TOWER R4A, ONE SYDNEY HARBOUR

PEDESTRIAN WIND ENVIRONMENT STUDY

WA567-11F01(REV7)- WE REPORT R4A

NOVEMBER 27, 2015

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DOCUMENT CONTROL

Date	Revision History	Non-Issued Revision	Issued Revision	Prepared By (initials)	Instructed By (initials)	Reviewed & Authorised by (initials)
April 24,2015	Initial.	-	0	BU	TR	AB
May 13,2015	Reference updated drawings.	-	1	BU	TR	AB/KP
June 11,2015	Updates to treatments.	-	2	BU	TR	KP
July 14,2015	Updates to treatments / wording.	-	3	BU	TR	KP
August 12,2015	Remove pool and updated canopy design.	-	4	KP	TR	KP
October 30,2015	Update neighbouring site descriptions.	-	5	BU	TR	KP
November 26,2015	Updated treatments with Watermans Cove concept.	-	6	BU/KP	TR	KP
November 27,2015	Updated wording and treatment figures.	-	7	BU	TR	KP

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EXECUTIVE SUMMARY

This report presents the results of a detailed wind tunnel study for the wind conditions at the critical outdoor areas within and around the development known as Tower R4A of One Sydney Harbour. Testing was performed using Windtech's boundary layer wind tunnel, which has a 3.0m wide working section and has a fetch length of 14m.

Measurements were carried out using a 1:400 scale detailed model of the development, which has been constructed based on the latest available architectural drawings prepared by Renzo Piano Building Workshop, received during April and May 2015. Tower R4A is a 72 storey building with 327 apartments (SSD 6964).

The effect of nearby buildings and land topography has been accounted for through the use of a proximity model, which represents a radius of approximately 500m from the centre of the development site. Since the site is located within a major redevelopment precinct, with other proposed nearby buildings which are yet to commence construction, testing for this project was performed for the following scenarios:

- Scenario 1: Towers R4B, R5, Crown Hotel Resort and Barangaroo Central are not included in this scenario. Additionally, the bridge and canopy between Towers R4A and R4B are not included in this scenario.
- Scenario 2: Towers R4B, R5, Crown Hotel Resort and Barangaroo Central are included in this scenario. Additionally, the bridge and canopy between Towers R4A and R4B are included in this scenario.

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. 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 results of the study indicate that treatments are required for certain locations to achieve the desired wind speed criteria for pedestrian comfort and safety. A set of treatments have been formulated and tested in the wind tunnel to verify their effectiveness for wind mitigation for each scenario tested in the wind tunnel. Where possible, the same treatment strategy has been suggested for both scenarios. The suggested treatments are summarised as follows:

Scenario 1:

- The inclusion of strategic planting in the form of densely foliating trees at ground level around the site, as per the latest landscape drawing.
- The inclusion of portable café screening on the north-eastern aspect of Tower R4A to be controlled by the operator to provide suitable conditions for patrons during adverse wind conditions. Conditions will be suitable as a pedestrian thoroughfare when the café area is not in operation.
- The inclusion of a 3m high screen on the western aspect of the podium roof level.

Scenario 2:

- The inclusion of strategic planting in the form of densely foliating trees at ground level around the site, as per the latest landscape drawing.
- The inclusion of portable café screening on the north-eastern aspect of Tower R4A to be controlled by the operator to provide suitable conditions for patrons during adverse wind conditions. Conditions will be suitable as a pedestrian thoroughfare when the café area is not in operation.

Desirable wind conditions within the Strada precinct have been a notable area of concern to ensure a suitable and effective outcome for the project. Amelioration measures outside of the precinct to mitigate the potential for funnelling through this area have been suggested with the optimisation of the canopy design and landscaping arrangement. Allowance has also been made in the current design to allow for an airlock/baffle arrangement within the Strada space to mitigate any adverse winds during strong westerly and north-easterly wind events.

The inclusion of the wintergarden design for the upper levels of the apartment balcony areas will help ensure that conditions are suitable and controllable by the occupants for long duration activities.

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

CONTENTS

1 WIND CLIMATE FOR THE SYDNEY REGION

Details of the wind climate of the Sydney region have been determined from a detailed statistical analysis of measured mean wind speed data from the meteorological observation station located at Kingsford Smith airport (Sydney Airport). The data has been collected from this station from 1939 to 2009, and corrected so that it represents winds over standard open terrain at a height of 10m above ground. The corrected data is summarised Table 1 for the weekly and annual return periods in the form of hourly means and the corresponding 3-second gust values. These directional wind speeds are also presented in Figure 1 (referenced as hourly mean wind speeds), as well as the directional frequency of occurrences for the region.

The data indicates that, for the weekly and annual return periods, the southerly winds are by far the most frequent wind for the Sydney region, and are also the strongest. 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: Directional Mean and Gust Wind Speeds for the Sydney Region (referenced to 10m height above ground in standard open terrain)

Wind Direction	Reference Wind Speeds (m/s)			
	Weekly Recurrence		Annual Recurrence	
	Hourly Mean	3-second Gust	Hourly Mean	3-second Gust
N	6.1	9.3	9.6	14.6
NNE	9.2	14.1	12.7	19.4
NE	8.1	12.4	11.0	16.8
ENE	6.1	9.3	9.3	14.2
E	5.6	8.6	8.6	13.2
ESE	5.1	7.8	8.6	13.2
SE	6.3	9.6	9.4	14.4
SSE	8.0	12.2	12.1	18.4
S	10.3	15.7	13.7	21.0
SSW	8.4	12.8	12.8	19.5
SW	5.6	8.6	10.9	16.7
WSW	7.9	12.0	12.6	19.3
W	9.3	14.2	13.7	21.0
WNW	6.4	9.8	12.4	18.9
NW	5.7	8.7	11.0	16.8
NNW	5.0	7.7	9.9	15.1

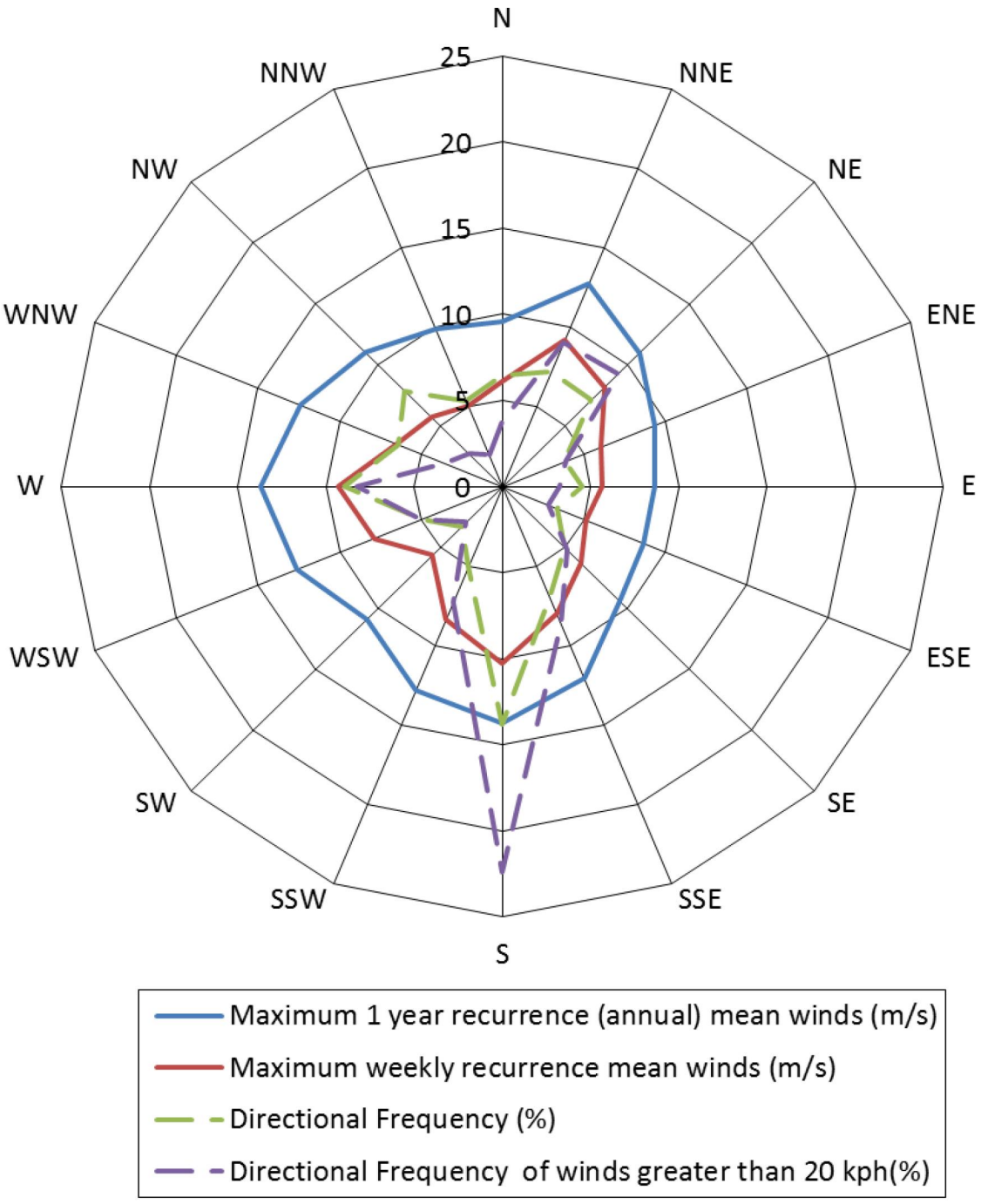

Figure 1: Directional Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Sydney Region (for the annual and weekly return periods, referenced to standard open terrain at a height of 10m above ground)

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 1:400 scale model. The study model incorporates all necessary architectural features on the development to ensure an accurate wind flow is achieved around the model, and has been constructed based on the latest available architectural drawings prepared by the project architect Renzo Piano Building Workshop, received during April and May 2015. Tower R4A is a 72 storey building with 327 apartments (SSD 6964).

A proximity model has also been constructed and represents the surrounding buildings and significant topographical effects within a radius of 500m, centred on the development site. Since the site is located within a major redevelopment precinct, with other proposed nearby buildings which are yet to commence construction, testing for this project was performed for the following scenarios:

- Scenario 1: Towers R4B, R5, Crown Hotel Resort and Barangaroo Central are not included in this scenario. Additionally, the bridge and canopy between Towers R4A and R4B are not included in this scenario. Photographs of this wind tunnel model configuration are presented in Figures 2a to 2f.
- Scenario 2: Towers R4B, R5, Crown Hotel Resort and Barangaroo Central are included in this scenario. Additionally, the bridge and canopy between Towers R4A and R4B are included in this scenario. Photographs of this wind tunnel model configuration are presented in Figures 2g to 2l.

The model of the proposed development 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. The effect of vegetation was also excluded from the initial testing. For areas not achieving appropriate wind conditions, treatments have been formulated and tested in the wind tunnel to ensure their effectiveness. Treatments considered were 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
(Scenario 1, view from the north)

Figure 2b: Photograph of the Wind Tunnel Model
(Scenario 1, view from the south-east)

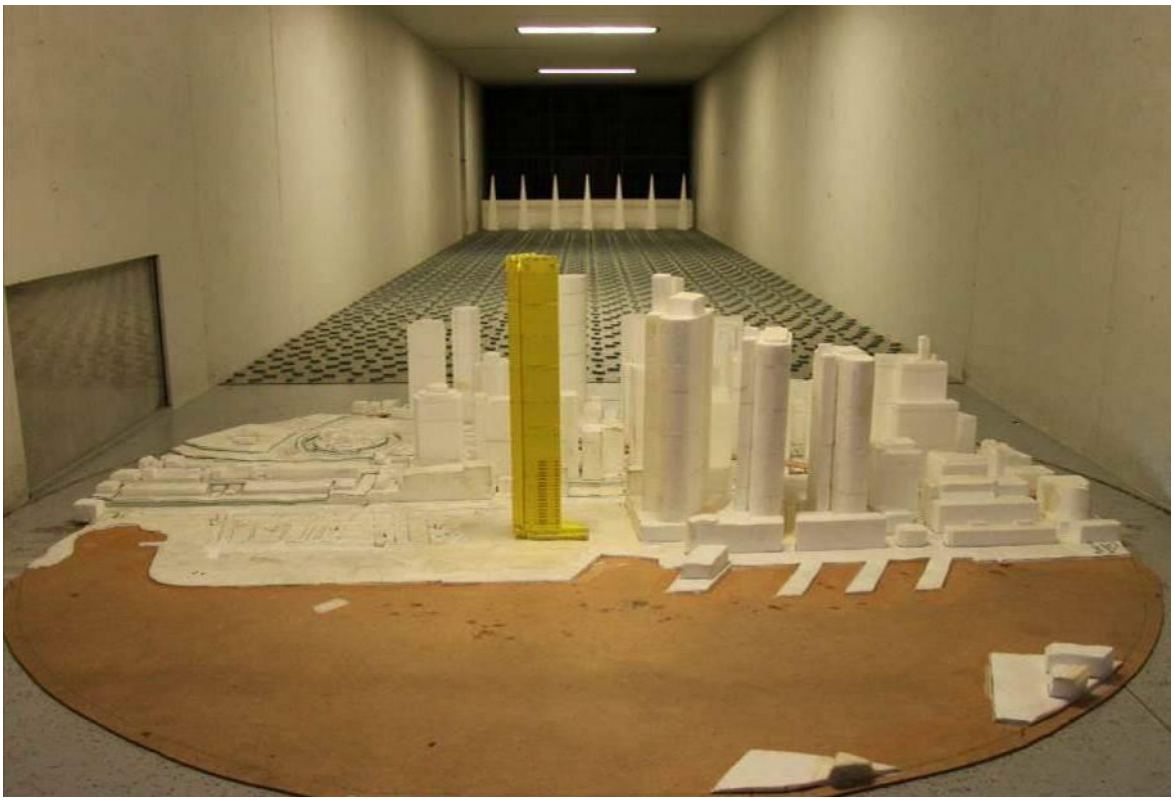

Figure 2c: Photograph of the Wind Tunnel Model
(Scenario 1, view from the west)

Figure 2d: Photograph of the Wind Tunnel Model
(Scenario 1, view from the north-west)

Figure 2e: Photograph of the Wind Tunnel Model
(Scenario 1, view from the south-east)

Figure 2f: Photograph of the Wind Tunnel Model
(Scenario 1, view from the north)

Figure 2g: Photograph of the Wind Tunnel Model
(Scenario 2, view from the north)

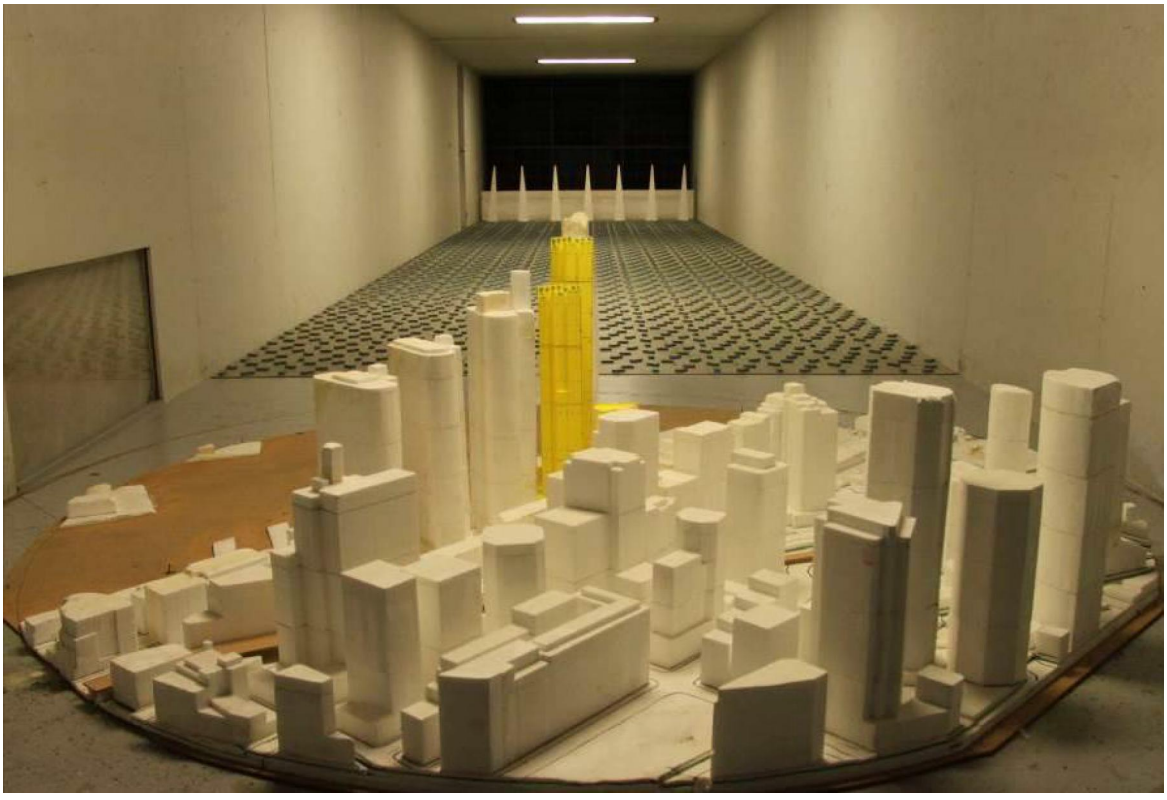

Figure 2h: Photograph of the Wind Tunnel Model
(Scenario 2, view from the south-east)

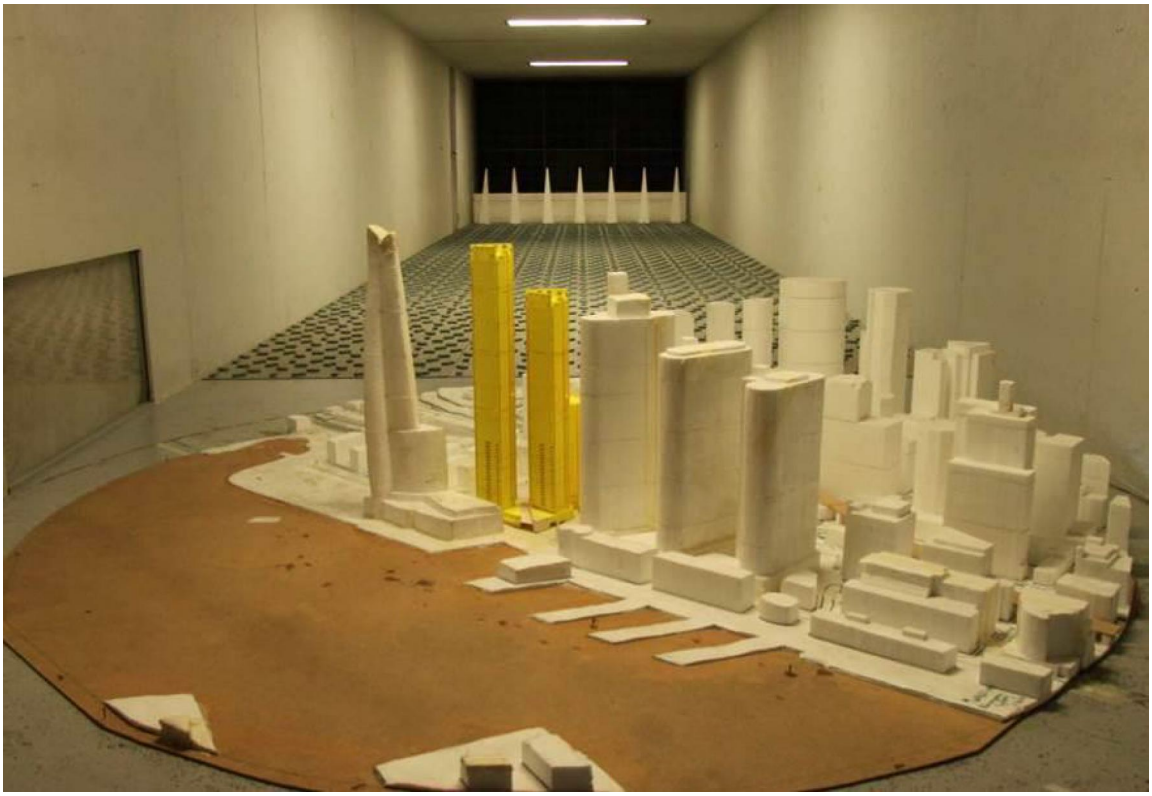

Figure 2i: Photograph of the Wind Tunnel Model
(Scenario 2, view from the south-west)

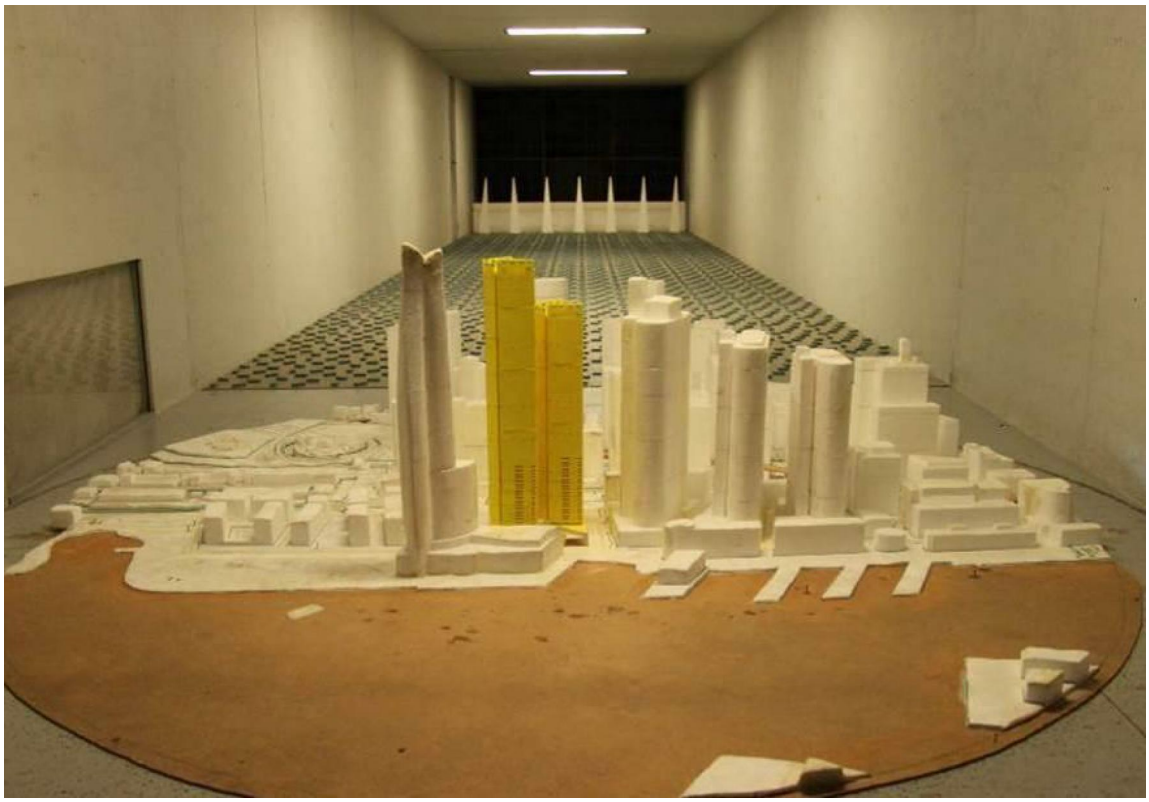

Figure 2j: Photograph of the Wind Tunnel Model
(Scenario 2, view from the west)

Figure 2k: Photograph of the Wind Tunnel Model
(Scenario 2, view from the north)

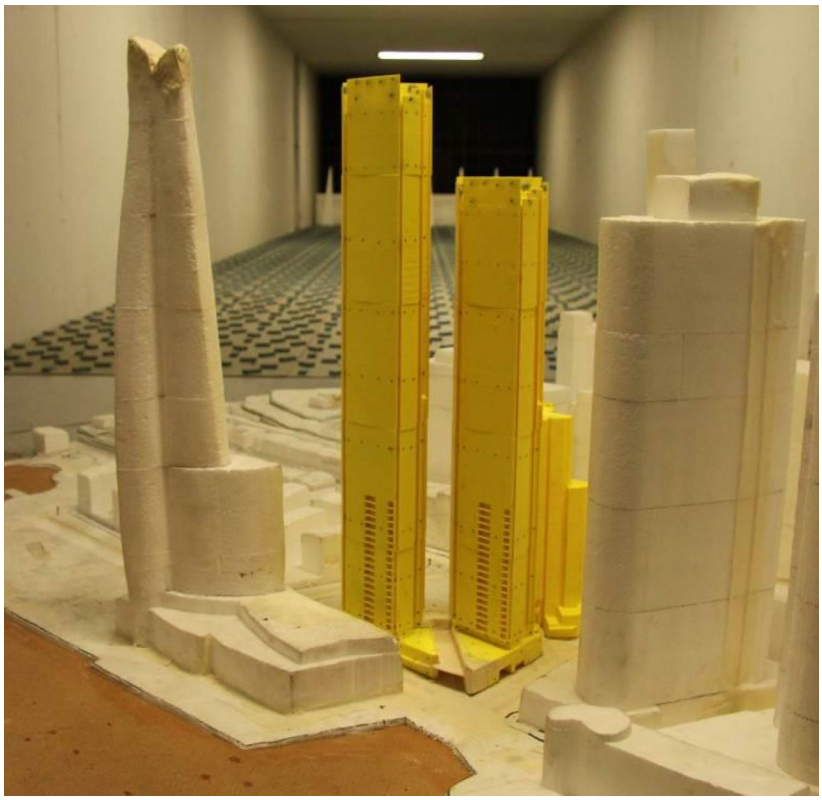

Figure 2l: Photograph of the Wind Tunnel Model
(Scenario 2, view from the south-west)

3 BOUNDARY LAYER WIND FLOW MODEL

Testing was performed using Windtech's boundary layer wind tunnel, which has a 3.0m 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 (ie: 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 (as per the definitions in AS/NZS1170.2:2011):

- **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 150m 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 Iv	Terrain Roughness Length z_0 (m)
	$k_{tr,T\ 3600s}$ *(hourly)*	$k_{tr,T\ 600s}$ *(10-minute)*	$k_{tr,T\ 3s}$ *(3-second)*		
1.0	1.09	1.11	1.36	0.084	0.003
1.5	1.04	1.07	1.35	0.099	0.01
2.0	0.99	1.02	1.33	0.115	0.03
2.5	0.93	0.96	1.31	0.139	0.1
3.0	0.86	0.90	1.29	0.168	0.3
3.5	0.77	0.81	1.25	0.213	1
4.0	0.66	0.71	1.21	0.274	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 40 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 9.0km 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.

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 500m radius of the proximity model. Plots of the wind tunnel boundary layer wind profiles are presented in Appendix B of this report.

Table 3: Directional Mean and Gust Terrain and Height Multipliers at the Site (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	0.86	0.90	1.29
30	0.89	0.93	1.30
60	1.04	1.07	1.35
90	1.01	1.04	1.34
120	0.90	0.94	1.30
150	0.89	0.93	1.30
180	0.81	0.86	1.27
210	0.88	0.92	1.30
240	0.86	0.90	1.29
270	0.94	0.97	1.31
300	0.95	0.98	1.32
330	0.89	0.93	1.30

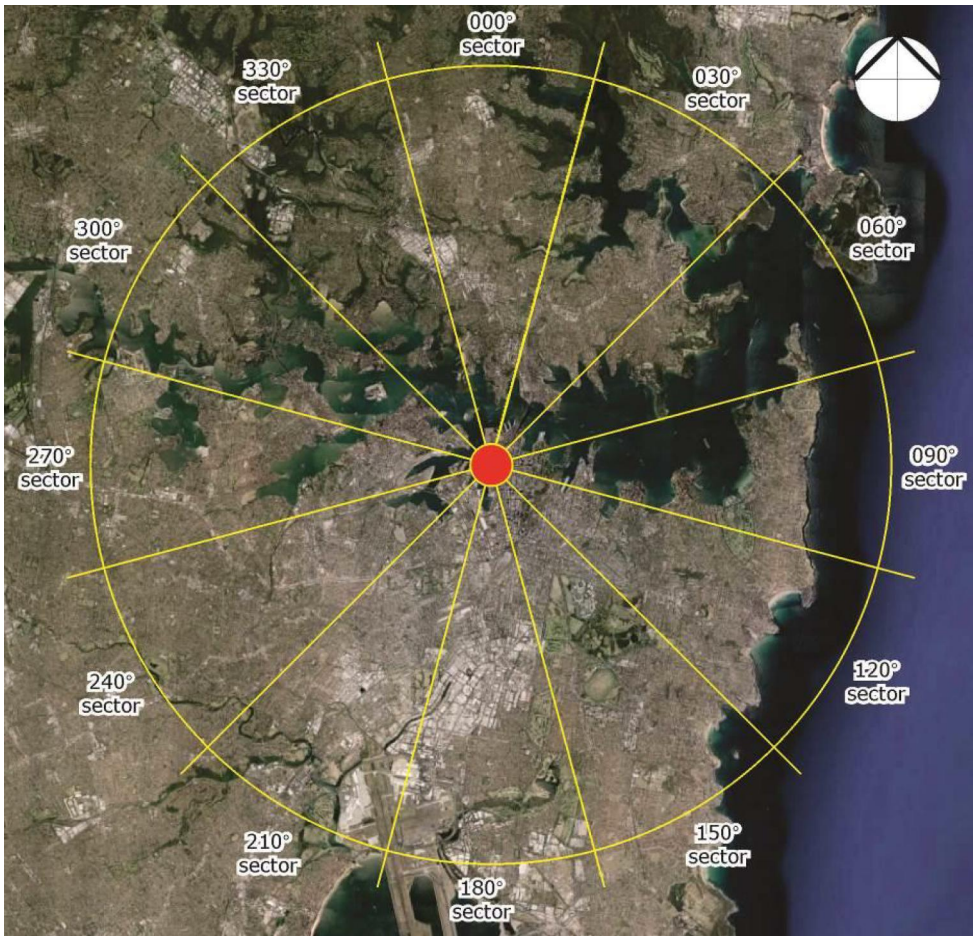

Figure 3: Aerial Image of the Surrounding Terrain (radius of 9.0km from the edge of the proximity model, which is coloured red)

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 10°C to 30°C 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%.

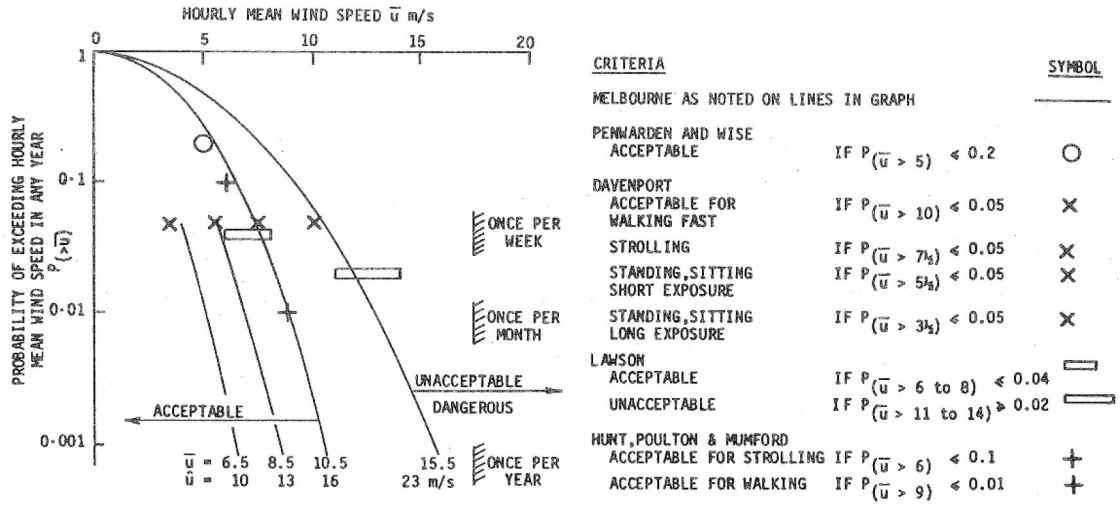

Figure 4: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (after Melbourne, 1978)

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.

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).
- **Fast Walking:** 10.0m/s maximum GEM wind speeds (representative of approximately a weekly recurrence).
- **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) 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, main retail centres and retail streets, parks, communal recreational areas etc.
- Comfortable Walking applies typically to areas used mainly for pedestrian thoroughfares and other pedestrian access ways. This also includes private swimming pools and communal areas.
- Fast Walking applies typically to areas used infrequently as pedestrian thoroughfares only.
- 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 3.0m 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 1,024Hz was used, which is more than acceptable for the 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:

$$\hat{C}_V \quad \overline{C}_V + g.\sigma_V \qquad (4.1)$$

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 10.3m/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 10 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:

$$V_{study} \quad V_{ref,RH}\left(\frac{k_{200m,tr,T\ 3600s}}{k_{RH,tr,T\ 3600s}}\right)C_V \qquad (4.2)$$

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:

$$C_V \quad \frac{C_{V,study}}{C_{V,200m}} \qquad (4.3)$$

$C_{V,study}$ 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 (ie: 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 46 study point locations have been selected for analysis in the wind tunnel. As detailed in Section 2 of this report, note that wind conditions have been measured in the wind tunnel for two scenarios. The locations of the various study points tested for this study are presented in Figures 5a to 5d in the form of marked-up plan drawings. It should be noted that only the most critical outdoor locations of the development have been selected for analysis.

