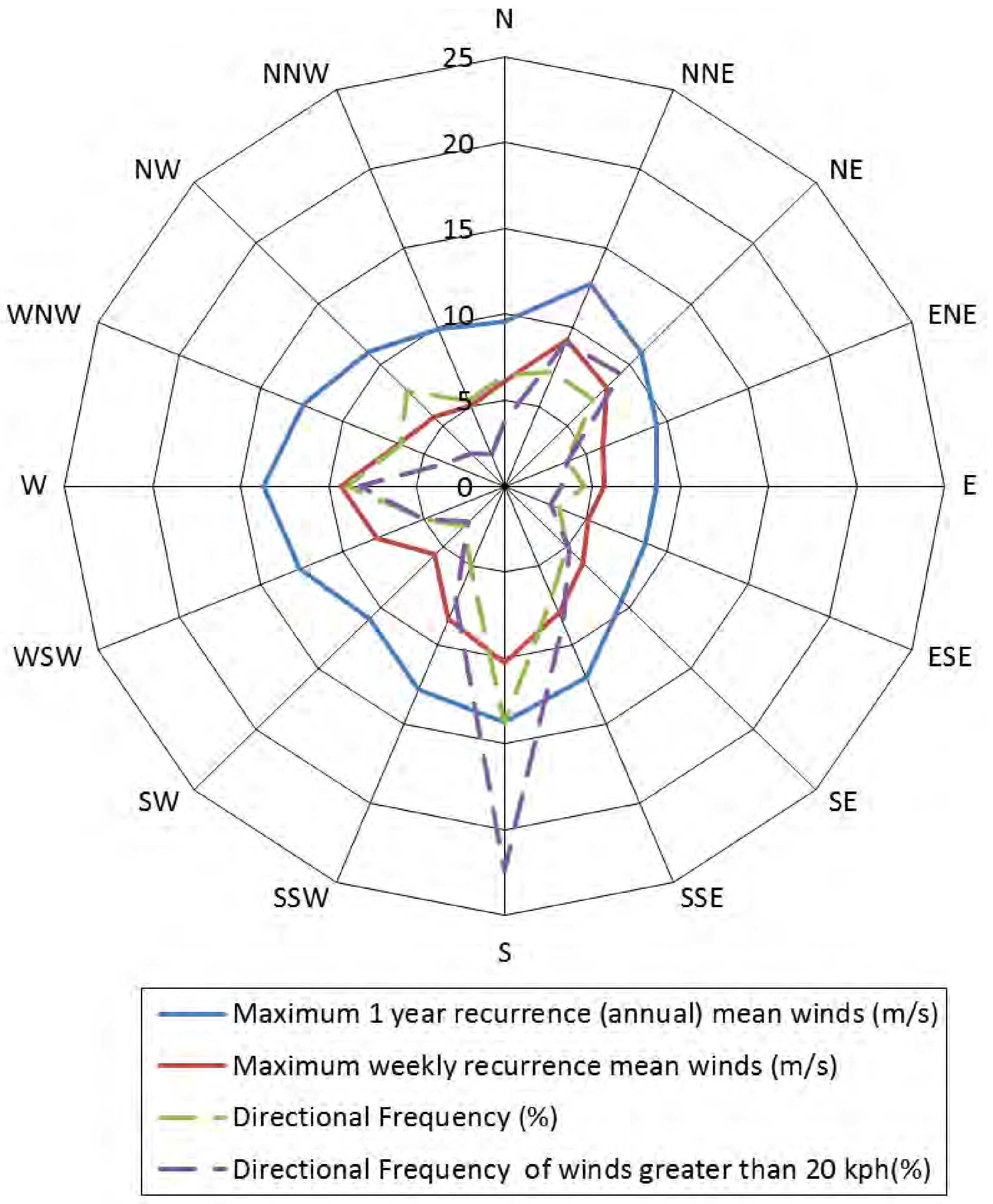


Figure 1: Annual and Weekly Recurrence Mean Wind Speeds, and Frequencies of Occurrence, for the Sydney Region (based on 10-minute mean observations from Kingsford Smith Airport from 1939 to 2008, corrected to open terrain at 10m)

2 THE WIND TUNNEL MODEL

Wind tunnel testing was undertaken to obtain accurate wind speed measurements at selected critical outdoor locations within and around the development using a 1:300 scale model. The study model incorporates all necessary architectural features on the development to ensure an accurate wind flow is achieved around the model. A proximity model has also been constructed and represents the surrounding buildings and significant topographical effects within a radius of 375m. Photographs of the wind tunnel model are presented in Figures 2a to 2g on the following pages.

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. If the results of the study indicate that any area is exposed to strong winds, in-principle treatments have been recommended. These treatments could be in the form of vegetation that is already proposed for the site, and/or additional trees, shrubs, screens, awnings, etc.

Figure 2a: Photograph of the Wind Tunnel Model
(view from the south)

Figure 2b: Photograph of the Wind Tunnel Model (view from the east)

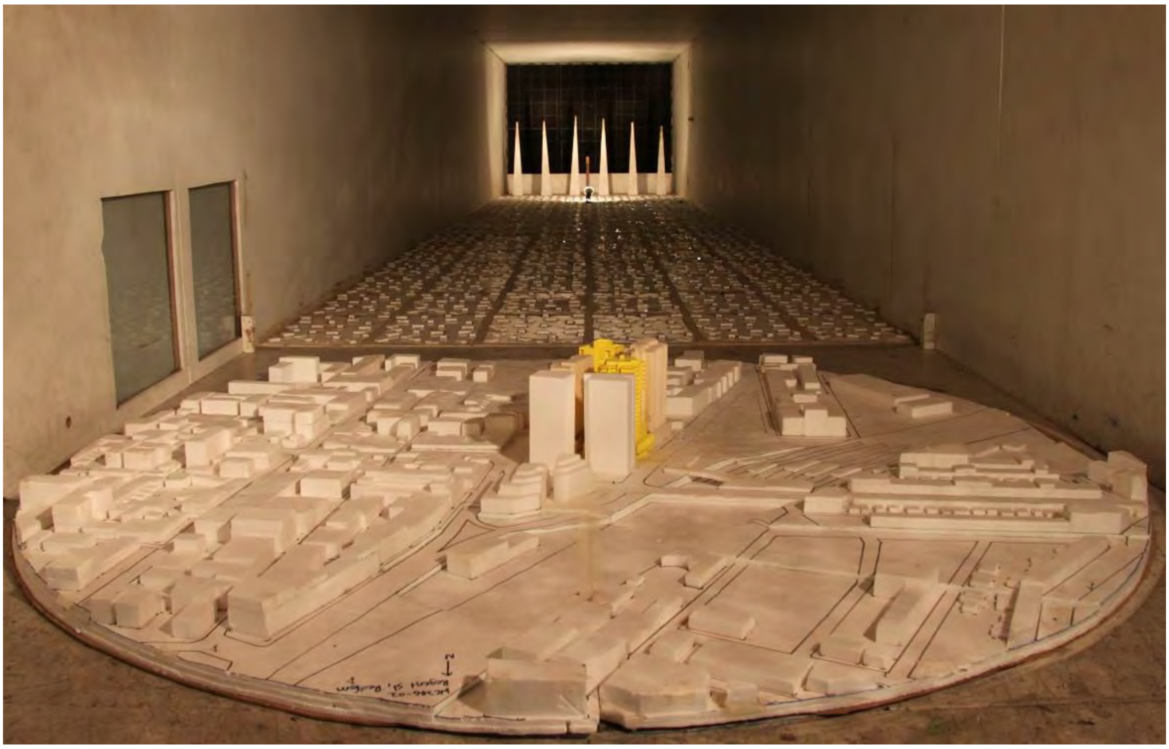


Figure 2c: Photograph of the Wind Tunnel Model (view from the north)

Figure 2d: Photograph of the Wind Tunnel Model
(view from the west)

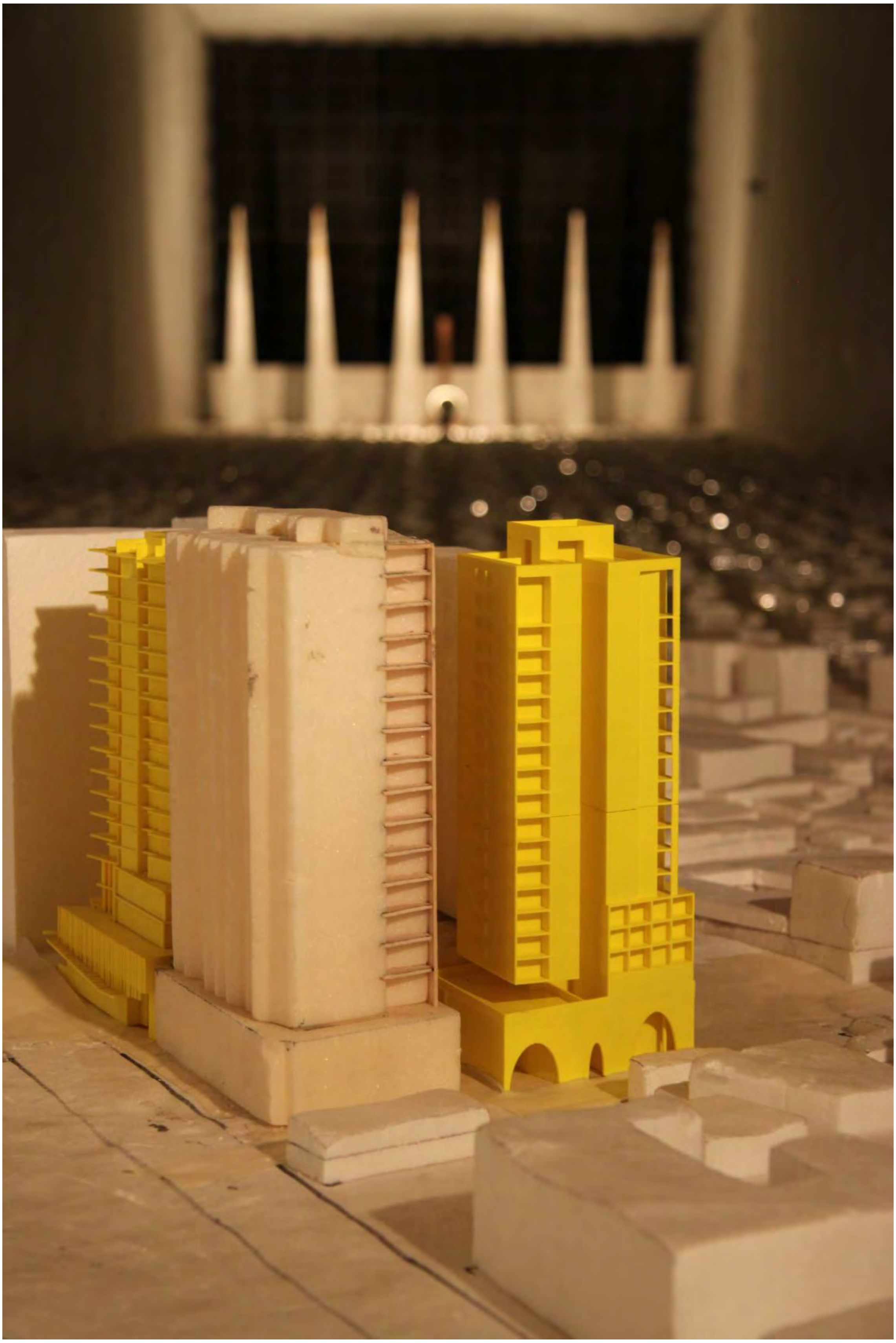


Figure 2e: Photograph of the Wind Tunnel Model
(close up view from the south-west)

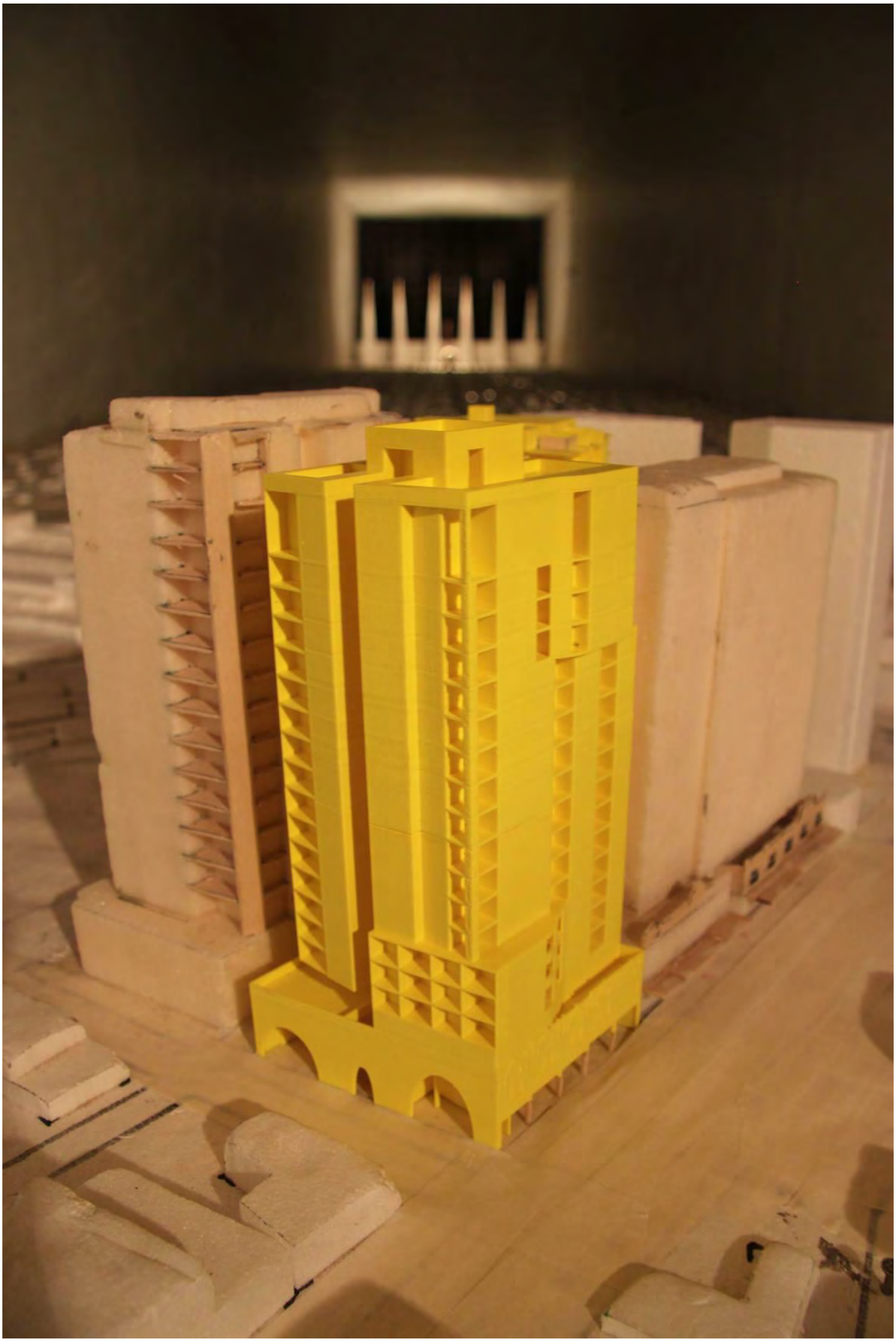


Figure 2f: Photograph of the Wind Tunnel Model
(close up view from the south-east)

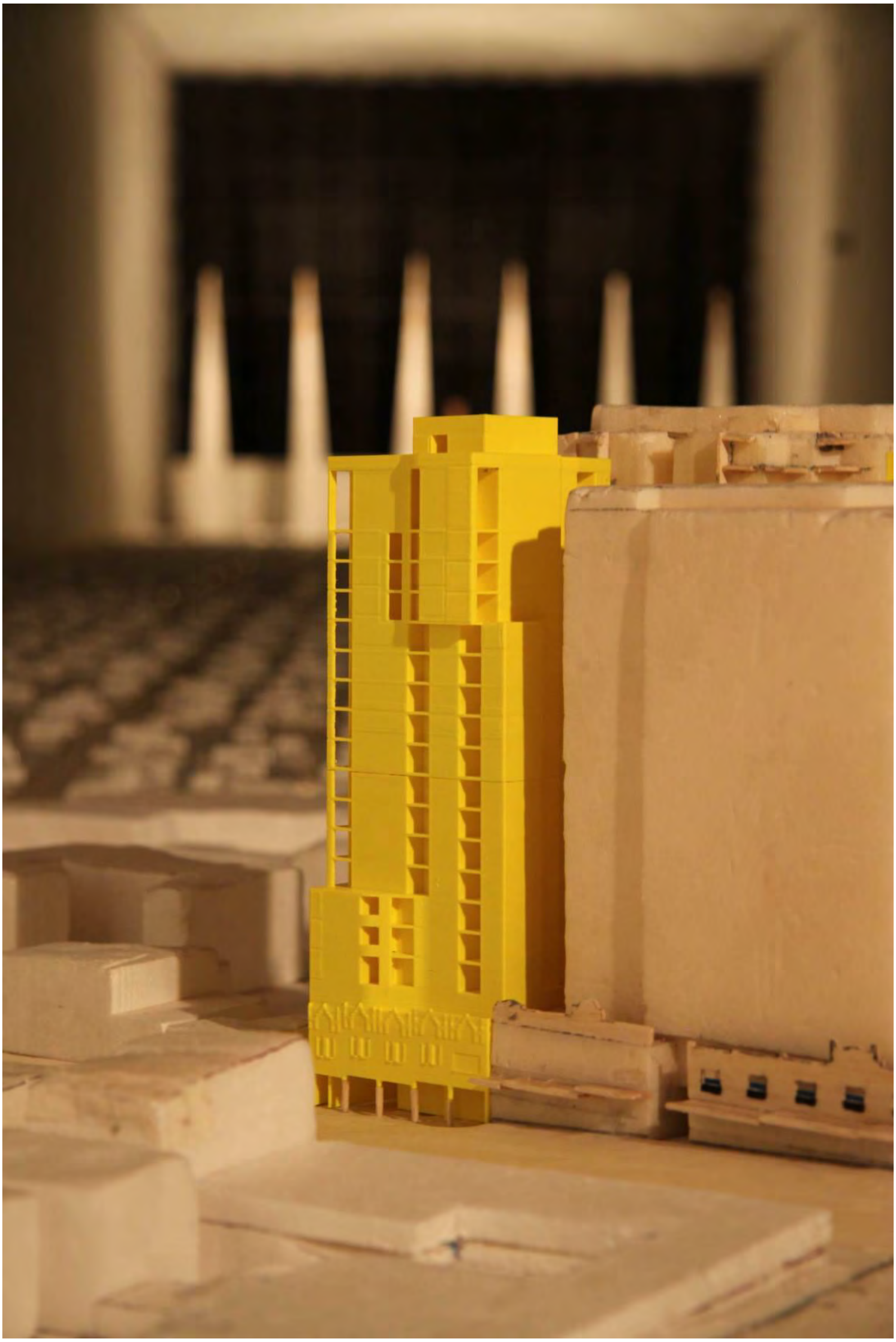


Figure 2g: Photograph of the Wind Tunnel Model
(close up view from the east)

3 BOUNDARY LAYER WIND FLOW MODEL

Testing was performed using Windtech's boundary layer wind tunnel, which has a 2.6m wide working section and has a fetch length of 14m. The model was placed in the appropriate standard boundary layer wind flow for each of the prevailing wind directions for the wind tunnel testing. The type of wind flow used in a wind tunnel study is determined by a detailed analysis of the surrounding terrain types around the subject site. Details of the analysis of the surrounding terrain for this study are provided in the following pages of this report.

The roughness of the earth's surface has the effect of slowing down the prevailing wind near the ground. This effect is observed up to what is known as the *boundary layer height*, which can range between 500m to 3km above the earth's surface depending on the roughness of the surface (i.e. oceans, open farmland, dense urban cities, etc. Within this range the prevailing wind forms what is known as a *boundary layer wind profile*.

Various wind codes and standards classify various types of boundary layer wind flows depending on the surface roughness. However, it should be noted that the 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 profile to achieve a state of equilibrium. Descriptions of the standard boundary layer profiles for various terrain types are summarised as follows:

- **Terrain Category 1.0:** Extremely flat terrain. Examples include enclosed water bodies such as lakes, dams, rivers, bays, etc.
- **Terrain Category 1.5:** Relatively flat terrain. Examples include the open ocean, deserts, and very flat open plains.
- **Terrain Category 2.0:** Open terrain. Examples include grassy fields and plains and open farmland (without buildings or trees).
- **Terrain Category 2.5:** Relatively open terrain. Examples include farmland with scattered trees and buildings and very low-density suburban areas.
- **Terrain Category 3.0:** Suburban and forest terrain. Examples include suburban areas of towns and areas with dense vegetation such as forests, bushland, etc.
- **Terrain Category 3.5:** Relatively dense suburban terrain. Examples include centres of small cities, industrial parks, etc.
- **Terrain Category 4.0:** Dense urban terrain. Examples include CBD's of large cities with many high-rise towers, and areas with many closely-spaced mid-rise buildings.

For this study, the shape of the boundary layer wind flows over standard terrain types is defined as per ISO4354:2009. These are summarised in Table 2, referenced to the study reference height of 35m above ground.

Table 2: Terrain and Height Multipliers, Turbulence Intensities and Corresponding Roughness Lengths, for the Standard ISO4354:2009 Boundary Layer Profiles (at the study reference height)

Terrain Category	Terrain and Height Multipliers			Turbulence Intensity I_v	Roughness Length (m) $z_{0,r}$
	$k_{tr,T=3600s}$ (hourly)	$k_{tr,T=600s}$ (10-minute)	$k_{tr,T=3s}$ (3-second)		
1.0	0.92	0.95	1.24	0.118	0.003
1.5	0.86	0.89	1.21	0.135	0.01
2.0	0.80	0.83	1.17	0.154	0.03
2.5	0.72	0.76	1.12	0.183	0.1
3.0	0.64	0.68	1.06	0.220	0.3
3.5	0.53	0.57	0.97	0.284	1
4.0	0.40	0.45	0.87	0.392	3

An analysis of the effect of changes in the upwind terrain roughness was carried out for each of the wind directions studied. This has been undertaken based on the method given in AS/NZS1170.2:2011, which uses a "fetch" length of 60 times the study reference height. However, it should be noted that this "fetch" commences *beyond* a "lag distance" area, which has a length of 20 times the study 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 study reference height away from the site. An aerial image showing the surrounding terrain is presented in Figure 3 for a radius of 2.1km from the edge of the wind tunnel proximity model. The resulting mean and gust terrain and height multipliers at the site location are presented in Table 3, referenced to the study reference height.

Table 3: Mean and Gust Terrain and Height Multipliers at the Site for Each Directional Sector (at the study reference height)

Wind Sector (degrees)	$k_{tr,T=3600s}$ (hourly mean)	$k_{tr,T=600s}$ (10-minute mean)	$k_{tr,T=3s}$ (3-second gust)
0	0.53	0.57	0.97
30	0.57	0.61	1.00
60	0.64	0.68	1.06
90	0.65	0.69	1.07
120	0.65	0.68	1.06
150	0.53	0.57	0.97
180	0.53	0.57	0.97
210	0.57	0.61	1.01
240	0.64	0.68	1.06
270	0.64	0.68	1.06
300	0.64	0.68	1.06
330	0.61	0.65	1.04

For each of the 16 wind directions tested in this study, the approaching boundary layer wind profiles modelled in the wind tunnel matched the model scale and the overall surrounding terrain characteristics beyond the 375m radius of the proximity model. Plots of the wind tunnel boundary layer wind profiles are presented in Appendix B of this report.

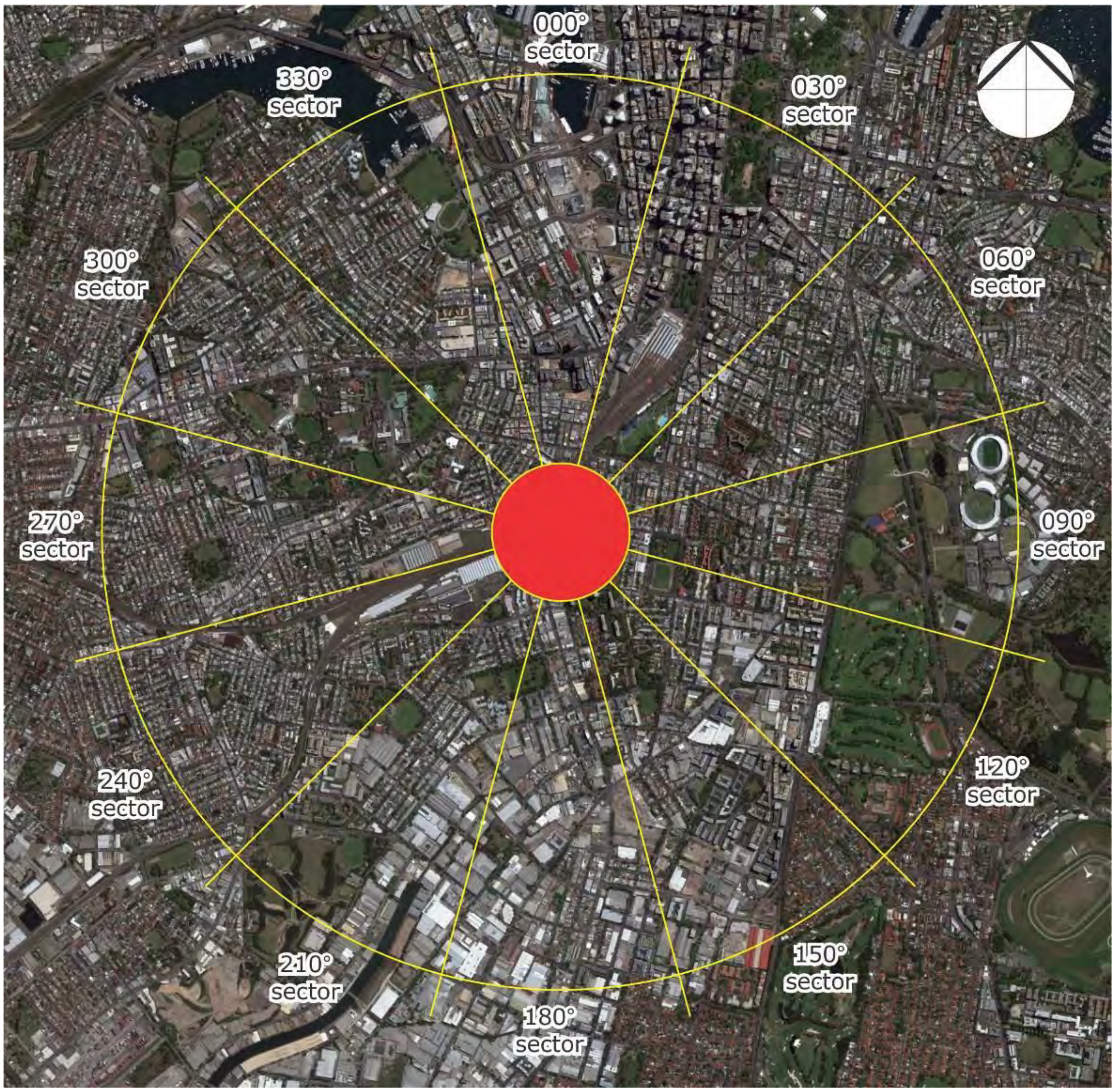


Figure 3a: Aerial Image showing the Surrounding Terrain
(radius of 2.1km from the edge of the proximity model, which is coloured red)

4 ENVIRONMENTAL WIND SPEED CRITERIA

4.1 Wind Effects on People

The acceptability of wind in any area is dependent upon its use. For example, people walking or window-shopping will tolerate higher wind speeds than those seated at an outdoor restaurant. Various other researchers, such as Davenport, Lawson, Melbourne, Penwarden, etc., have published criteria for pedestrian comfort for pedestrians in outdoor spaces for various types of activities. These are discussed in the following sub-sections of this report.

