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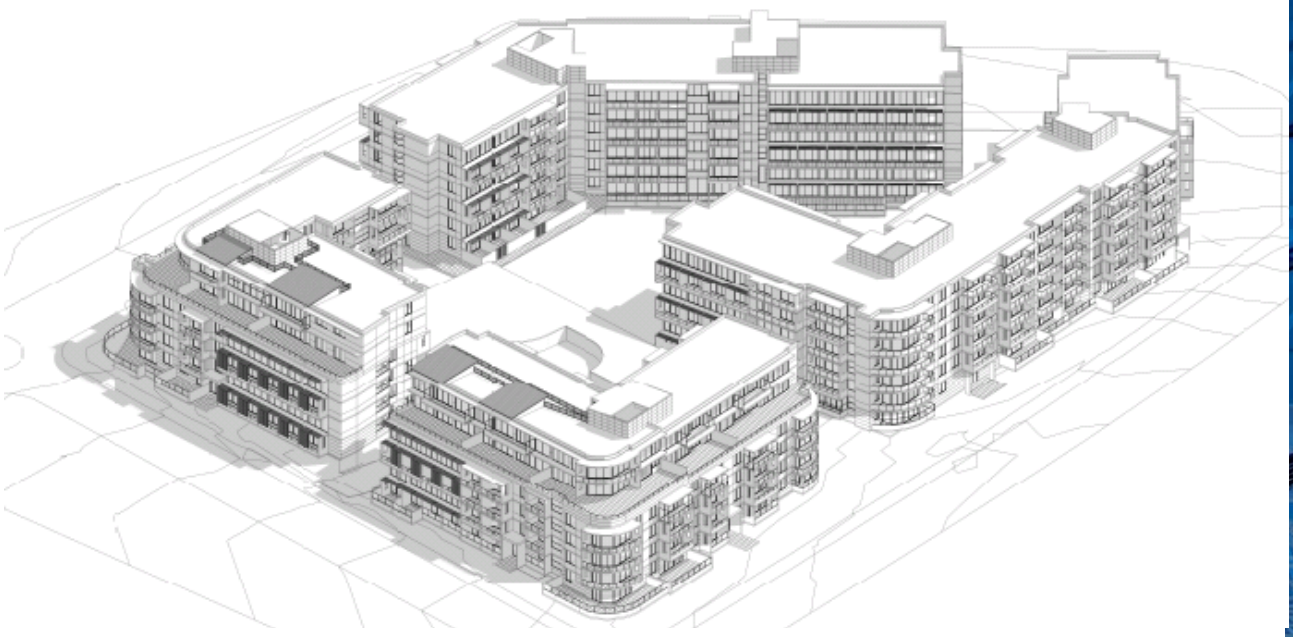

# Pedestrian Wind Environment Study

## for the proposed development at

## 12-40 Bonar St, Arncliffe

April 14, 2009

Report Reference No. W930-02F02(rev0)- WE Report

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## Document Control

| Revision Number | Date | Revision History | Prepared By (initials) | Initial Review By (initials) | Reviewed & Authorised By (initials) |
|---|---|---|---|---|---|
| 0 | 14/04/2009 | Initial | TH | NT/AB | TR |
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## Table of Contents

## 1.0 Executive Summary

This report presents the results of a detailed investigation into the wind environment impact in relation to the proposed development at 12-40 Bonar St, located in Arncliffe.

The proposed development consists of four residential buildings, a pool building and associated landscaping. The apartment complex is bounded by Bonar Street to the east, Hirst Street to the south and Loftus Street to the west.

Wind speed measurements were carried out using a 1:300 scale model of the development. A surrounds model incorporating the neighbouring buildings and local land topography was placed around the model of the proposed development. The surrounds model extends to a radius of 375m from the site. Testing was performed using Windtech's blockage tolerant boundary layer wind tunnel facility, which has a 3.0m wide work section and has a fetch length of 14m.

Peak gust wind speeds were measured and related to reference velocities at a height of 200m upstream of the proximity model. Wind speed velocity coefficients representing the local wind speeds are derived from the wind tunnel and are combined with the meteorological data for this region to provide the equivalent full-scale wind speeds. These wind speed measurements are compared with criteria for long and short duration stationary activities and for pedestrian comfort, based on annual maximum peak wind speeds and weekly maximum Gust Equivalent Mean (GEM) wind speeds, and where appropriate against the existing site wind conditions. The results have also been compared against the requirements of Section 5 of the Rockdale City Council Development Control Plan No. 62 for Wolli Creek.

The results of this study indicate that wind conditions for most of the outdoor areas of the site will require treatments to be implemented to be acceptable for their intended uses. Solutions have been investigated in this study to treat the adverse winds affecting the outdoor areas of the proposed development. A set of treatments have been recommended in this report to ameliorate these effects, and are summarised as follows;

- A strategic layout of densely foliating trees and shrubs for the ground level areas within and around the development site.
- 1.2m high impermeable balustrades along the perimeter of all private terrace and balconies on the south-east corner of Building C of the proposed development.

Note that for vegetation to be effective in mitigating adverse westerly winds, which occur predominantly during the winter months for the Sydney region, densely foliating evergreen species should be used. The results of this study indicate that adverse westerly winds affect the pedestrian areas along Loftus Street.

With the recommended treatments made in this report included into the final design of the development, the wind conditions within and around the proposed development will be acceptable for their intended uses and satisfy the requirements for wind comfort as required by Section 5 of the Rockdale City Council Development Control Plan No. 62 for Wolli Creek.

## 2.0 Model Description

### 2.1 Model of the Study Building and Surrounds

Wind speed measurements were carried out using a 1:300 scale model of the development. A surrounds model incorporating the neighbouring buildings and local land topography was placed around the study building model. The surrounds model extends to a radius of 375m from the site. Photographs of the wind tunnel model with the proposed development are presented in Figures 1a to 1h.

The proposed development consists of four residential buildings, a pool building and associated landscaping. The apartment complex is bounded by Bonar Street to the east, Hirst Street to the south and Loftus Street to the west.

The model was placed in a suburban terrain boundary layer wind flow based on the Deaves and Harris (1978) model, as described in Section 2.2 of this report. The reference wind speeds were corrected for changes in the upstream building morphology and land topography.

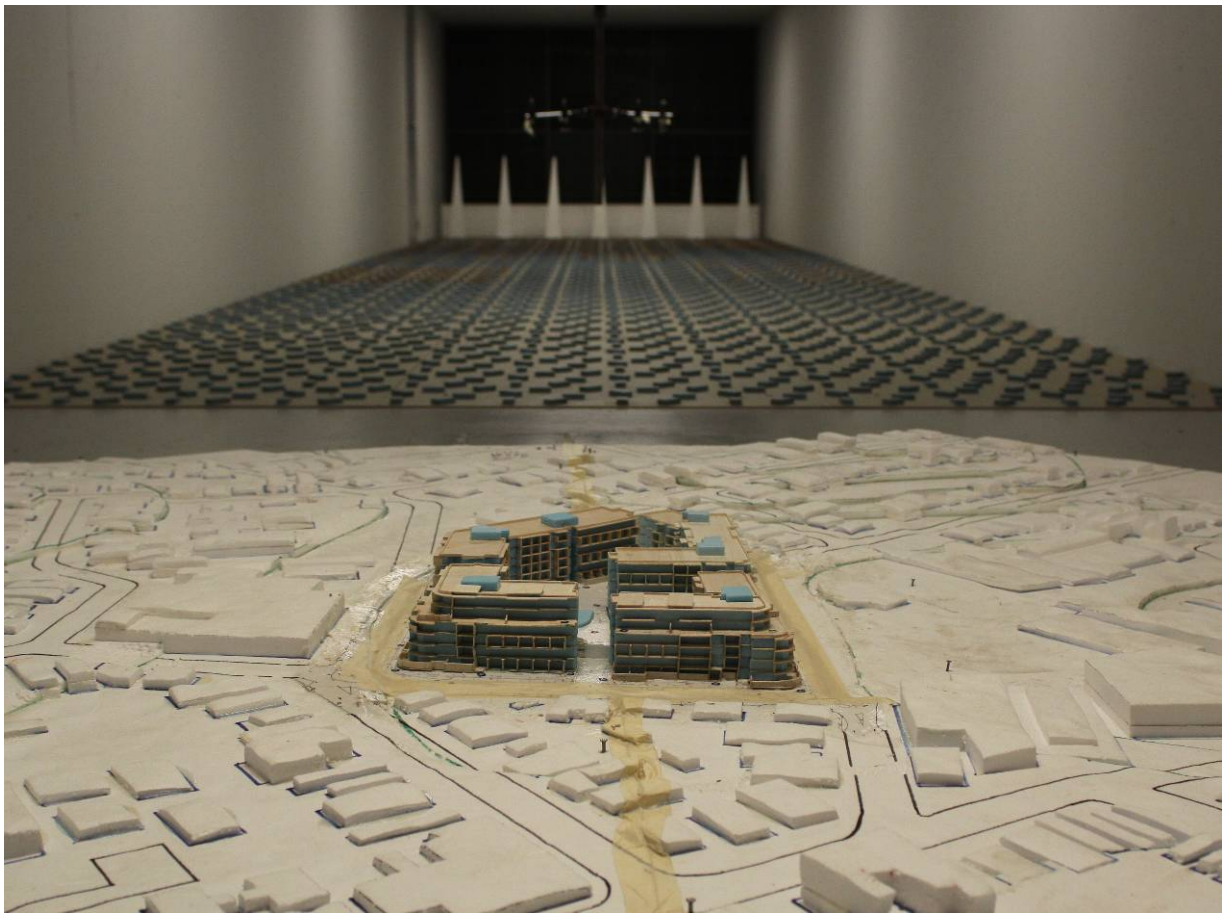

**Figure 1a: Photograph of the Model in the Wind Tunnel (view from the South – with the inclusion of the proposed development)**

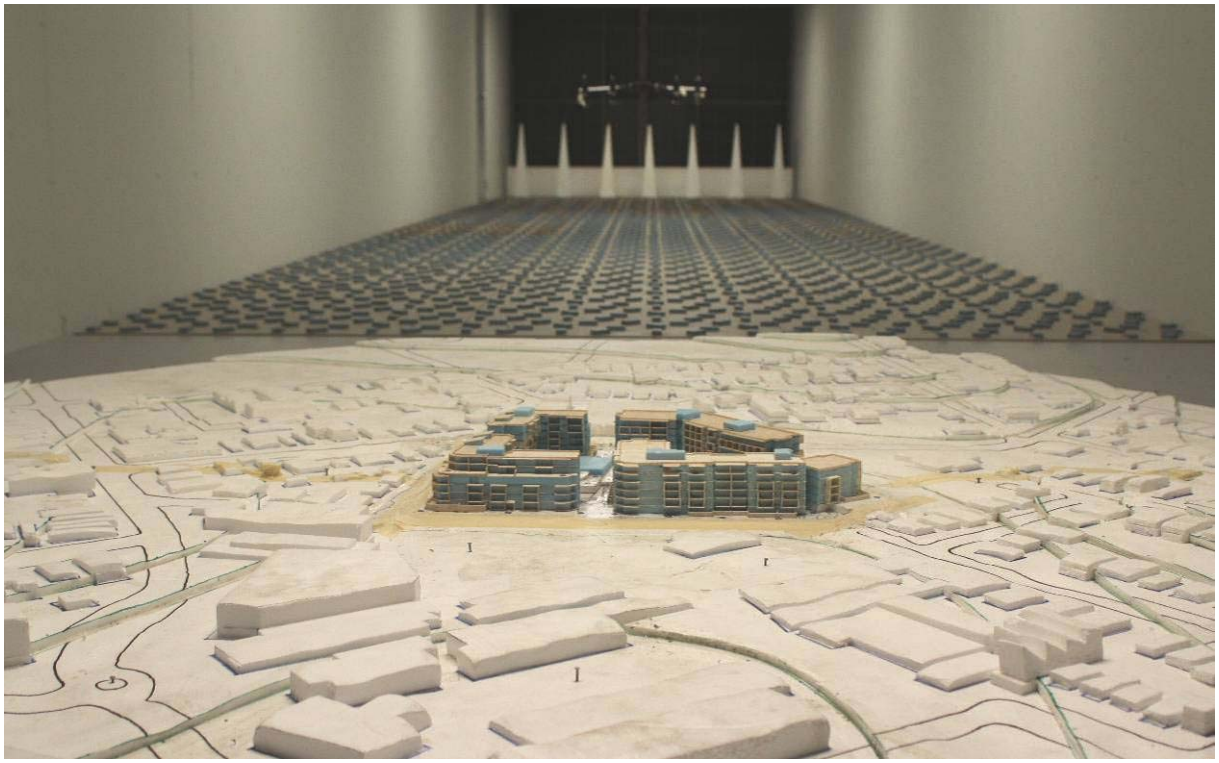

**Figure 1b: Photograph of the Model in the Wind Tunnel (view from the East - with the inclusion of the proposed development)**

**Figure 1c: Photograph of the Model in the Wind Tunnel (view from the North - with the inclusion of the proposed development)**

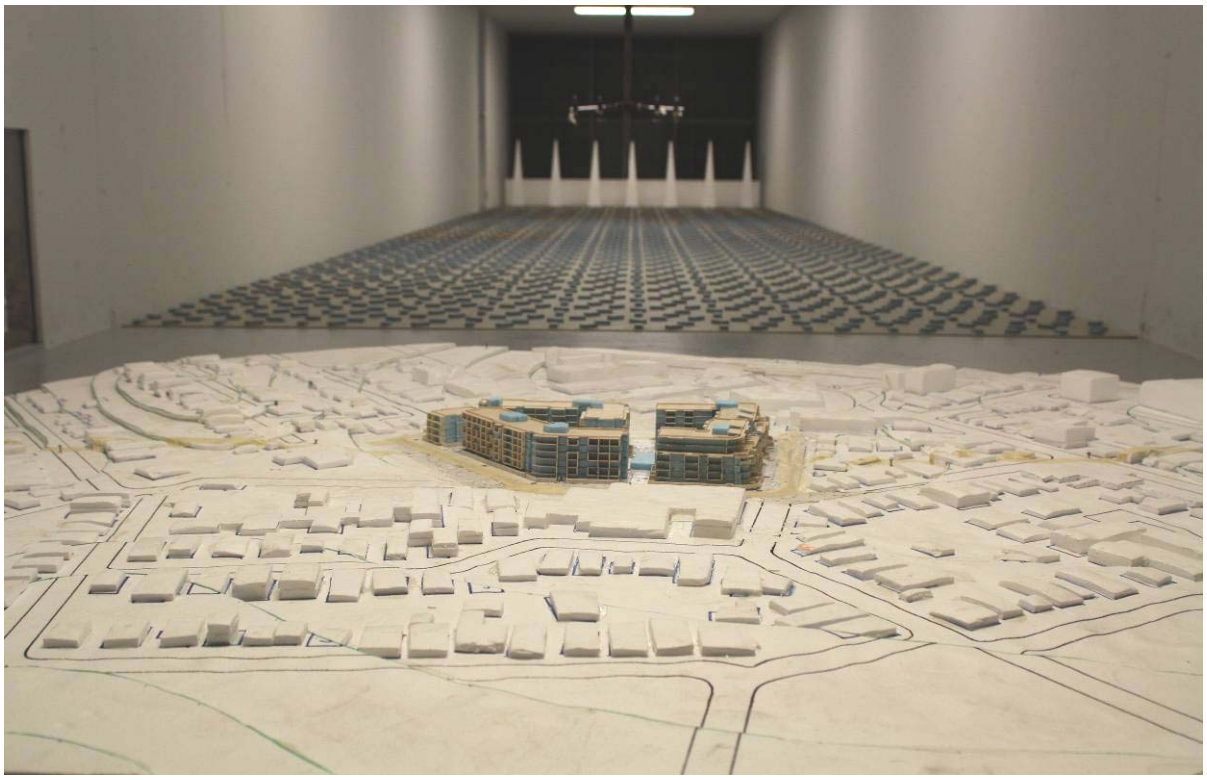

**Figure 1d: Photograph of the Model in the Wind Tunnel**
**(view from the West - with the inclusion of the proposed development)**

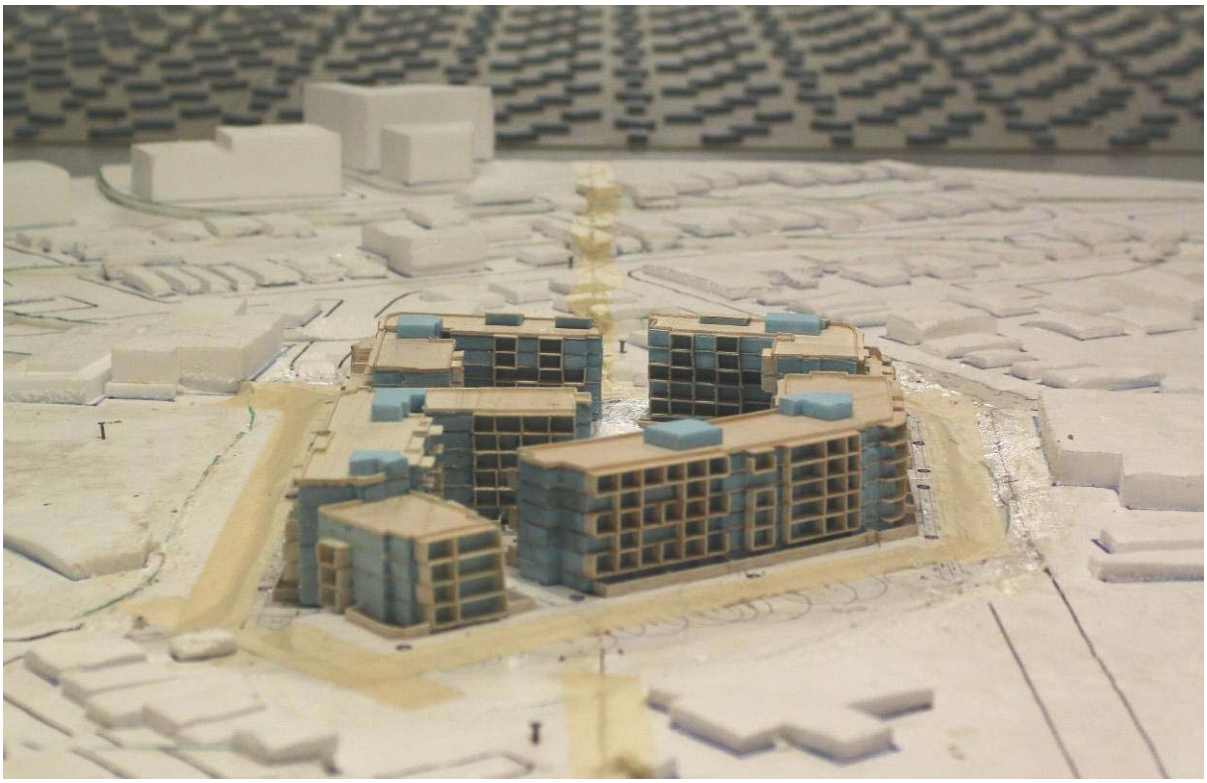

**Figure 1e: Photograph of the Model in the Wind Tunnel**
**(close-up view of the proposed development, from the North)**

**Figure 1f: Photograph of the Model in the Wind Tunnel**
**(close-up view of the proposed development, from the South)**

**Figure 1g: Photograph of the Model in the Wind Tunnel**
**(close-up view of the proposed development, from the East)**

**Figure 1h: Photograph of the Model in the Wind Tunnel**
**(close-up view of the proposed development, from the West)**

## 2.2 Wind Climate Model

The boundary layer wind flows matched the model scale and the overall surrounding terrain characteristics beyond the 375m radius of the physical surrounds model tested in the wind tunnel for each wind direction tested. For the fetch beyond the extent of the surround model the wind profiles are simulated based on the Deaves and Harris model (1978). The wind profile shape is calculated based on an analysis of the surrounding terrain for each wind direction tested. Figure 2 shows an aerial image of the site and surrounds for a radius of 40$h$ from the site, where $h$ is the reference height of the development. For this project a fetch length of 1.0km is analysed. The terrain types indicated in Figure 2 are classified as open, suburban or urban.

The length of each terrain type, and the distance each terrain type is from the site, is analysed for each wind direction tested. When the wind travels from one terrain type to another, the mean velocity profile does not change instantly. A lag occurs, and is measured as a distance by the following formula, which is adapted from Davenport et al (1997):

$$x_i = z_{0,r}\left[\frac{z}{0.3z_{0,r}}\right]^{1.25} \qquad (2.1)$$

where $x_i$ is the lag length caused by the change in terrain type.

$z$ is the height above ground.

$z_{0,r}$ is the larger of the two roughness lengths of the two terrain types (see Table 1).

The wind profile for each wind direction is calculated using the lag distance equation above, and the site terrain analysis data measured from the image shown in Figure 2.

For example, for wind coming from 292.5 degrees (a west-north-westerly wind), it is assumed that the approaching wind profile at the edge of the study zone (1.0km from the site for this study) is the standard Deaves and Harris (1978) open terrain profile, since this is coming from over the Turrella Reserve. The wind continues over the open terrain until, approximately 0.71km from the site, the wind reaches the suburban houses of Wolli Creek. This is where the Deaves and Harris (1978) suburban terrain profile is most appropriate. The wind profile then begins to adapt from the open terrain profile to the suburban terrain profile as it passes over the suburban houses of Arncliffe and Wolli Creek to the north-west of the site. However, by the lag distance equation, at a height of 100m above ground, the profile requires 2.1km to fully change to the standard Deaves and Harris (1978) suburban terrain profile. Hence, by the time the wind reaches the site, at a height of 100m above ground, the profile is only 16% developed into the suburban wind profile from the open wind profile. At the study reference height it is 89% developed into the suburban wind profile. The wind profile plot in Appendix B for wind angle 292.5 degrees shows that, by the time the wind reaches the site, the profile has already adapted to the standard suburban terrain profile for heights below the 20m, and above this it is still adapting into the suburban terrain profile from the open terrain profile.

The wind profiles used for this study are shown in Appendix B of this report for each wind direction tested.

**Table 1: Mean and Gust Terrain and Height Multipliers and Turbulence Intensity at Building Height, and the Corresponding Roughness Length for the Standard Deaves & Harris Profiles (1978) (at the study reference height)**

| Terrain Description | $\overline{M}_{(z,cat)}$ at BH | $M_{(z,cat)}$ at BH | Turbulence Intensity | Roughness Length (m) $z_{0,r}$ |
|---|---|---|---|---|
| Flat | 0.79 | 1.21 | 0.144 | 0.002 |
| Open | 0.68 | 1.10 | 0.167 | 0.02 |
| Suburban | 0.55 | 0.97 | 0.209 | 0.2 |
| Dense Urban | 0.37 | 0.78 | 0.324 | 2 |

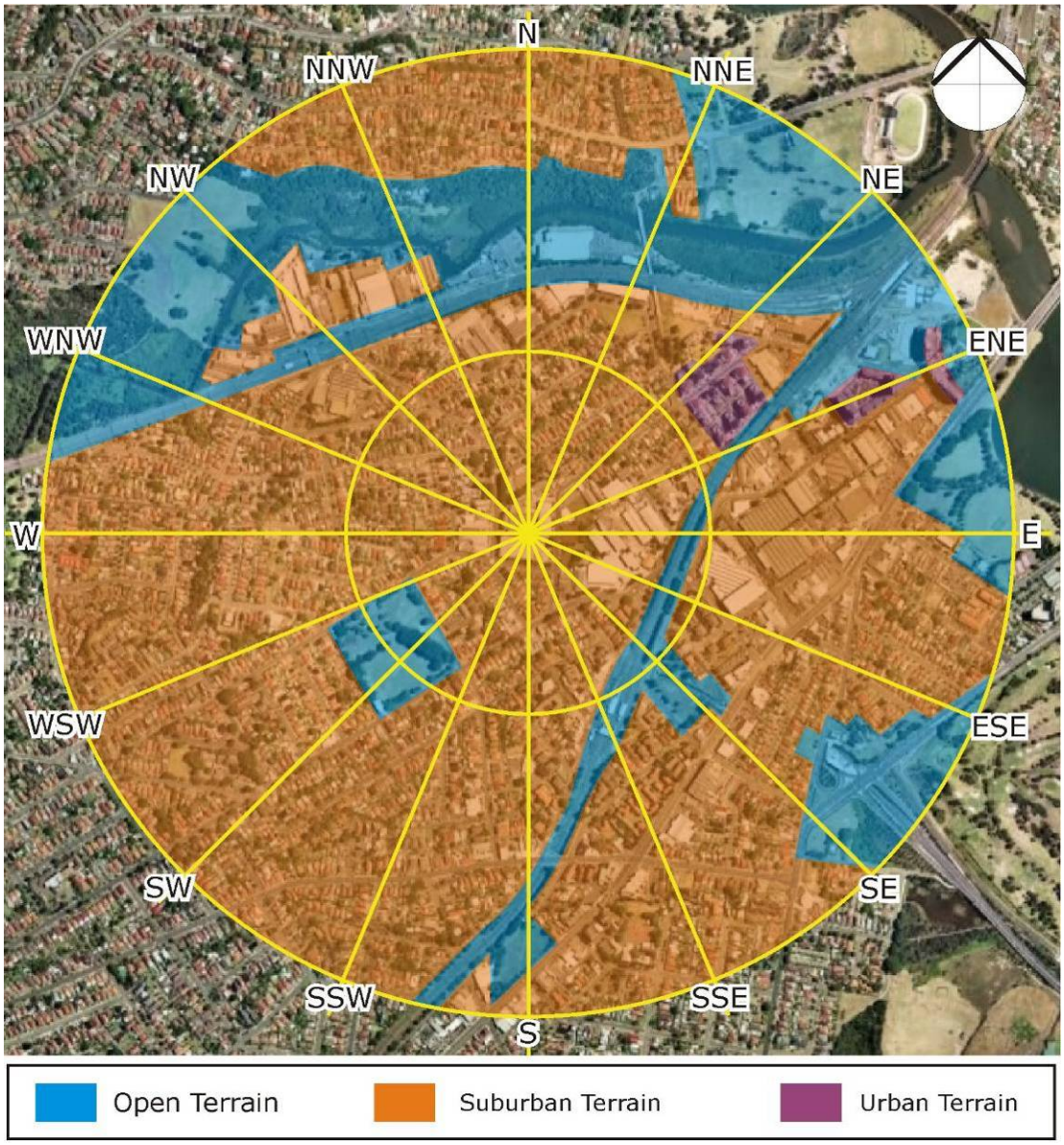


**Figure 2: Aerial Image of the Site and Surrounds – 1.0km Radius (terrain category types also indicated)**

## 3.0 Test Procedure

Testing was performed in Windtech's blockage tolerant boundary layer wind tunnel facility. No correction is required for blockage effects. The mean free stream wind speed at the reference height in the tunnel is approximately 11 m/sec. This corresponds to a velocity scale range of approximately 1:1.2 to 1:2.1 for the annual maximum peak wind speeds. Hence the sample length in the model scale of 12 seconds is equivalent to a range of approximately 30 minutes to 50 minutes in full-scale for the annual maximum peak wind speeds, which is suitable for this type of study.

A detailed analysis involving sixteen wind directions at 22.5 degrees intervals was carried out. This procedure provides comprehensive information about the wind environment to be expected for the various wind directions.

The freestream and test-location air currents were monitored using a pair of Dantec hot wire probe anemometers. The probe support was set vertically as much as possible. This 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.

The output from both probes was obtained using a National Instruments 12-bit data acquisition card. The signal was low-pass filtered at 32 Hz and results in peak gust being the equivalent of the 2 to 3 second gust on which the criteria are based. A sample rate of 1000 samples per second was used, which is more than adequate for the given frequency band.

The mean and the maximum 3 second duration peak gust coefficients were obtained. The largest qualifying single peak was taken as the maximum gust velocity. To ensure that the largest measured peak is not a 'false' peak, the maximum peak would not qualify if it is more than 25% greater than the average of the second and third largest peaks. Any non-qualifying peak is replaced by the average of the second and third largest peaks. The measured mean and gust wind speeds are compared against the appropriate criteria for each of the outdoor areas tested.

For each of the sixteen wind directions, peak gust and mean wind speeds were measured at selected points at a full-scale height of approximately 1.5m and were normalised by the mean value at a reference scale height of 200m up-wind of the model. The reference velocity measurements are used to relate the mean and peak wind speed measurements to actual mean and gust velocities, based on available meteorological data for Sydney.

The meteorological data for Sydney was analysed statistically from frequency of occurrence tables prepared by the National Climate Centre, which are based on continuous data collected at 3 hour intervals over 53 years, ending March 1992. Data was collected from the Sydney Airport Observation Office at a height of 6 metres.

The directional distributions of the statistical 3 hourly 10 minute mean wind speeds for Sydney, corrected to a reference height of 10m in open terrain, are shown in Figure 3 on the following page.

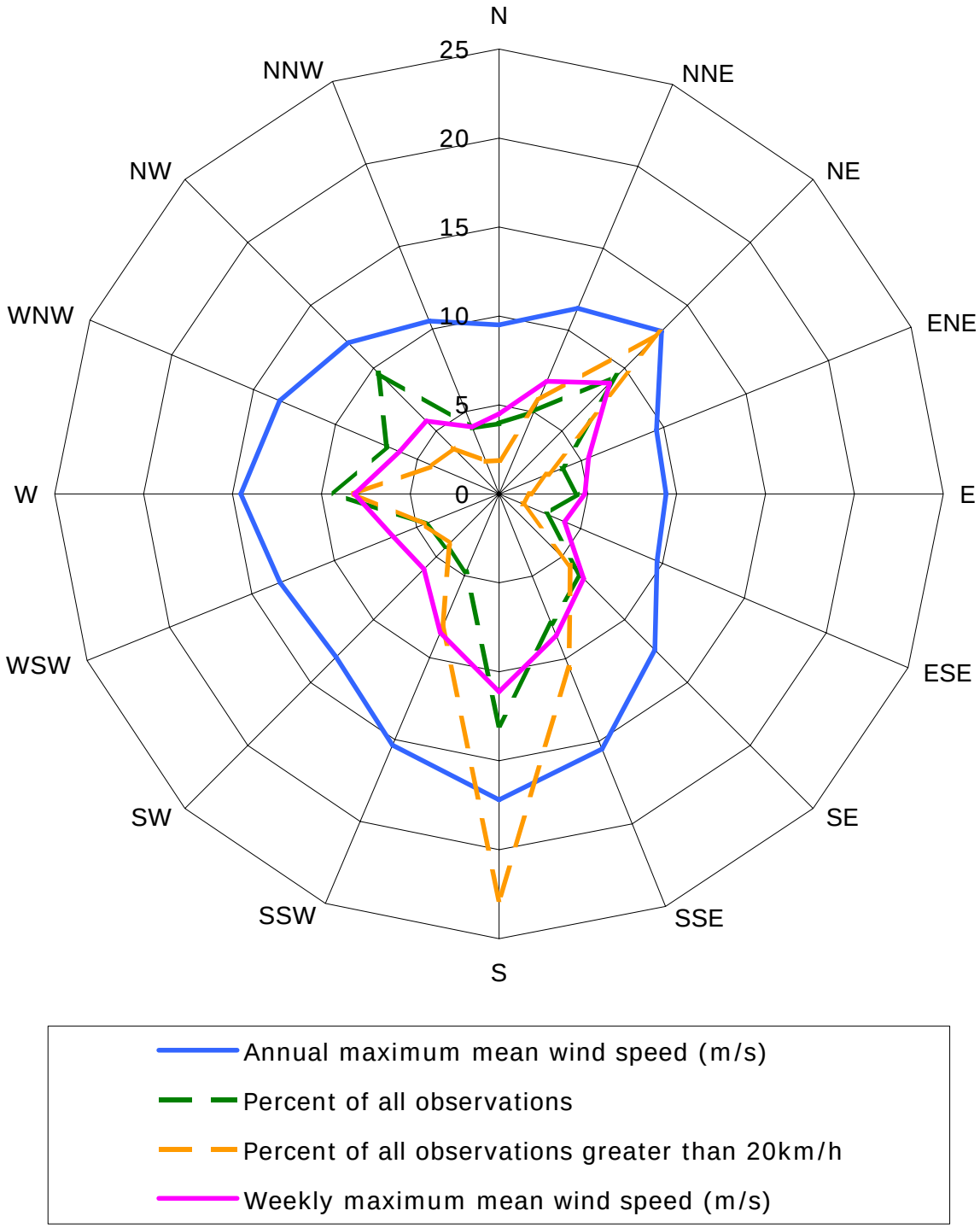


**Figure 3: Reference Wind Speeds and Frequencies for Sydney (based on 3 hourly 10 minute mean observations at Kingsford Smith Airport, from 1939 to 1992, at 10m height in open terrain)**

## 4.0 Environmental Wind Speed Criteria

The three principal wind directions affecting this development prevail from the North-East, South and West. Table 2 is a summary of the principal time of occurrence of these winds. A full set of wind roses for the Sydney region, obtained from Sydney Airport (1939 to 2000) at 9am and 3pm for each month throughout the year, are attached in Appendix C of this report.

**Table 2: Principle Time of Occurrence of Wind for the Sydney Region**

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

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. The following table (see Table 3), 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 3: 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***. |

Lawson (1973) quotes that Beaufort 4 wind speeds (6 to 8m/s means) would be acceptable if it is not exceeded for more than 4% of the time; and a Beaufort 6 (11 to 14m/s means) as being unacceptable if it is exceeded more than 2% of the time.

## 4.1 Davenport's Criteria for Mean Wind Speeds

Davenport (1972) had also come up with a set of criteria in terms of the Beaufort Scale and for various return periods. The values presented in Table 4 below are based on a frequency of exceedance of once per week (a probability of exceedance of 5%).

**Table 4: Criteria by Davenport (1972)**

| Classification | Human Activities | 95 Percentile Maximum Mean (once per week) |
|---|---|---|
| Walking Fast | Acceptable for walking, main public accessways | 10 m/s > *u* > 7.5 m/s |
| Strolling, Skating | Slow walking, etc. | 7.5 m/s > *u* > 5.5 m/s |
| Short Exposure Activities | Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas. | 5.5 m/s > *u* > 3.5 m/s |
| Long Exposure Activities | Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks. | 3.5 m/s > *u* |

## 4.2 Lawson's Criteria for Mean Wind Speeds

Later, Lawson (1975) came up with a set of criteria very similar to those of Davenport's. These are presented in Tables 5a and 5b, below.

**Table 5a: Safety Criteria by Lawson (1975)**

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

**Table 5b: Comfort Criteria by Lawson (1975)**

| Classification | Human Activities | 95 Percentile Maximum Mean (once per week) |
|---|---|---|
| Business Walking | Objective Walking from A to B | 10 m/s > *u* > 8m/s |
| Pedestrian Walking | Slow walking, etc. | 8 m/s > *u* > 6 m/s |
| Short Exposure Activities | Pedestrian Standing or sitting for a short time | 6 m/s > *u* > 4 m/s |
| Long Exposure Activities | Pedestrian sitting for a long duration | 4 m/s > *u* |

## 4.3 Melbourne's Criteria for Peak Wind Speeds

Melbourne (1978) introduced a set of criteria for the assessment of environmental wind conditions. These criteria were developed for temperatures in the range from 10$^{O}$C to 30$^{O}$C and for people suitably dressed for outside temperature conditions. These criteria are based on peak gust wind speeds. Melbourne's criteria are outlined in Table 5 below. This set of criteria tends to be more conservative than criteria suggested by other researchers such as those indicated in Figure 4.

**Table6: Criteria by Melbourne (1978)**

| Classification | Human Activities | Annual Maximum Gust |
|---|---|---|
| Limit for safety | Completely unacceptable: people likely to get blown over. | *u* > 23m/s |
| Marginal | Unacceptable as main public accessways. | 23 m/s > *u* > 16 m/s |
| Comfortable Walking | Acceptable for walking, main public accessways | 16 m/s > *u* > 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 > *u* > 10 m/s |
| Long Exposure Activities | Generally acceptable for long duration stationary activities such as in outdoor restaurants and theatres and in parks. | 10 m/s > *u* |

## 4.4 Comparison of the Various Wind Speed Criteria

The criteria mentioned in Table 6, as well as other criteria, are compared on a probabilistic basis in Figure 4, below.

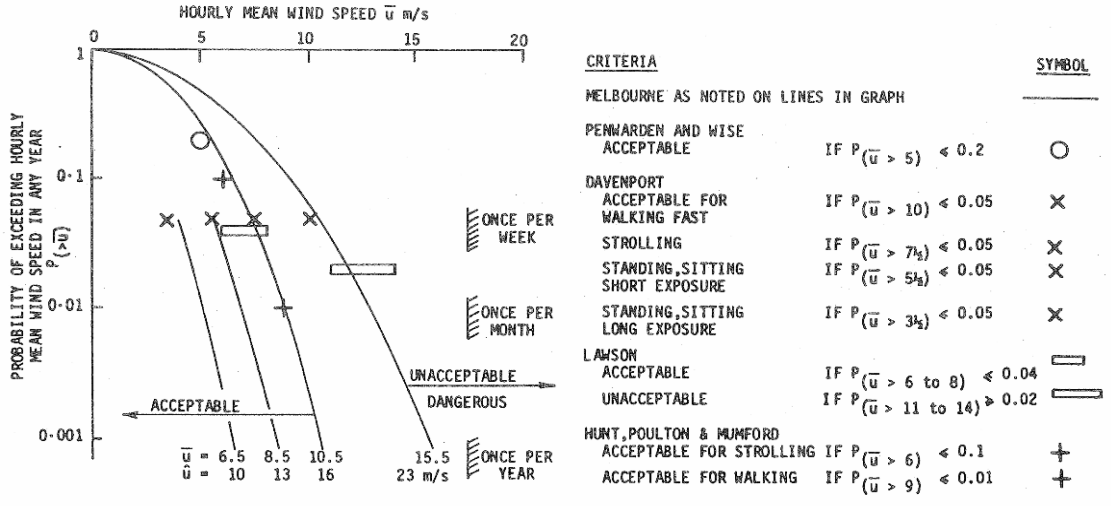


**Figure 4: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (after Melbourne, 1978)**

However, a comparative study presented by Ratcliff and Peterka (1990) based on measurements taken from a total of 246 locations in various urban situations tends to indicate that the criteria suggested by Melbourne (1978) can be considerably more conservative than the other criteria set out above. The results are in indicated in Figure 5. This agrees with our own observations (Rofail, 2007). This discrepancy in the criteria by Melbourne is due to the assumption of a fixed 15% turbulence intensity for all areas, which in our experience tends to be at the lower end of the range of turbulence intensities.

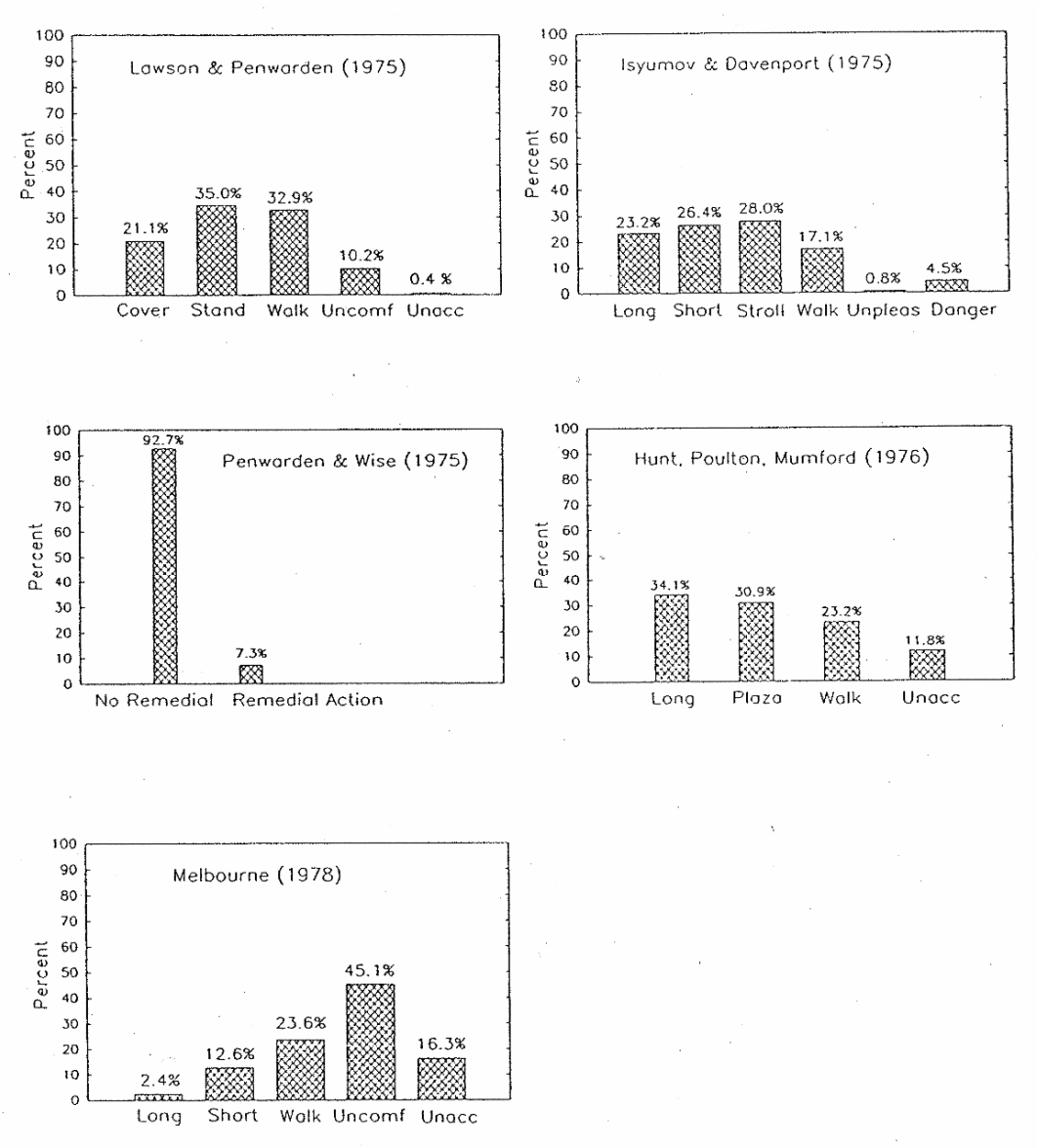


**Figure 5: Distribution of Pedestrian Wind Comfort over Five Criteria for 246 locations examined in the Wind Tunnel (after Ratcliff & Peterka, 1990)**

## 4.5 Wind Speed Criteria for the Rockdale DCP

For this study, the local wind climate has been compared against the existing wind conditions and the annual maximum peak wind speed criteria, as required by Section 5 of the Rockdale City Council Development Control Plan No. 62 for Wolli Creek. These are partly based on criteria by Melbourne (1978), as described in Section 4.3 in this report.

The wind comfort criteria used for this study are as follows;

- Wind conditions for all pedestrian accessible ground level areas within and around the proposed development should satisfy the following;
    - **Comfortable Walking Criteria of 16m/s for annual maximum gust wind speeds** in walkways, pedestrian transit areas, streets where pedestrians do not generally stop, sit, stand, window shop and the like.
    - **Short Exposure Criteria of 13m/s for annual maximum gust wind speeds** where pedestrians are involved in stationary short-exposure activities such as window shopping, standing or sitting (including areas such as bus stops, public open space and private open space).
    - **Long Exposure Criteria of 10m/s for annual maximum gust wind speeds** in areas for stationary long-exposure activity, such as outdoor dining.

  However, it is also considered acceptable if the measured wind speed exceeds the above criteria if it is better than the existing conditions (however note that the wind conditions must satisfy the safety criterion of 23m/s for the annual maximum peak wind speeds at all location).
- Wind conditions for private balconies and terraces of the proposed development should satisfy the safety limit of 23m/s for the annual maximum peak wind speeds.