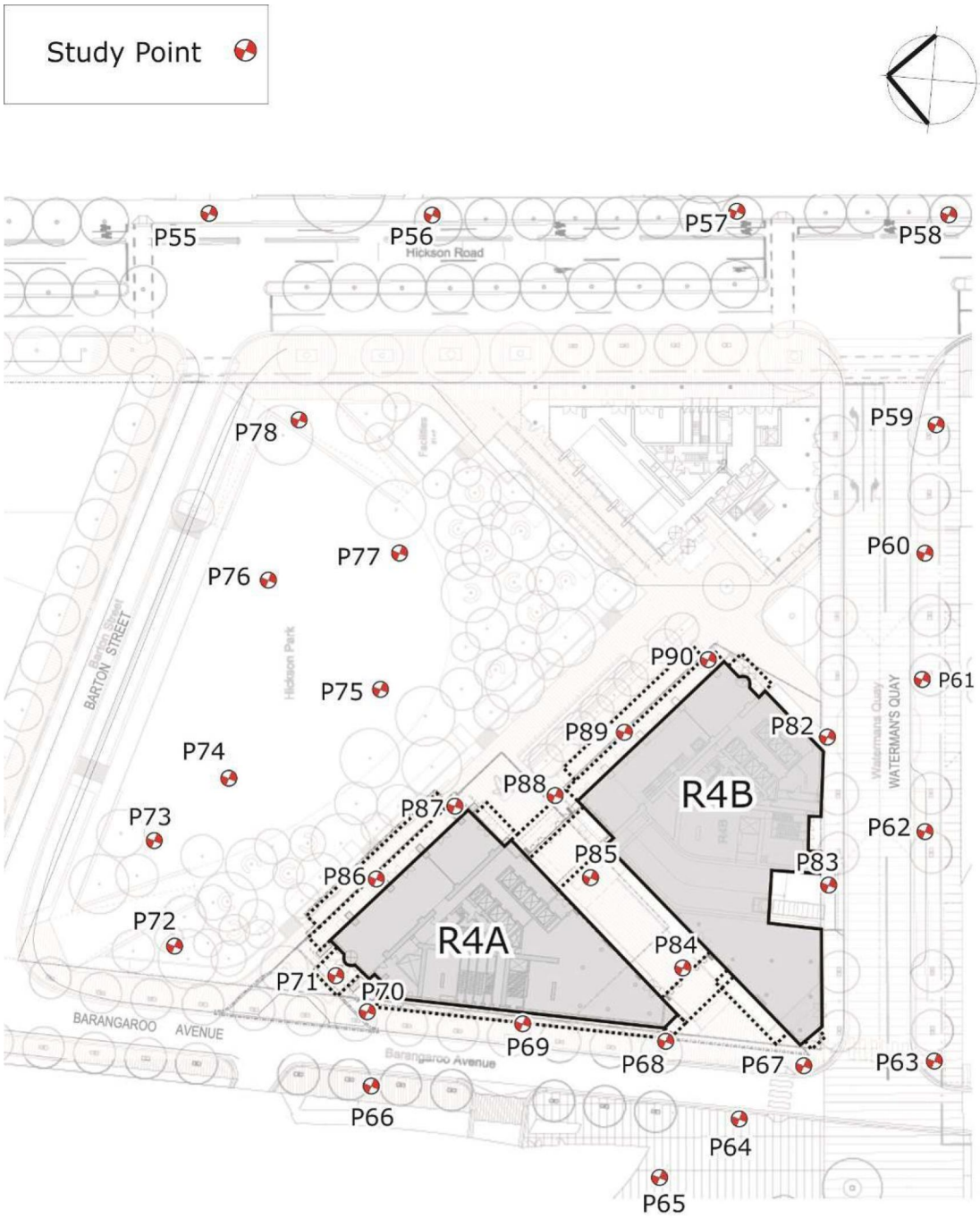

Figure 5a: Study Point Locations – Ground Level

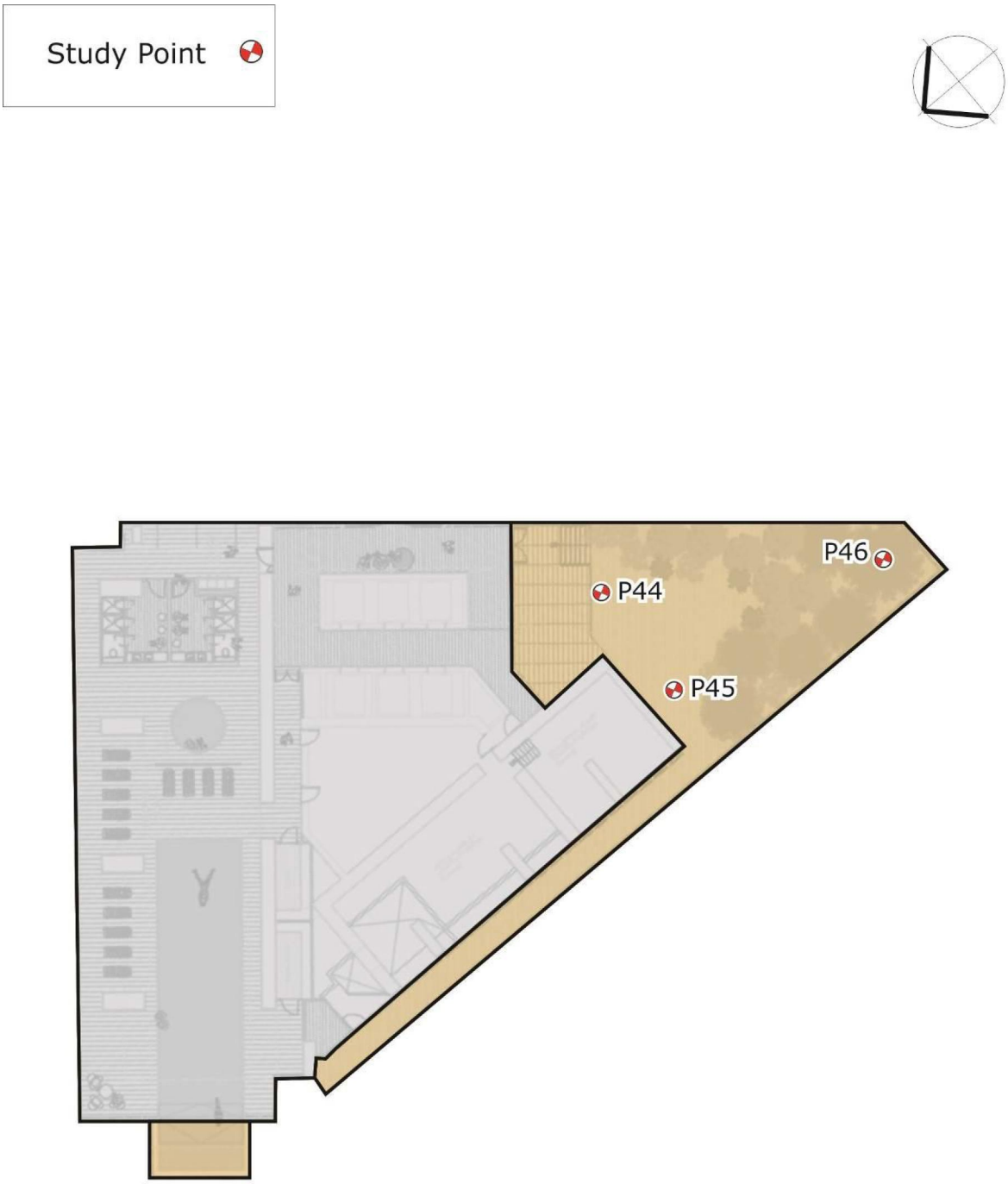

Figure 5b: Study Point Locations – Tower R4A Podium Level

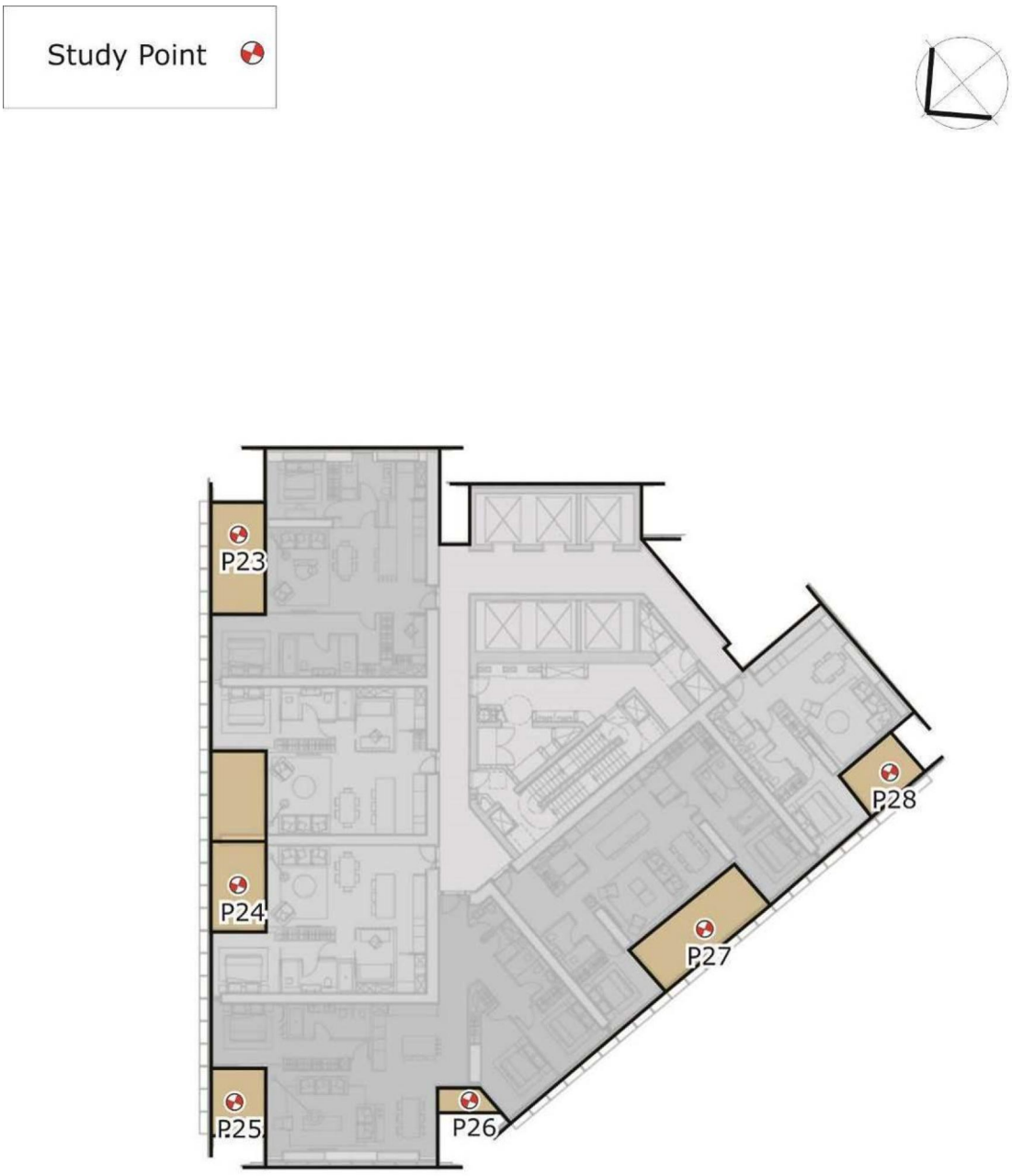

Figure 5c: Study Point Locations – Tower R4A Level 08

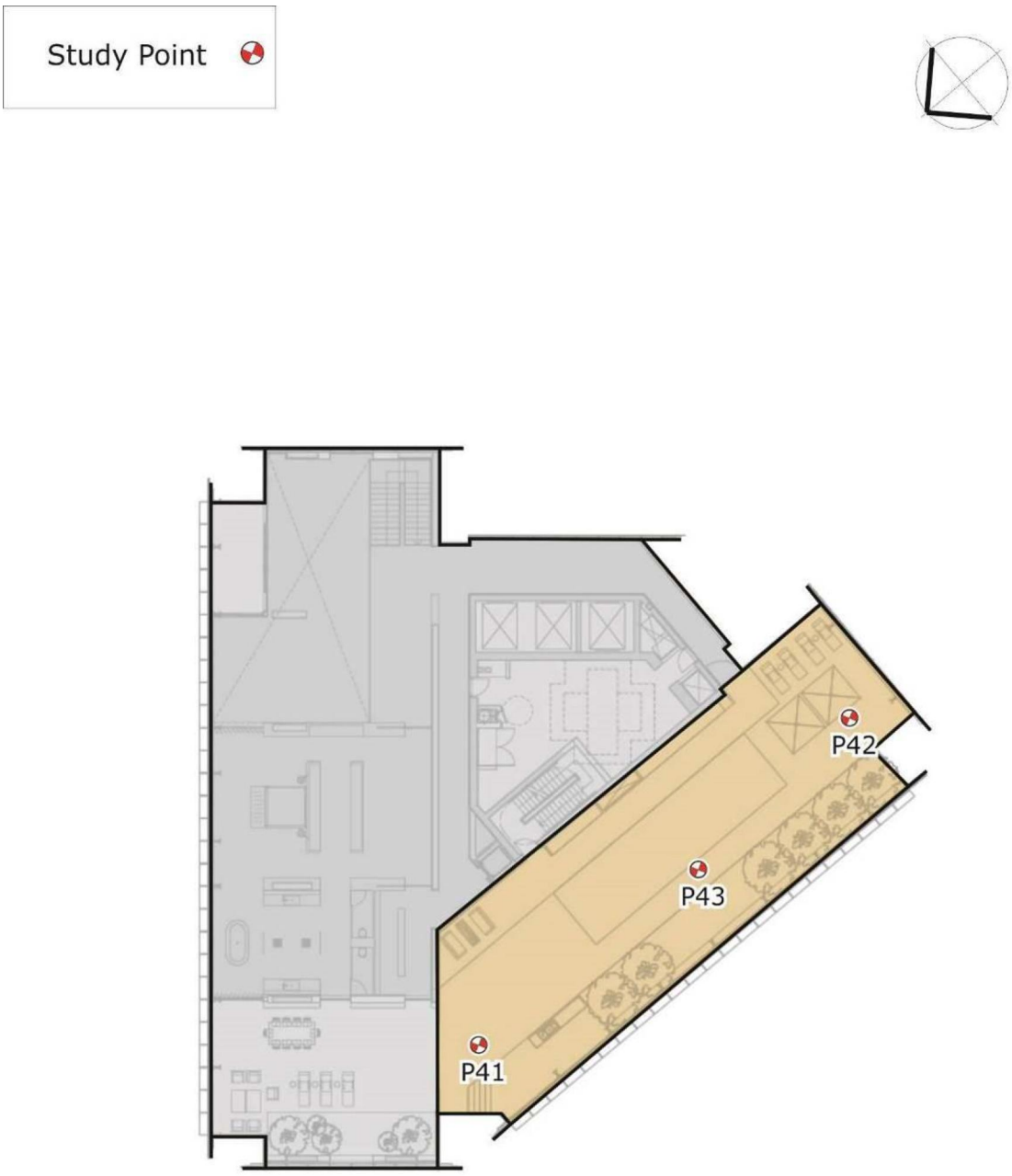

Figure 5d: Study Point Locations – Tower R4A Penthouse Terrace

6 RESULTS AND DISCUSSION

As detailed in Section 2 of this report, note that wind conditions have been measured in the wind tunnel for two scenarios. Furthermore, the model of the proposed development 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. The effect of vegetation was also excluded from the initial testing. For areas not achieving appropriate wind conditions, treatments have been formulated and tested in the wind tunnel to ensure their effectiveness.

The results for all study points locations are presented in the form of directional plots in Appendix A, and are summarised in Tables 9a and 9b below. The wind speed criteria that the wind conditions should achieve are also listed in Tables 9a and 9b for each study point location. The results in Table 9a are for Scenario 1, and the results for Scenario 2 presented in Table 9b.

The results of the study indicate that treatments are necessary for certain locations to achieve the desired wind speed criteria for pedestrian comfort and safety. The suggested treatments are defined in Figures 6a to 6c in the form of marked-up plan figures. Where possible, the same treatment strategy has been suggested for both scenarios. The suggested treatments are summarised as follows:

Scenario 1:

- The inclusion of strategic planting in the form of densely foliating trees at ground level around the site. A tree species such as the Harpullia Pendula or similar will be effective in providing the suitable level of wind mitigation for these areas. This tree species is capable of growing to a height of approximately 7m to 10m, with a canopy diameter of approximately 3m to 6m. The suggested layout of the trees is presented in Figure 6a, based on the provided landscape drawing.

  A concept design is being developed (subject to separate application) for Watermans Cove and will include significant tree planting which is likely to have a positive impact on wind conditions. The arrangement of the landscaping for a number of the options for this precinct is expected to provide suitable lower level mitigation of the approaching westerly to south-westerly winds.

- The inclusion of portable café screening on the north-eastern aspect of Tower R4A to be controlled by the operator to provide suitable conditions for patrons during adverse wind conditions. Conditions will be suitable as a pedestrian thoroughfare when the café area is not in operation. This is shown in Figure 6a.

- The inclusion of a 3m high screen on the western aspect of the podium roof level. This is shown in Figure 6c.

Scenario 2:

- The inclusion of strategic planting in the form of densely foliating trees at ground level around the site. A tree species such as the Harpullia Pendula or similar will be effective in providing the suitable level of wind mitigation for these areas. This tree species is capable of growing to a height of approximately 7m to 10m, with a canopy diameter of approximately 3m to 6m. The suggested layout of the trees is presented in Figure 6b, based on the provided landscape drawing.

  A concept design is being developed (subject to separate application) for Watermans Cove and will include significant tree planting which is likely to have a positive impact on wind conditions. The arrangement of the landscaping for a number of the options for this precinct is expected to provide suitable lower level mitigation of the approaching westerly to south-westerly winds.

- The inclusion of portable café screening on the north-eastern aspect of Tower R4A to be controlled by the operator to provide suitable conditions for patrons during adverse wind conditions. Conditions will be suitable as a pedestrian thoroughfare when the café area is not in operation. This is shown in Figure 6b.

Desirable wind conditions within the Strada precinct have been a notable area of concern to ensure a suitable and effective outcome for the project. Amelioration measures outside of the precinct to mitigate the potential for funnelling through this area have been suggested in Figure 6b with the optimisation of the canopy design and landscaping arrangement. Allowance has also been made in the current design to allow for an airlock/baffle arrangement within the Strada space to mitigate any adverse winds during strong westerly and north-easterly wind events.

The inclusion of the wintergarden design for the upper levels of the apartment balcony areas will help ensure that conditions are suitable and controllable by the occupants for long duration activities.

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 balconies. Furthermore, lightweight furniture is not recommended unless it is securely attached to the balcony floor slab.

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

Table 9a: Wind Tunnel Results Summary – Scenario 1

Study Point	Desired Criterion (m/s)		Treatment Necessary to Pass?	Description of Suggested Treatment
	Weekly GEM	Annual Peak		
Point 23	-	23.0	NO	
Point 24	-	23.0	NO	
Point 25	-	23.0	NO	
Point 26	-	23.0	NO	
Point 27	-	23.0	NO	
Point 28	-	23.0	NO	
Point 41	5.5	23.0	NO	
Point 42	5.5	23.0	NO	
Point 43	5.5	23.0	NO	
Point 44	5.5	23.0	NO	
Point 45	5.5	23.0	YES	With the inclusion of trees
Point 46	7.5	23.0	NO	
Point 55	7.5	23.0	NO	
Point 56	7.5	23.0	NO	
Point 57	7.5	23.0	NO	
Point 58	7.5	23.0	YES	With the inclusion of trees
Point 59	7.5	23.0	YES	With the inclusion of trees
Point 60	7.5	23.0	NO	
Point 61	7.5	23.0	YES	With the inclusion of trees
Point 62	7.5	23.0	NO	
Point 63	7.5	23.0	YES	With the inclusion of trees
Point 64	7.5	23.0	NO	
Point 65	7.5	23.0	YES	With the inclusion of trees
Point 66	7.5	23.0	YES	With the inclusion of trees
Point 67	7.5	23.0	YES	With the inclusion of trees
Point 68	7.5	23.0	YES	With the inclusion of trees
Point 69	7.5	23.0	NO	
Point 70	7.5	23.0	YES	With the inclusion of trees
Point 71	7.5	23.0	YES	With the inclusion of trees
Point 72	7.5	23.0	NO	
Point 73	7.5	23.0	YES	With the inclusion of trees
Point 74	7.5	23.0	YES	With the inclusion of trees
Point 75	7.5	23.0	YES	With the inclusion of trees
Point 76	7.5	23.0	YES	With the inclusion of trees
Point 77	7.5	23.0	NO	
Point 78	7.5	23.0	NO	
Point 82	7.5	23.0	YES	With the inclusion of trees
Point 83	7.5	23.0	YES	With the inclusion of trees

Study Point	Desired Criterion (m/s)		Treatment Necessary to Pass?	Description of Suggested Treatment
	Weekly GEM	Annual Peak		
Point 84	5.5	23.0	YES	With the inclusion of trees
Point 85	5.5	23.0	YES	With the inclusion of trees
Point 86	7.5	23.0	NO	
Point 87	3.5	23.0	YES	With the inclusion of localised screening
Point 88	7.5	23.0	YES	With the inclusion of trees
Point 89	7.5	23.0	YES	With the inclusion of trees
Point 90	7.5	23.0	YES	With the inclusion of trees

Table 9b: Wind Tunnel Results Summary – Scenario 2

Study Point	Desired Criterion (m/s)		Treatment Necessary to Pass?	Description of Suggested Treatment
	Weekly GEM	Annual Peak		
Point 23	-	23.0	NO	
Point 24	-	23.0	NO	
Point 25	-	23.0	NO	
Point 26	-	23.0	NO	
Point 27	-	23.0	NO	
Point 28	-	23.0	NO	
Point 41	5.5	23.0	NO	
Point 42	5.5	23.0	NO	
Point 43	5.5	23.0	NO	
Point 44	5.5	23.0	NO	
Point 45	5.5	23.0	NO	
Point 46	7.5	23.0	NO	
Point 55	7.5	23.0	YES	With the inclusion of trees
Point 56	7.5	23.0	YES	With the inclusion of trees
Point 57	7.5	23.0	NO	
Point 58	7.5	23.0	NO	
Point 59	7.5	23.0	NO	
Point 60	7.5	23.0	YES	With the inclusion of trees
Point 61	7.5	23.0	YES	With the inclusion of trees
Point 62	7.5	23.0	YES	With the inclusion of trees
Point 63	7.5	23.0	YES	With the inclusion of trees
Point 64	7.5	23.0	YES	With the inclusion of trees
Point 65	7.5	23.0	YES	With the inclusion of trees
Point 66	7.5	23.0	YES	With the inclusion of trees
Point 67	7.5	23.0	NO	

Study Point	Desired Criterion (m/s)		Treatment Necessary to Pass?	Description of Suggested Treatment
	Weekly GEM	Annual Peak		
Point 68	7.5	23.0	NO	
Point 69	7.5	23.0	NO	
Point 70	7.5	23.0	YES	With the inclusion of trees
Point 71	7.5	23.0	YES	With the inclusion of trees
Point 72	7.5	23.0	YES	With the inclusion of trees
Point 73	7.5	23.0	YES	With the inclusion of trees
Point 74	7.5	23.0	YES	With the inclusion of trees
Point 75	7.5	23.0	NO	
Point 76	7.5	23.0	NO	
Point 77	7.5	23.0	NO	
Point 78	7.5	23.0	YES	With the inclusion of trees
Point 82	7.5	23.0	YES	With the inclusion of trees
Point 83	7.5	23.0	NO	
Point 84	3.5	23.0	YES	With the inclusion of a cluster of trees and northern canopy adjoining bridge, operable doors to thoroughfare during stronger wind events, as per the latest architectural drawings.
Point 85	3.5	23.0	YES	With the inclusion of a cluster of trees and northern canopy adjoining bridge, operable doors to thoroughfare during stronger wind events, as per the latest architectural drawings.
Point 86	7.5	23.0	NO	
Point 87	3.5	23.0	YES	With the inclusion of localised screening
Point 88	7.5	23.0	NO	
Point 89	3.5	23.0	YES	With the inclusion of localised screening
Point 90	7.5	23.0	YES	With the inclusion of trees

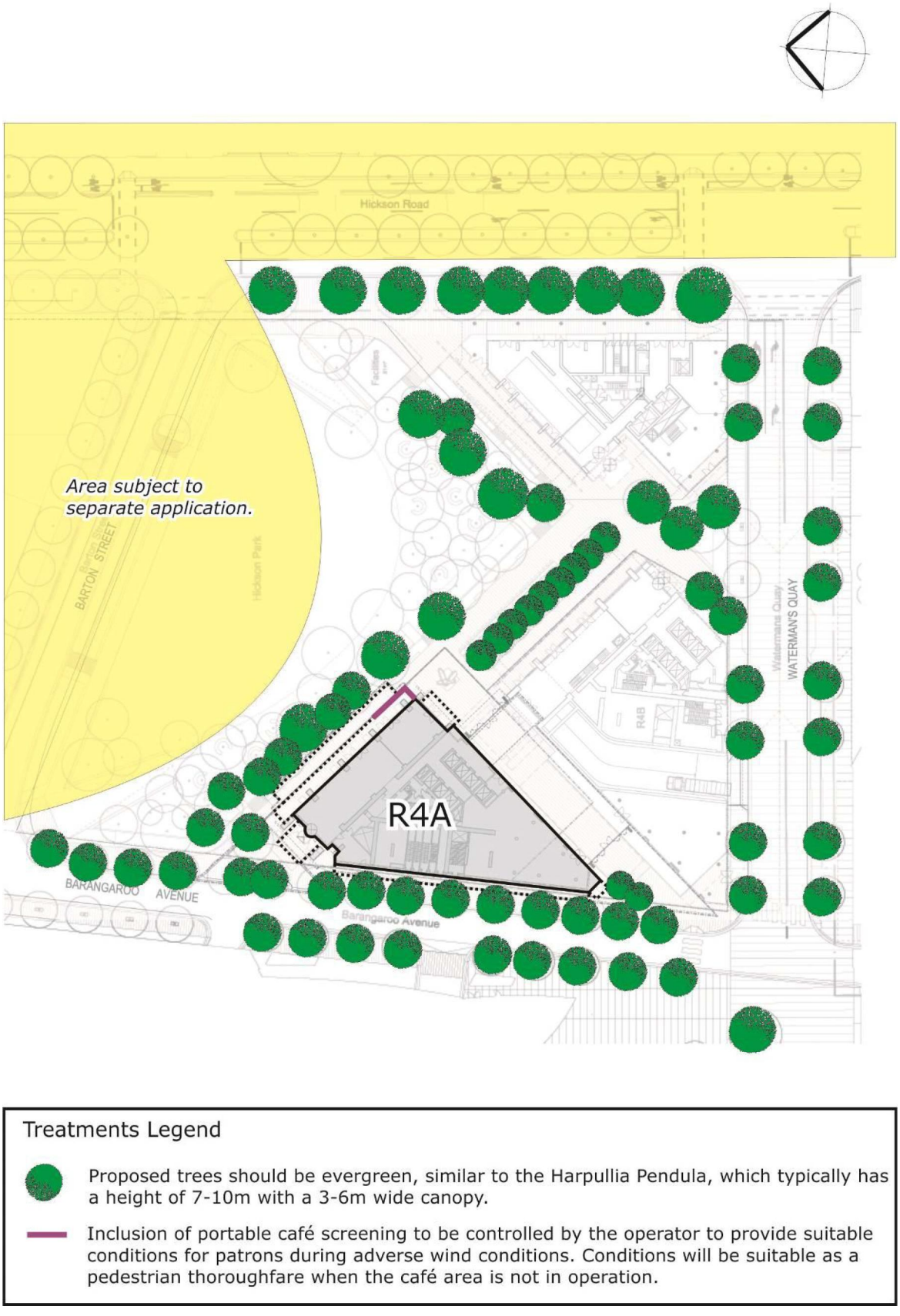

Figure 6a: Suggested Treatments for Ground Level – Scenario 1

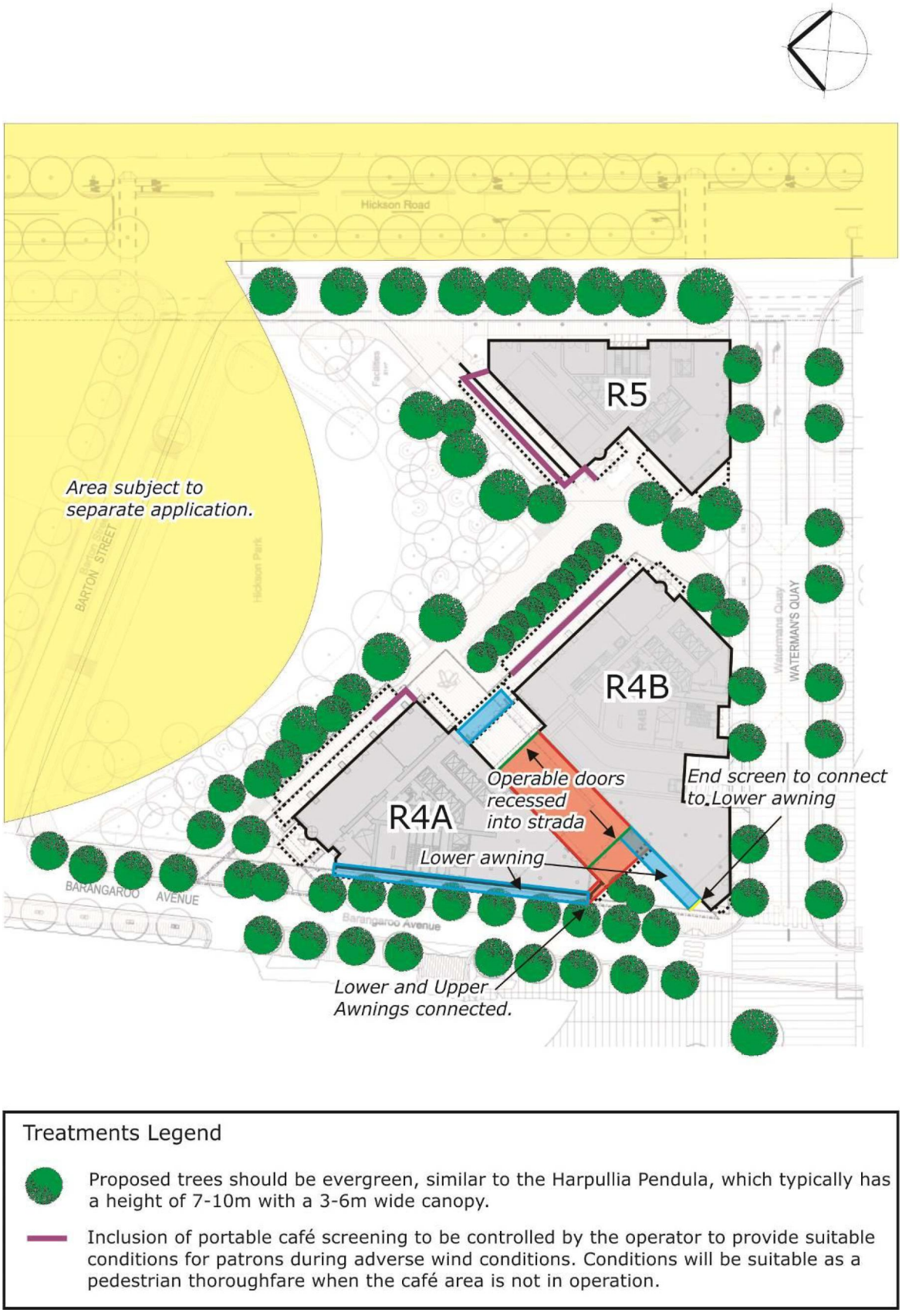

Figure 6b: Suggested Treatments for Ground Level – Scenario 2

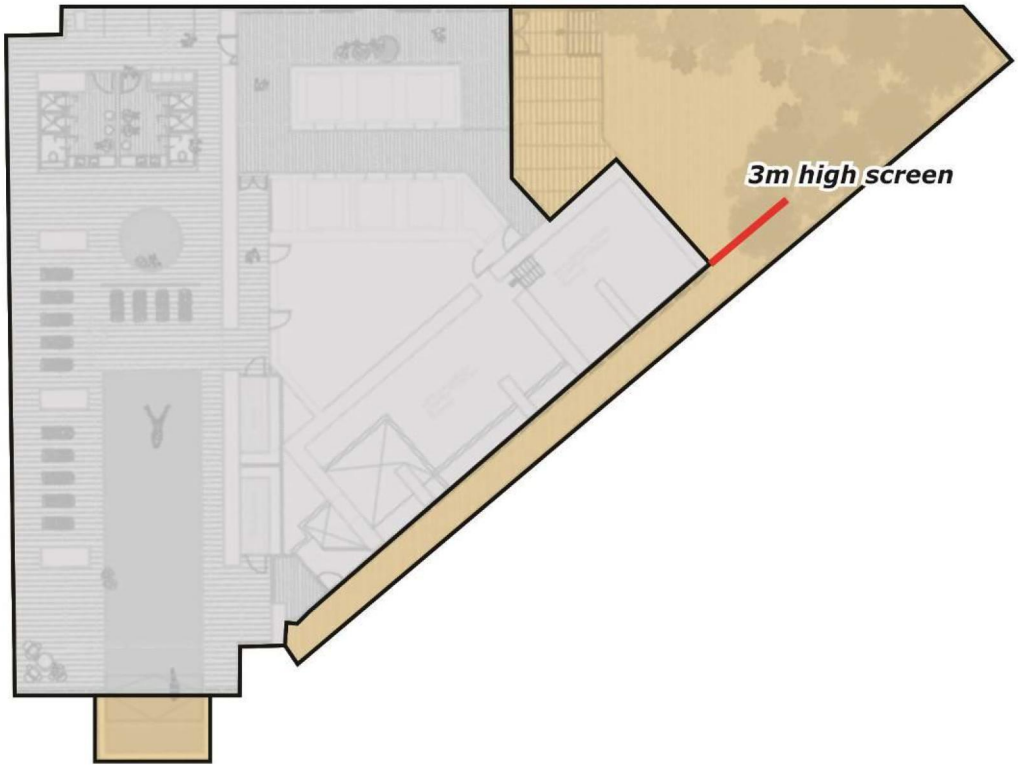

Figure 6c: Suggested Treatments for Tower R4A Podium Level – Scenario 1

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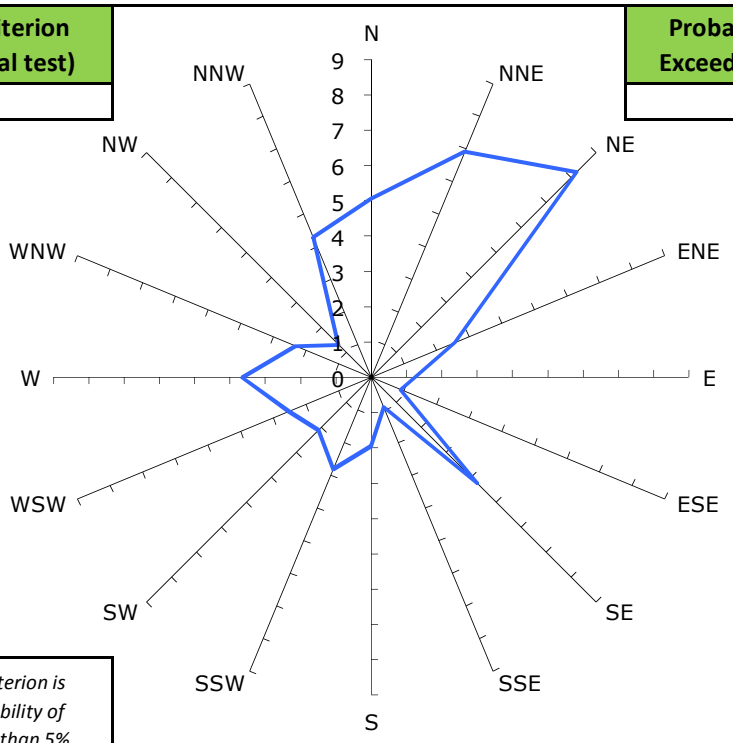
APPENDIX A - DIRECTIONAL PLOTS OF THE WIND TUNNEL RESULTS