4.1.1 Penwarden (1975) Criteria for Gust Wind Speeds

The following table developed by Penwarden (1975) is a modified version of the Beaufort Scale, and describes the effects of various wind intensities on people. Note that the applicability column related to wind conditions occurring frequently (approximately once per week on average). Higher ranges of wind speeds can be tolerated for rarer events.

Table 4: Summary of Wind Effects on People (after Penwarden, 1975)

Type of Winds	Beaufort Number	Mean Wind Speed (m/s)	Effects
Calm, light air	1	0 - 1.5	Calm, no noticeable wind
Light breeze	2	1.6 - 3.3	Wind felt on face
Gentle breeze	3	3.4 - 5.4	Hair is disturbed, Clothing flaps
Moderate breeze	4	5.5 - 7.9	Raises dust, dry soil and loose paper - Hair disarranged
Fresh breeze	5	8.0 – 10.7	Force of wind felt on body
Strong breeze	6	10.8 – 13.8	Umbrellas used with difficulty, Hair blown straight, Difficult to walk steadily, Wind noise on ears unpleasant.
Near gale	7	13.9 – 17.1	Inconvenience felt when walking.
Gale	8	17.2 - 20.7	Generally impedes progress, Great difficulty with balance.
Strong gale	9	20.8 – 24.4	People blown over by gusts.

4.1.2 Davenport (1972) Criteria for Mean Wind Speeds

Davenport (1972) had also determined a set of criteria in terms of the Beaufort Scale and for various return periods. The values presented in Table 5 below are based on a frequency of exceedance of approximately once per week (a probability of exceedance of 5%).

Table 5: Criteria by Davenport (1972)

Classification	Activities	95 Percentile Maximum Mean (approximately once per week)
Walking Fast	Acceptable for walking, main public accessways.	7.5 m/s < $\overline{V}$ < 10.0 m/s
Strolling, Skating	Slow walking, etc.	5.5 m/s < $\overline{V}$ < 7.5 m/s
Short Exposure Activities	Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas.	3.5 m/s < $\overline{V}$ < 5.5 m/s
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	$\overline{V}$ < 3.5 m/s

4.1.3 Lawson (1975) Criteria for Mean Wind Speeds

In 1973, Lawson quotes that Penwarden's Beaufort 4 wind speeds (as listed in Table 4) would be acceptable if it is not exceeded for more than 4% of the time; and a Beaufort 6 as being unacceptable if it is exceeded more than 2% of the time. Later, in 1975, Lawson presented a set of criteria very similar to those of Davenport's. These are presented in Tables 6 and 7.

Table 6: Safety Criteria by Lawson (1975)

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

Table 7: Comfort Criteria by Lawson (1975)

Classification	Activities	95 Percentile Maximum Mean (approximately once per week)
Business Walking	Objective Walking from A to B.	8 m/s < $\overline{V}$ < 10m/s
Pedestrian Walking	Slow walking, etc.	6 m/s < $\overline{V}$ < 8 m/s
Short Exposure Activities	Pedestrian standing or sitting for short times.	4 m/s < $\overline{V}$ < 6 m/s
Long Exposure Activities	Pedestrian sitting for a long duration.	$\overline{V}$ < 4 m/s

4.1.4 Melbourne (1978) Criteria for Gust Wind Speeds

Melbourne (1978) introduced a set of criteria for the assessment of environmental wind conditions, which were developed for a temperature range of 10ºC to 30ºC and for people suitably dressed for outdoor conditions. These criteria are based on peak annual maximum gust wind speeds, and are outlined in Table 8 below. It should be noted that this criteria tends to be more conservative than criteria suggested by other researchers.

Table 8: Criteria by Melbourne (1978)

Classification	Human Activities	Annual Maximum Gust
Limit for safety	Completely unacceptable: people likely to get blown over.	$\hat{V}$ > 23m/s
Marginal	Unacceptable as main public accessways.	23 m/s > $\hat{V}$ > 16 m/s
Comfortable Walking	Acceptable for walking, main public accessways	16 m/s > $\hat{V}$ > 13 m/s
Short Exposure Activities	Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas.	13 m/s > $\hat{V}$ > 10 m/s
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	10 m/s > $\hat{V}$

4.2 Comparison of the Various Wind Speed Criteria

The criteria by Melbourne (1978) mentioned in Table 8, and criteria from other researchers, are compared on a probabilistic basis in Figure 4. This indicates that the criteria by Melbourne (1978) are quite conservative. This was also observed by Rofail (2007) when undertaking on-site remedial studies, who concluded that the criteria by Melbourne (1978) generally overstates the wind effects in a typical urban setting, which is caused by Melbourne's assumption of a fixed 15% turbulence intensity for all areas. This value tends to be at the lower end of the range of turbulence intensities, and the Rofail (2007) study found that, in an urban setting, the range of the *minimum* turbulence intensities is typically in the range of 20% to 60%.

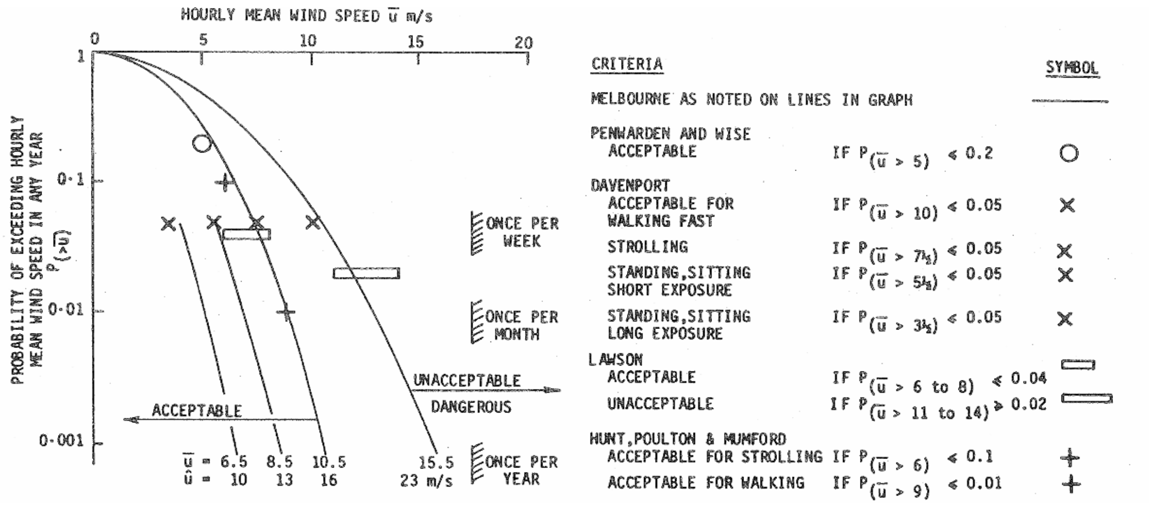


Figure 4: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (after Melbourne, 1978)

4.3 Wind Speed Criteria Used for This Study

For this study, the measured wind conditions for the various critical outdoor trafficable areas within and around the subject development are compared against two sets of criteria. For comfort, the Davenport (1972) criteria are used in conjunction with a maximum Gust-Equivalent Mean (GEM) wind speed (defined below), which are representative of approximately a weekly recurrence. The safety limit criterion by Melbourne (1978) of 23m/s for the annual maximum peak gust wind speeds is also used. Note that the Davenport (1972) criteria, used in conjunction with a GEM wind speed (defined below), has proven over time, and through field observations, to be the most reliable indicator of pedestrian comfort (Rofail, 2007). Note also that the safety limit criterion by Melbourne (1978) of 23m/s for annual maximum peak gust wind speeds is also applied to all areas. Section 3.2.6 of The City of Sydney DCP (2012) requires that ground level annual gust wind speeds not exceed 10m/s for active frontages and 16m/s for all other streets. Wind conditions for the existing site configuration were tested as part of this study to determine the impact of the subject development. The basic criteria for a range of outdoor activities are described as follows:

- **Long Exposure:** 3.5m/s maximum GEM wind speeds (representative of approximately a weekly recurrence).
- **Short Exposure:** 5.5m/s maximum GEM wind speeds (representative of approximately a weekly recurrence).
- **Comfortable Walking:** 7.5m/s maximum GEM wind speeds (representative of approximately a weekly recurrence).
- **City of Sydney DCP Requirement for Street Frontages:** 16m/s annual maximum gust wind speed.
- **Safety Limit:** 23.0m/s annual maximum gust wind speeds.

The results of the wind tunnel study are summarised in the following section, and presented in the form of directional plots attached in Appendix A of this report. Each study point has 2 plots, one comparing to the modified version of the Davenport (1972) criteria for the maximum GEM wind speeds (which are representative of approximately a weekly recurrence), and the other comparing to the Melbourne (1978) and City of Sydney DCP criteria for the annual maximum peak gust wind speeds.

Notes:

- The GEM is defined as the maximum of the mean wind speed and the gust wind speed divided by a gust factor of 1.85.
- The gust wind speed is defined as 3.5 standard deviations from the mean.
- Long Exposure applies typically to outdoor dining areas in restaurants, amphitheatres, etc.
- Short Exposure applies typically to areas where short duration stationary activities are involved (less than 1 hour). This includes window shopping, waiting areas, etc.
- Comfortable Walking applies typically to areas used mainly for pedestrian thoroughfares. This also includes private swimming pools and communal areas.
- In all areas, the wind conditions are also checked against the safety limit.

5 TEST PROCEDURE AND METHODOLOGY

5.1 Measurement of the Velocity Coefficients

Testing was performed using Windtech's boundary layer wind tunnel facility, which has a 2.6m wide working section and has a fetch length of 14m. The test procedures followed for the wind tunnel testing performed for this study generally adhere to the guidelines set out in the Australasian Wind Engineering Society Quality Assurance Manual (AWES-QAM-1-2001), ASCE 7-10 (Chapter C31), and CTBUH guidelines.

The model of the subject development was setup within the wind tunnel, and the wind velocity measurements were monitored using Dantec hot-wire probe anemometers at selected critical outdoor locations at a full-scale height of approximately 1.5m above ground/slab level. The probe support for each study location was mounted such that the probe wire was vertical as much as possible, which ensures 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 are 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. A sample rate of 1024Hz was used, which is more than adequate for he given frequency band. The signal was low pass filtered at 32Hz, which results in the peak gust being the equivalent of a 2 to 3 second gust (which is what the criteria for pedestrian comfort and safety are based upon).

The mean and the maximum 3-second duration peak gust velocity coefficients are derived from the wind tunnel test by the following relation:

$$\hat{C}_V = \overline{C}_V + g.\sigma_V \tag{5.1}$$

where: $\hat{C}_V$ is the 3-second gust velocity coefficient.

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

g is the gust factor, which is taken to be 3.5.

σ_V is the standard deviation of the velocity measurement.

The mean free-stream wind speed measured in the wind tunnel for this study was approximately 10.8m/s. Note that the measurement location for the mean free-stream wind speed is at a height of 200m at the upwind edge of the proximity model. A sample length of 12 seconds was used for each wind direction tested, which is equivalent to a minimum sample time of approximately 34 minutes in full-scale for the annual maximum gust wind speeds, which is suitable for this type of study.

5.2 Calculation of the Full-Scale Results

To determine if the wind conditions at each study point location will satisfy the relevant criteria for pedestrian comfort and safety, the measured velocity coefficients need to be combined with information about the local wind climate. The aim of combining the wind tunnel measurements with wind climate information is to determine the probability of exceedance of a given wind speed at the site. The local wind climate is normally described using a statistical model, which relates wind speed to a probability of exceedance. Details of the wind climate model used in this study are outlined in Section 1.

A feature of this process is to include the impact of wind directionality, which includes any local variations in wind speed or frequency with wind direction. This is important as the wind directions which produce the highest wind speed events for a region may not coincided with the most wind exposed direction at the site.

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

5.2.1 Annual Maximum Gust Wind Speeds

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

$$V_{study} = V_{ref,RH}\left(\frac{k_{200m,tr,T=3600s}}{k_{RH,tr,T=3600s}}\right)C_V \qquad (5.2)$$

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

$V_{ref,RH}$ is the full-scale reference wind speed at the upwind edge of the proximity model at the study reference height. This value is determined by combining the directional wind speed data for the region (detailed in Section 1) and the upwind terrain and height multipliers for the site (detailed in Section 3).

$k_{200m,tr,T=3600s}$ is the hourly mean terrain and height multiplier at 200m for the standard terrain category setup used in the wind tunnel tests.

$k_{RH,tr,T=3600s}$ is the hourly mean terrain and height multiplier at the study reference height (see Table 3).

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

$$C_V = \frac{C_{V,study}}{C_{V,200m}} \qquad (5.3)$$

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

$C_{V,200m}$ is the 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 will 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.

5.2.2 Weekly Maximum Gust-Equivalent Mean Wind Speeds

The contribution to the probability of exceedance of a specified wind speed (i.e. the desired wind speed for pedestrian comfort, as per the criteria) is 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 Lawson (1980).

The criteria of Davenport (1972), which is used in this study, is referenced to a probability of exceedance of 5% of a specified wind speed and is representative of approximately a weekly recurrence interval.

5.3 Layout of Study Points

For this study a total of 30 study point locations have been selected for analysis in the wind tunnel. The locations of the various study points tested for this study are presented in Figures 5a to 5e in the form of a marked-up plan drawings, along with the wind criteria each point is required to meet. It should be noted that only the most critical outdoor locations of the development have been selected for analysis.

Target Criteria

A.G. Davenport (1972) criterion of 7.5m/s (weekly GEM's) for comfortable walking activity.
City of Sydney DCP criterion of 16m/s (annual gusts).

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 5a: Study Point Locations – Ground Level Plan

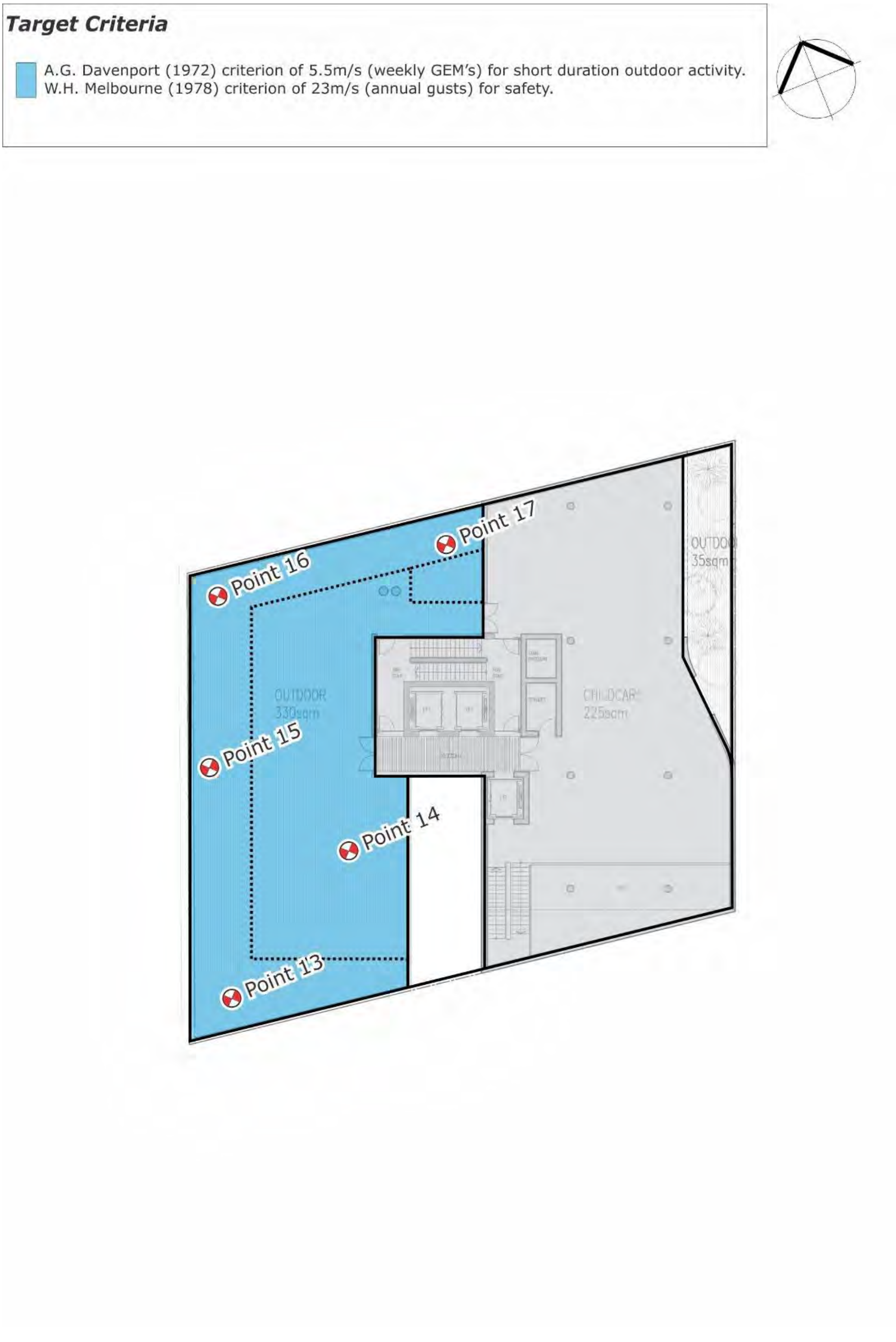
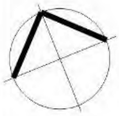


Figure 5b: Study Point Locations – Level 01 Plan

Target Criteria

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



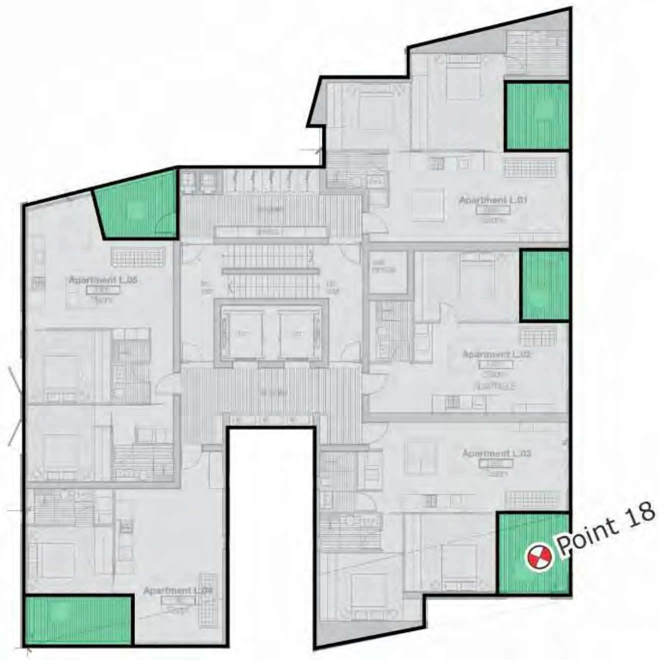


Figure 5c: Study Point Locations – Lower Tower Levels

Target Criteria

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

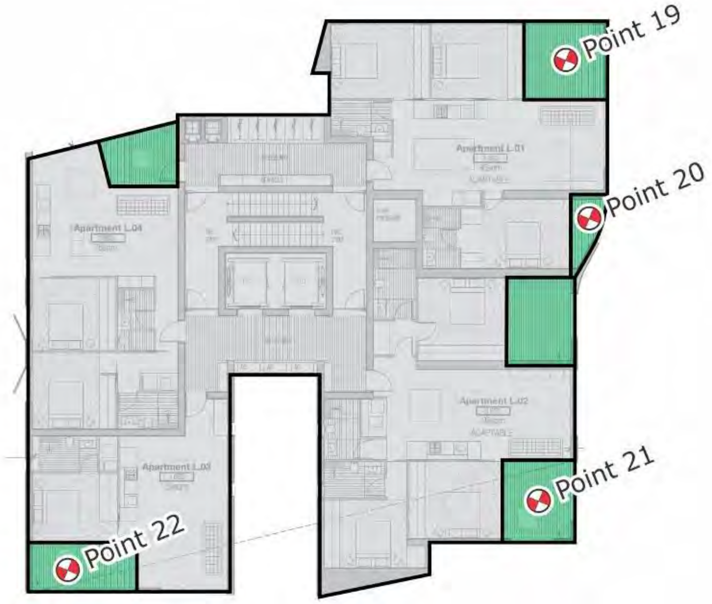


Figure 5d: Study Point Locations – Upper Tower Levels

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.

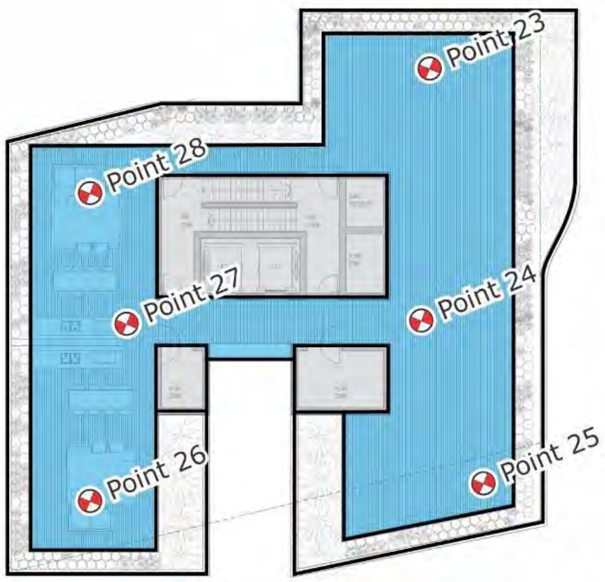


Figure 5e: Study Point Locations – Roof Level Plan

6 RESULTS AND DISCUSSION

The model was initially tested in the wind tunnel without the effect of any forms of wind ameliorating devices such as screens, balustrades, awnings, etc. that are not already shown in the architectural drawings. If the results of the initial study indicate that any area is exposed to strong winds, treatments have been recommended in-principle.

The results for all study points locations are presented in the form of directional plots in Appendix A, and are summarised in Table 9 below and also in Figures 6a to 6e. The wind speed criteria that the wind conditions should achieve are also listed in Table 9 for each study point location, as well as in Figures 5a to 5e.

Wind conditions at ground level along the southern aspect of the development exceed the City of Sydney DCP requirements but are comparable to, and in some cases better than the existing wind conditions. In particular, strong westerly winds are experienced along Marian Street, which is an existing condition and is improved by the addition of the proposed development. Note that a future development on the corner of Marian Street and Gibbon Street would help alleviate the impact of these westerly winds.

The south-eastern corner balconies and Level 1 terrace area are exposed to the prevailing southerly winds due to the exposure of the site in this direction. The rooftop area is noted to be exposed to the wind up-washing over the built form. The interaction of the tower with the adjacent Iglu development to the north is noted to exacerbate this effect.

The abovementioned results of the study indicate that treatments are required for certain locations to achieve the desired wind speed criteria for pedestrian comfort and safety. The suggested treatments are detailed in marked-up plan figures from Figure 7a to 7h, and are also summarised as follows:

Level 1:

- Inclusion of 4m tall densely foliating evergreen trees along the southern aspect. Trees should have interlocking canopies where possible and should meet with the overhanging tower slab above.
- Include a 1.8m tall porous screen along the southern and eastern aspects of the outdoor terrace area as proposed.

Levels 5-13:

- Include one of the following treatment options:
    - *Option 1:* Full height impermeable screen along the southern aspect of the south-eastern corner balconies.

- *Option 2:* Louvres along the southern aspect of the south-eastern corner balconies. Louvres must be oriented as shown in Figure 7c.

Levels 14-17:

- Include one of the following treatment options:
  - *Option 1:* 2m tall impermeable screen along the southern aspect of the south-eastern corner balconies.
  - *Option 2:* Louvres along the southern aspect of the south-eastern corner balconies. Louvres must be oriented as shown in Figure 7e.

Rooftop Terrace:

- Include dense landscaping along the perimeter of the rooftop terrace area as shown in Figure 7g. Landscaping should be evergreen variety to be effective throughout the entire year and capable of growing to at least 1.8m tall.
- Inclusion of one of the following treatment options:
  - *Option 1:* Dense landscaping in the centre of the eastern section of the outdoor terrace area as shown in Figure 7f. Landscaping should be evergreen variety to be effective throughout the entire year and capable of growing to at least 1.8m tall.
  - *Option 2:* 1.8m impermeable screen running north-south, located in the centre of the eastern section of the outdoor terrace area as shown in Figure 7g.

With the inclusion of these recommended treatments to the final design, the results of this study indicate that wind conditions for all outdoor trafficable areas within and around the development will be suitable for their intended uses.