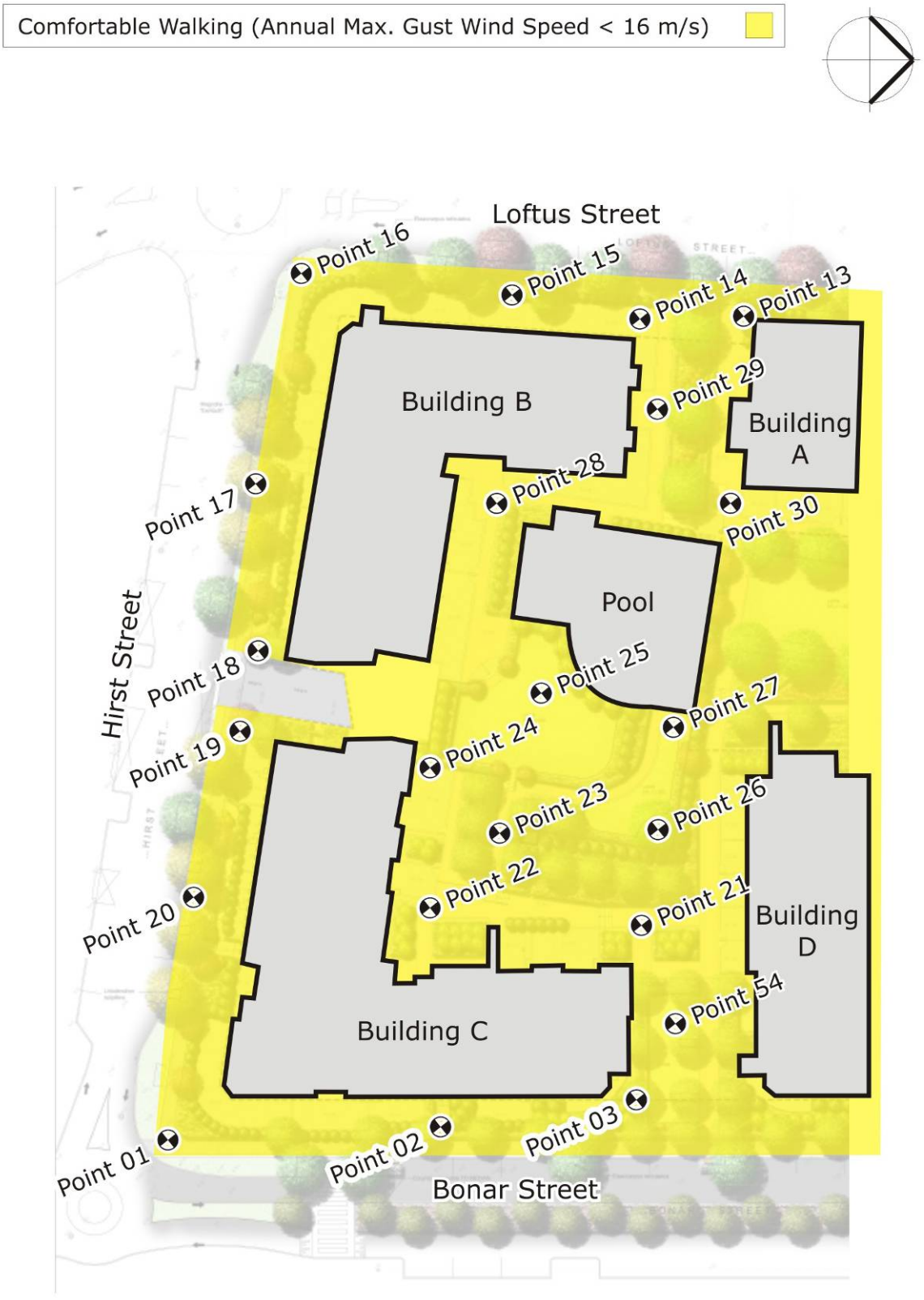


**Figure 6a: Study Point Locations - Ground Level within and around Building B and Building C (recommended wind comfort criteria also shown)**

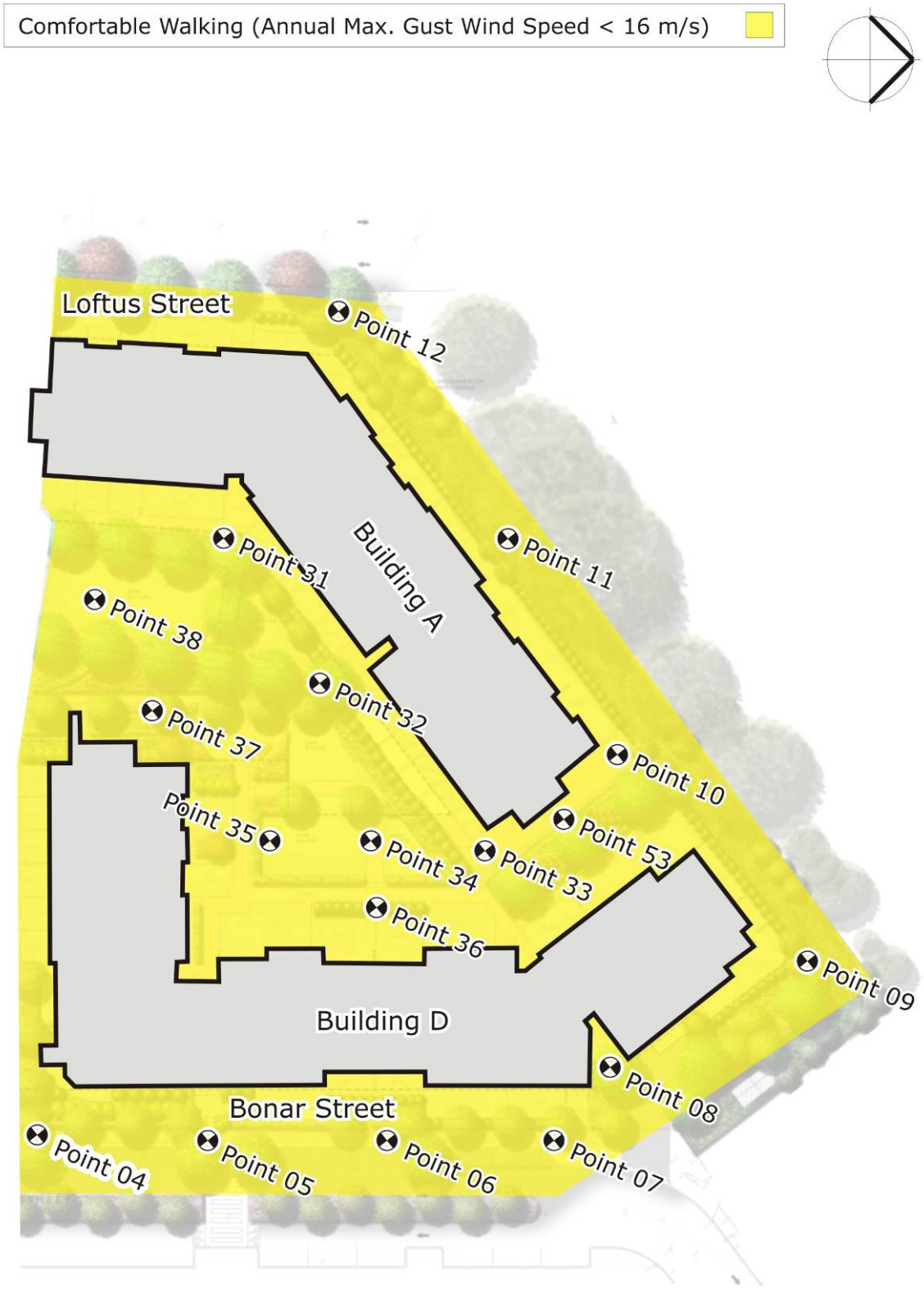


**Figure 6b: Study Point Locations - Ground Level within and around Building A and Building D (recommended wind comfort criteria also shown)**

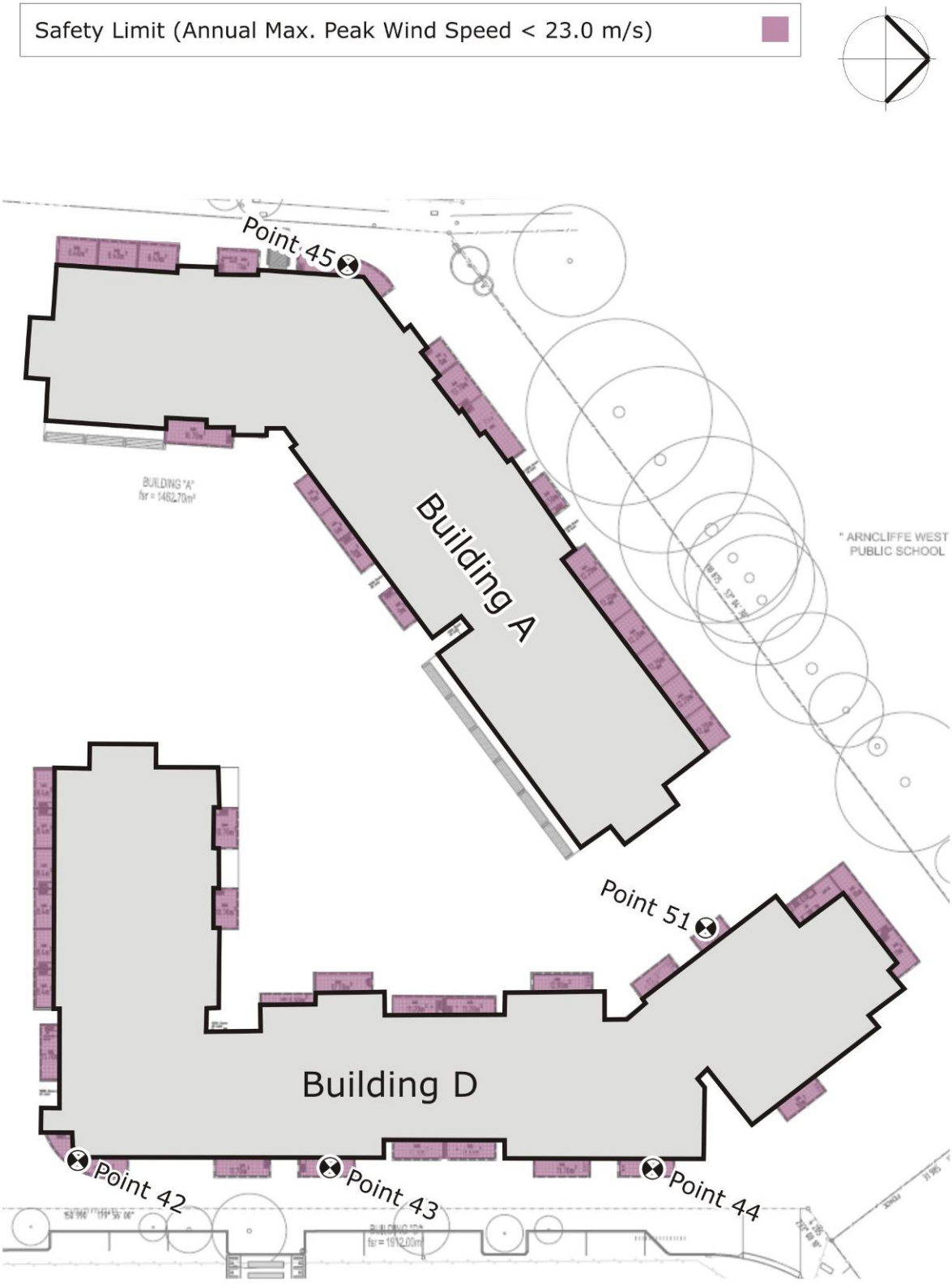


**Figure 6c: Study Point Locations – Balcony Levels on Building A and Building D (recommended wind comfort criteria also shown)**

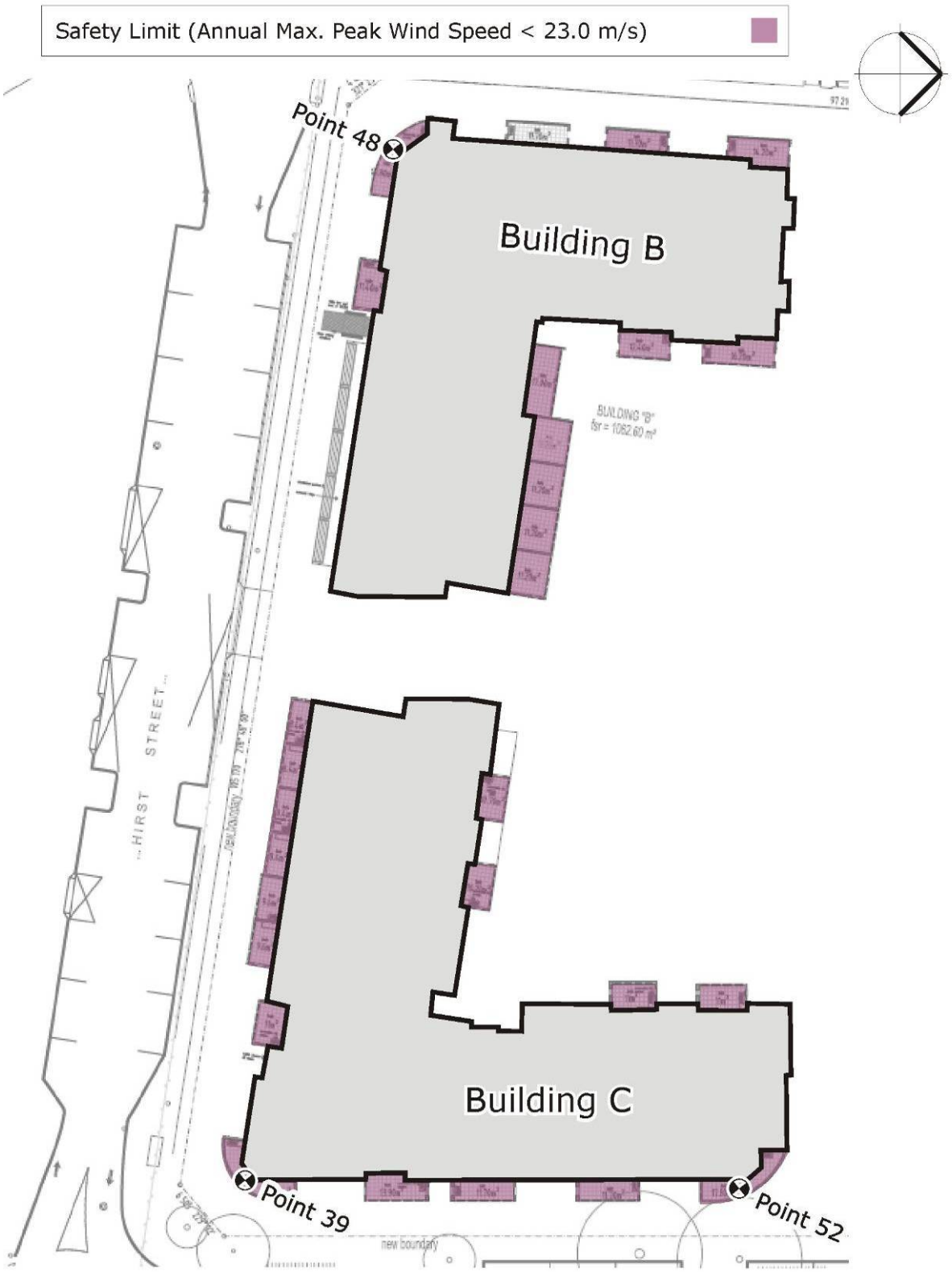


**Figure 6d: Study Point Locations – Balcony Levels on Building A and Building D (recommended wind comfort criteria also shown)**

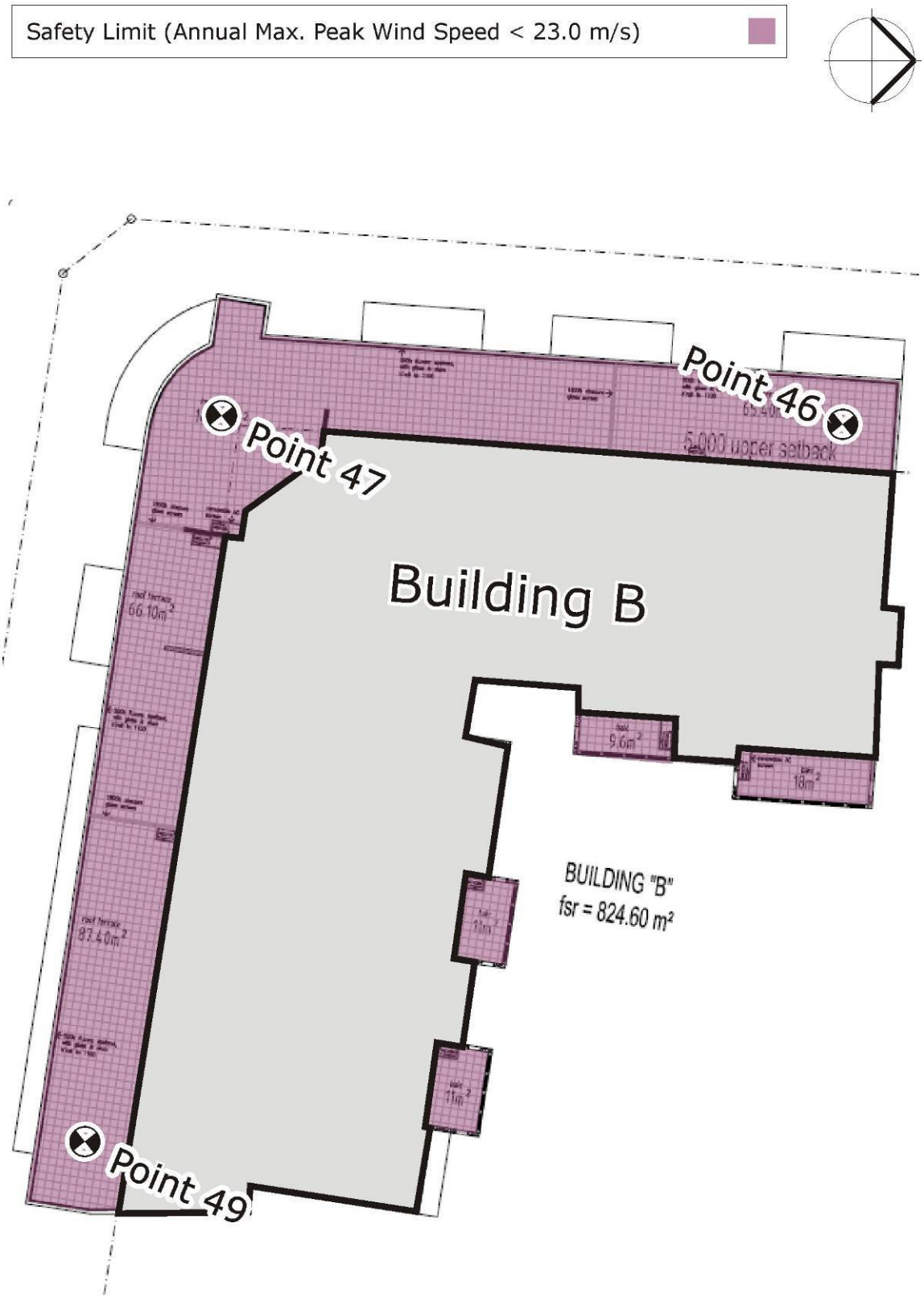


**Figure 6e: Study Point Locations – Level 7 Roof Terrace on Building B (recommended wind comfort criteria also shown)**

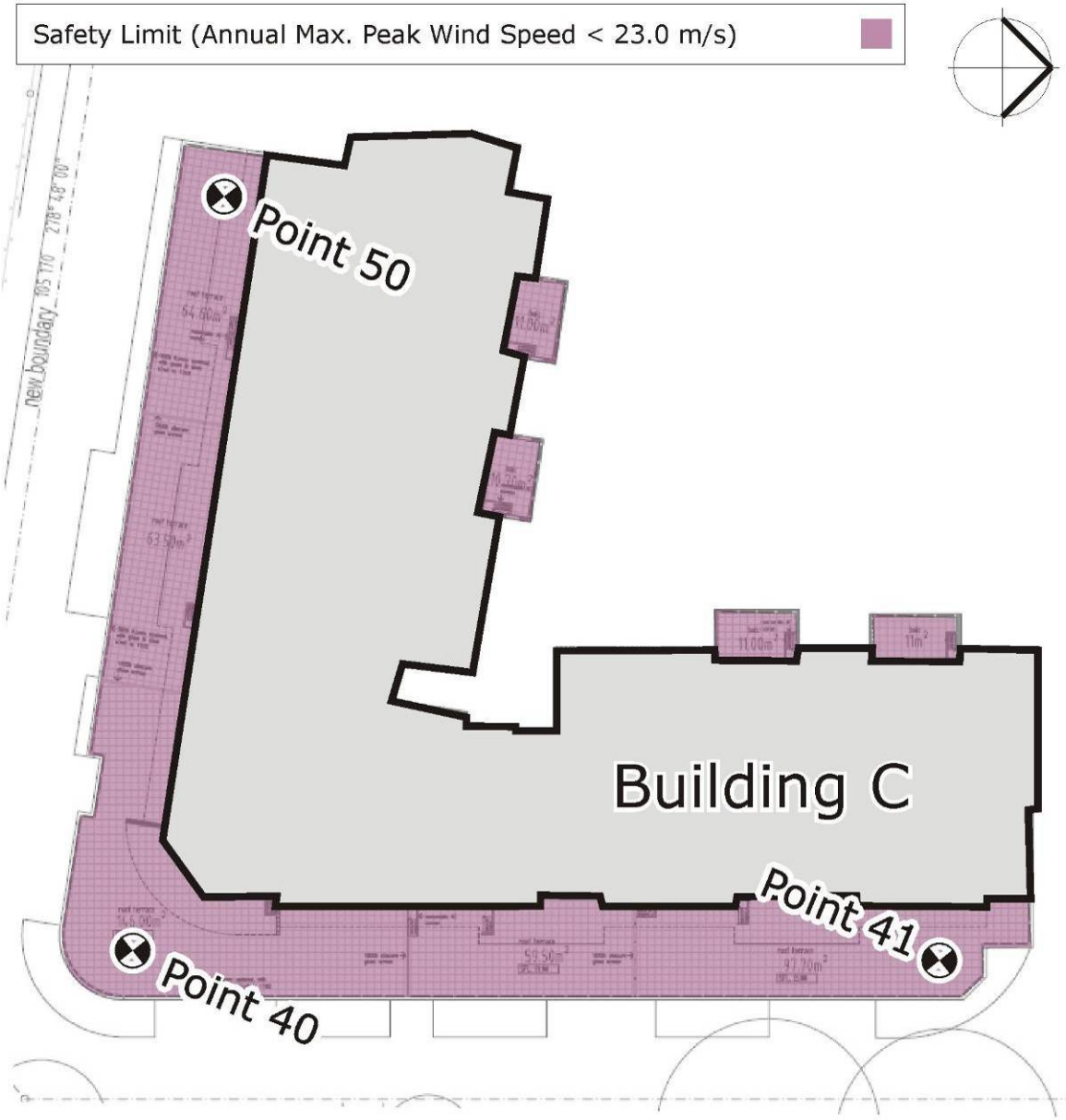


**Figure 6f: Study Point Locations – Level 6 Roof Terrace on Building C (recommended wind comfort criteria also shown)**

## 5.0 Results of Study

A detailed study of wind activity around and within the various outdoor areas of the proposed development was carried out. A total of 54 study locations were chosen for detailed analysis as shown in Figures 6a to 6f. These include 40 ground level test point locations and 14 test point locations on various private balconies of the proposed development. Wind conditions around the perimeter of the existing buildings on the site were also measured for comparison.

The wind conditions around the existing buildings on the site were measured with the inclusion of the existing trees within and around the site. It should be noted that the initial tests of the proposed development were undertaken without the effect of any forms of wind ameliorating devices such as balustrades, screens, and trees. However, existing neighbouring trees were included in these tests. For areas not achieving the appropriate wind conditions retesting was undertaken with various forms of ameliorative treatments until an effective outcome was reached.

Plots of results of the local directional wind speeds for the various test locations, as derived from the wind tunnel tests, are presented in the attached Appendix A. These results were assessed using the annual maximum peak wind speed criteria, as required by the Rockdale City Council Development Control Plan (DCP), as outlined in Section 4.5 of this report, for the public areas of the development. The weekly maximum GEM wind speeds are also presented for comparison. If existing conditions already exceed the criteria set by the Rockdale City Council DCP for the annual maximum peak wind speeds, then wind conditions for the subject development are not to result in an exceedence of the existing wind speeds.

### 5.1 Bonar Street – Ground Level

#### *The Study Points*

Test Points 1 to 8 and 54 are used to monitor the ground level wind conditions of the pedestrian footpath areas along Bonar Street on the eastern perimeter of the proposed development. The location of each Test Point is shown in Figures 6a and 6b.

#### *Applicable Criteria*

Test Points 1 to 8 and 54 represent the ground level pedestrian areas along Bonar Street that are accessible by pedestrians. These areas are primarily used as pedestrian thoroughfares. Hence for these locations the comfortable walking wind comfort criterion for the annual maximum gust wind speeds of 16m/s is recommended to be achieved. If existing wind conditions for these areas already exceed the criteria for the annual maximum gust wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedance of the existing wind speeds.

### *Results and Recommendations*

The initial test results indicate that wind conditions at Test Points 7 and 8 will satisfy the recommended comfortable walking comfort criterion without the need for additional treatments. Wind conditions at Test Points 2, 3 and 6, despite exceeding the comfortable walking comfort criterion, will be better than the existing wind conditions for those locations, and hence these areas will be suitable for their intended uses. However, wind conditions at Test Points 1, 4, 5 and 54 were exposed to adverse wind conditions and exceeded the relevant wind comfort criteria. Retests were undertaken with the addition of the vegetation scheme indicated in Figures 7a and 7b. The results of the retest indicate that the vegetation scheme was effective in mitigating the adverse wind conditions, and wind conditions at these locations will satisfy the relevant wind comfort criteria. Hence wind conditions at these areas will be suitable for their intended uses with the addition of the treatments indicated in Figures 7a and 7b.

## 5.2 Northern Boundary of Buildings A and D – Ground Level

### *The Study Points*

Test Points 9 to 11 and 53 are used to monitor the ground level wind conditions of the pedestrian footpath areas along the northern perimeter of Building A and Building D of the proposed development. The location of each Test Point location is shown in Figure 6b.

### *Applicable Criteria*

Test Points 9 to 11 and 53 represent the ground level pedestrian areas along the driveway the northern perimeter of Building A and Building D of the proposed development. These areas are primarily used as pedestrian thoroughfares. Hence for these locations the comfortable walking wind comfort criterion for the annual maximum gust wind speeds of 16m/s is recommended to be achieved. If existing wind conditions for these areas already exceed the criteria for the annual maximum gust wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedance of the existing wind speeds.

### *Results and Recommendations*

The initial test results indicate that wind conditions at Test Point 53 will satisfy the recommended comfortable walking wind comfort criterion of 16m/s without the need for additional treatments. Wind conditions at Test Point 9, despite exceeding the comfortable walking comfort criterion, will be better than the existing wind conditions for those locations, and hence these areas will be suitable for their intended uses.

The initial test results for Test Points 10 and 11 indicate that this area of the site is exposed to adverse west-south-westerly to north-easterly winds. Test Points 10 and 11 were retested with the addition of the vegetation scheme indicated in Figure 7b. The result of these retests indicates that the vegetation scheme was effective in mitigating the adverse wind conditions. Hence, with the addition of the vegetation scheme as indicated in Figure 7b, wind conditions at these areas will be suitable for their intended uses.

## 5.3 Loftus Street – Ground Level

### *The Study Points*

Test Points 12 to 15 and 29 are used to monitor the ground level wind conditions of the pedestrian footpath areas along Loftus Street on the western perimeter of the proposed development. The location of each Test Point location is shown in Figure 6a and 6b.

### *Applicable Criteria*

Test Points 12 to 15 and 29 represent the ground level pedestrian areas along Loftus Street that are accessible by pedestrians. These areas are primarily used as pedestrian thoroughfares. Hence for these locations the comfortable walking wind comfort criterion for the annual maximum gust wind speeds of 16m/s is recommended to be achieved. If existing wind conditions for these areas already exceed the criteria for the annual maximum gust wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedance of the existing wind speeds.

### *Results and Recommendations*

The initial test results indicate that all of these study point locations are exposed to strong north-westerly through to southerly winds, which cause exceedence the recommended wind comfort criterion. Test Point 29 was retested with the addition of densely foliating trees along the northern boundary of the Test Point. The results of the retest indicate the treatment was effective in reducing the effect of the adverse winds, however the relevant criteria was still exceeded. An additional retest was performed with an additional tree south-west of Test Point 29 as indicated in Figure 7a. The results of the retest indicate that the vegetation scheme was effective in mitigating the adverse wind condition, and the applicable wind comfort criterion will be satisfied.

Retests of Test Points 12 to 15 were undertaken with the addition of the vegetation scheme indicated in Figures 7a and 7b. The result of these retests indicates that the vegetation scheme was effective in mitigating the adverse wind conditions. Hence, with the addition of the vegetation scheme as indicated in Figures 7a and 7b, these areas will be suitable for their intended uses to be included into the final design of the proposed development.

## 5.4 Hirst Street – Ground Level

### *The Study Points*

Test Points 16 to 20 are used to monitor the ground level wind conditions of the pedestrian footpath areas along Hirst Street on the southern perimeter of the proposed development. The location of each Test Point location is shown in Figure 6a.

### *Applicable Criteria*

Test Points 16 to 20 represent the ground level pedestrian areas along Hirst Street that are accessible by pedestrians. These areas are primarily used as pedestrian thoroughfares. Hence for these locations the comfortable walking wind comfort criterion for the annual maximum gust wind speeds of 16m/s is recommended to be achieved. If existing wind conditions for these areas already exceed the criteria for the annual maximum gust wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedance of the existing wind speeds.

### *Results and Recommendations*

The results of the initial tests of these study points indicate that the site is exposed to strong west-north-westerly to south-south-easterly winds. The recommended wind comfort criteria at all of the ground level Test Points except Test Point 20 were exceeded. Test Point 18 was retested with the addition of densely foliating trees south-west of the study point location. The results of the retest indicate the treatment was effective in reducing the wind speeds from the westerly direction, however wind conditions at this location still exceeded the applicable wind comfort criterion. Another retest was performed with an additional densely foliating tree modelled north of the study point location as indicated in the vegetation scheme in Figure 7a. The results indicated the vegetation scheme was effective in mitigating the adverse wind conditions and wind conditions will now satisfy the applicable wind comfort criterion.

Retests were undertaken on Test Points 16, 17 and 19 with the addition of the vegetation scheme indicated in Figure 7a. The results of the retest indicate that the vegetation scheme was effective in mitigating the adverse wind conditions. Hence, with the addition of the vegetation scheme indicated in Figure 7a, wind conditions for these areas will be suitable for their intended uses.

## 5.5 Internal Courtyard – Ground Level

### *The Study Points*

Test Points 21 to 38 are used to monitor the ground level wind conditions of the pedestrian footpath areas of the courtyard within the proposed development. The location of each Test Point location is shown in Figures 6a and 6b.

### *Applicable Criteria*

Test Points 24 to 26 represent the ground level pedestrian areas within the courtyard of the proposed development that are accessible by pedestrians. These areas are primarily used as pedestrian thoroughfares. Hence for these locations the comfortable walking wind comfort criterion for the annual maximum gust wind speeds of 16m/s is recommended to be achieved. If existing wind conditions for these areas already exceed the criteria for the annual maximum gust wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedance of the existing wind speeds.

### *Results and Recommendations*

The initial test results indicate that wind conditions for a majority of the Test Point locations within the courtyard will satisfy the applicable comfortable walking wind comfort criterion of 16m/s for the annual maximum peak wind speeds. The area represented by Test Point 21 is exposed to strong north-easterly winds funnelled between Buildings C and D, which exceed the comfortable walking wind comfort criterion. Test Point 30 is exposed to strong winds from the westerly to south-westerly directions caused by the funnelling effect between Buildings A and B. Wind conditions at Test Points 25, 26 and 32 exceeded the comfortable walking comfort criterion due to exposure to the adverse funnelling effect between Buildings C and D from the southerly to south-south-easterly directions.

Retests were undertaken on these Test Point locations with the addition of the vegetation scheme indicated in Figures 7a and 7b. The result of these retests indicates that the vegetation scheme was effective in mitigating the adverse wind conditions. Hence, with the addition of the vegetation scheme as indicated in Figures 7a and 7b, wind conditions at these areas will be suitable for their intended uses.

## 5.6 Private Balconies and Terraces

### *The Study Points*

Test Points 39 to 52 are used to monitor the wind conditions on the various private balconies and terraces of the proposed development. The location of each study point is summarised as follows:

- Test Point 39 represents conditions on the south-eastern aspect corner balconies of Building C, located at the south-eastern corner of the site. This is shown in Figure 6d.

- Test Point 52 represents conditions on the north-eastern aspect corner balconies of Building C, located at the south-eastern corner of the site. This is shown in Figure 6d.

- Test Point 48 represents conditions on the south-western aspect corner balconies of Building B, located at the north-eastern corner of the site. This is shown in Figure 6d.

- Test Points 40, 41 and 50 represents conditions on the Level 6 roof balcony areas of Building C, located at the south-eastern end of the building at the north-eastern corner of the site. This is shown in Figure 6f.

- Test Points 46, 47 and 49 represents conditions on the Level 7 roof balcony areas of Building B, located at the south-eastern end of the building at the north-eastern corner of the site. This is shown in Figure 6e.

- Test Point 45 represents conditions on the western aspect corner

balconies of Building A, located at the north-eastern corner of the site. This is shown in Figure 6c.

- Test Point 42 represents conditions on the south-eastern aspect corner balconies of Building D, located at the north-eastern corner of the site. This is shown in Figure 6c.

- Test Point 43 and 44 represents conditions on the eastern aspect balconies of Building D, located at the north-eastern corner of the site. This is shown in Figure 6c.

- Test Point 51 represents conditions on the north-western aspect balconies of Building D, located at the north-eastern corner of the site. This is shown in Figure 6c.

***Applicable Criteria***

The appropriate wind comfort criterion for private balconies and terraces is the safety limit of 23m/s for annual maximum peak wind speeds. This is also shown in Figures 6c to 6f for the various study points used to monitor wind conditions at these locations.

***Results and Recommendations***

The initial test results indicate that, with the exception of Test Points 39 and 40, wind conditions at all of the Test Point locations will satisfy the applicable wind comfort criterion without the need for additional treatments. The initial test results indicate that the south-eastern aspect corner of Building C, represented by Test Points 39 and 40, is exposed to strong southerly and north-easterly winds that exceed the criteria for safety of 23m/s for the annual maximum peak wind speeds. Retests were undertaken for these areas with the addition of 1.2m high impermeable balustrades around the perimeter of the trafficable areas of the various private balconies and terraces as indicated in Figures 7c and 7d. The results indicated that with this form of treatment wind conditions at Test Points 39 and 40 satisfied the recommended criterion for wind comfort. Hence, with the inclusion of the 1.2m high impermeable balustrades as indicated in Figures 7c and 7d, wind conditions for all of the various private outdoor balconies and terraces of the proposed development will be acceptable.

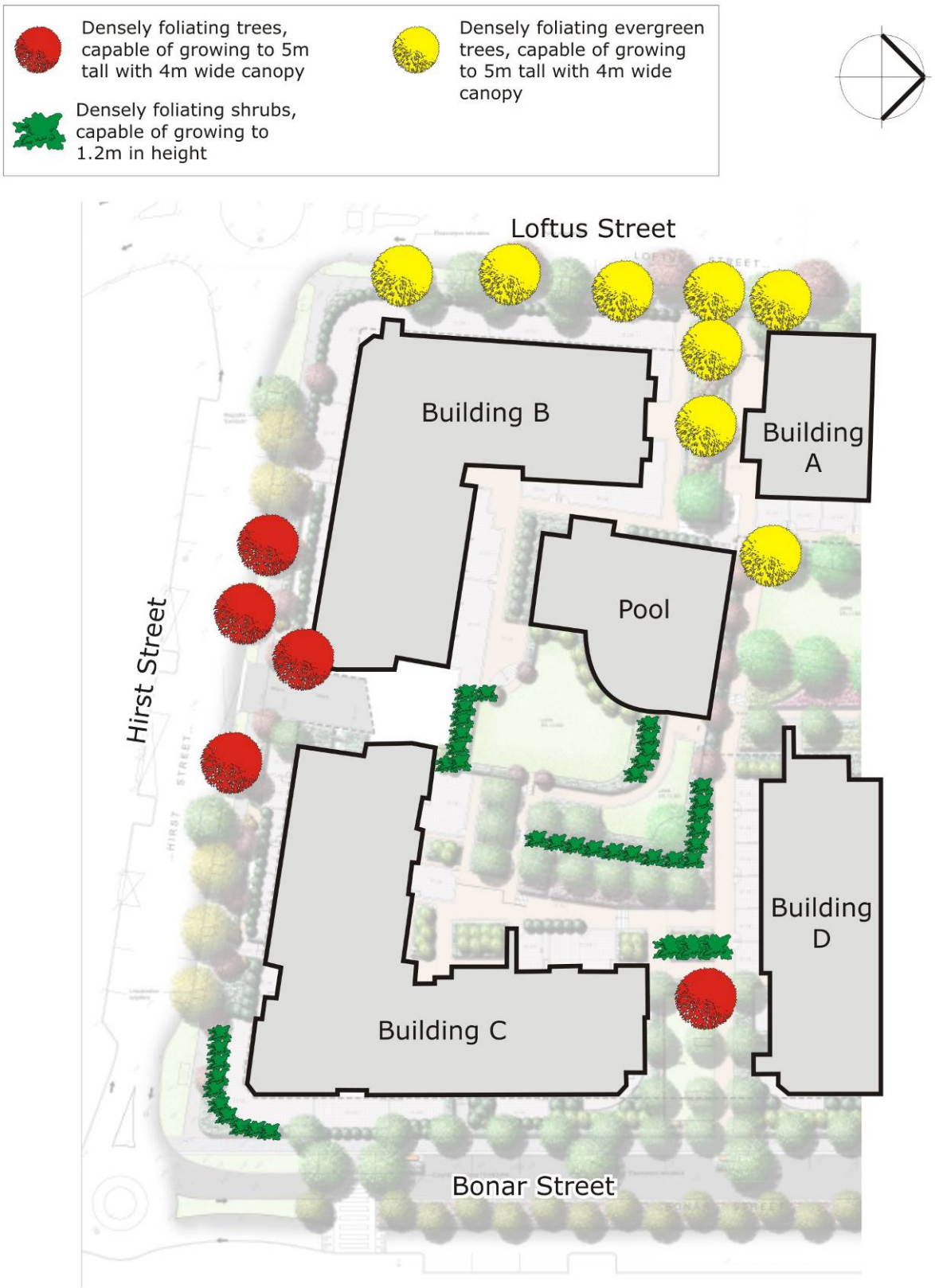


**Figure 7a: Recommended Treatments for the Ground Level within and around Building B and Building C**

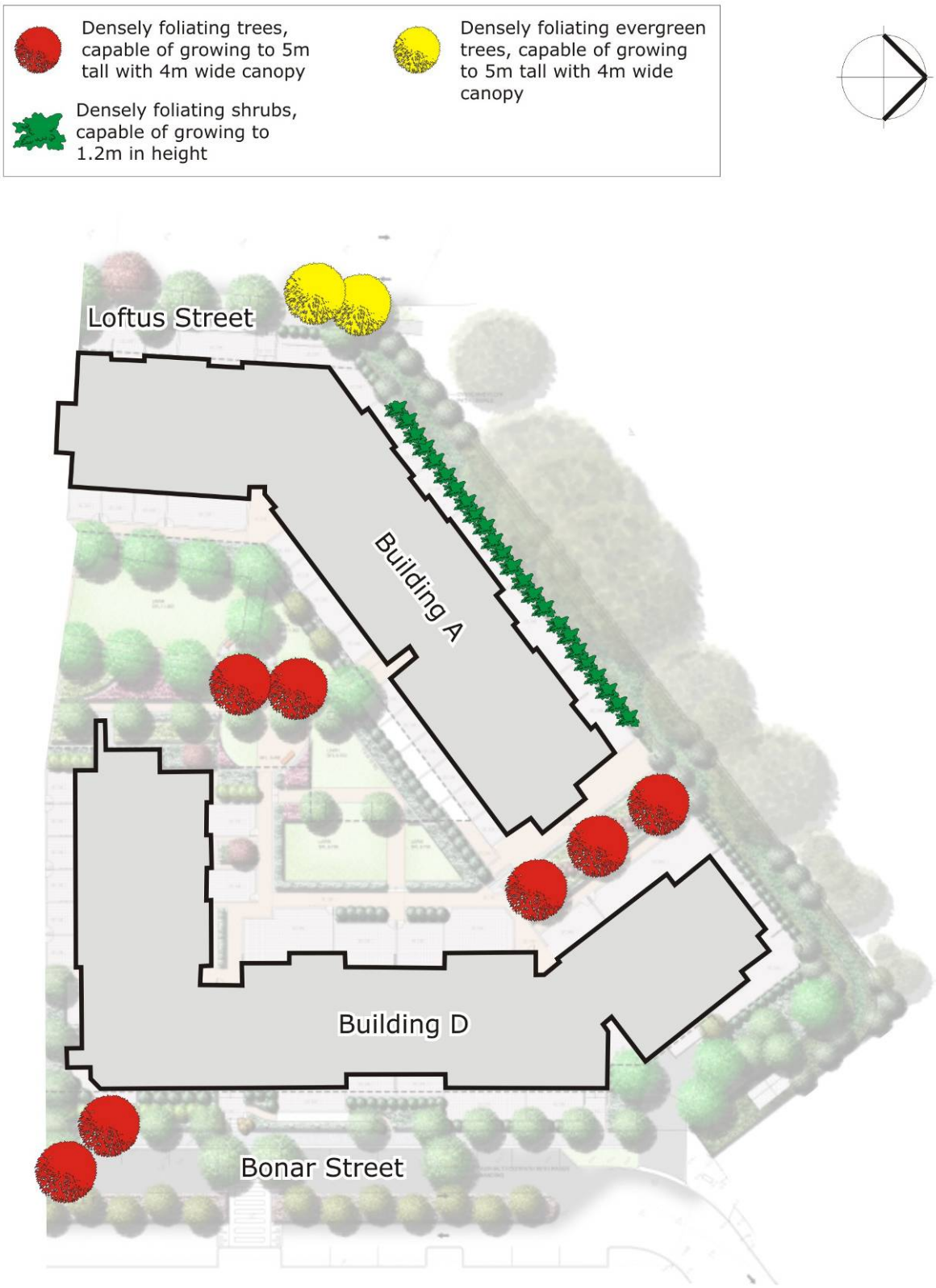


**Figure 7b: Recommended Treatments for the Ground Level within and around Building B and Building C**

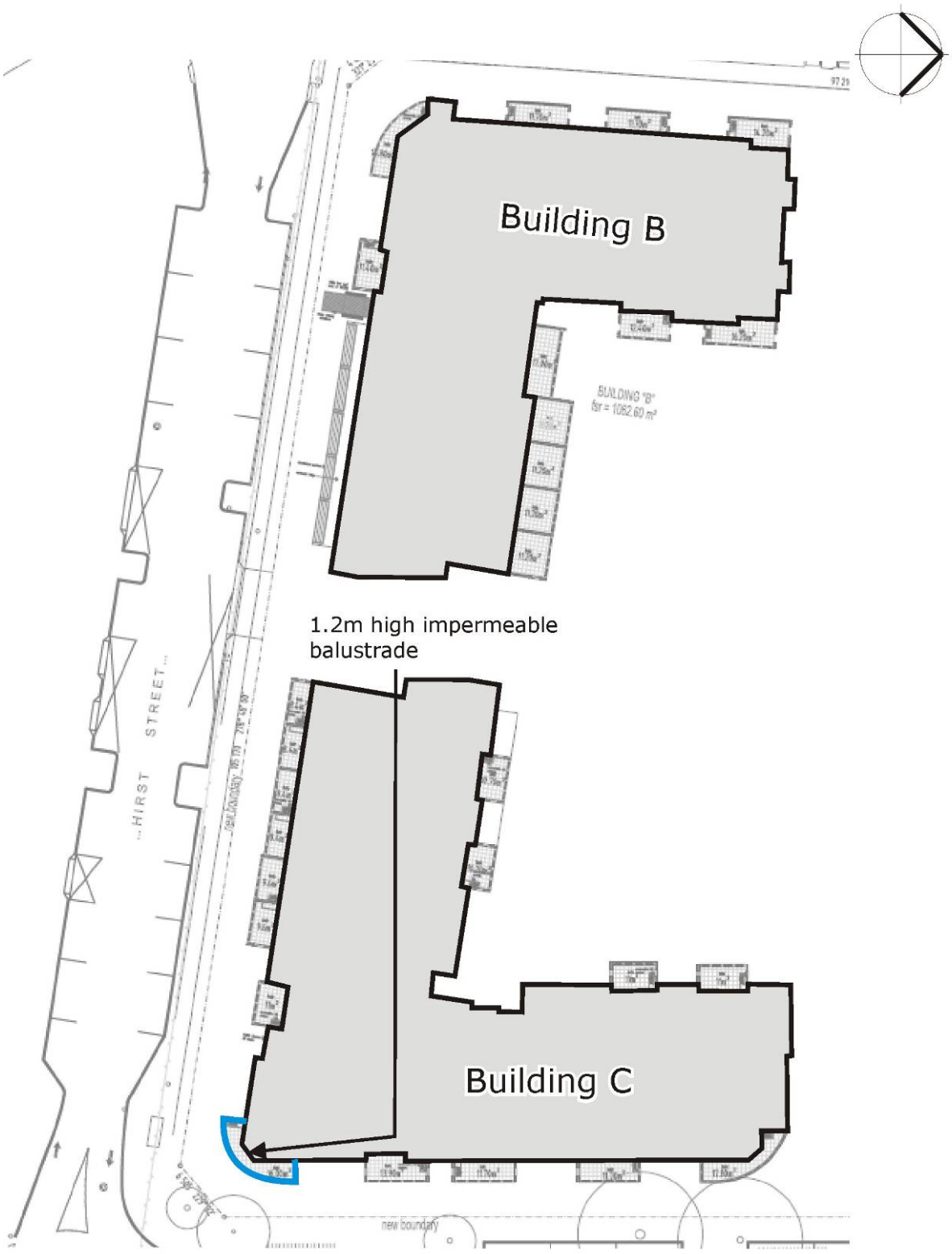


**Figure 7c: Recommended Treatments for the Balcony Levels on Building C**

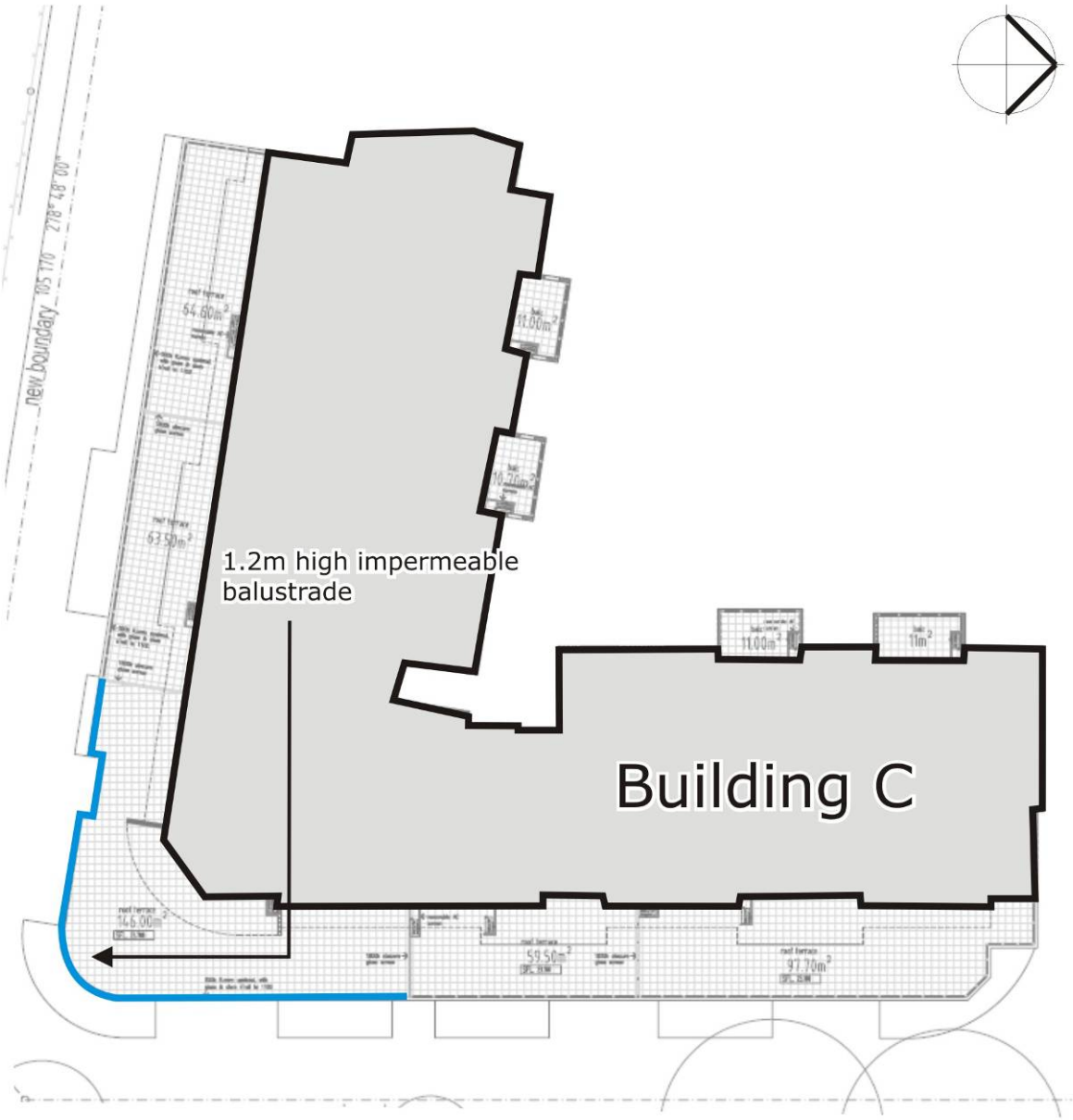


**Figure 7d: Recommended Treatments for the Level 7 roof terrace on Building C**

## 6.0 Conclusion

A wind tunnel study has been carried out to investigate the wind environment effects pertaining to development at 12-40 Bonar Street, located in Arncliffe.