Measured Wind Speeds at Point 23

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

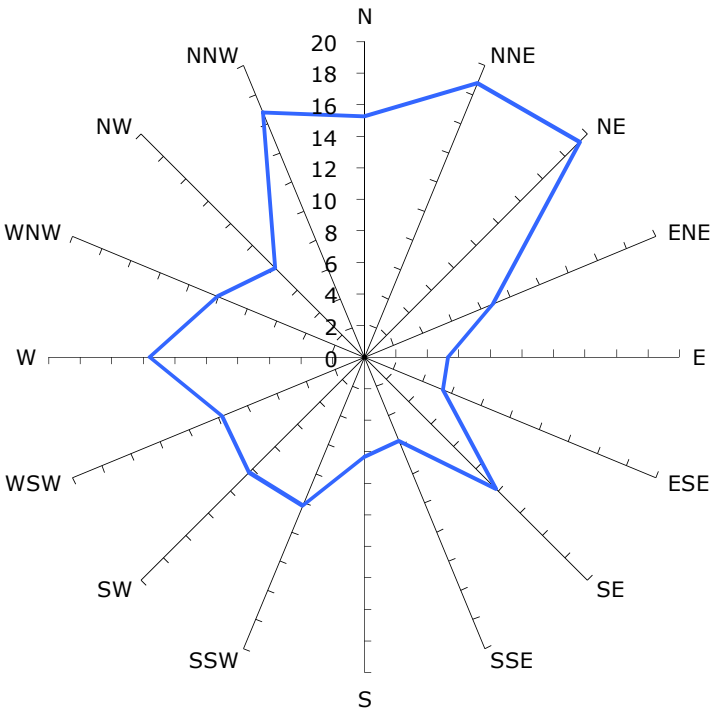


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

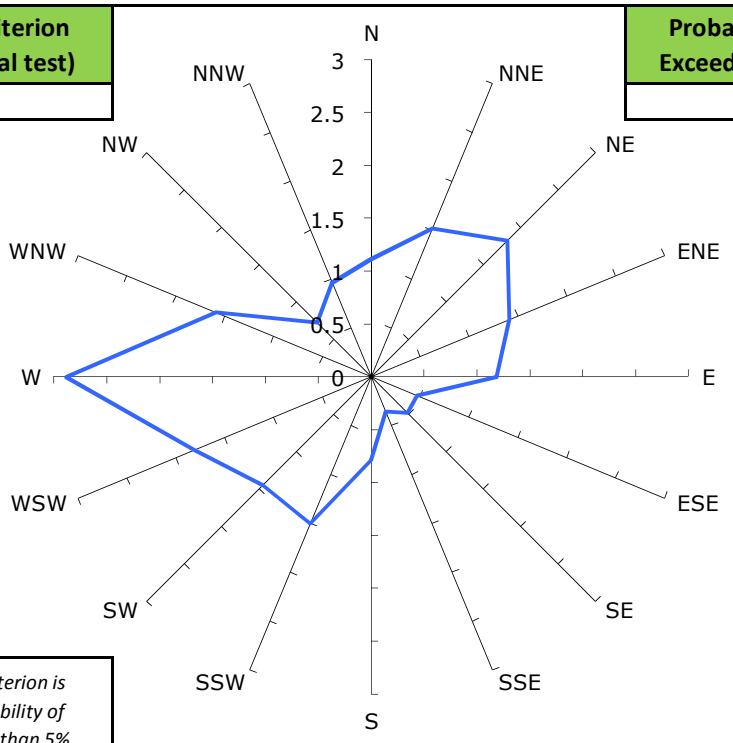


Desired Criterion
23m/s

Measured Wind Speeds at Point 24

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

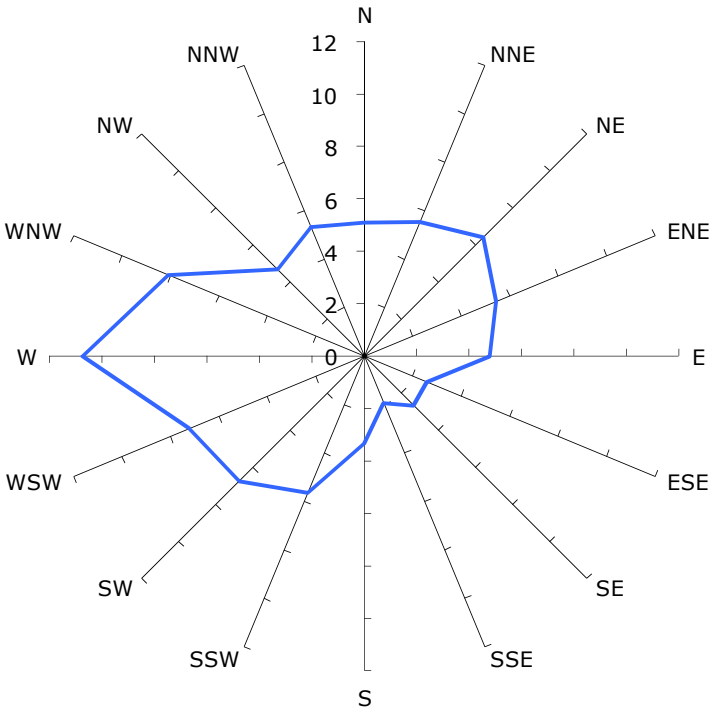


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

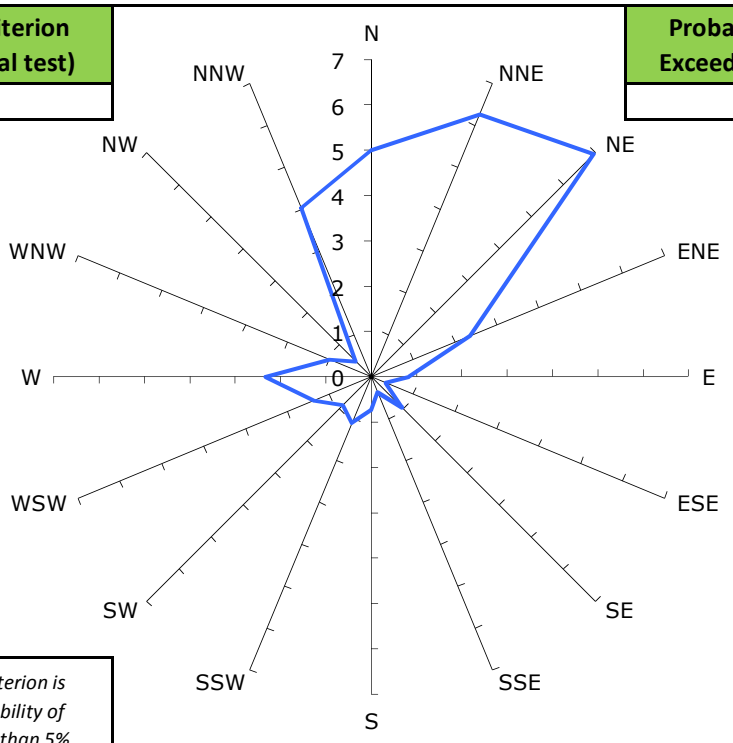


Desired Criterion
23m/s

Measured Wind Speeds at Point 25

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

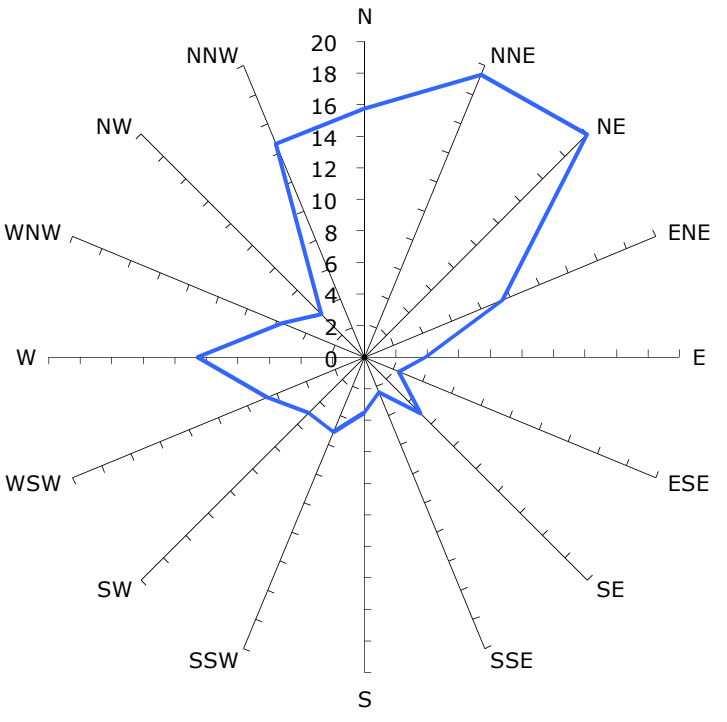


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

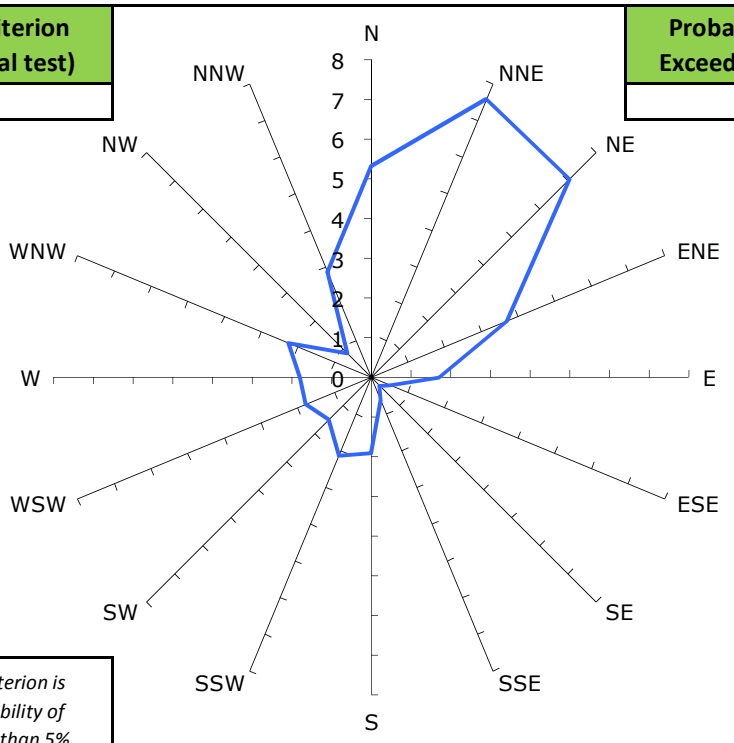


Desired Criterion
23m/s

Measured Wind Speeds at Point 26

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

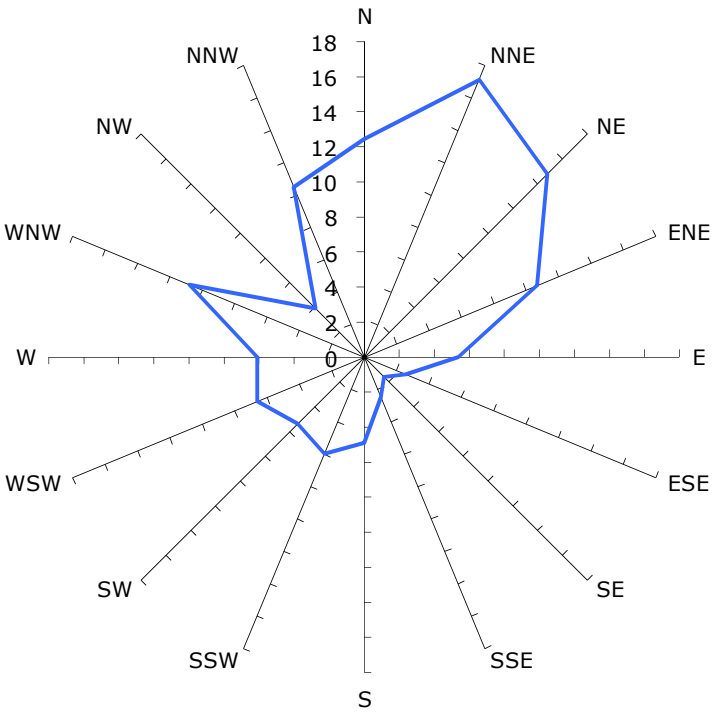


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

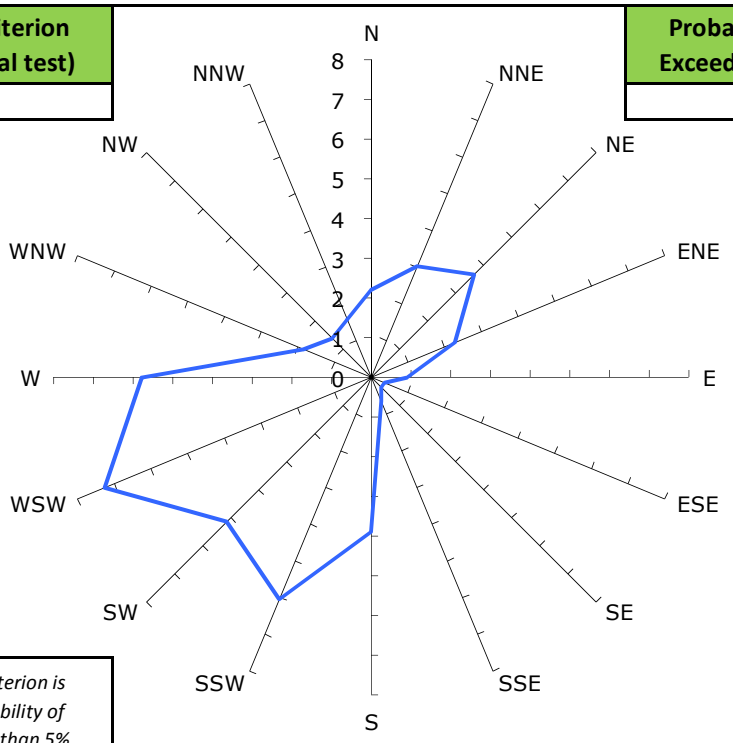


Desired Criterion
23m/s

Measured Wind Speeds at Point 27

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

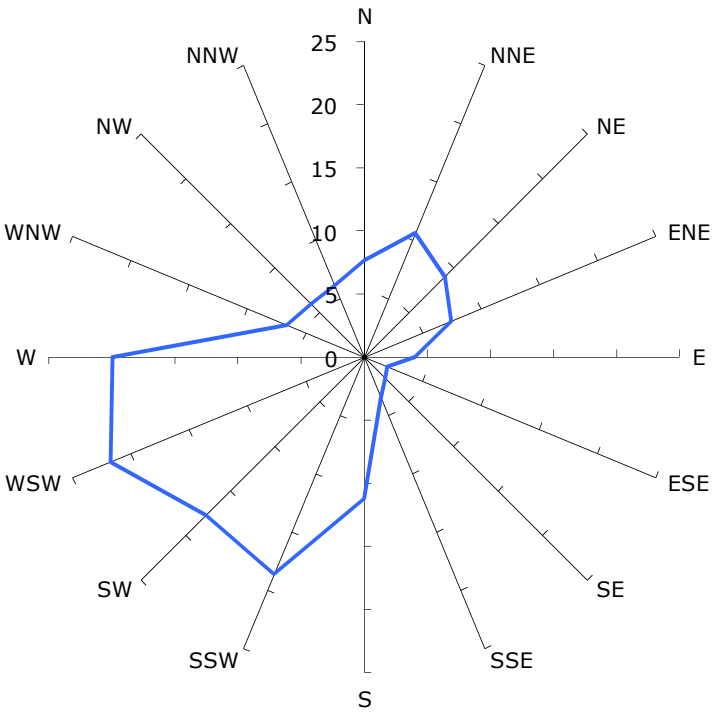


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

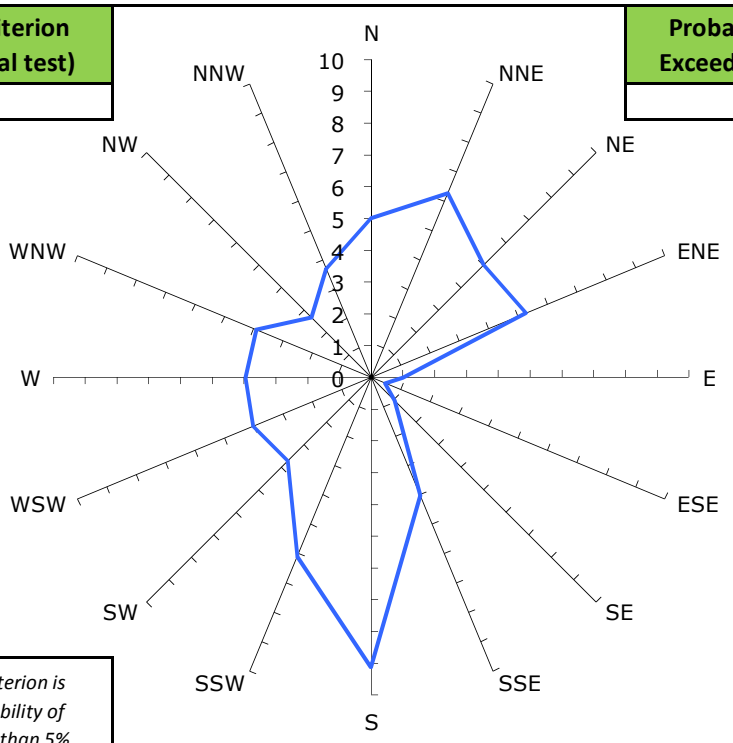


Desired Criterion
23m/s

Measured Wind Speeds at Point 28

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

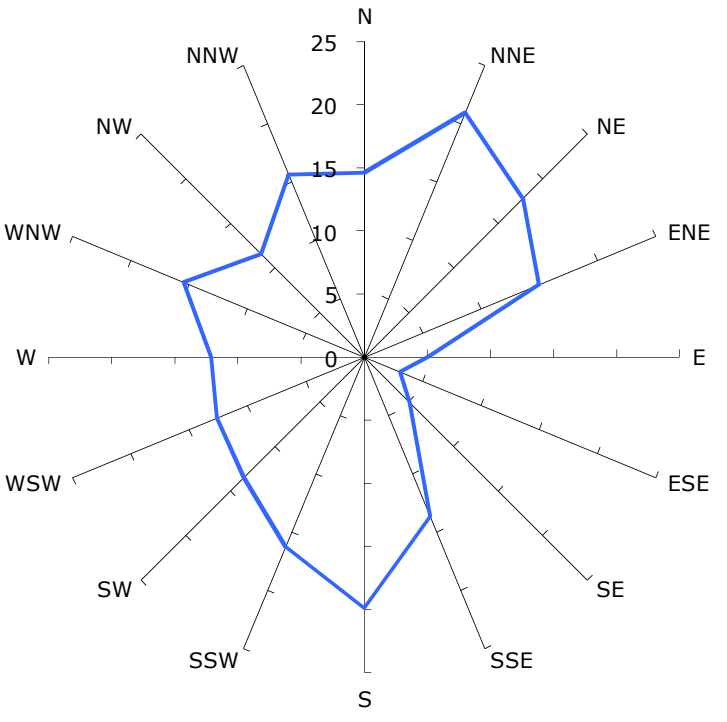


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

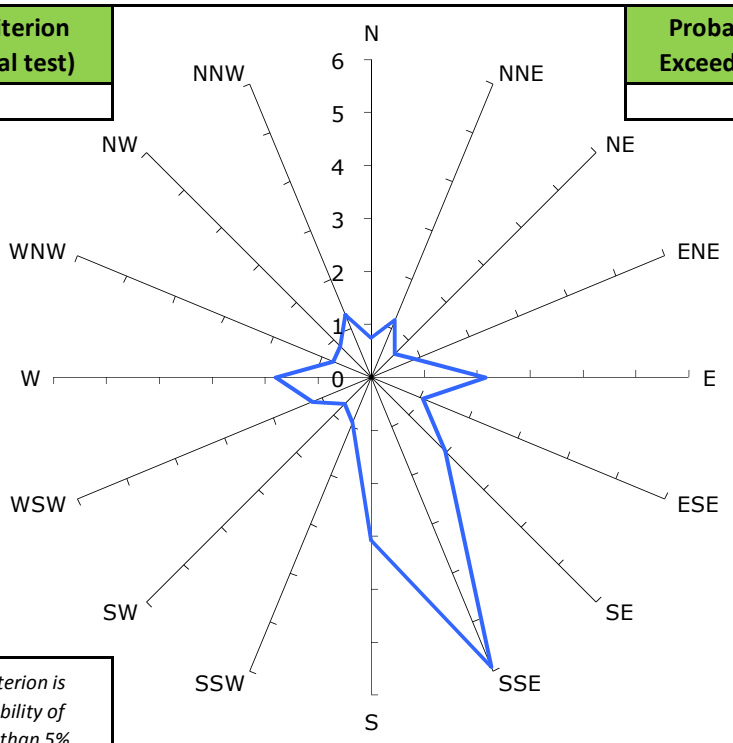


Desired Criterion
23m/s

Measured Wind Speeds at Point 41

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
1%	N/A

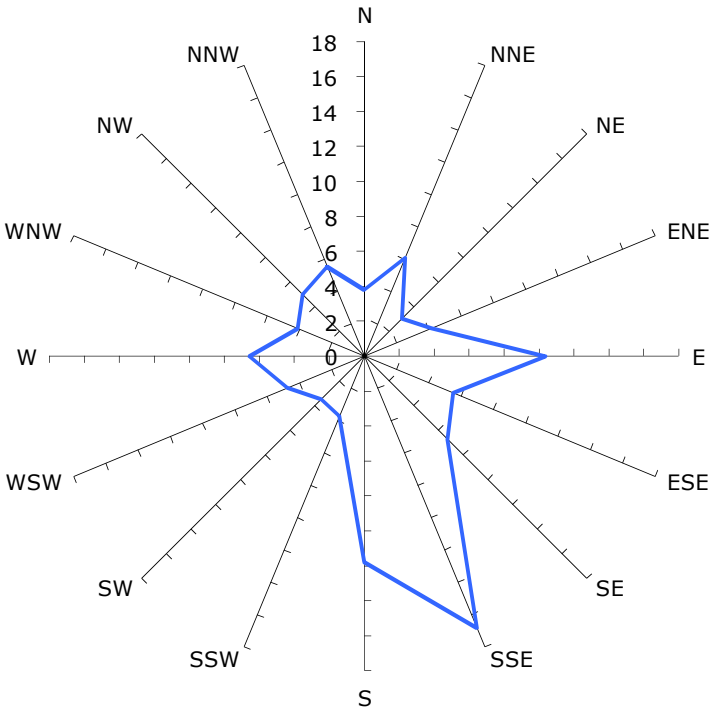


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

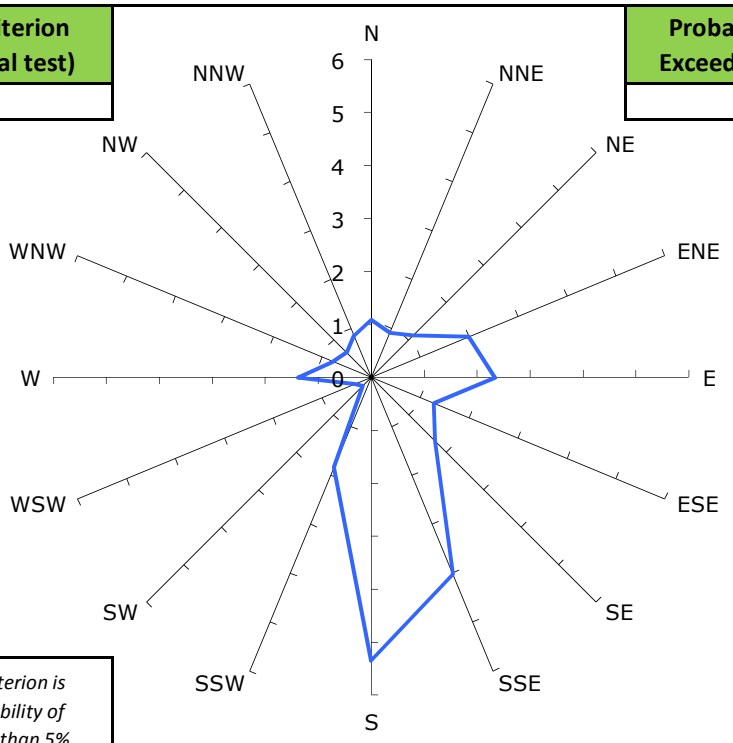


Desired Criterion
23m/s

Measured Wind Speeds at Point 42

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
1%	N/A

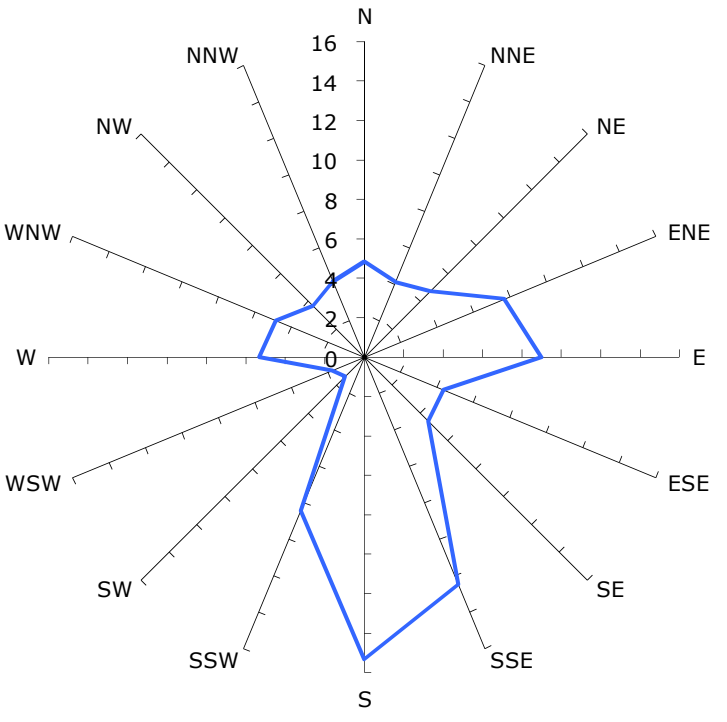


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

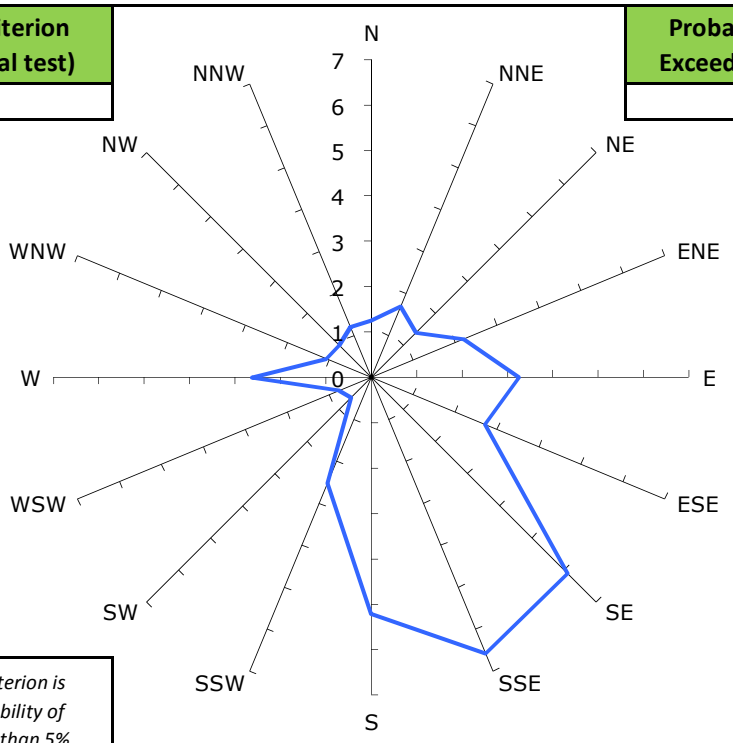


Desired Criterion
23m/s

Measured Wind Speeds at Point 43

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
5%	N/A

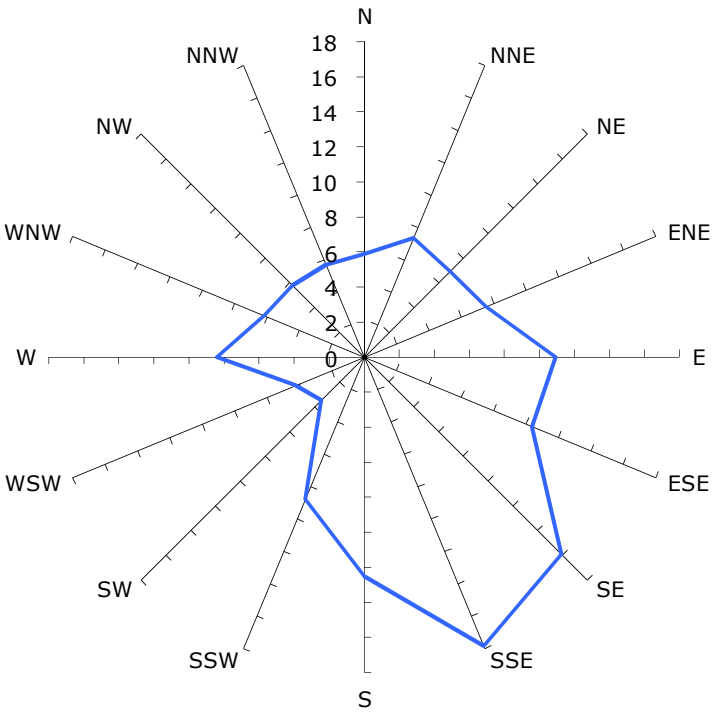


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

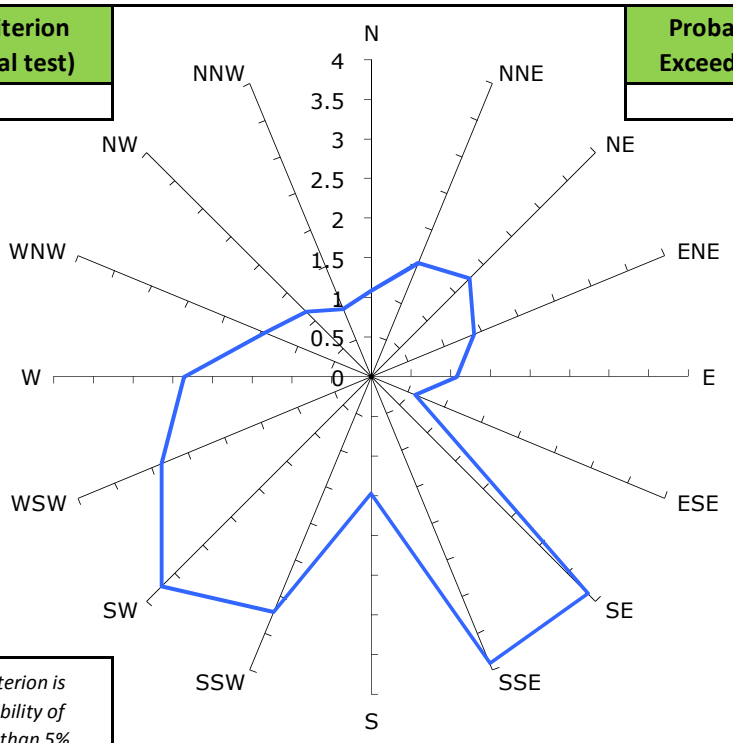


Desired Criterion
23m/s

Measured Wind Speeds at Point 44

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
1%	N/A

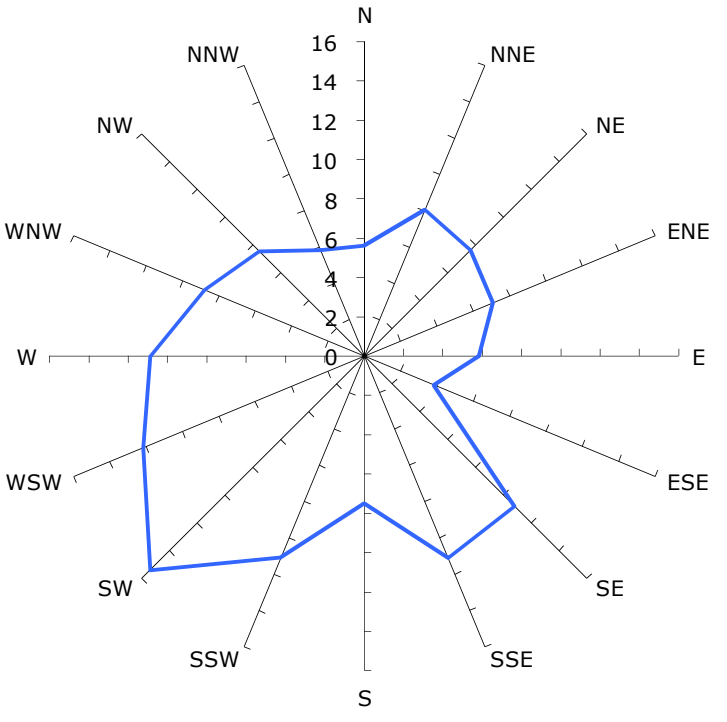


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

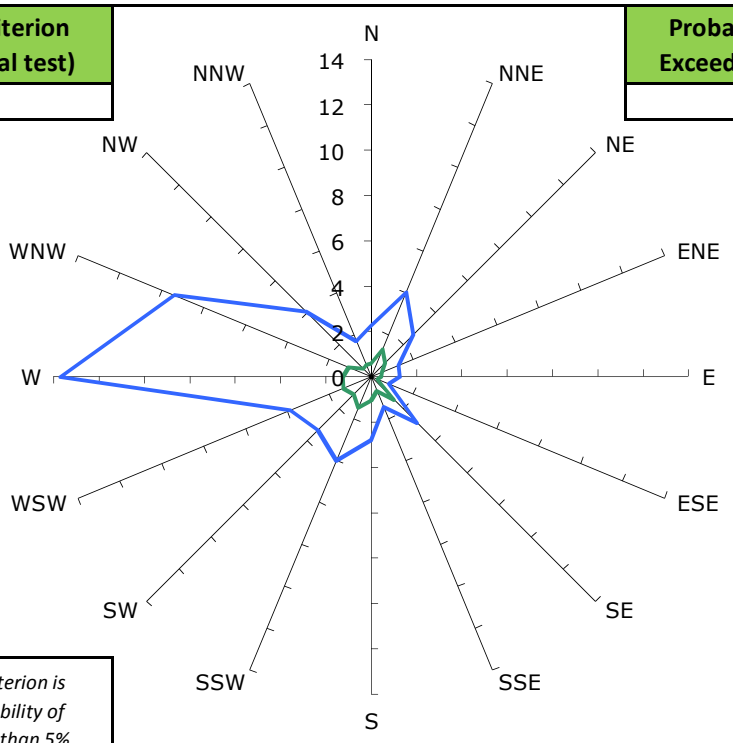


Desired Criterion
23m/s

Measured Wind Speeds at Point 45

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
9%	0%



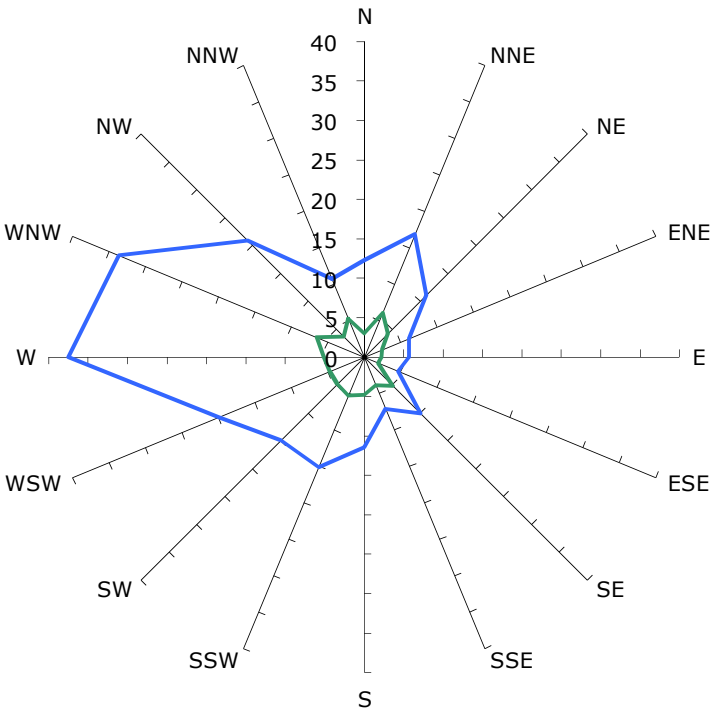
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of a 3m high screen