Table 9: Results Summary

Point Name	Desired Criterion (m/s)		Treatment Necessary to Pass?	Description of Treatment
	Weekly GEM	Annual Peak		
Point 01	7.5	16.0	NO	
Point 02	7.5	16.0	NO	
Point 03	7.5	16.0	NO	
Point 04	7.5	16.0	NO	
Point 05	7.5	16.0	NO	
Point 06	5.5	16.0	NO	
Point 07	7.5	16.0	NO	
Point 08	5.5	16.0	NO	
Point 09	7.5	16.0	NO	
Point 10	7.5	16.0	NO	

Point Name	Desired Criterion (m/s)		Treatment Necessary to Pass?	Description of Treatment
	Weekly GEM	Annual Peak		
Point 11	7.5	16.0	NO	
Point 12	7.5	16.0	NO	
Point 13	5.5	23.0	NO	
Point 14	5.5	23.0	YES	Refer to Figure 7a.
Point 15	5.5	23.0	YES	Refer to Figure 7a.
Point 16	5.5	23.0	NO	
Point 17	5.5	23.0	NO	
Point 18	7.5	23.0	YES	Refer to Figure 7b/7c.
Point 19	7.5	23.0	NO	
Point 20	7.5	23.0	NO	
Point 21	7.5	23.0	YES	Refer to Figure 7d/7e.
Point 22	7.5	23.0	NO	
Point 23	5.5	23.0	YES	Refer to Figure 7f/7g.
Point 24	5.5	23.0	YES	Refer to Figure 7f/7g.
Point 25	5.5	23.0	YES	Refer to Figure 7f/7g.
Point 26	5.5	23.0	NO	
Point 27	5.5	23.0	NO	
Point 28	5.5	23.0	YES	Refer to Figure 7f/7g.
Point 29	5.5	23.0	NO	
Point 30	5.5	23.0	NO	

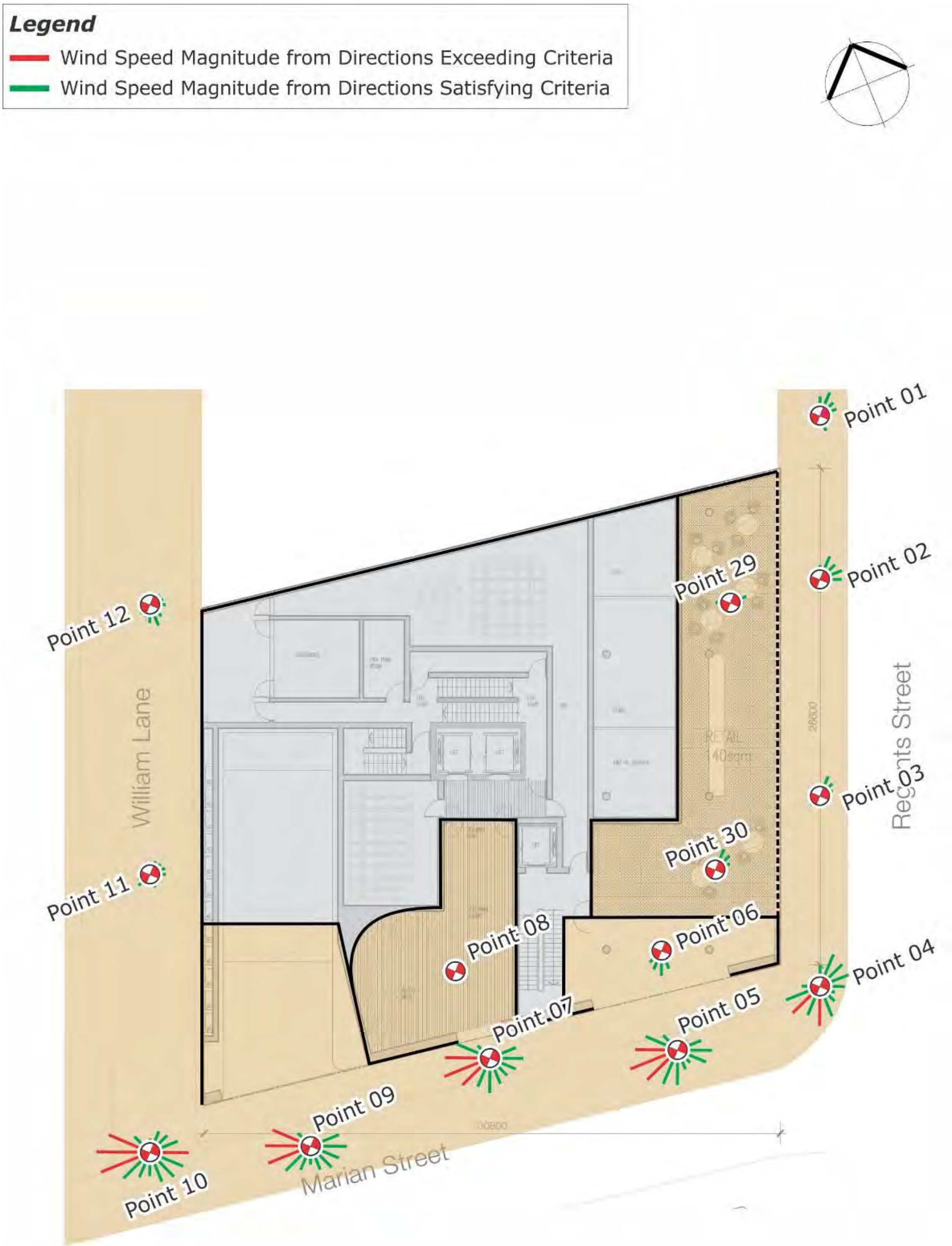


Figure 6a: Wind Direction Plots – Ground Level (results shown without treatments applied)

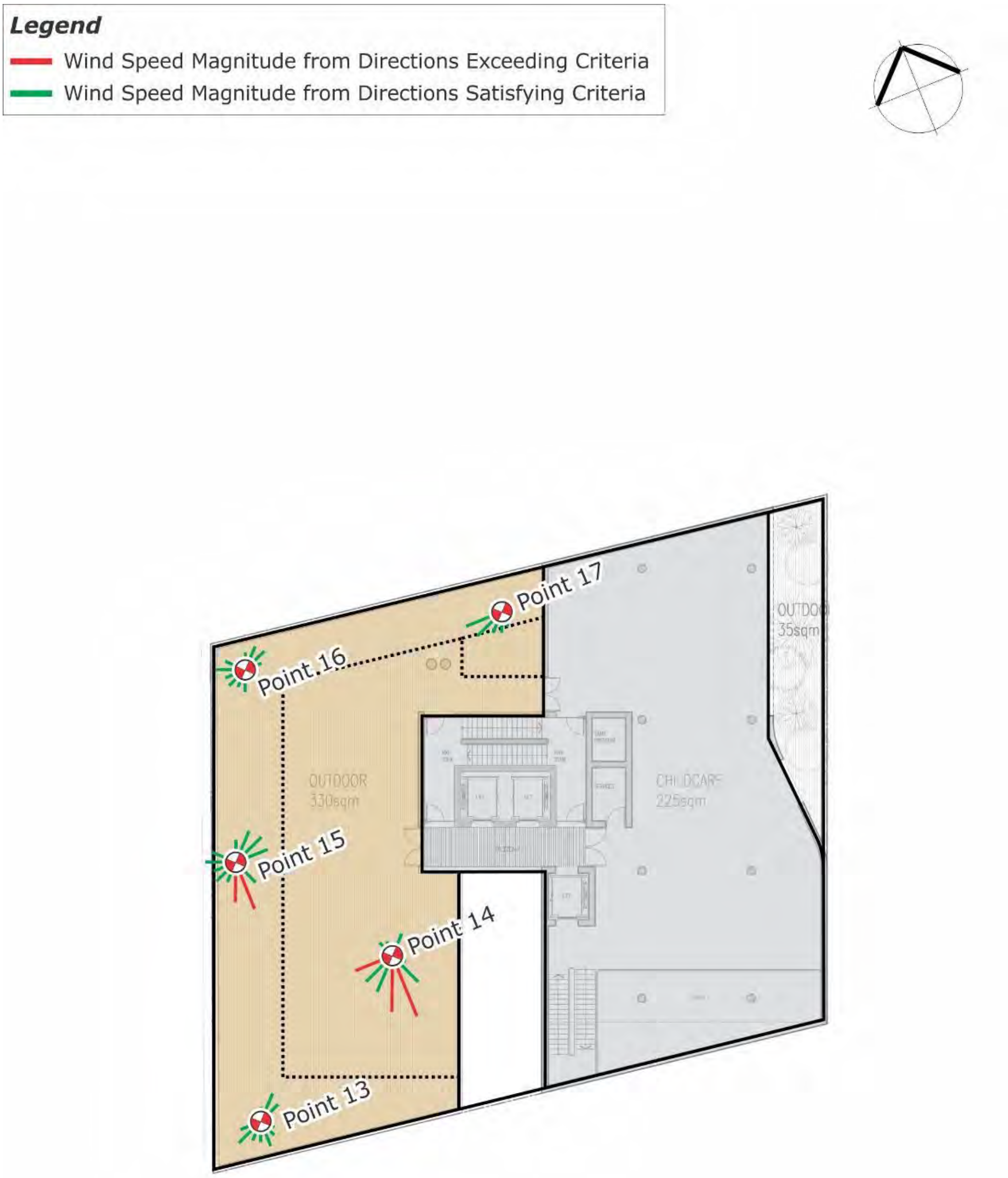


Figure 6b: Wind Direction Plots – Level 01
(results shown without treatments applied)

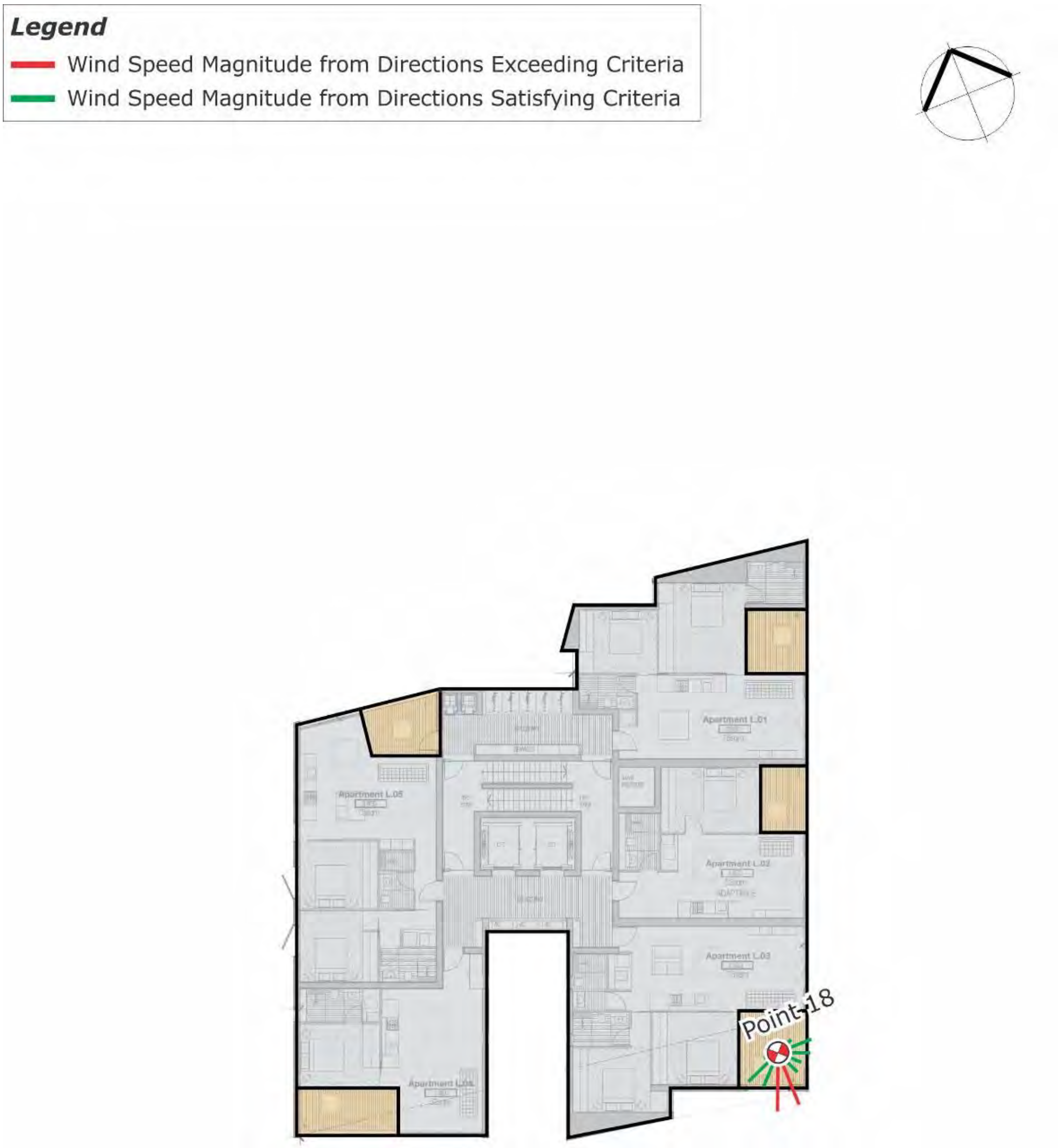


Figure 6c: Wind Direction Plots – Lower Tower Levels (results shown without treatments applied)

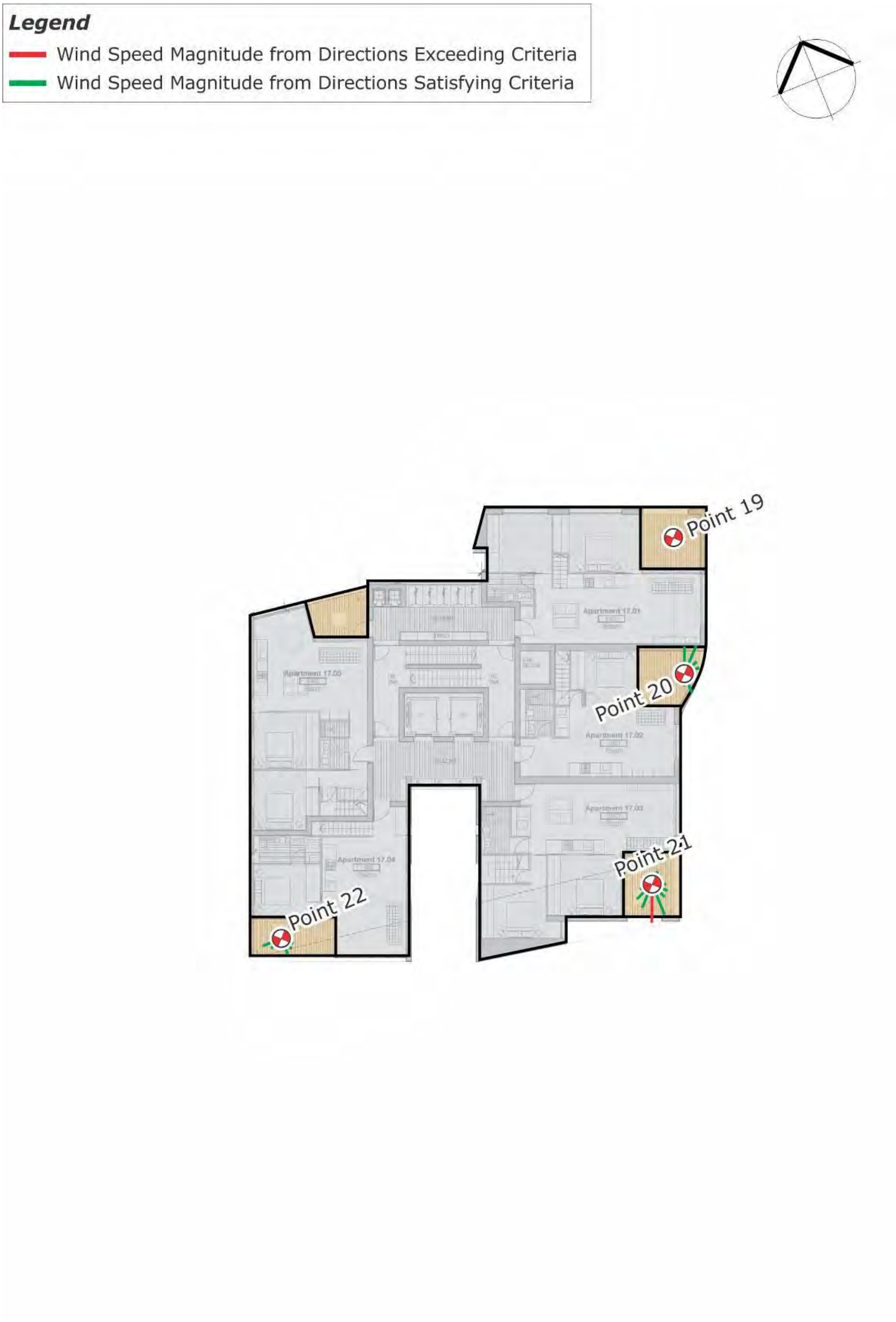


Figure 6d: Wind Direction Plots – Upper Tower Levels
(results shown without treatments applied)

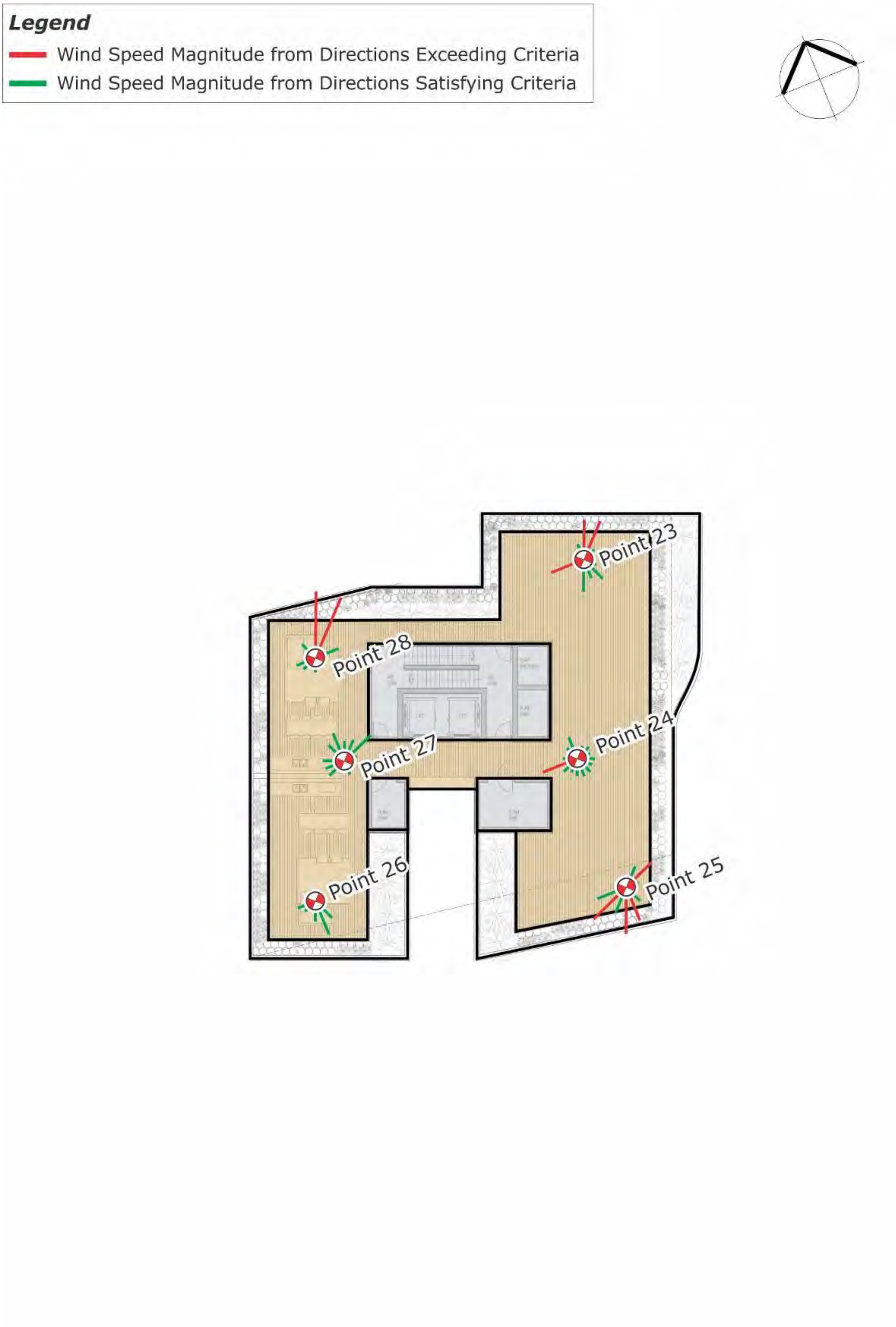


Figure 6e: Wind Direction Plots – Roof
(results shown without treatments applied)

Treatments Legend

Trees as proposed. Trees should be densely foliating, evergreen and capable of growing to a height to meet with the underside of the overhanging tower slab above. Trees should have interlocking canopies where possible.

1.8m tall porous or impermeable screen as proposed.

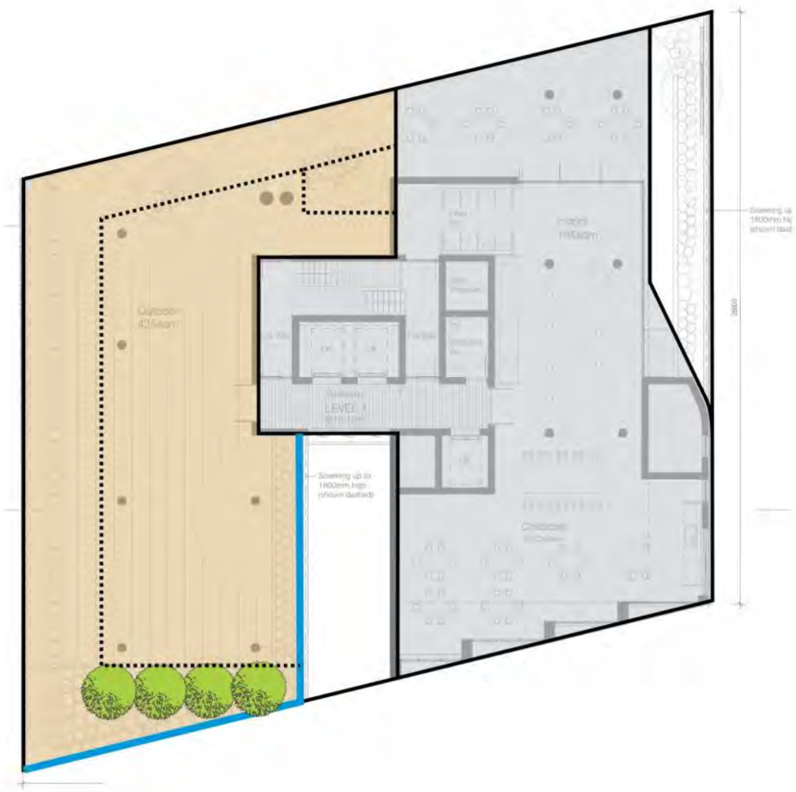


Figure 7a: Level 1 – Suggested Treatments

Treatments Legend

Full height impermeable screen.

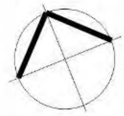


Figure 7b: Levels 5-13 – Suggested Treatments (Option 1)

Treatments Legend

Louvres oriented in direction indicated.

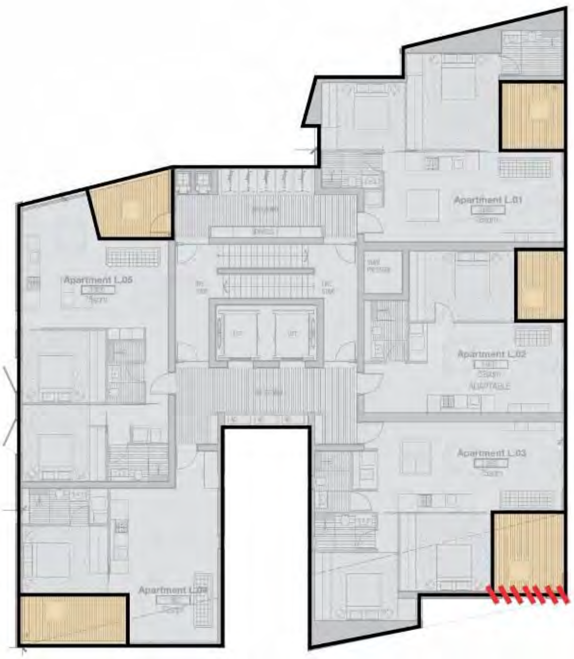


Figure 7c: Levels 5-13 – Suggested Treatments (Option 2)

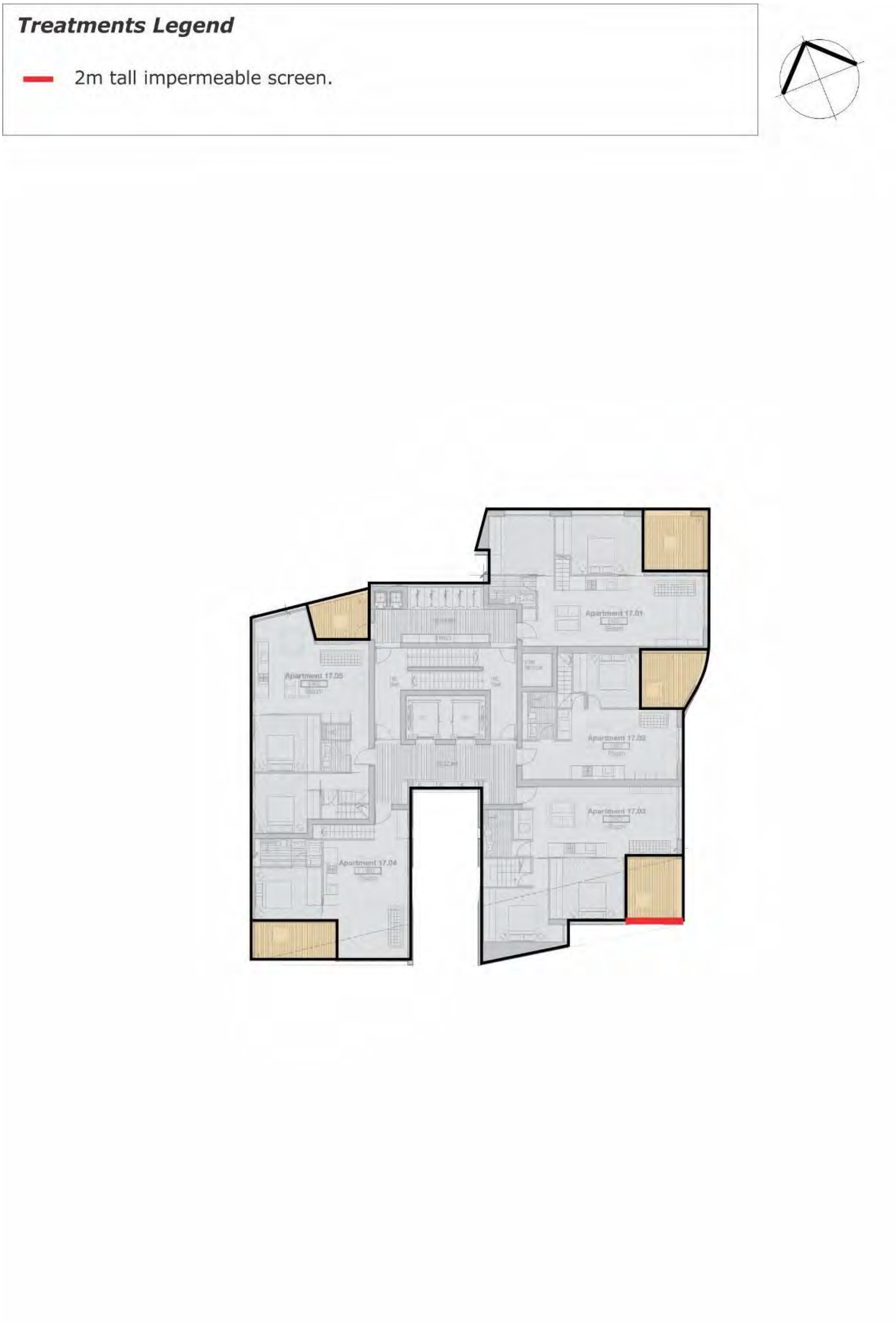
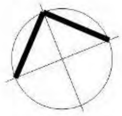


Figure 7d: Levels 14-17 – Suggested Treatments (Option 1)

Treatments Legend

Louvres oriented in direction indicated.