The results of this study indicate that wind conditions for most of the outdoor areas of the site will require treatments to be implemented to be acceptable for their intended uses. Solutions have been investigated in this study to treat the adverse winds affecting the outdoor areas of the proposed development. A set of treatments have been recommended in this report to ameliorate these effects, and are summarised as follows;

- A strategic layout of densely foliating trees and shrubs for the ground level areas within and around the development site.

- 1.2m high impermeable balustrades along the perimeter of all private terrace and balconies on the south-east corner of Building C of the proposed development.

Note that for vegetation to be effective in mitigating adverse westerly winds, which occur predominantly during the winter months for the Sydney region, densely foliating evergreen species should be used. The results of this study indicate that adverse westerly winds affect the pedestrian areas along Loftus Street.

With the recommended treatments made in this report included into the final design of the development, the wind conditions within and around the proposed development will be acceptable for their intended uses and satisfy the requirements for wind comfort as required by Section 5 of the Rockdale City Council Development Control Plan No. 62 for Wolli Creek.

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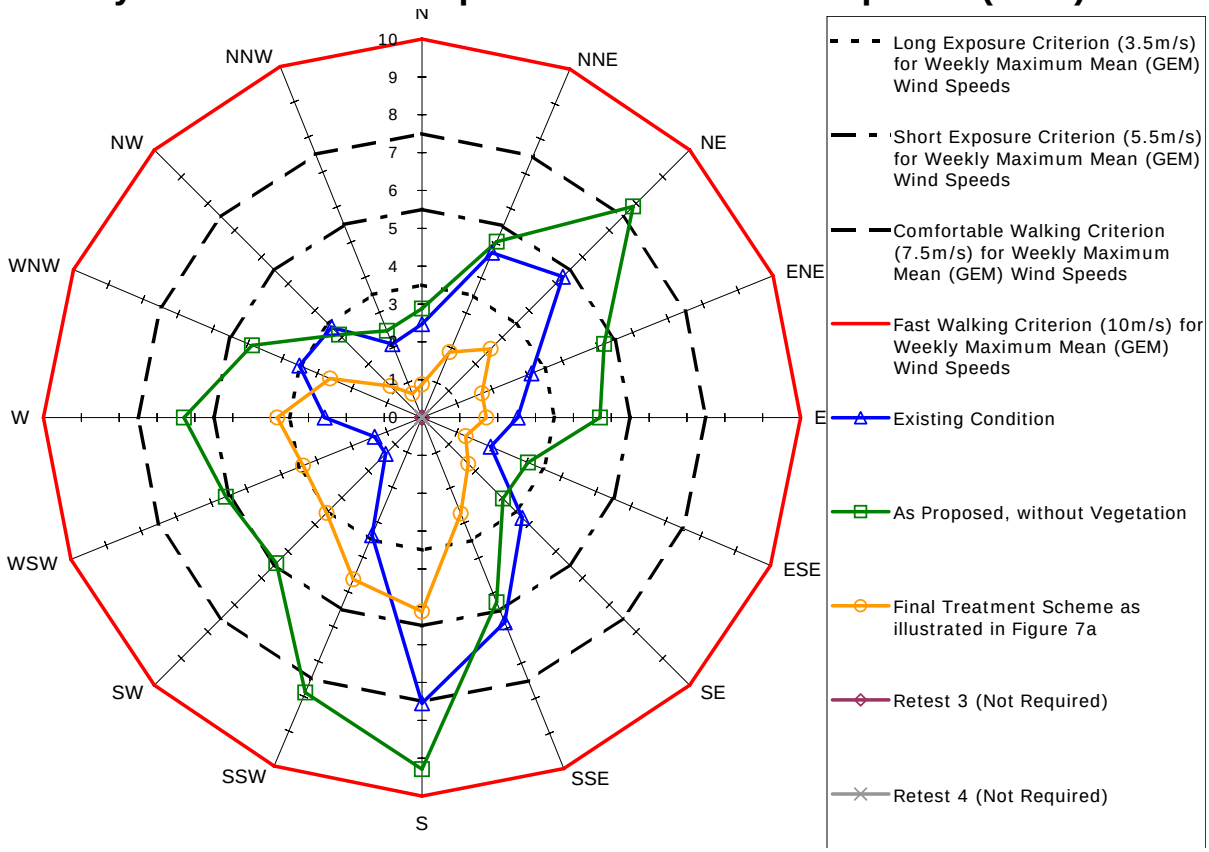
# Appendix A

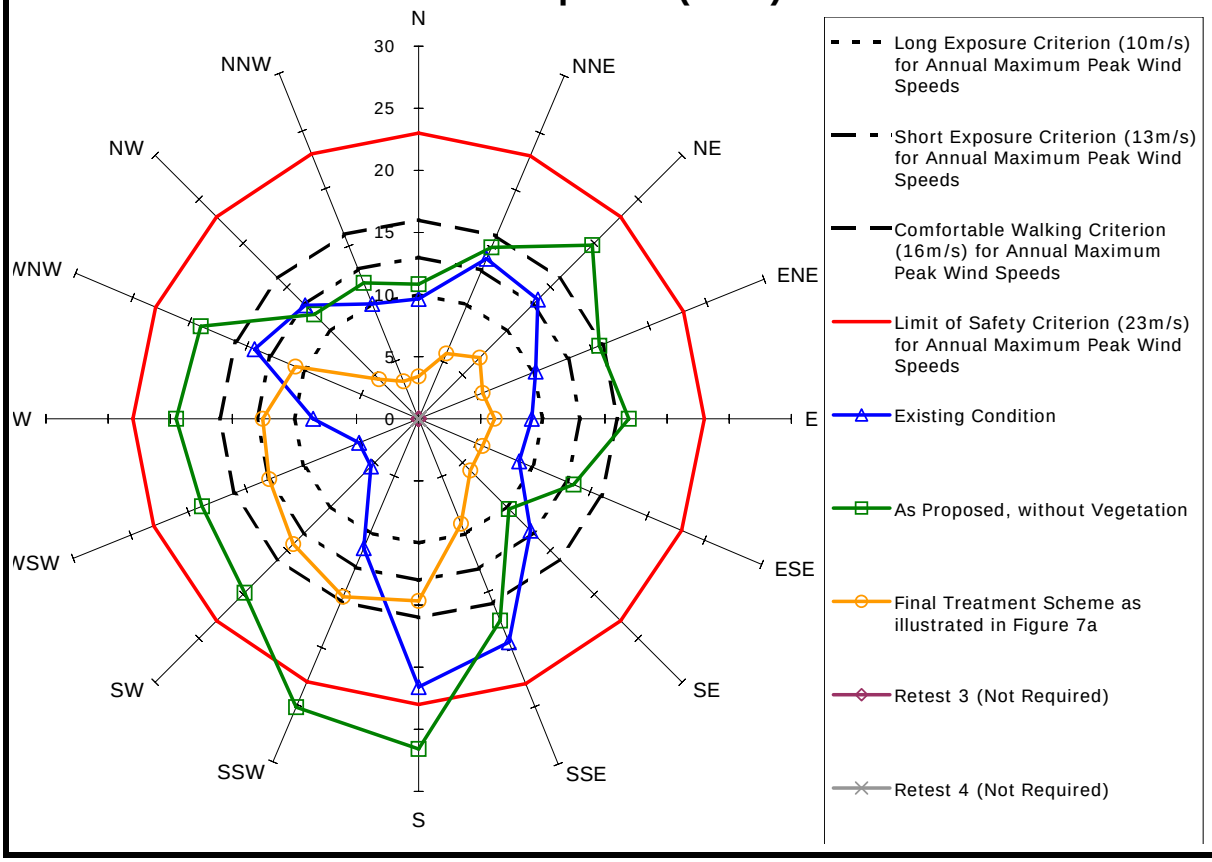
Plots of Wind Tunnel Results

# Measured Wind Speeds at Point 01

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

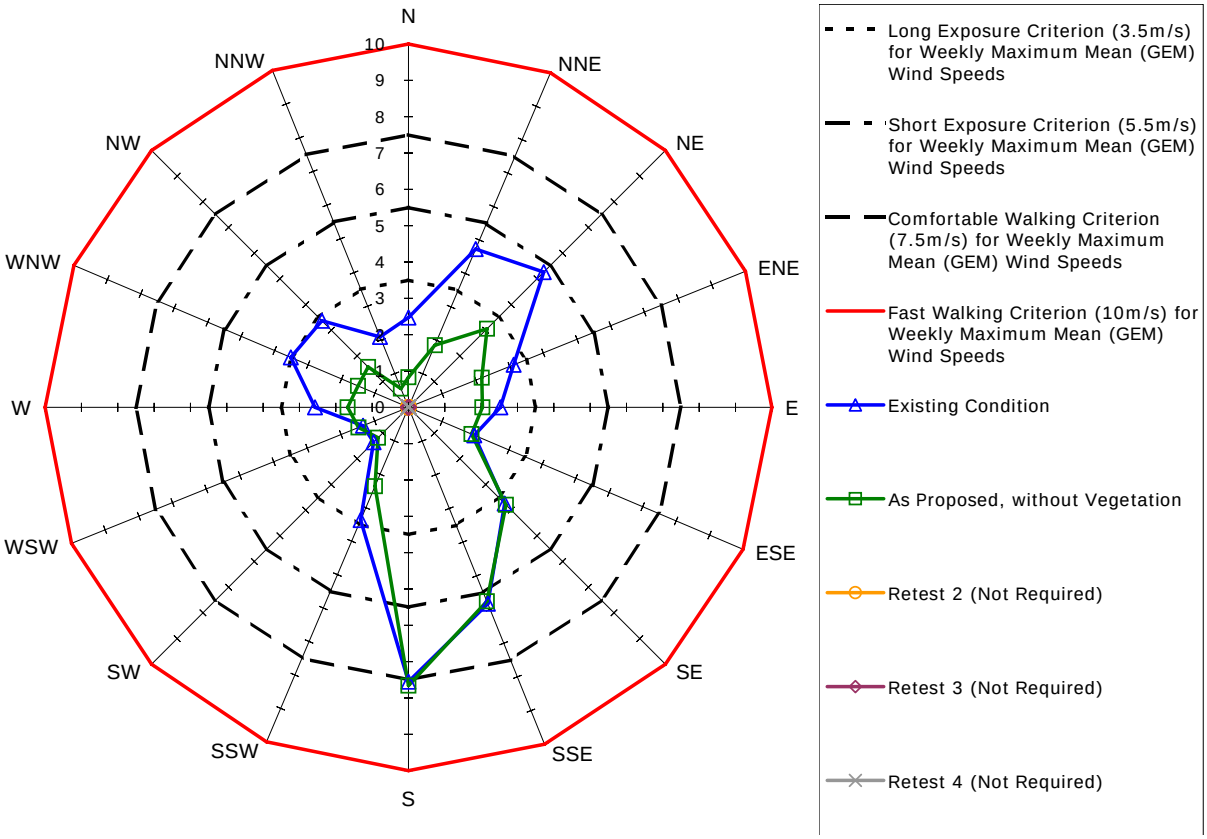



## Annual Maximum Gust Wind Speeds (m/s)

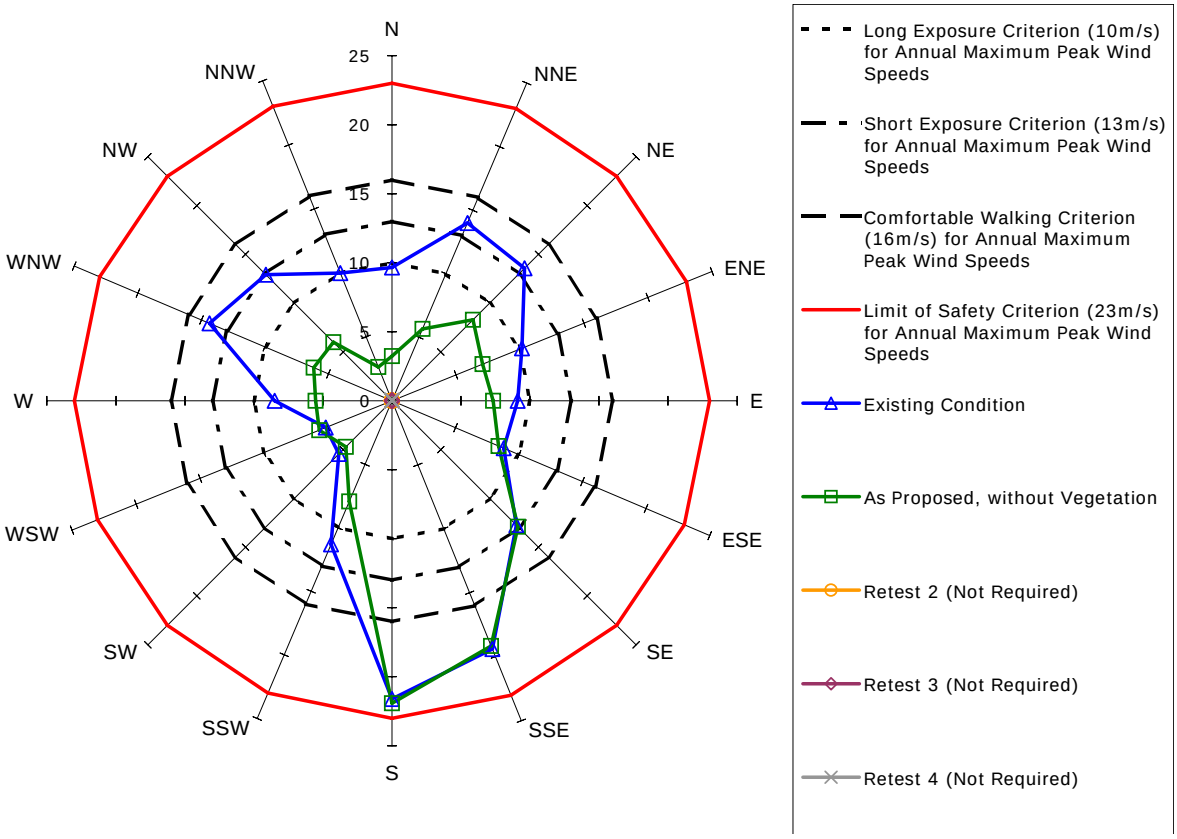


# Measured Wind Speeds at Point 02

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)




## Annual Maximum Gust Wind Speeds (m/s)



# Measured Wind Speeds at Point 03

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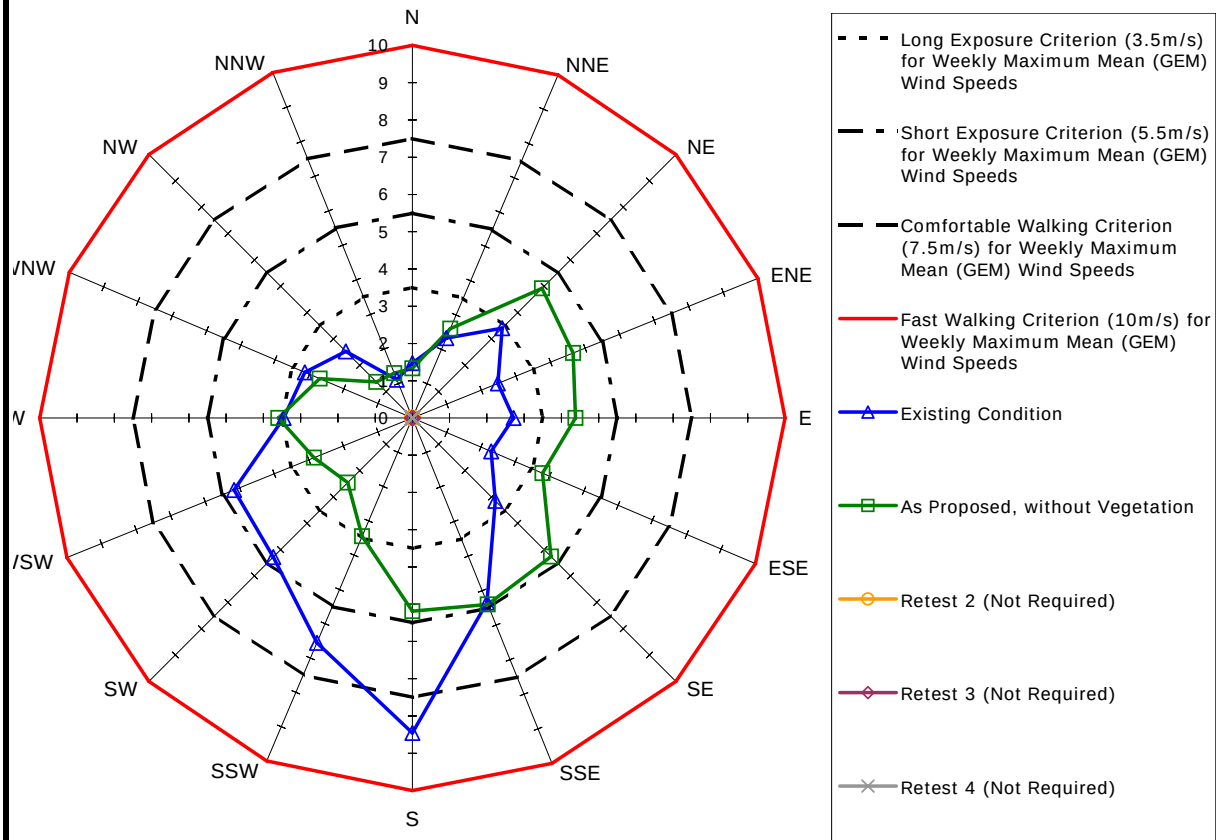
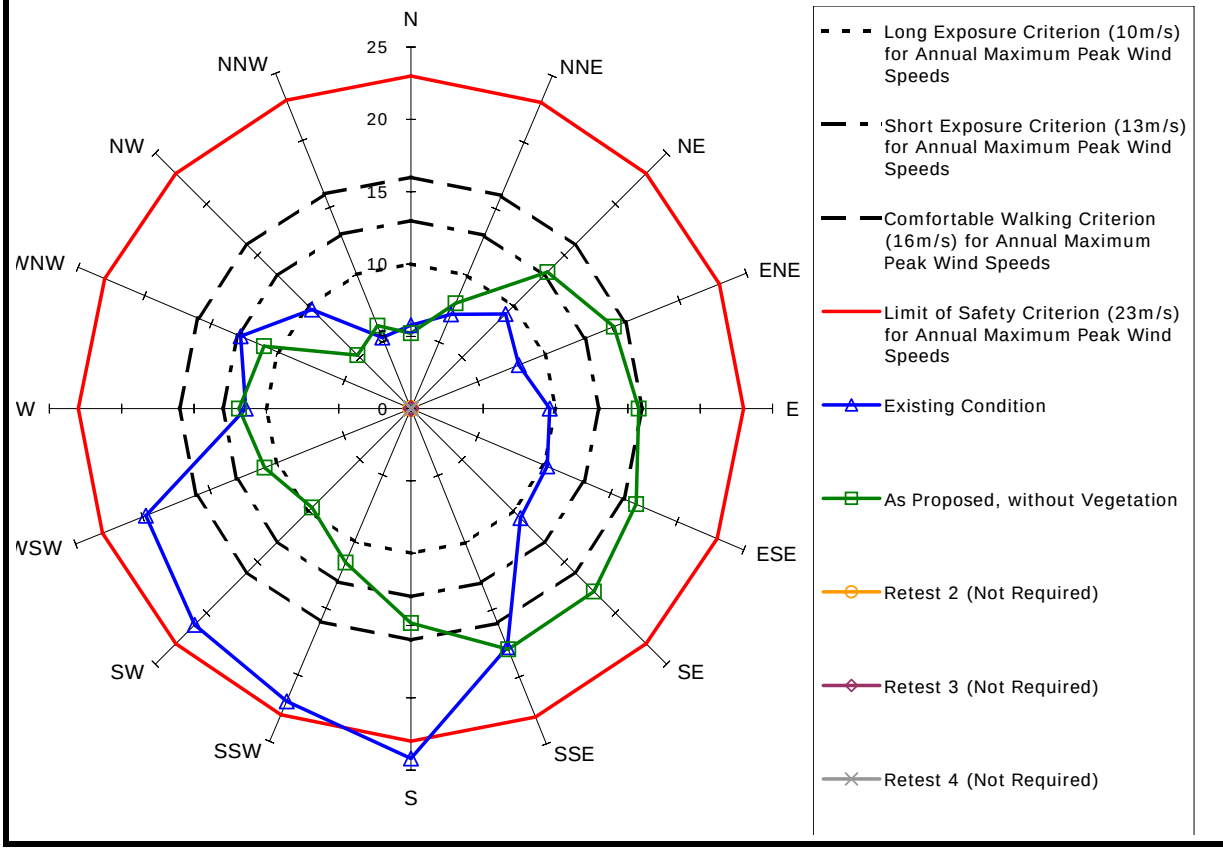
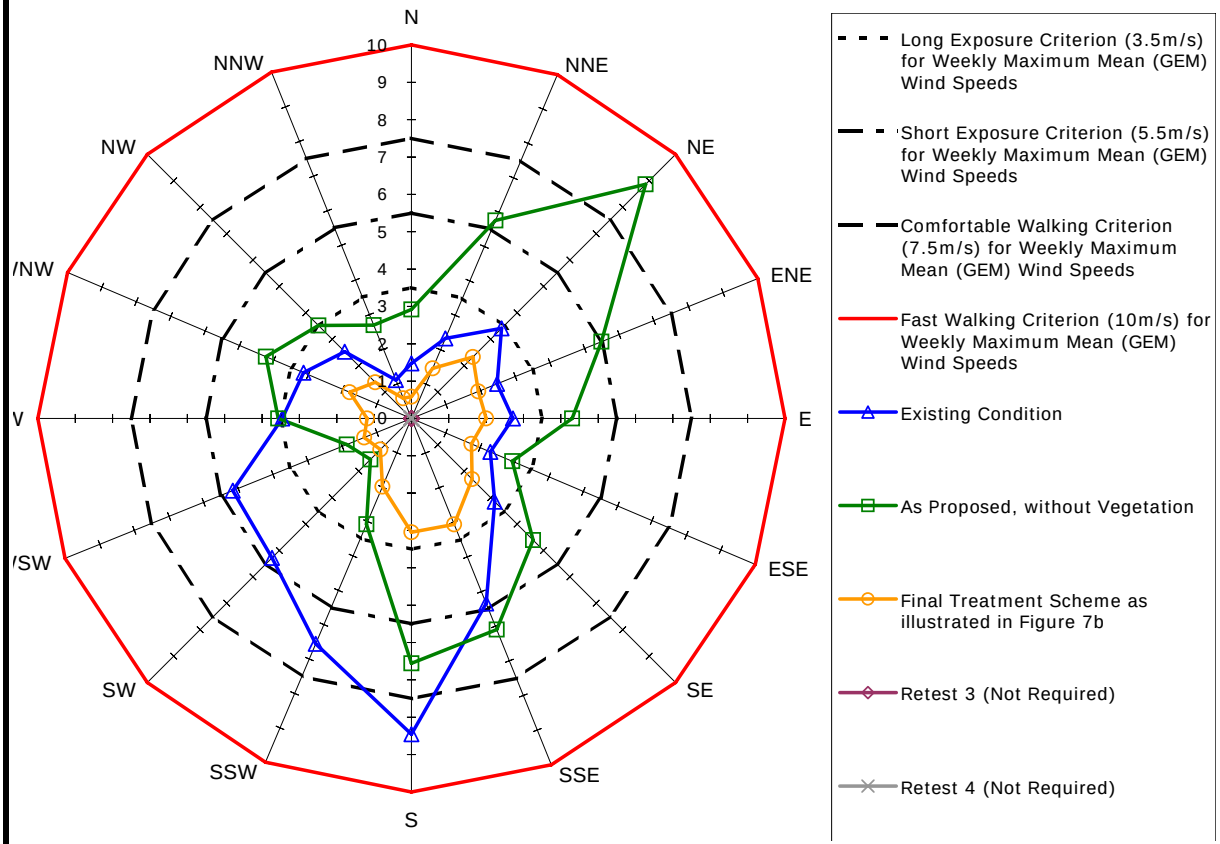



## Annual Maximum Gust Wind Speeds (m/s)

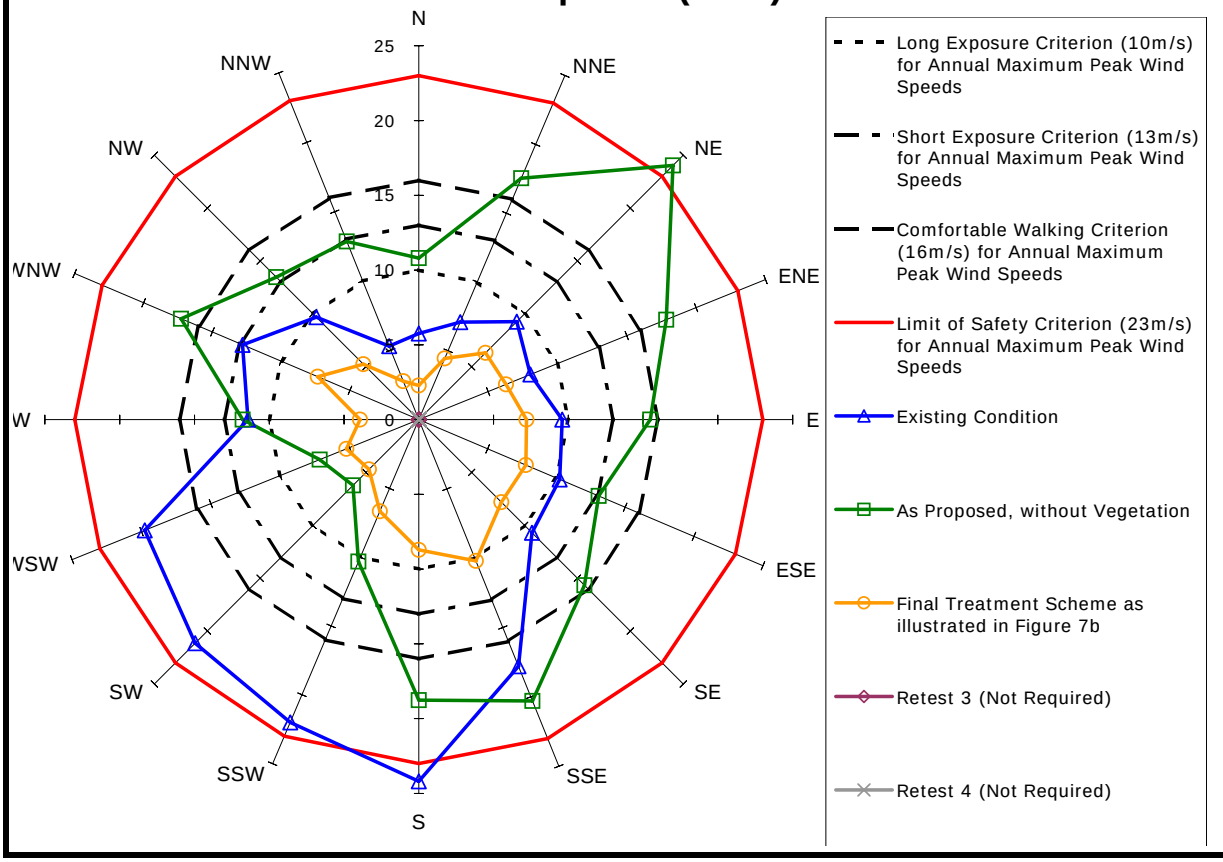


# Measured Wind Speeds at Point 04

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

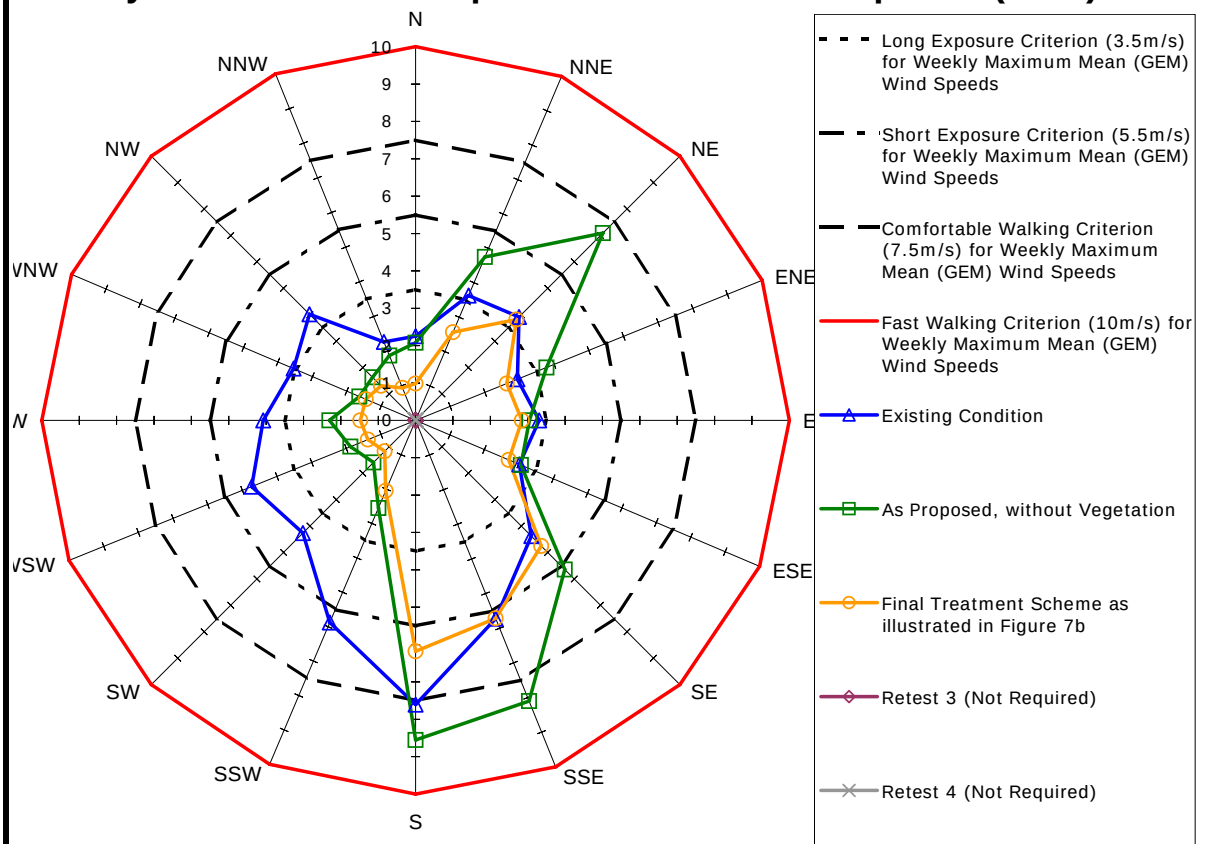



## Annual Maximum Gust Wind Speeds (m/s)

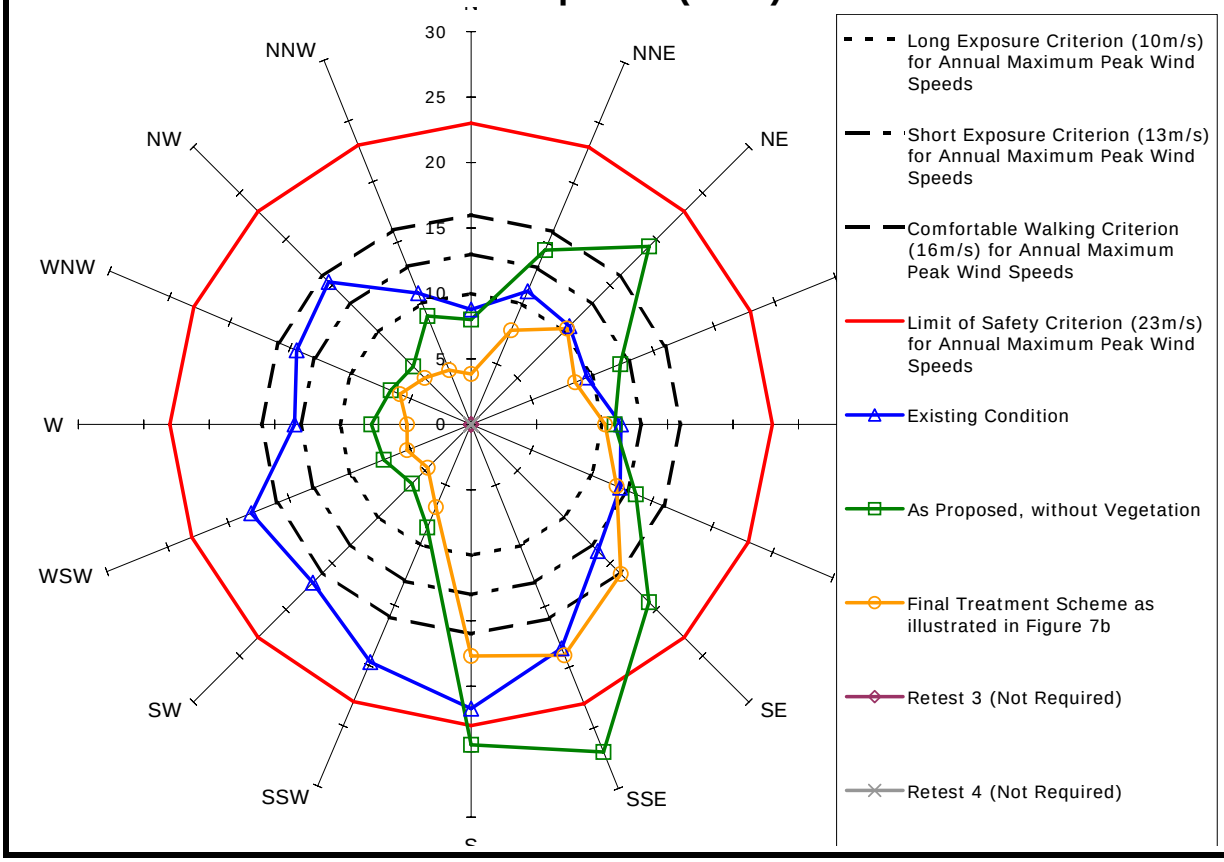


# Measured Wind Speeds at Point 05

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

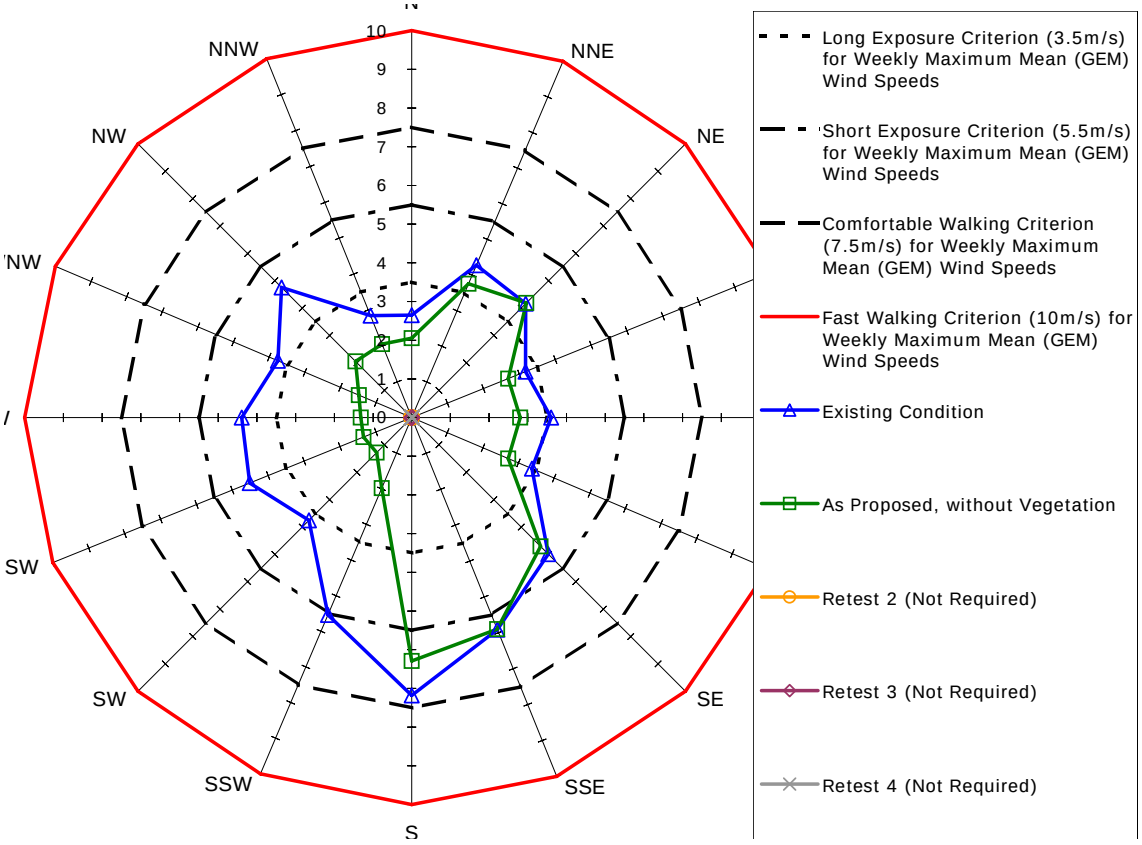



## Annual Maximum Gust Wind Speeds (m/s)

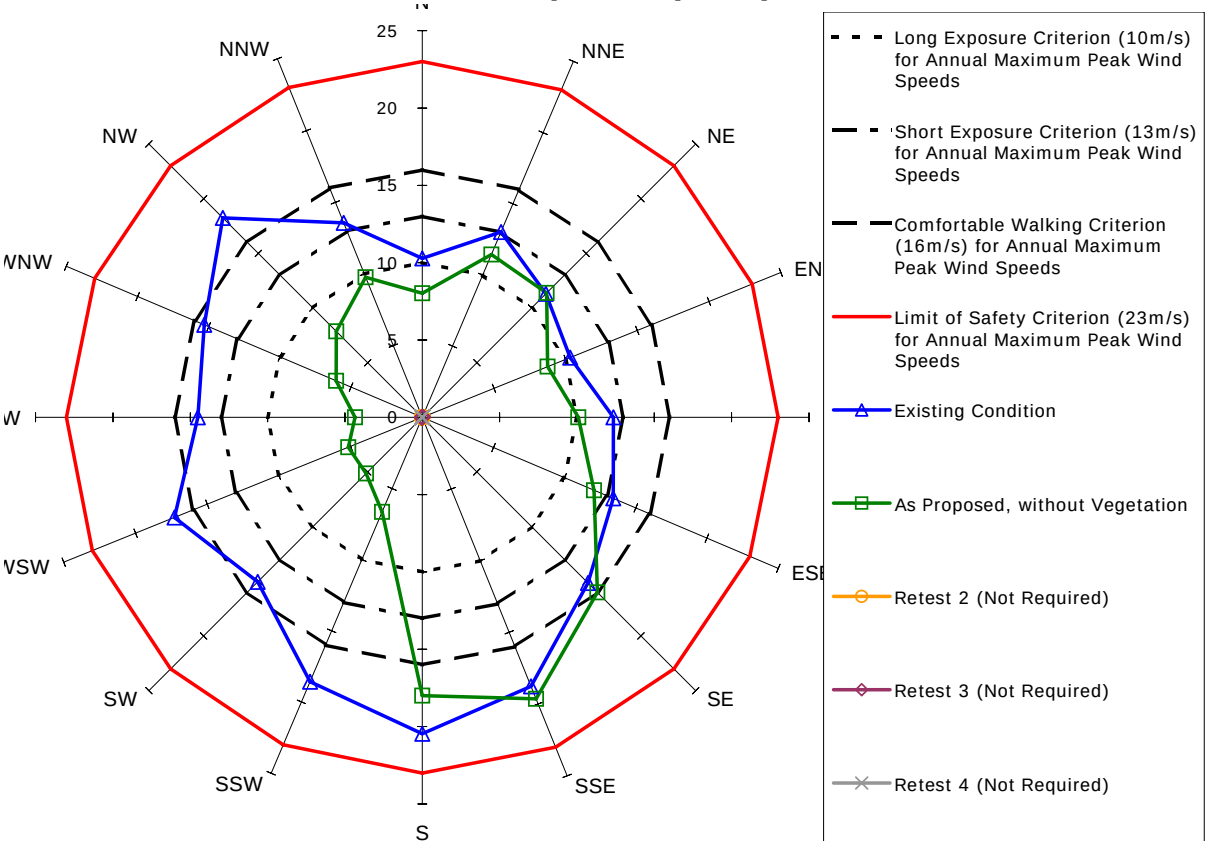


# Measured Wind Speeds at Point 06

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)




## Annual Maximum Gust Wind Speeds (m/s)



# Measured Wind Speeds at Point 07

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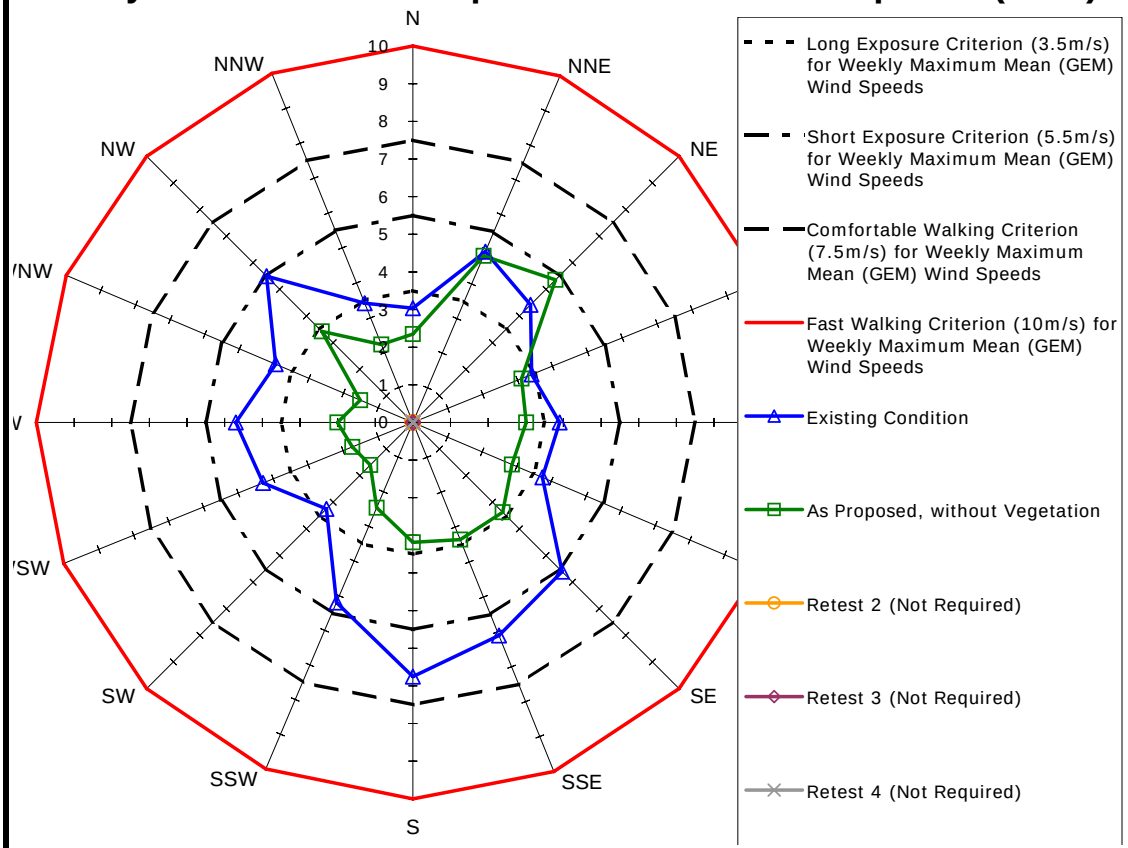
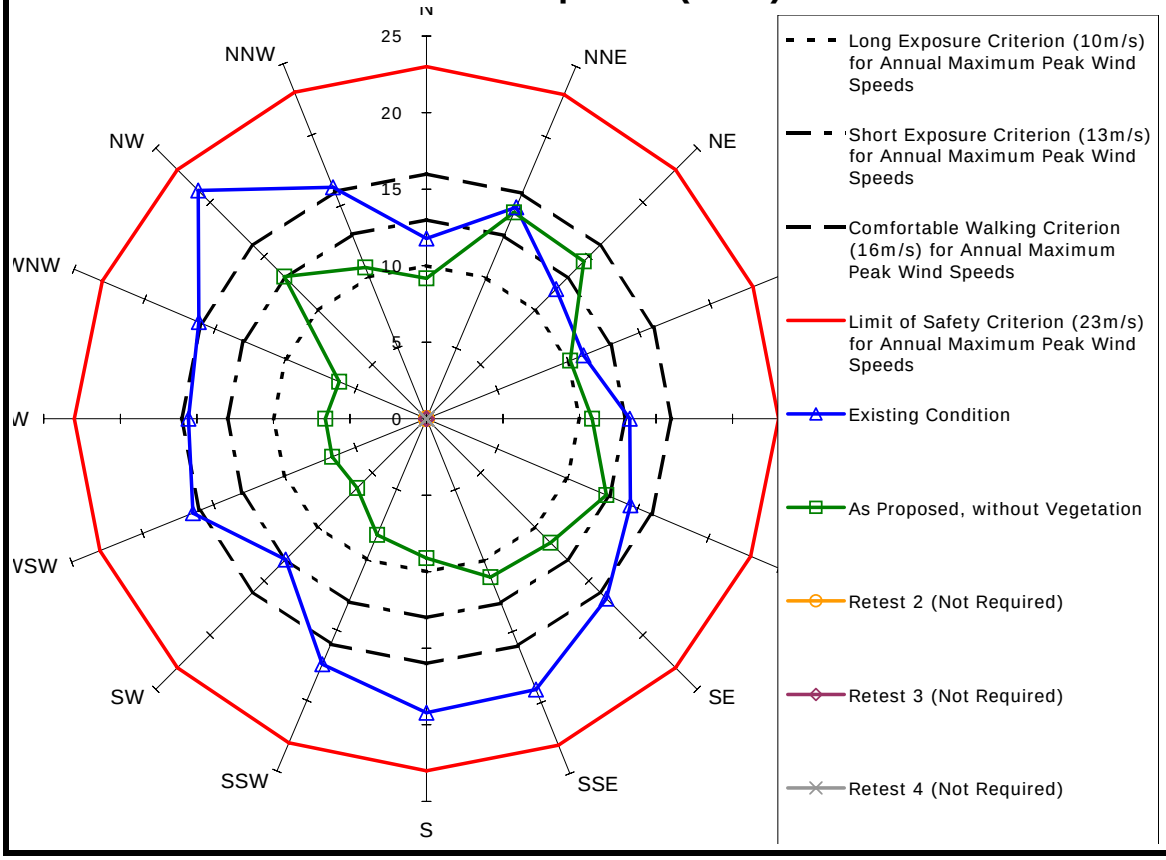