Annual Maximum Gust (m/s)

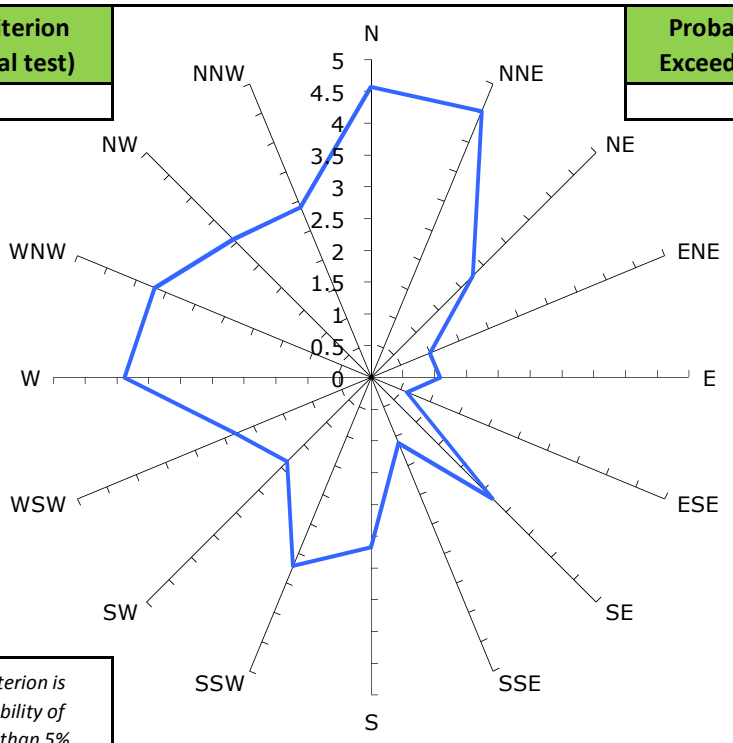


Desired Criterion
23m/s

Measured Wind Speeds at Point 46

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
0%	N/A

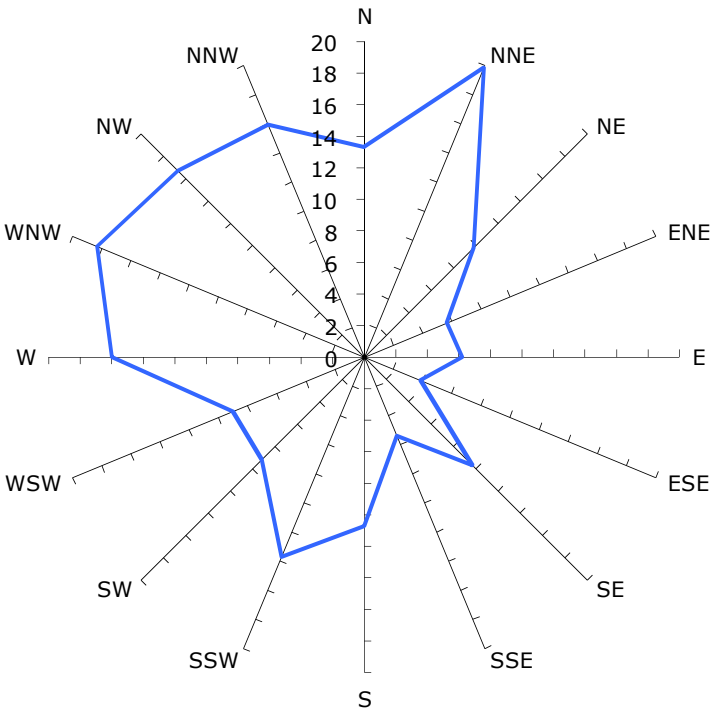


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

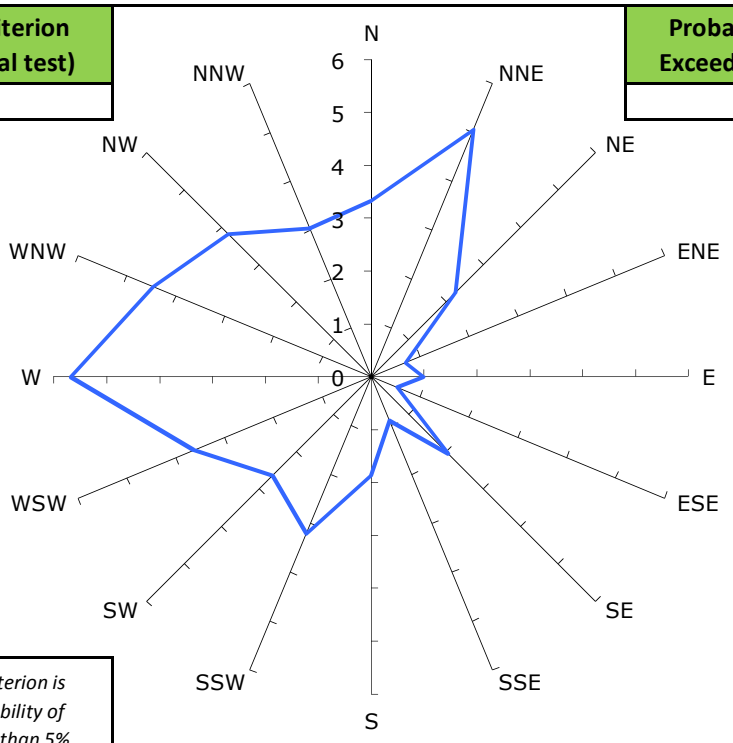


Desired Criterion
23m/s

Measured Wind Speeds at Point 55

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
0%	N/A

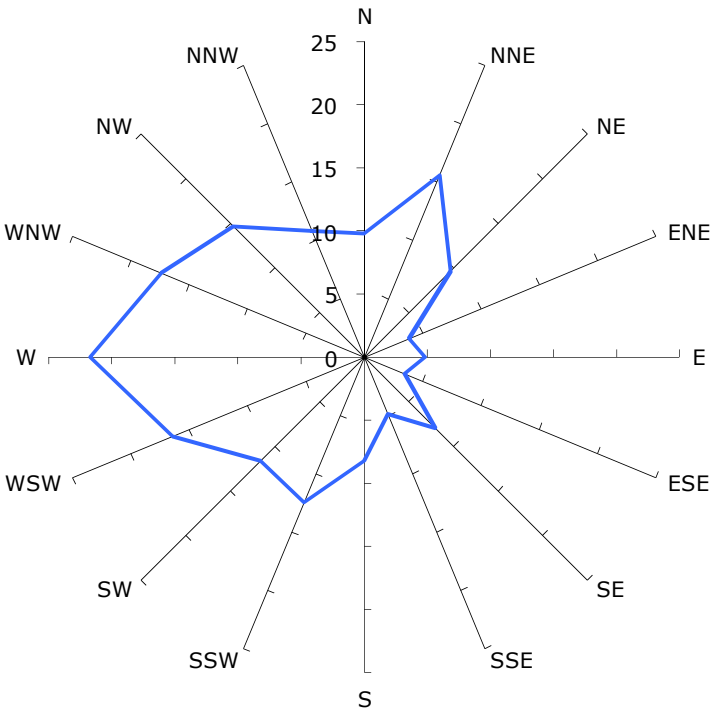


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

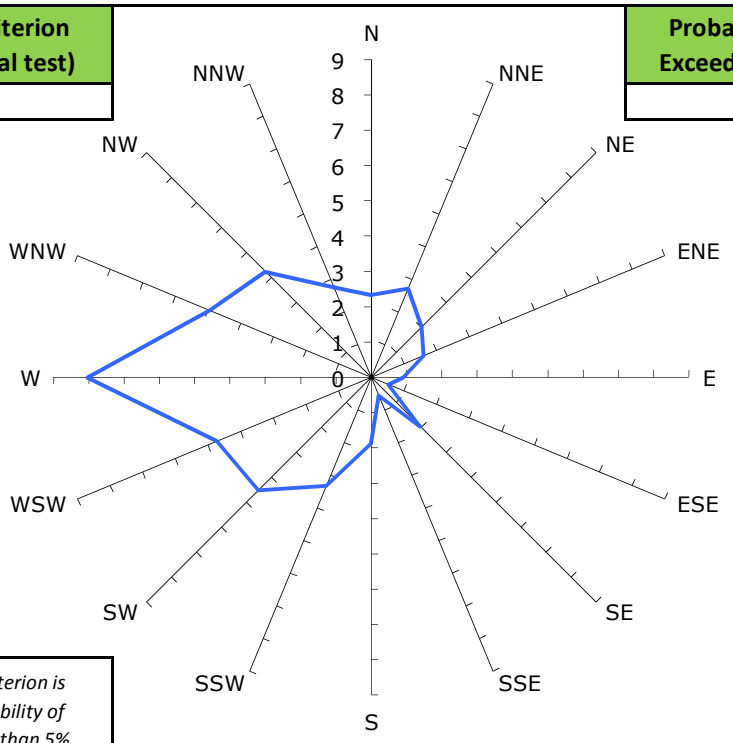


Desired Criterion
23m/s

Measured Wind Speeds at Point 56

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
1%	N/A

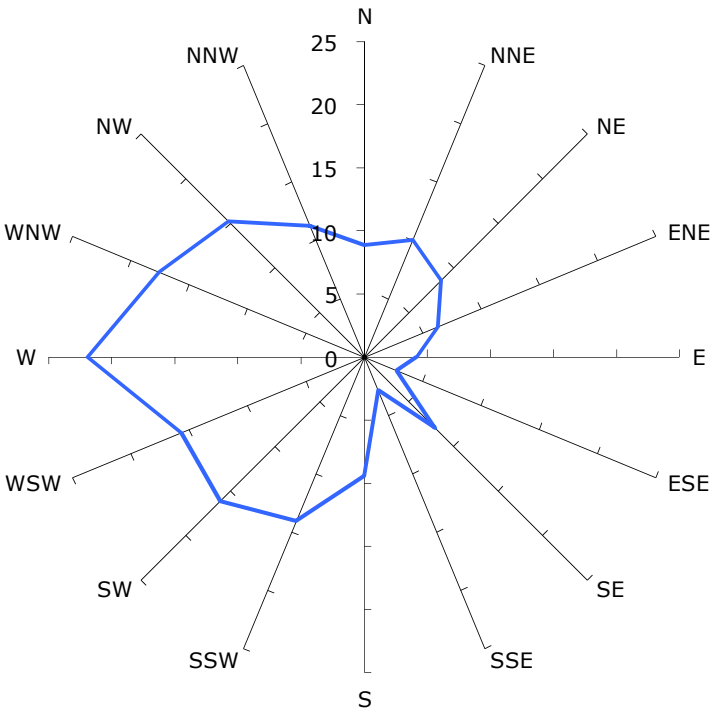


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

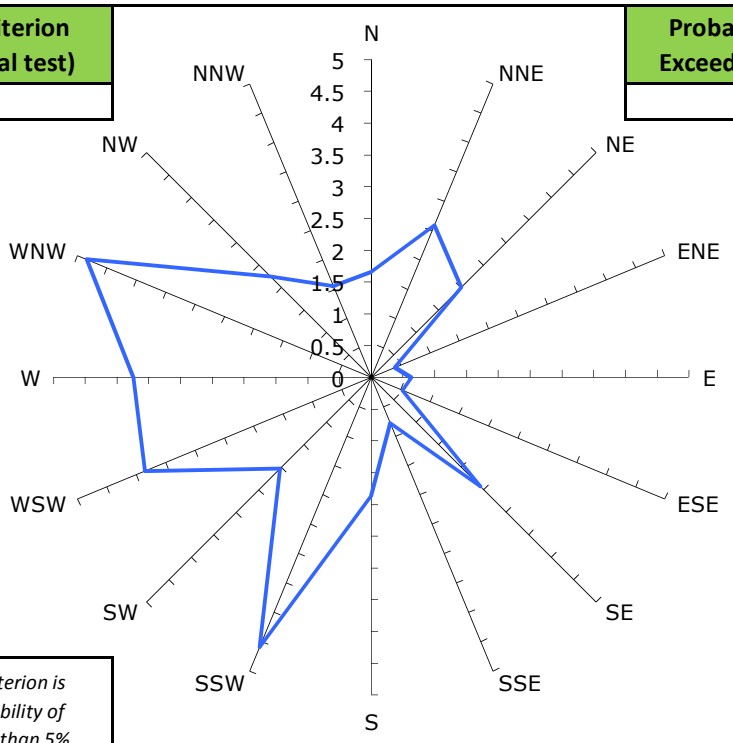


Desired Criterion
23m/s

Measured Wind Speeds at Point 57

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
0%	N/A

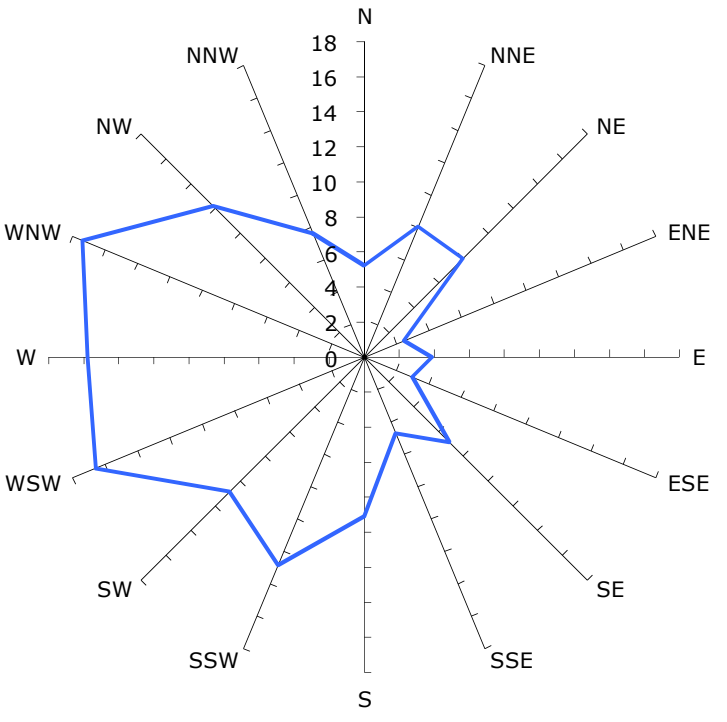


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

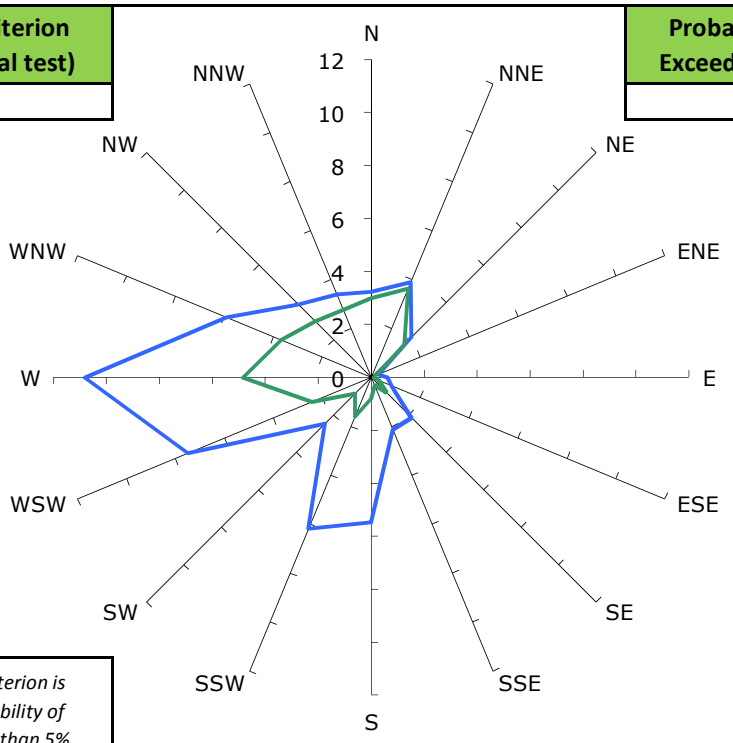


Desired Criterion
23m/s

Measured Wind Speeds at Point 58

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
5%	0%



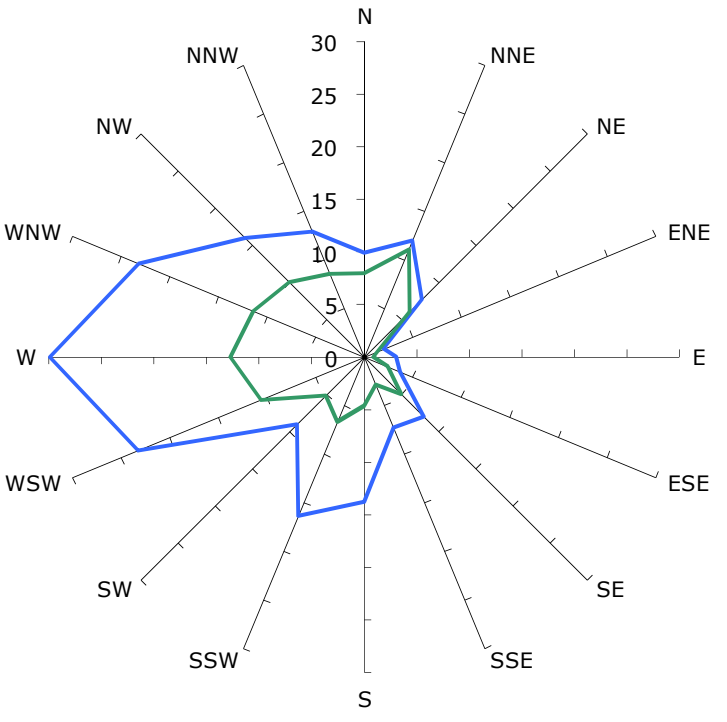
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

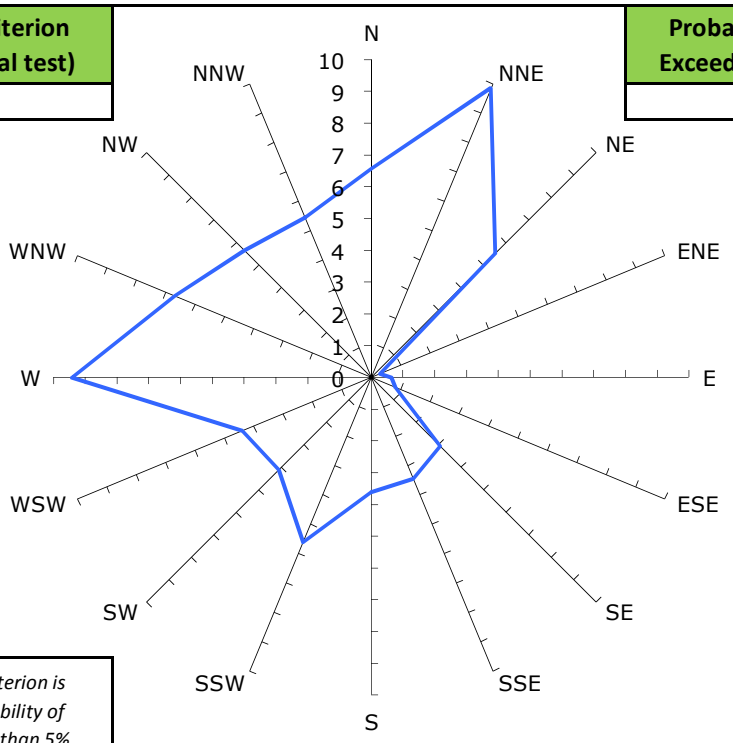


Desired Criterion
23m/s

Measured Wind Speeds at Point 59

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
7%	N/A

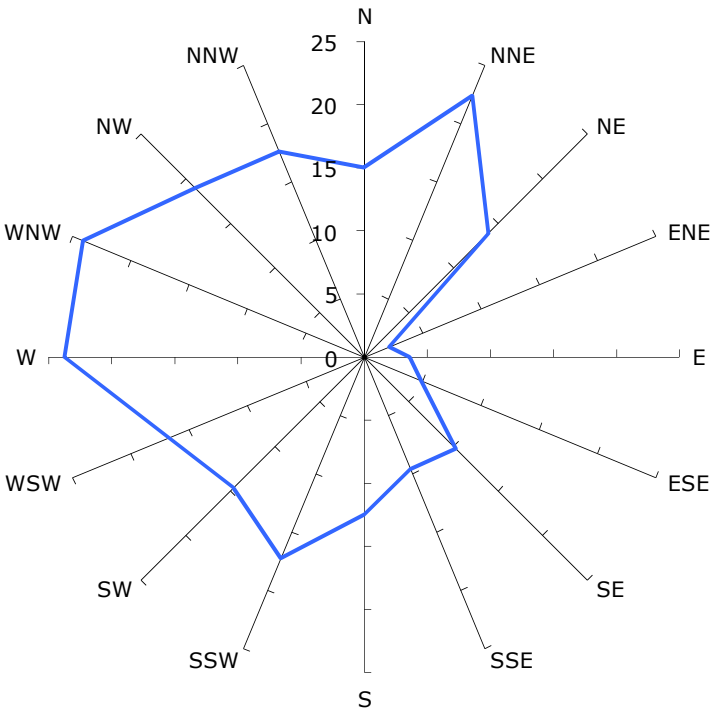


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

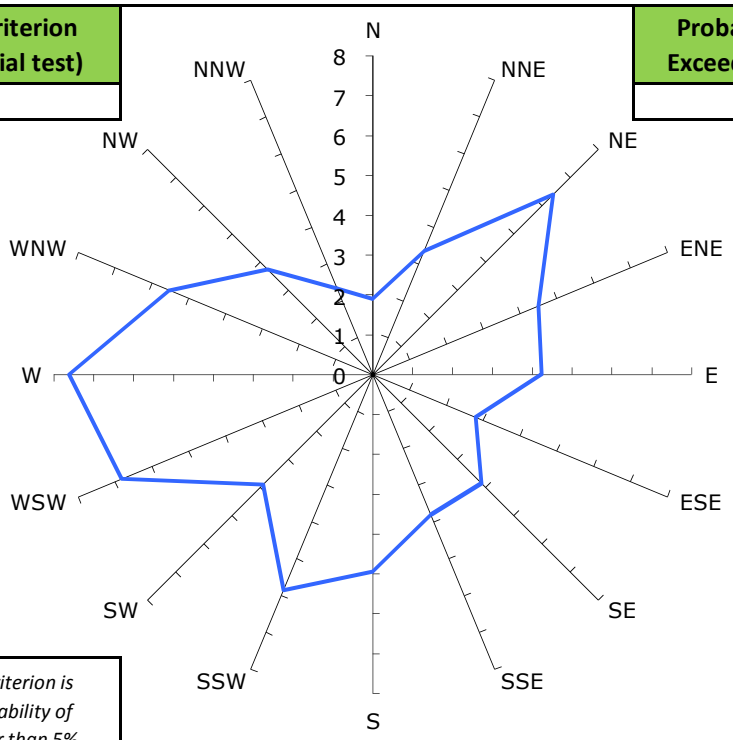


Desired Criterion
23m/s

Measured Wind Speeds at Point 60

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
2%	N/A

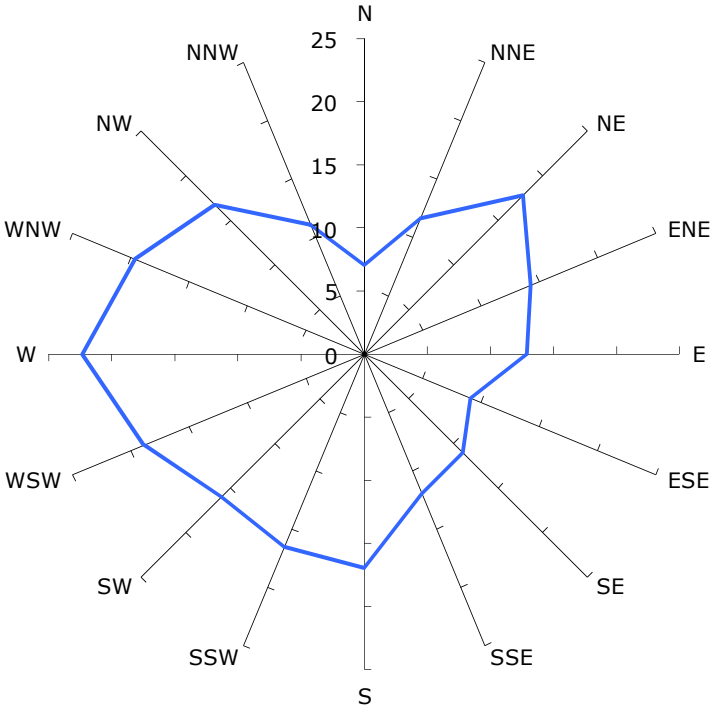


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

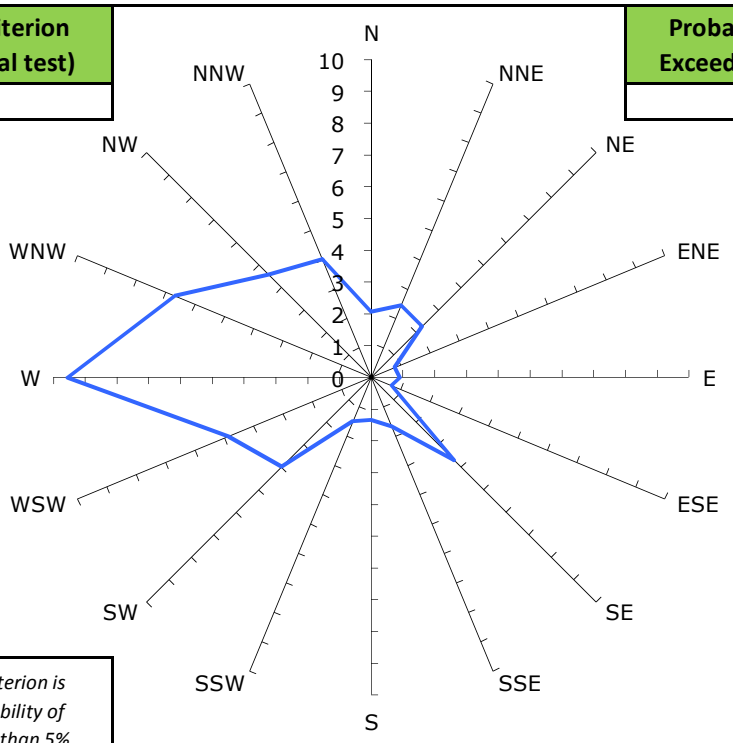


Desired Criterion
23m/s

Measured Wind Speeds at Point 61

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
3%	N/A

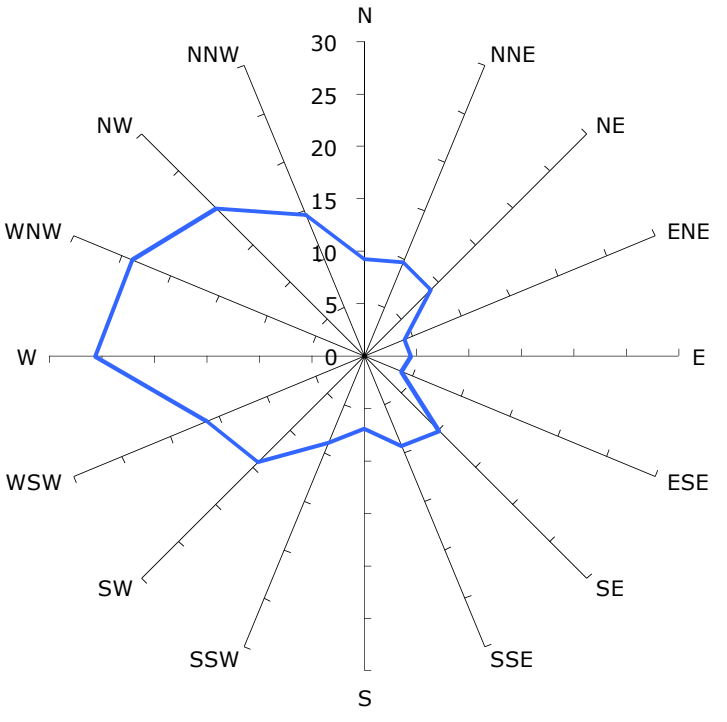


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

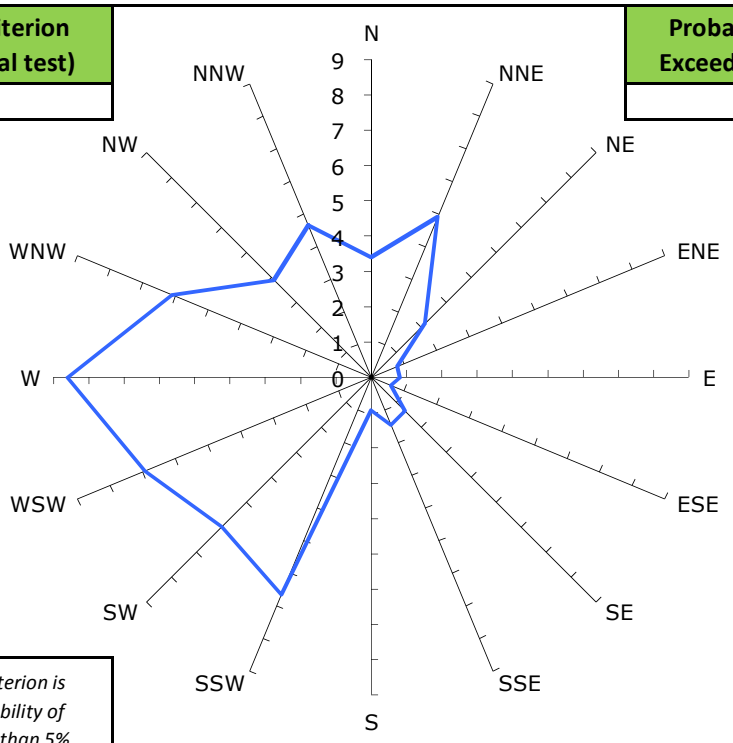


Desired Criterion
23m/s

Measured Wind Speeds at Point 62

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
4%	N/A

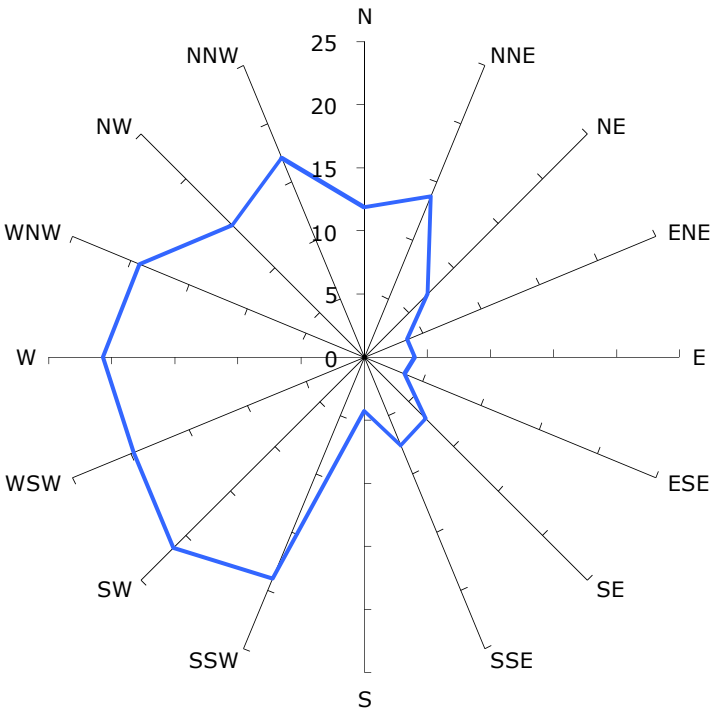


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

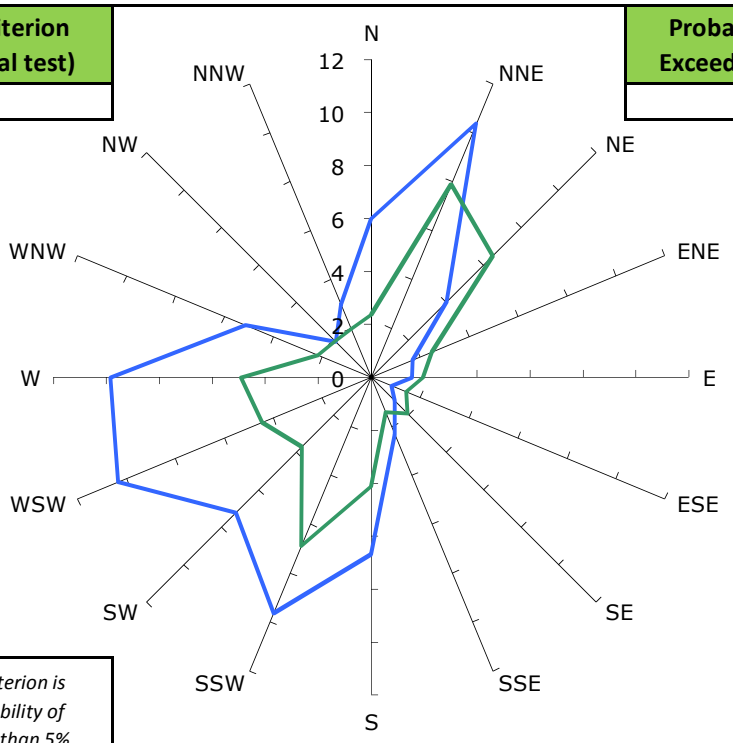


Desired Criterion
23m/s

Measured Wind Speeds at Point 63

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
11%	3%



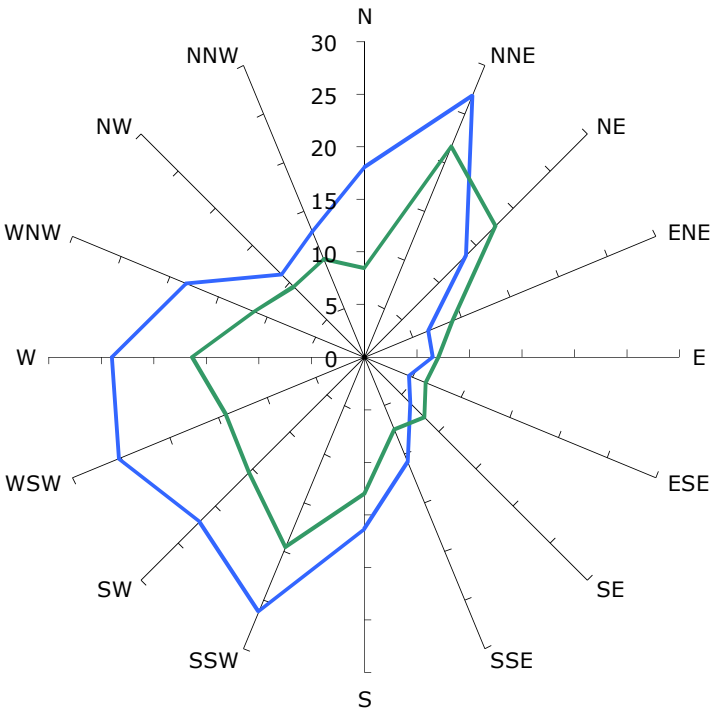
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