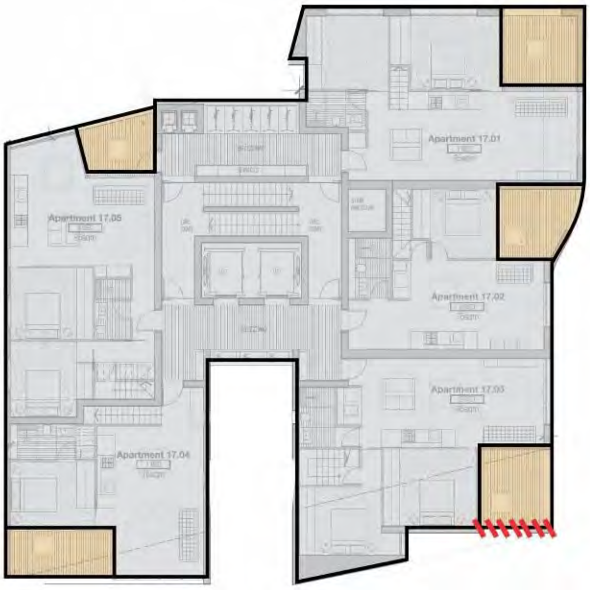


Figure 7e: Levels 14-17 – Suggested Treatments (Option 2)

Treatments Legend

Densely foliating, evergreen landscaping at least 1.8m tall.

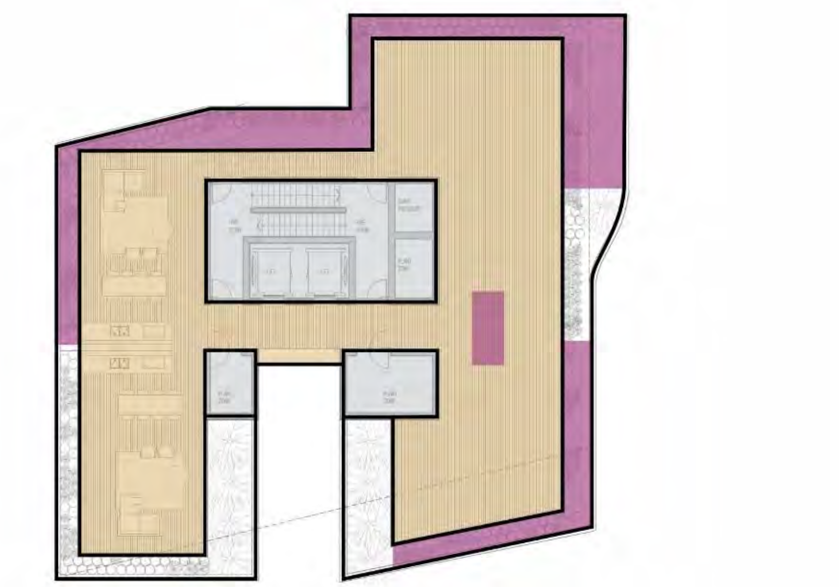


Figure 7f: Roof – Suggested Treatments (Option 1)

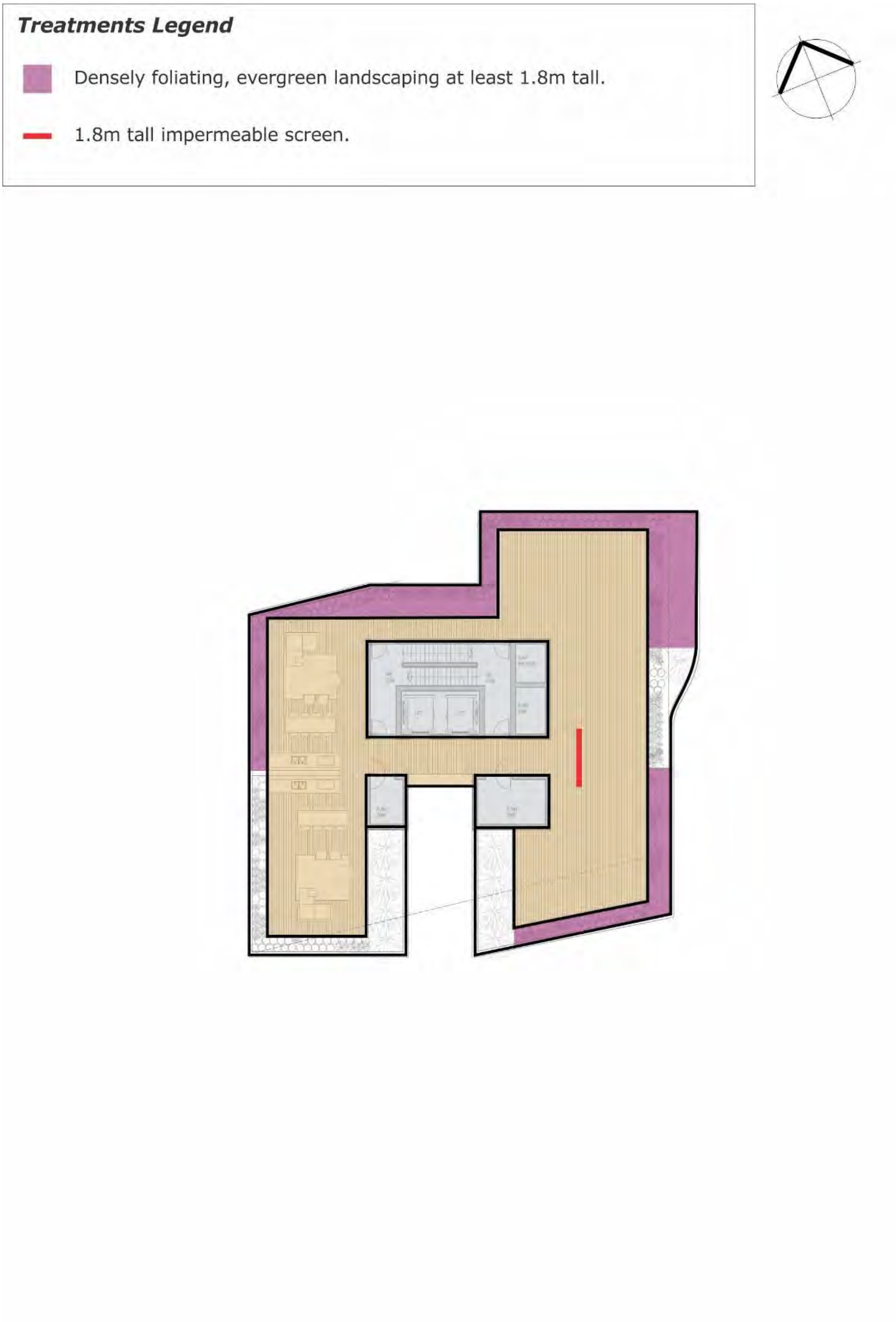


Figure 7g: Roof – Suggested Treatments (Option 2)

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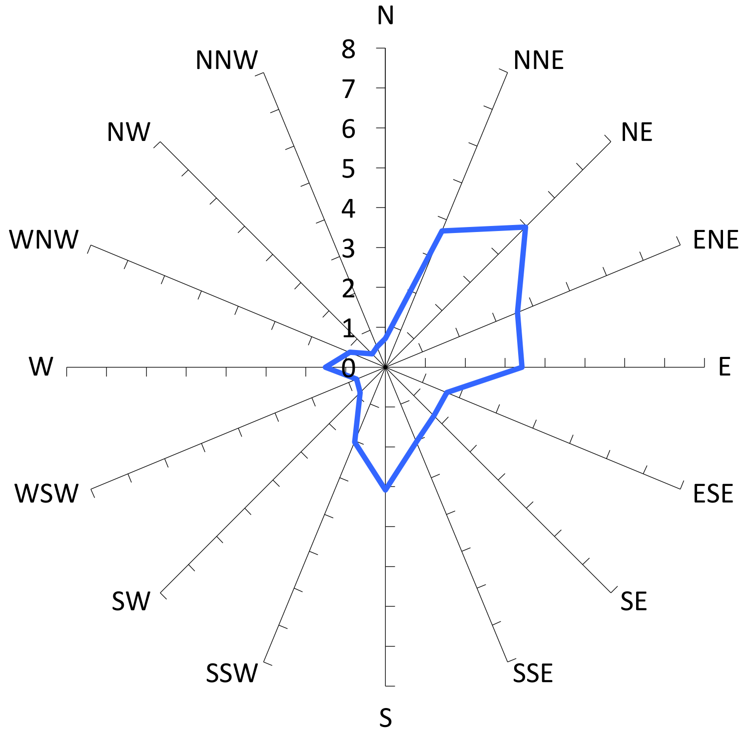
APPENDIX A - DIRECTIONAL PLOTS OF THE WIND TUNNEL RESULTS

Measured Wind Speeds at Point 01

Weekly Maximum GEM (m/s)



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

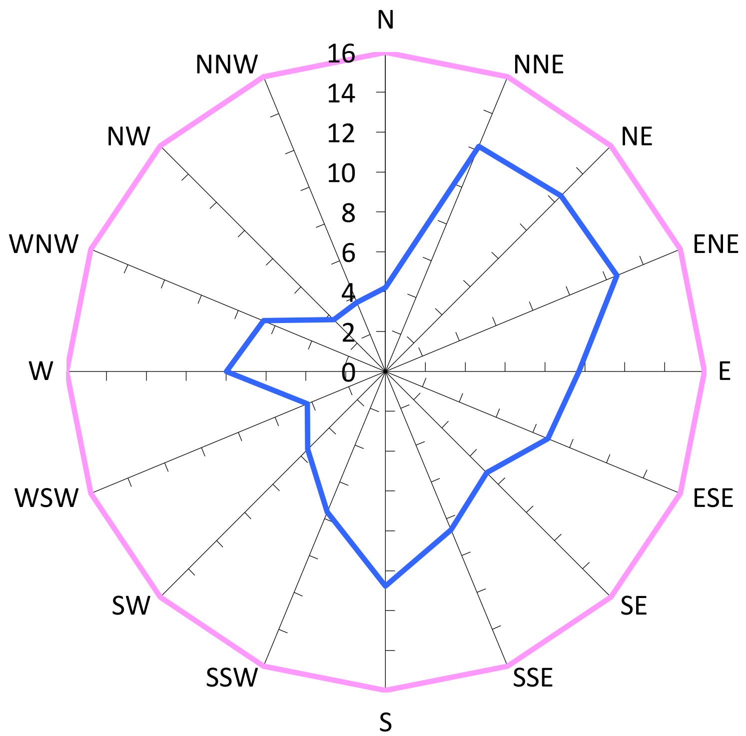
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

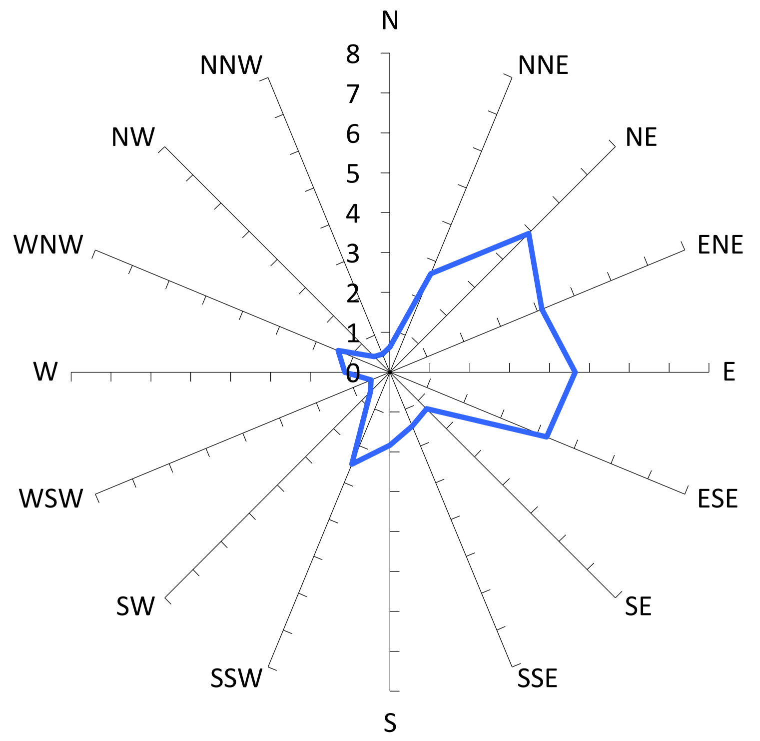
Annual Maximum Gust (m/s)



Desired Criterion
16m/s

Measured Wind Speeds at Point 02

Weekly Maximum GEM (m/s)



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

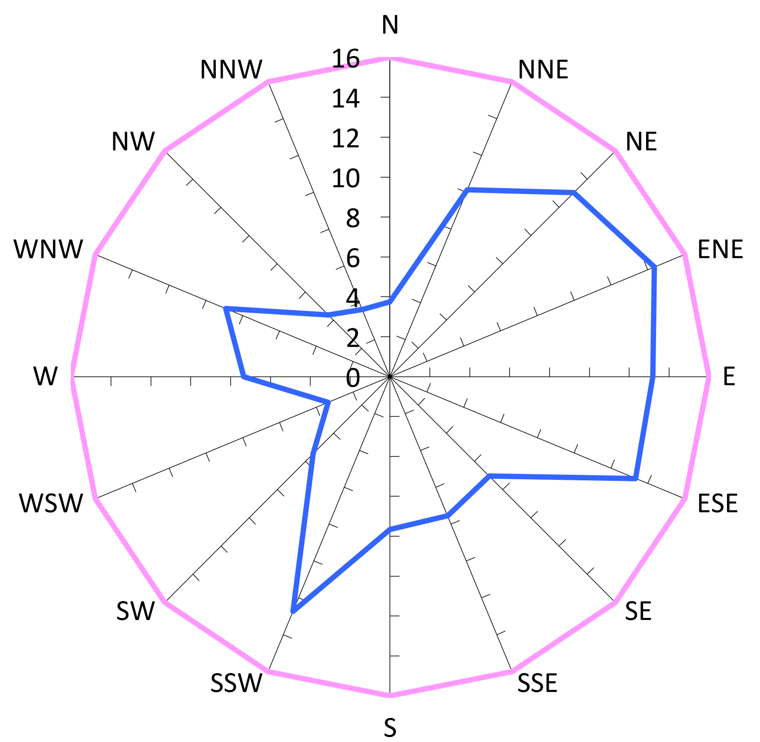
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

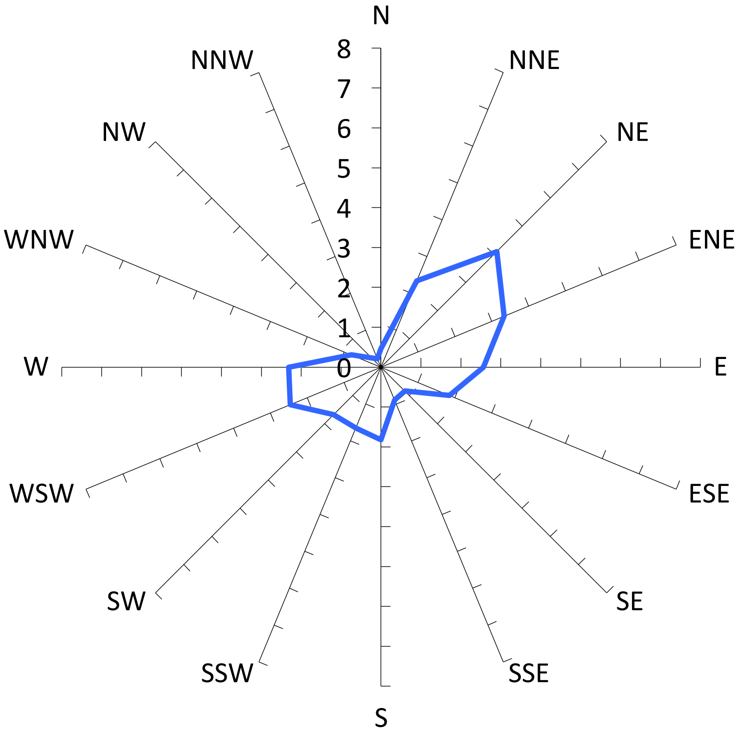
Annual Maximum Gust (m/s)



Desired Criterion
16m/s

Measured Wind Speeds at Point 03

Weekly Maximum GEM (m/s)



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

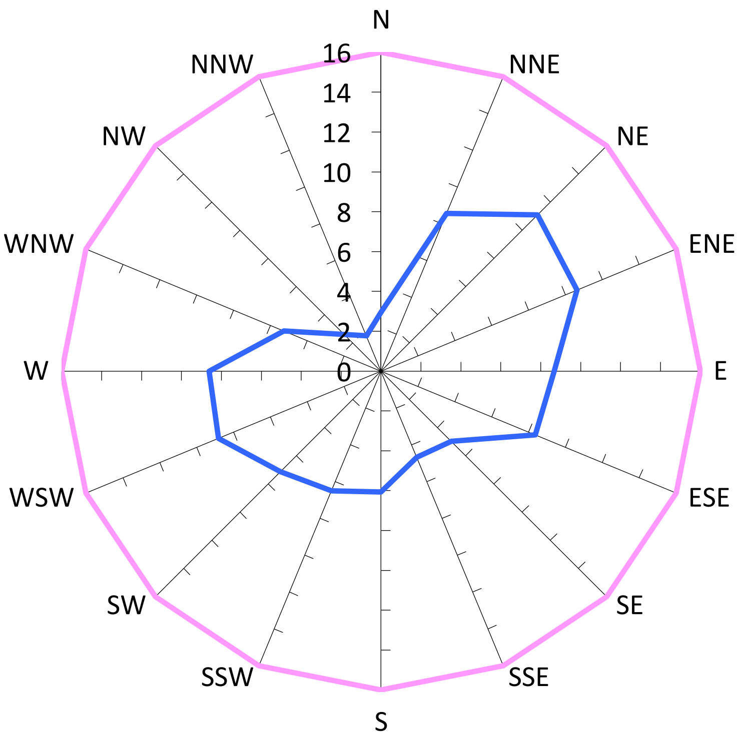
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

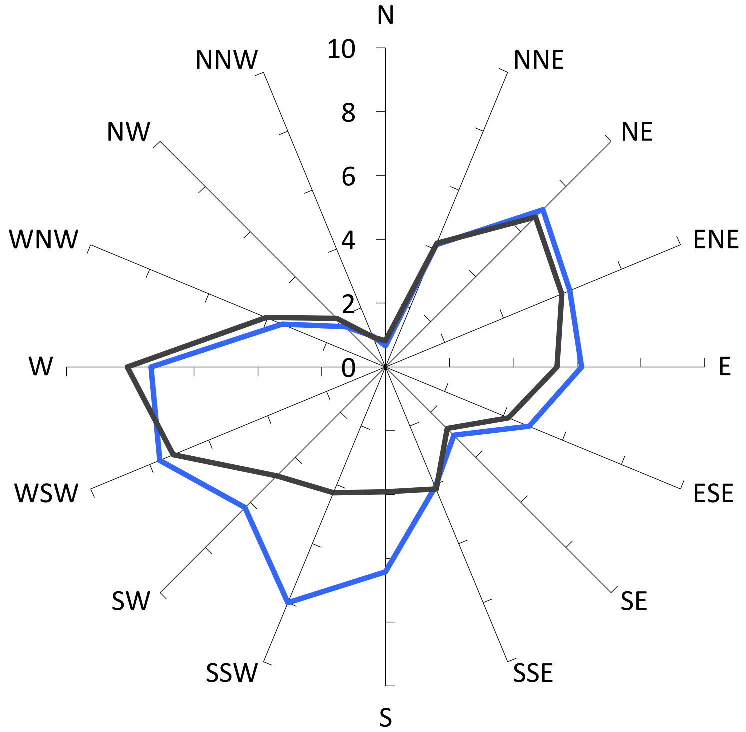
Annual Maximum Gust (m/s)



Desired Criterion
16m/s

Measured Wind Speeds at Point 04

Weekly Maximum GEM (m/s)



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
3%

Probability of Criterion Exceedence (initial test)
6%

Probability of Criterion Exceedence (final retest)
N/A

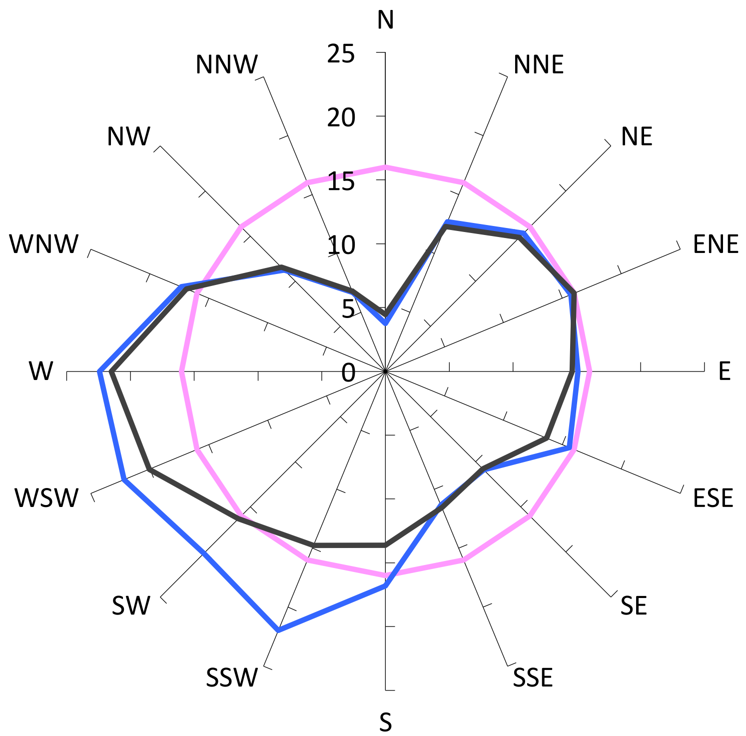
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

Existing site conditions.

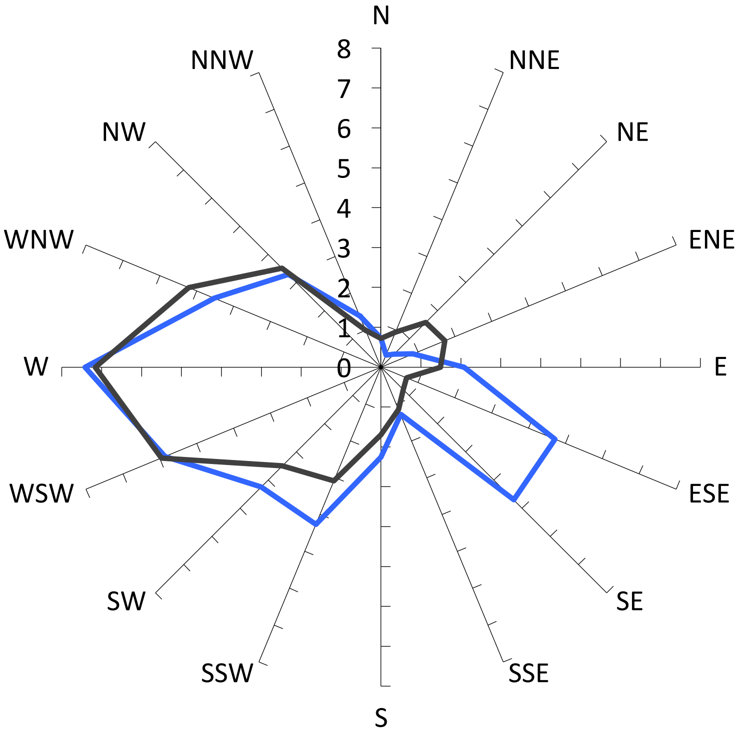
Annual Maximum Gust (m/s)



Desired Criterion
16m/s

Measured Wind Speeds at Point 05

Weekly Maximum GEM (m/s)



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
1%

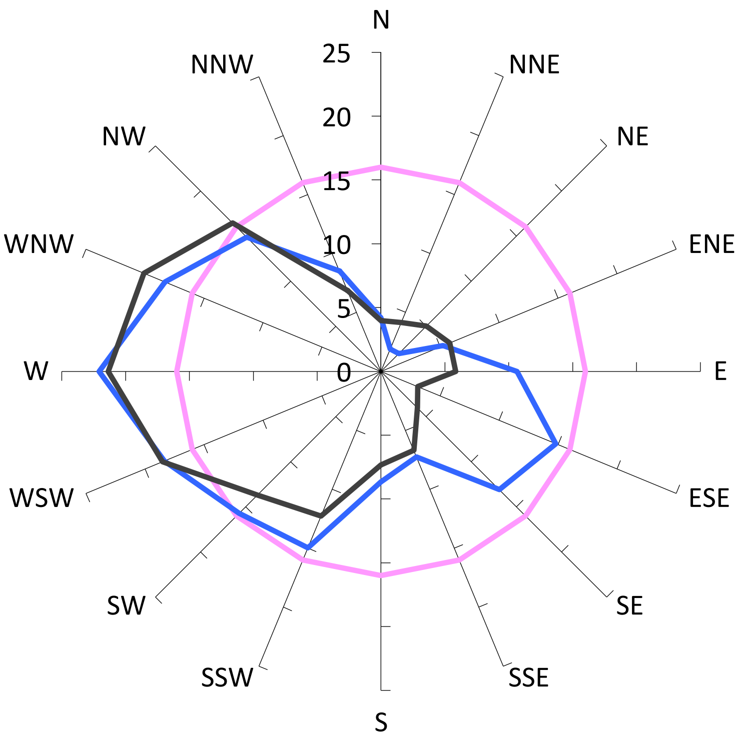
Probability of Criterion Exceedence (initial test)
1%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.
With development "as proposed", no vegetation or other treatments.
Existing site conditions.