## Annual Maximum Gust Wind Speeds (m/s)



# Measured Wind Speeds at Point 08

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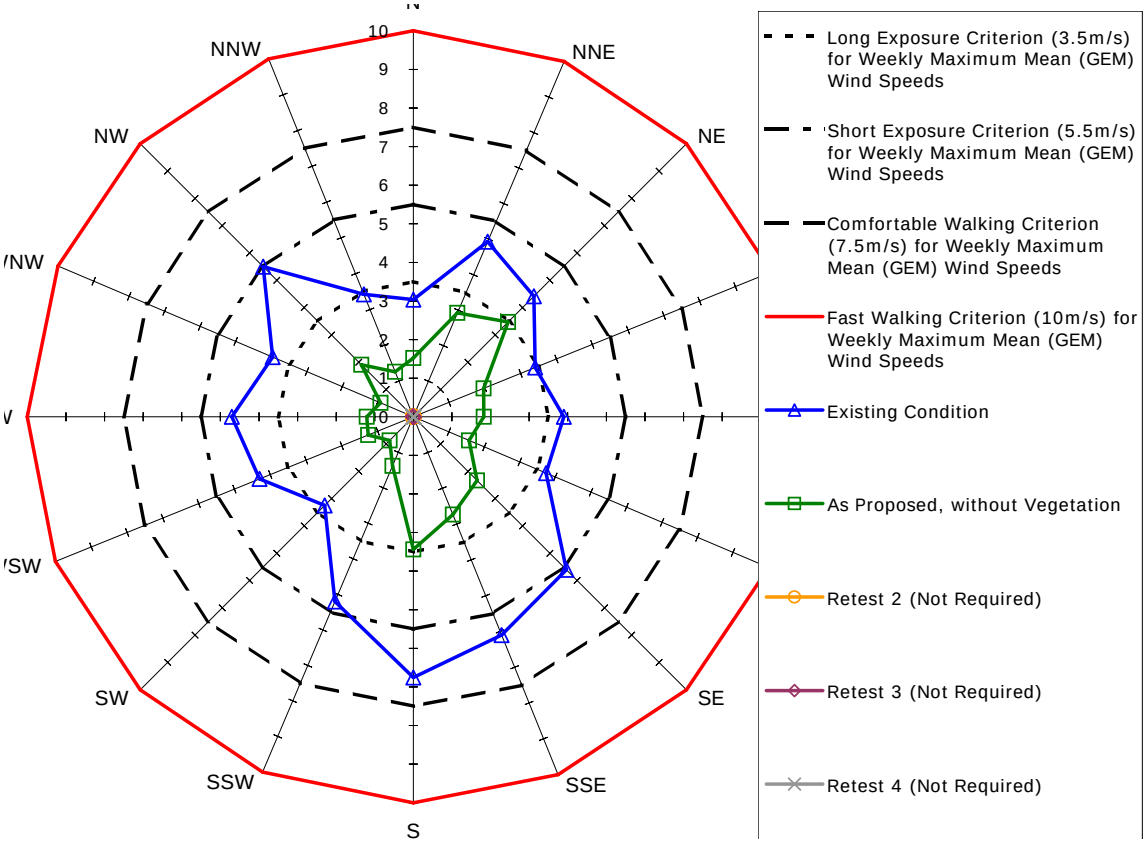
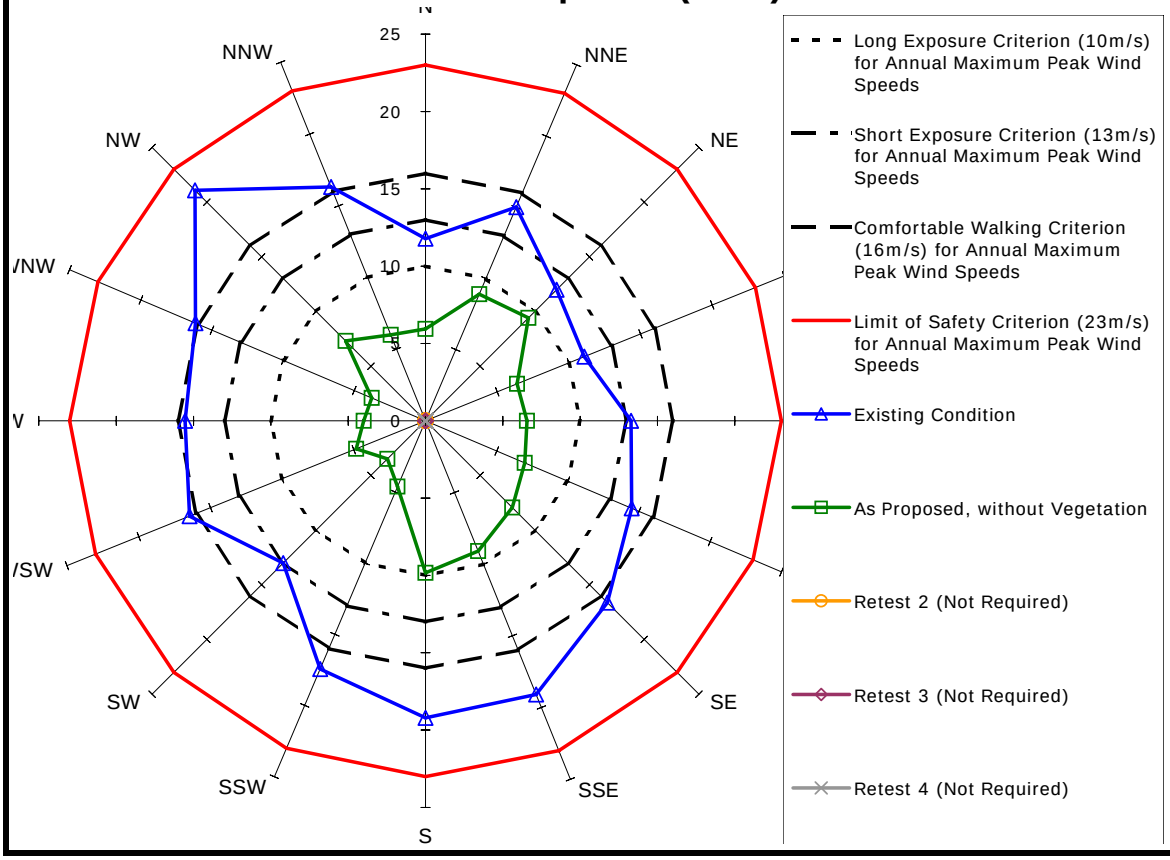



## Annual Maximum Gust Wind Speeds (m/s)



# Measured Wind Speeds at Point 09

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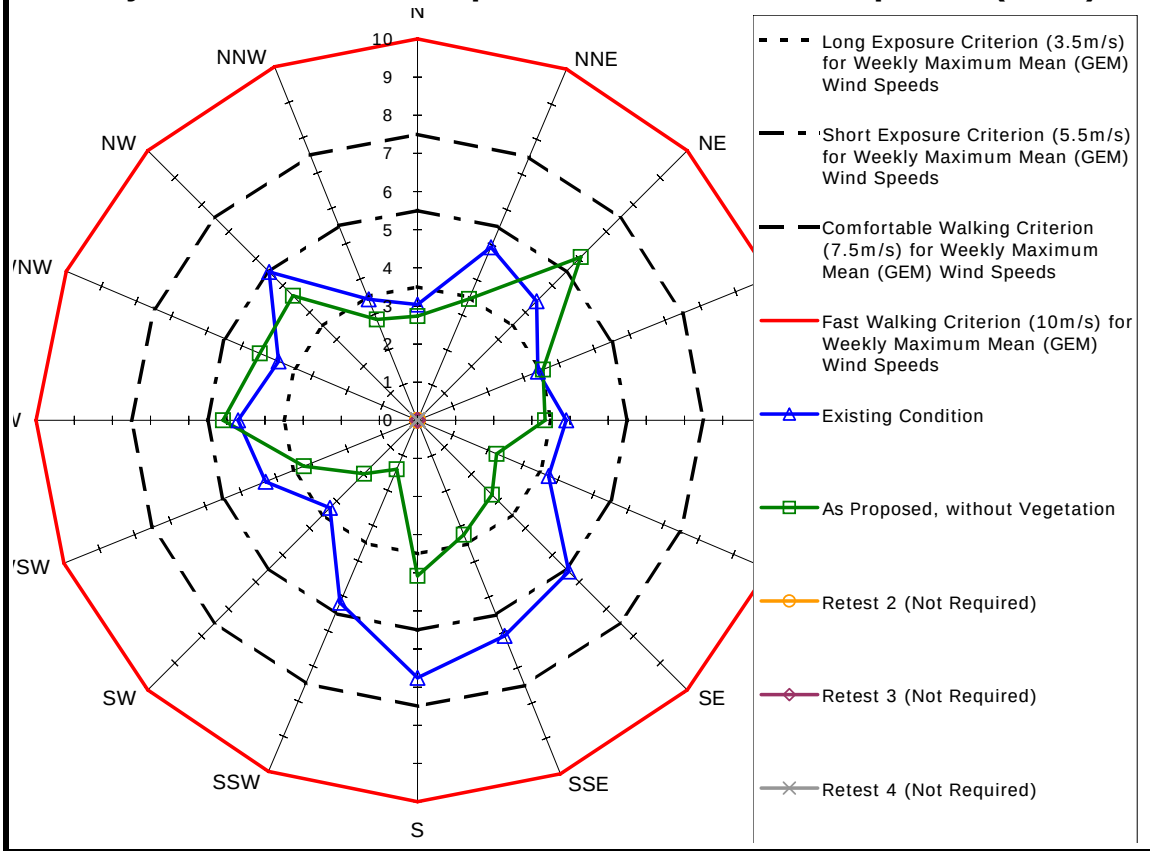


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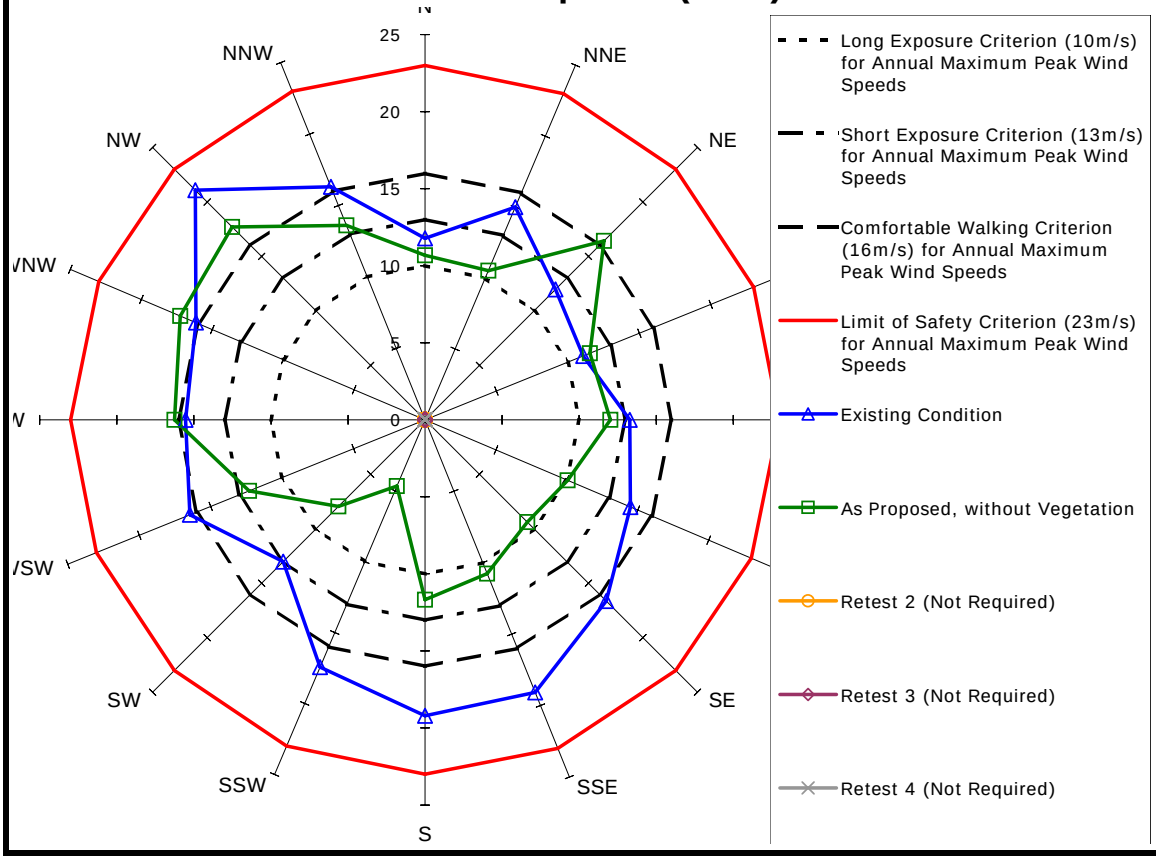

# Measured Wind Speeds at Point 10

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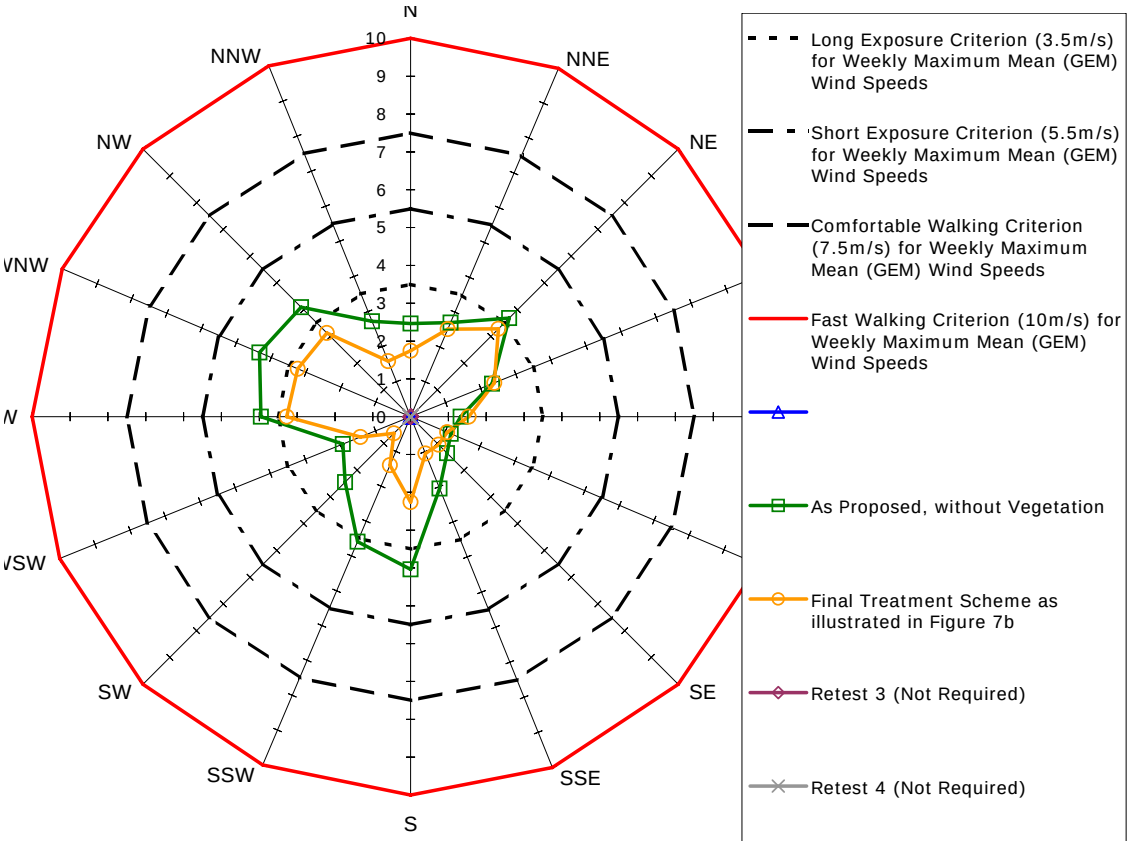


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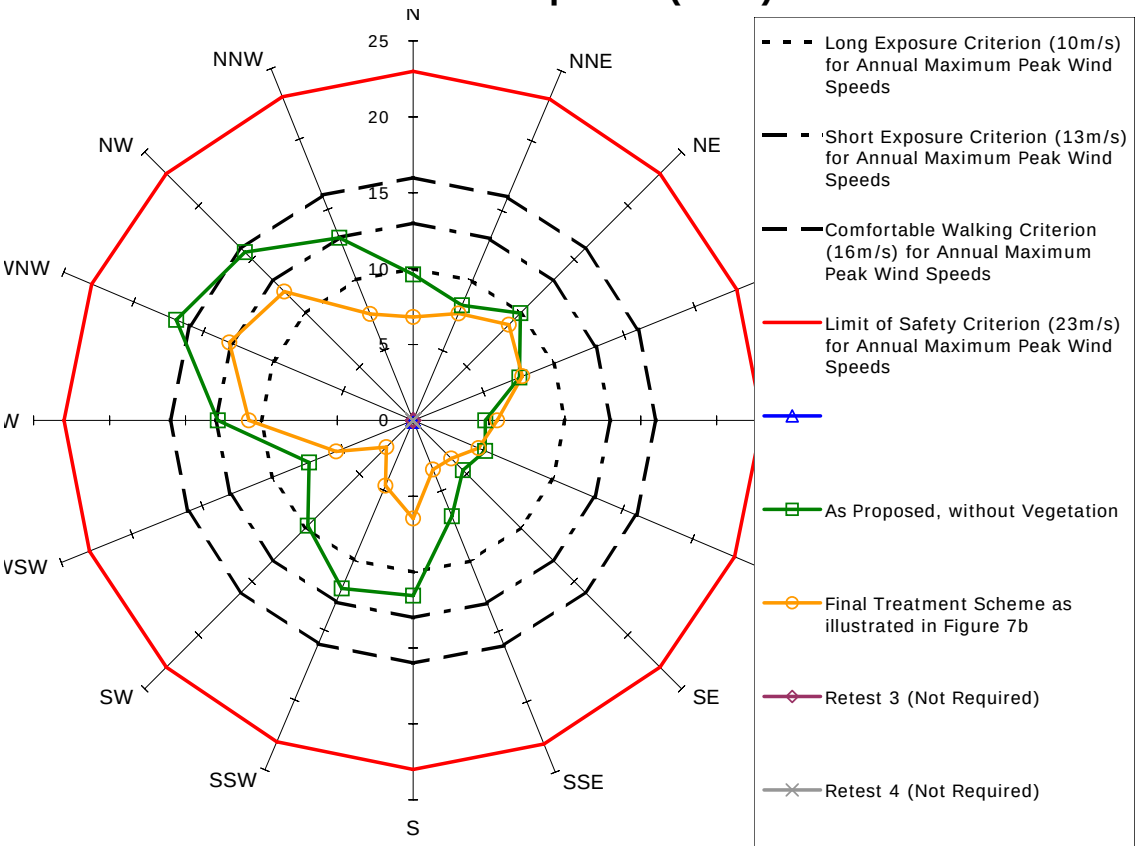
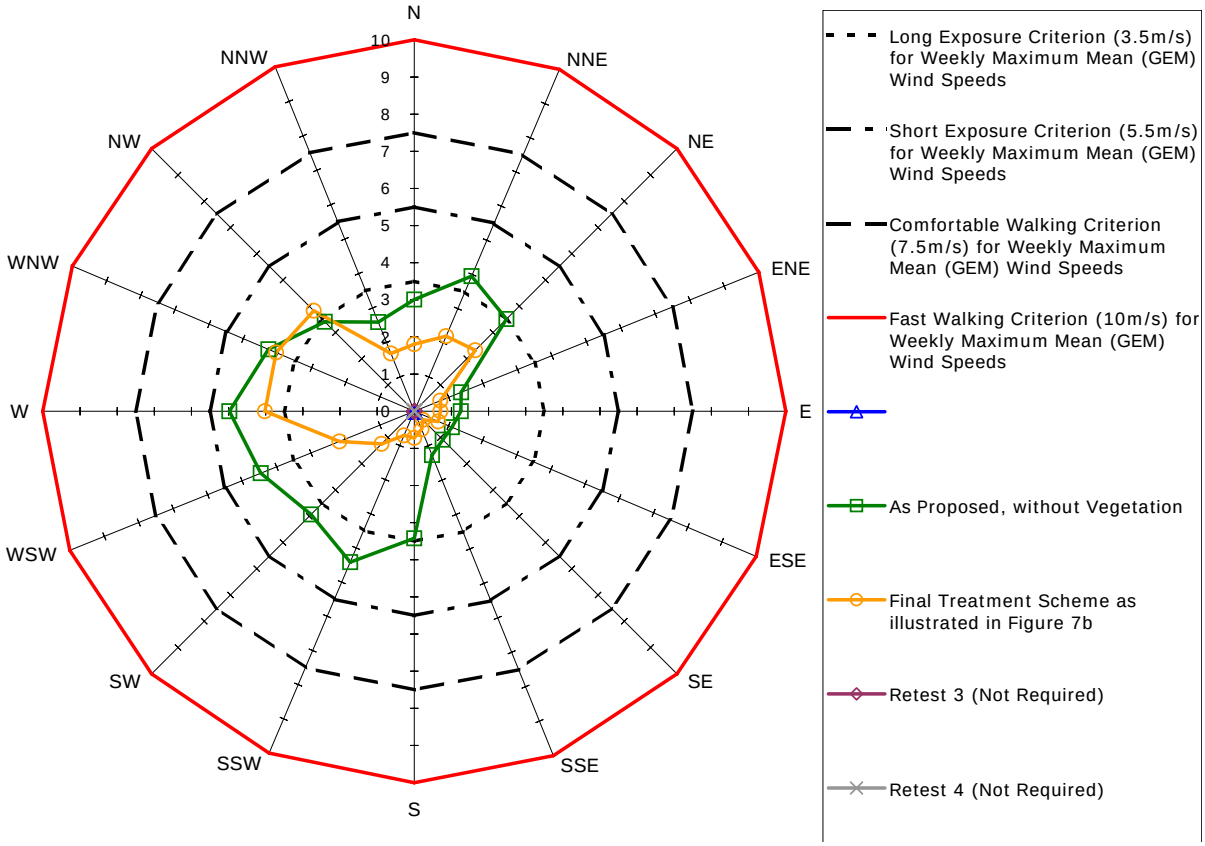
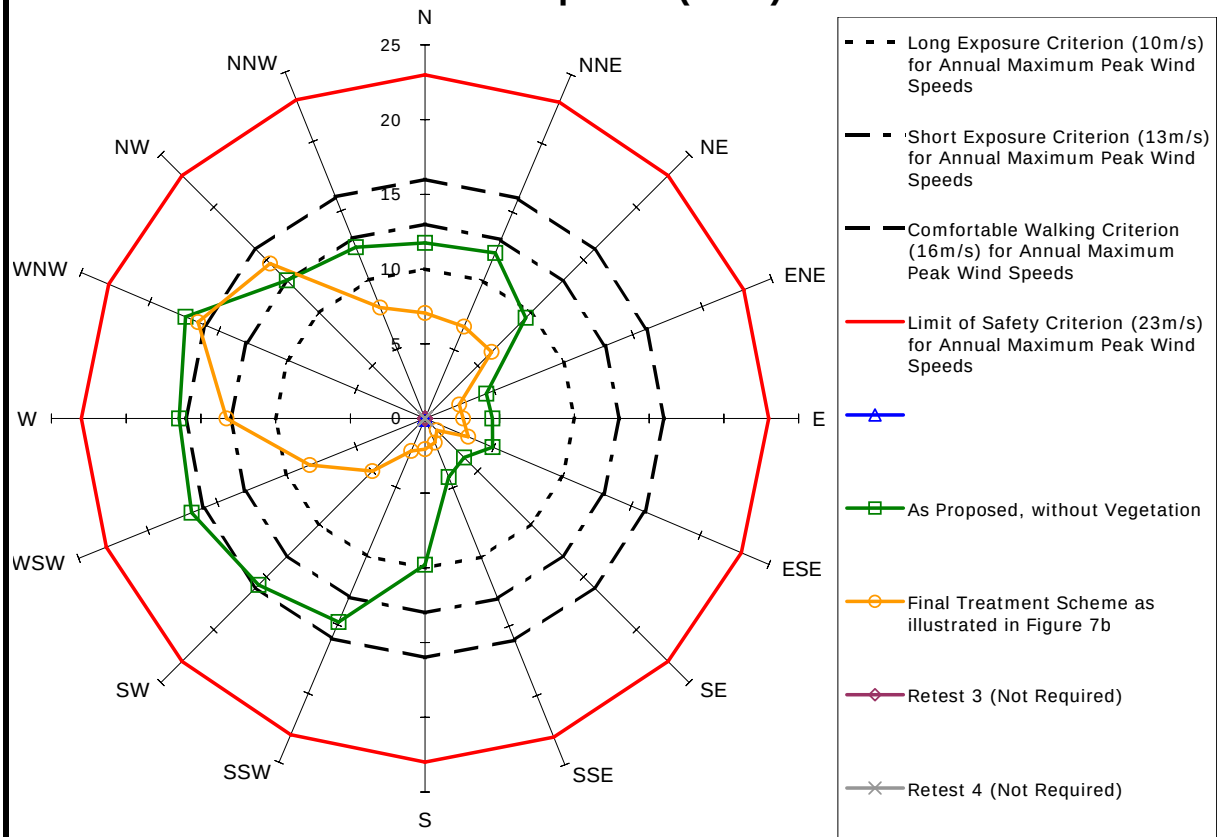


# Measured Wind Speeds at Point 11

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)




## Annual Maximum Gust Wind Speeds (m/s)



# Measured Wind Speeds at Point 12

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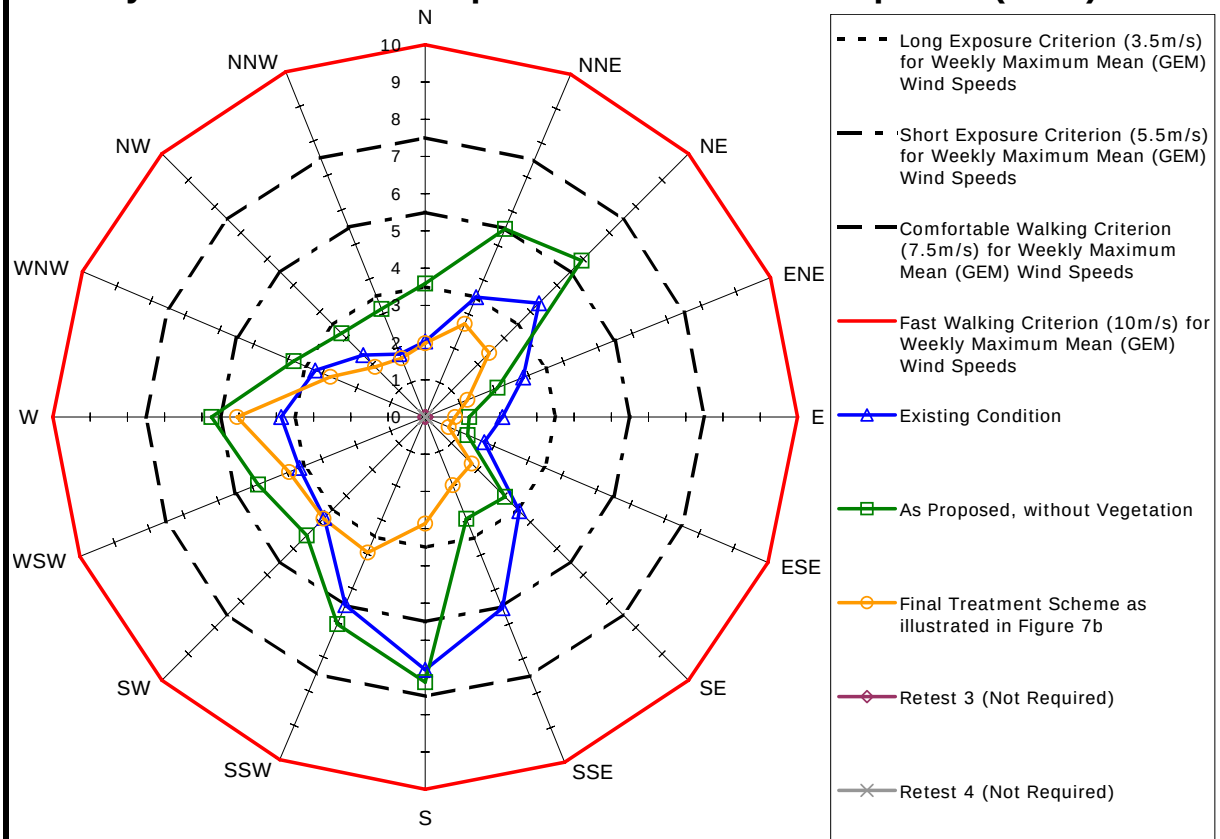
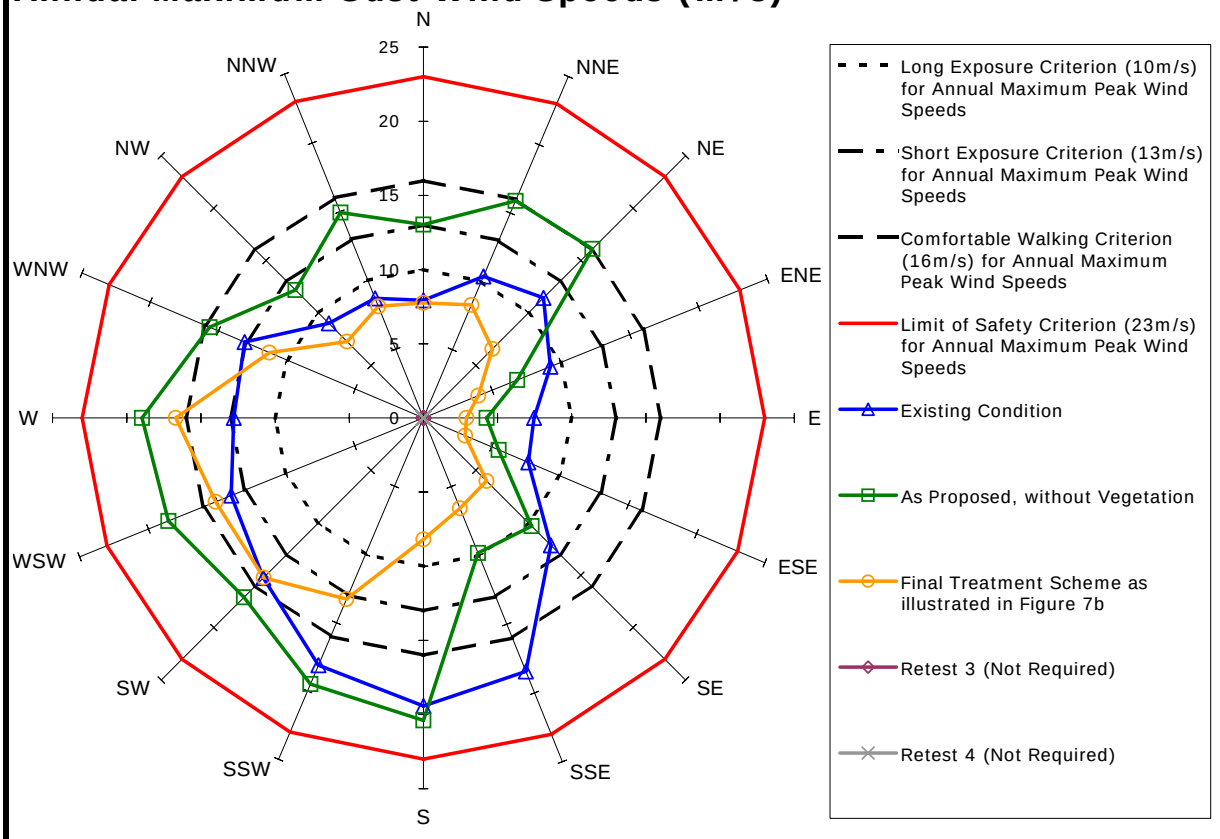
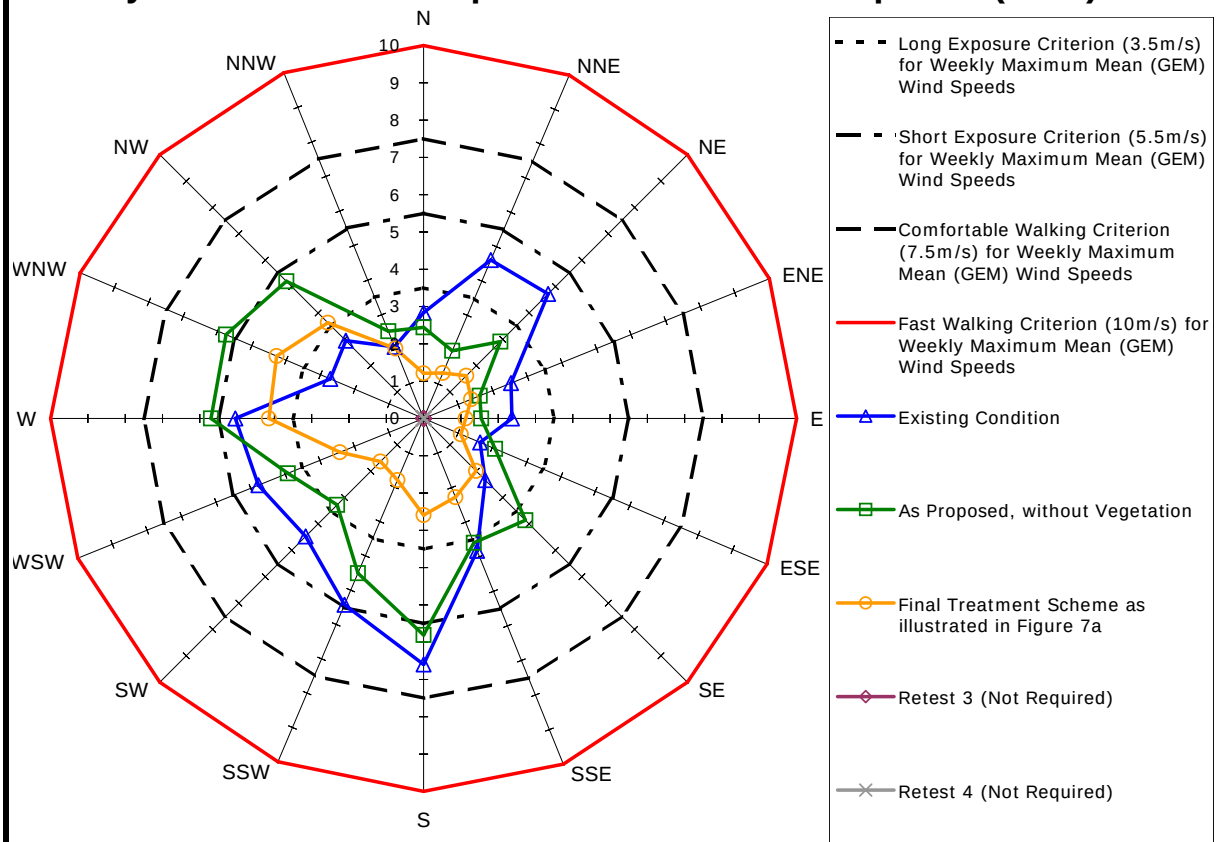



## Annual Maximum Gust Wind Speeds (m/s)

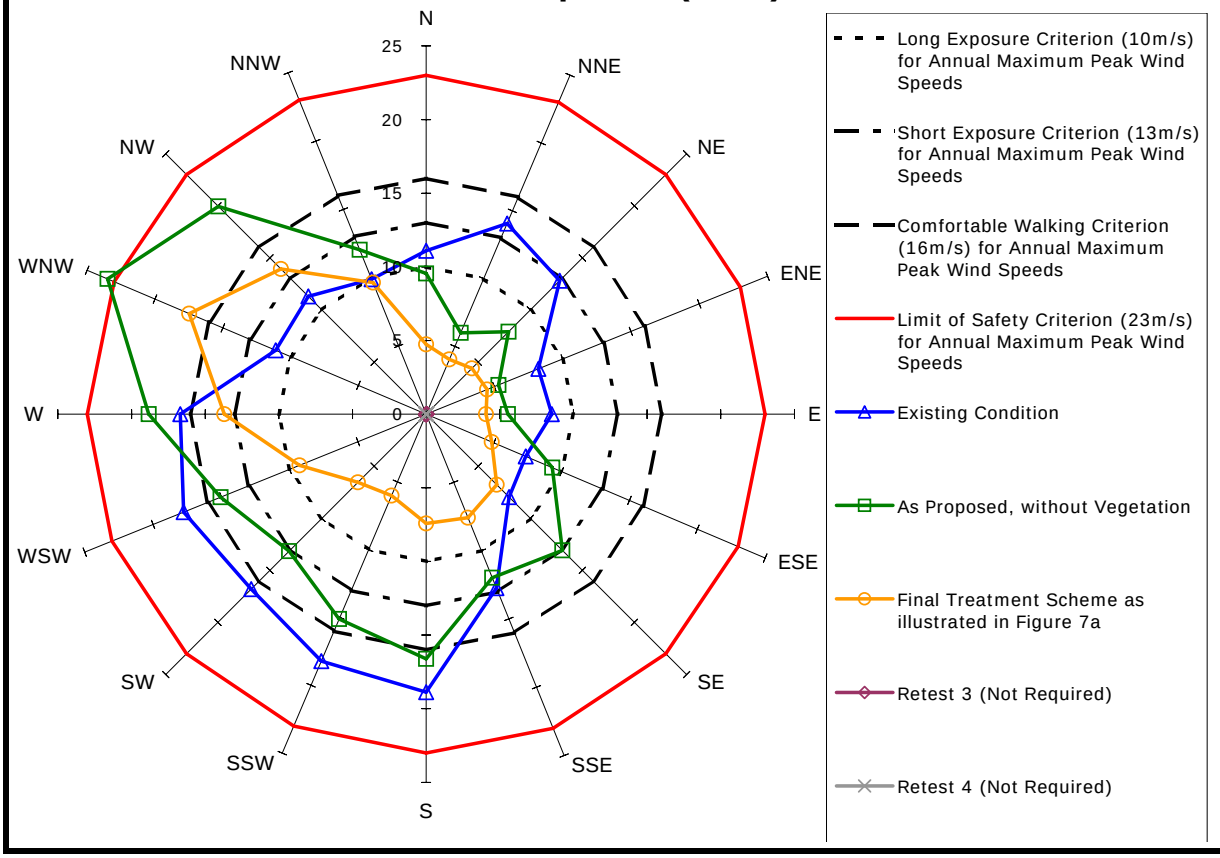


# Measured Wind Speeds at Point 13

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)




## Annual Maximum Gust Wind Speeds (m/s)



# Measured Wind Speeds at Point 14

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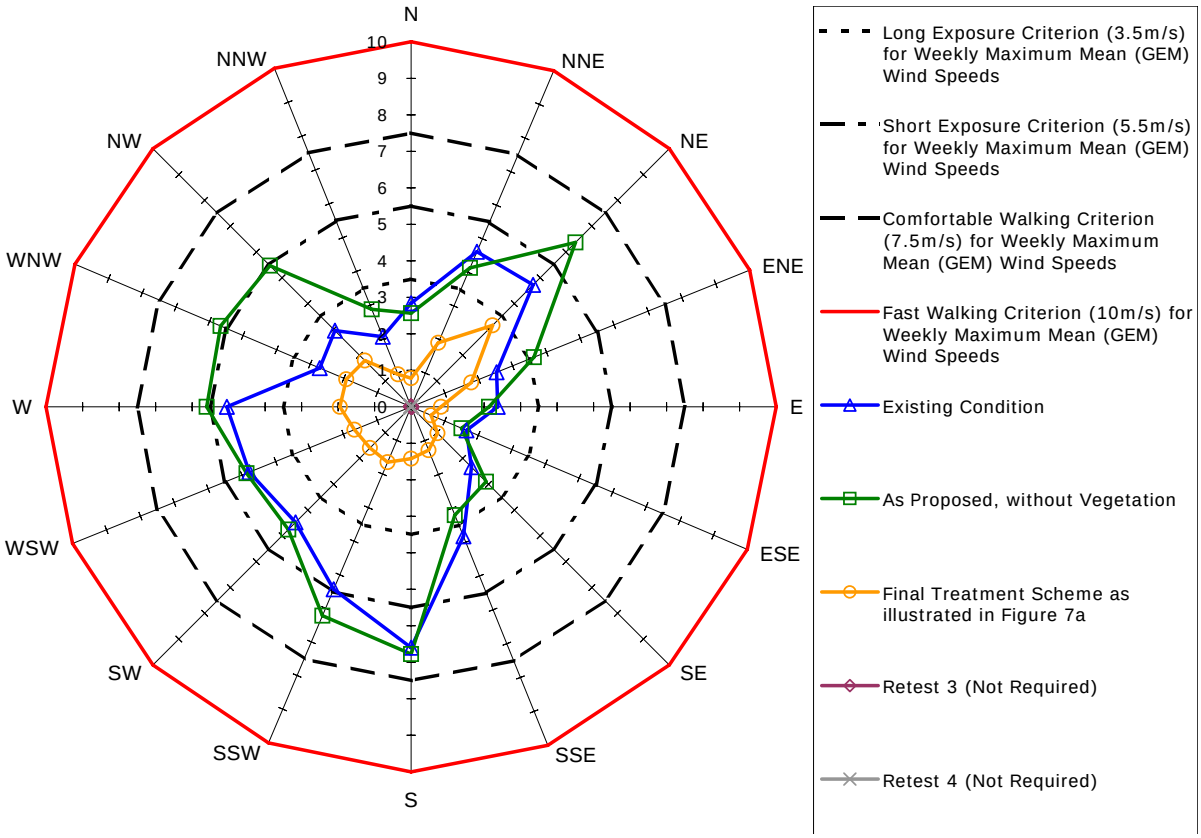
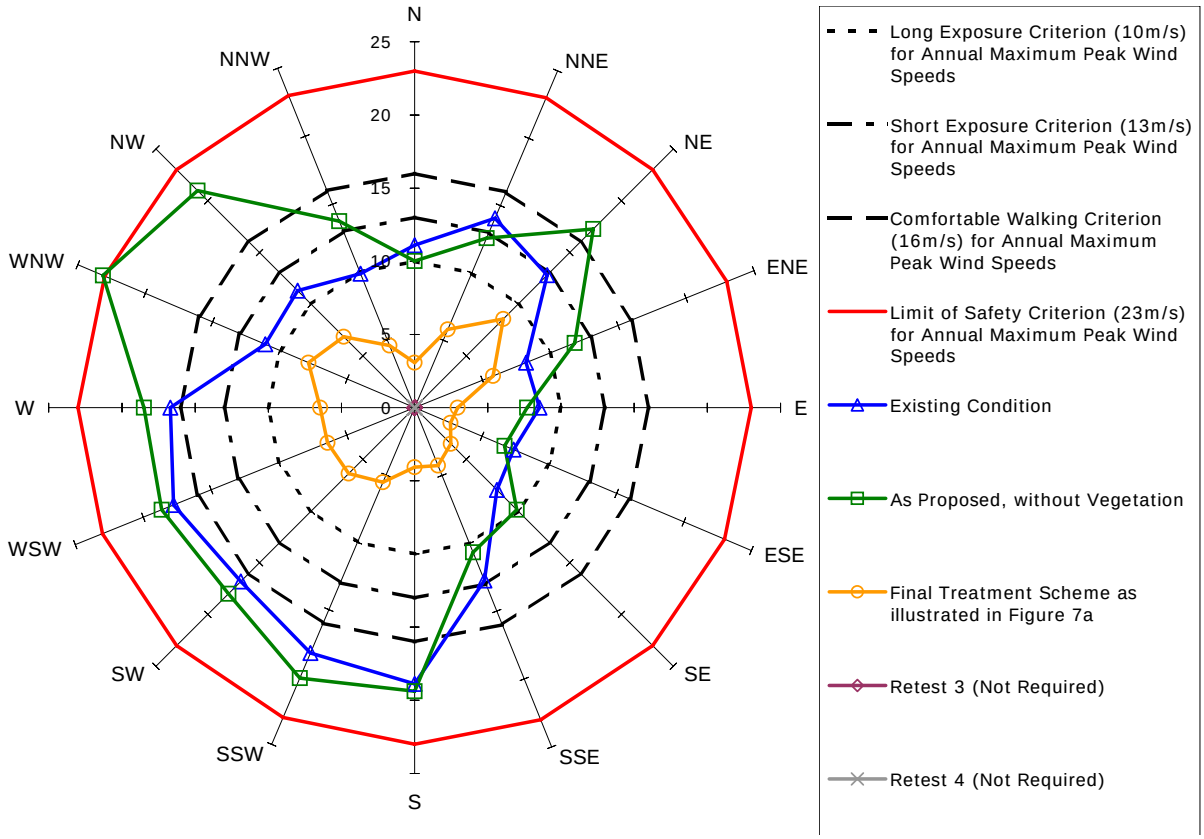
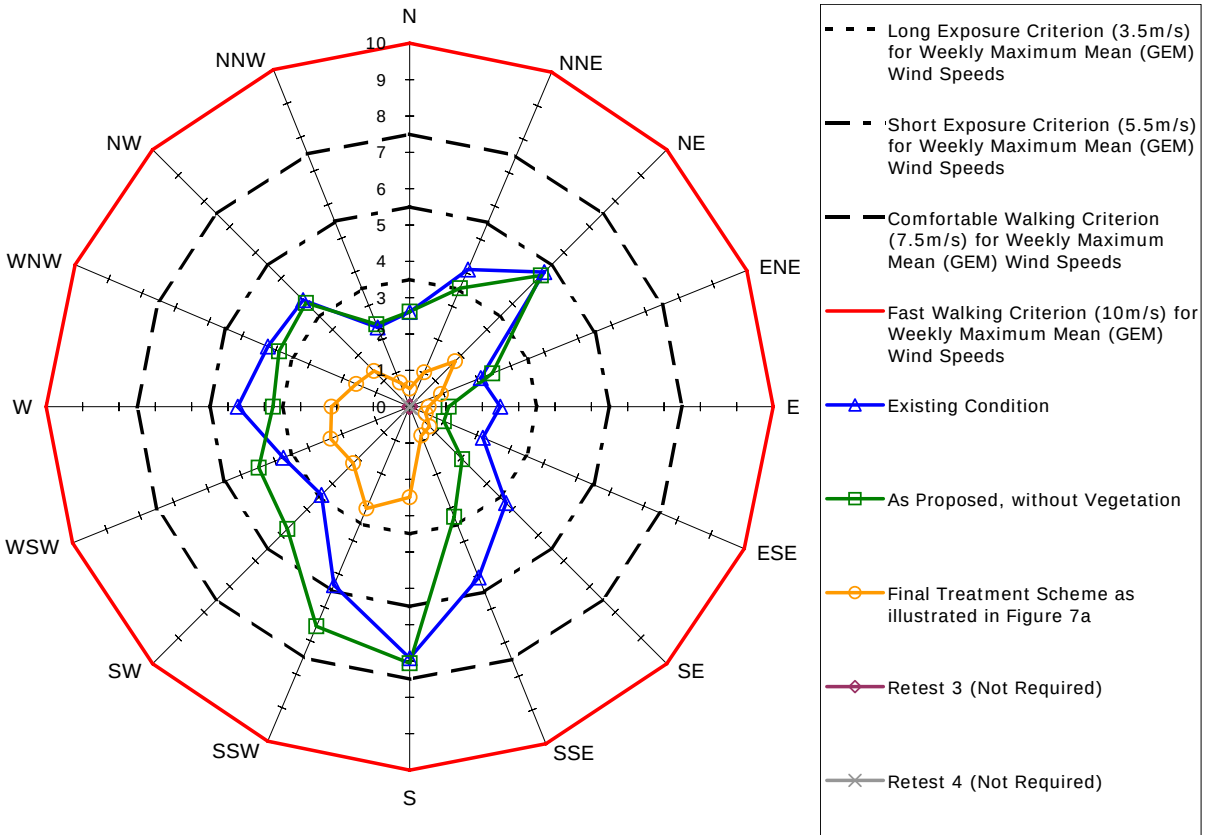