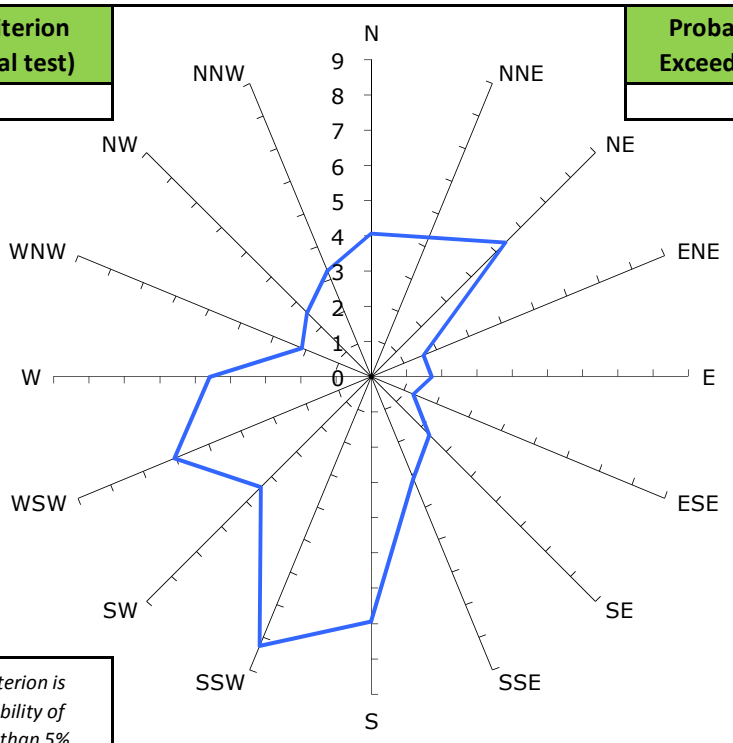


Desired Criterion
23m/s

Measured Wind Speeds at Point 64

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
3%	N/A

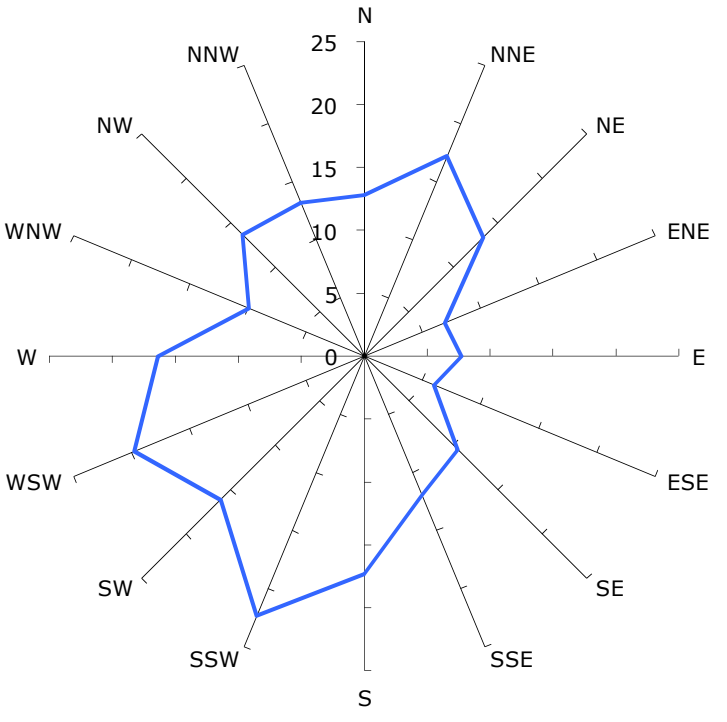


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

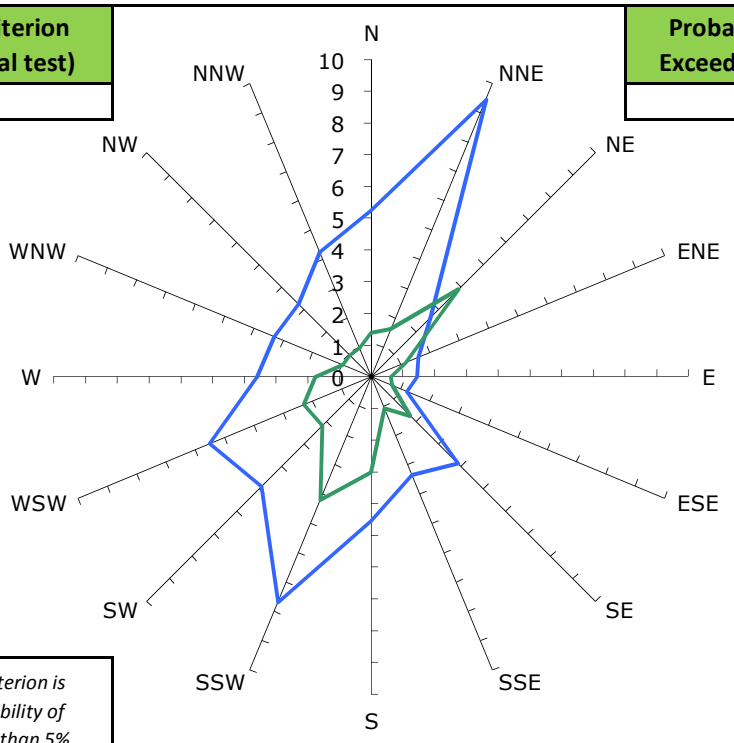


Desired Criterion
23m/s

Measured Wind Speeds at Point 65

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
4%	0%



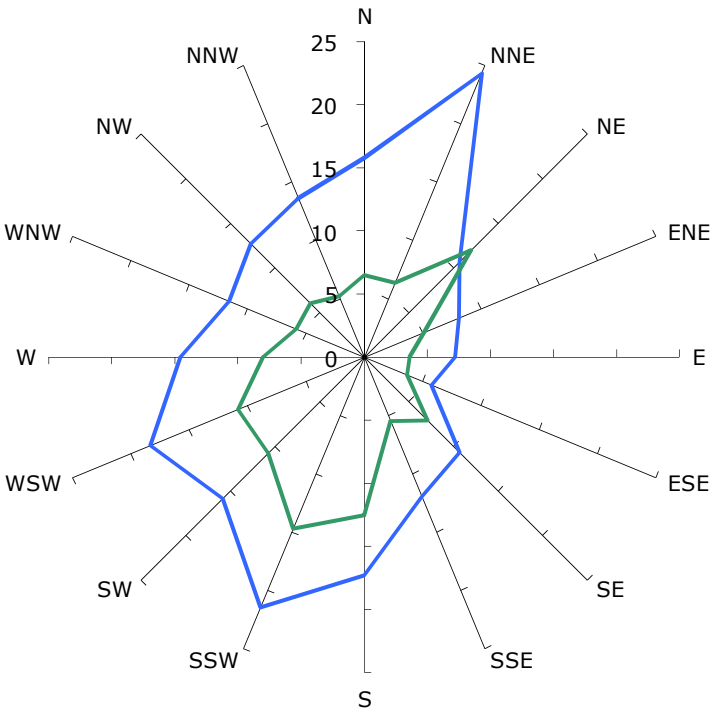
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

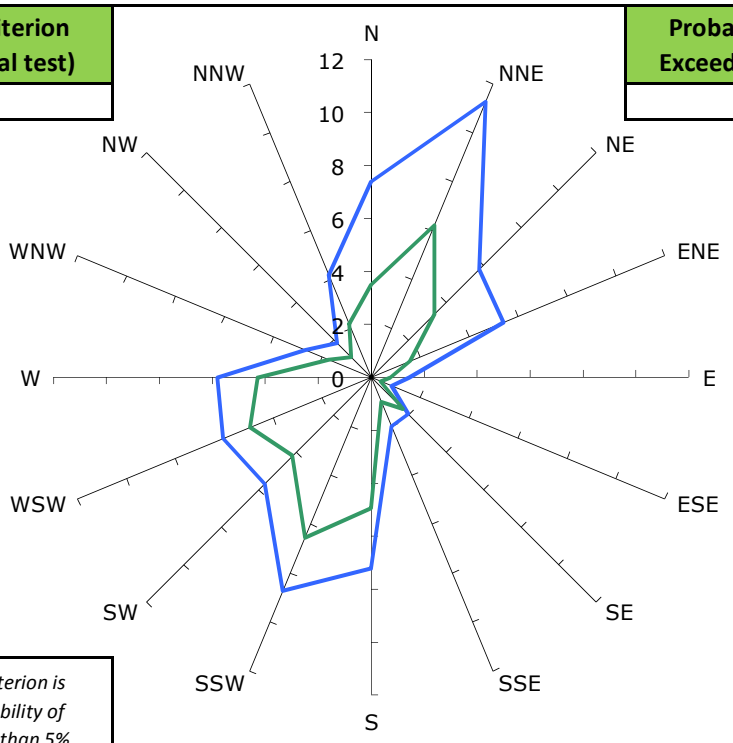


Desired Criterion
23m/s

Measured Wind Speeds at Point 66

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
8%	1%



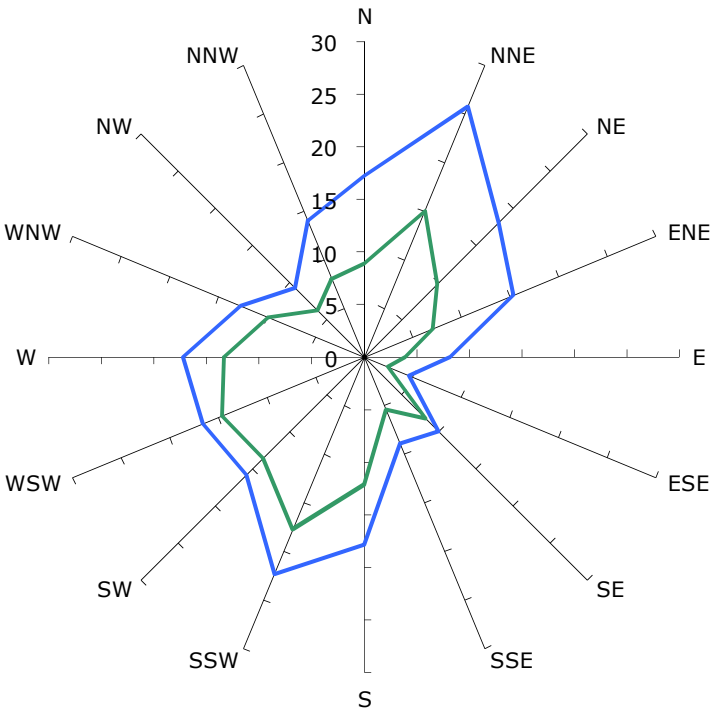
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

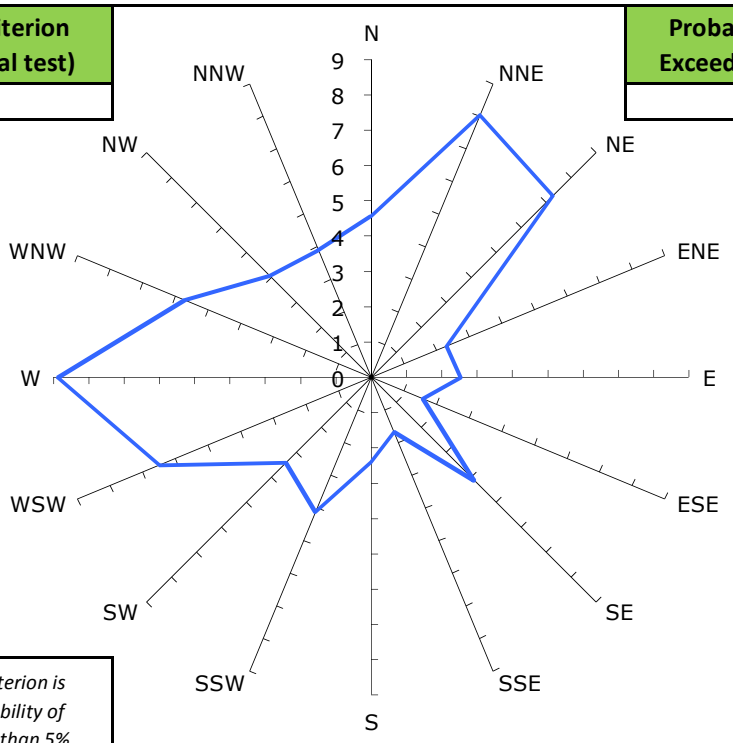


Desired Criterion
23m/s

Measured Wind Speeds at Point 67

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
6%	N/A

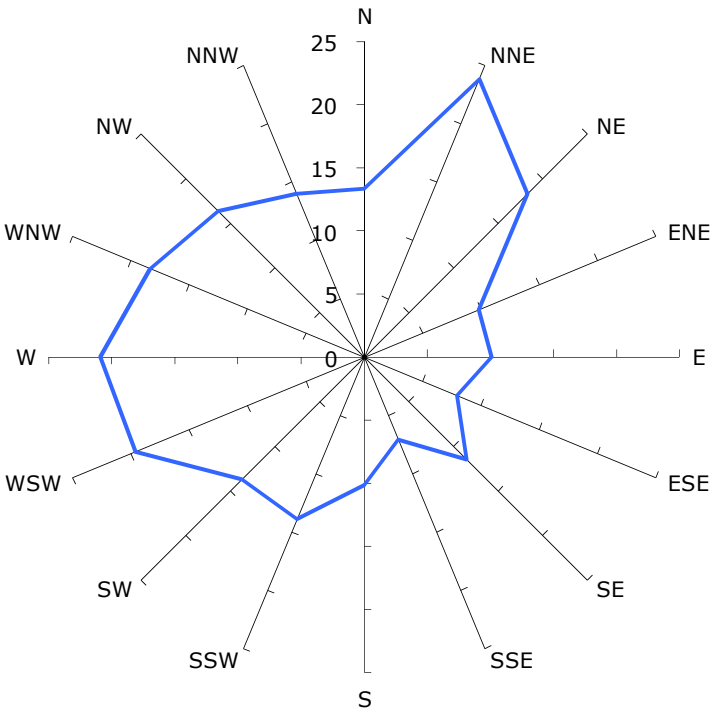


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

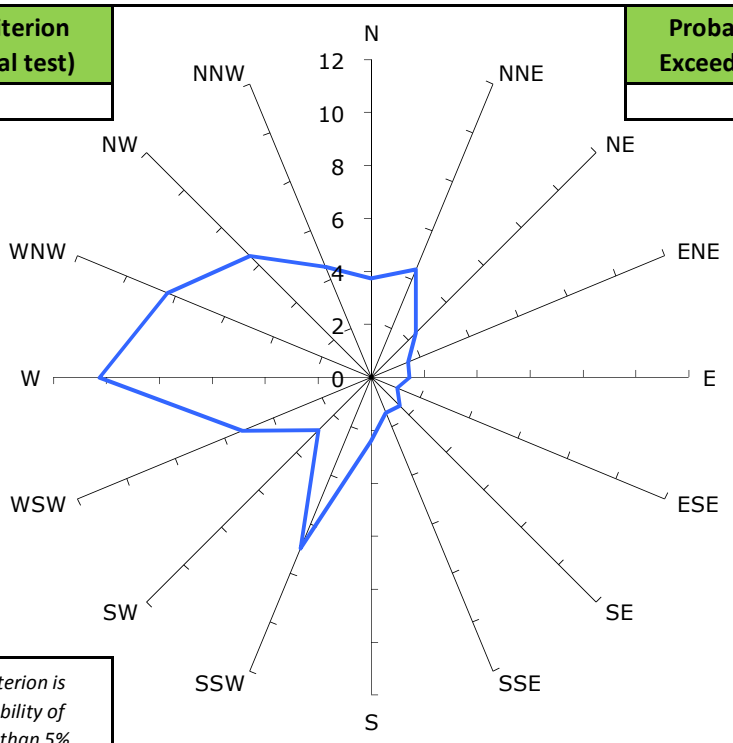


Desired Criterion
23m/s

Measured Wind Speeds at Point 68

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
6%	N/A

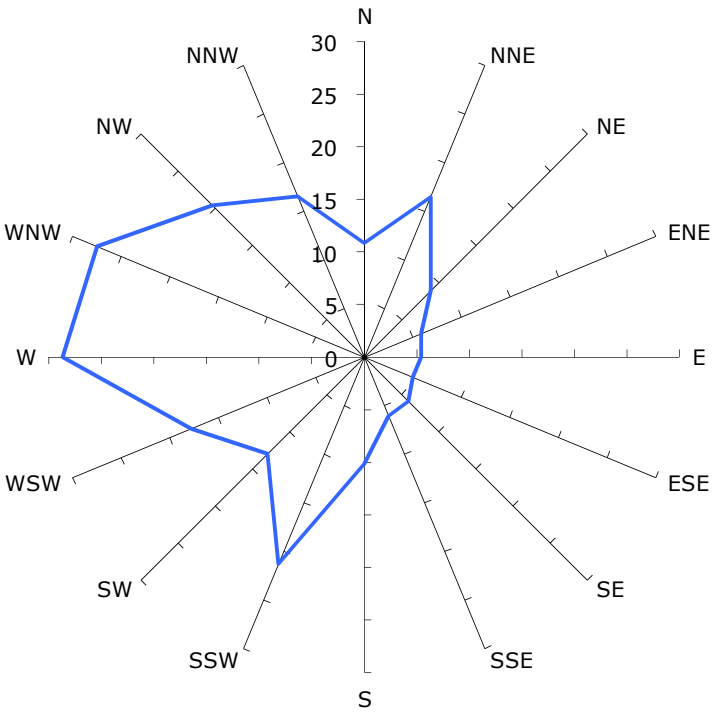


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

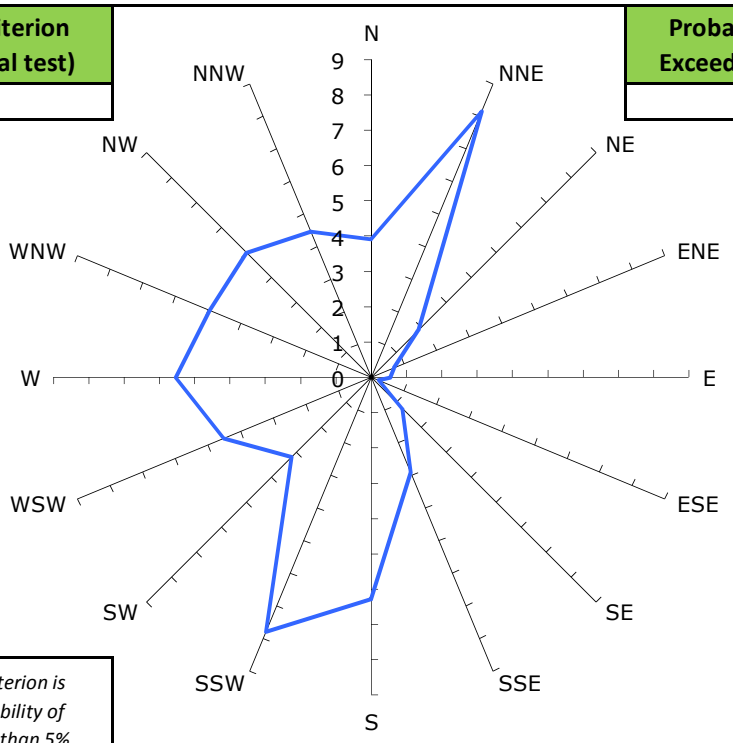


Desired Criterion
23m/s

Measured Wind Speeds at Point 69

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
5%	N/A

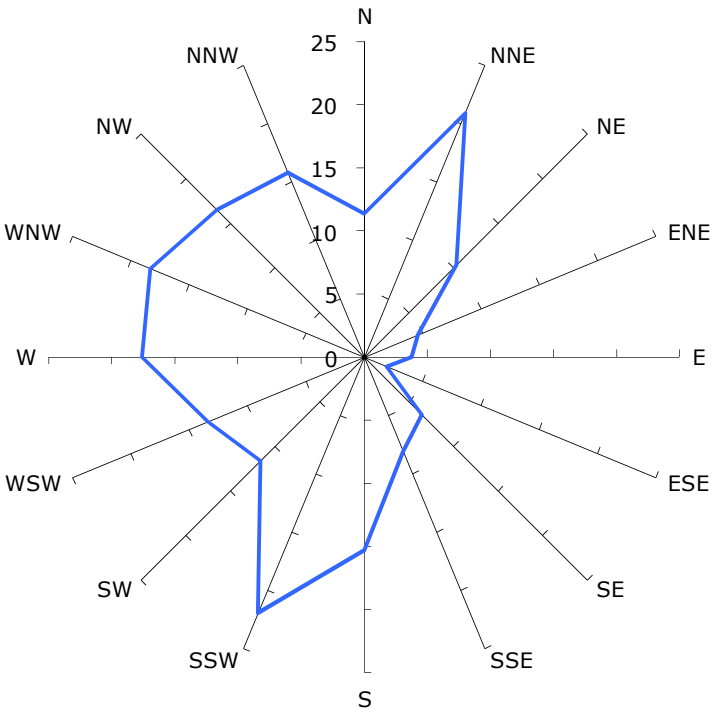


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

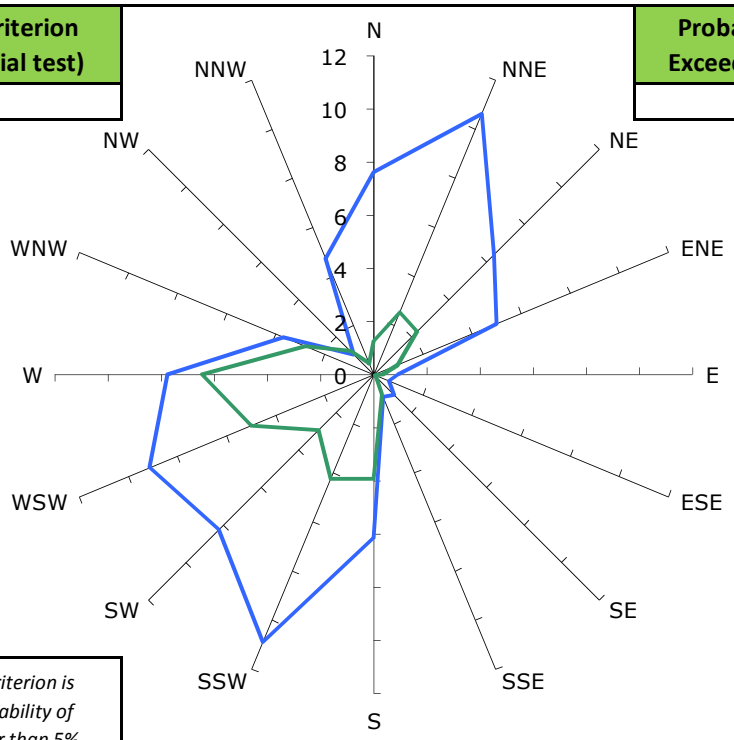


Desired Criterion
23m/s

Measured Wind Speeds at Point 70

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
10%	0%



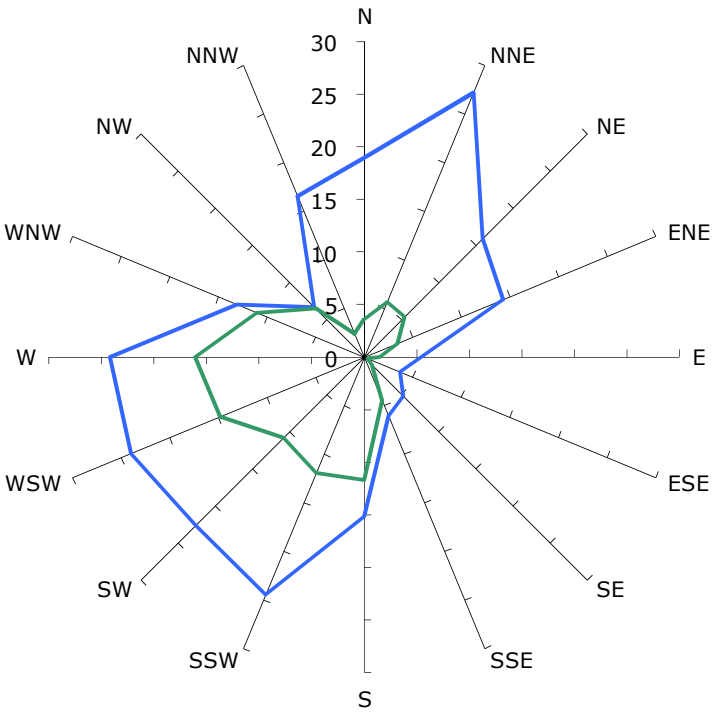
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

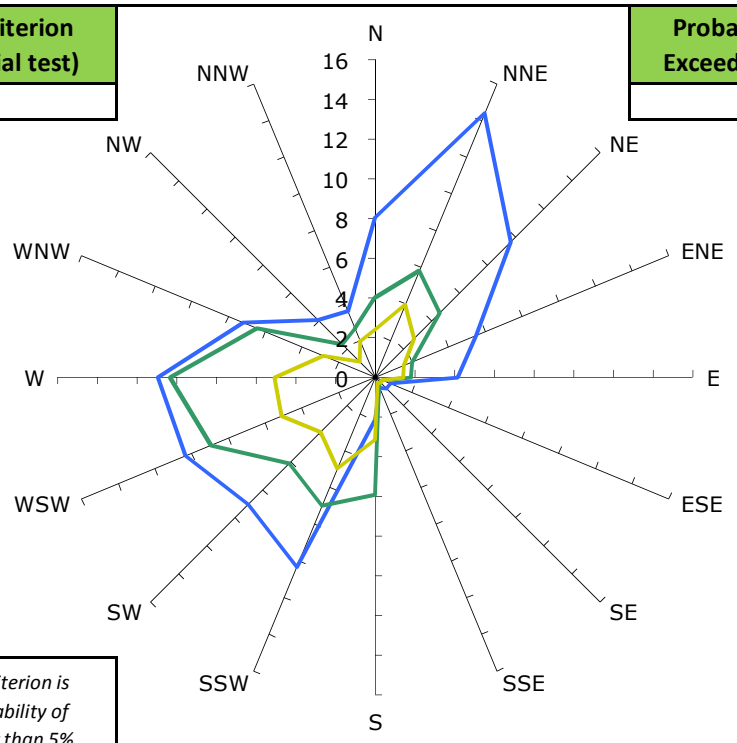


Desired Criterion
23m/s

Measured Wind Speeds at Point 71

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
17%	0%



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

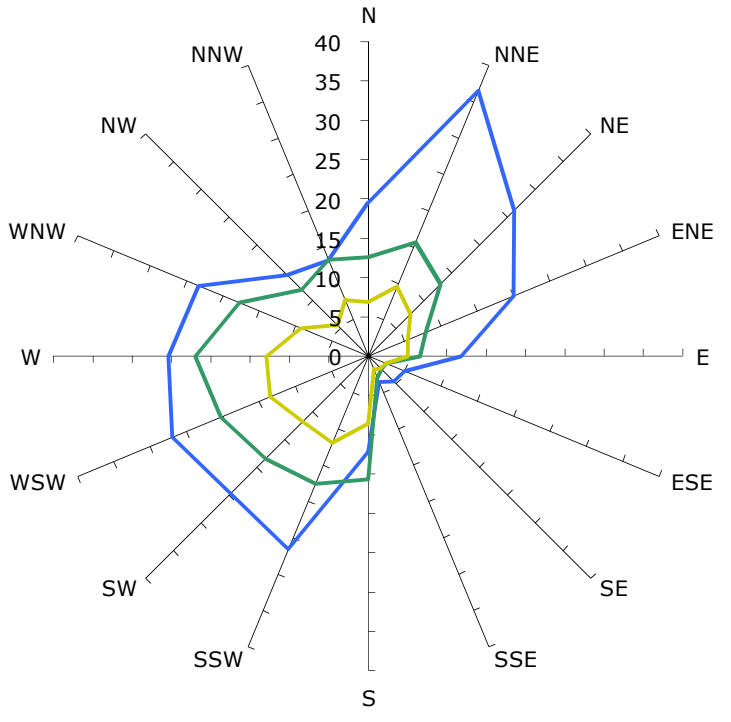
Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Inclusion of 4 more trees to the north

Annual Maximum Gust (m/s)

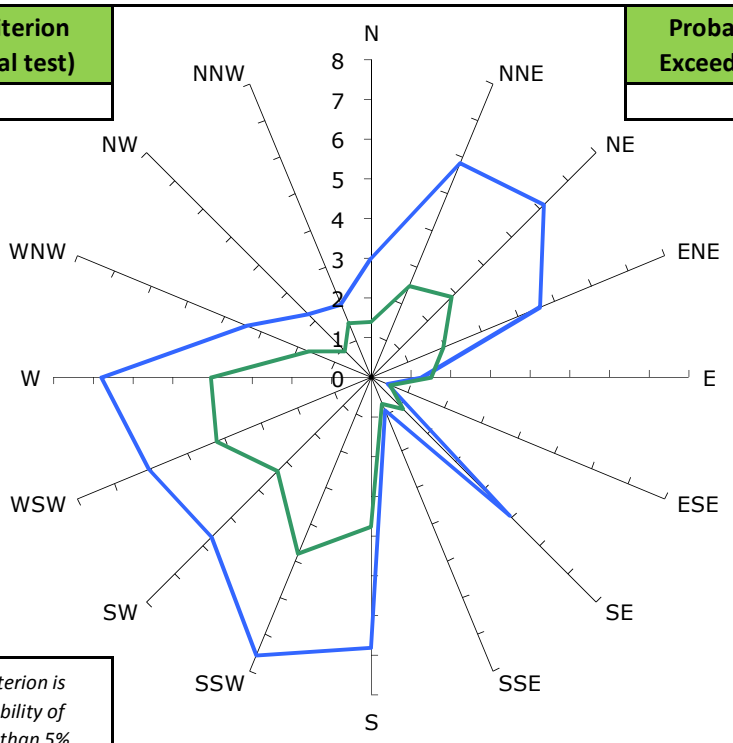


Desired Criterion
23m/s

Measured Wind Speeds at Point 72

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
4%	N/A



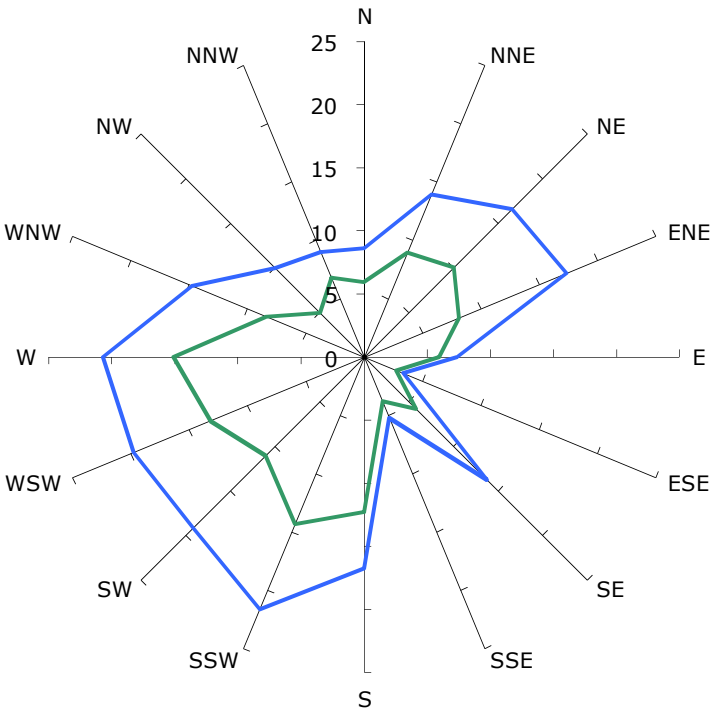
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