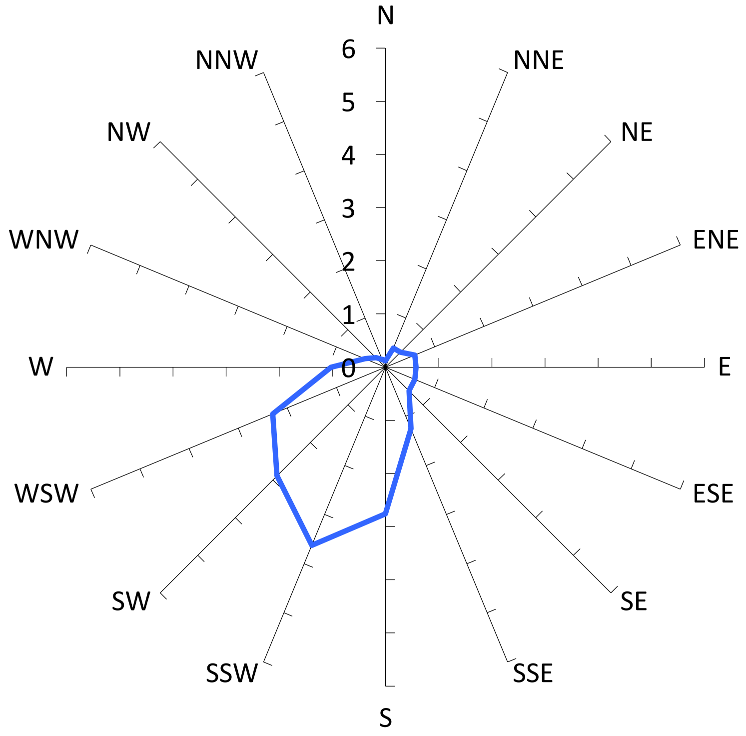
Annual Maximum Gust (m/s)



Desired Criterion
16m/s

Measured Wind Speeds at Point 06

Weekly Maximum GEM (m/s)



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

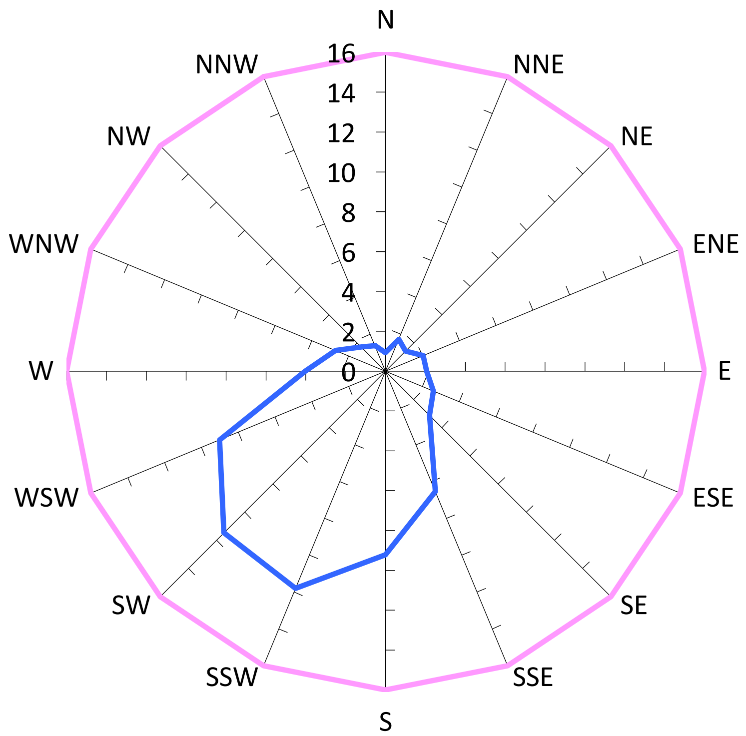
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

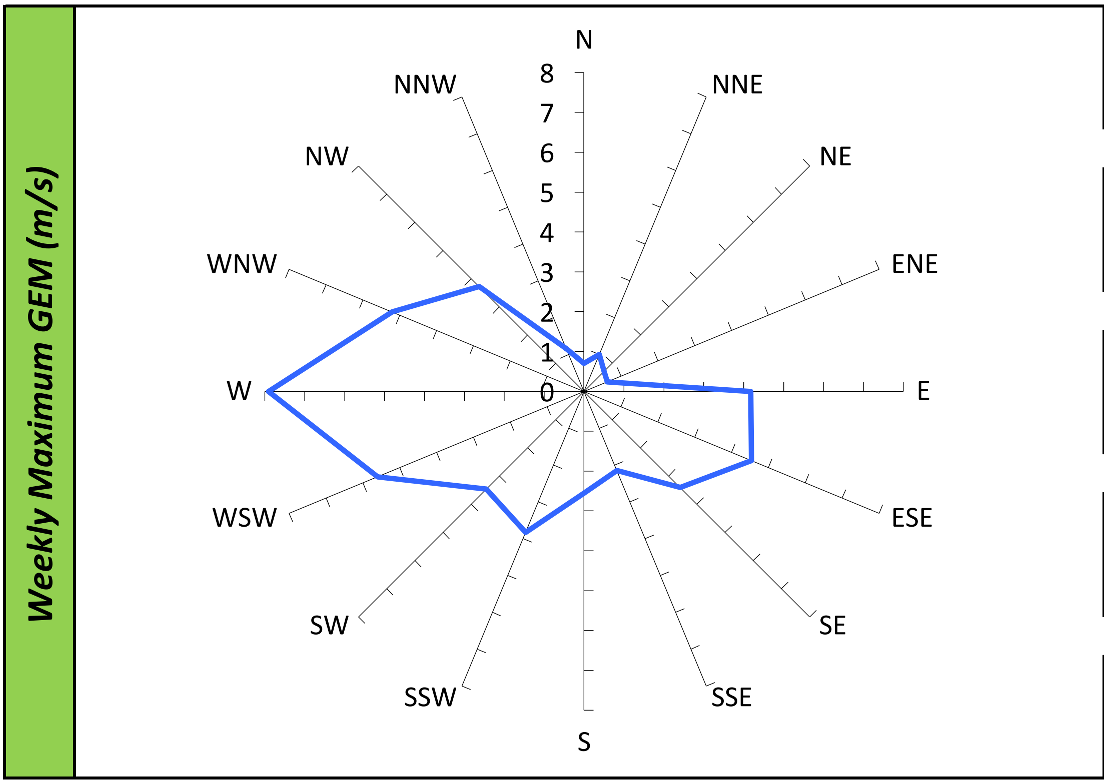
With development "as proposed", no vegetation or other treatments.

Annual Maximum Gust (m/s)



Desired Criterion
16m/s

Measured Wind Speeds at Point 07



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

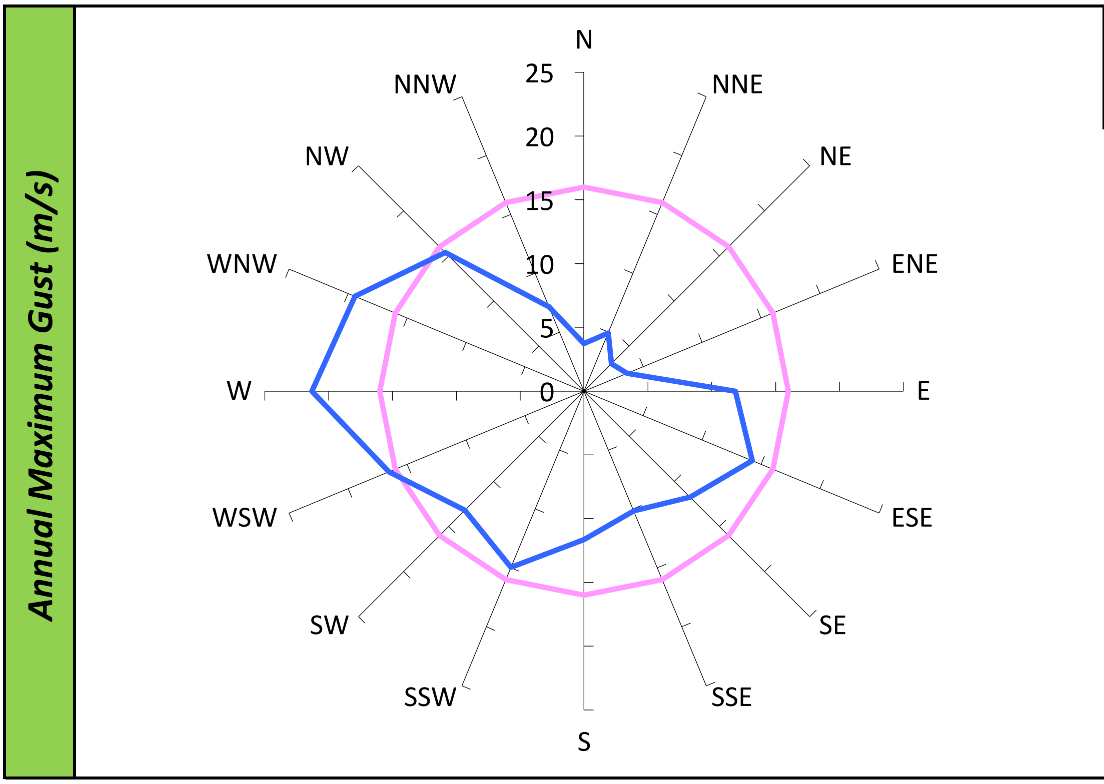
Probability of Criterion Exceedence (initial test)
1%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

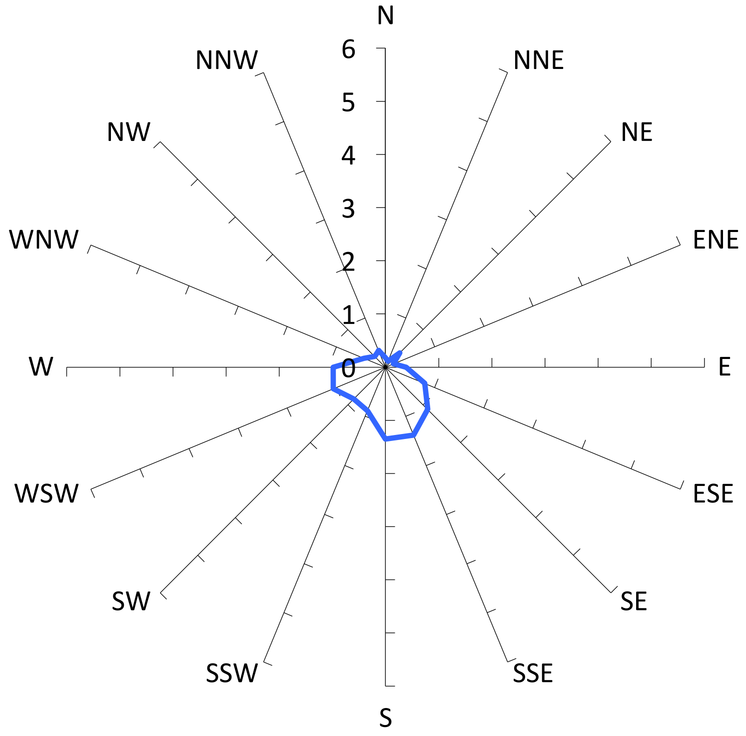
With development "as proposed", no vegetation or other treatments.



Desired Criterion
16m/s

Measured Wind Speeds at Point 08

Weekly Maximum GEM (m/s)



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

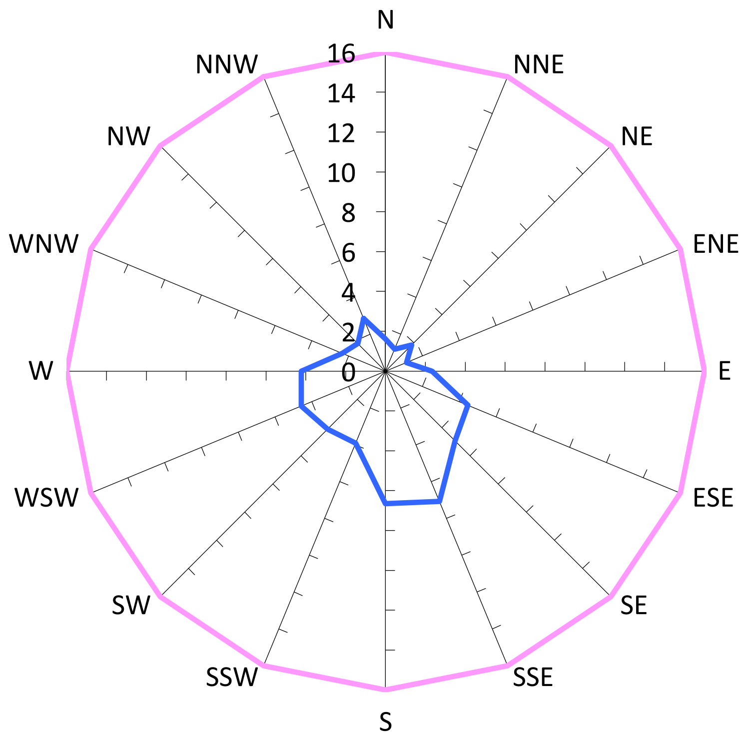
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

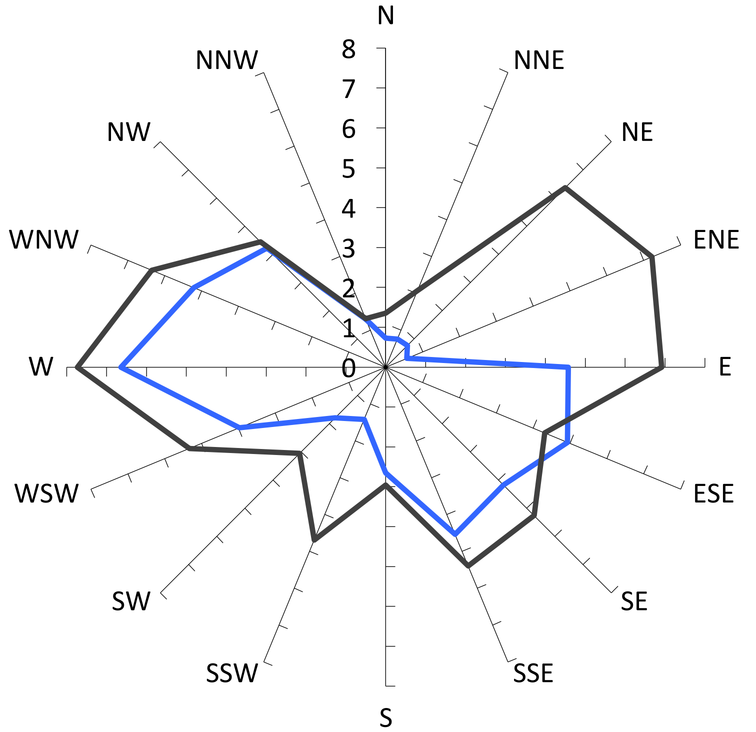
Annual Maximum Gust (m/s)



Desired Criterion
16m/s

Measured Wind Speeds at Point 09

Weekly Maximum GEM (m/s)



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
5%

Probability of Criterion Exceedence (initial test)
1%

Probability of Criterion Exceedence (final retest)
N/A

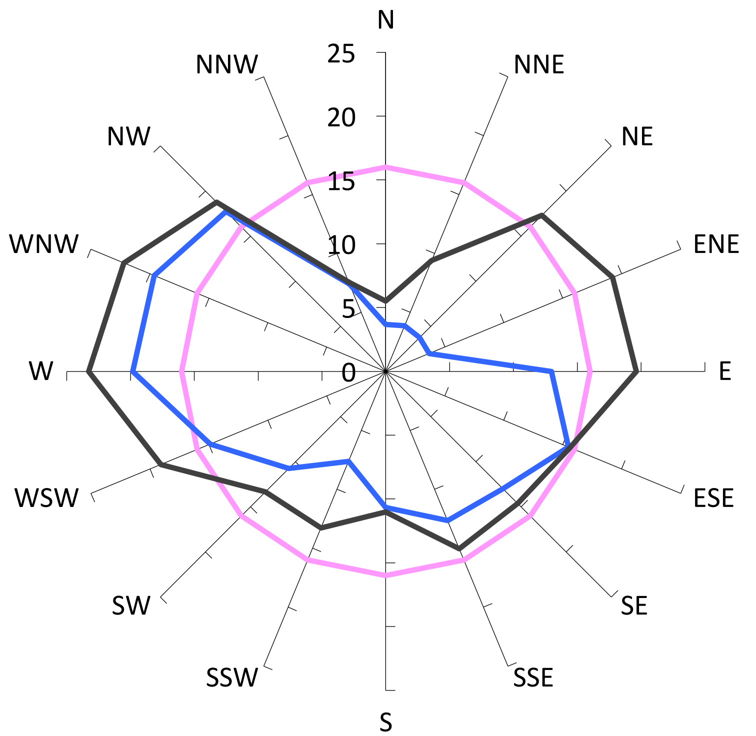
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

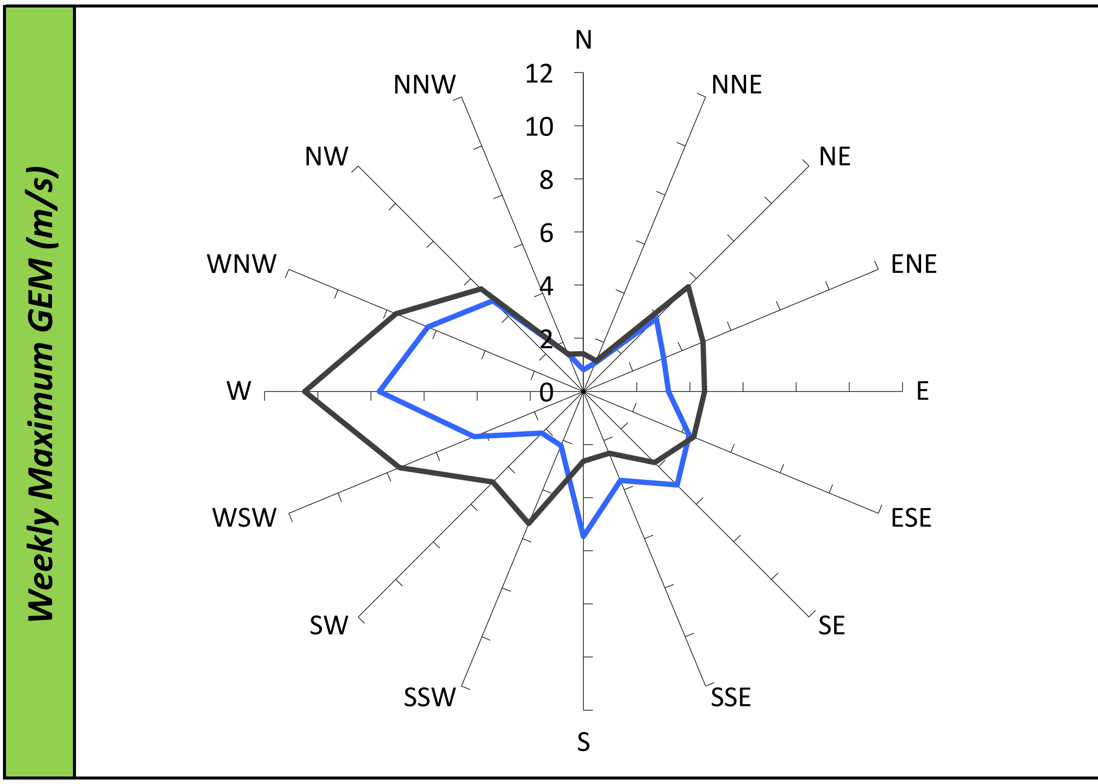
Existing site conditions.

Annual Maximum Gust (m/s)



Desired Criterion
16m/s

Measured Wind Speeds at Point 10



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
6%

Probability of Criterion Exceedence (initial test)
2%

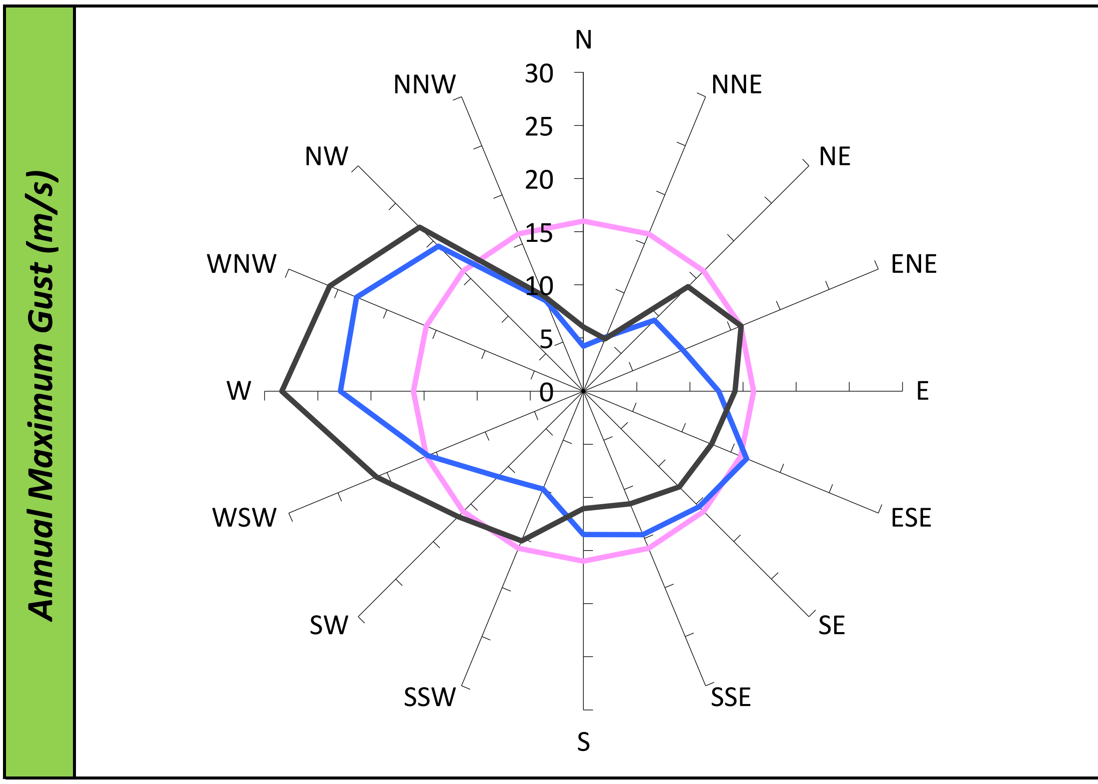
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

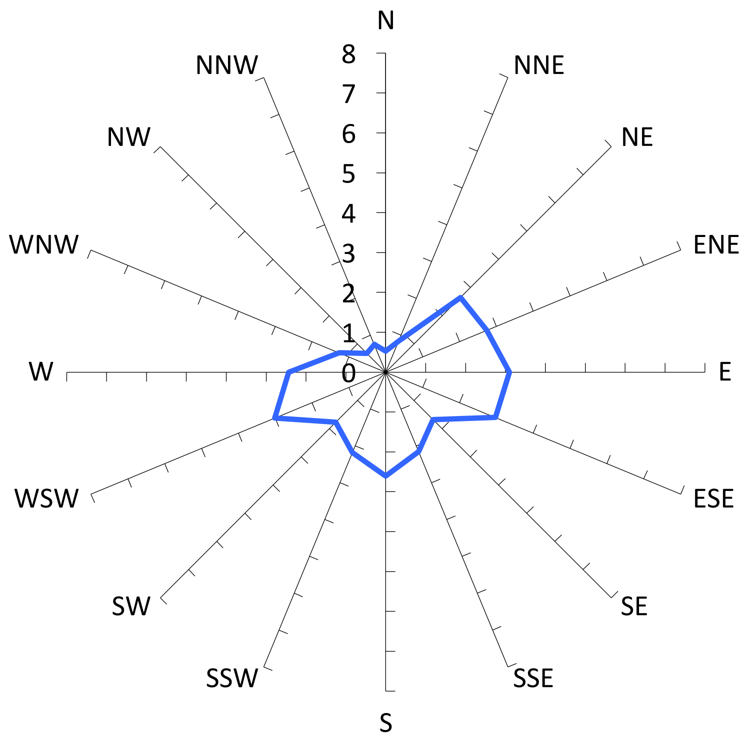
Existing site conditions.



Desired Criterion
16m/s

Measured Wind Speeds at Point 11

Weekly Maximum GEM (m/s)



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

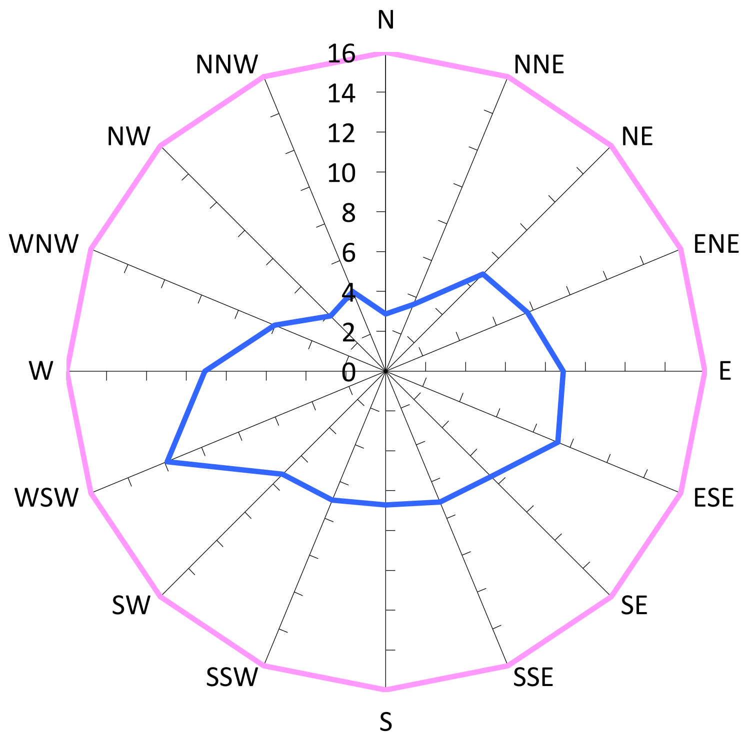
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

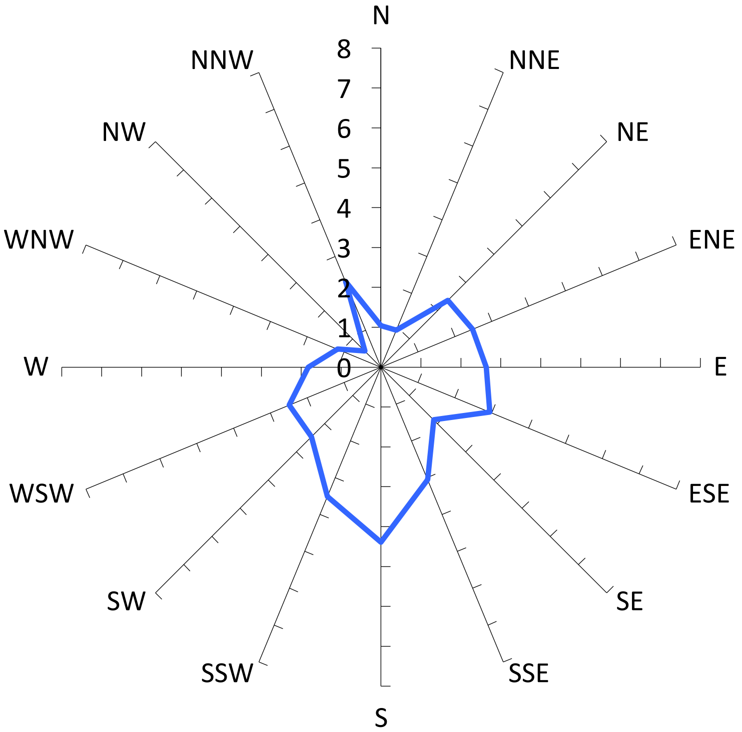
Annual Maximum Gust (m/s)



Desired Criterion
16m/s

Measured Wind Speeds at Point 12

Weekly Maximum GEM (m/s)



Desired Criterion

7.5m/s

Prob. of Criterion Exceedence (existing site conditions)

N/A

Probability of Criterion Exceedence (initial test)

0%

Probability of Criterion Exceedence (final retest)

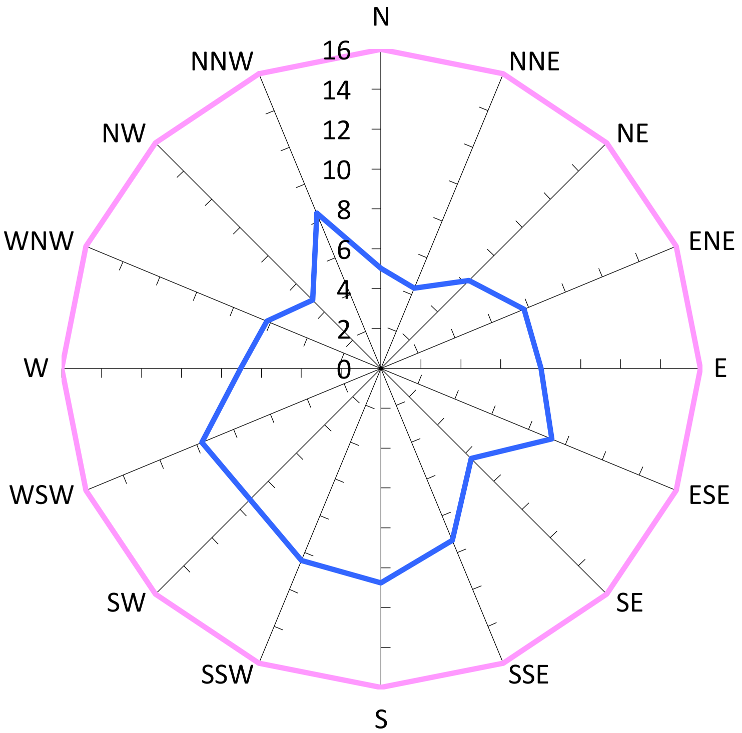
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