## Annual Maximum Gust Wind Speeds (m/s)

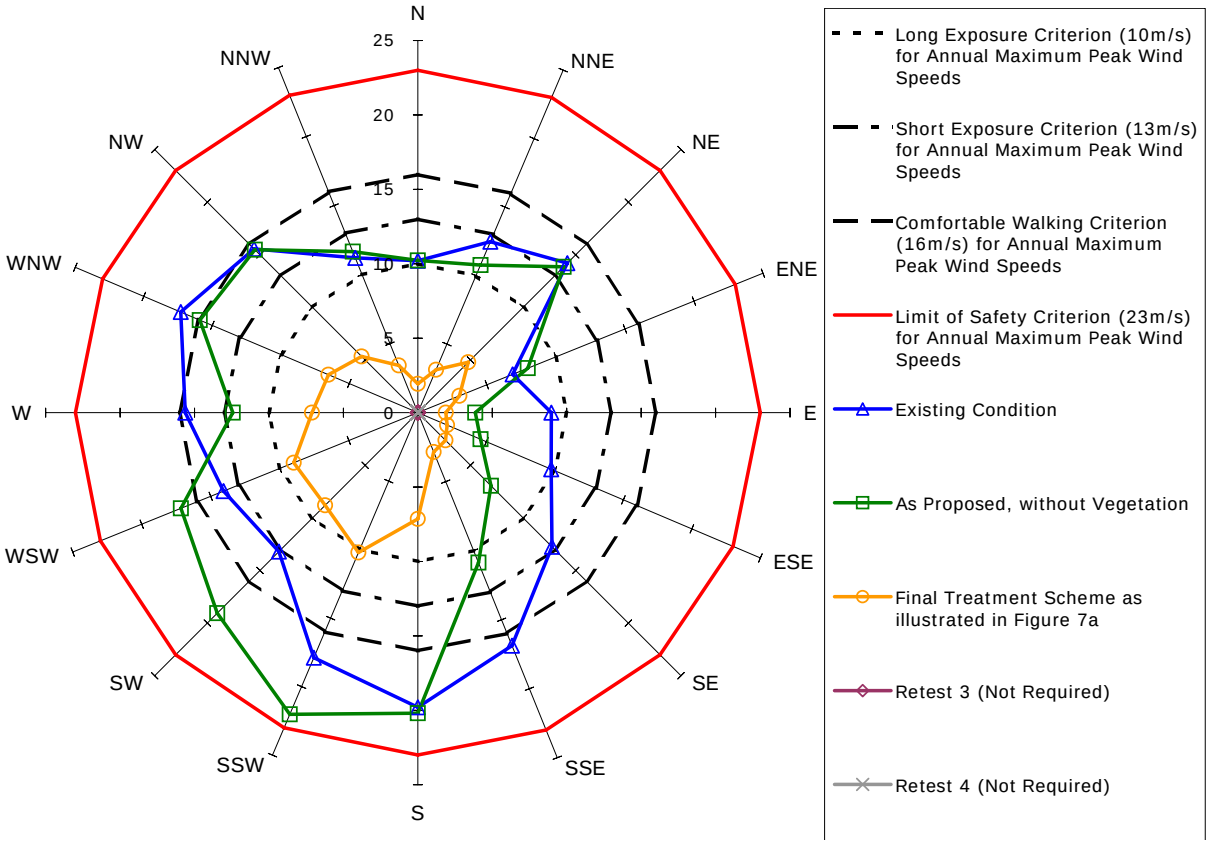


# Measured Wind Speeds at Point 15

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

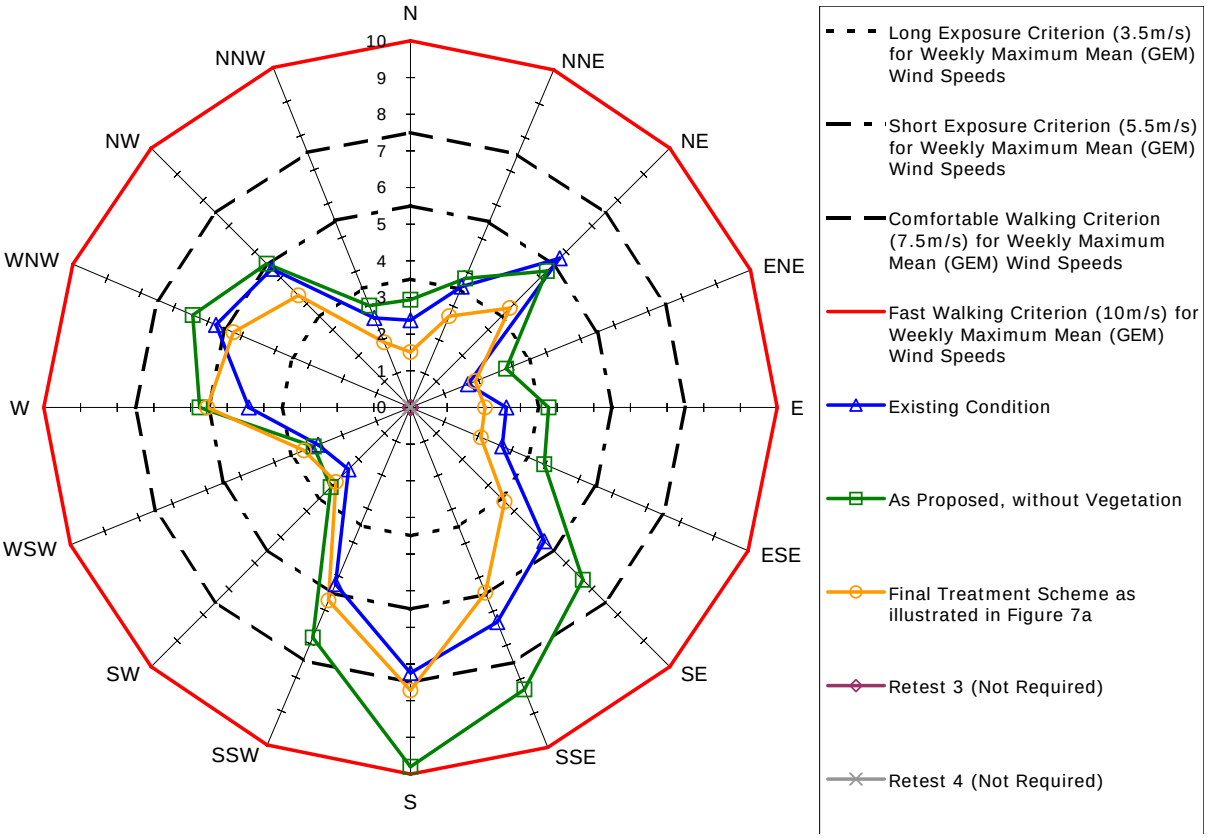



## Annual Maximum Gust Wind Speeds (m/s)

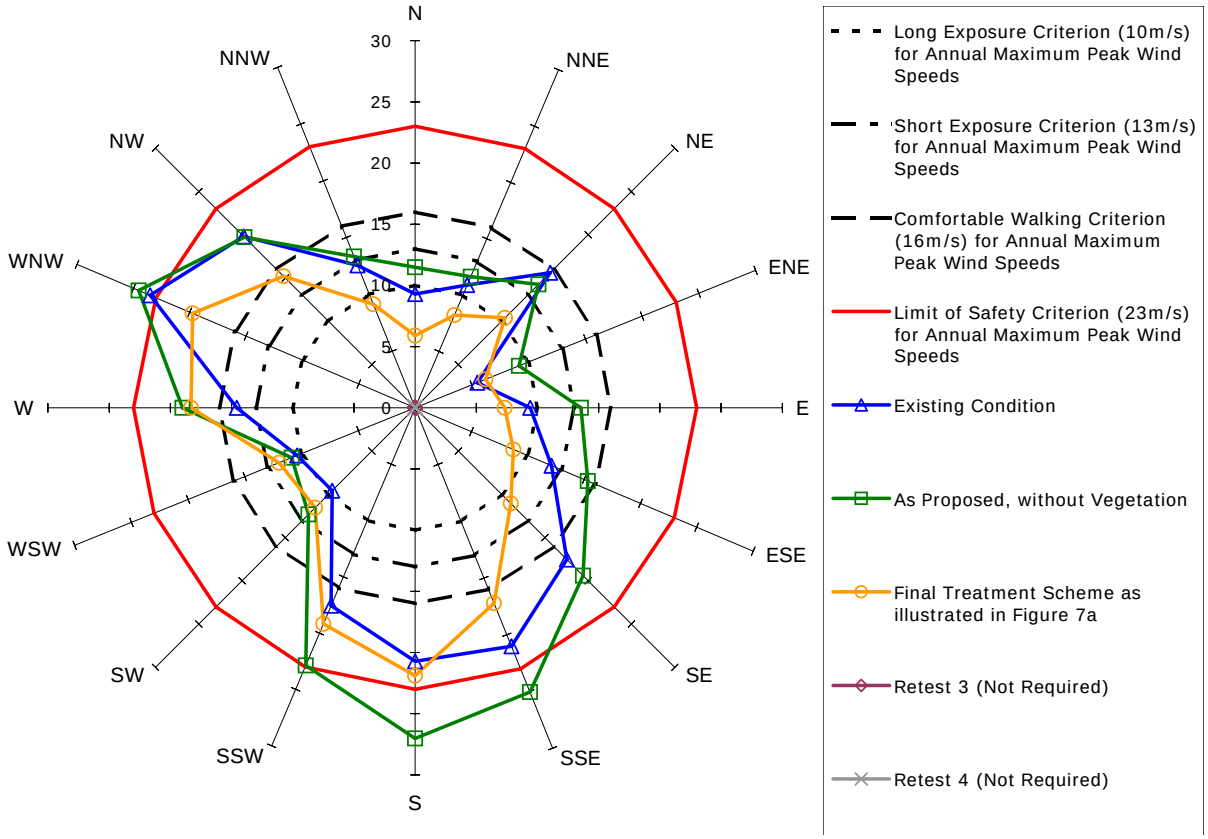


# Measured Wind Speeds at Point 16

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

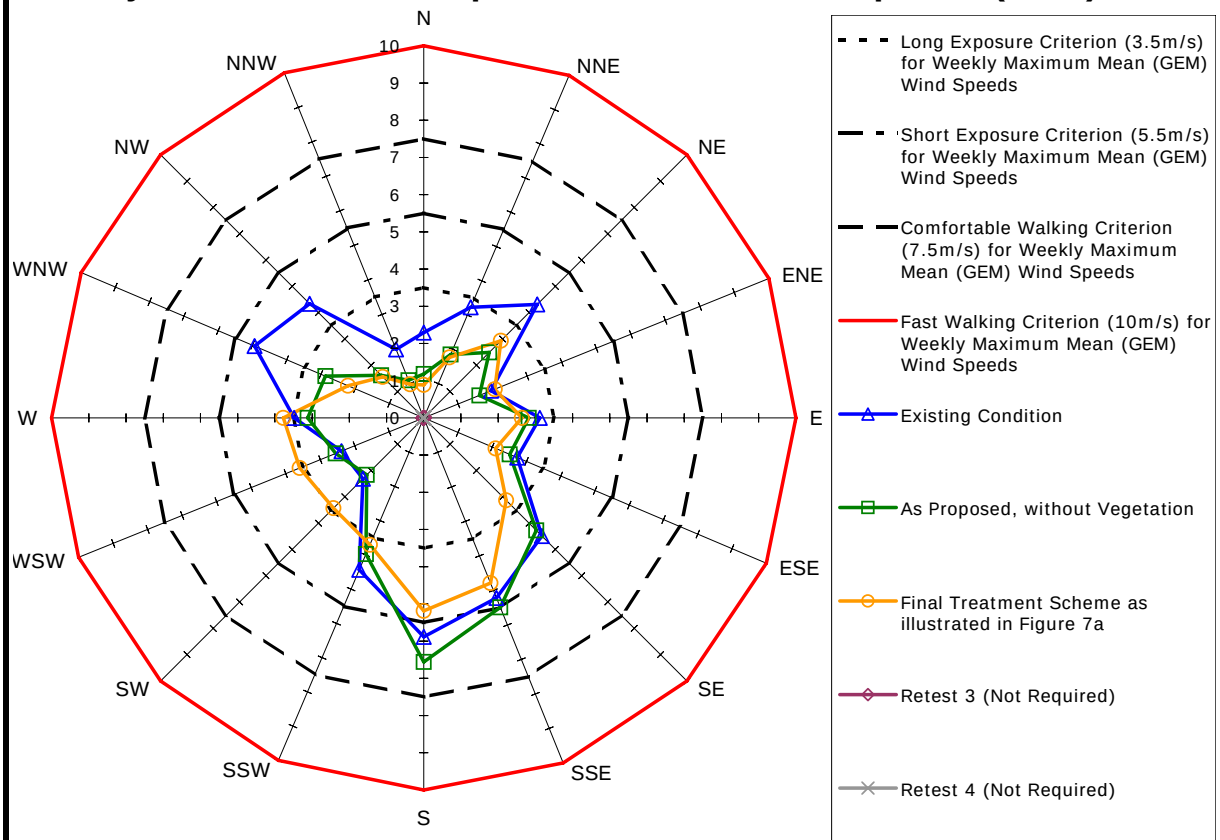



## Annual Maximum Gust Wind Speeds (m/s)

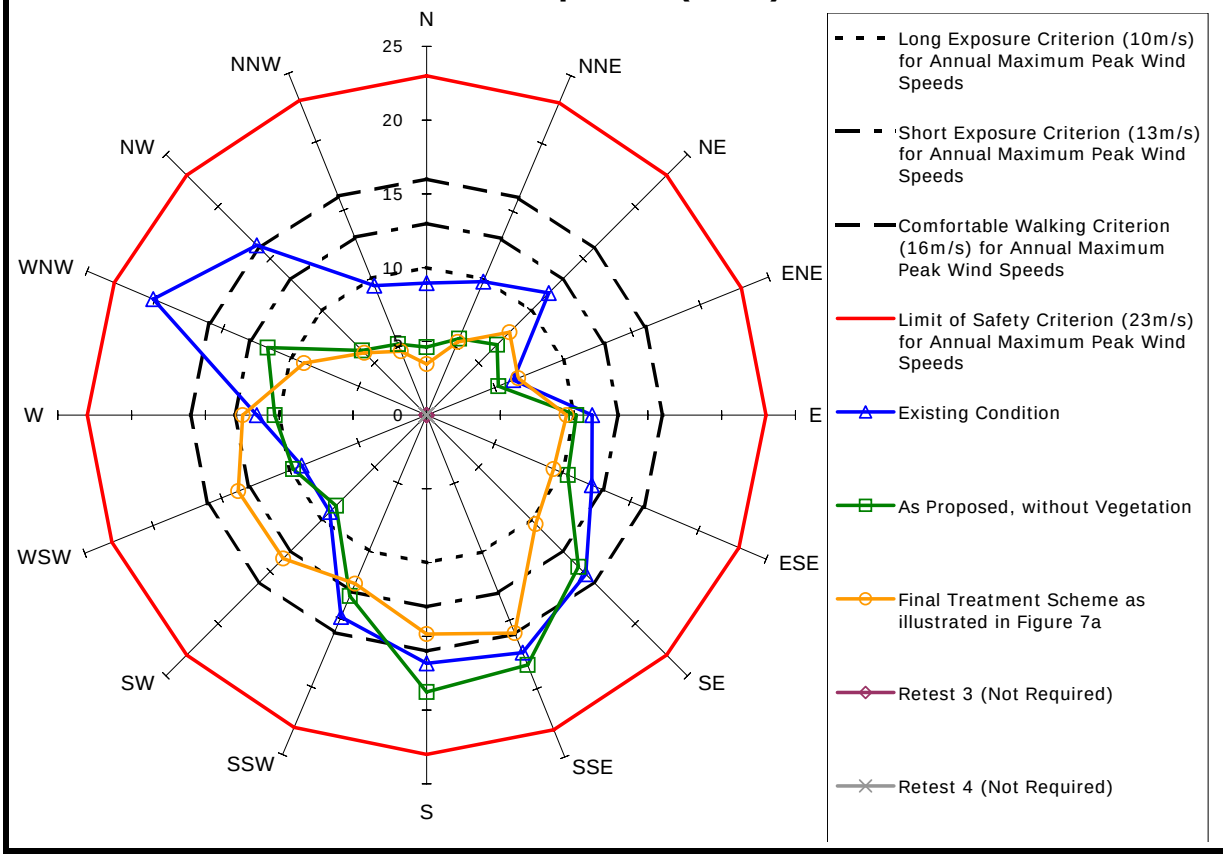


# Measured Wind Speeds at Point 17

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

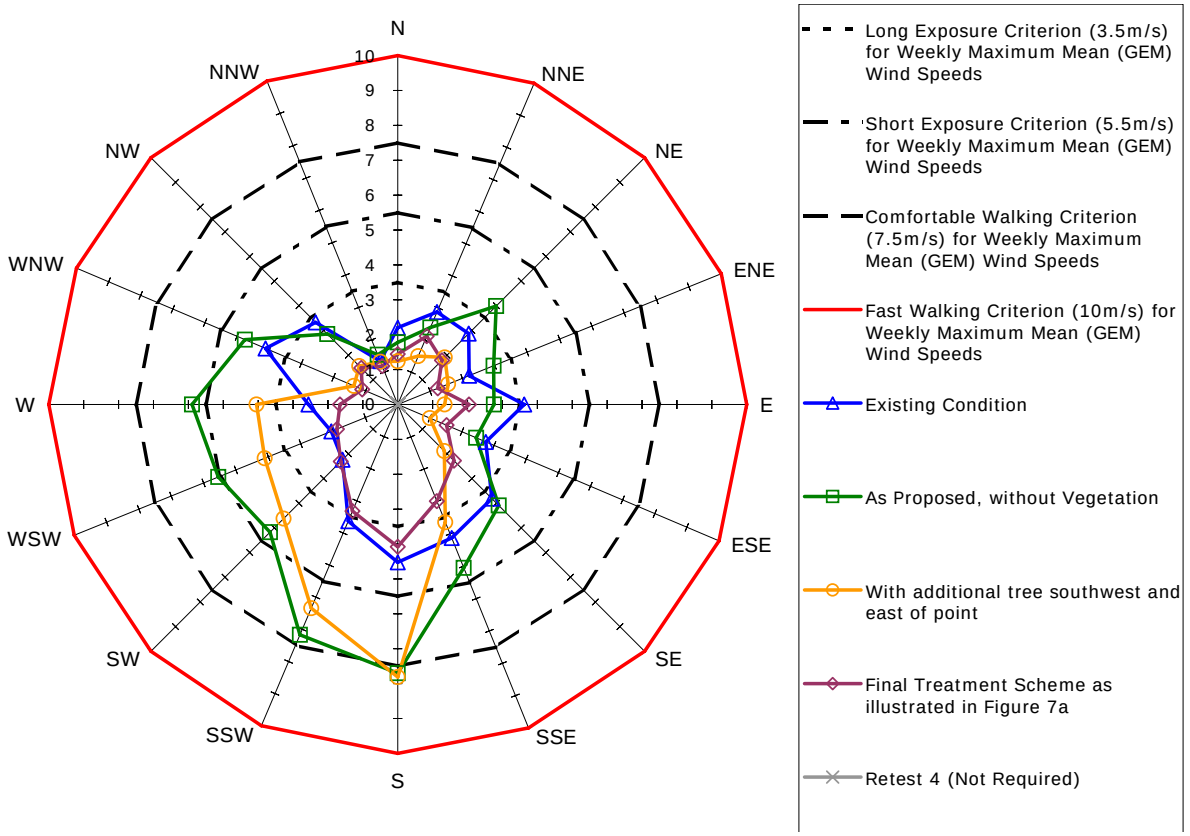



## Annual Maximum Gust Wind Speeds (m/s)

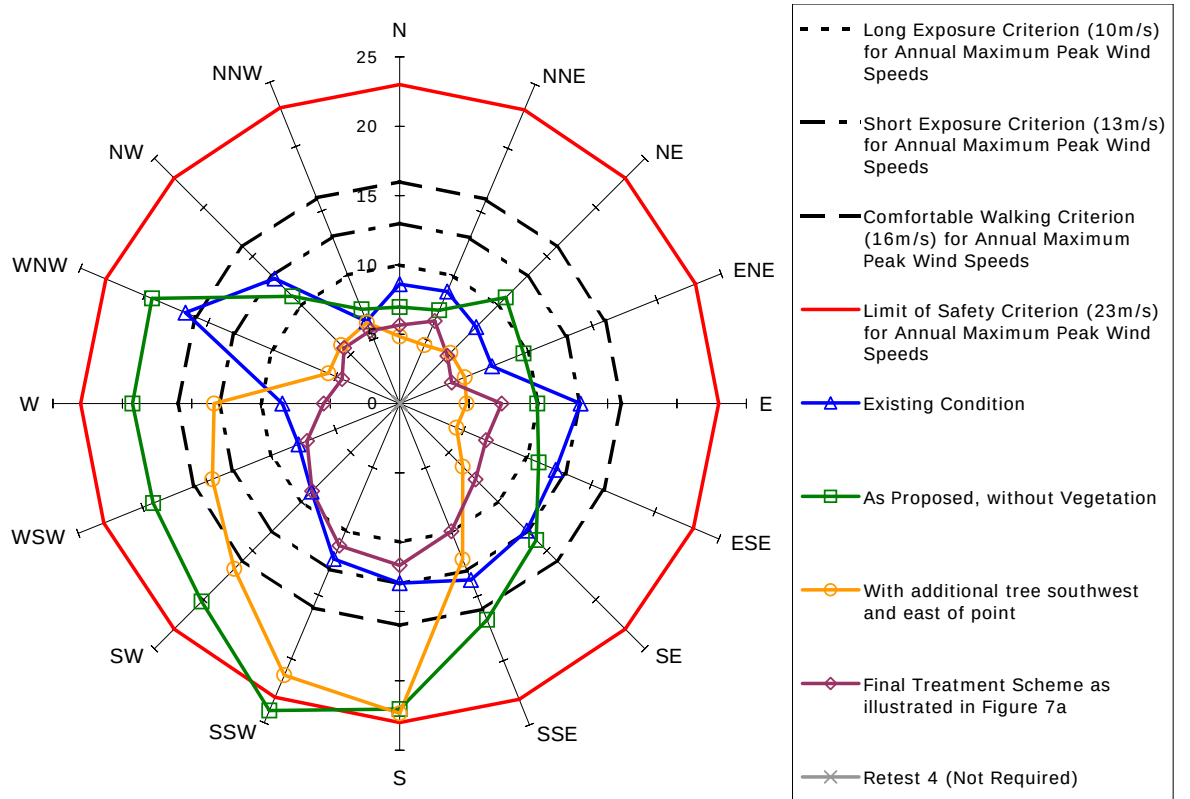


# Measured Wind Speeds at Point 18

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

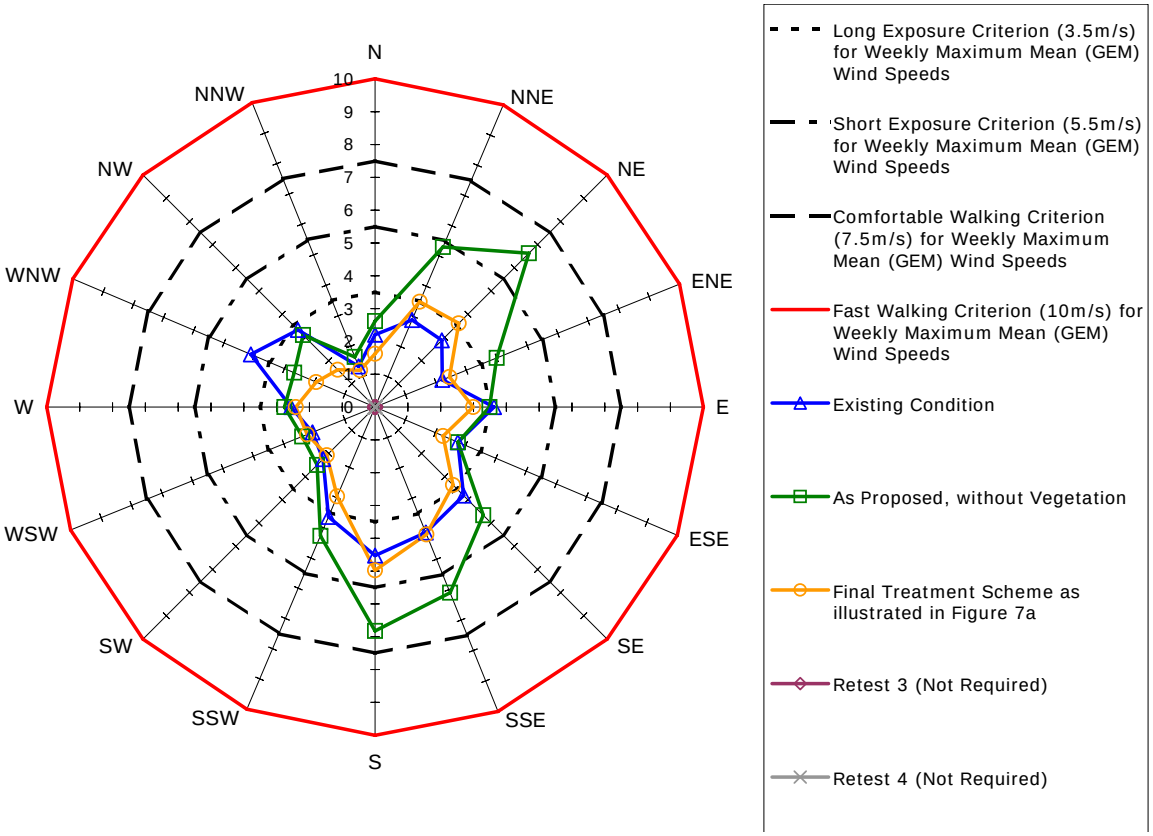



## Annual Maximum Gust Wind Speeds (m/s)

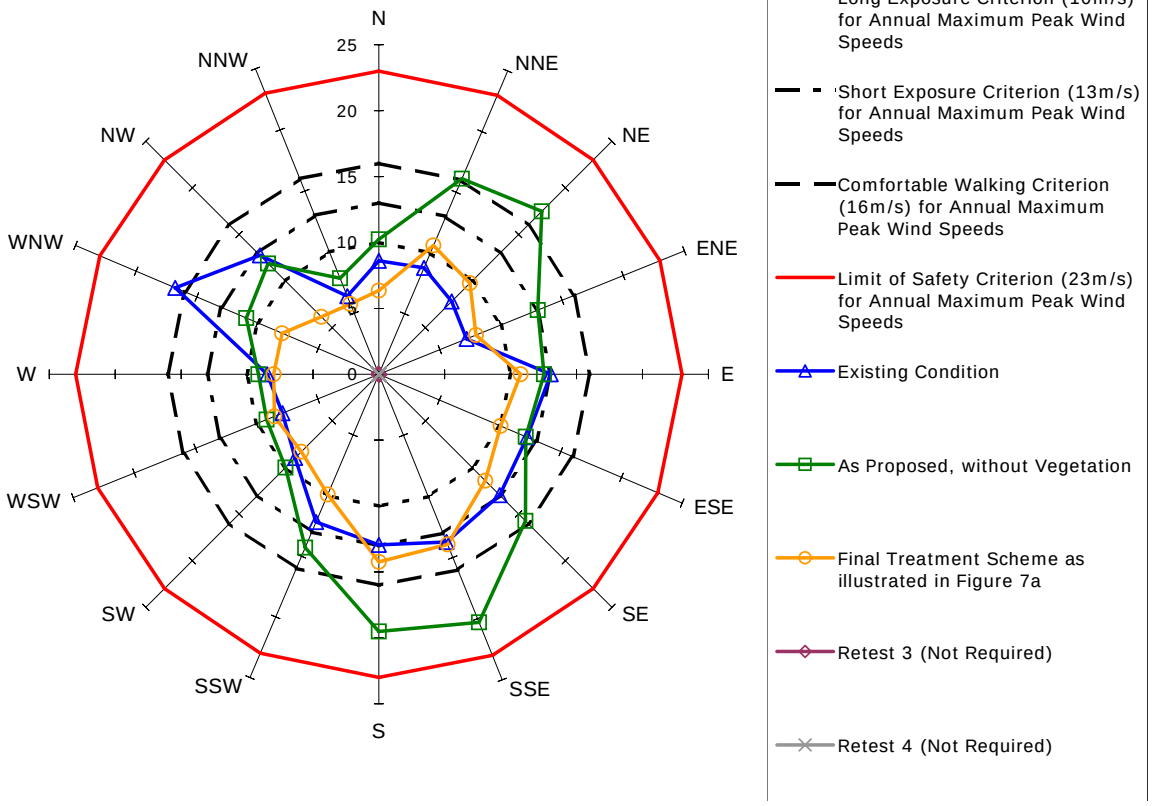


# Measured Wind Speeds at Point 19

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

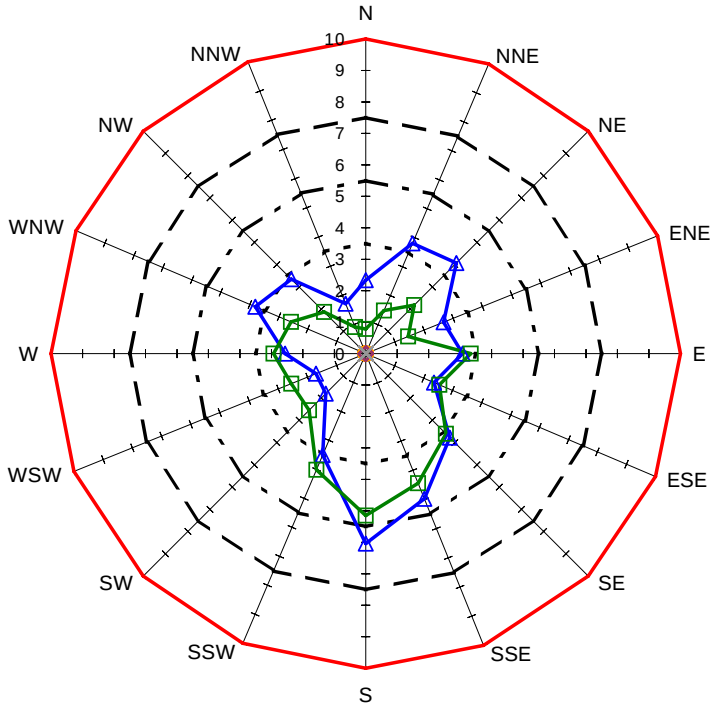



## Annual Maximum Gust Wind Speeds (m/s)



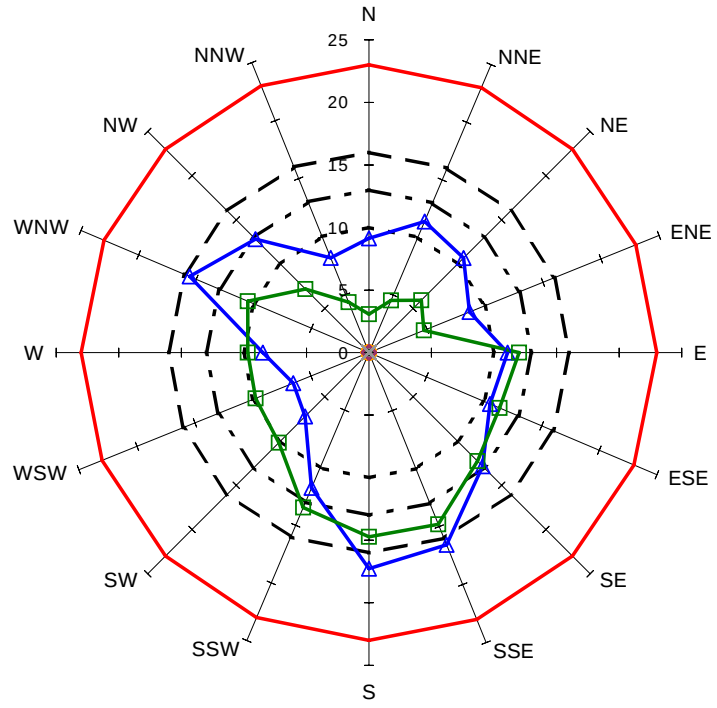
# Measured Wind Speeds at Point 20

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)




- Long Exposure Criterion (3.5m/s) for Weekly Maximum Mean (GEM) Wind Speeds
- Short Exposure Criterion (5.5m/s) for Weekly Maximum Mean (GEM) Wind Speeds
- Comfortable Walking Criterion (7.5m/s) for Weekly Maximum Mean (GEM) Wind Speeds
- Fast Walking Criterion (10m/s) for Weekly Maximum Mean (GEM) Wind Speeds
- Existing Condition
- As Proposed, without Vegetation
- Retest 2 (Not Required)
- Retest 3 (Not Required)
- Retest 4 (Not Required)

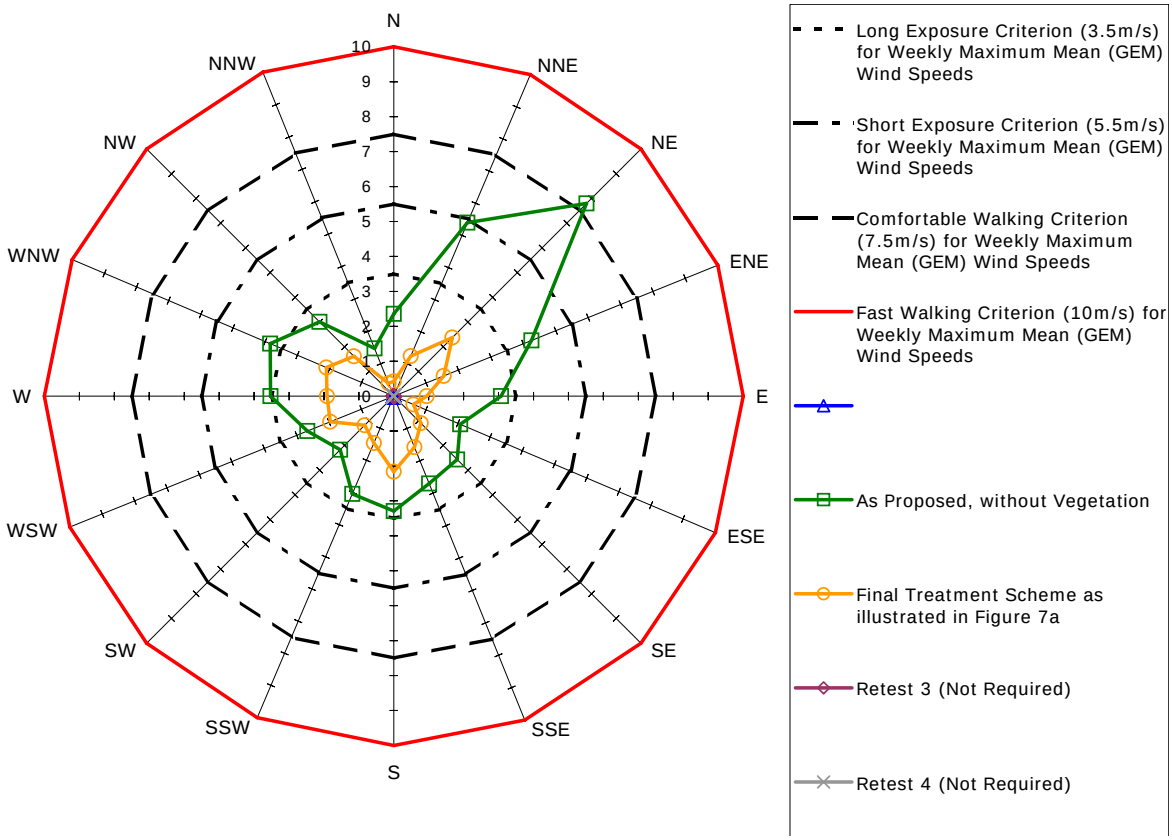
## Annual Maximum Gust Wind Speeds (m/s)



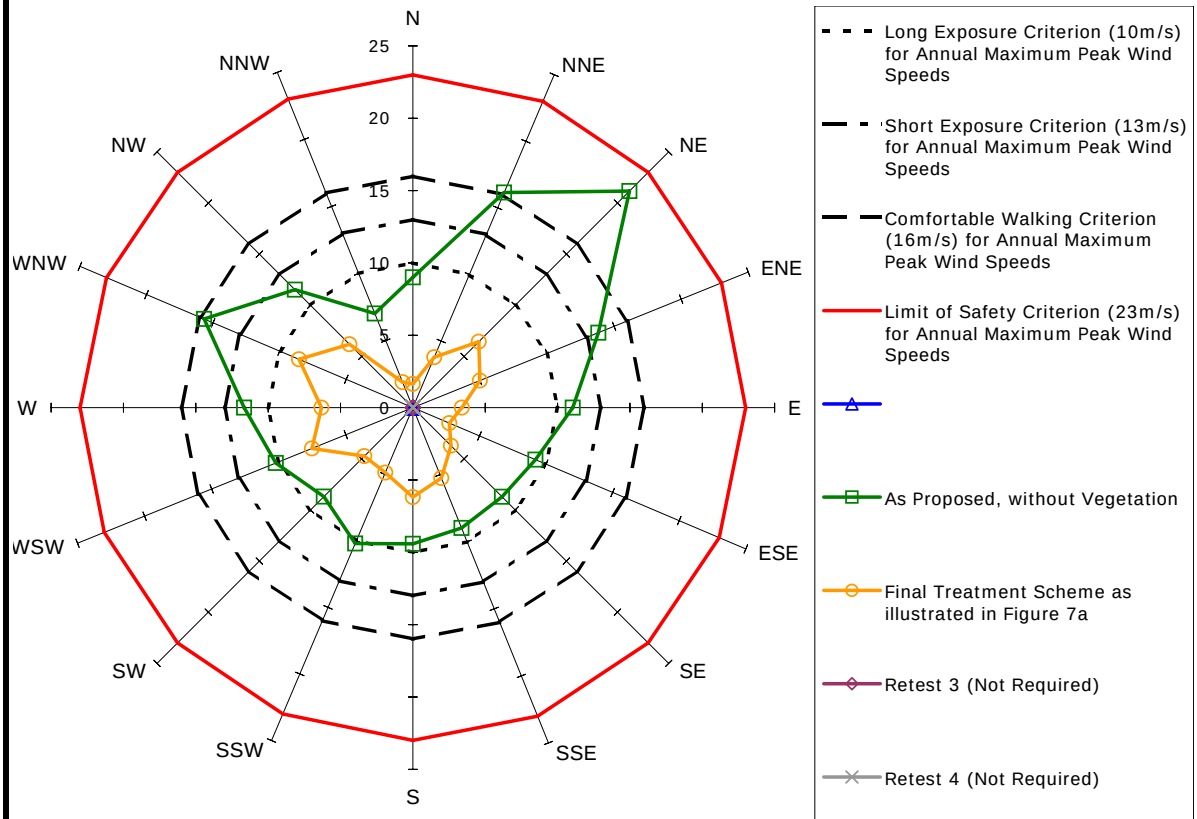

- Long Exposure Criterion (10m/s) for Annual Maximum Peak Wind Speeds
- Short Exposure Criterion (13m/s) for Annual Maximum Peak Wind Speeds
- Comfortable Walking Criterion (16m/s) for Annual Maximum Peak Wind Speeds
- Limit of Safety Criterion (23m/s) for Annual Maximum Peak Wind Speeds
- Existing Condition
- As Proposed, without Vegetation
- Retest 2 (Not Required)
- Retest 3 (Not Required)
- Retest 4 (Not Required)