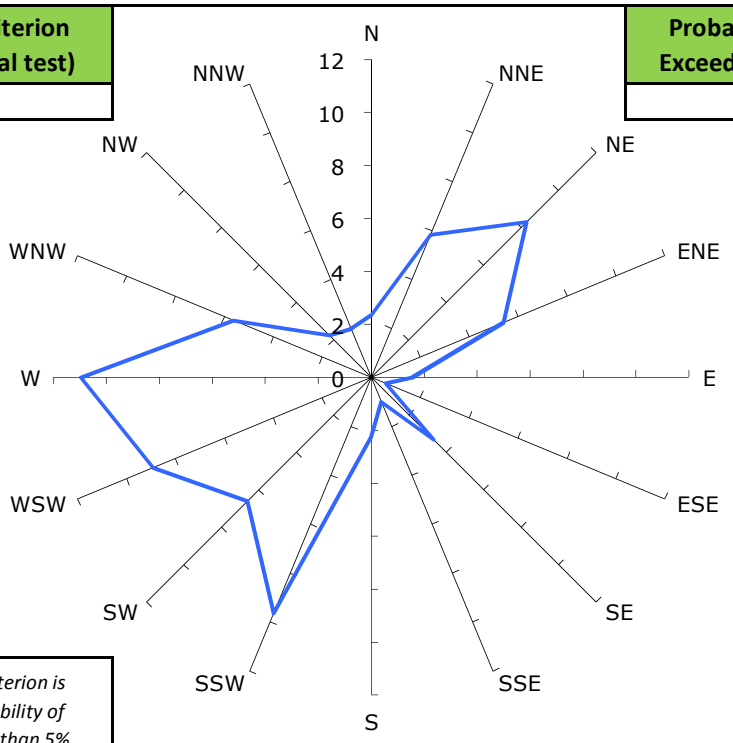


Desired Criterion
23m/s

Measured Wind Speeds at Point 73

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
10%	N/A

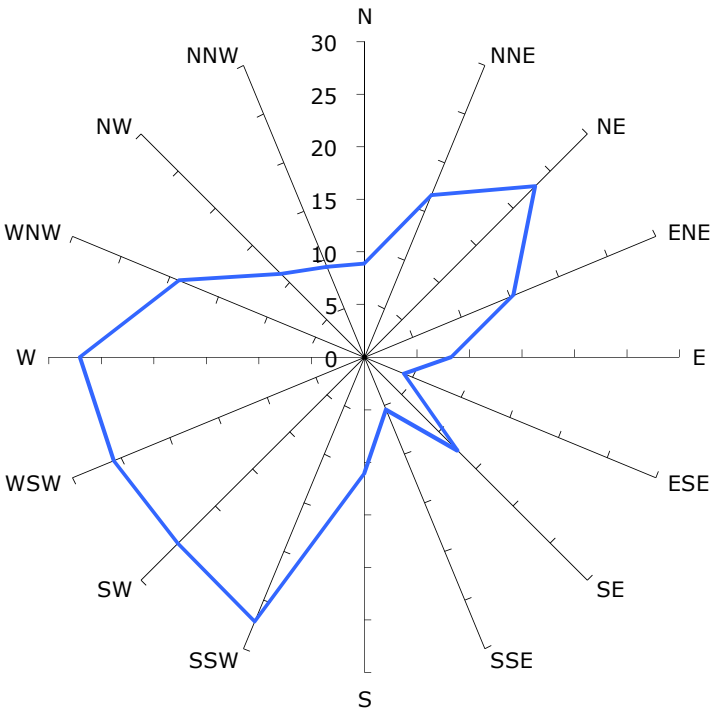


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

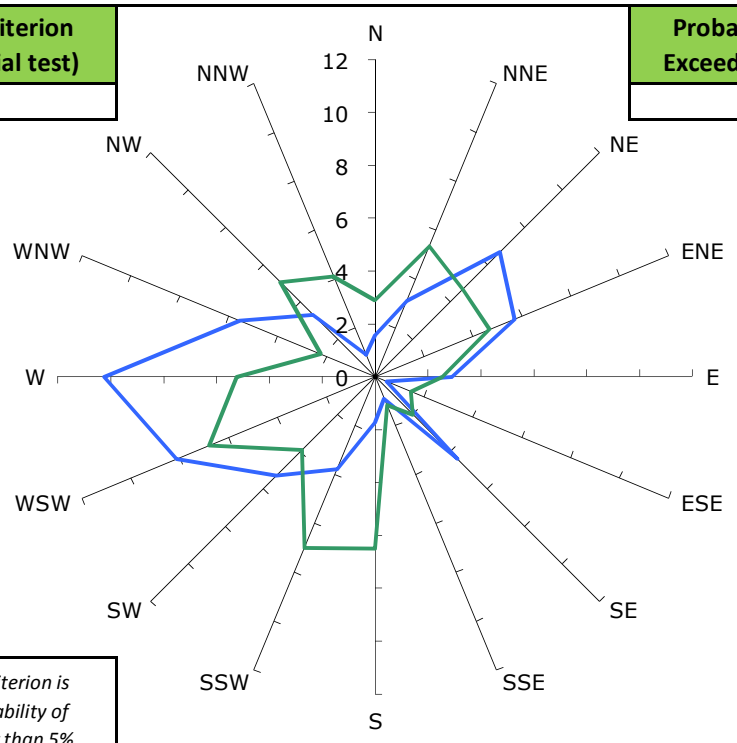


Desired Criterion
23m/s

Measured Wind Speeds at Point 74

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
5%	2%



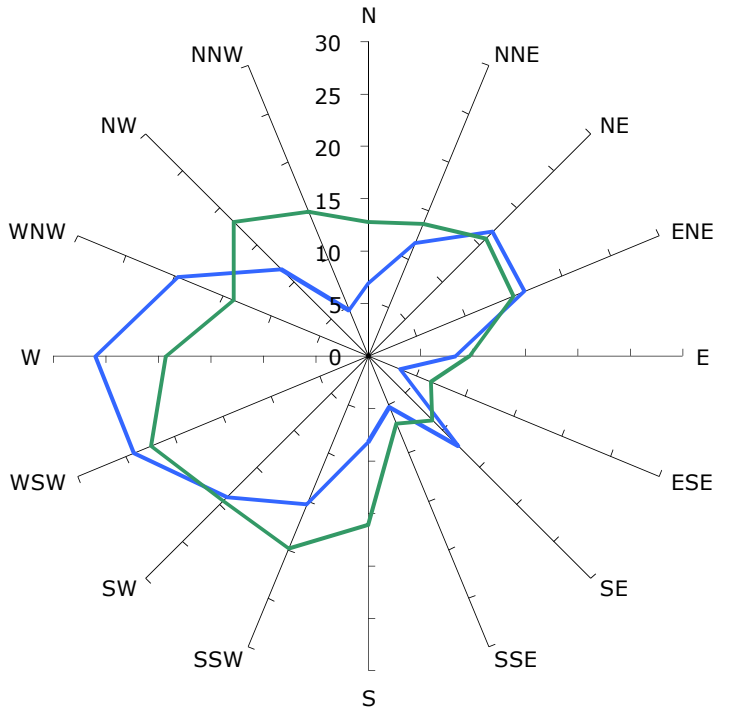
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

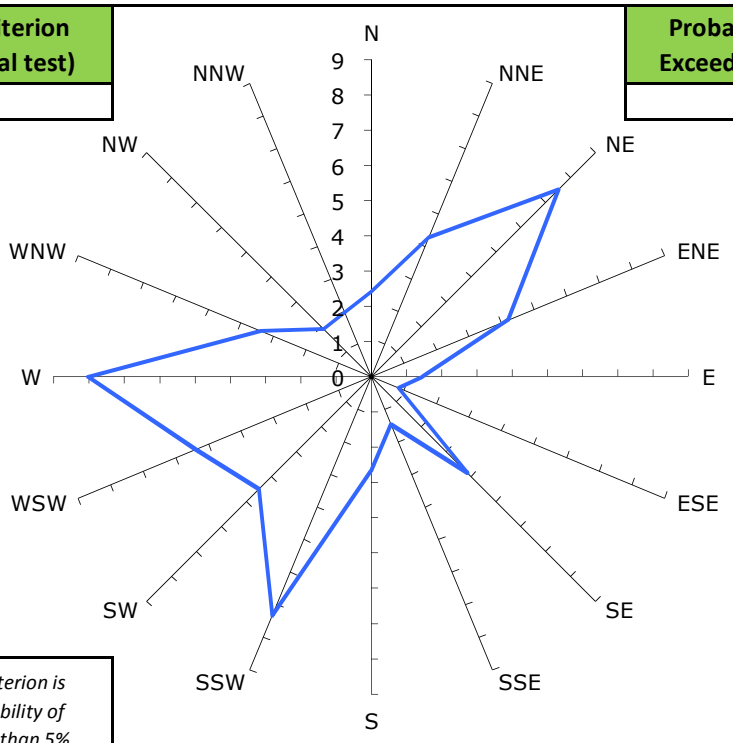


Desired Criterion
23m/s

Measured Wind Speeds at Point 75

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
4%	N/A

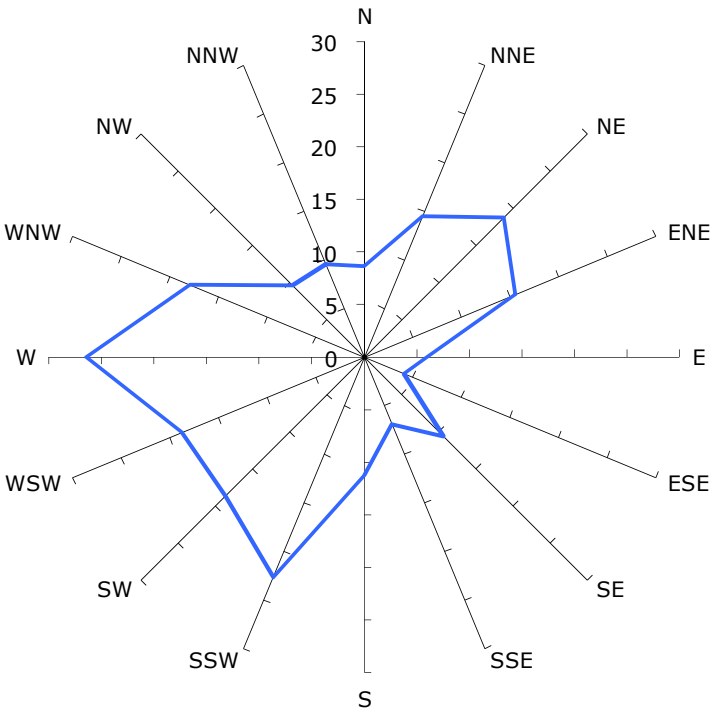


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

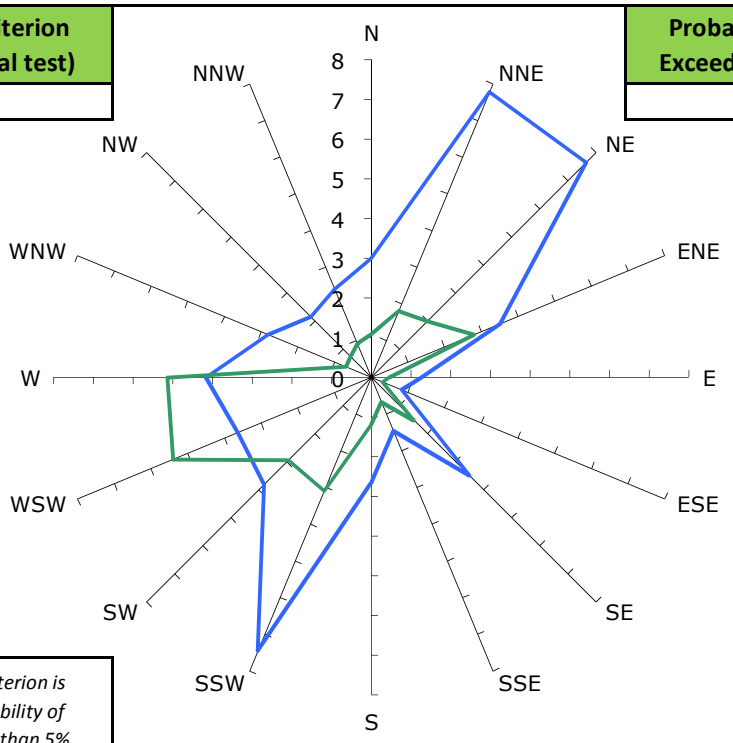


Desired Criterion
23m/s

Measured Wind Speeds at Point 76

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
5%	0%



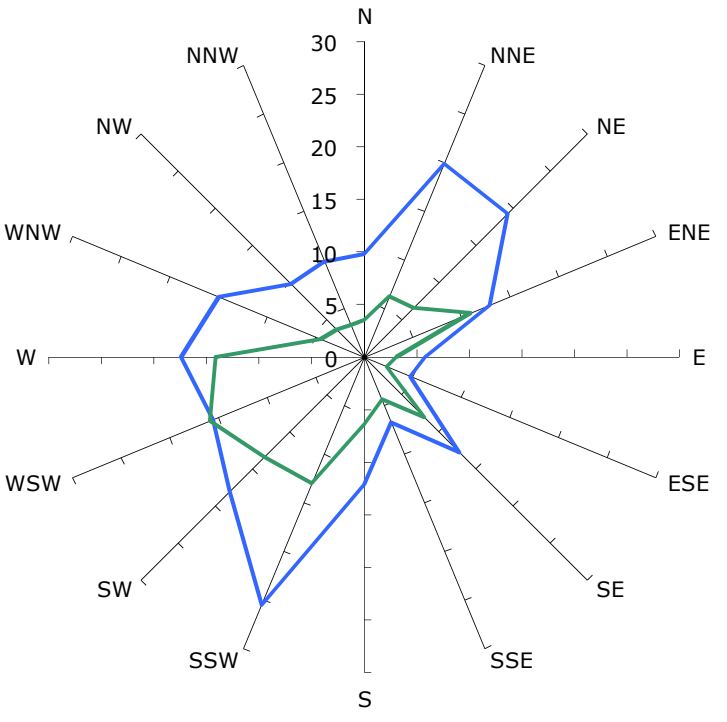
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

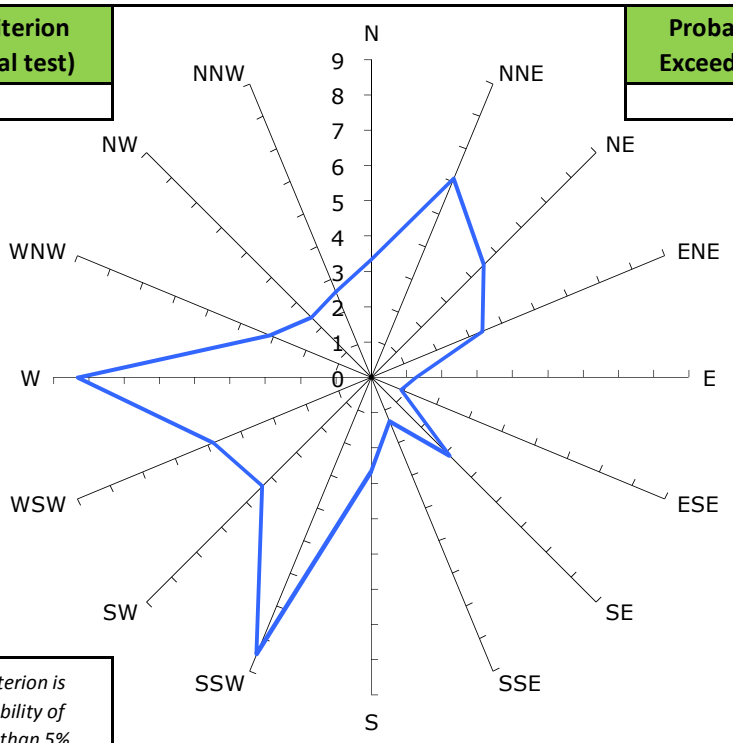


Desired Criterion
23m/s

Measured Wind Speeds at Point 77

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
4%	N/A

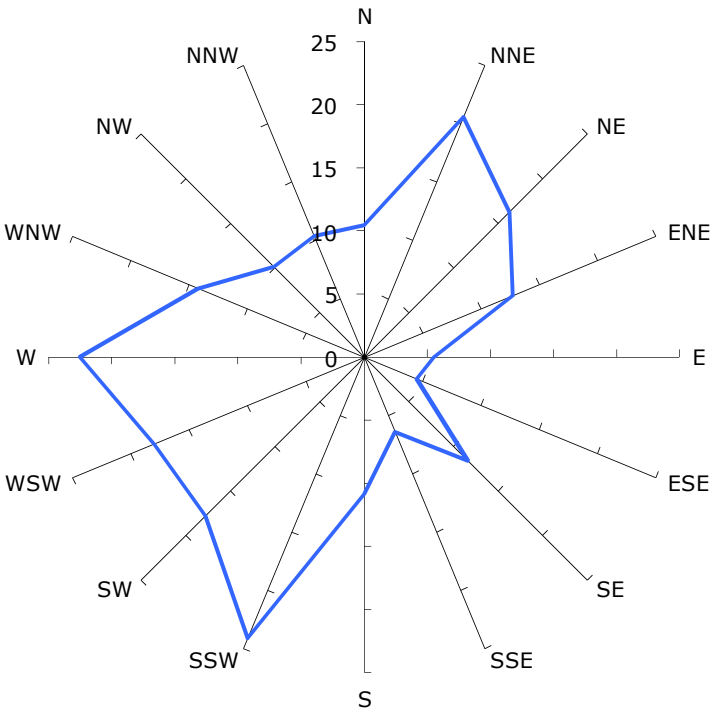


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

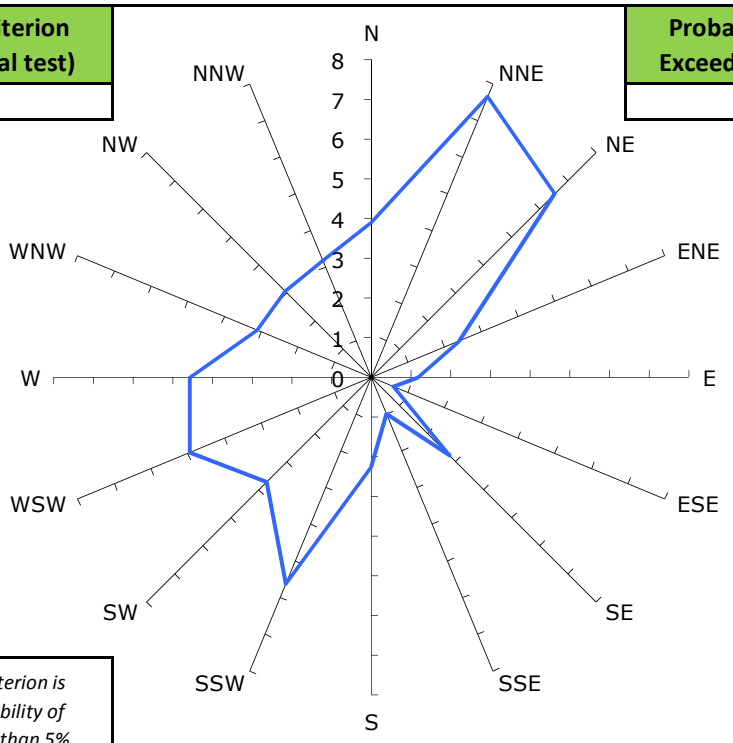


Desired Criterion
23m/s

Measured Wind Speeds at Point 78

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
3%	N/A

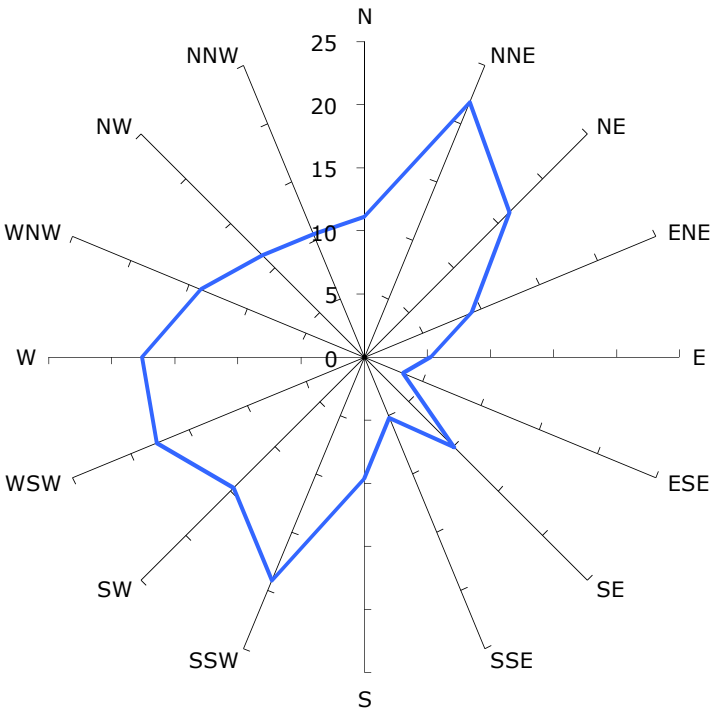


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

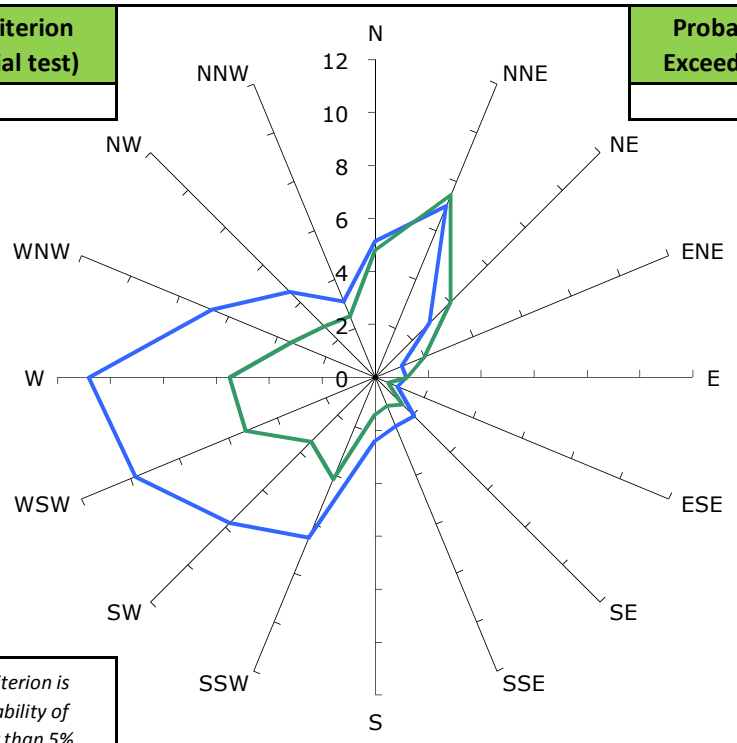


Desired Criterion
23m/s

Measured Wind Speeds at Point 82

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
8%	2%



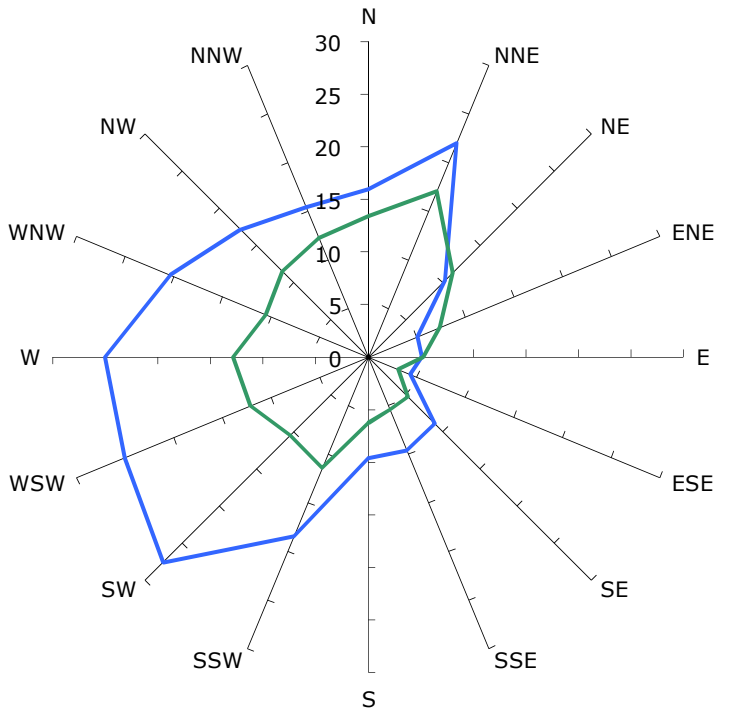
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

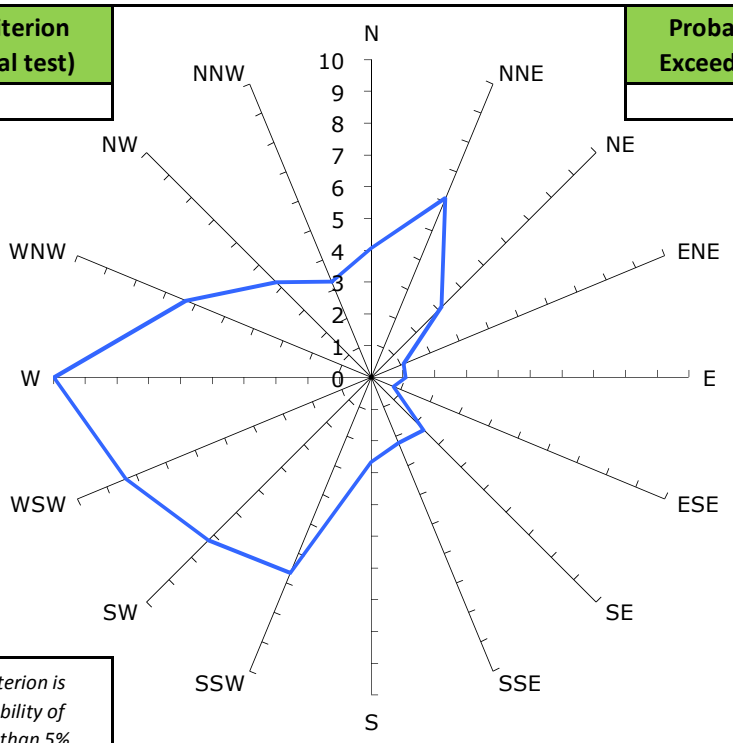


Desired Criterion
23m/s

Measured Wind Speeds at Point 83

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
6%	N/A

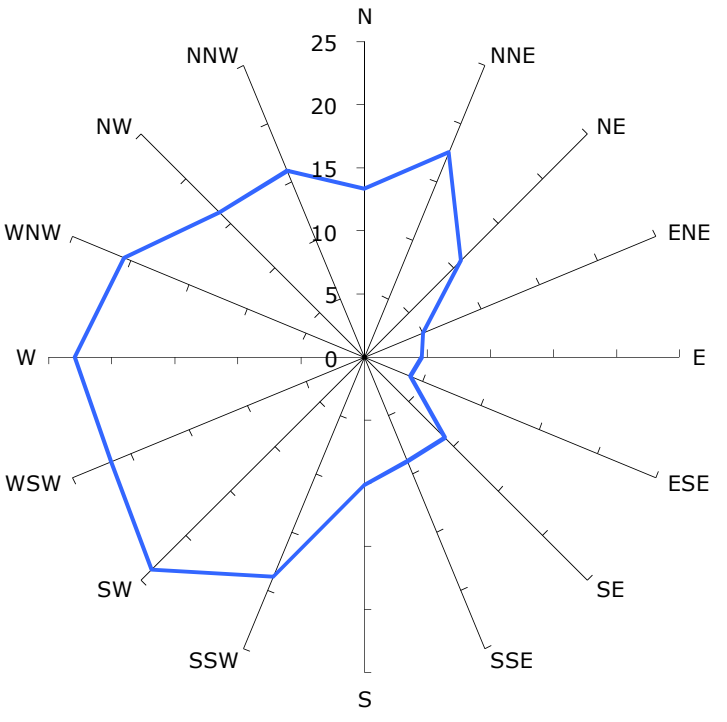


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

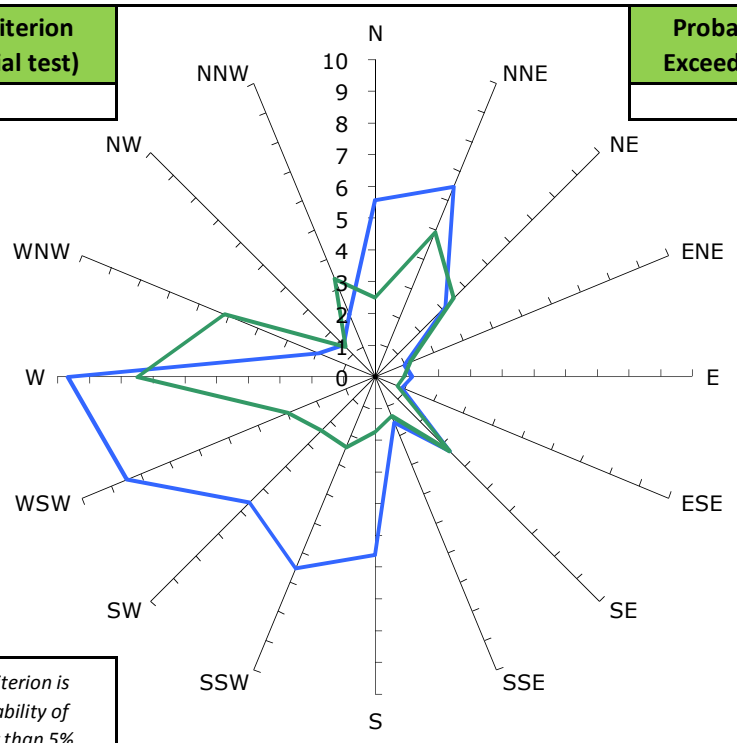


Desired Criterion
23m/s

Measured Wind Speeds at Point 84

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
14%	5%



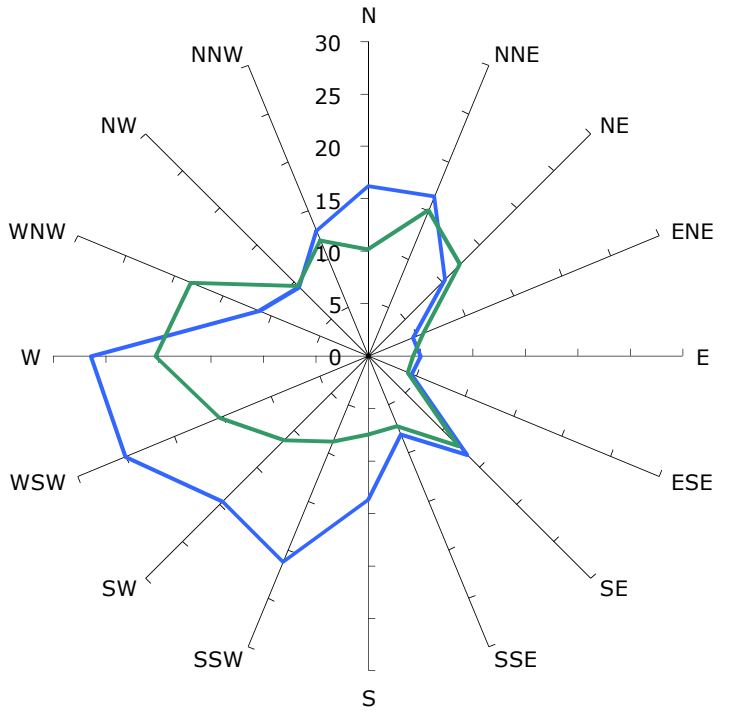
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

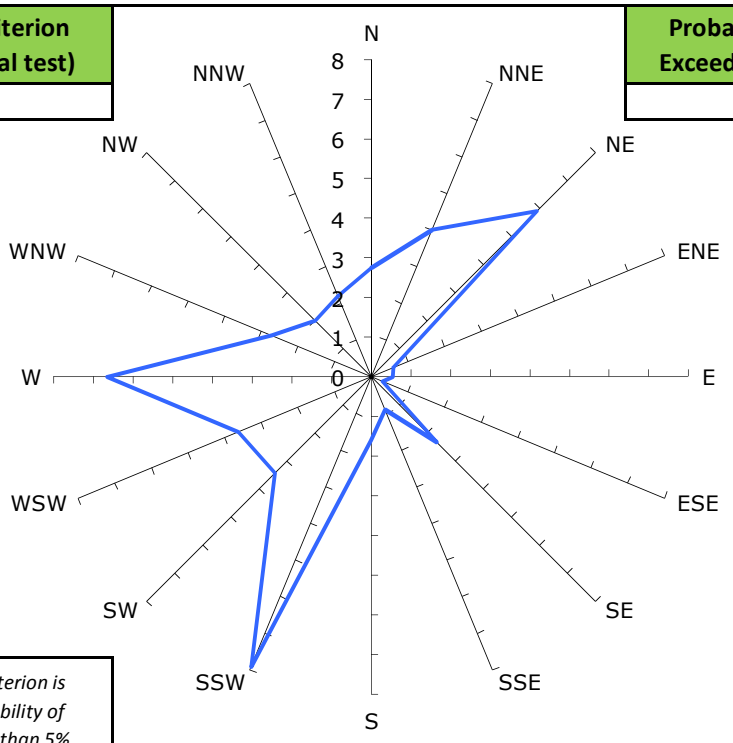


Desired Criterion
23m/s

Measured Wind Speeds at Point 85

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
7%	N/A

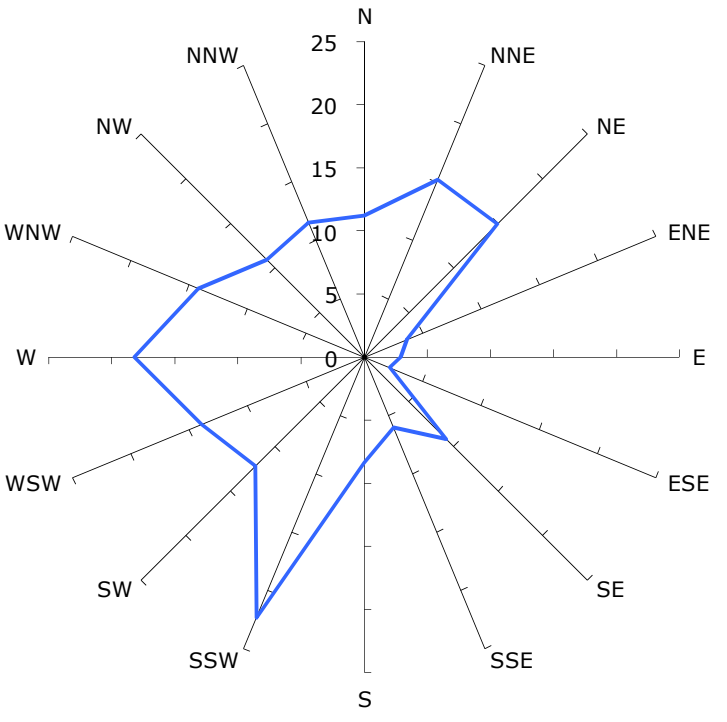


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

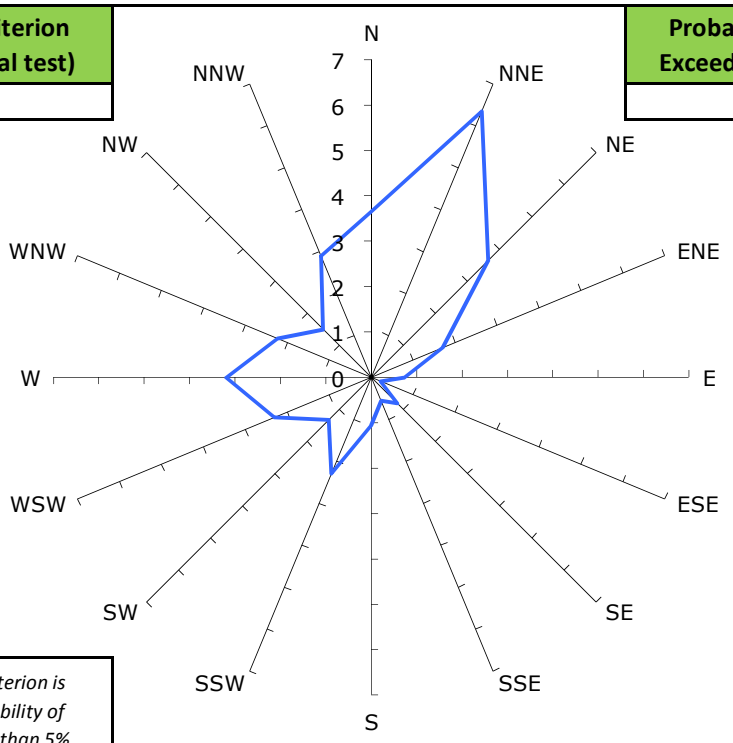


Desired Criterion
23m/s

Measured Wind Speeds at Point 86

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
0%	N/A

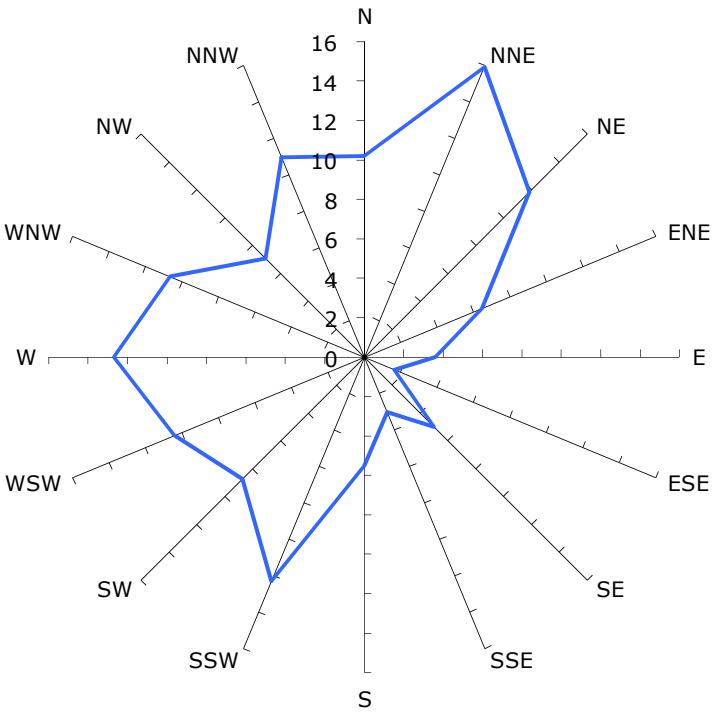


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

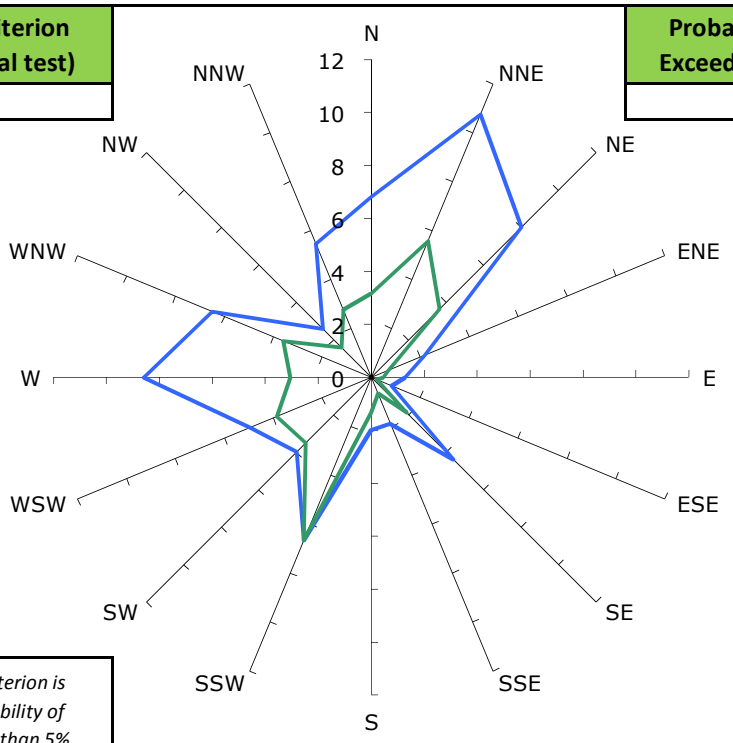


Desired Criterion
23m/s

Measured Wind Speeds at Point 87

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
9%	1%



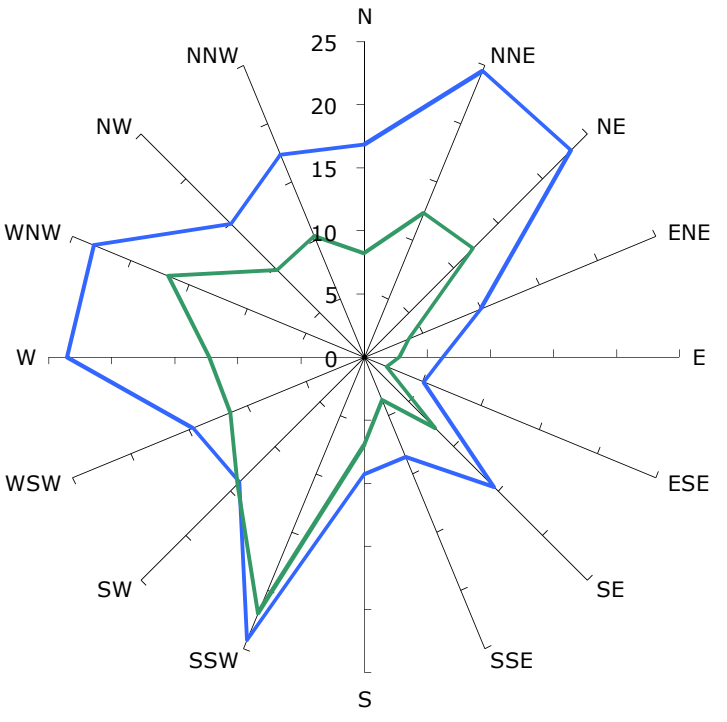
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