Annual Maximum Gust (m/s)

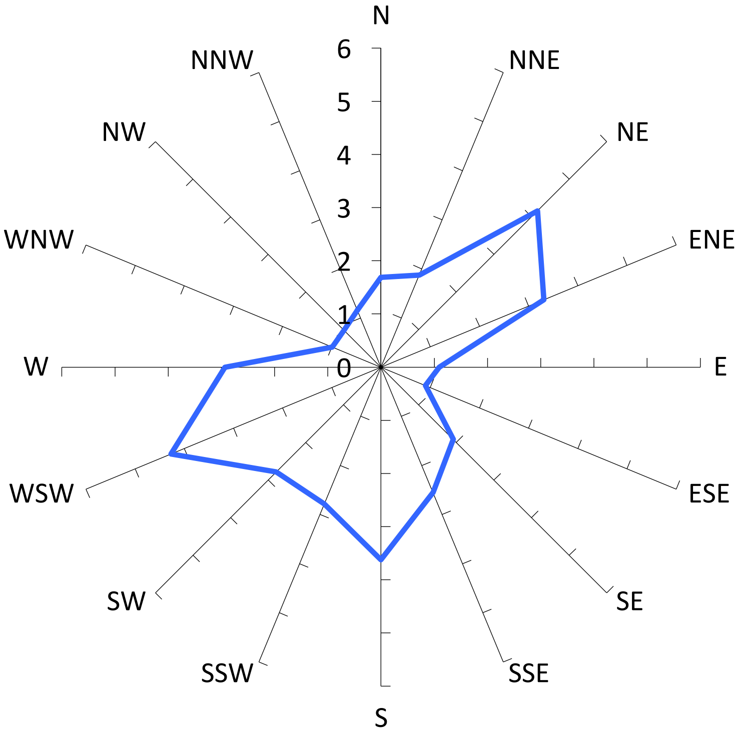


Desired Criterion

16m/s

Measured Wind Speeds at Point 13

Weekly Maximum GEM (m/s)



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
1%

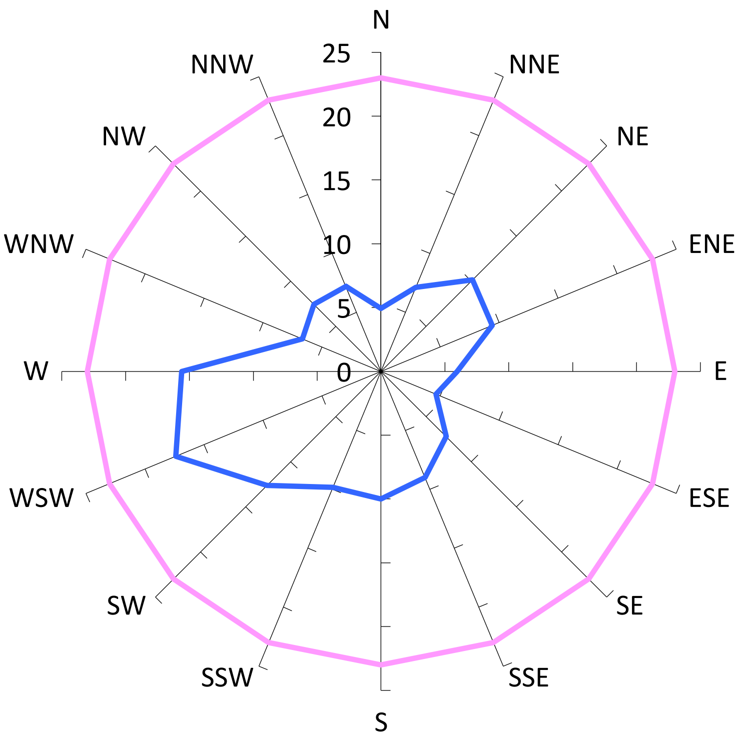
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

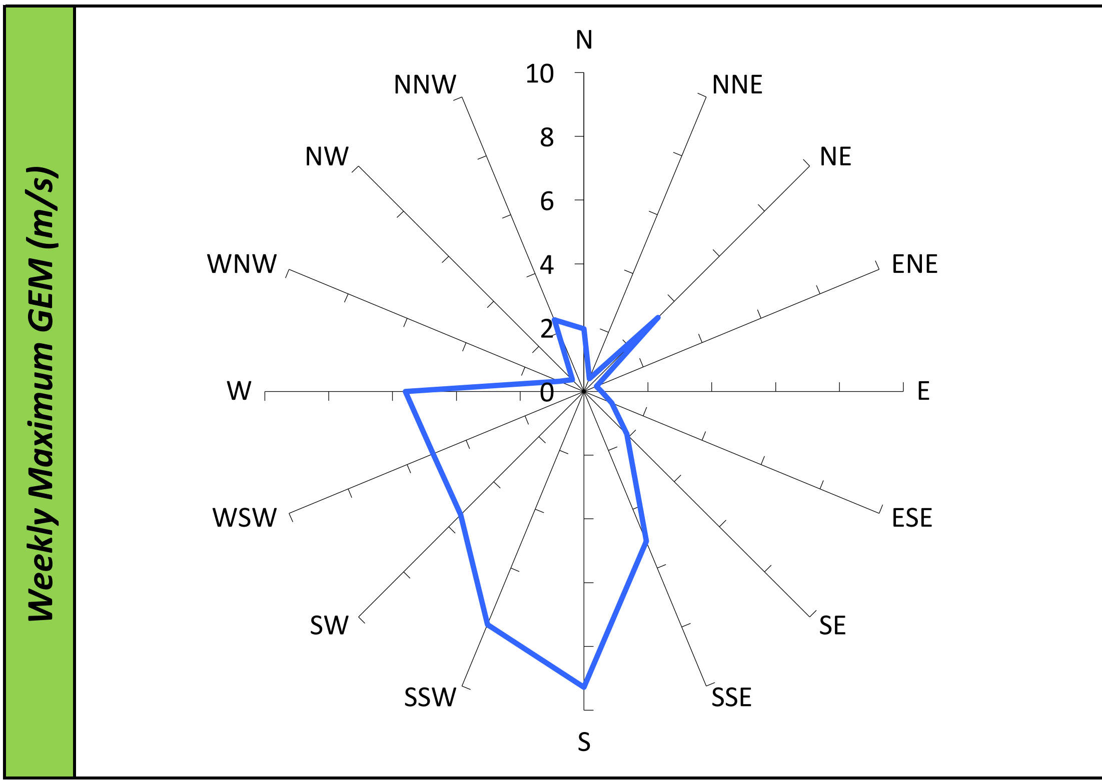
With development "as proposed", no vegetation or other treatments.

Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 14



Desired Criterion
5.5m/s

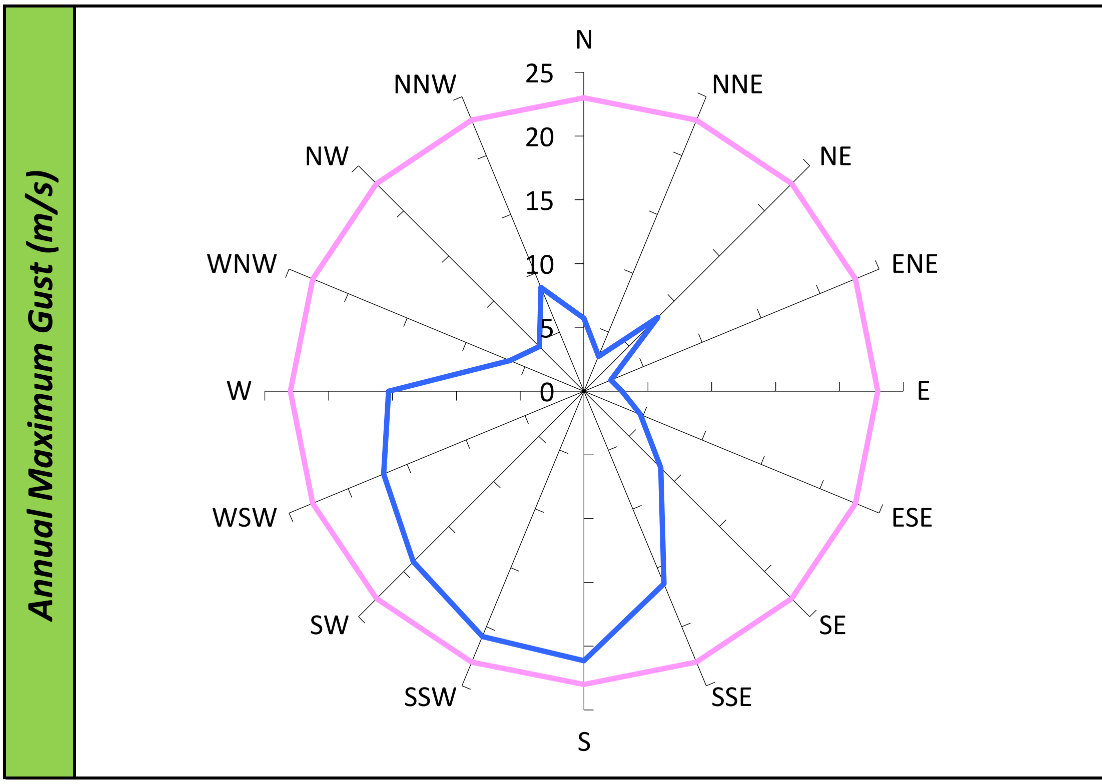
Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
12%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

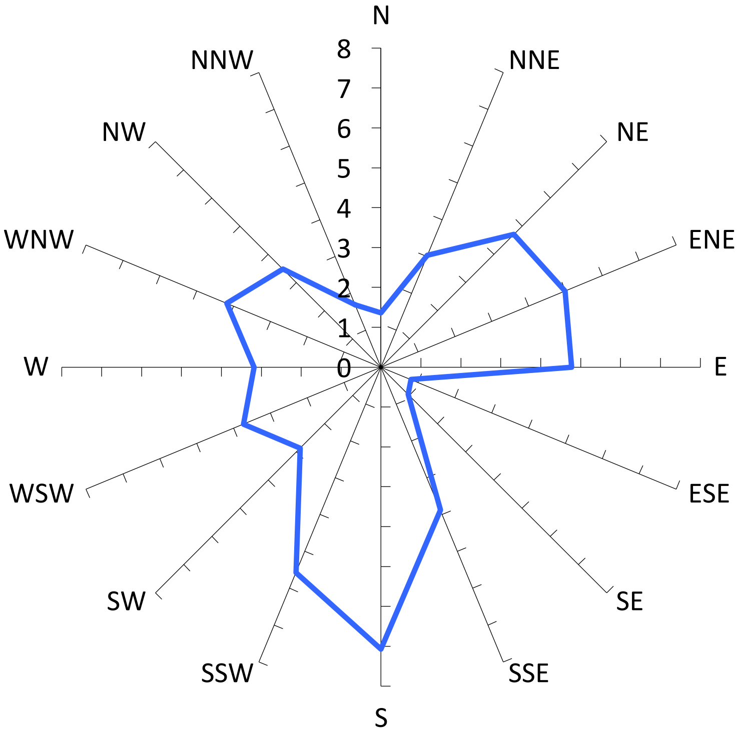
Criterion.
With development "as proposed", no vegetation or other treatments.



Desired Criterion
23m/s

Measured Wind Speeds at Point 15

Weekly Maximum GEM (m/s)



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
9%

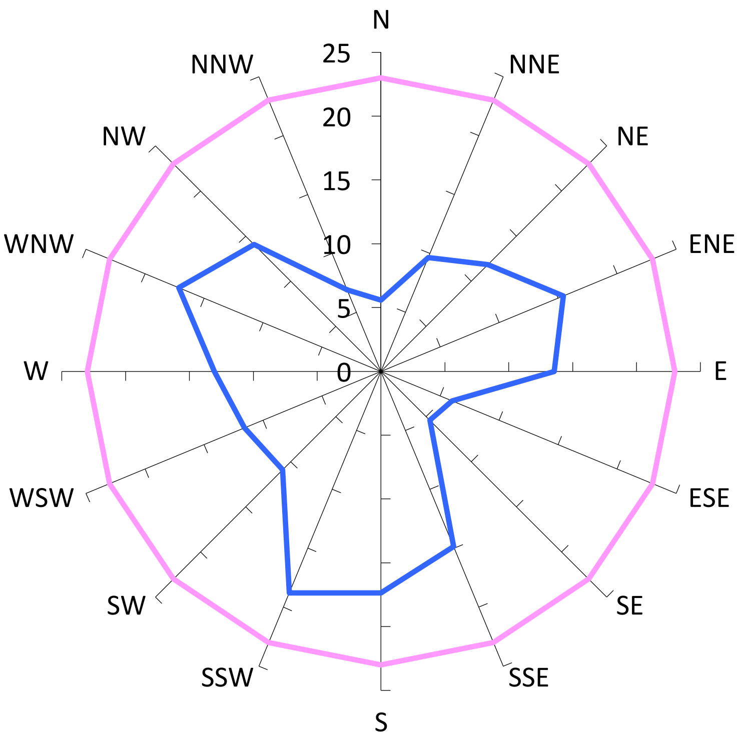
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

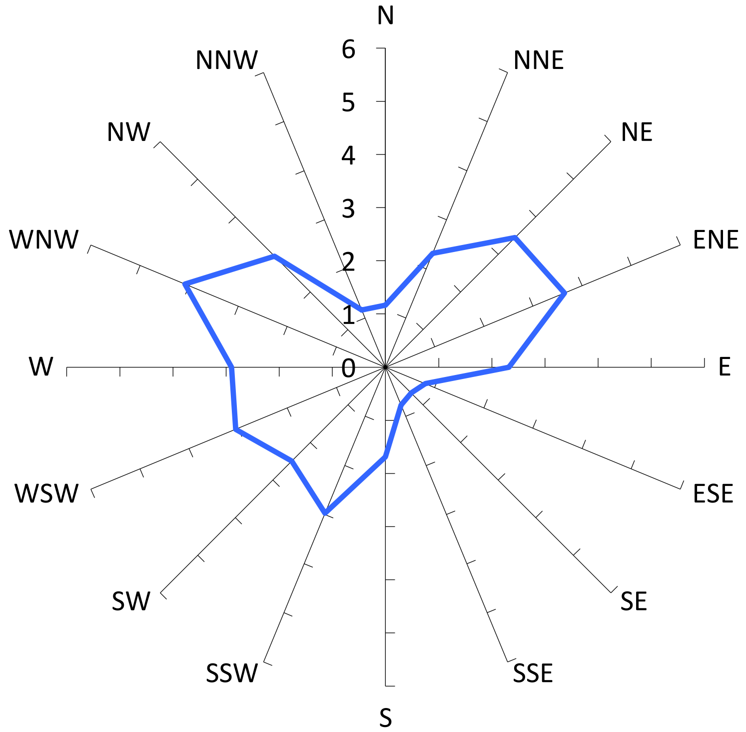
Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 16

Weekly Maximum GEM (m/s)



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
1%

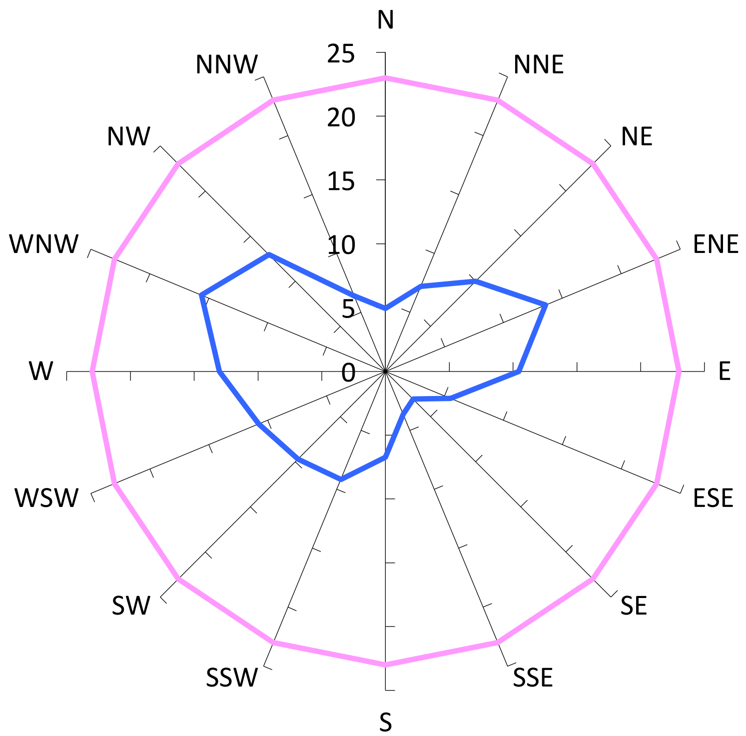
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

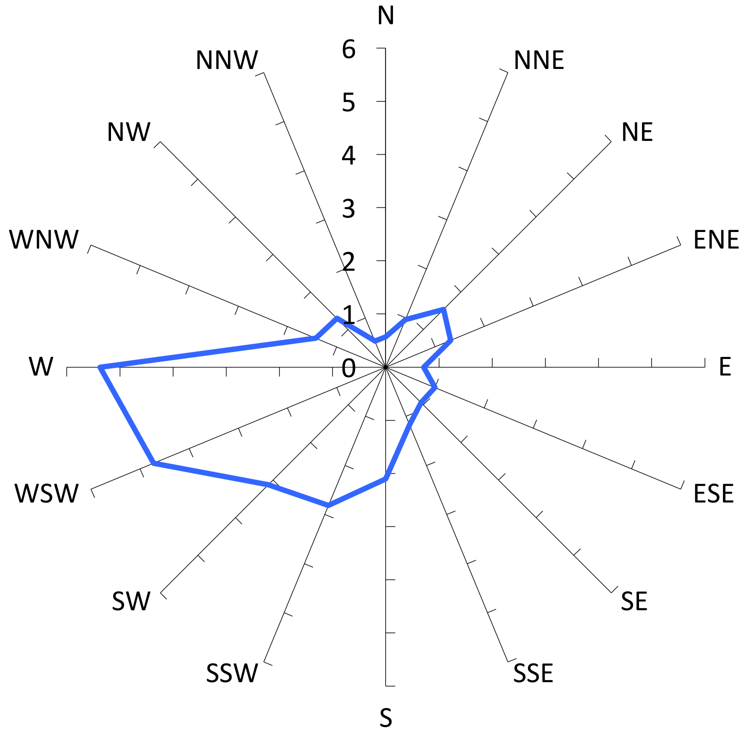
Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 17

Weekly Maximum GEM (m/s)



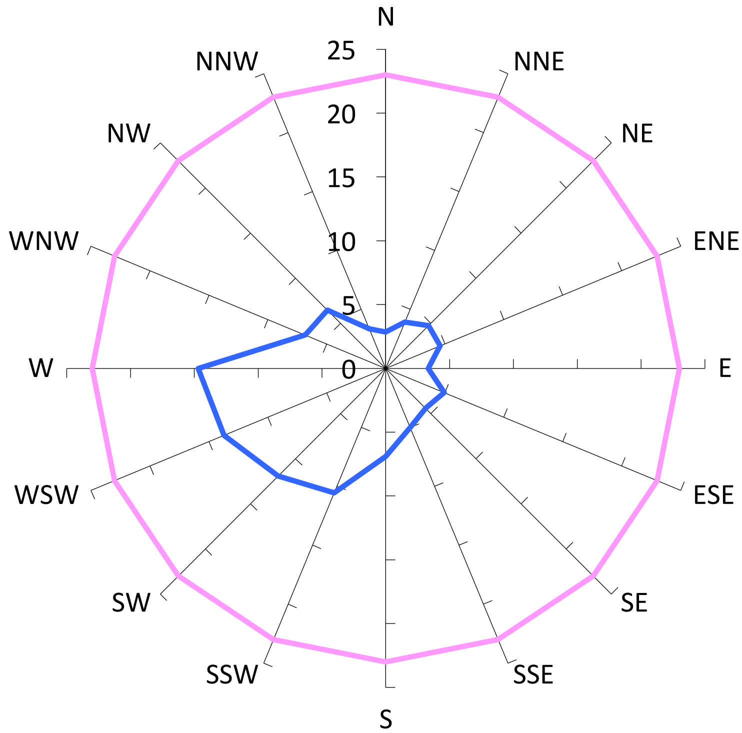
Desired Criterion
5.5m/s
Prob. of Criterion Exceedence (existing site conditions)
N/A
Probability of Criterion Exceedence (initial test)
1%
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

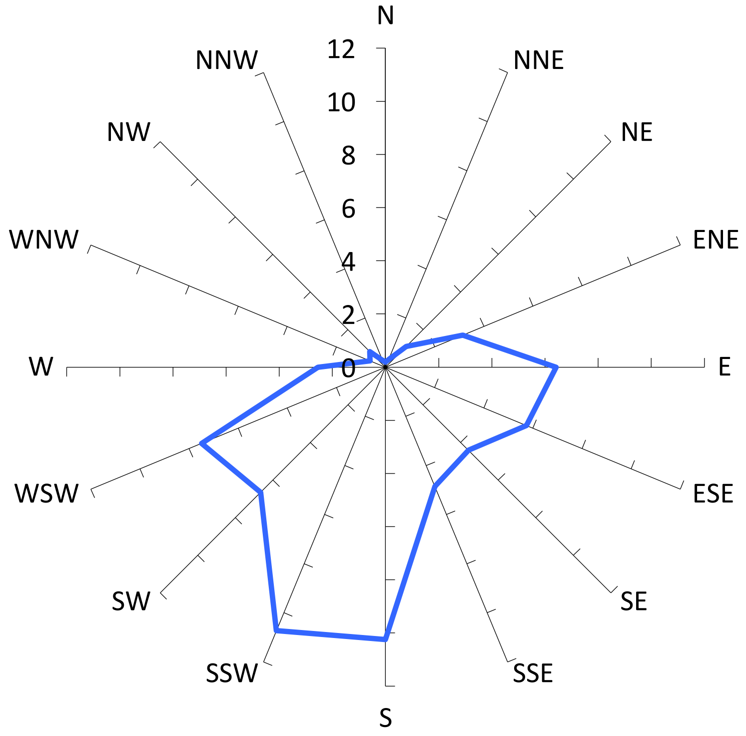
Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 18

Weekly Maximum GEM (m/s)



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
11%

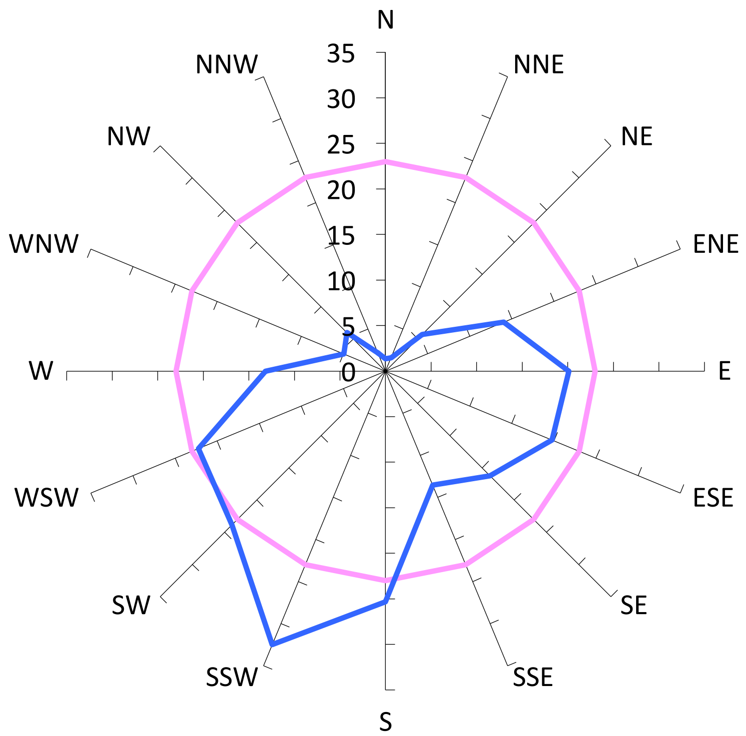
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

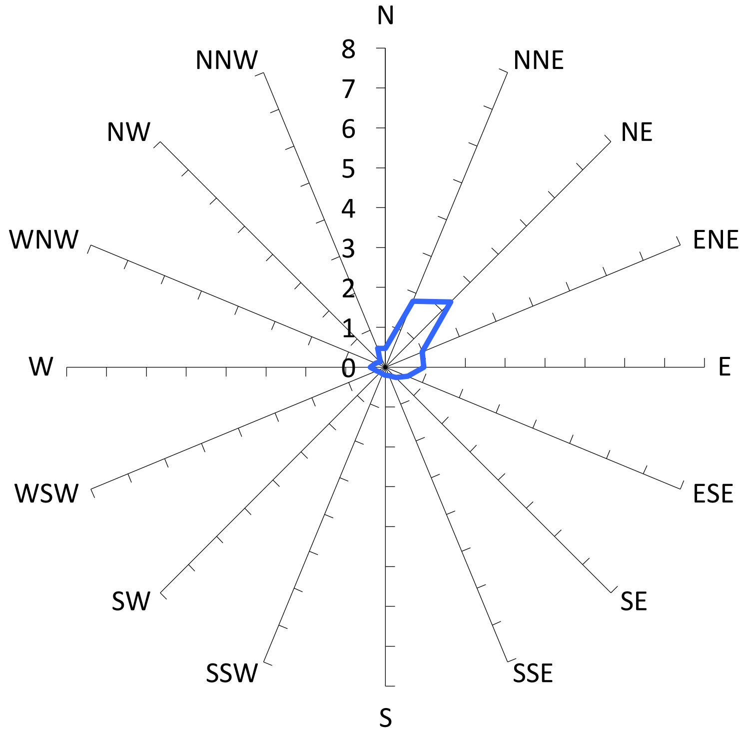
Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 19

Weekly Maximum GEM (m/s)