# Measured Wind Speeds at Point 21

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

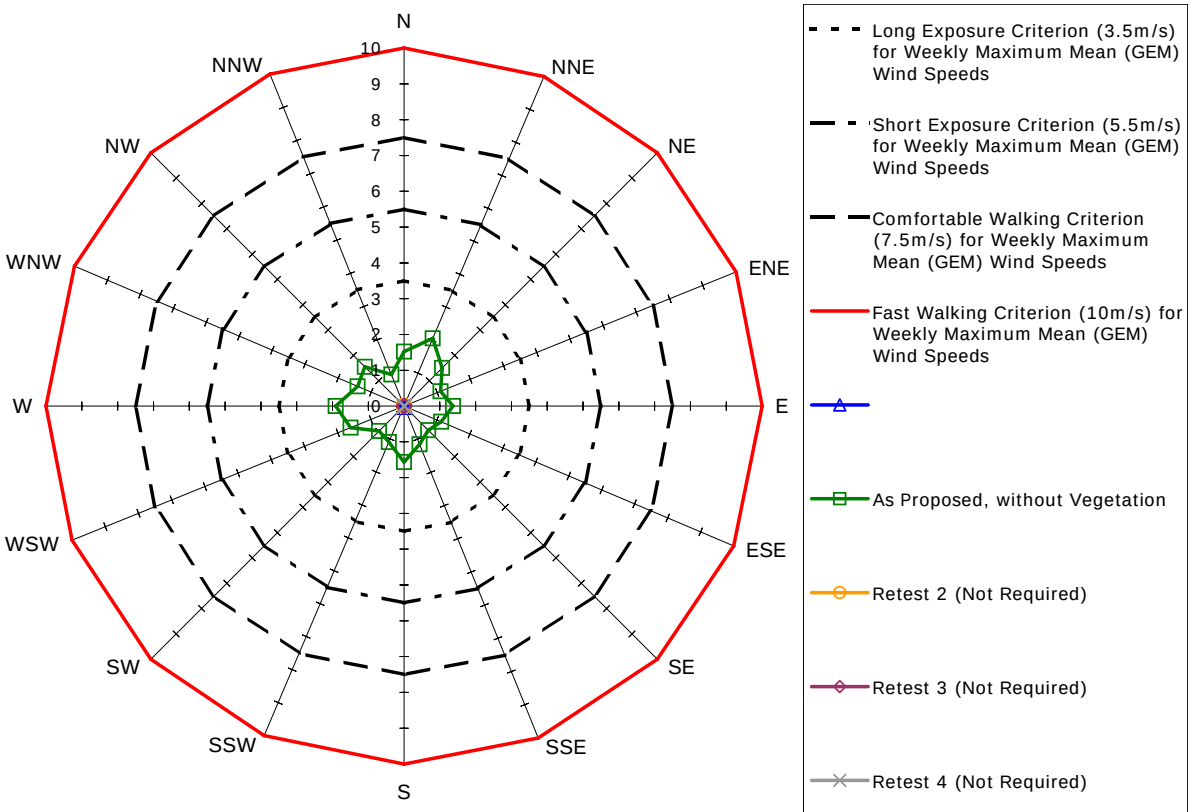



## Annual Maximum Gust Wind Speeds (m/s)

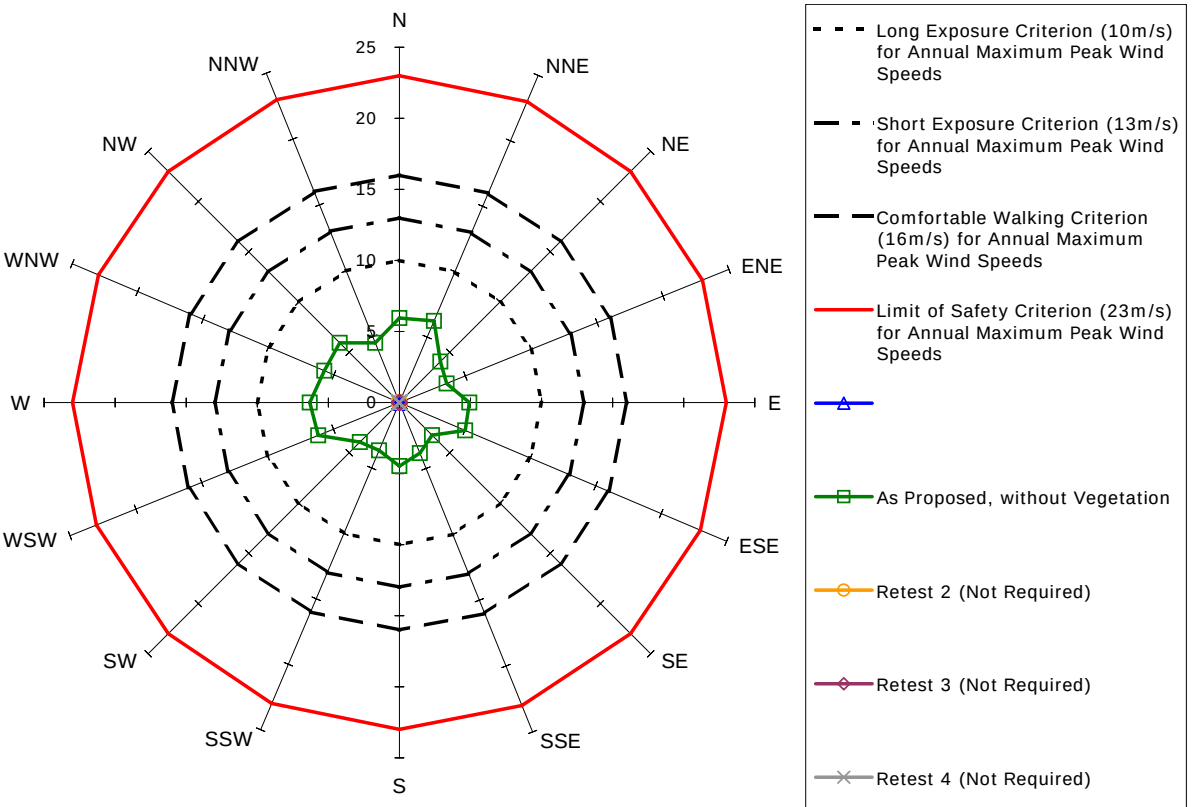


# Measured Wind Speeds at Point 22

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

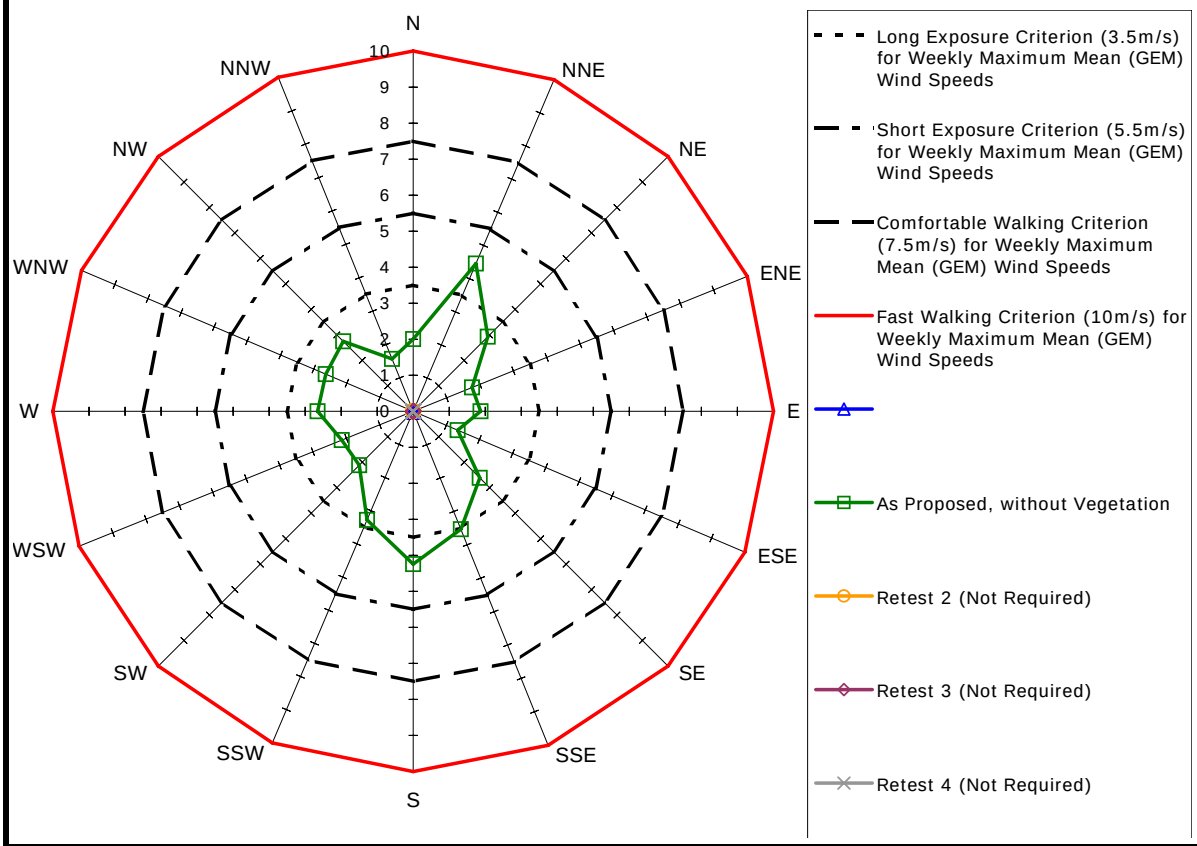



## Annual Maximum Gust Wind Speeds (m/s)

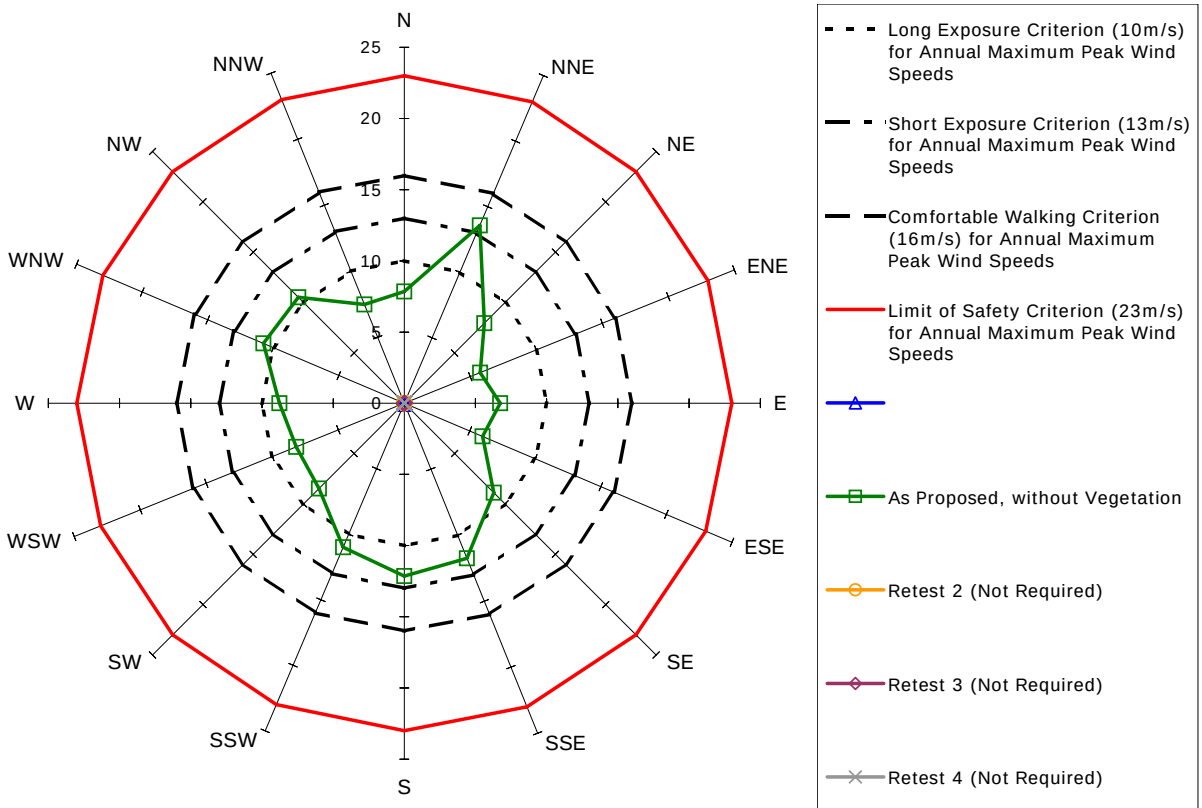


# Measured Wind Speeds at Point 23

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

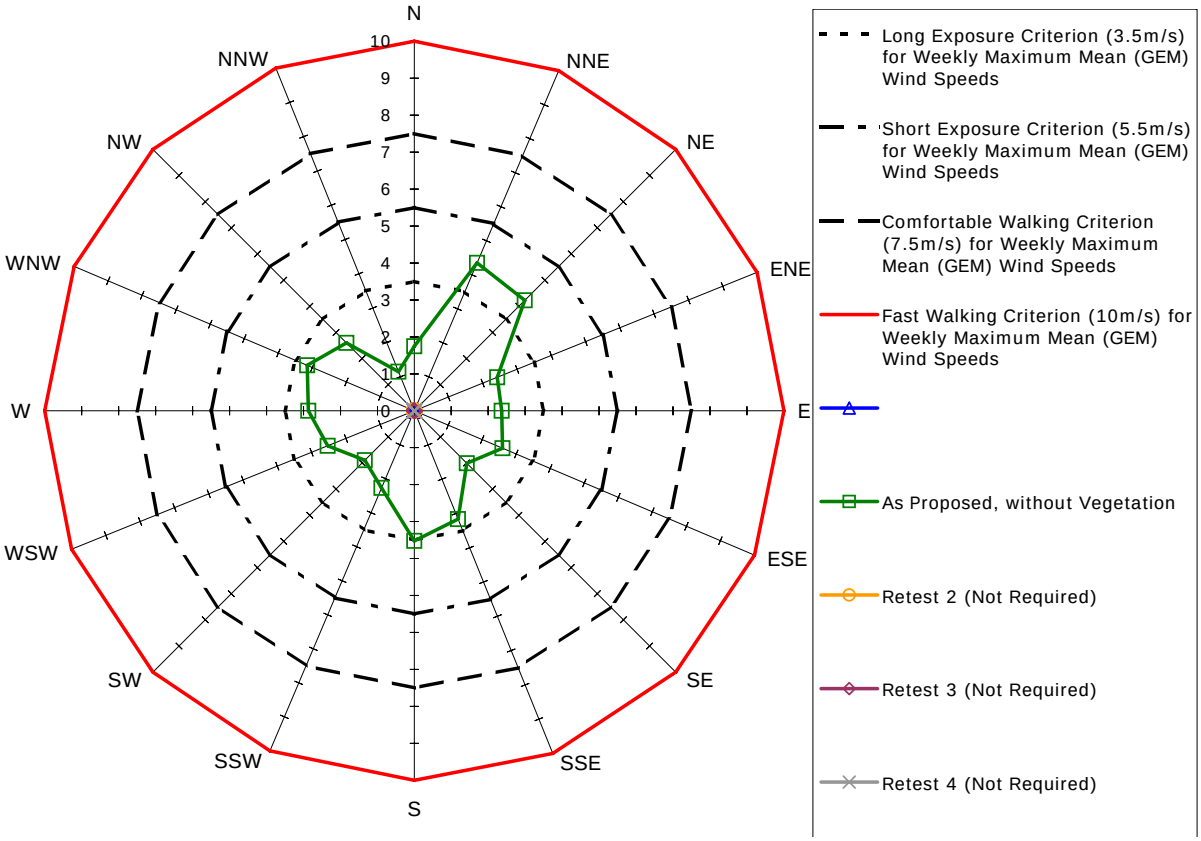



## Annual Maximum Gust Wind Speeds (m/s)

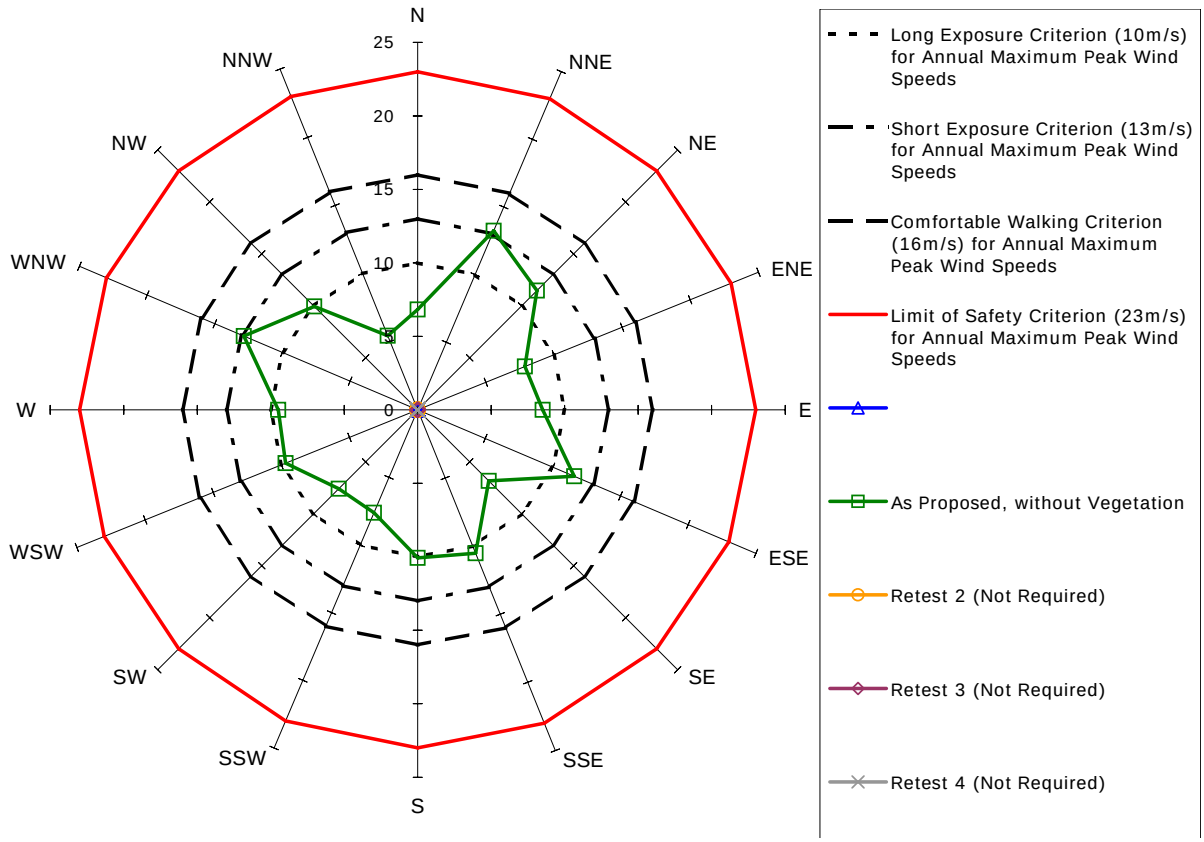


# Measured Wind Speeds at Point 24

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

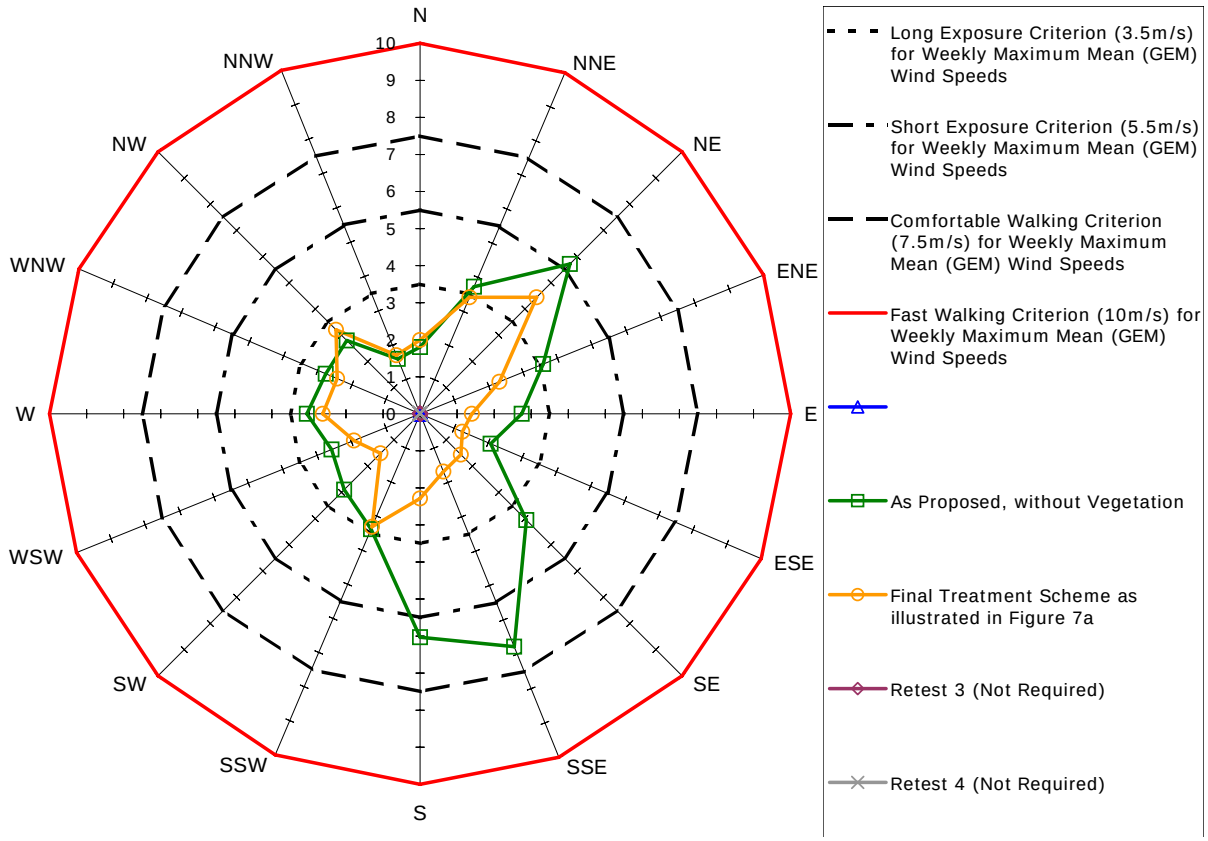



## Annual Maximum Gust Wind Speeds (m/s)

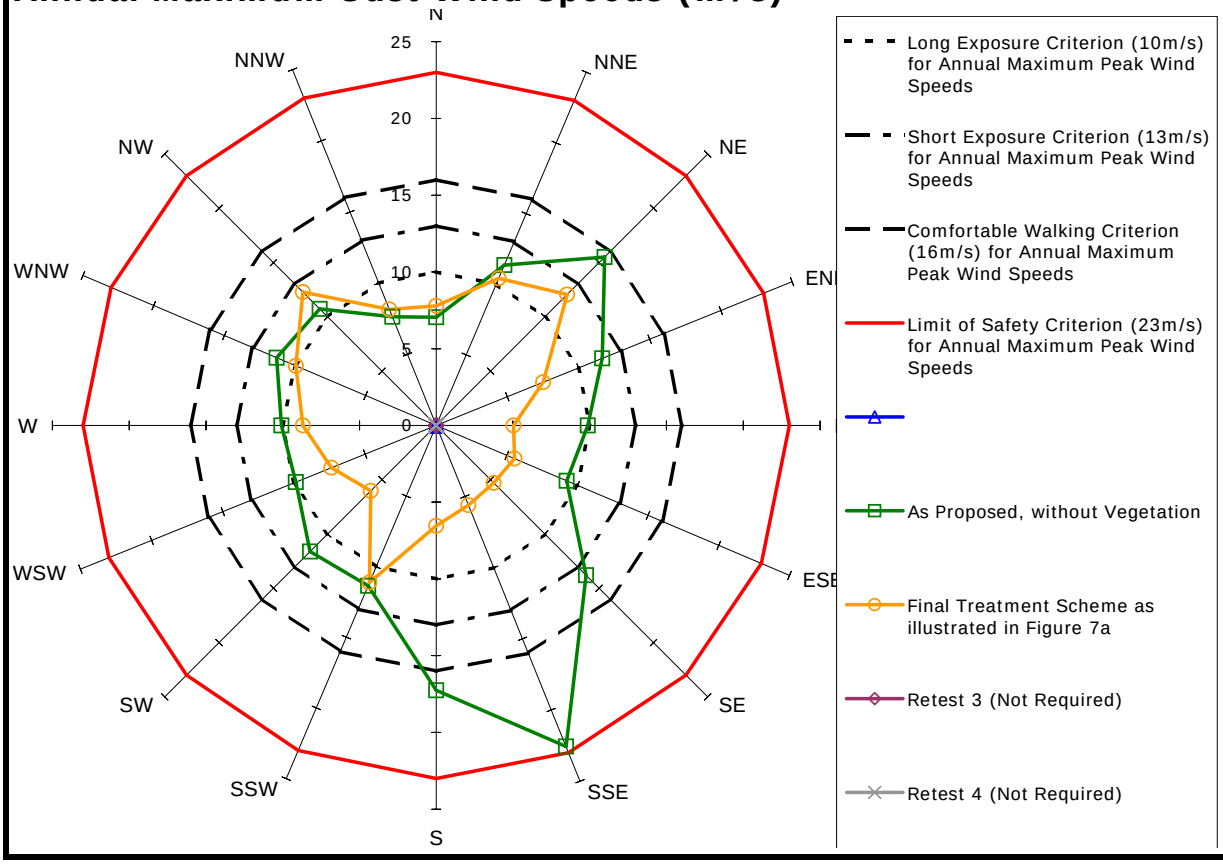


# Measured Wind Speeds at Point 25

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

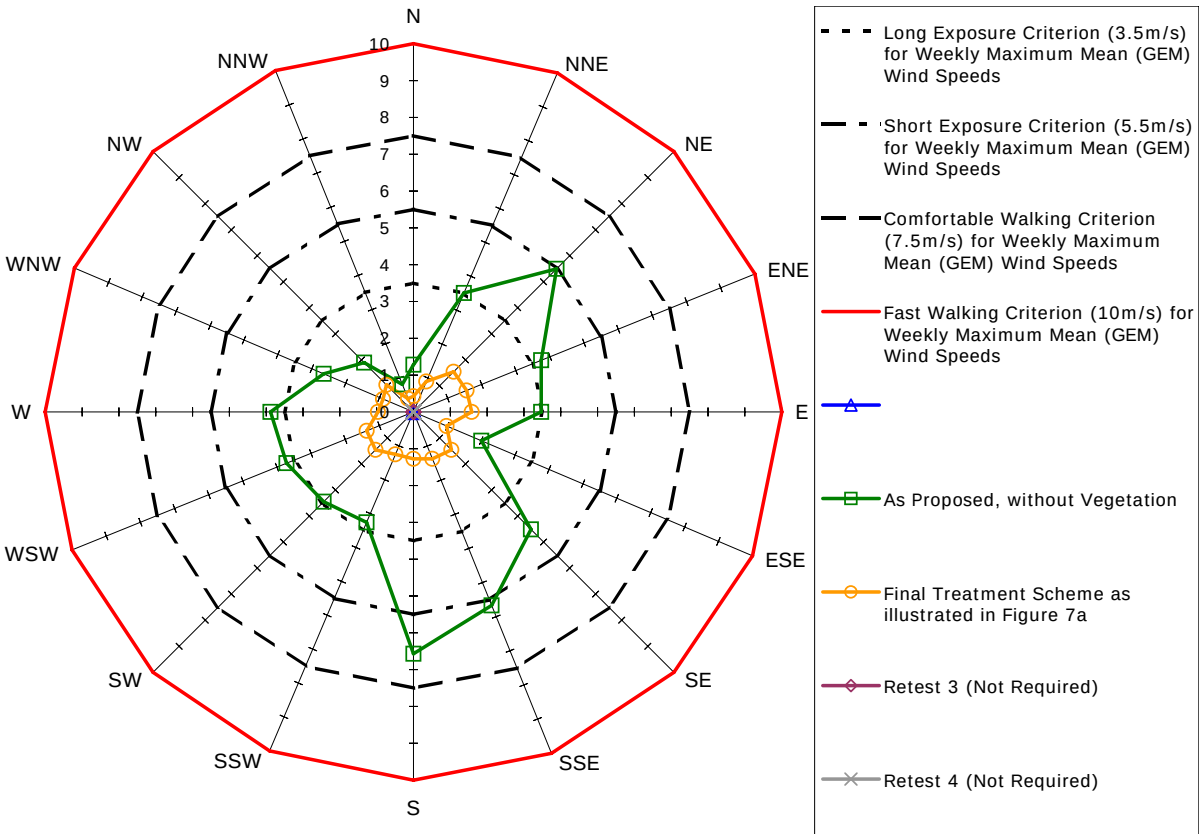



## Annual Maximum Gust Wind Speeds (m/s)

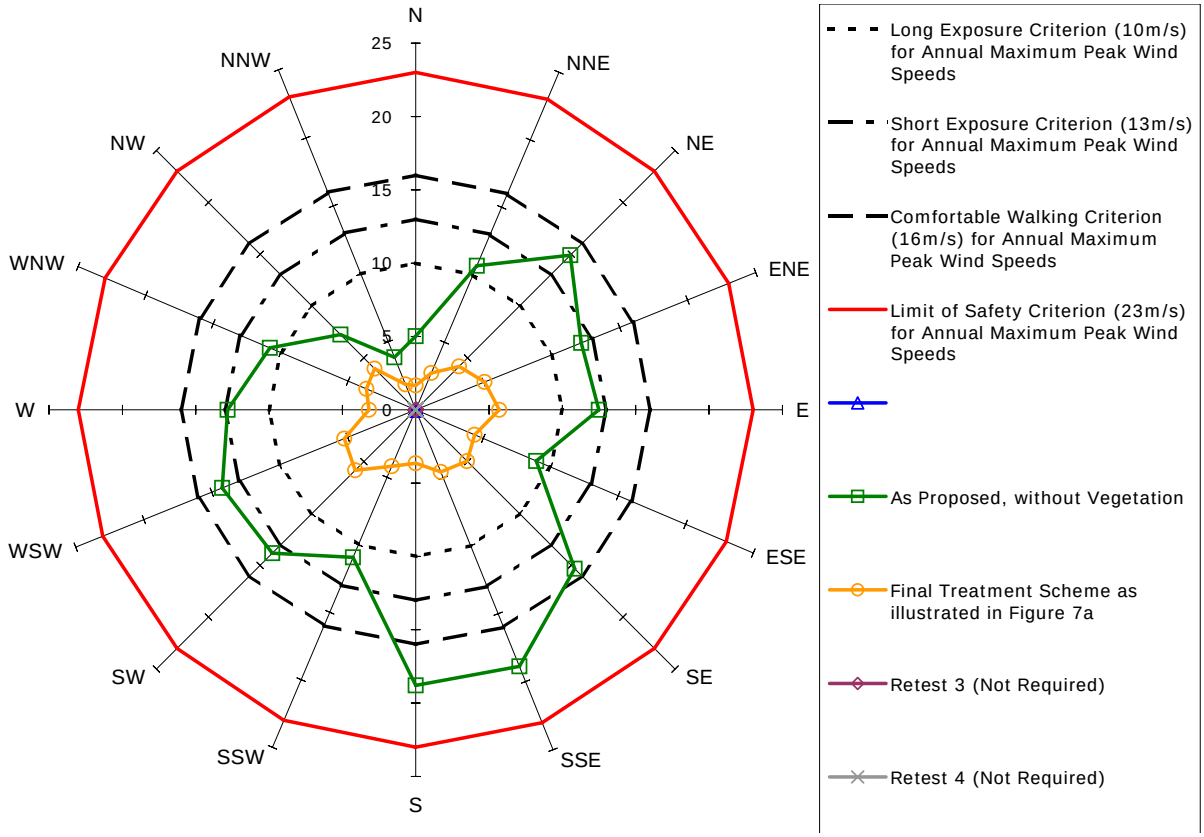


# Measured Wind Speeds at Point 26

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

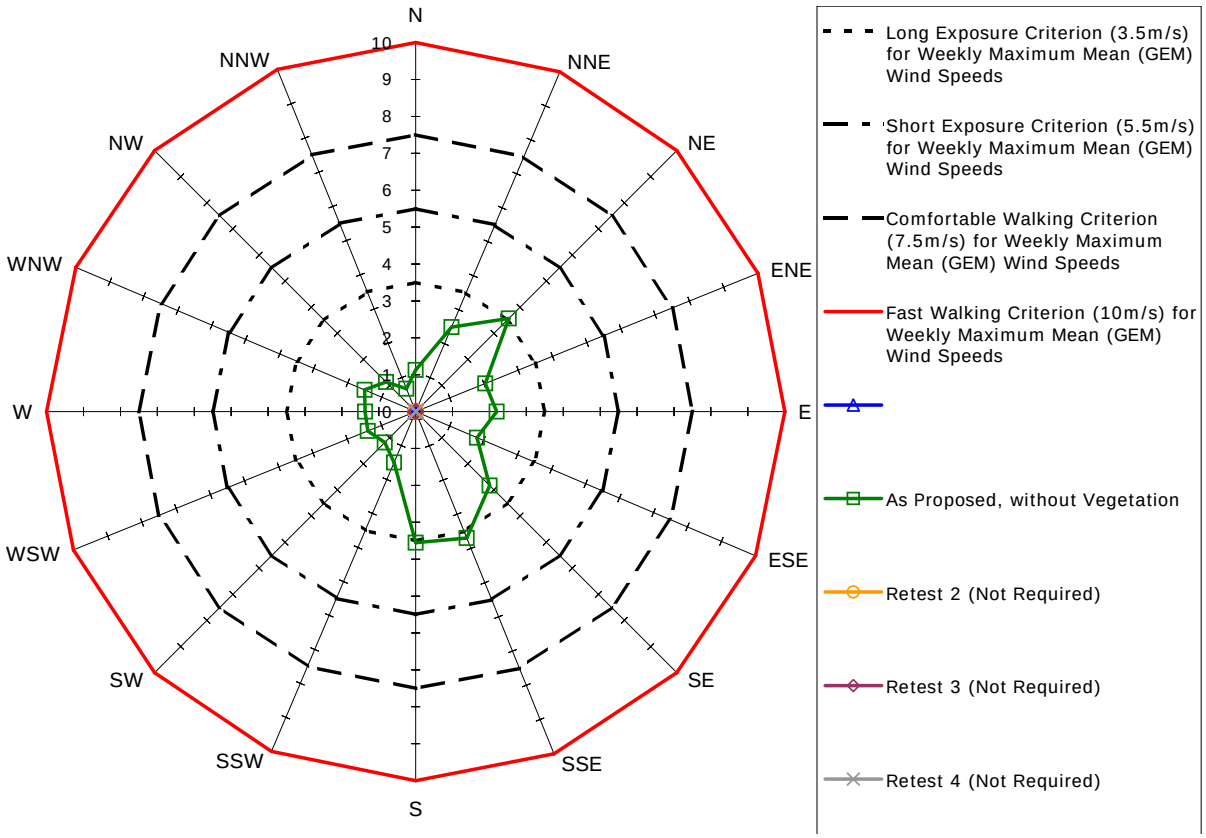



## Annual Maximum Gust Wind Speeds (m/s)

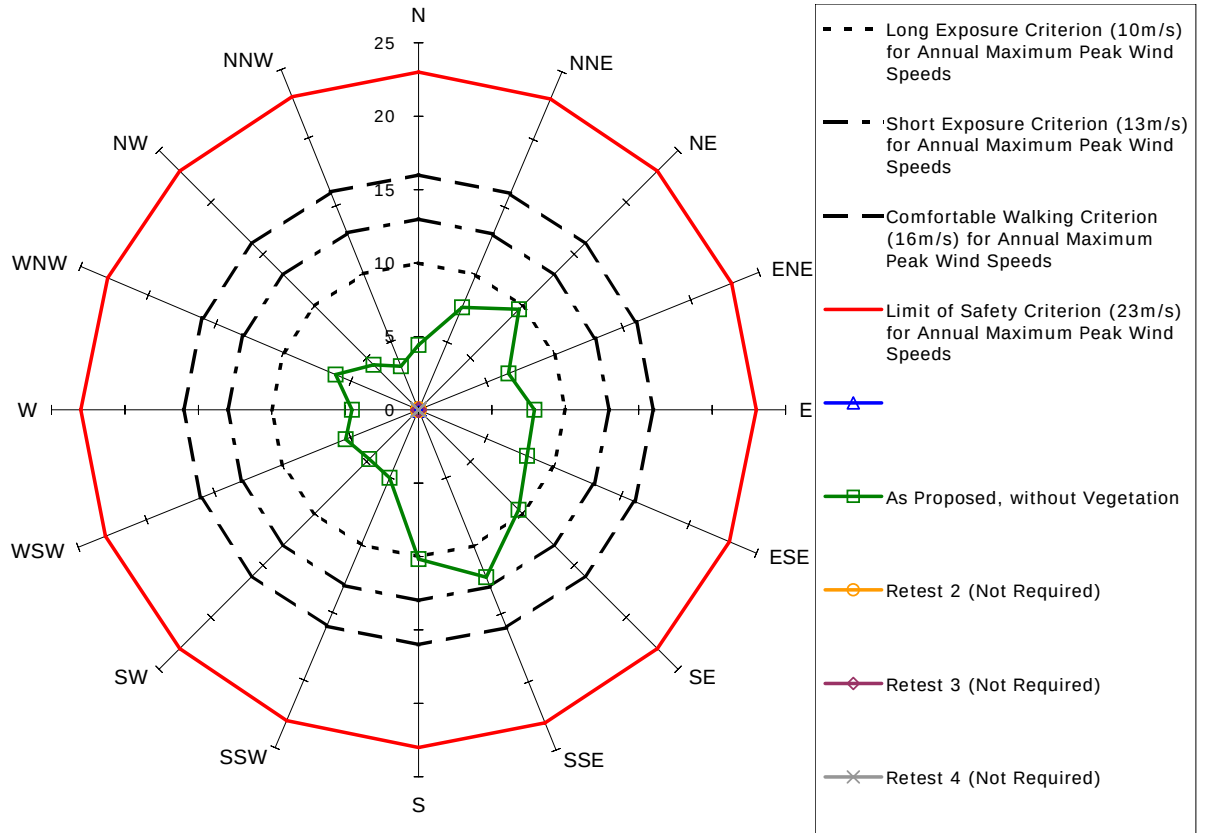


# Measured Wind Speeds at Point 27

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

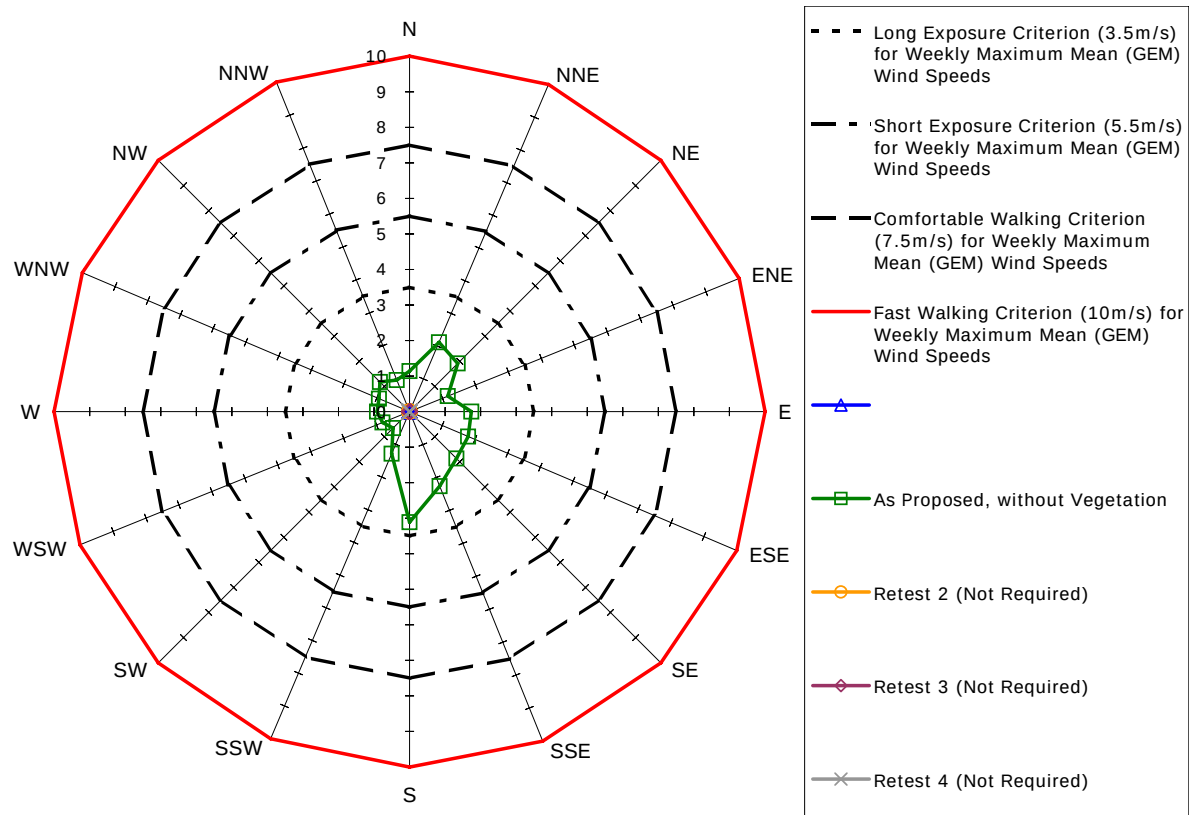



## Annual Maximum Gust Wind Speeds (m/s)

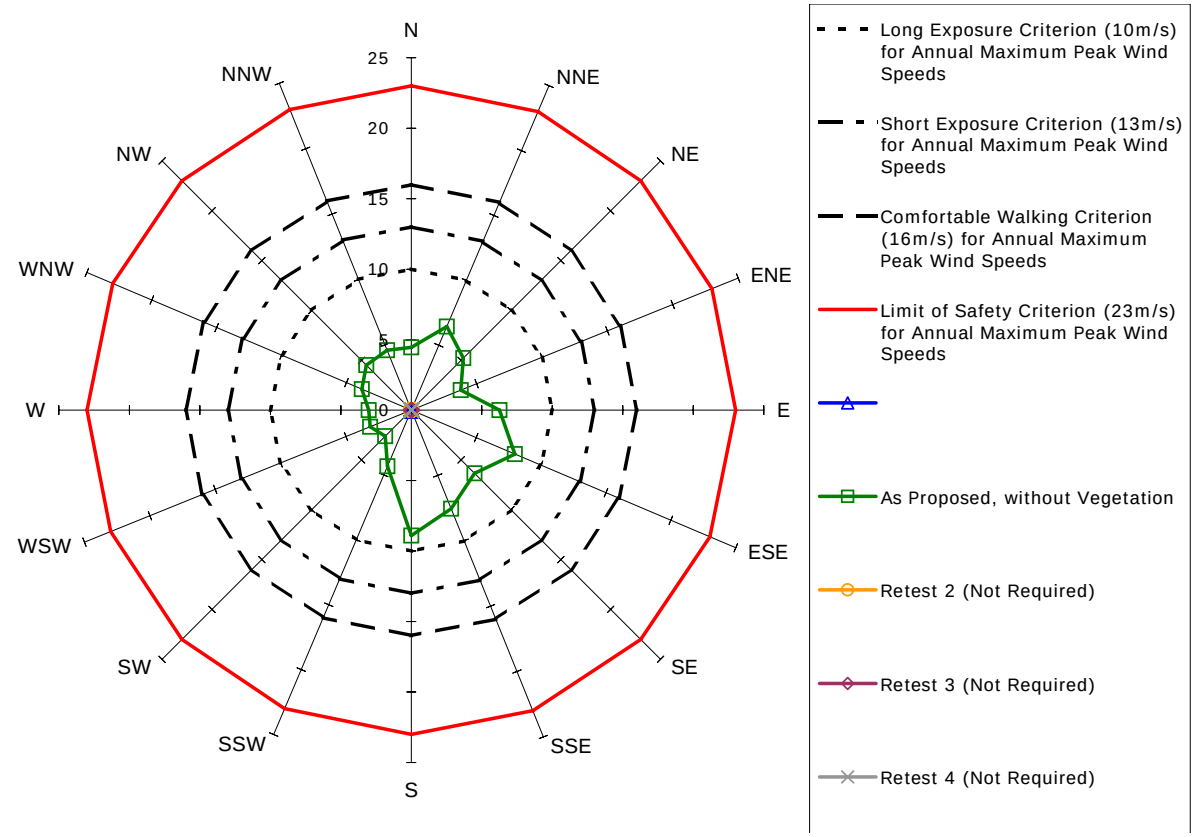


# Measured Wind Speeds at Point 28

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

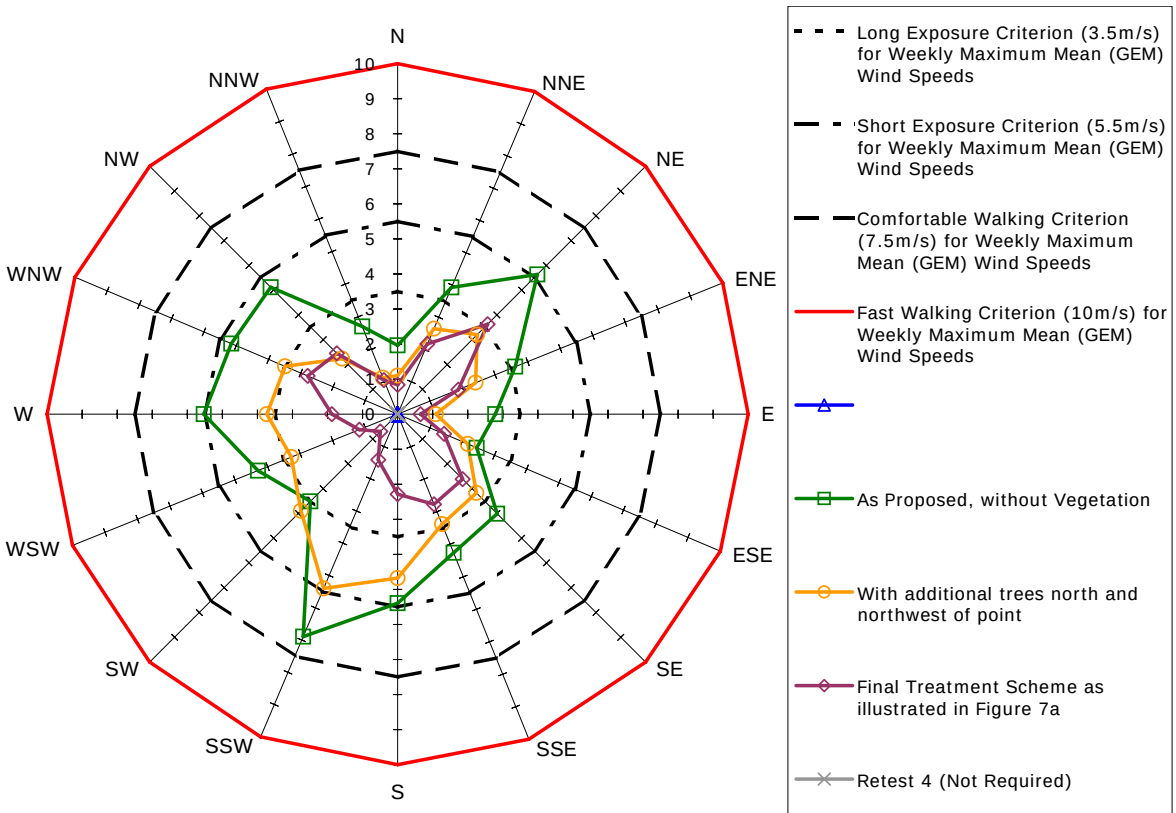



## Annual Maximum Gust Wind Speeds (m/s)

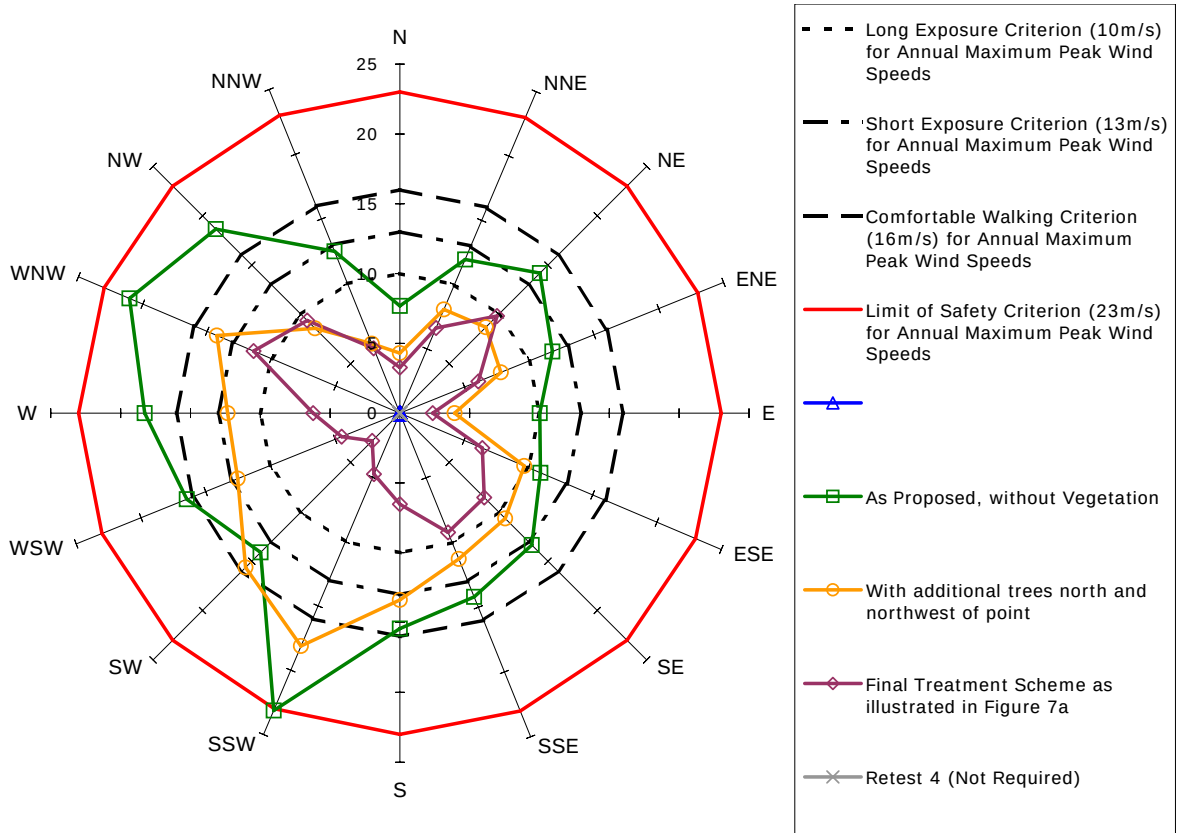