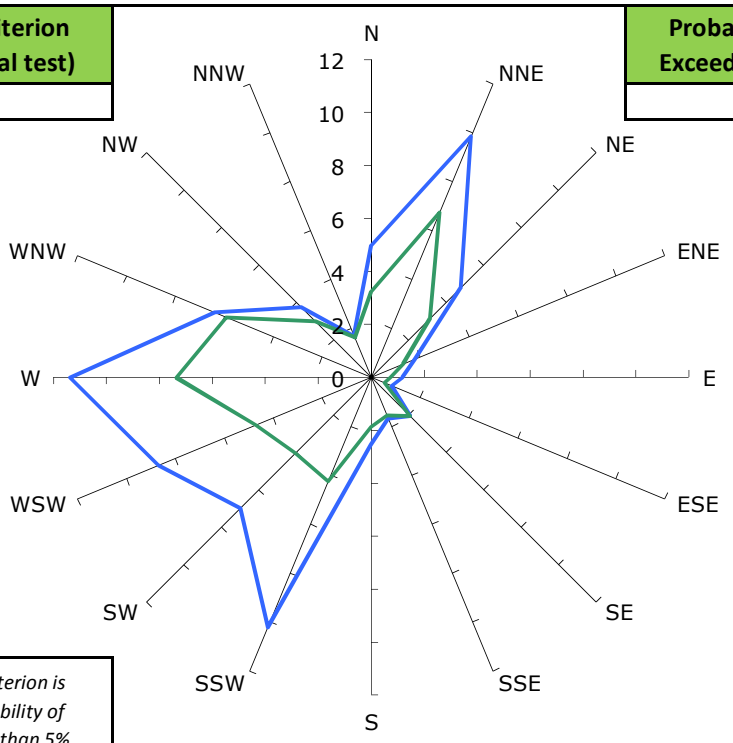


Desired Criterion
23m/s

Measured Wind Speeds at Point 88

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
11%	2%



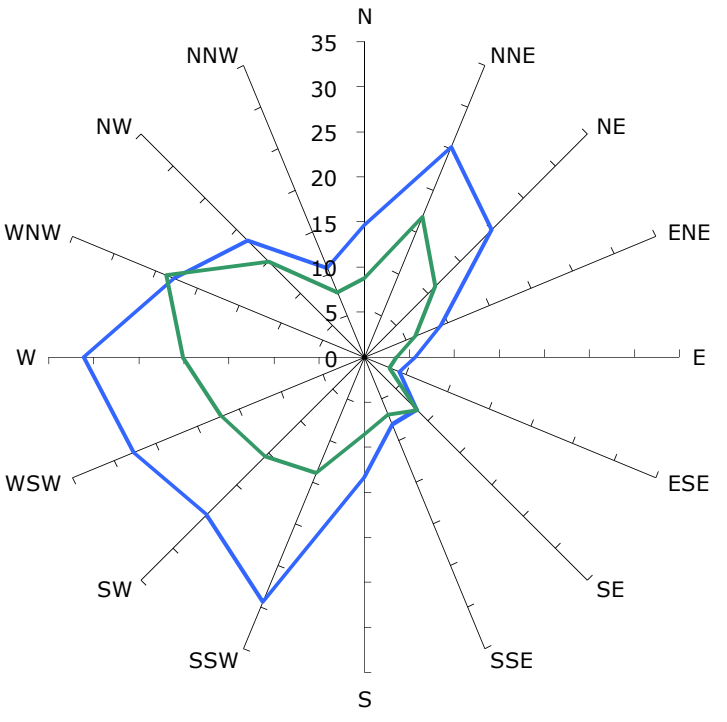
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

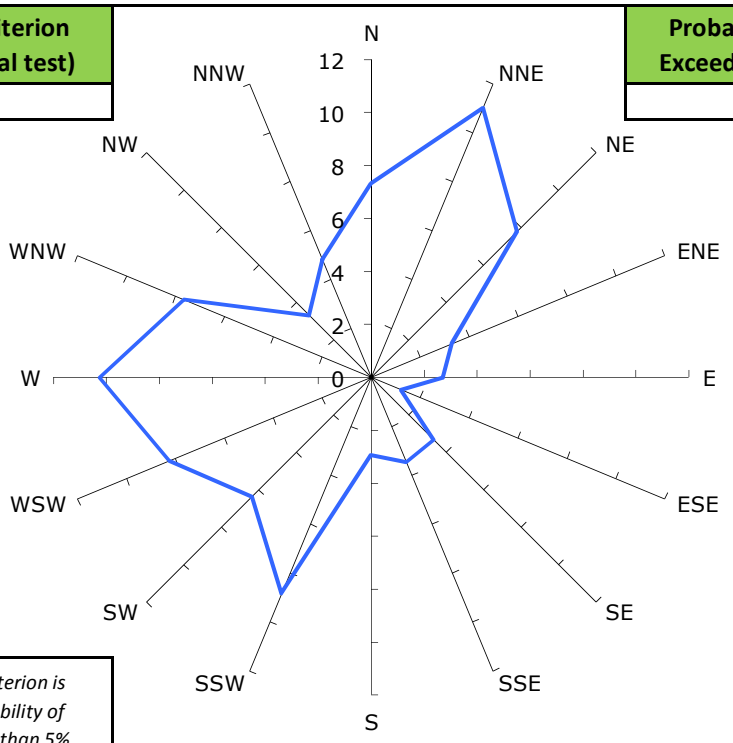


Desired Criterion
23m/s

Measured Wind Speeds at Point 89

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
14%	N/A

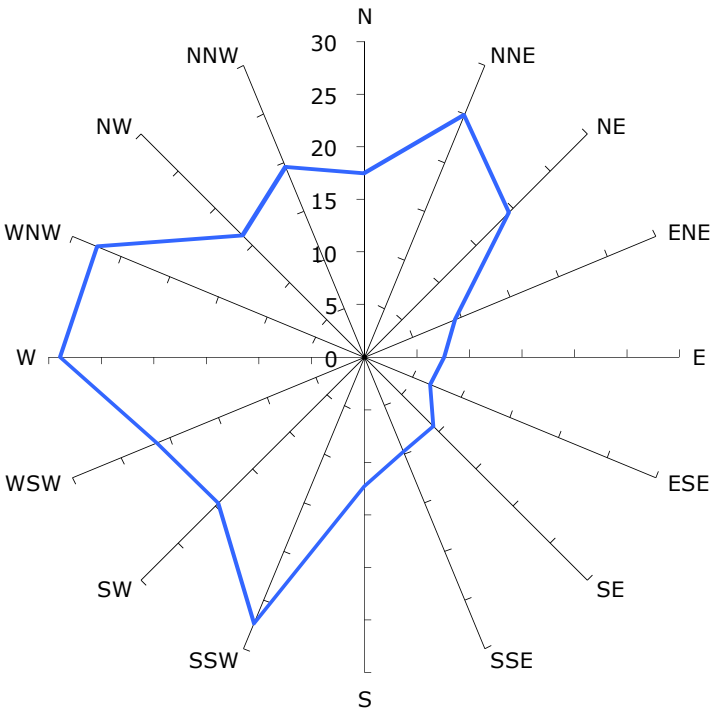


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

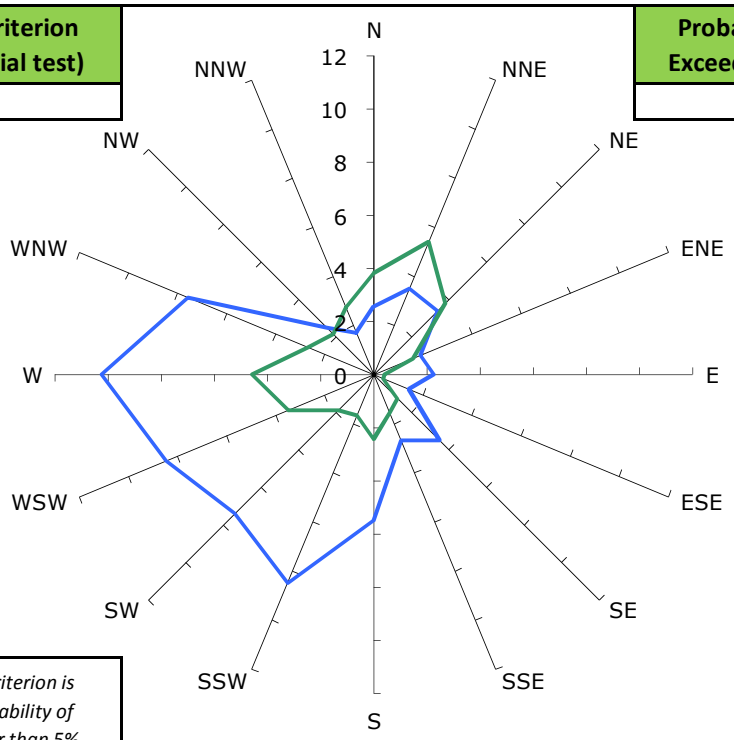


Desired Criterion
23m/s

Measured Wind Speeds at Point 90

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
8%	0%



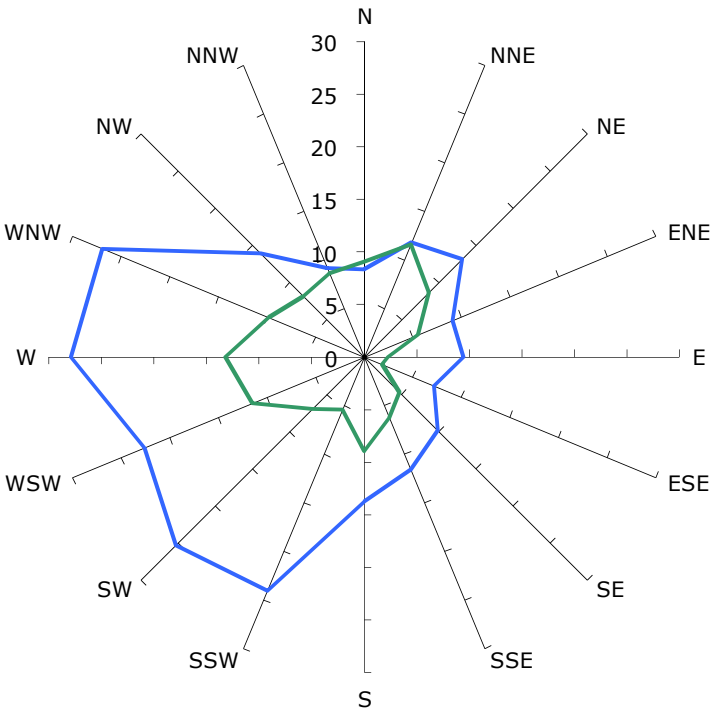
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 1 - With R4A only as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)

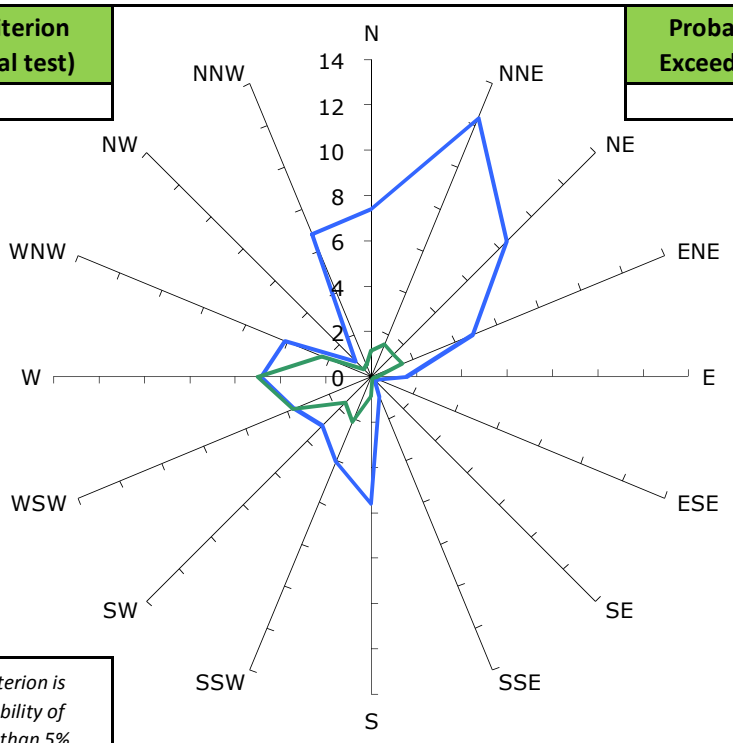


Desired Criterion
23m/s

Measured Wind Speeds at Point 95

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
14%	0%



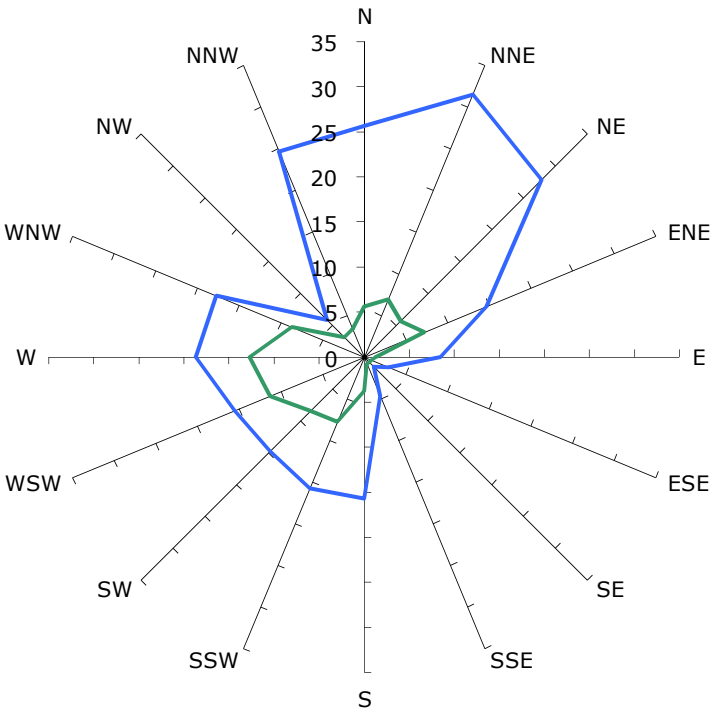
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 1 - With R4A only as proposed. Without the inclusion of 2m high screens

With the inclusion of 2m high screens

Annual Maximum Gust (m/s)