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

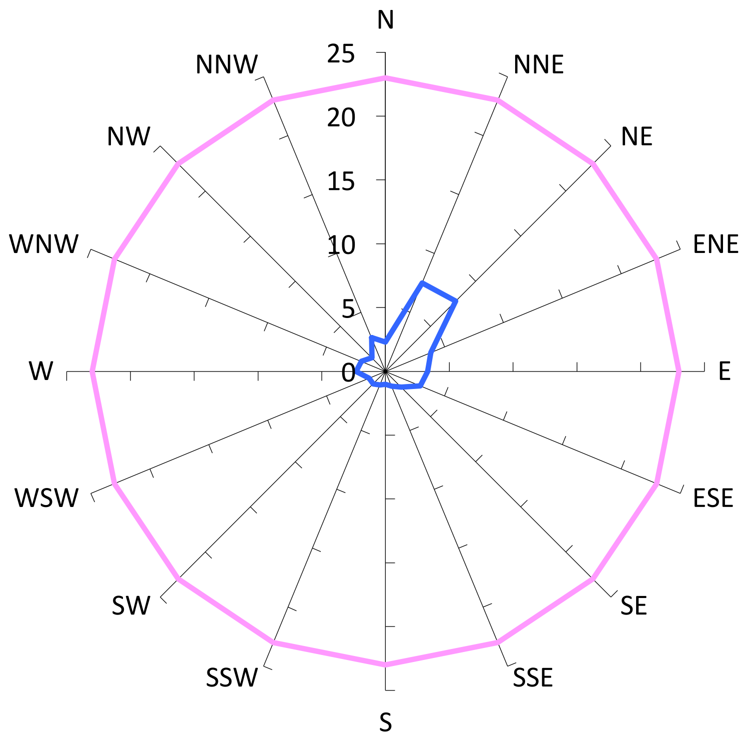
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

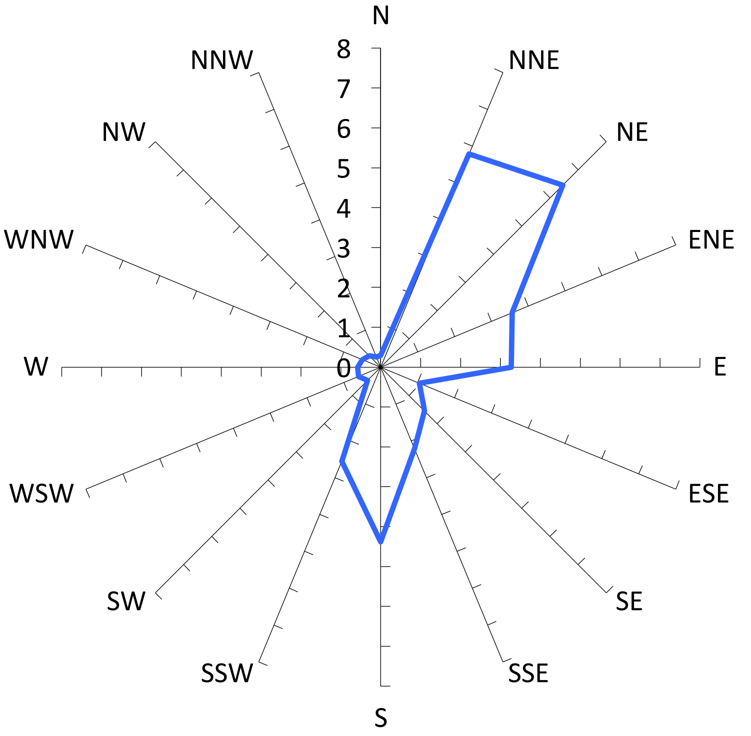
Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 20

Weekly Maximum GEM (m/s)



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
1%

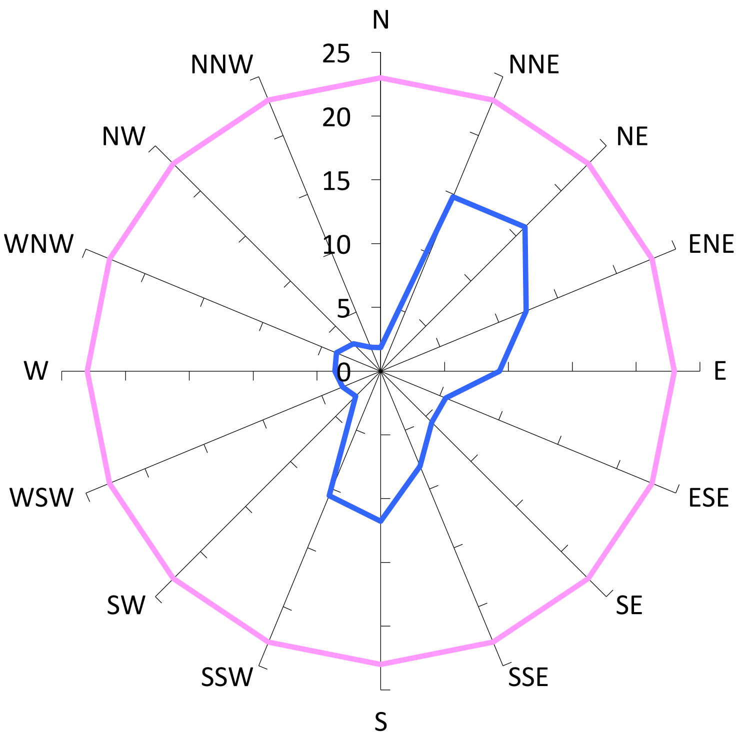
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

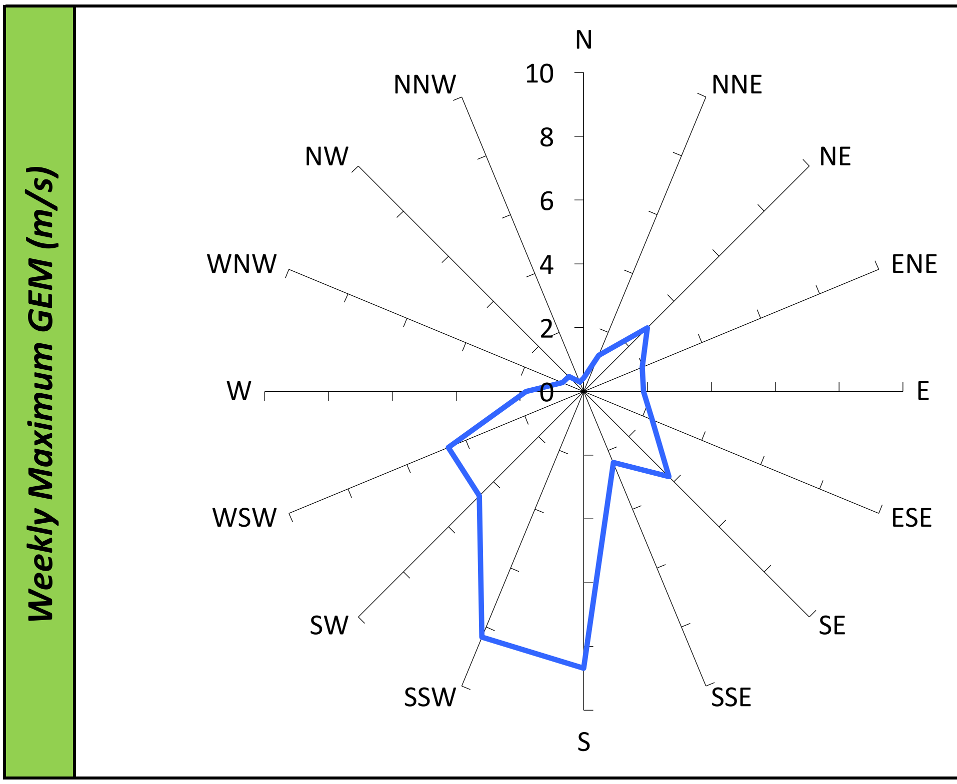
With development "as proposed", no vegetation or other treatments.

Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 21



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

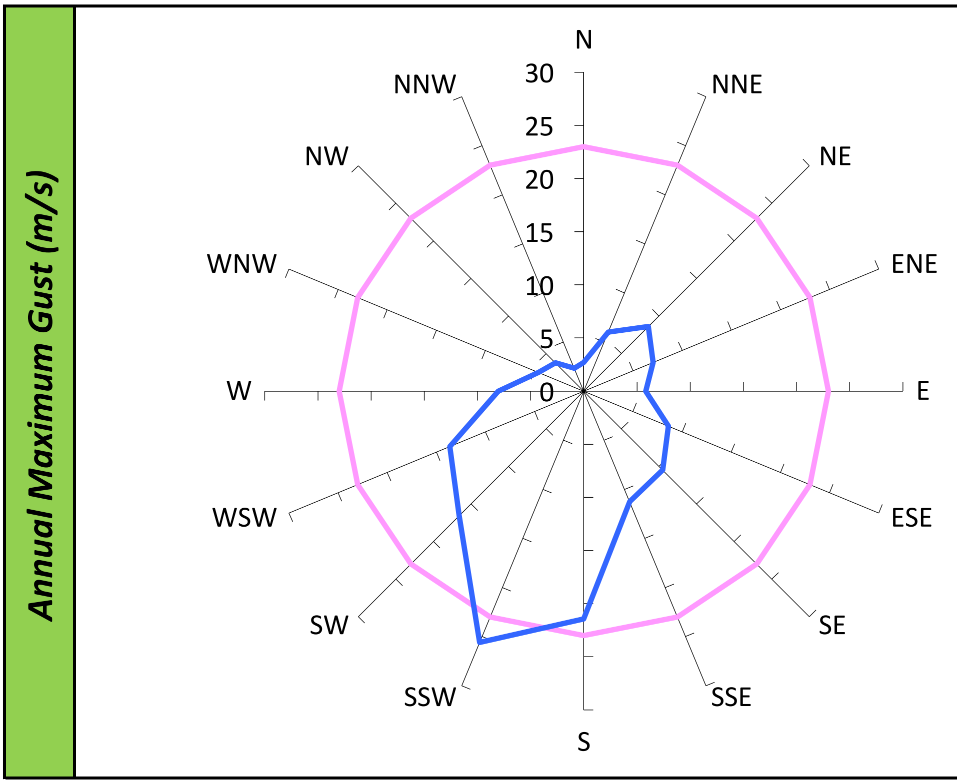
Probability of Criterion Exceedence (initial test)
5%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

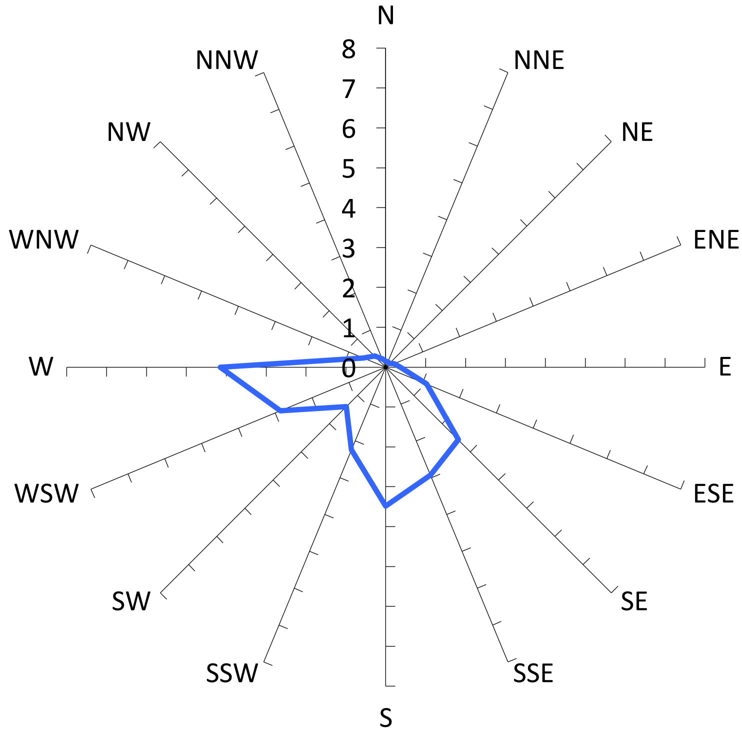
With development "as proposed", no vegetation or other treatments.



Desired Criterion
23m/s

Measured Wind Speeds at Point 22

Weekly Maximum GEM (m/s)



Desired Criterion
7.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

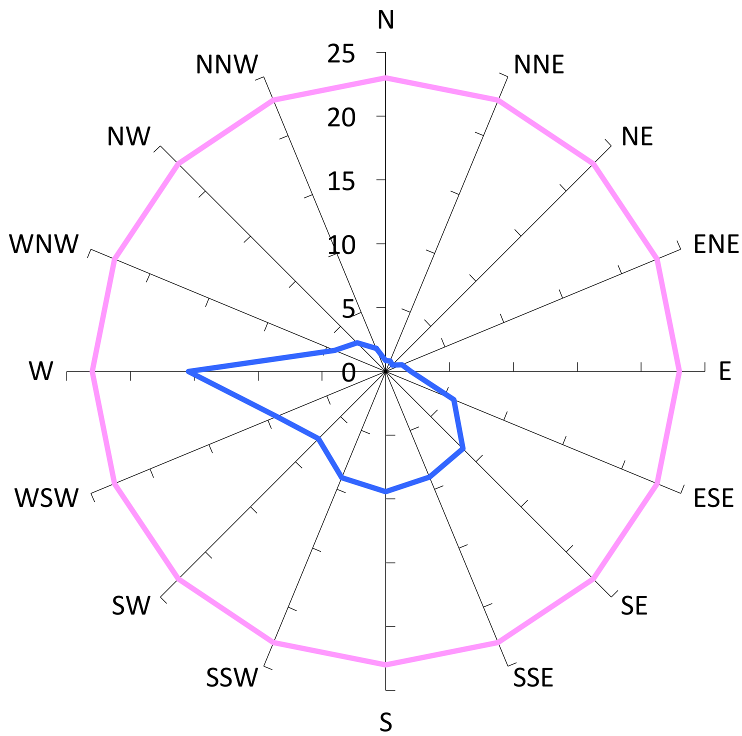
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

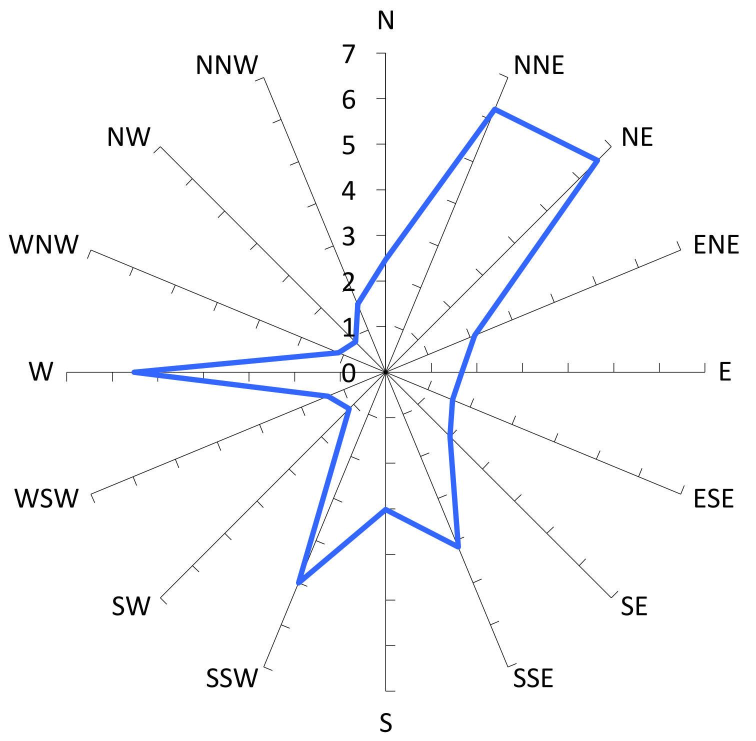
Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 23

Weekly Maximum GEM (m/s)



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
6%

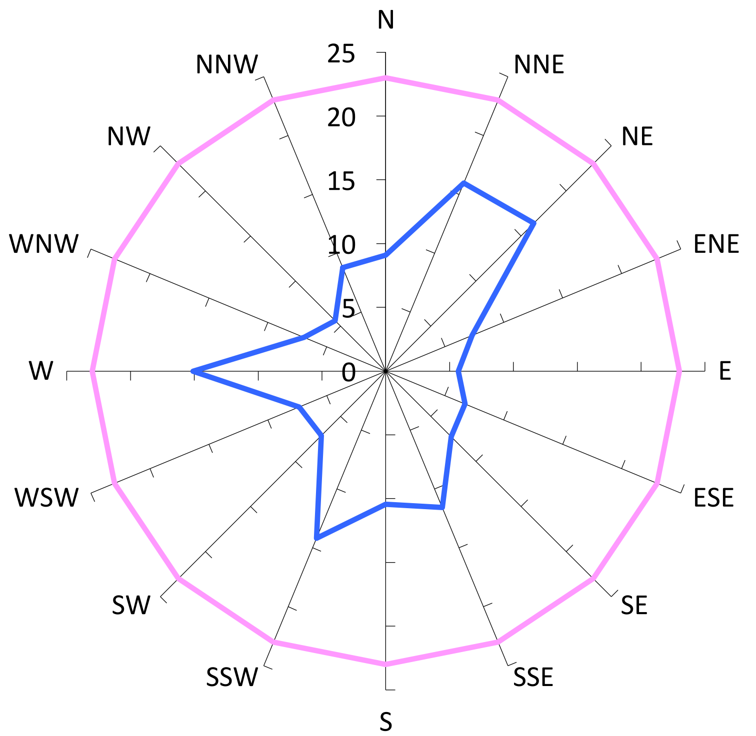
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

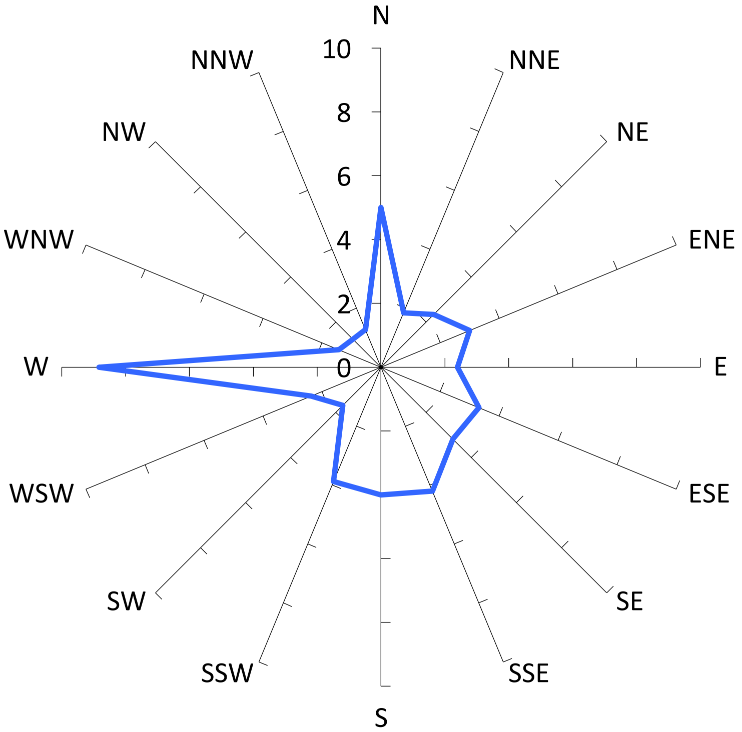
Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 24

Weekly Maximum GEM (m/s)



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
5%

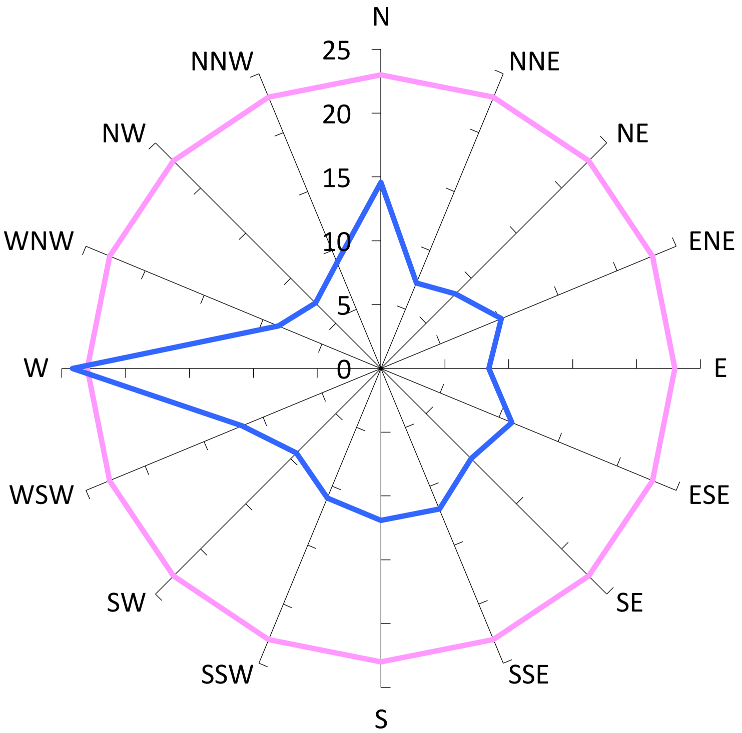
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

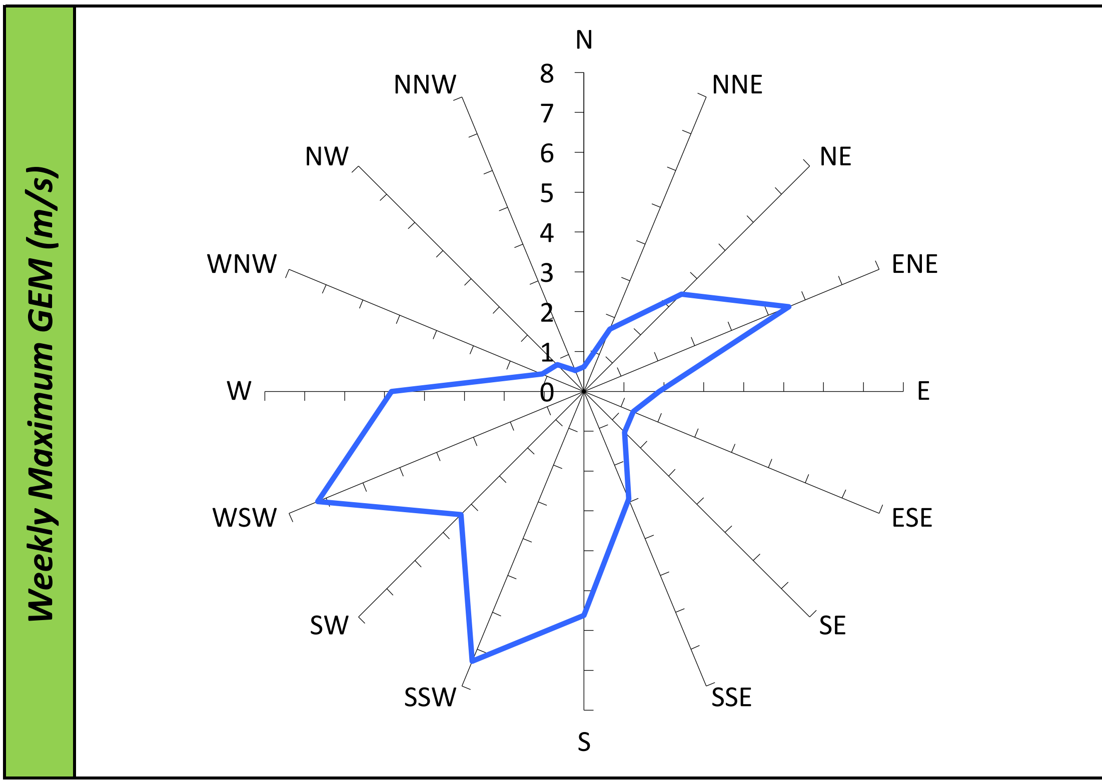
With development "as proposed", no vegetation or other treatments.

Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 25



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

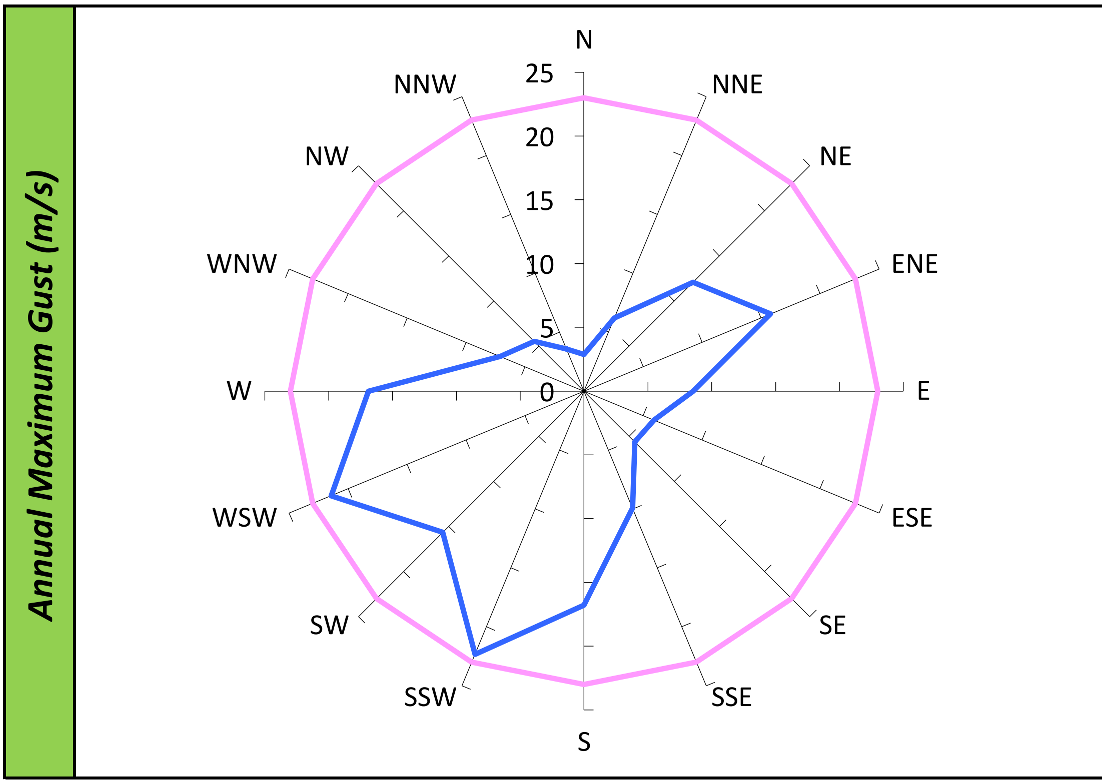
Probability of Criterion Exceedence (initial test)
7%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

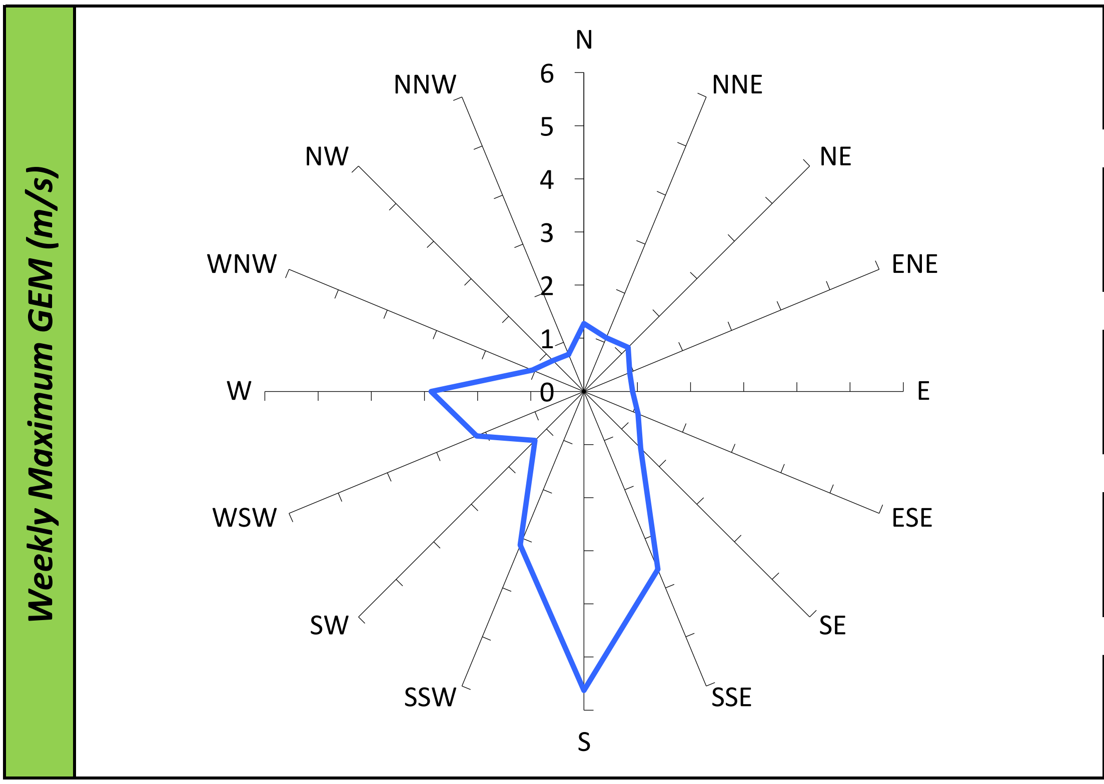
Criterion.