# Measured Wind Speeds at Point 29

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

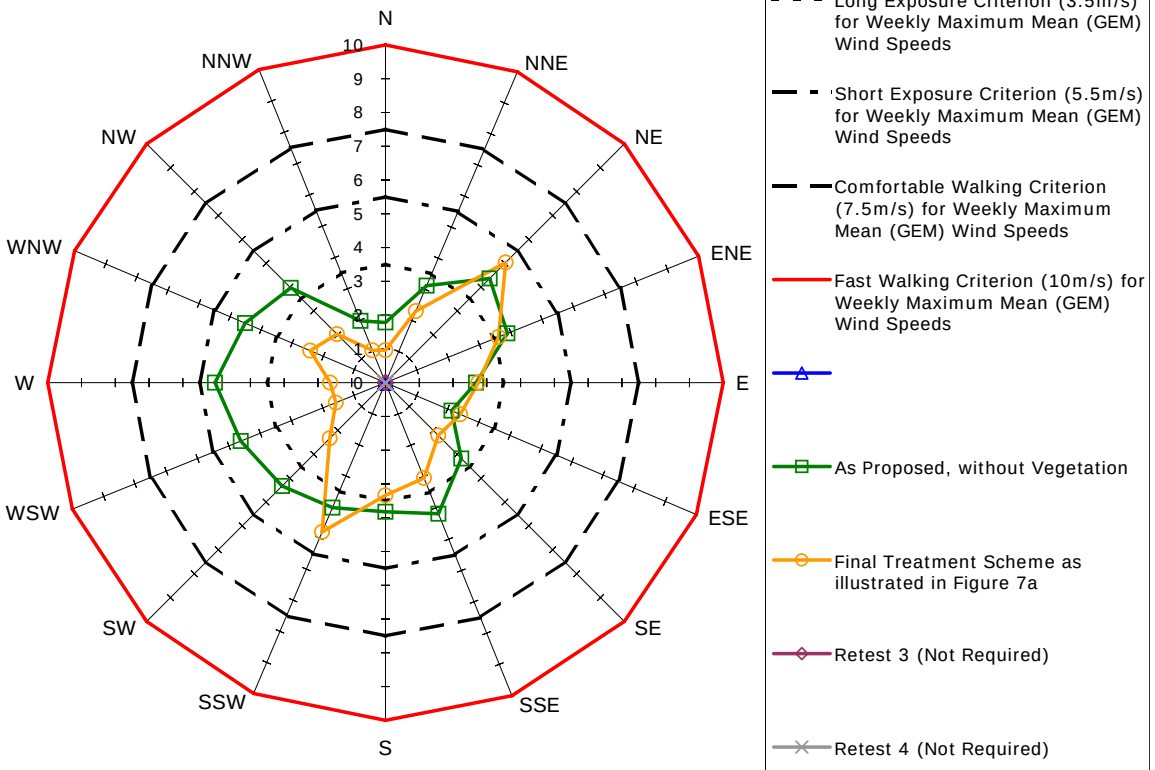



## Annual Maximum Gust Wind Speeds (m/s)

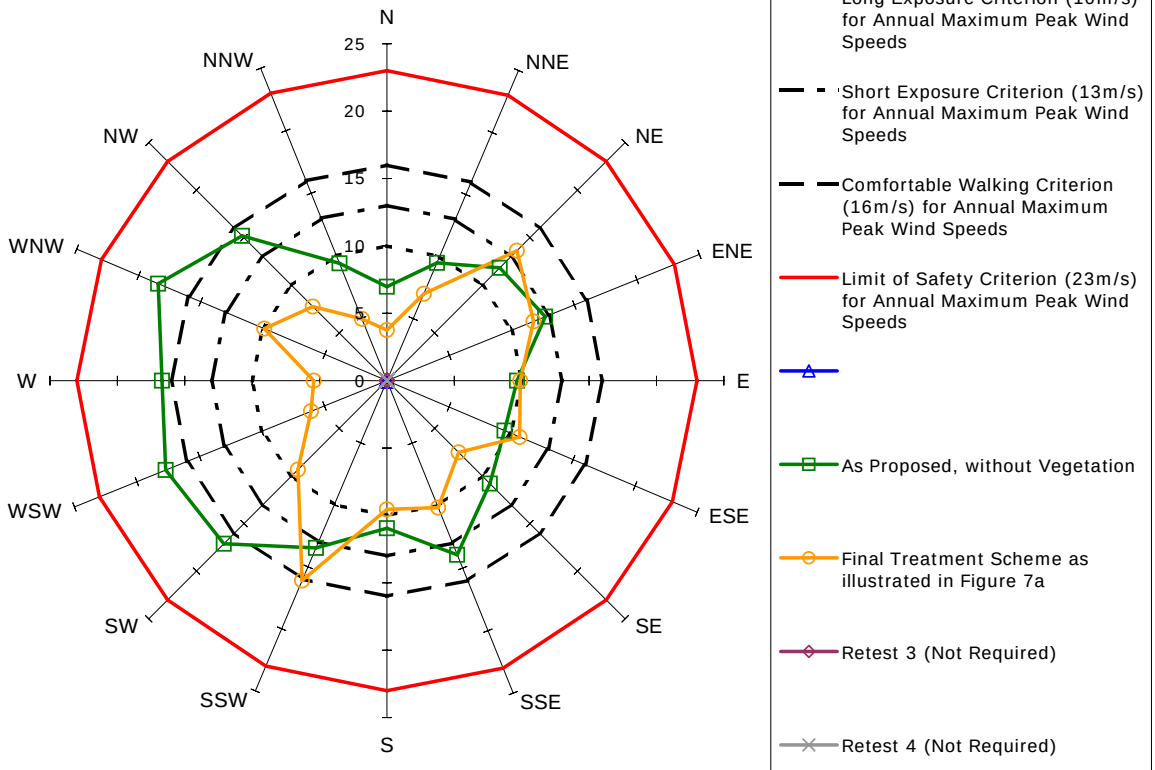


# Measured Wind Speeds at Point 30

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

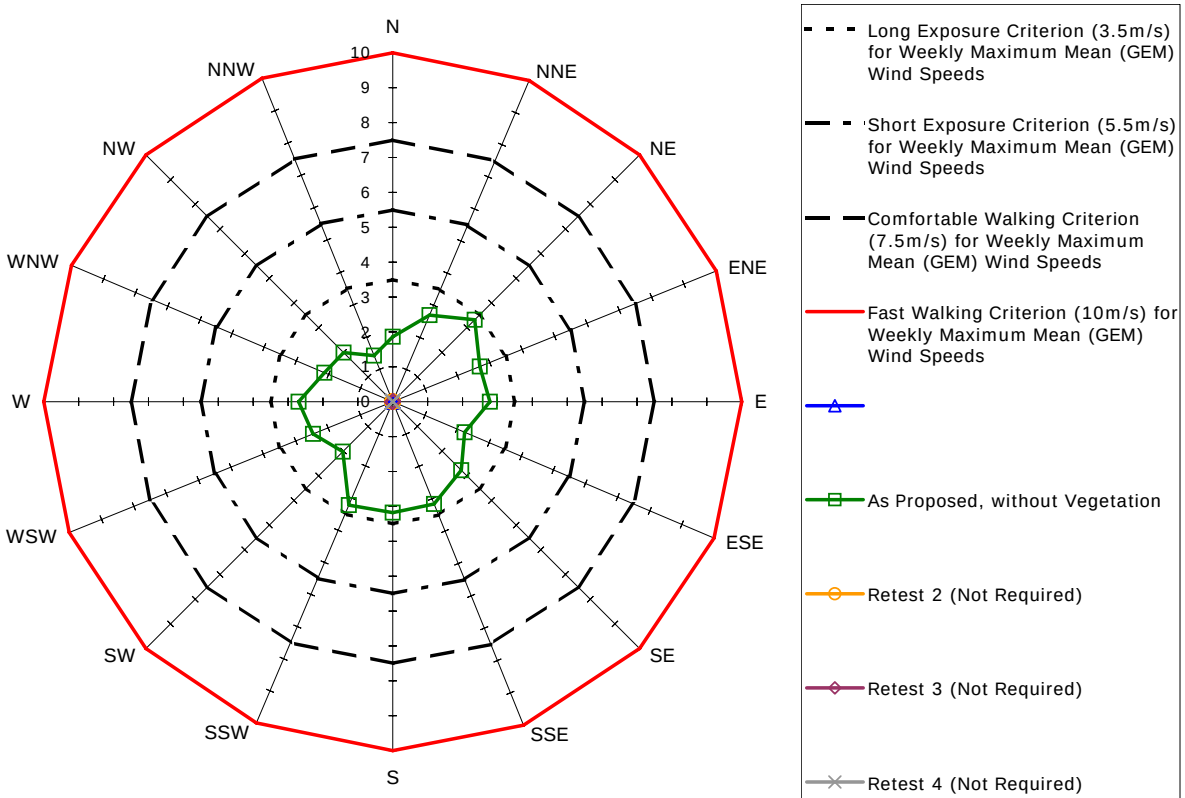



## Annual Maximum Gust Wind Speeds (m/s)

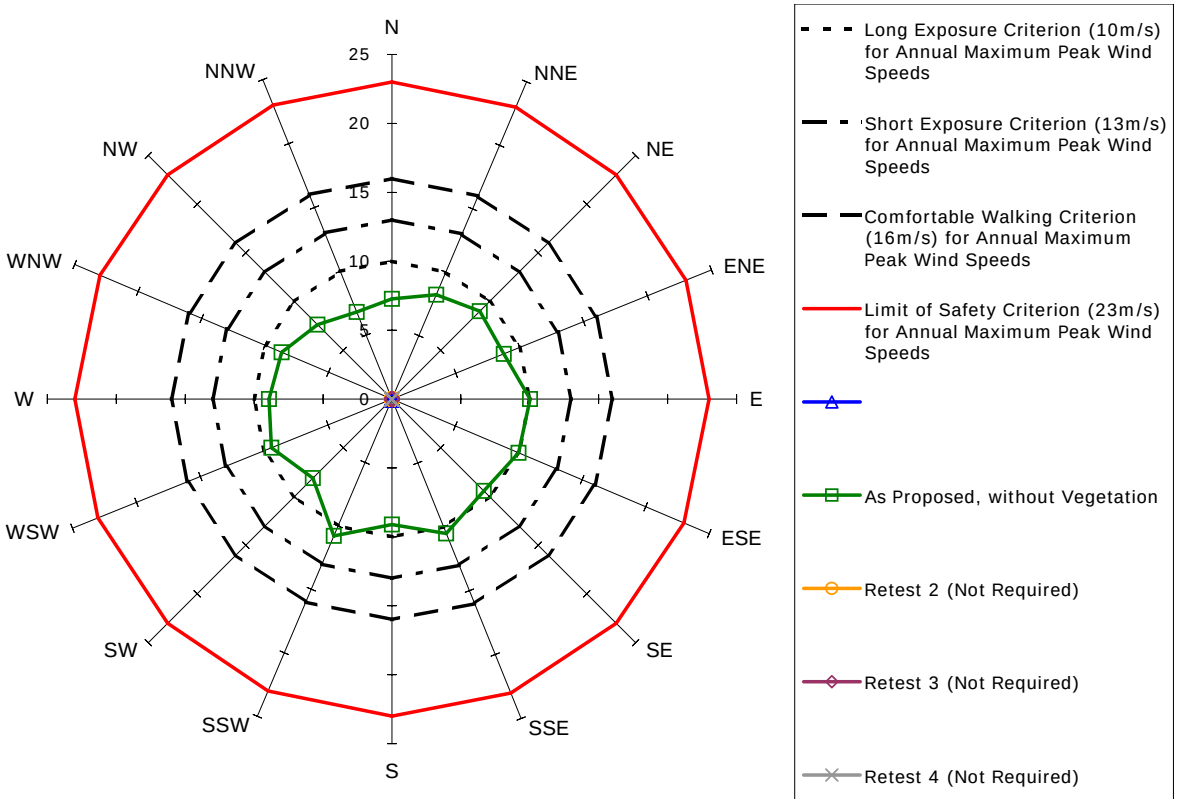


# Measured Wind Speeds at Point 31

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

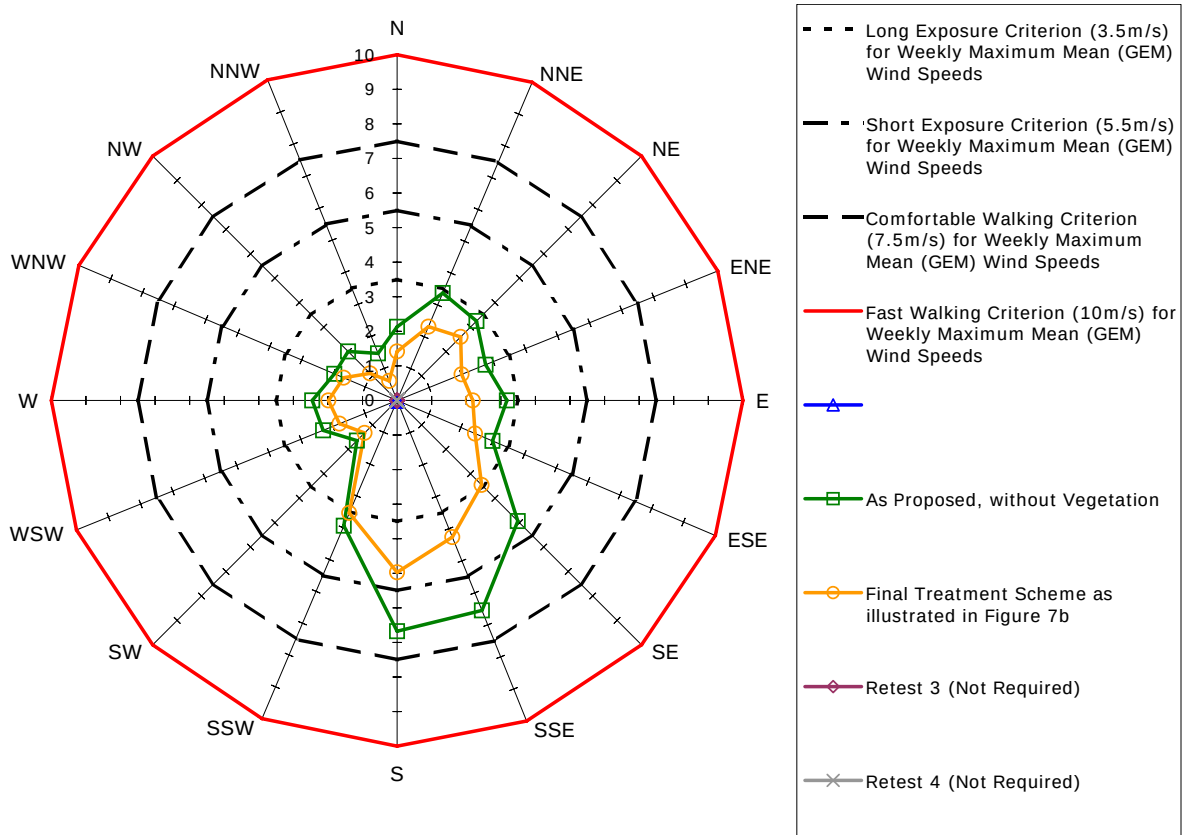



## Annual Maximum Gust Wind Speeds (m/s)

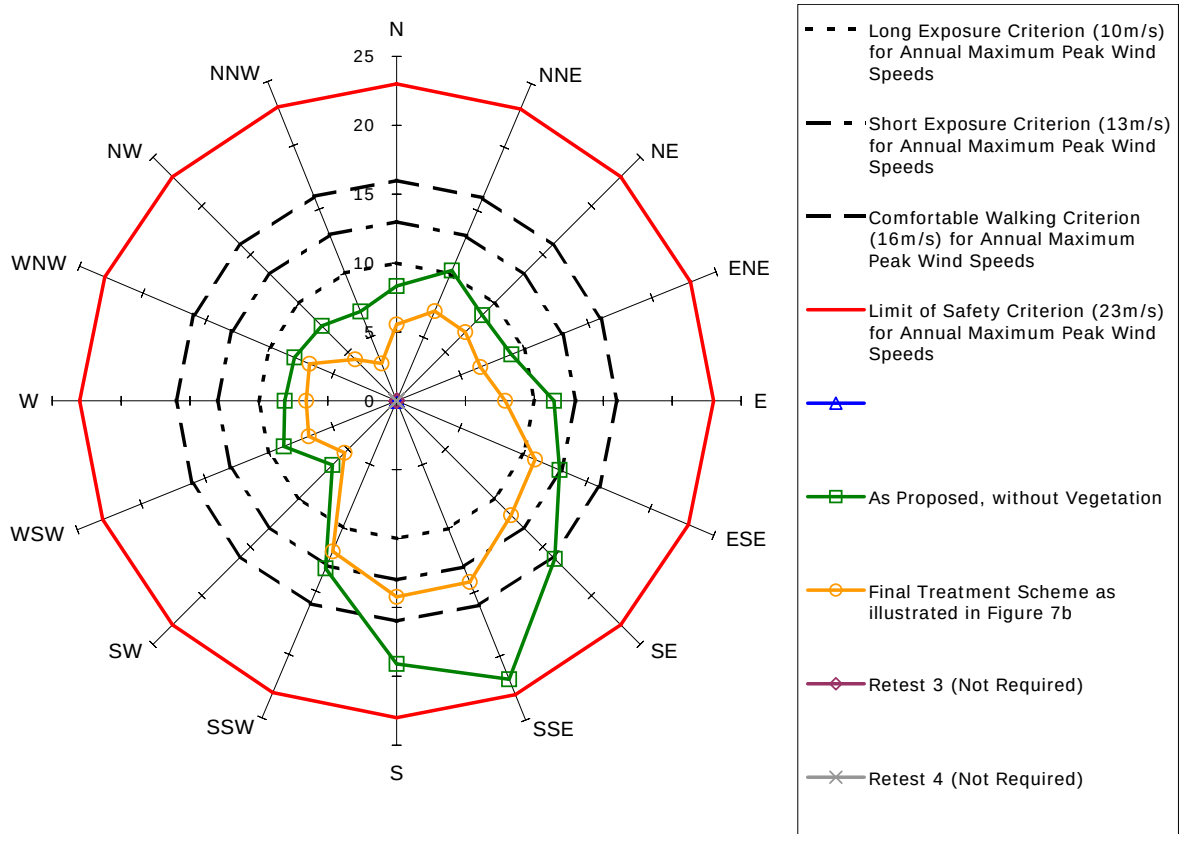


# Measured Wind Speeds at Point 32

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

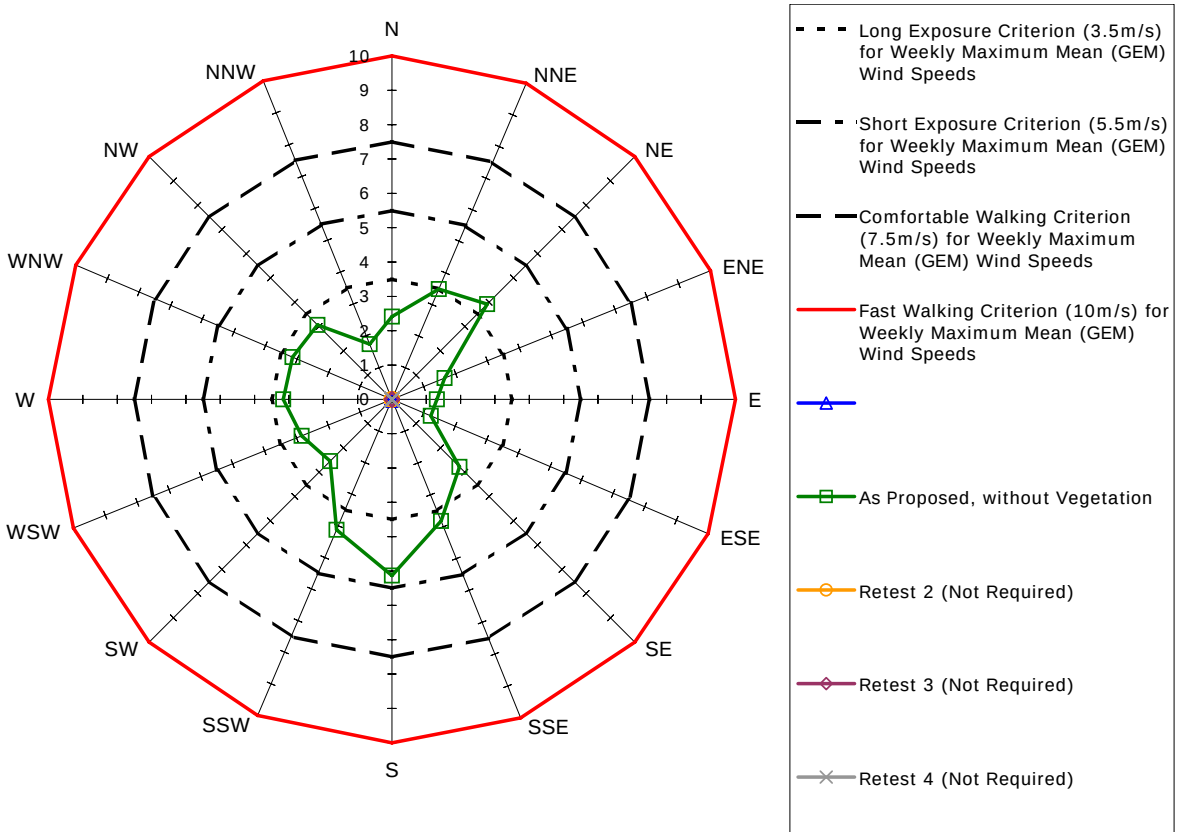



## Annual Maximum Gust Wind Speeds (m/s)

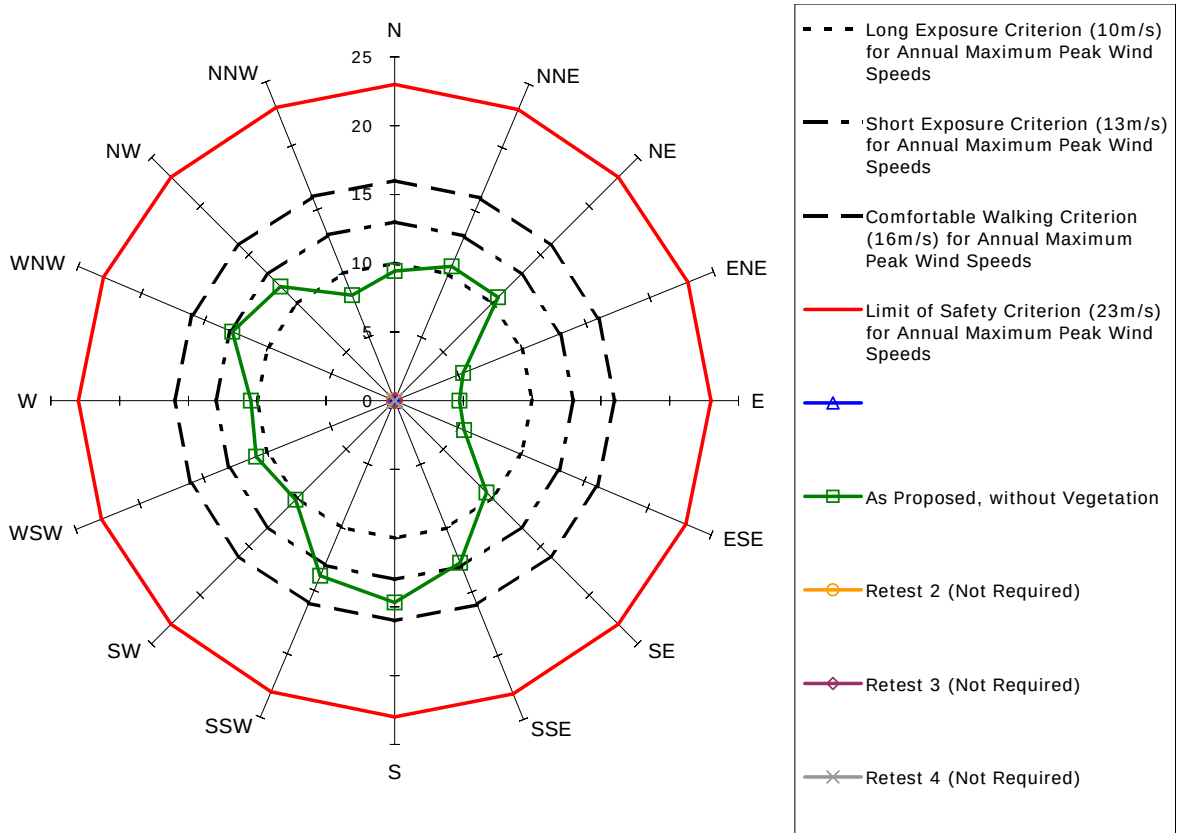


# Measured Wind Speeds at Point 33

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

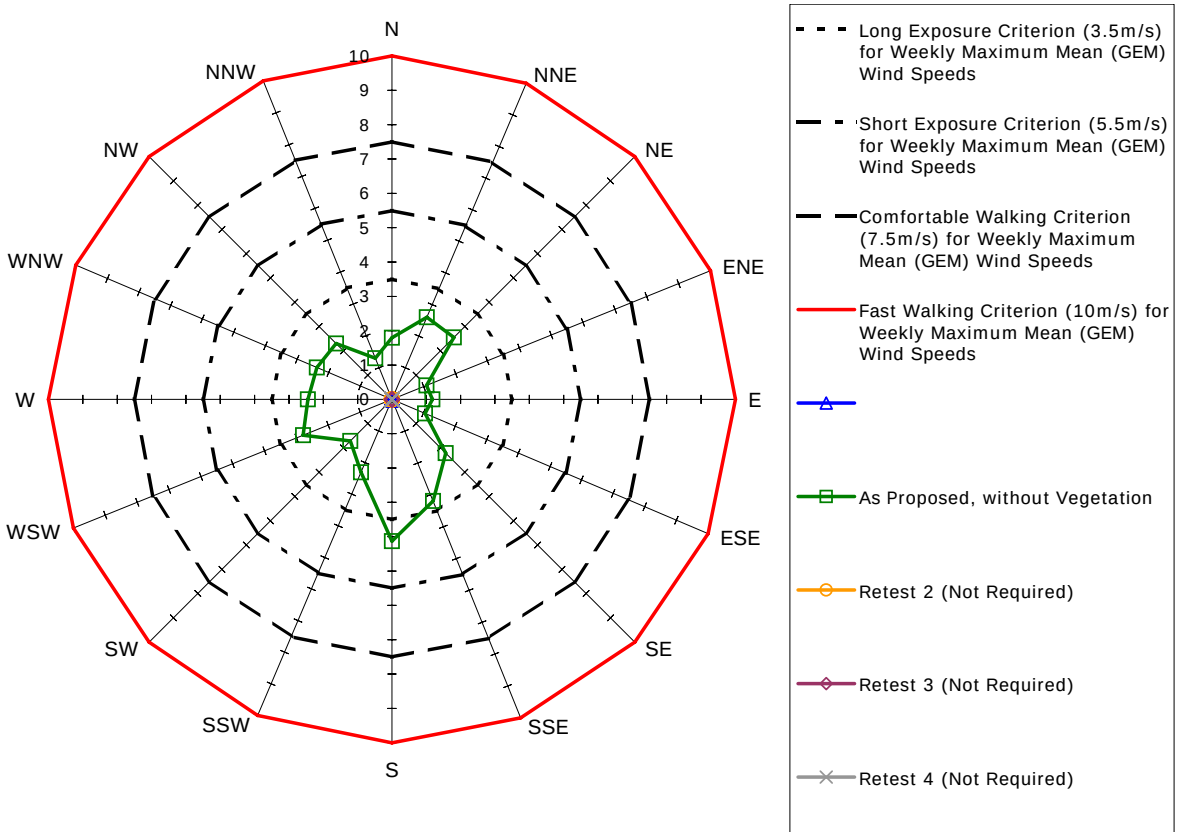



## Annual Maximum Gust Wind Speeds (m/s)

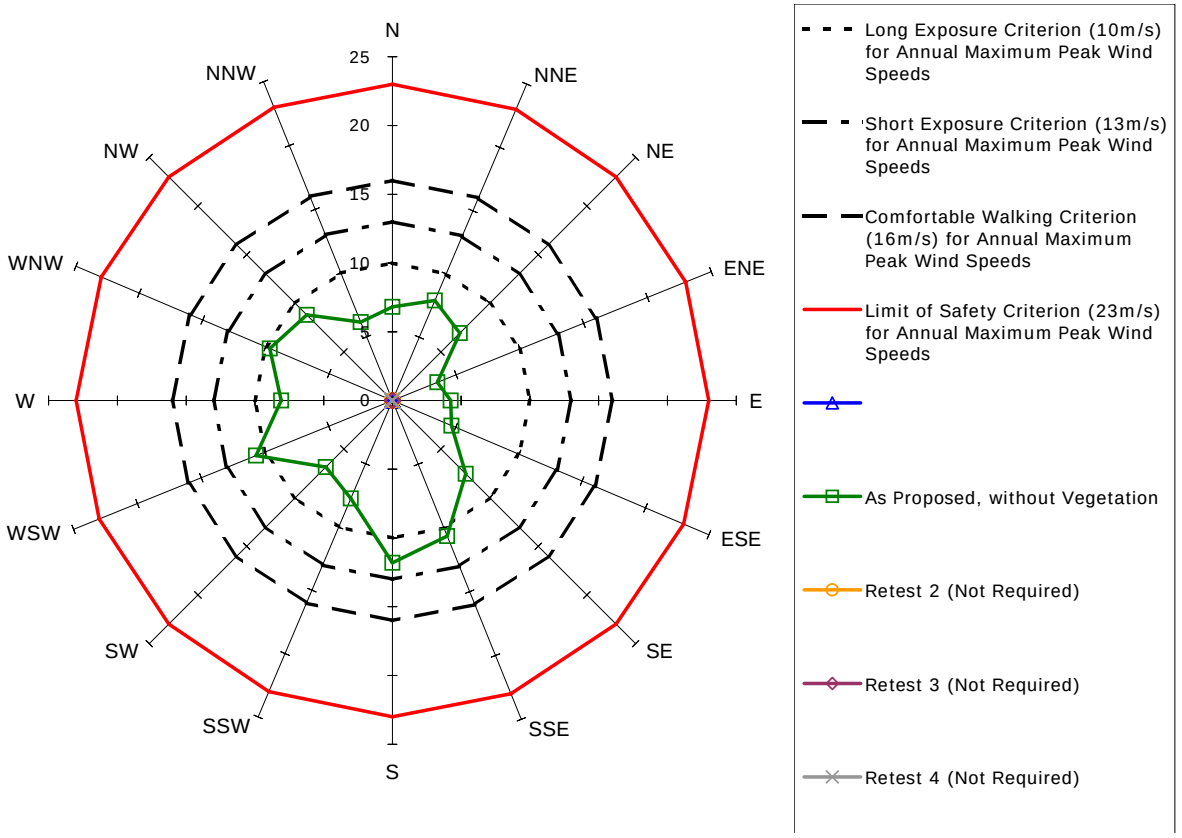


# Measured Wind Speeds at Point 34

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

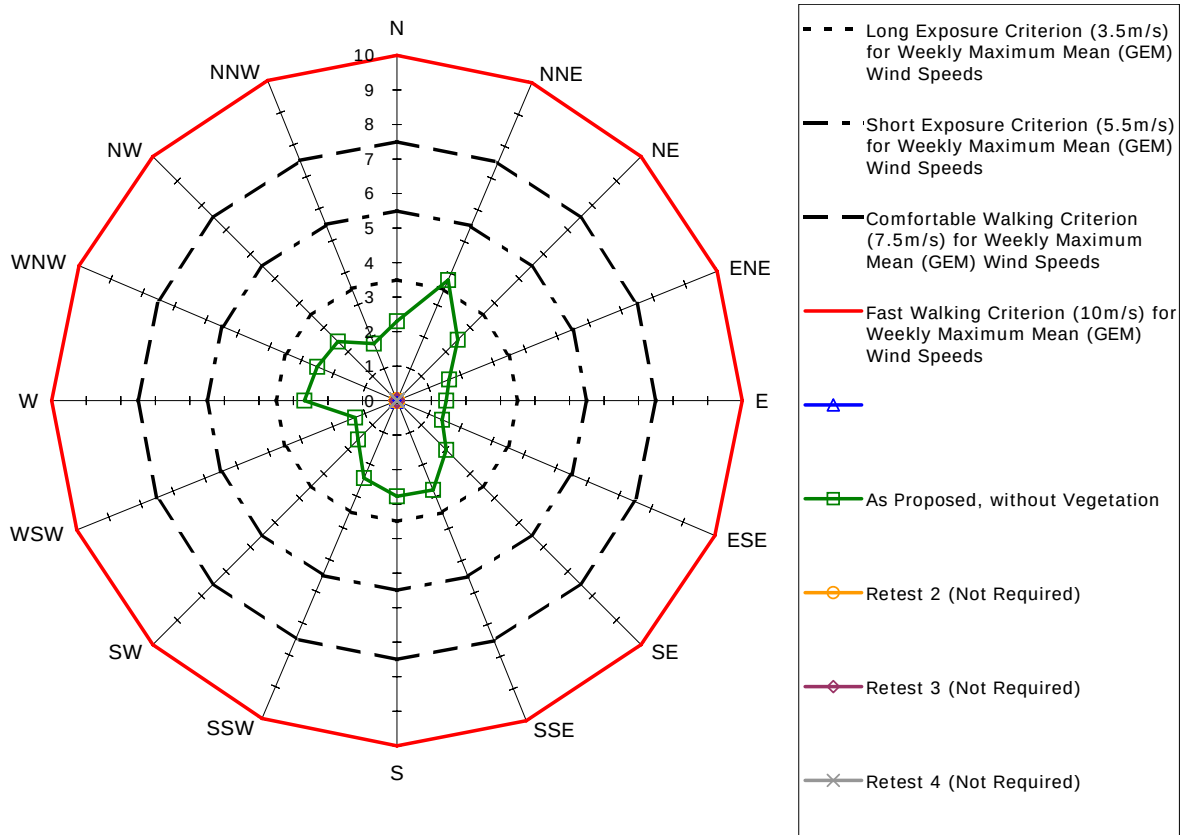



## Annual Maximum Gust Wind Speeds (m/s)

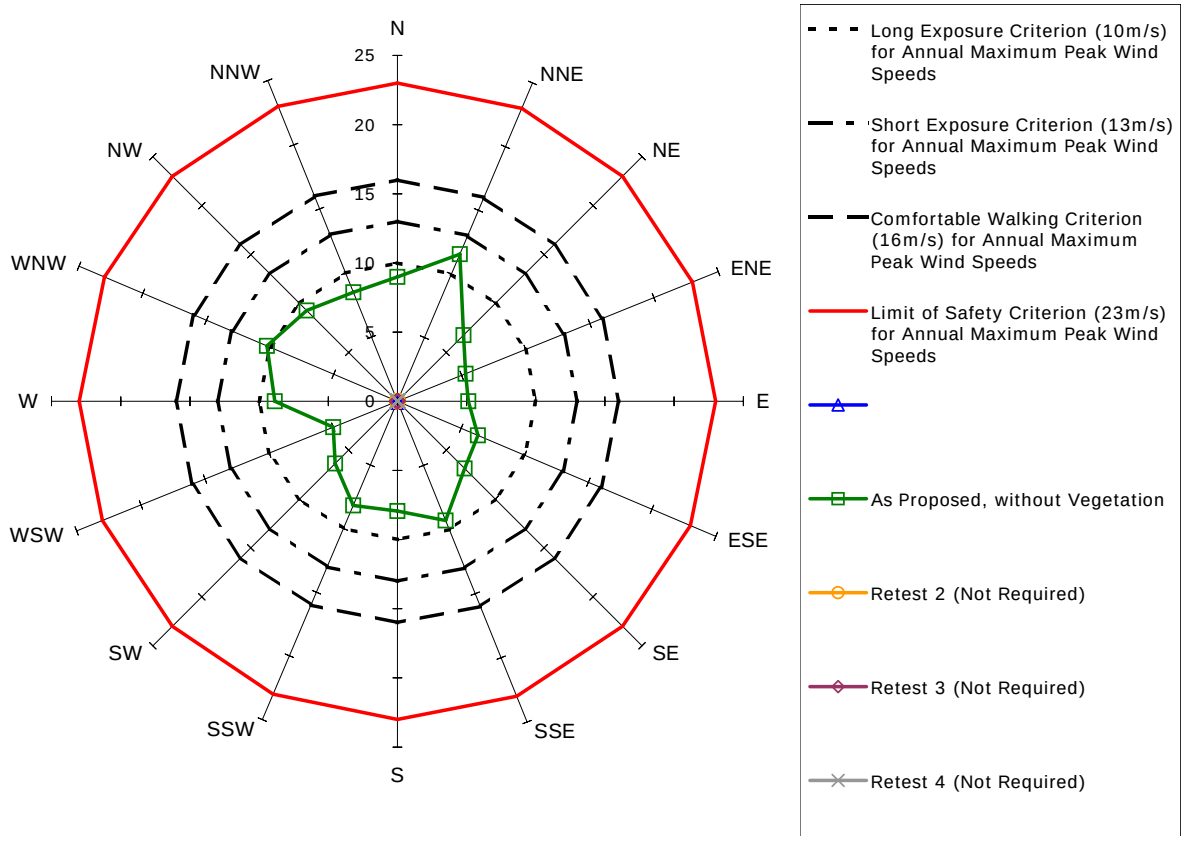


# Measured Wind Speeds at Point 35

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

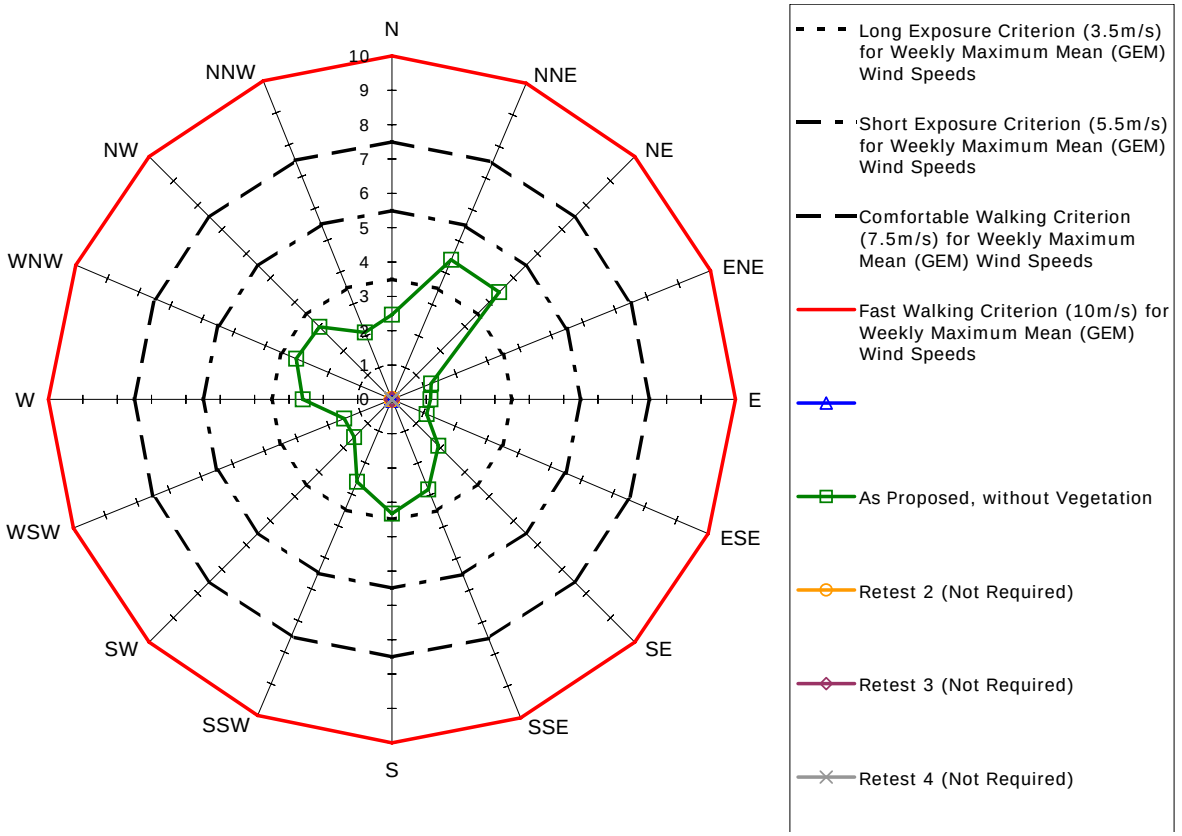



## Annual Maximum Gust Wind Speeds (m/s)

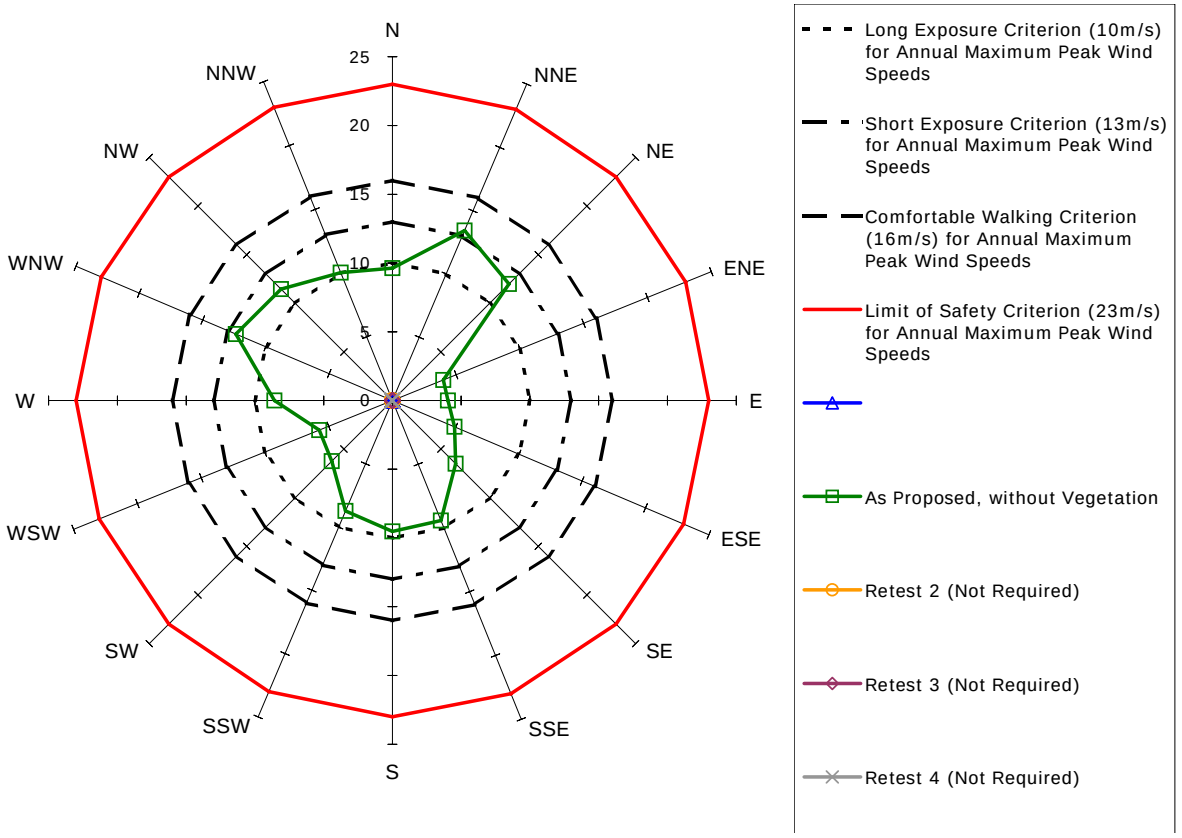


# Measured Wind Speeds at Point 36

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

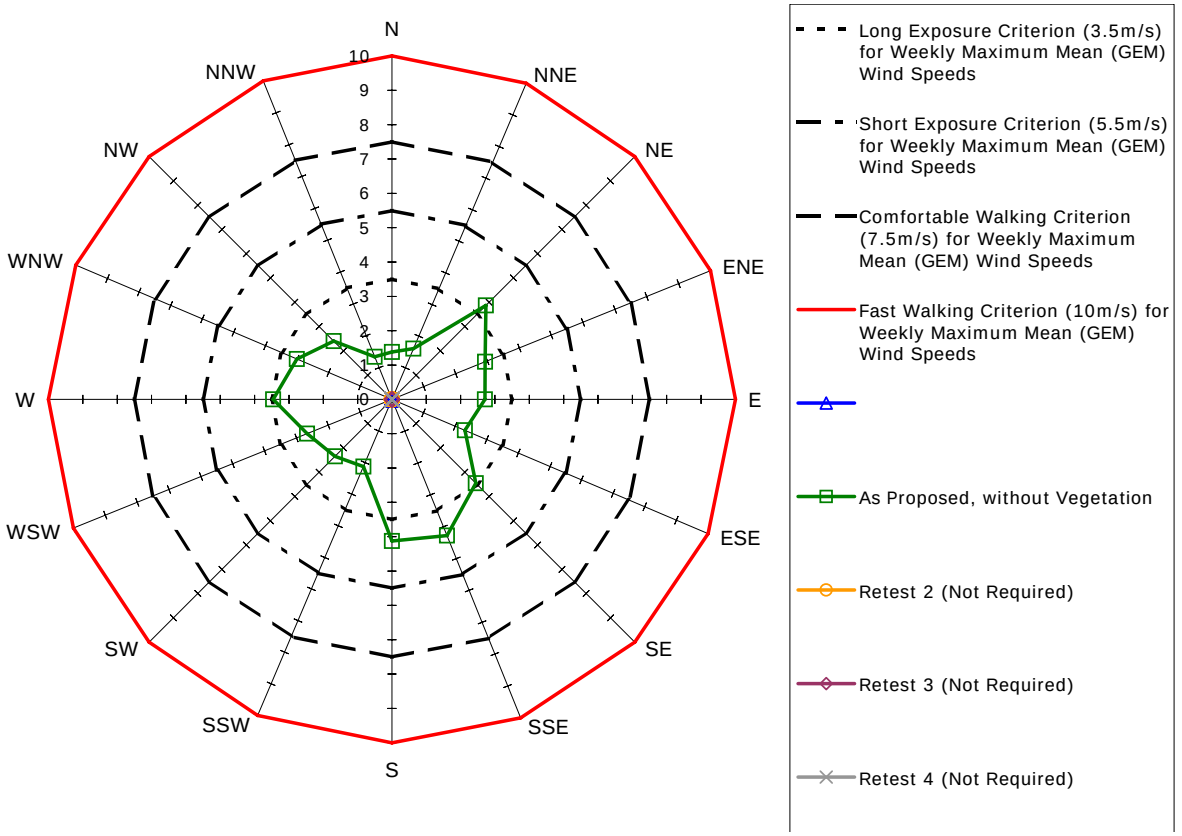



## Annual Maximum Gust Wind Speeds (m/s)

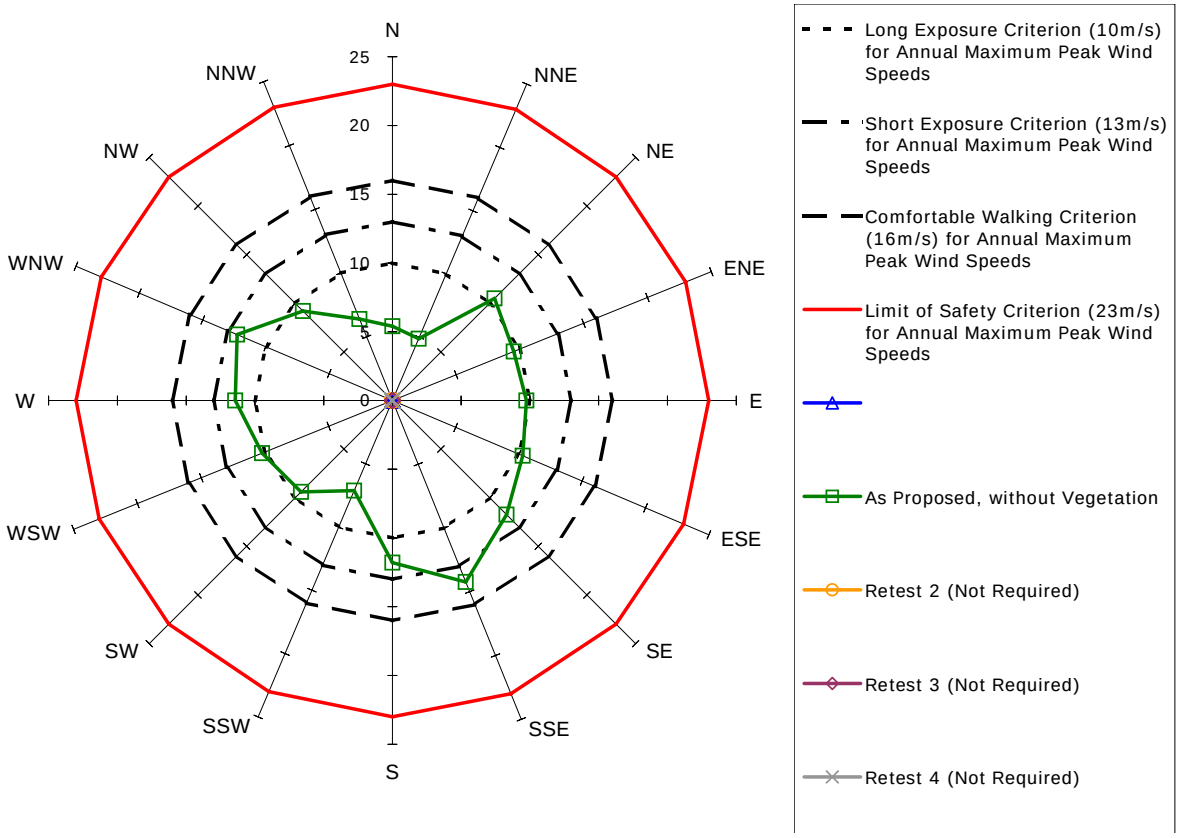