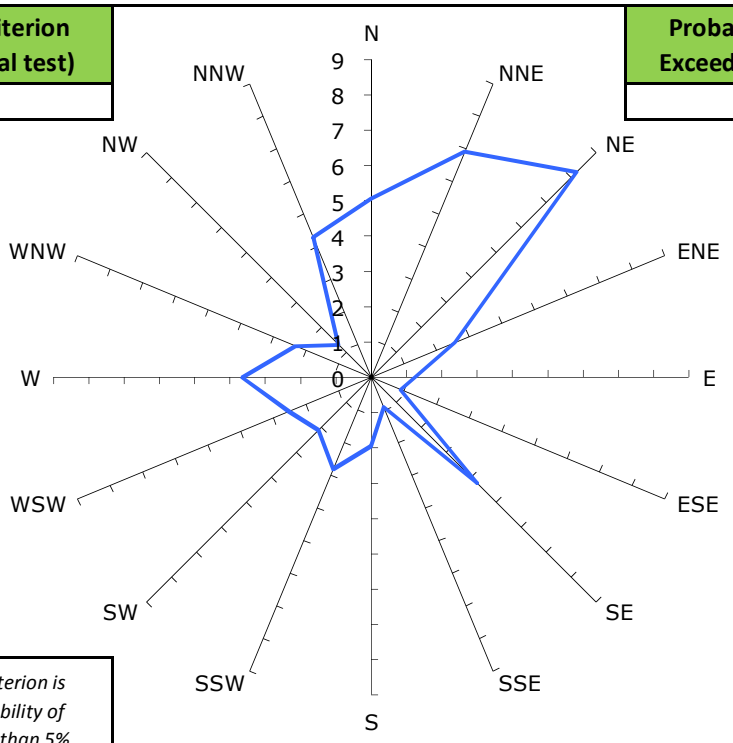


Desired Criterion
23m/s

Measured Wind Speeds at Point 23

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

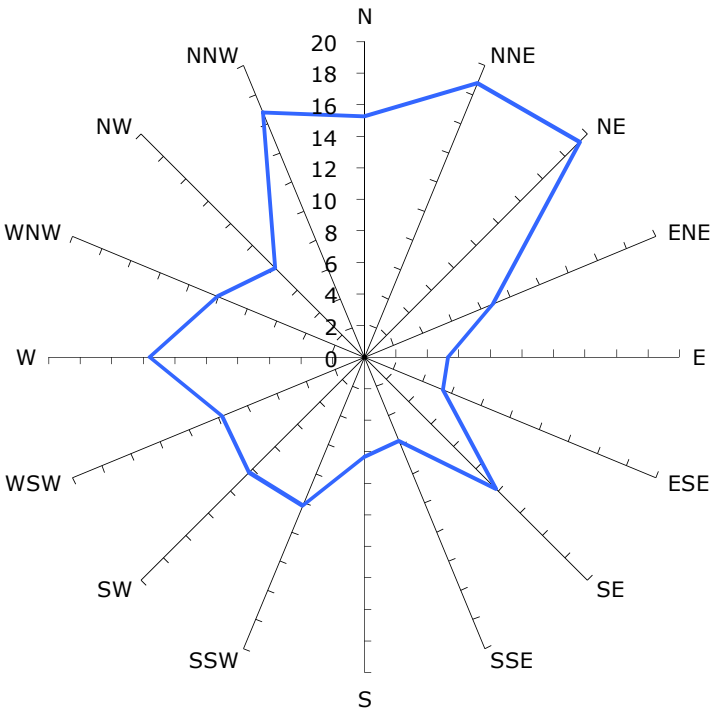


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

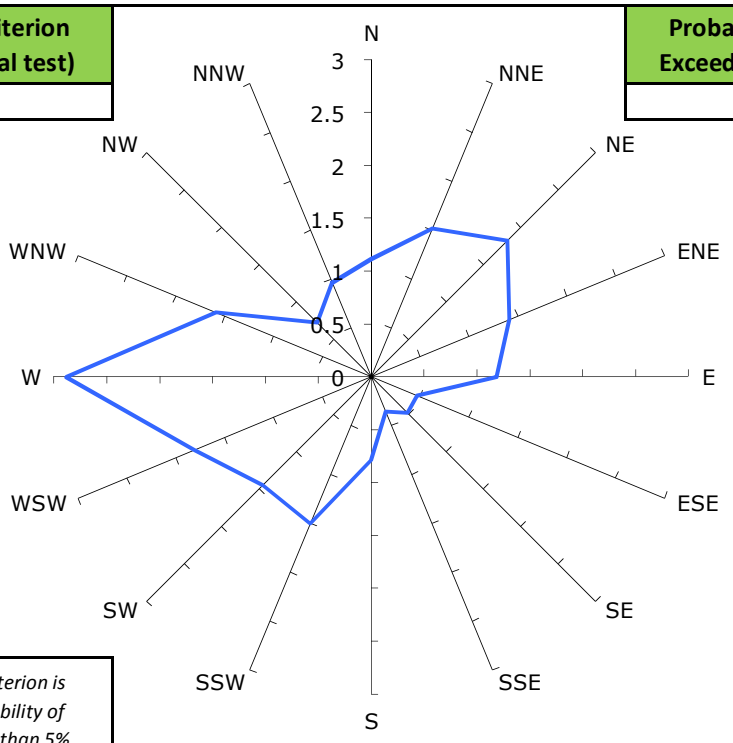


Desired Criterion
23m/s

Measured Wind Speeds at Point 24

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

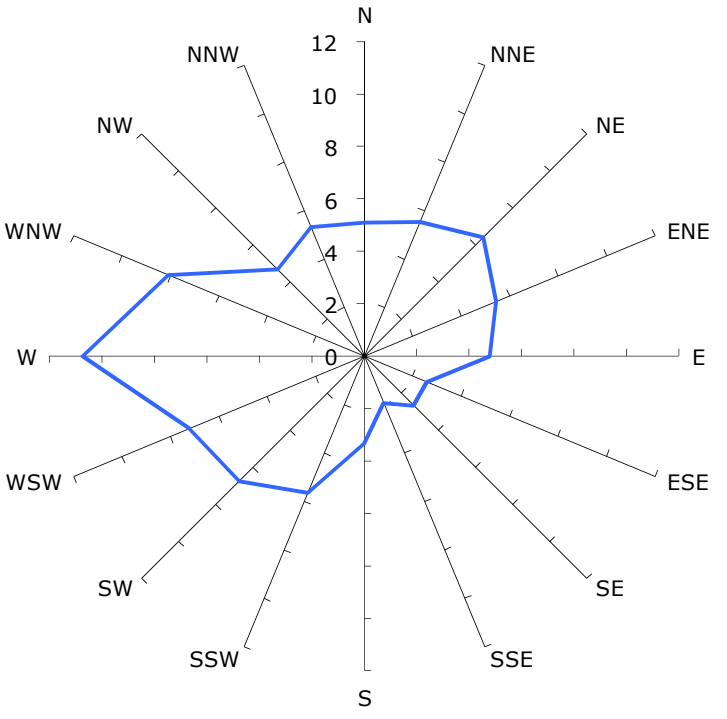


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

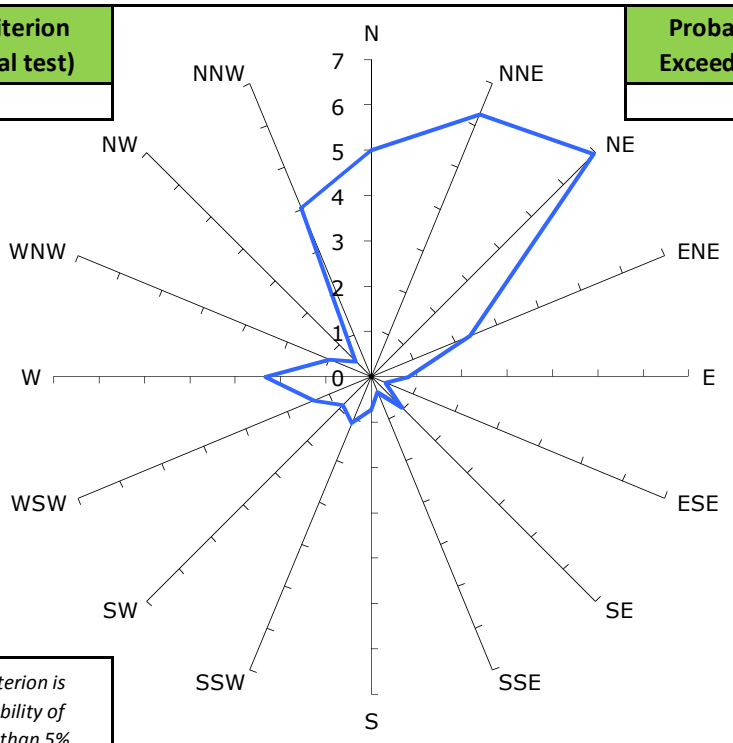


Desired Criterion
23m/s

Measured Wind Speeds at Point 25

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

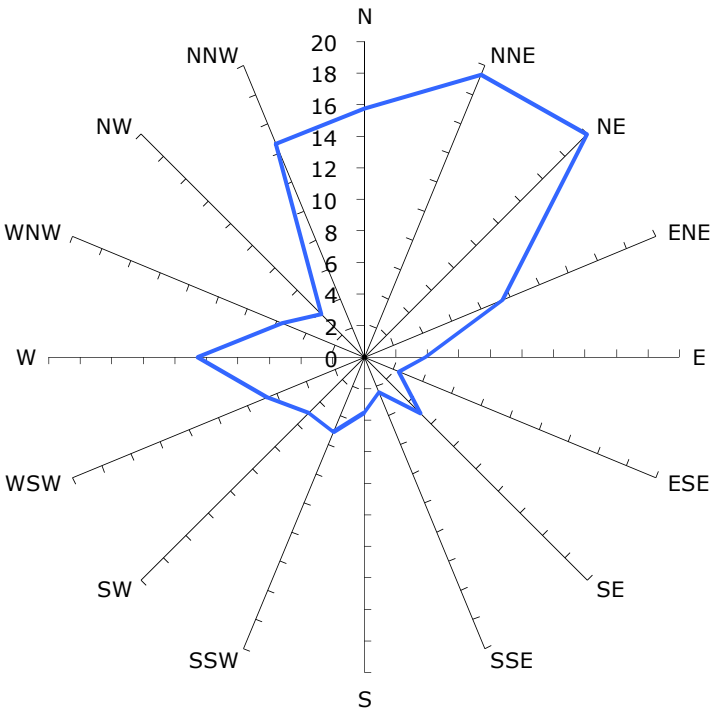


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

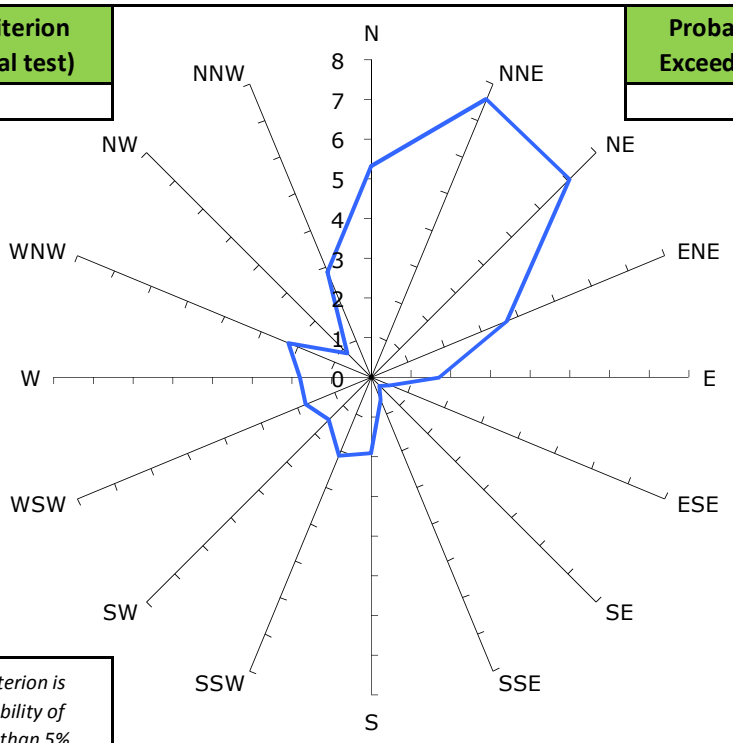


Desired Criterion
23m/s

Measured Wind Speeds at Point 26

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

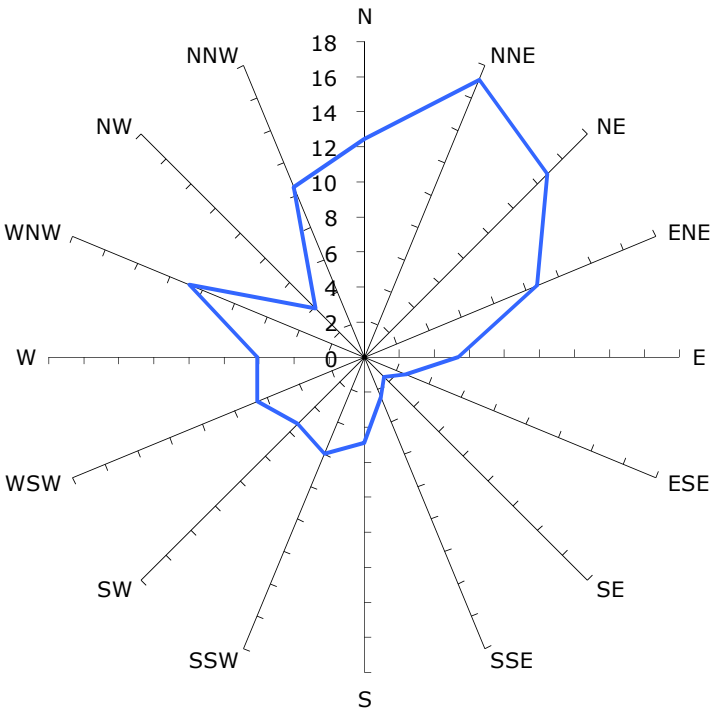


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

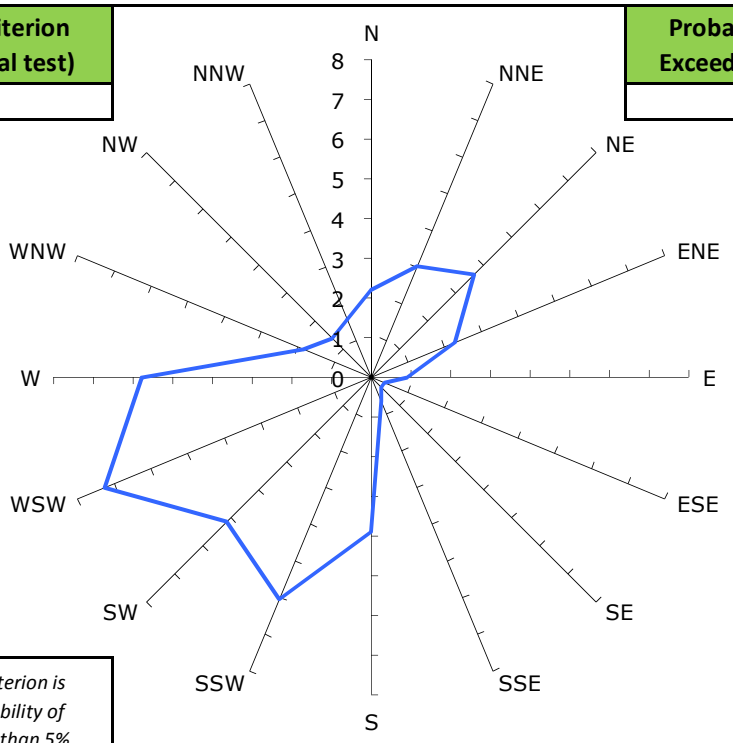


Desired Criterion
23m/s

Measured Wind Speeds at Point 27

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

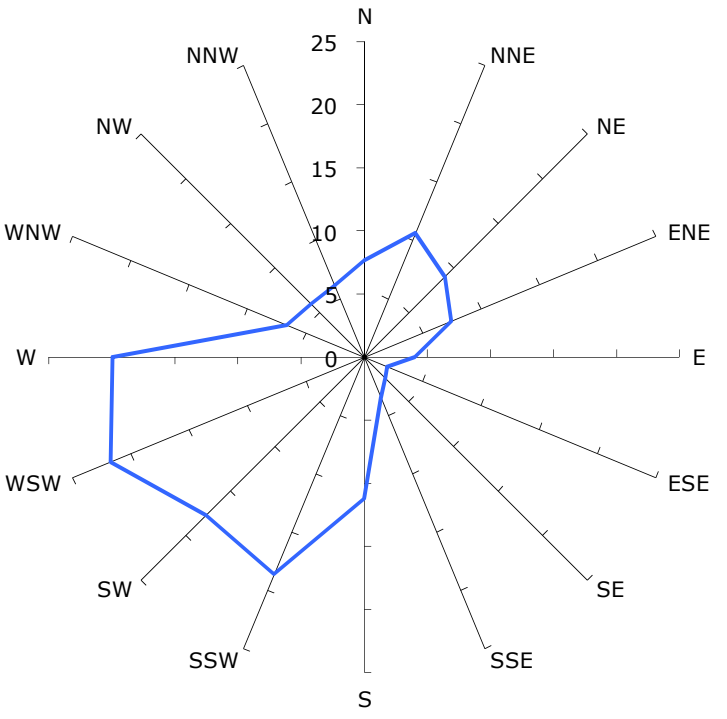


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

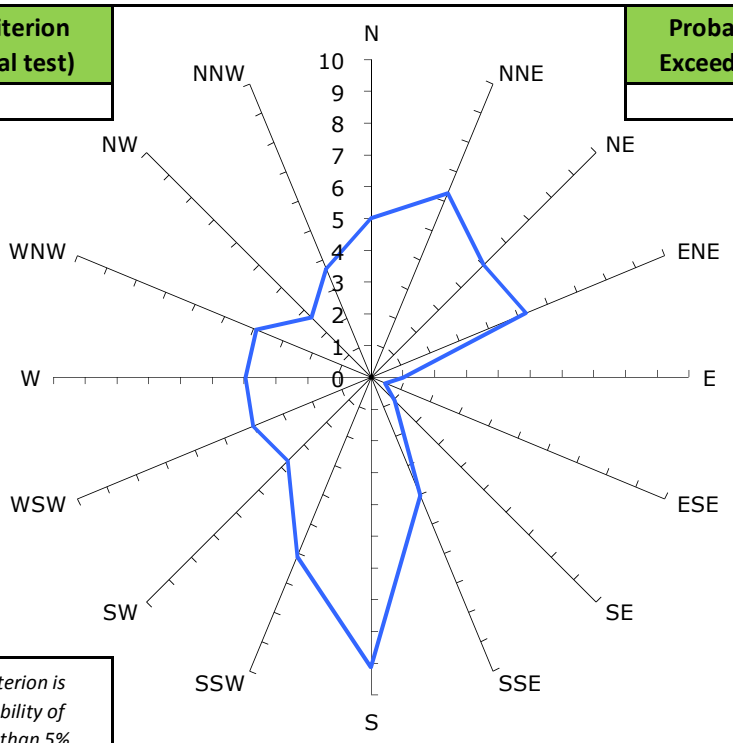


Desired Criterion
23m/s

Measured Wind Speeds at Point 28

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
N/A	N/A

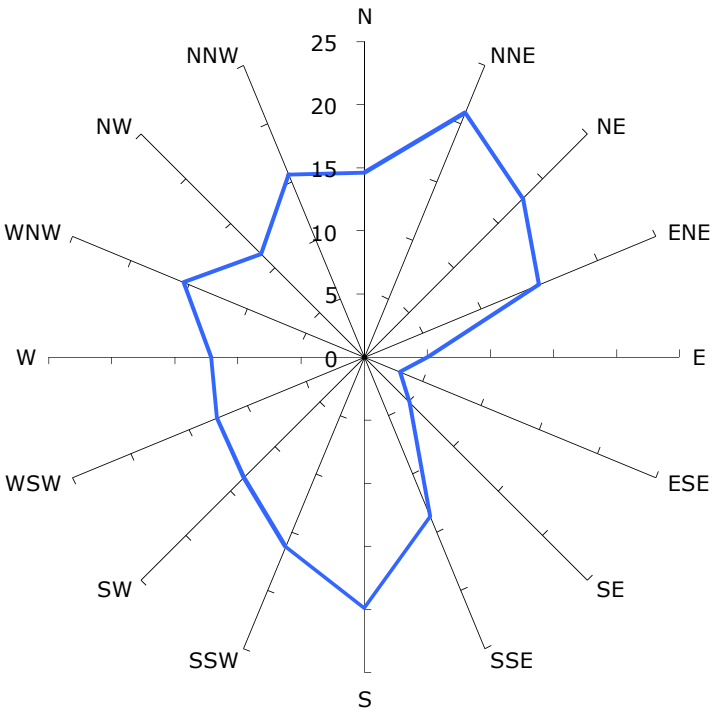


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
N/A

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

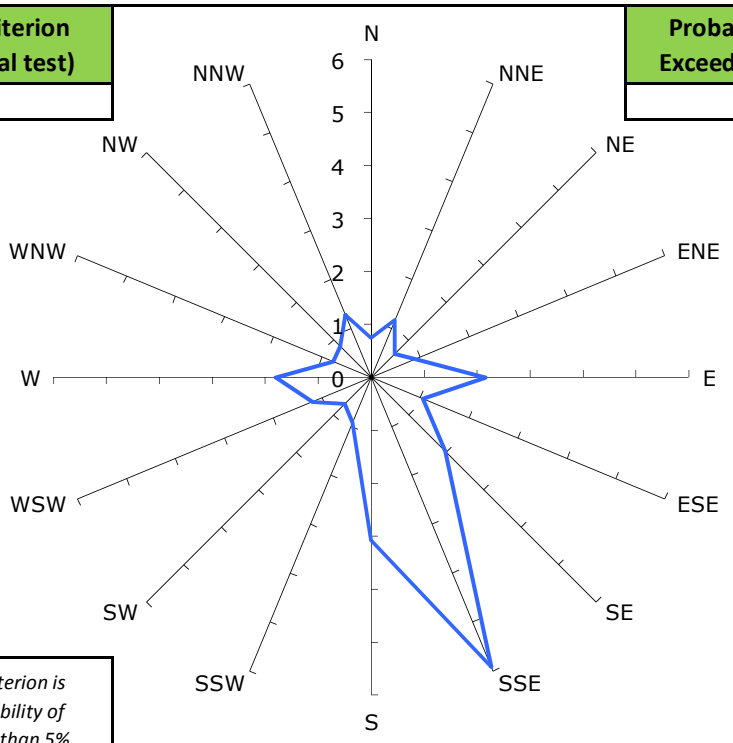


Desired Criterion
23m/s

Measured Wind Speeds at Point 41

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
1%	N/A

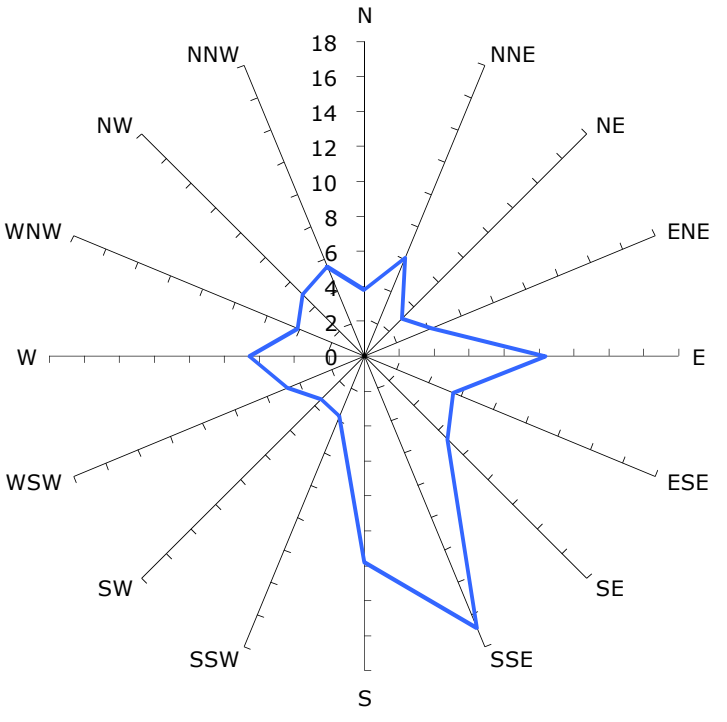


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

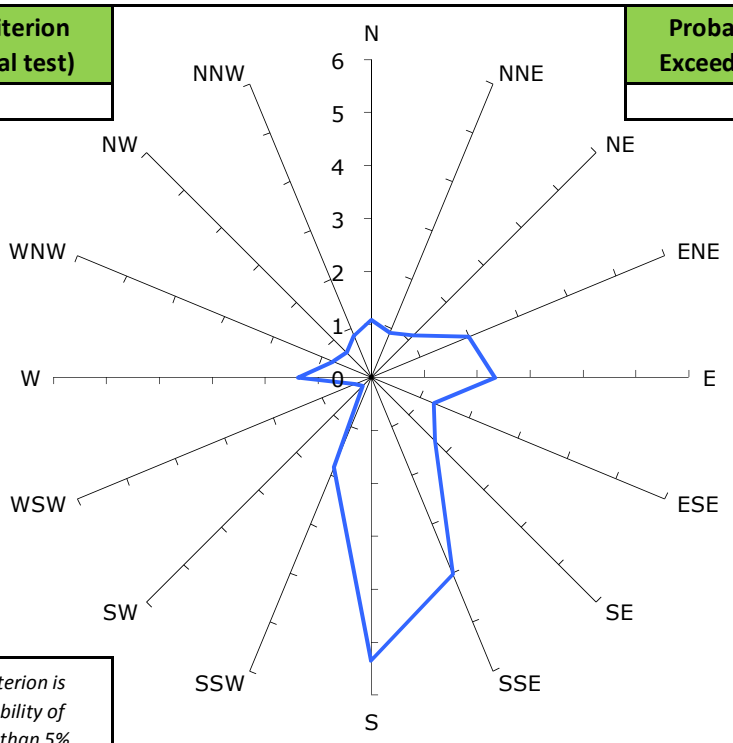


Desired Criterion
23m/s

Measured Wind Speeds at Point 42

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
1%	N/A

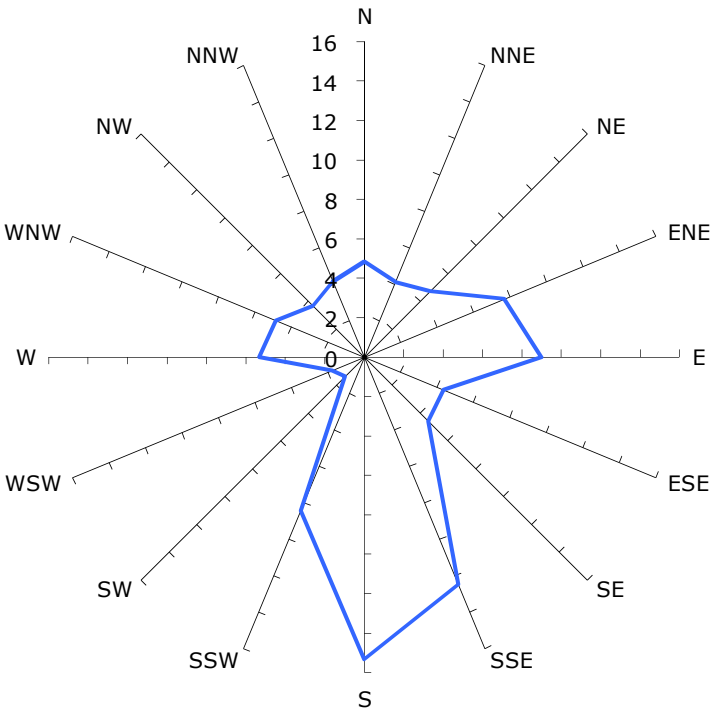


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

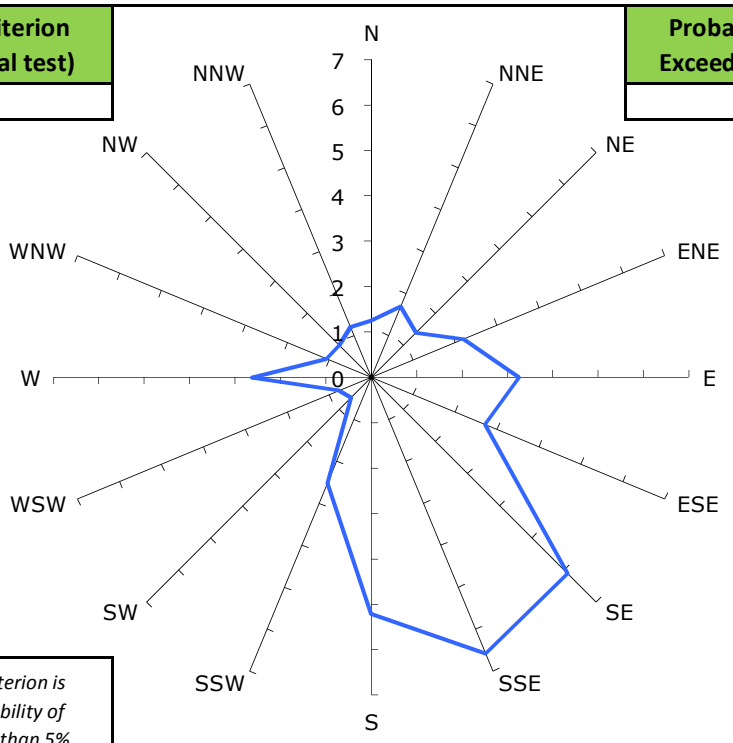


Desired Criterion
23m/s

Measured Wind Speeds at Point 43

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
5%	N/A

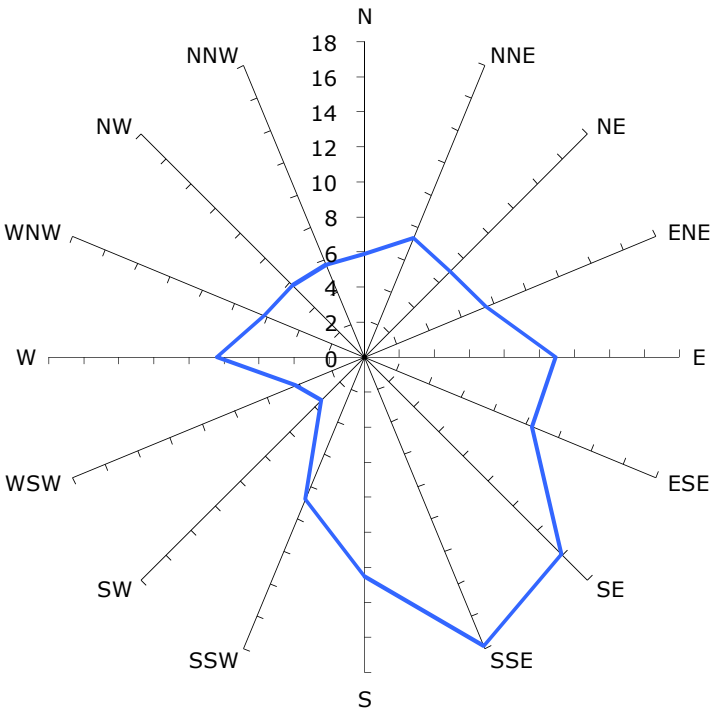


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

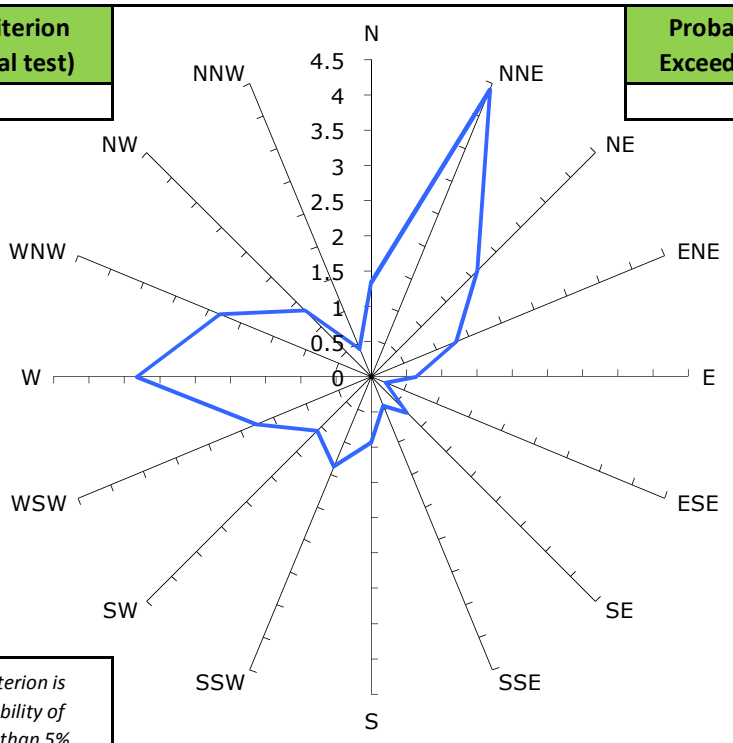


Desired Criterion
23m/s

Measured Wind Speeds at Point 44

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
0%	N/A

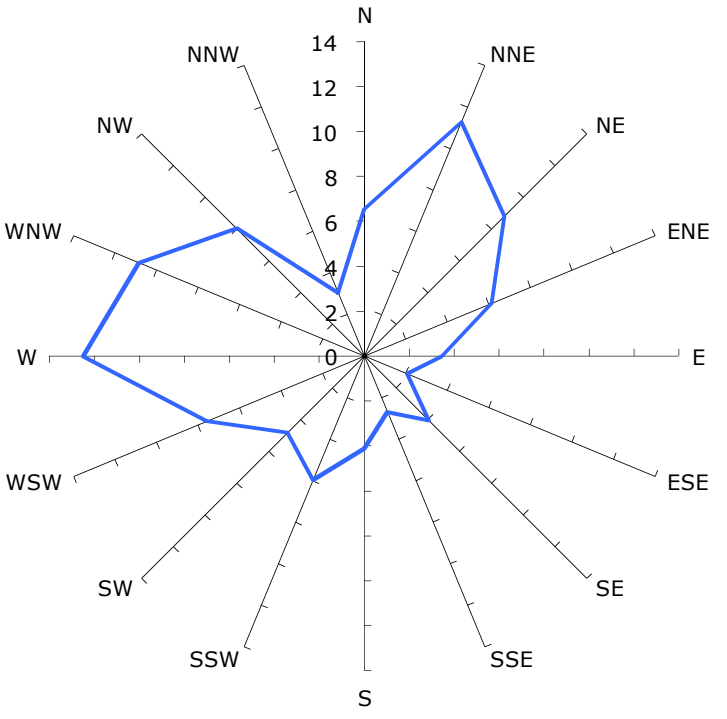


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

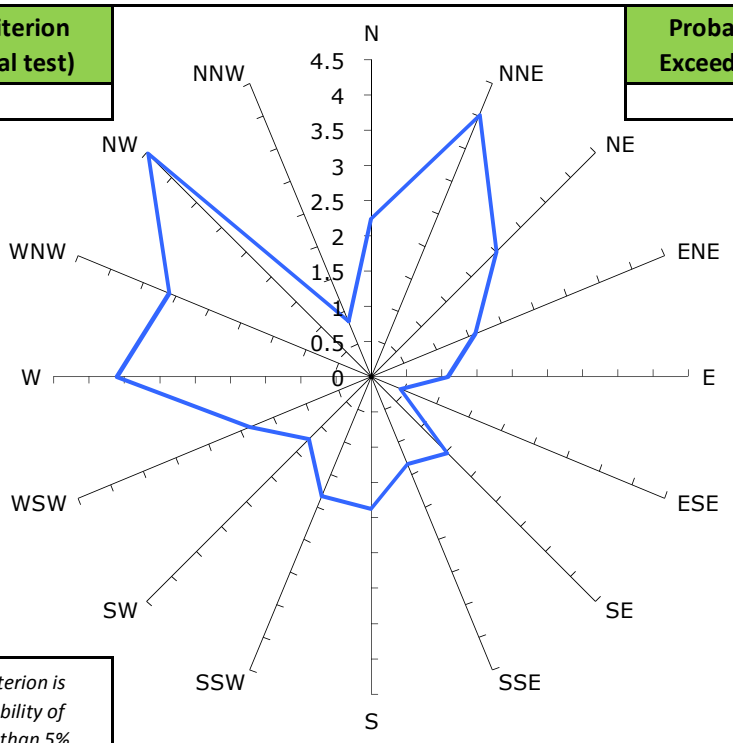


Desired Criterion
23m/s

Measured Wind Speeds at Point 45

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
1%	N/A

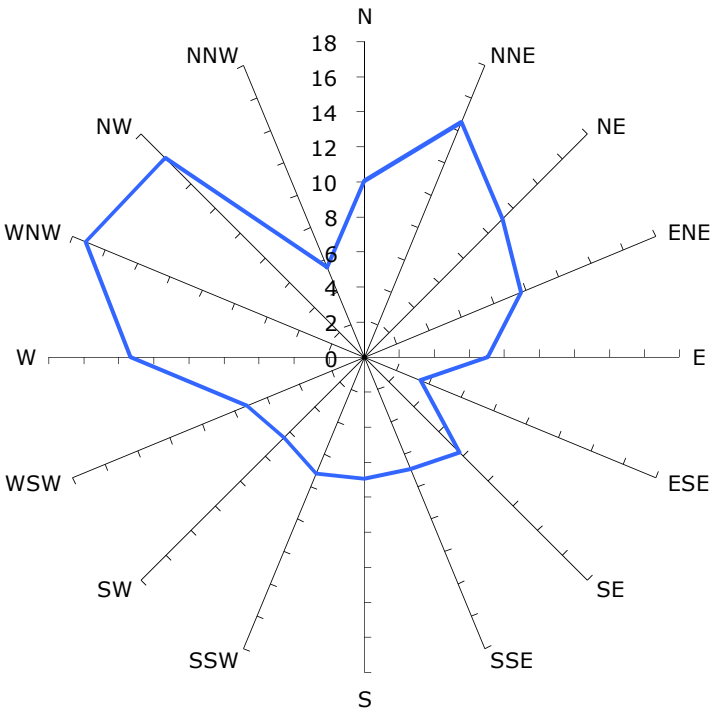


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
5.5m/s

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

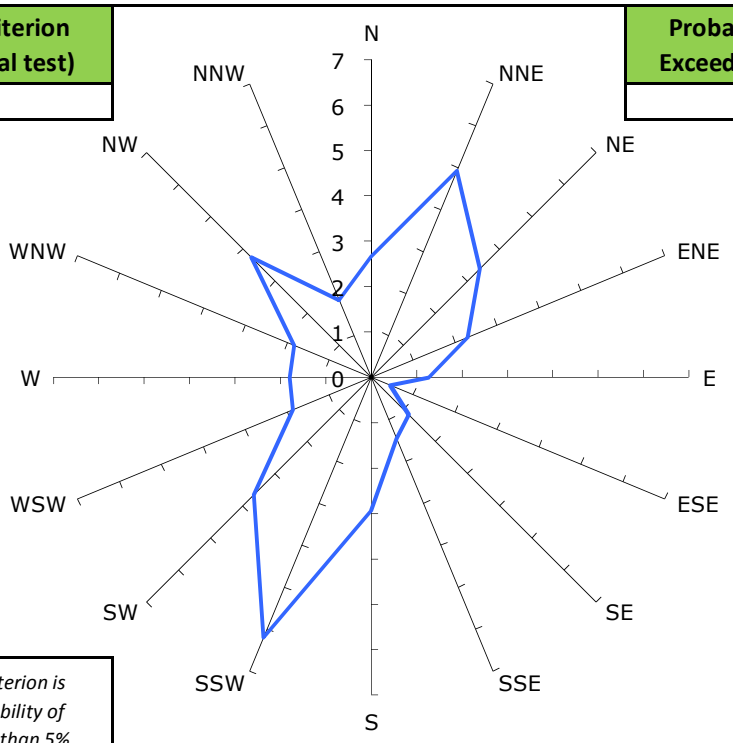


Desired Criterion
23m/s

Measured Wind Speeds at Point 46

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
1%	N/A

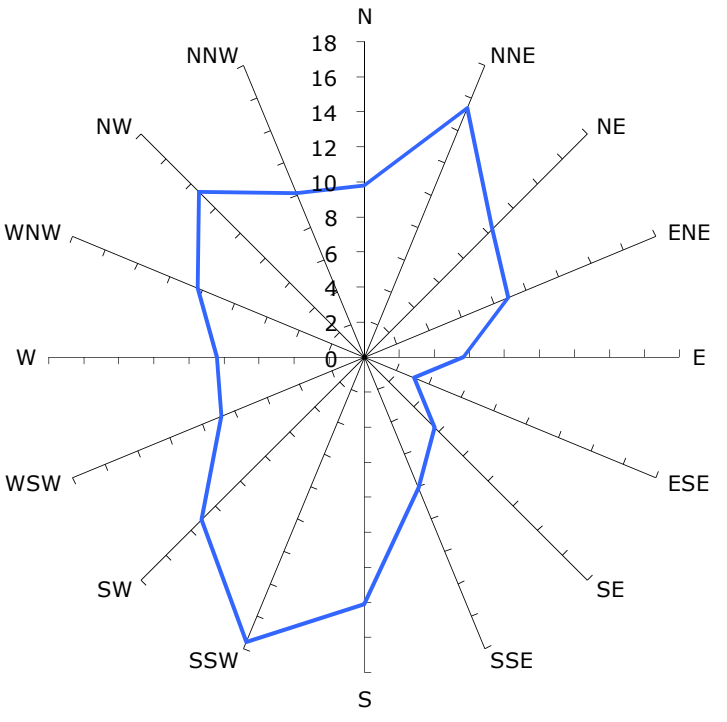


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

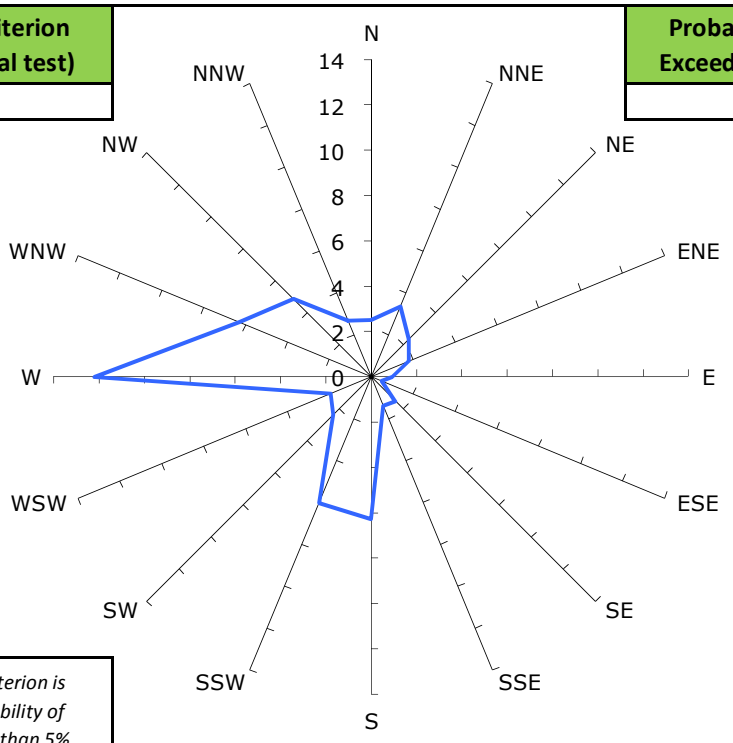


Desired Criterion
23m/s

Measured Wind Speeds at Point 55

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
5%	N/A

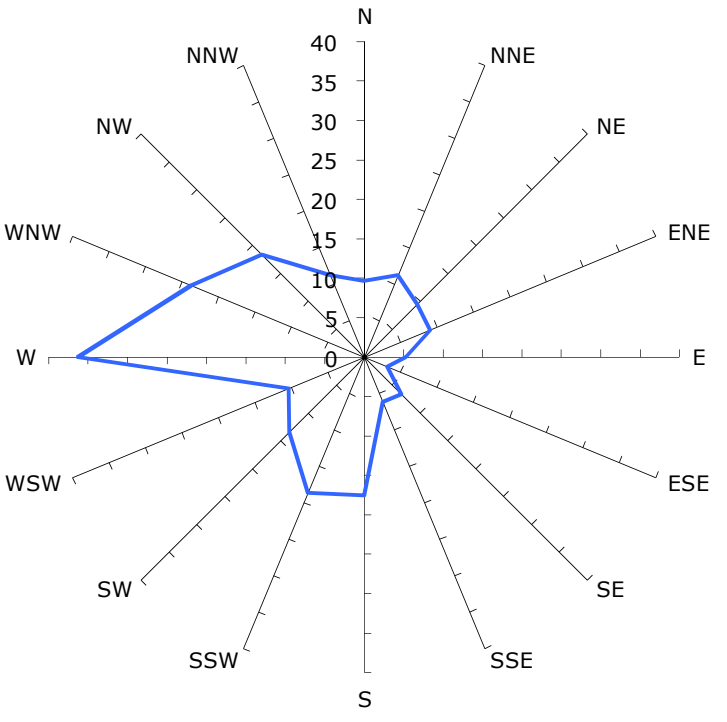


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

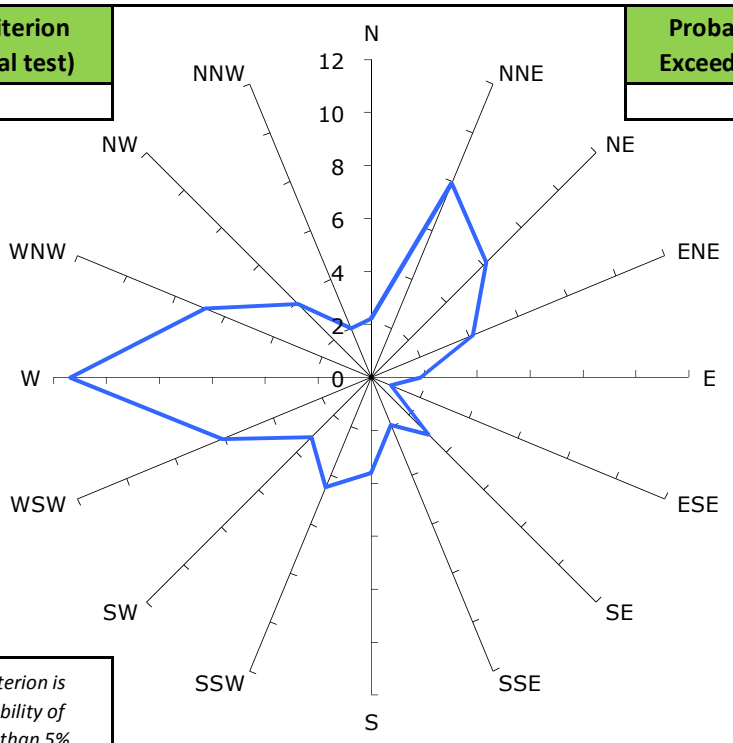


Desired Criterion
23m/s

Measured Wind Speeds at Point 56

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
7%	N/A

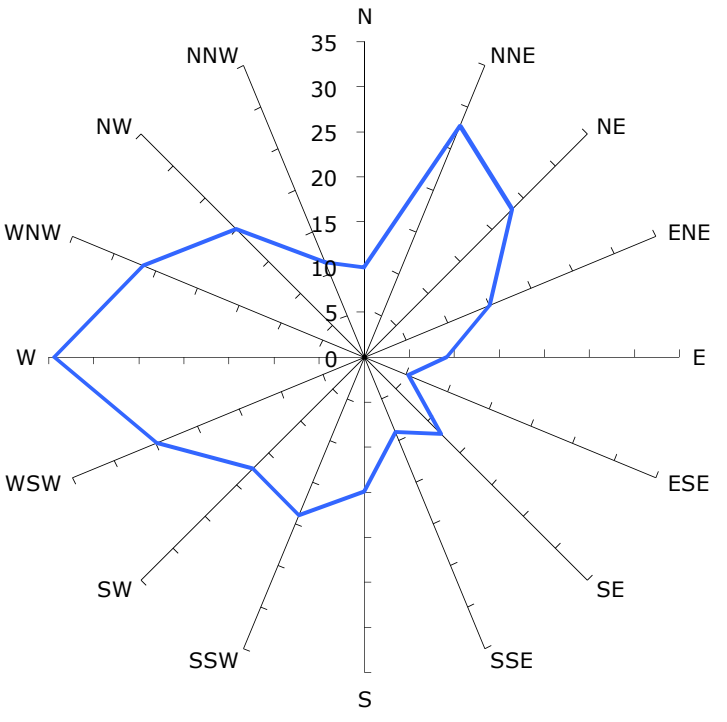


NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 2 - With development as proposed. No vegetation or other treatments.

Annual Maximum Gust (m/s)

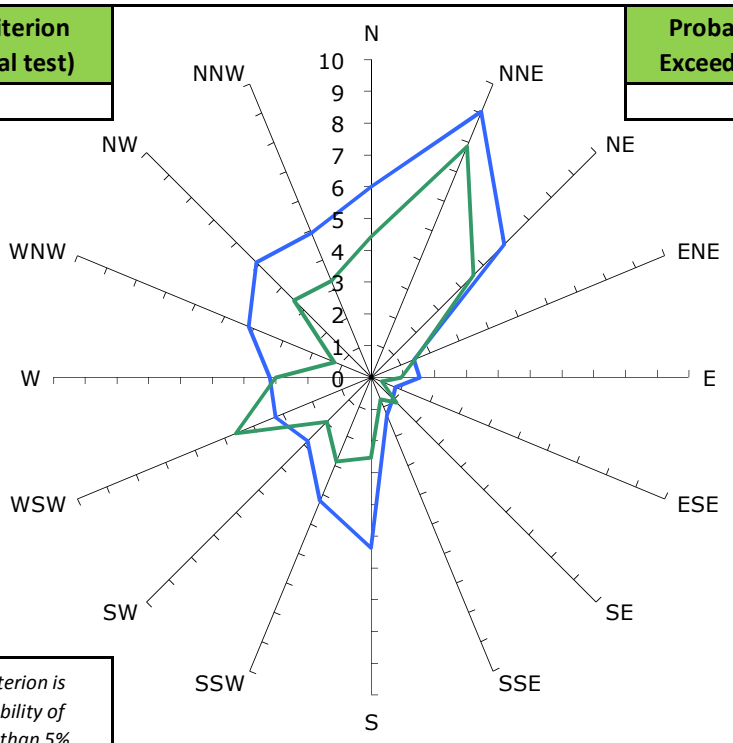


Desired Criterion
23m/s

Measured Wind Speeds at Point 57

Weekly Maximum GEM (m/s)

Probability of Criterion Exceedence (initial test)	Probability of Criterion Exceedence (final retest)
4%	N/A



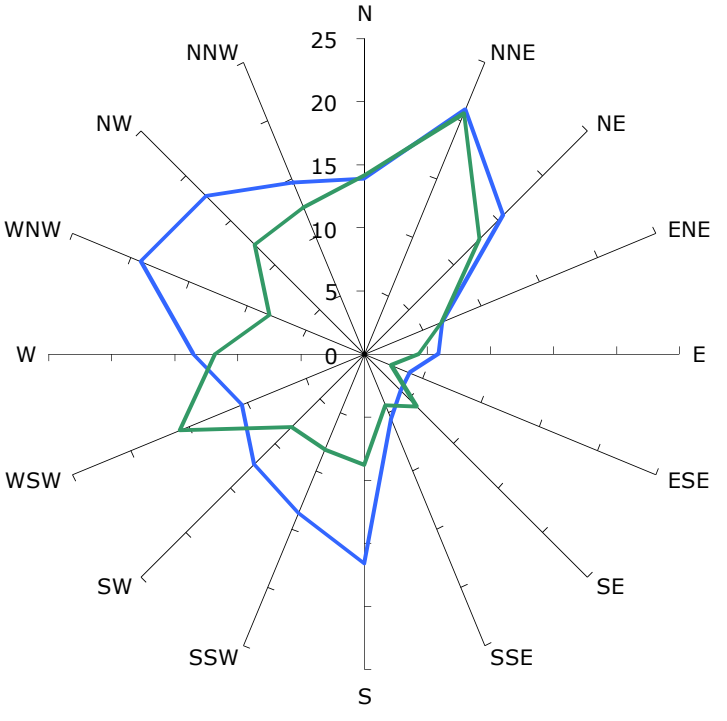
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Desired Criterion
7.5m/s

Scenario 2 - With development as proposed. No vegetation or other treatments.

With the inclusion of trees

Annual Maximum Gust (m/s)



Desired Criterion
23m/s