With development "as proposed", no vegetation or other treatments.



Desired Criterion
23m/s

Measured Wind Speeds at Point 26



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

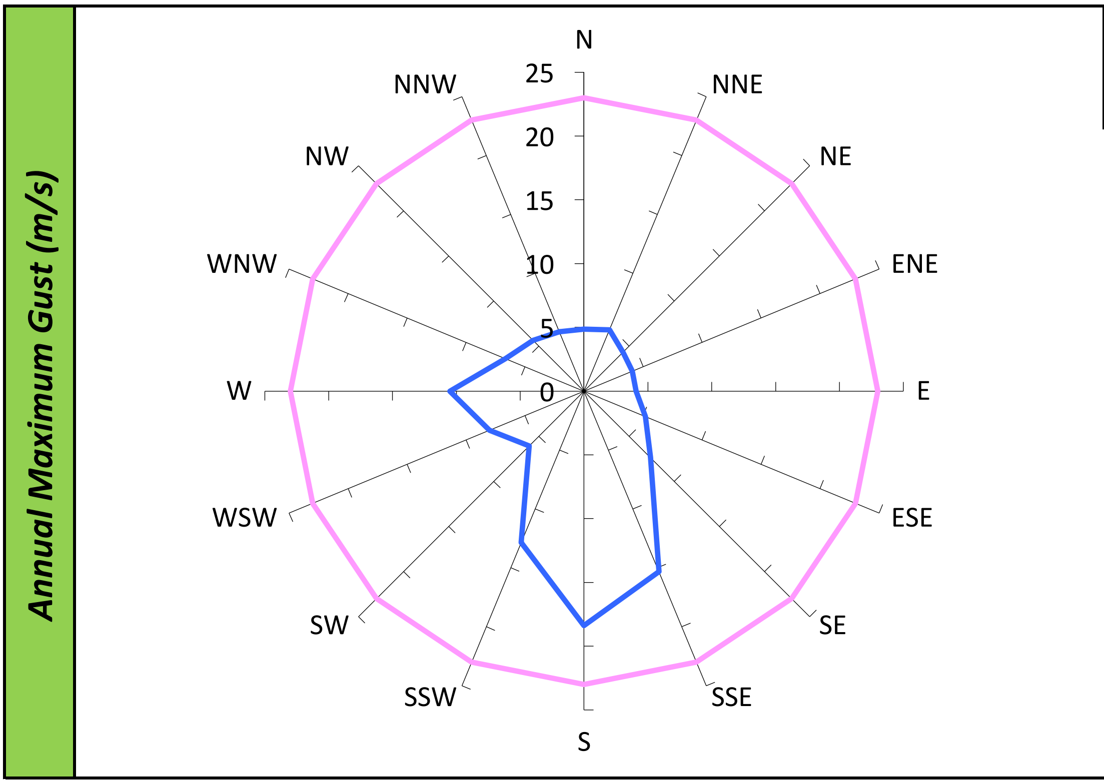
Probability of Criterion Exceedence (initial test)
2%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

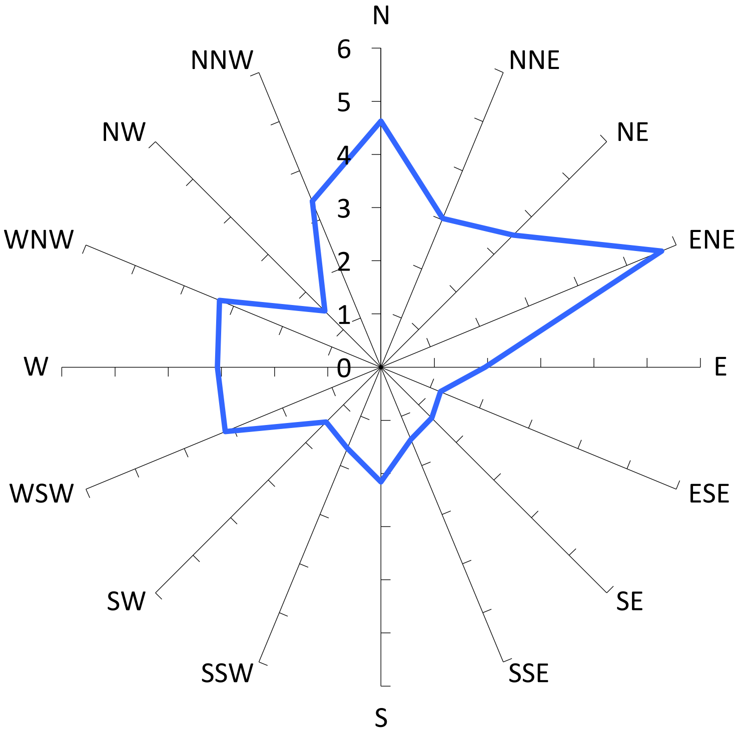
With development "as proposed", no vegetation or other treatments.



Desired Criterion
23m/s

Measured Wind Speeds at Point 27

Weekly Maximum GEM (m/s)



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
2%

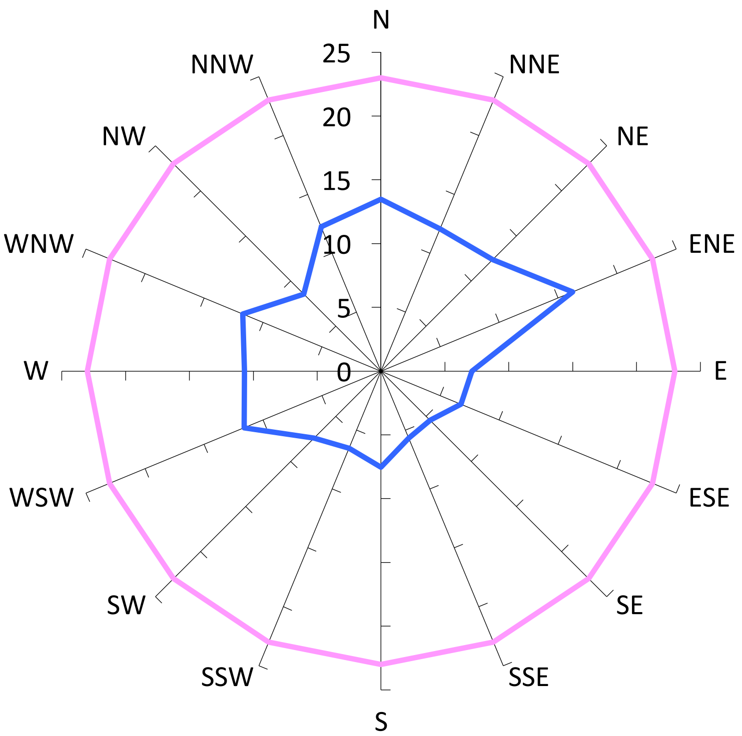
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

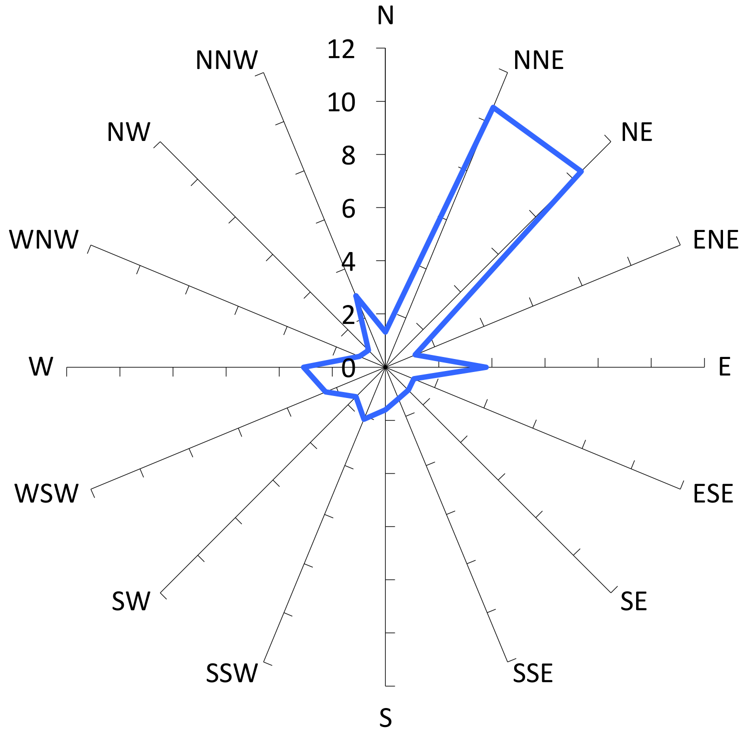
Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 28

Weekly Maximum GEM (m/s)



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
7%

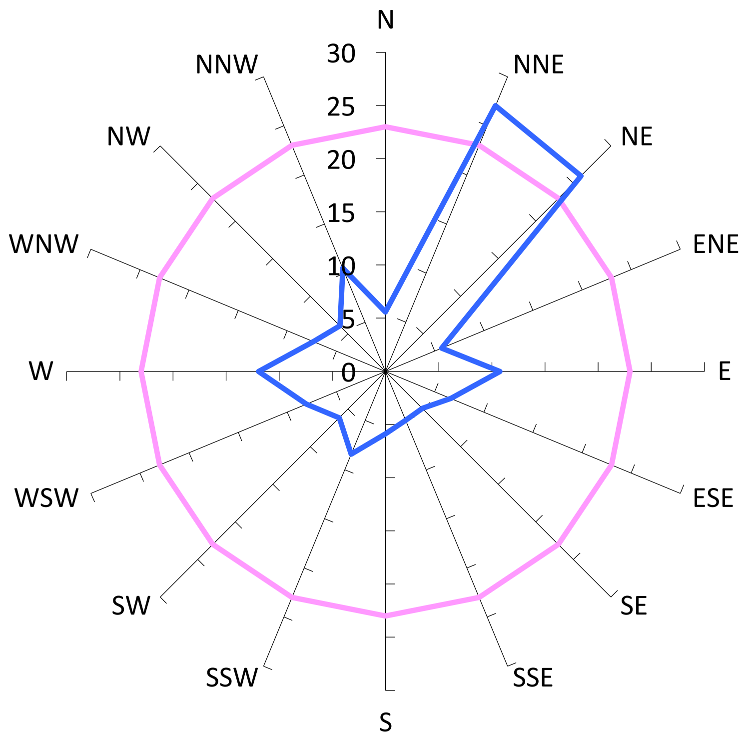
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

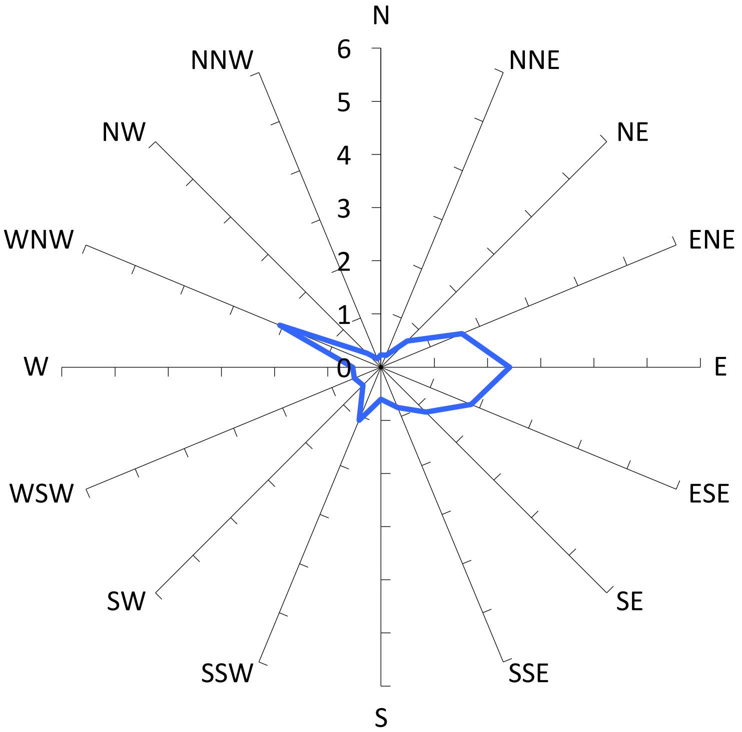
Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 29

Weekly Maximum GEM (m/s)



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

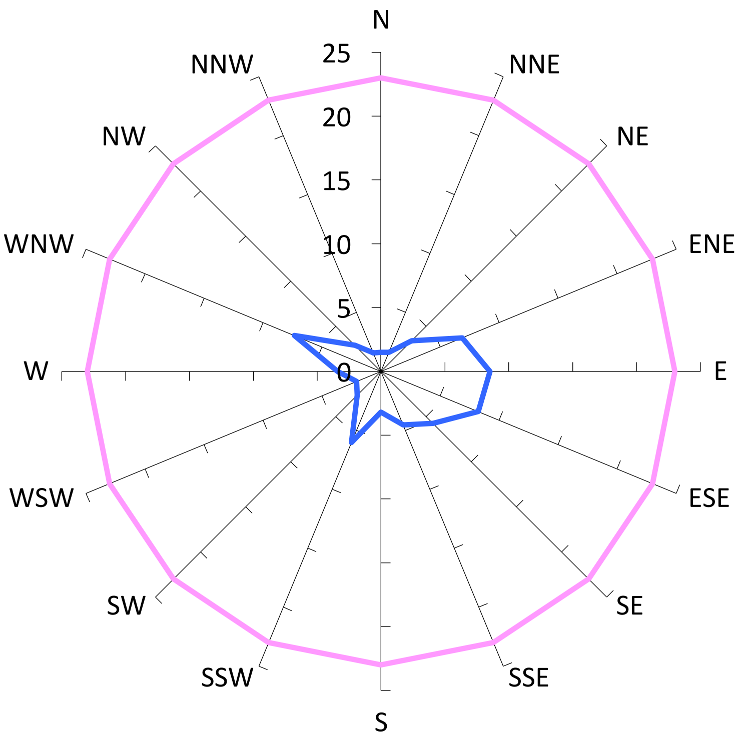
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

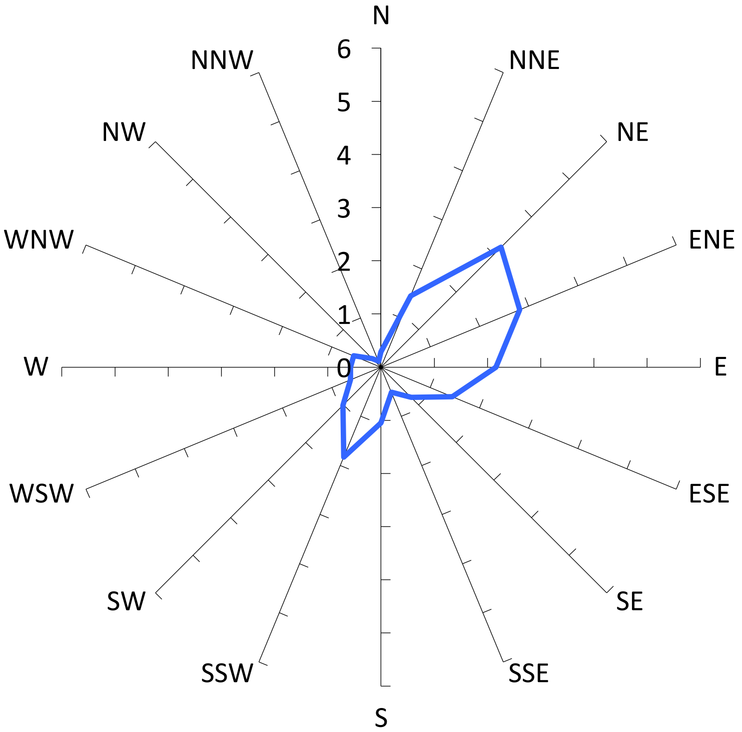
Annual Maximum Gust (m/s)



Desired Criterion
23m/s

Measured Wind Speeds at Point 30

Weekly Maximum GEM (m/s)



Desired Criterion
5.5m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

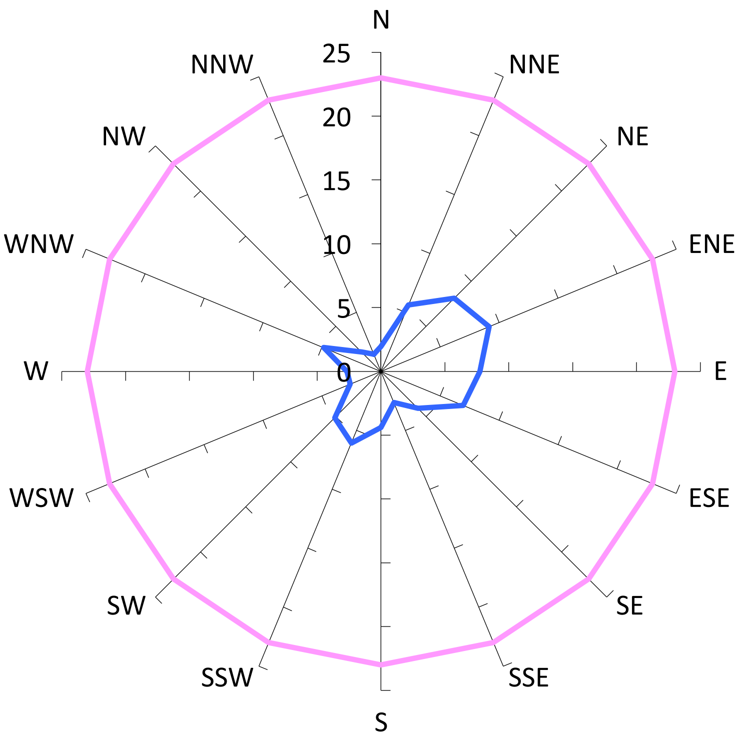
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", no vegetation or other treatments.

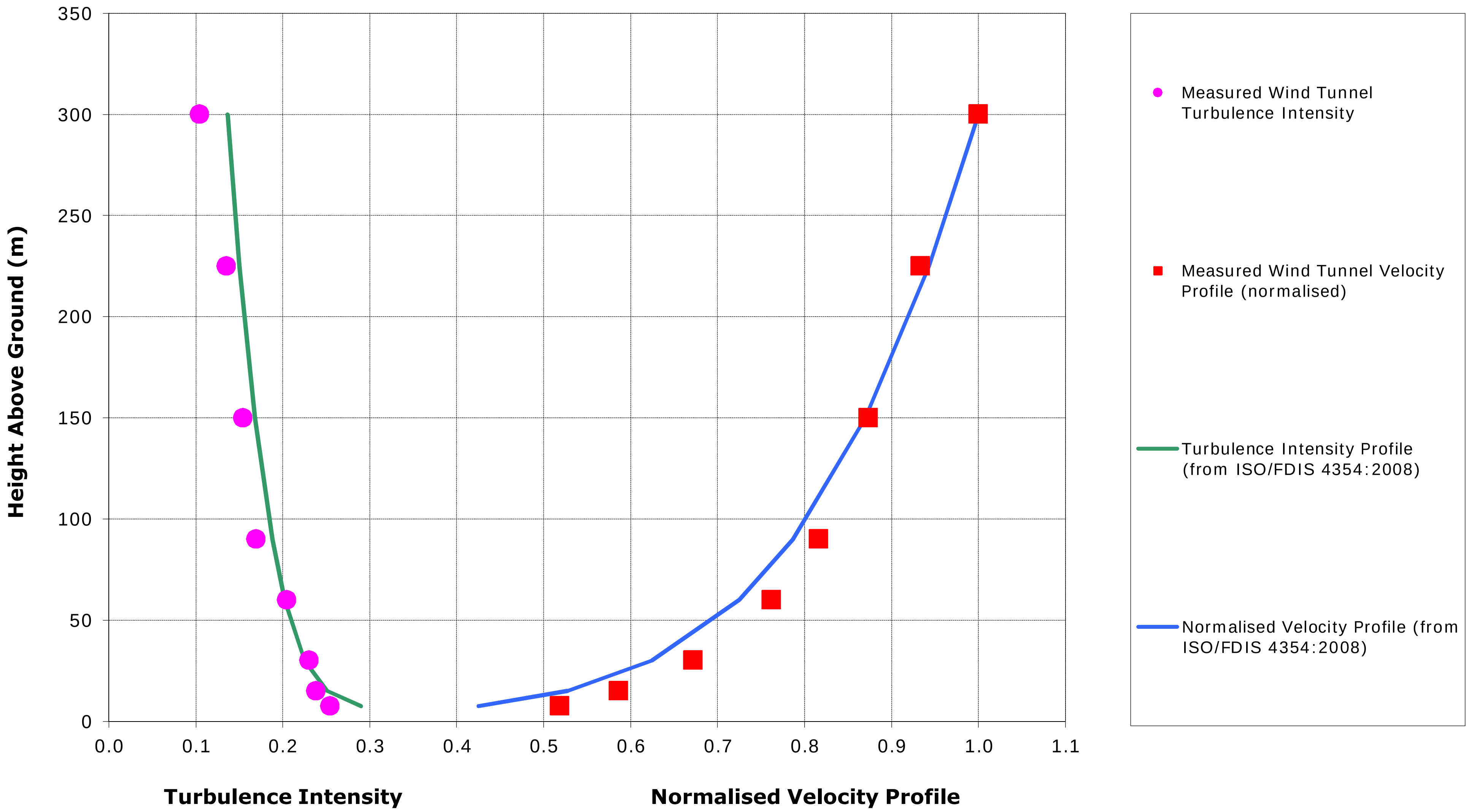
Annual Maximum Gust (m/s)

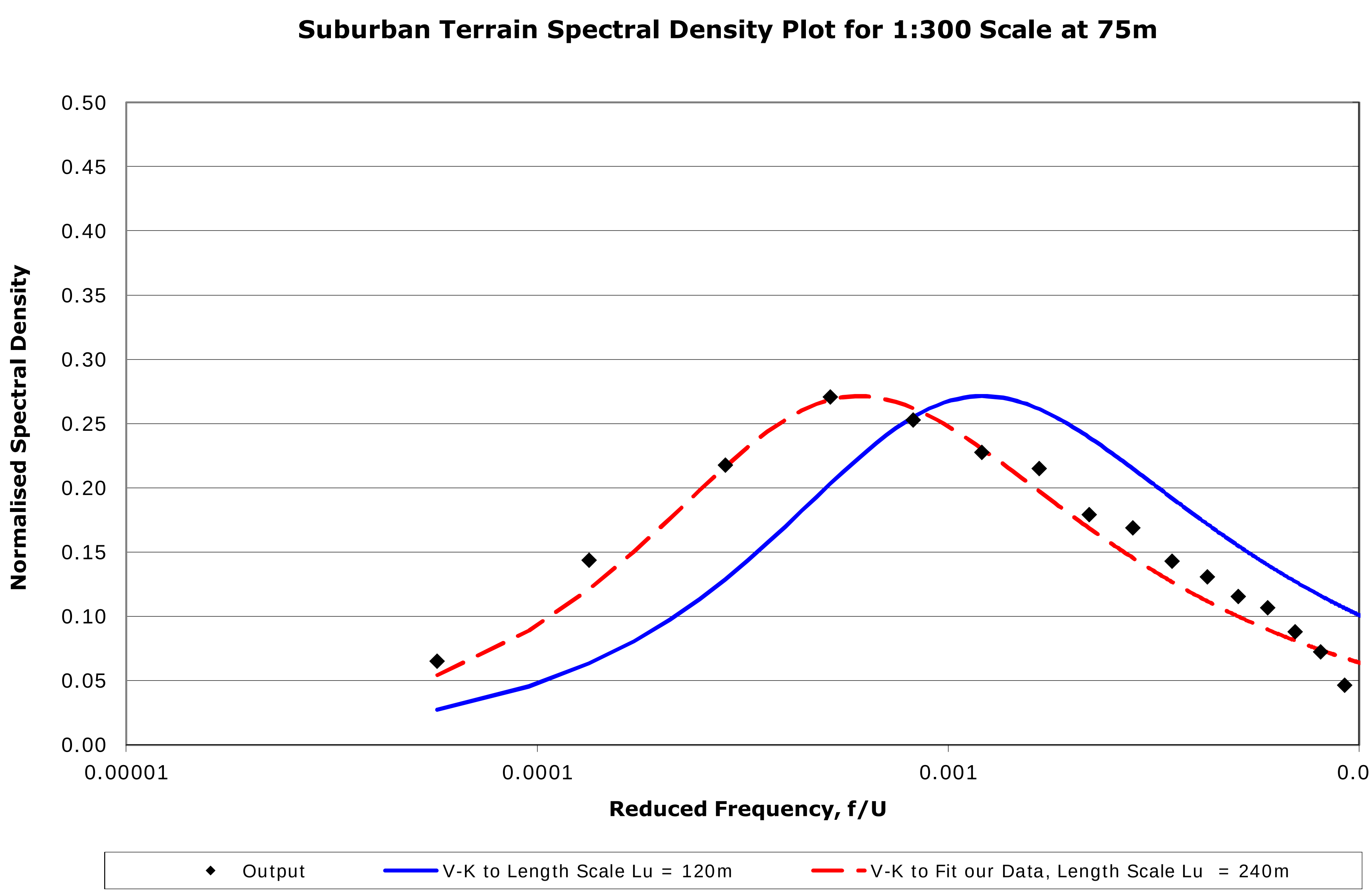


Desired Criterion
23m/s

APPENDIX B - VELOCITY AND TURBULENCE INTENSITY PROFILES

Suburban Terrain Velocity and Turbulence Intensity Profile, 1:300 Scale




Suburban Terrain Spectral Density Plot for 1:300 Scale at 75m
Normalised Spectral Density
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00001
0.0001
0.001
0.01
Reduced Frequency, f/U
Output
V-K to Length Scale Lu = 120m
V-K to Fit our Data, Length Scale Lu = 240m