# Measured Wind Speeds at Point 37

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

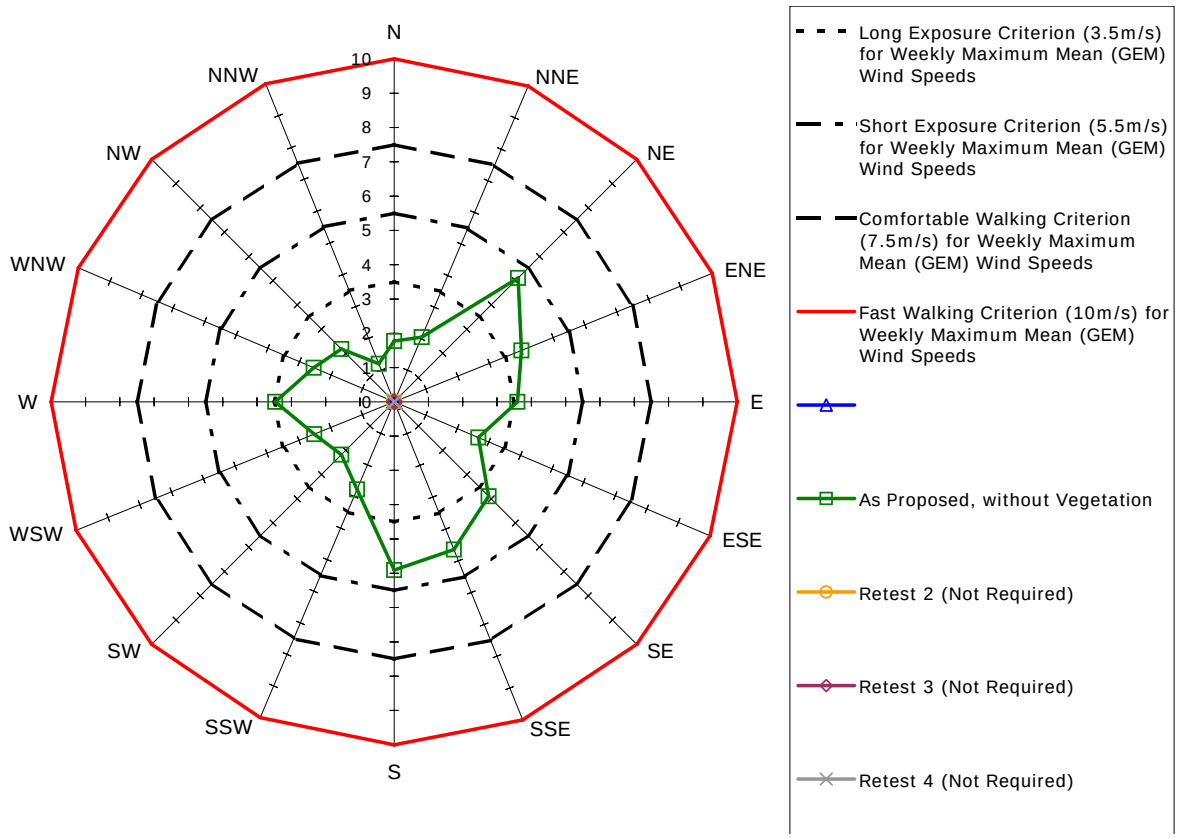



## Annual Maximum Gust Wind Speeds (m/s)

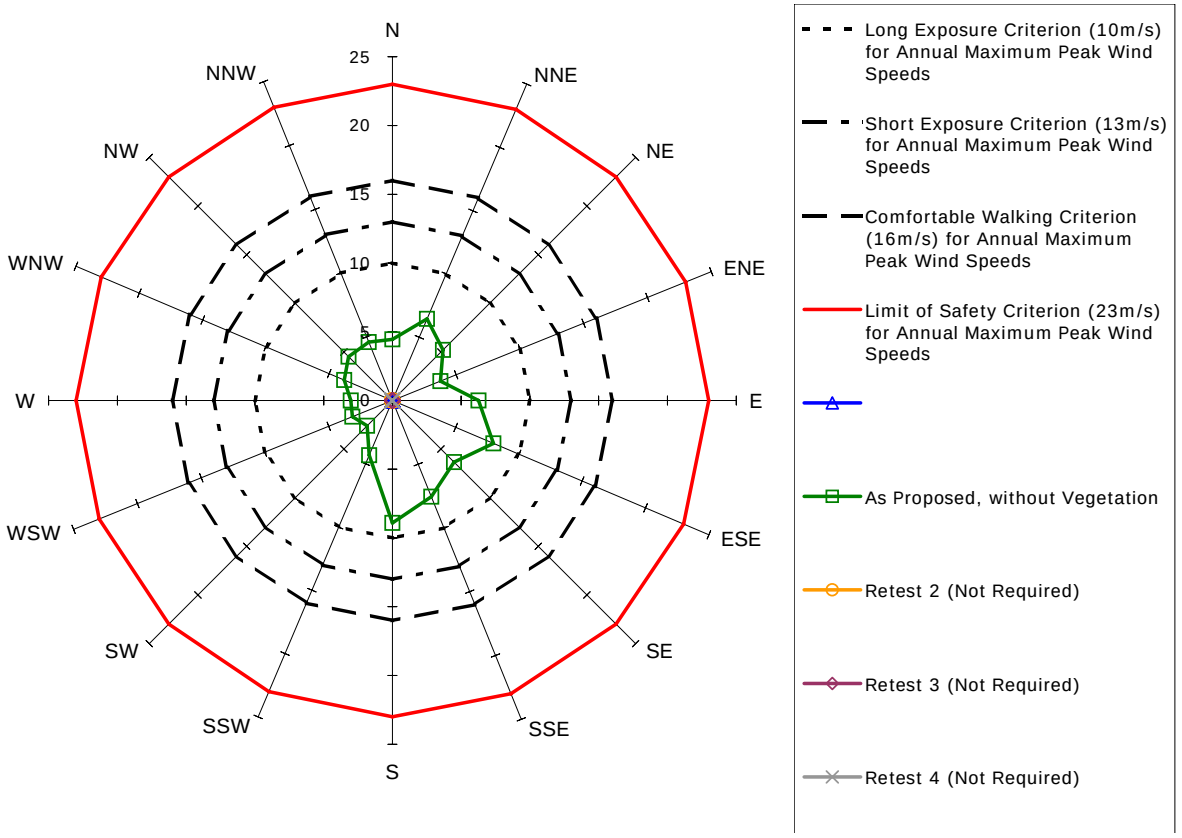


# Measured Wind Speeds at Point 38

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

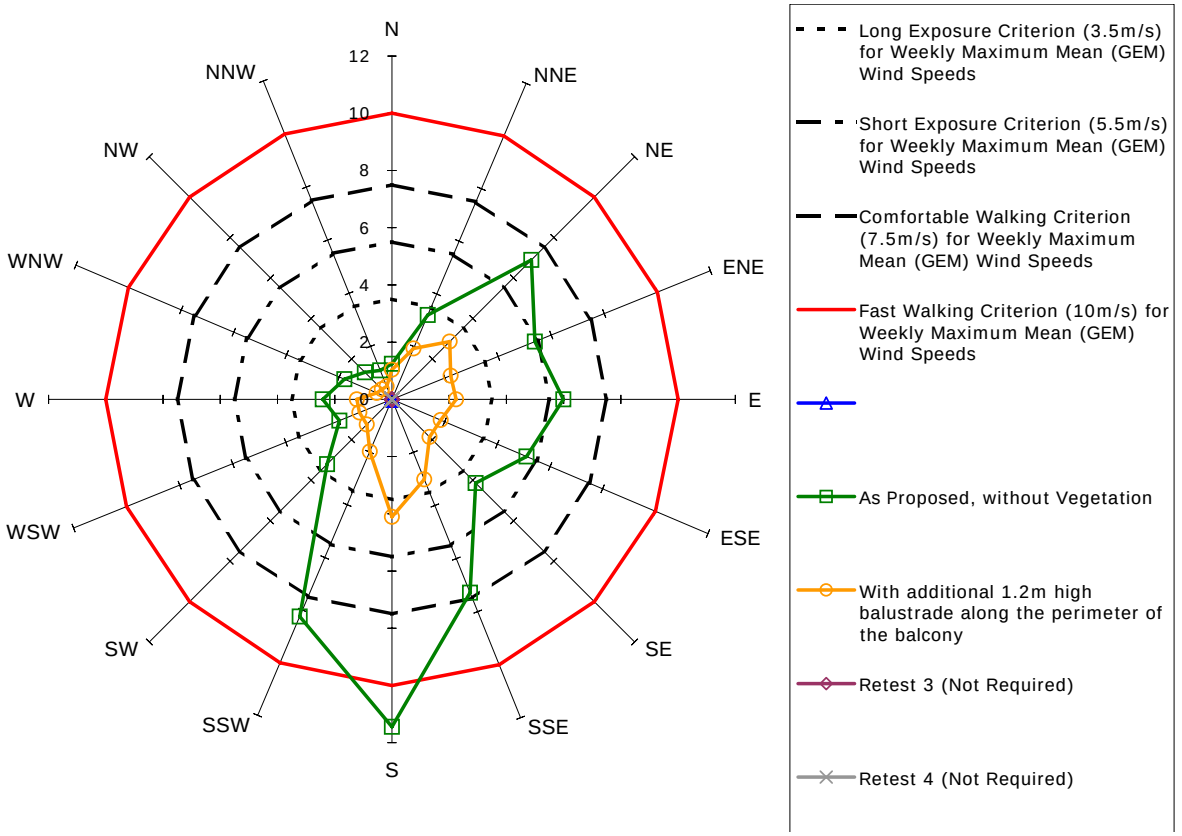



## Annual Maximum Gust Wind Speeds (m/s)

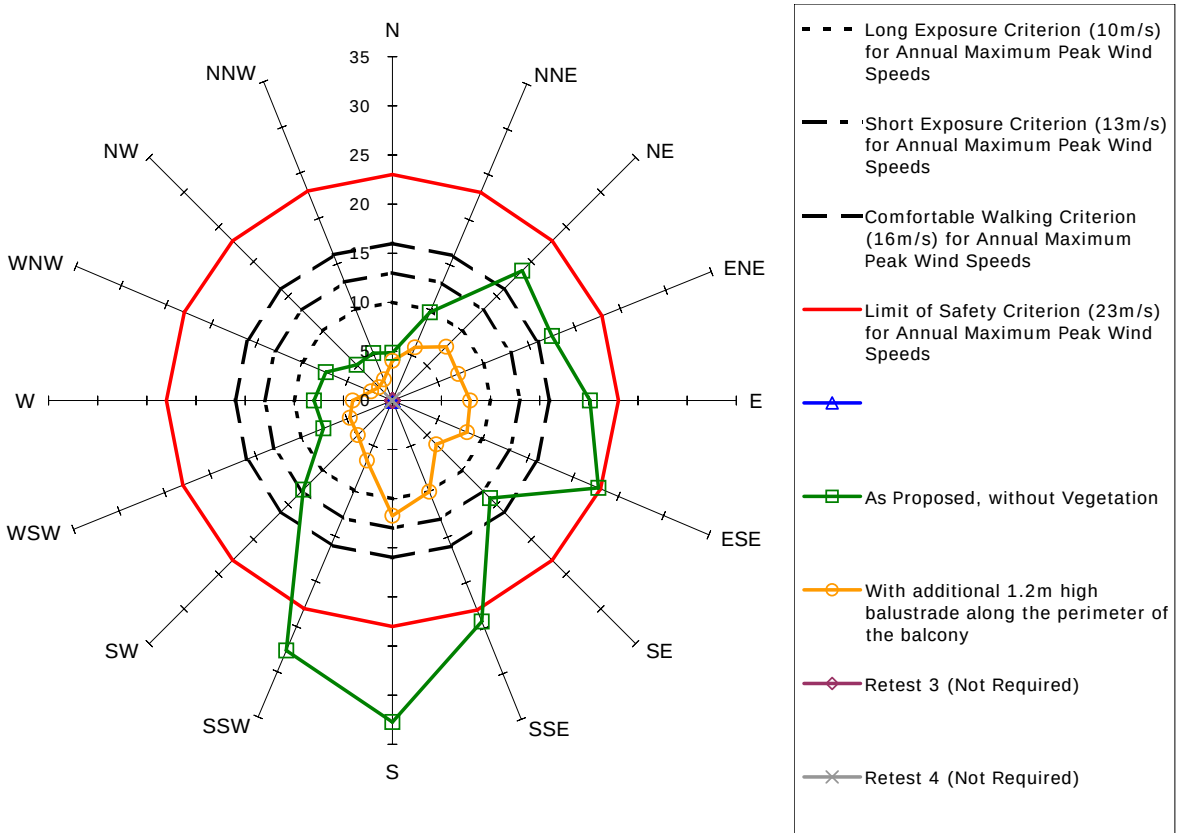


# Measured Wind Speeds at Point 39

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

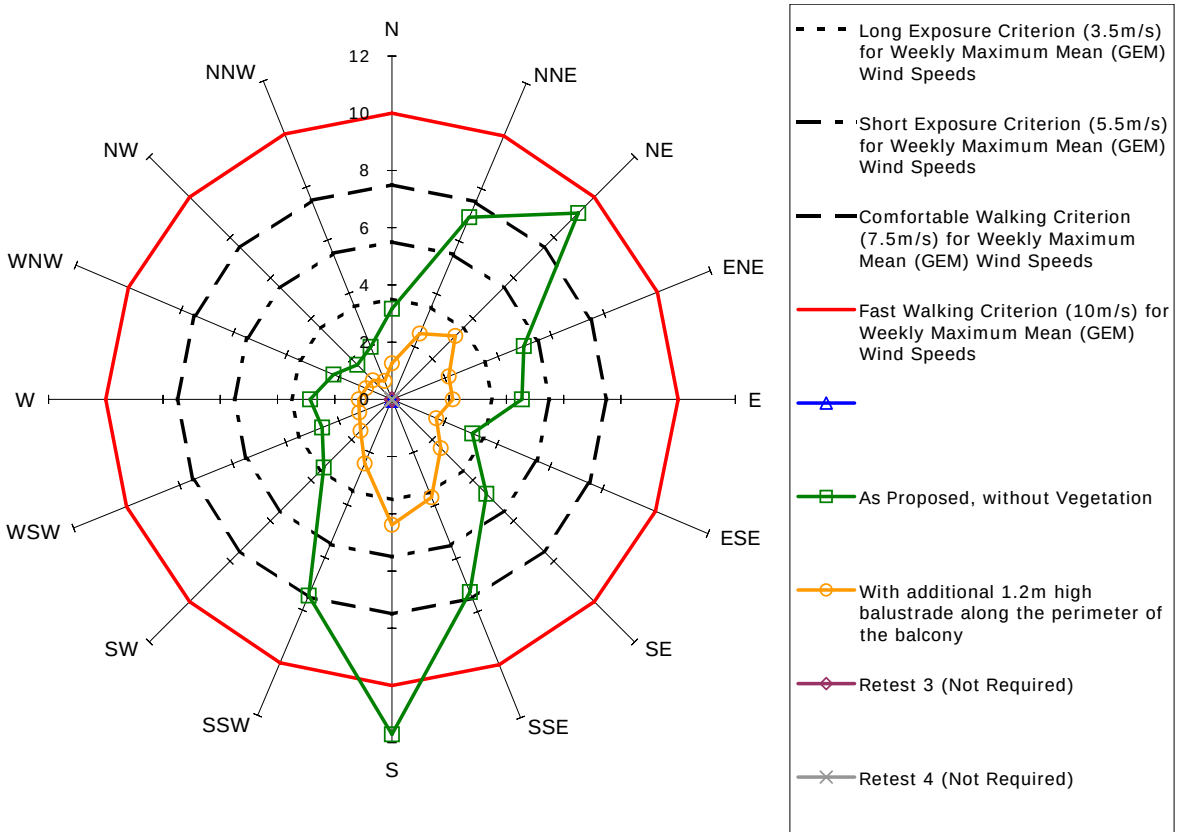



## Annual Maximum Gust Wind Speeds (m/s)

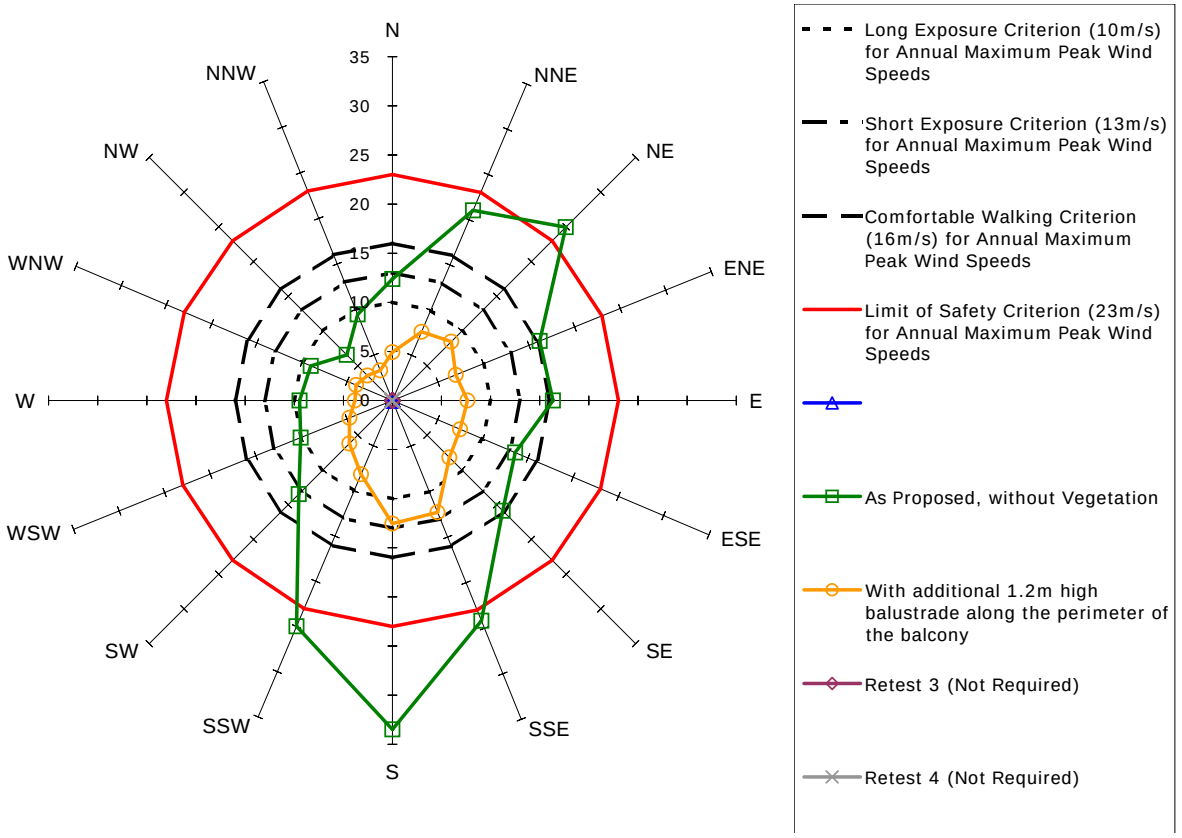


# Measured Wind Speeds at Point 40

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

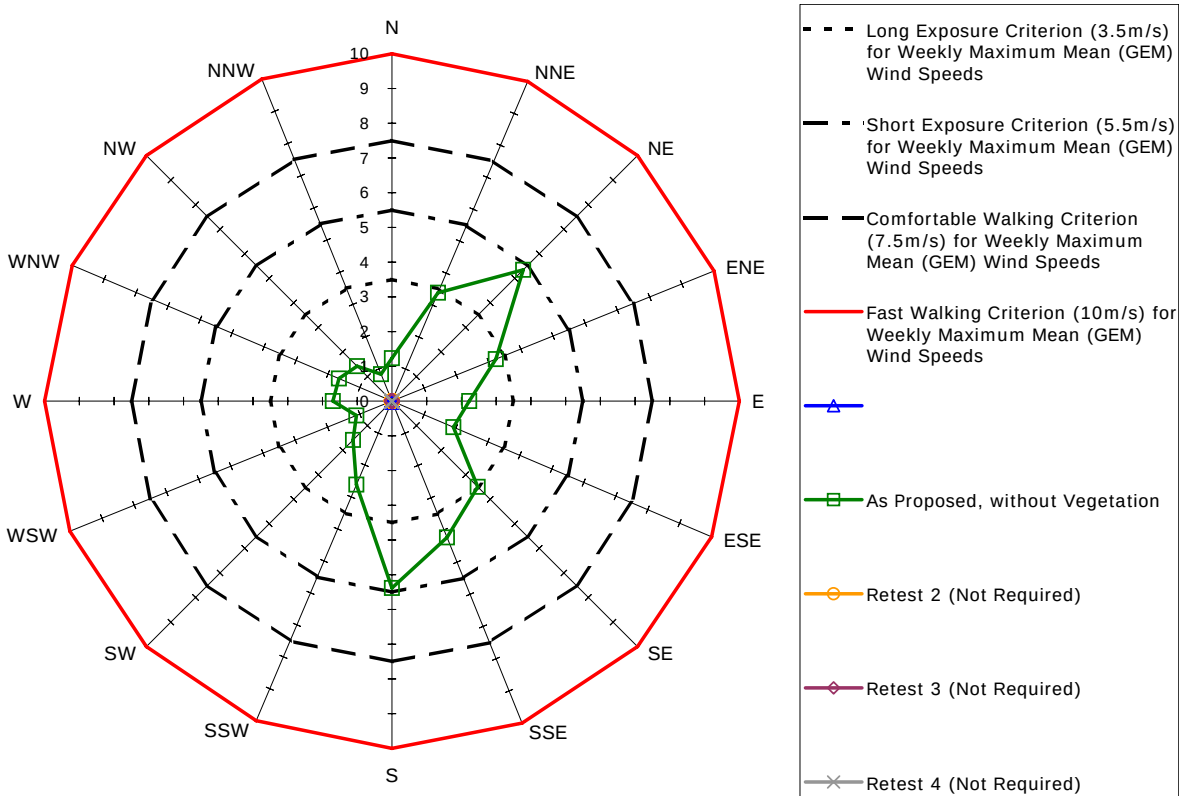



## Annual Maximum Gust Wind Speeds (m/s)

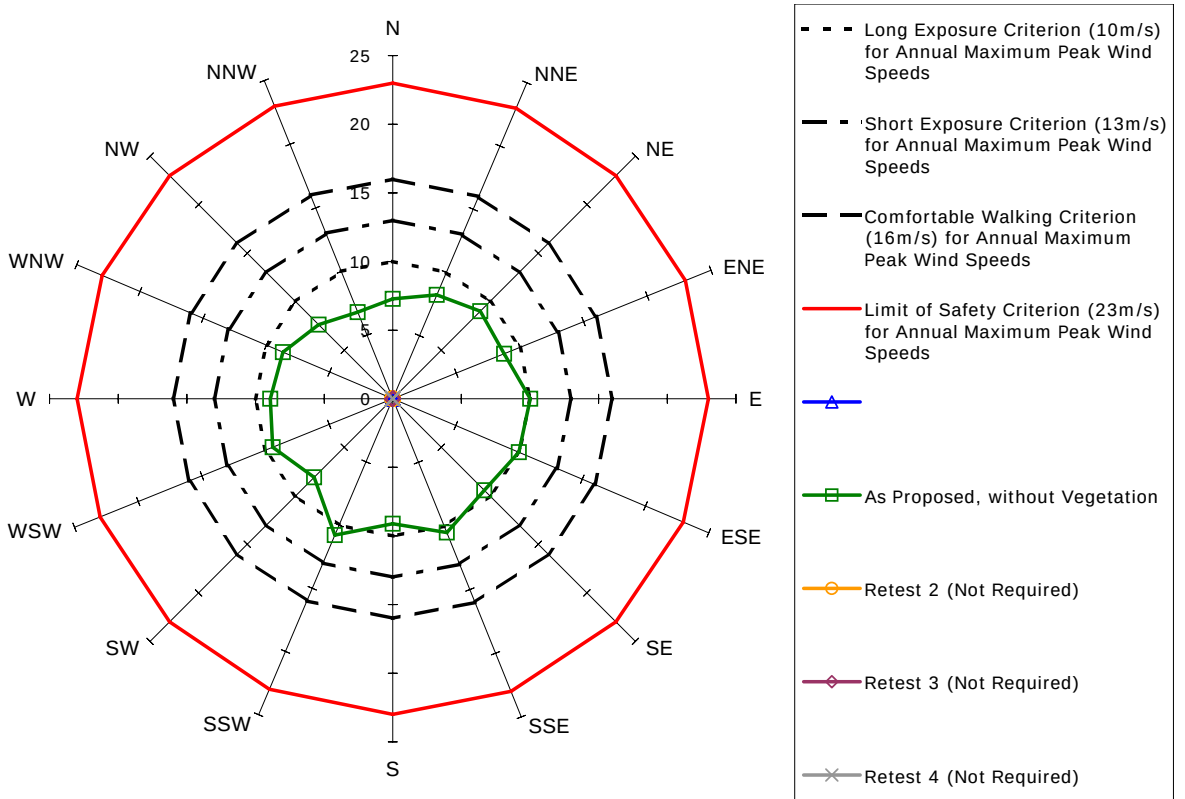


# Measured Wind Speeds at Point 41

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

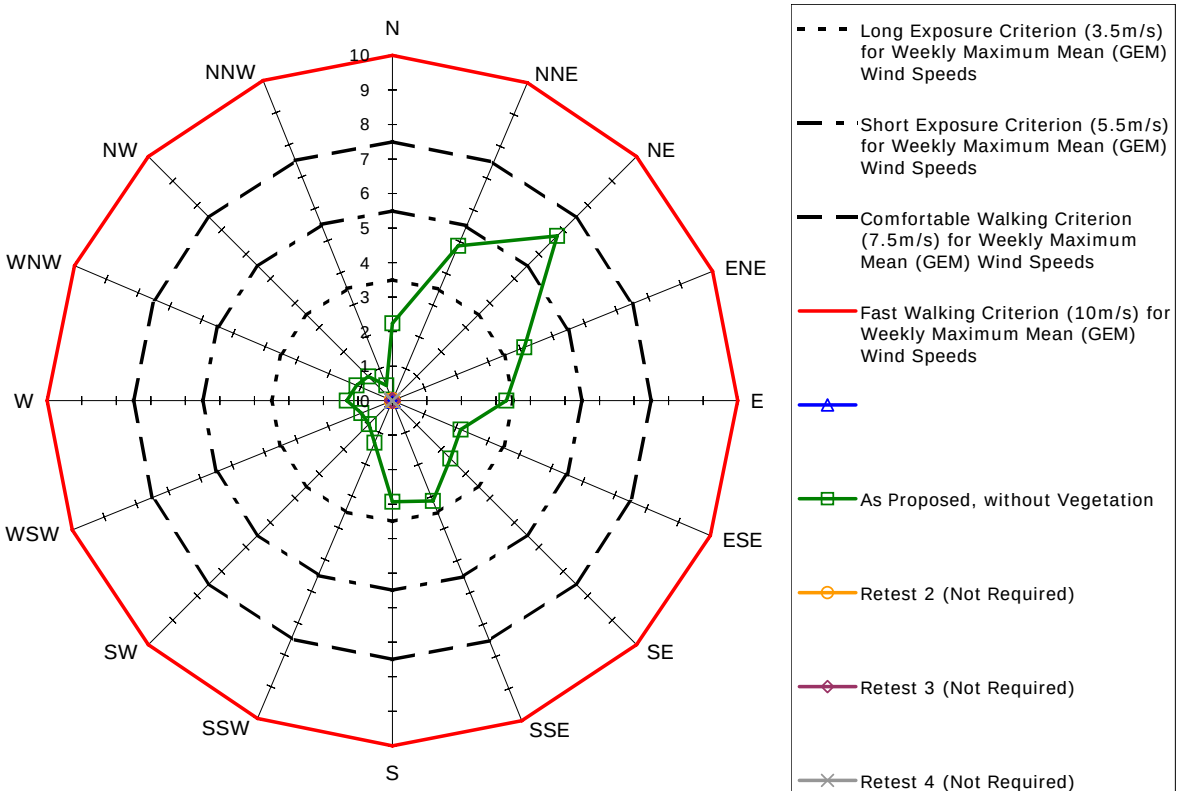



## Annual Maximum Gust Wind Speeds (m/s)

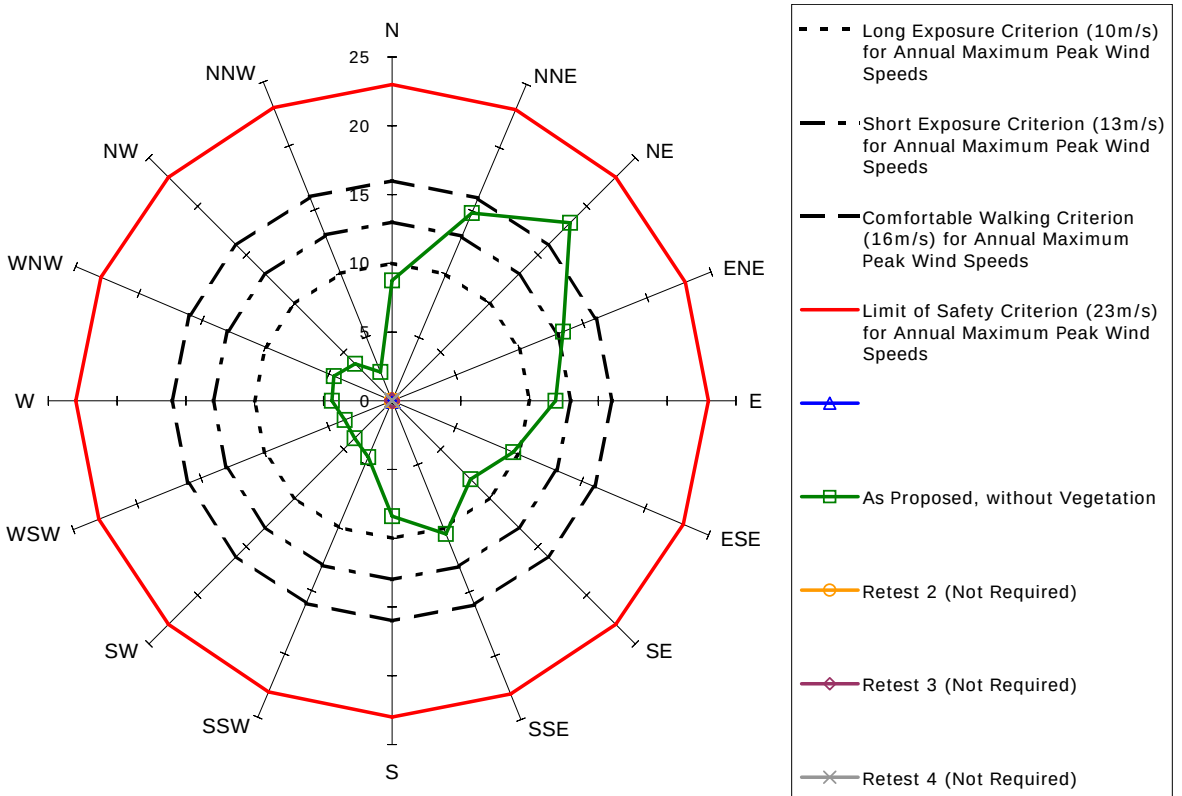


# Measured Wind Speeds at Point 42

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

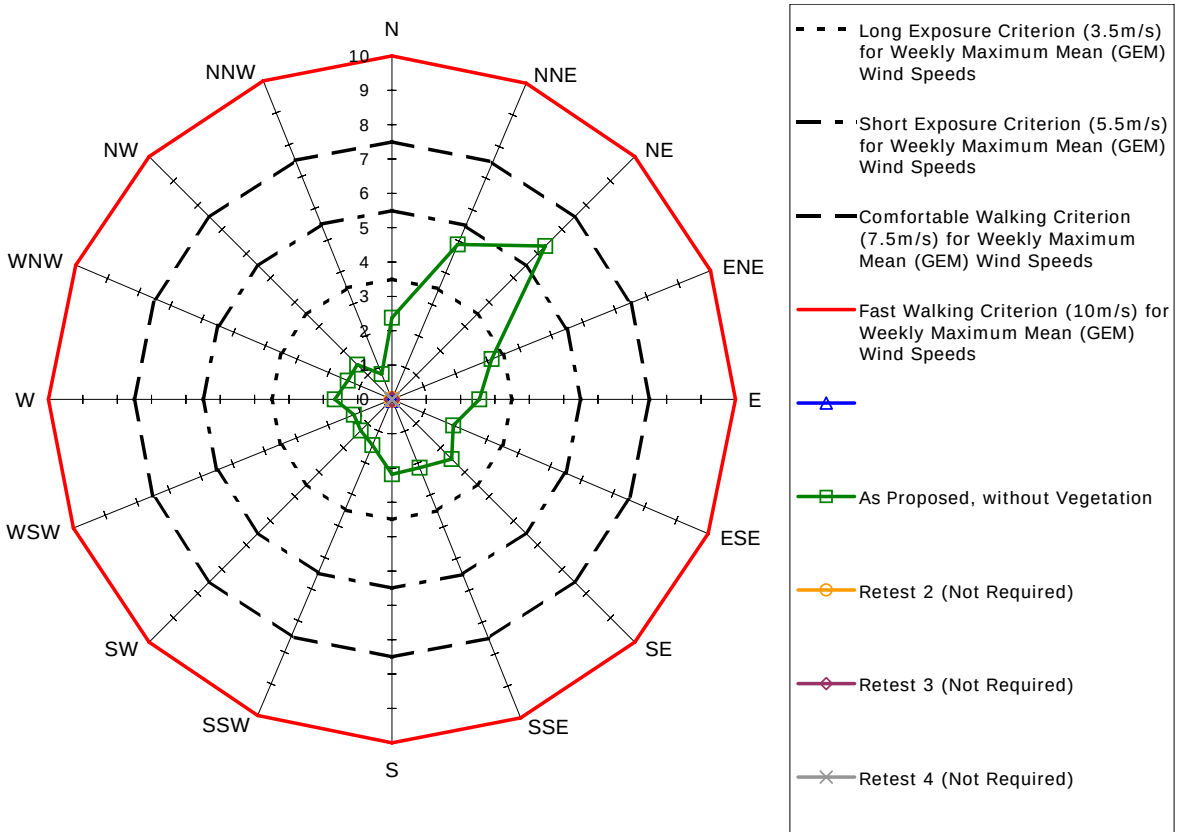



## Annual Maximum Gust Wind Speeds (m/s)

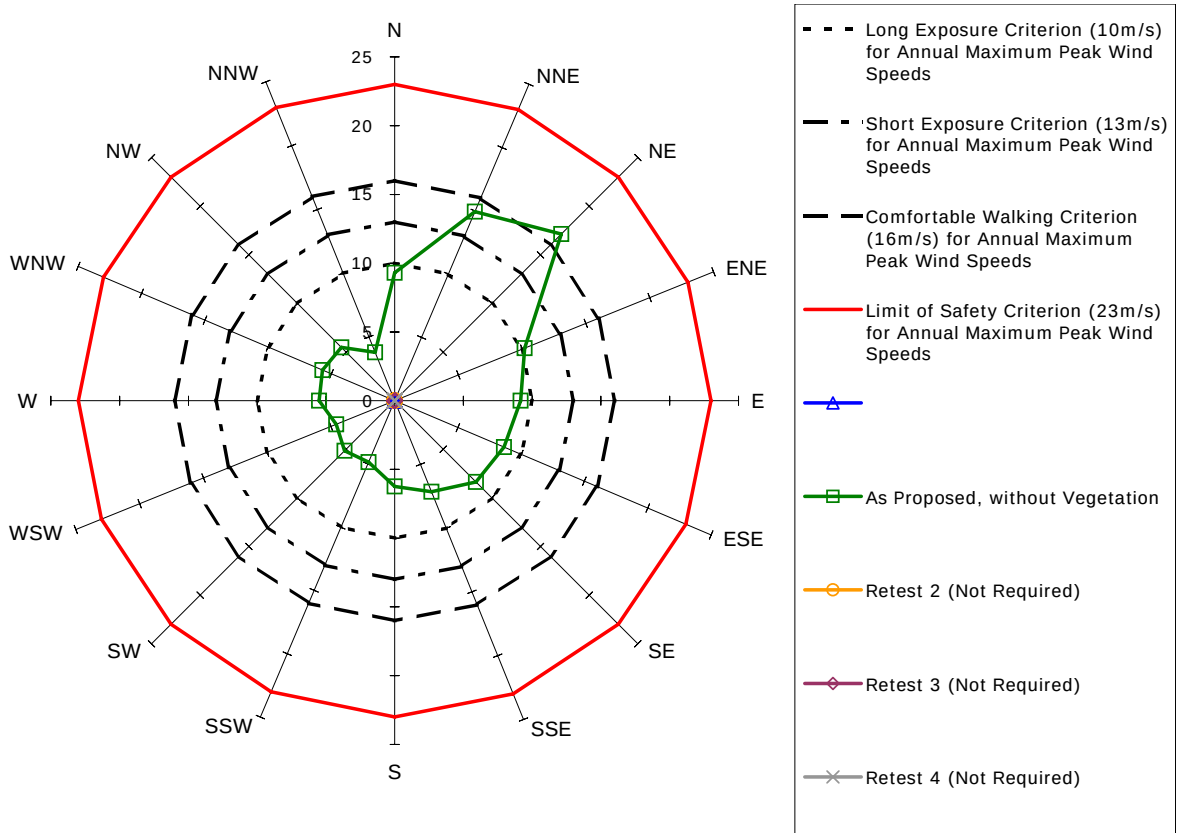


# Measured Wind Speeds at Point 43

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

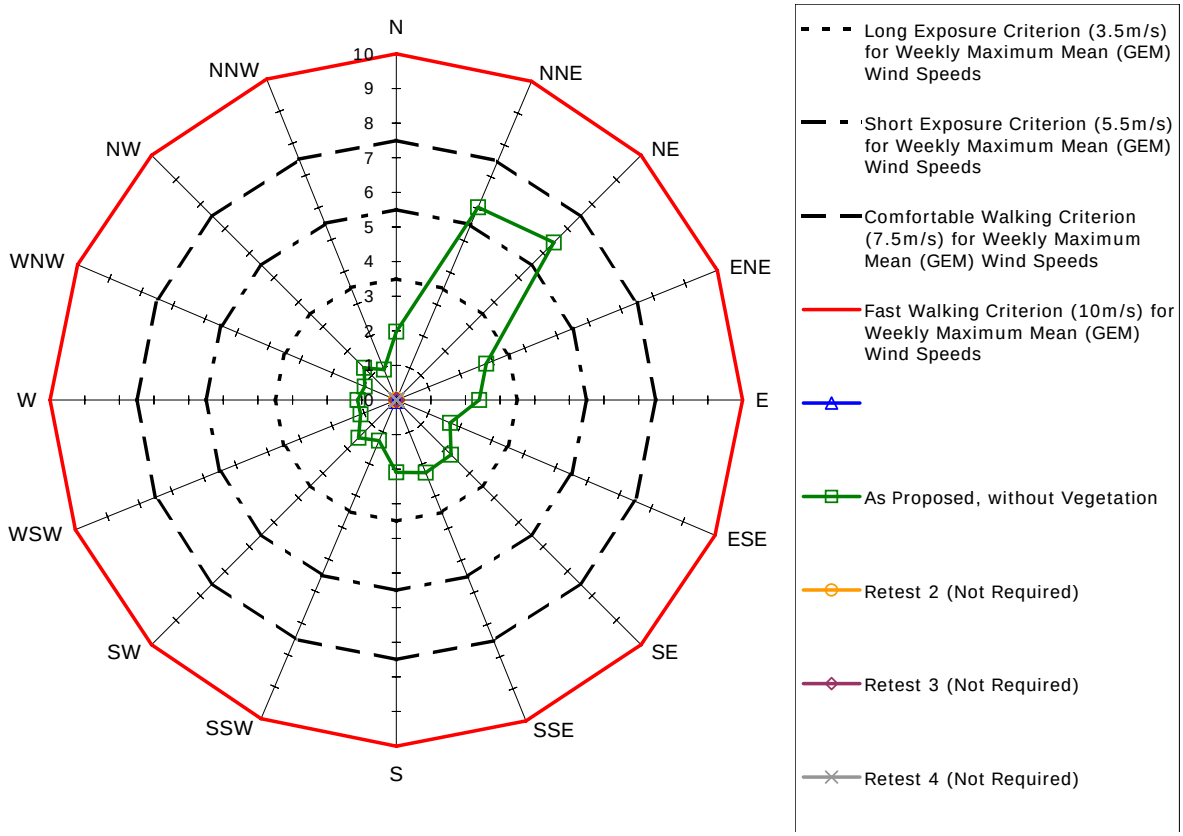



## Annual Maximum Gust Wind Speeds (m/s)

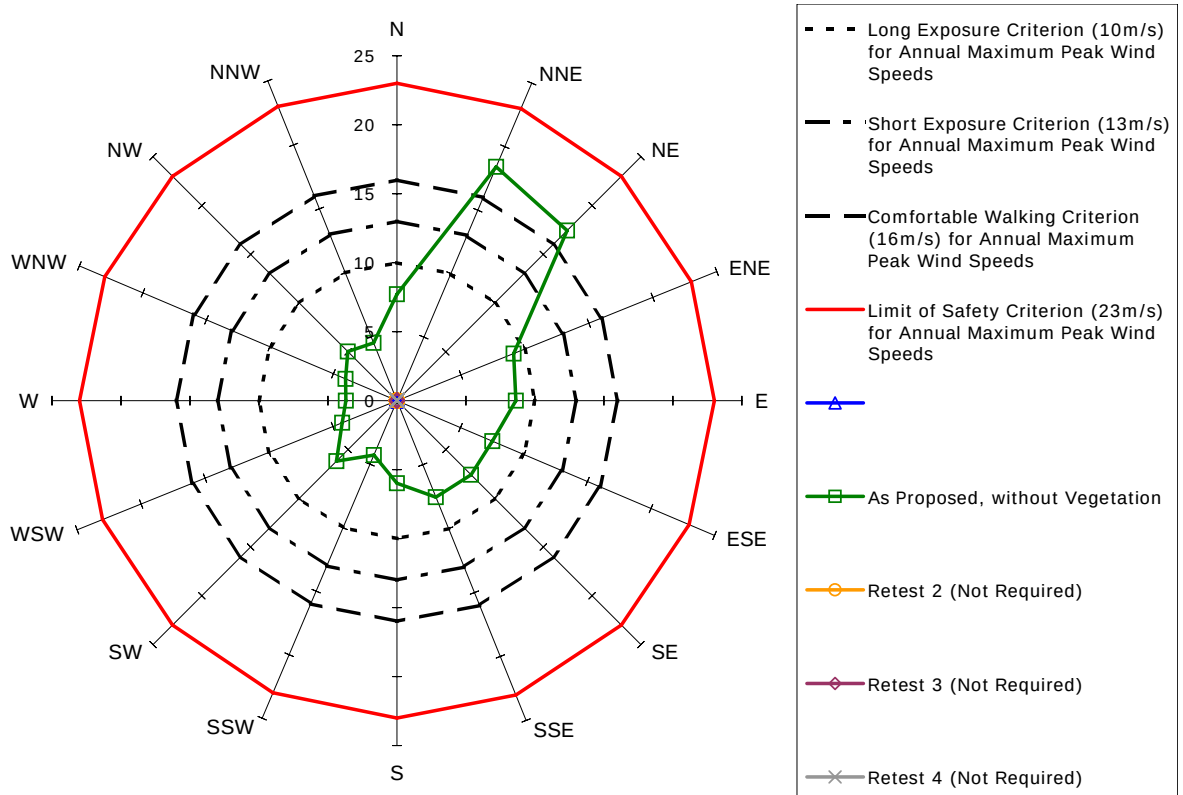


# Measured Wind Speeds at Point 44

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

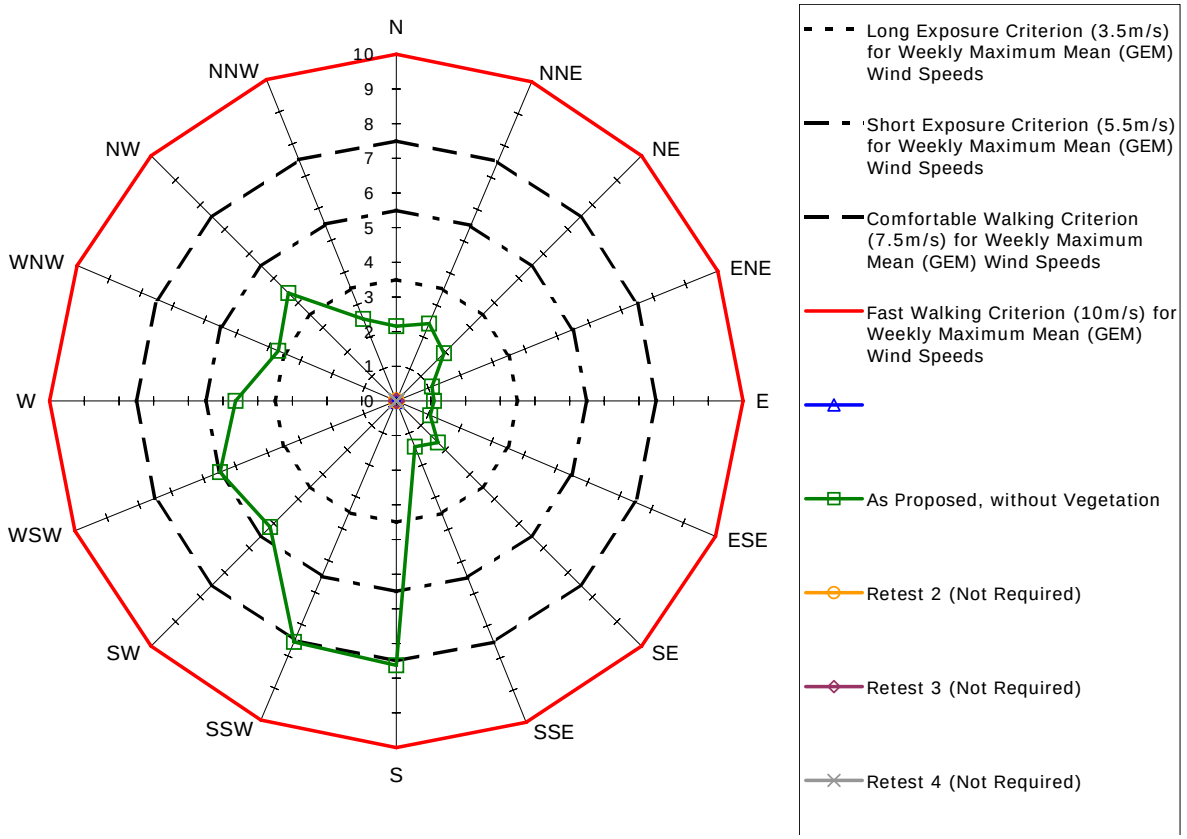



## Annual Maximum Gust Wind Speeds (m/s)

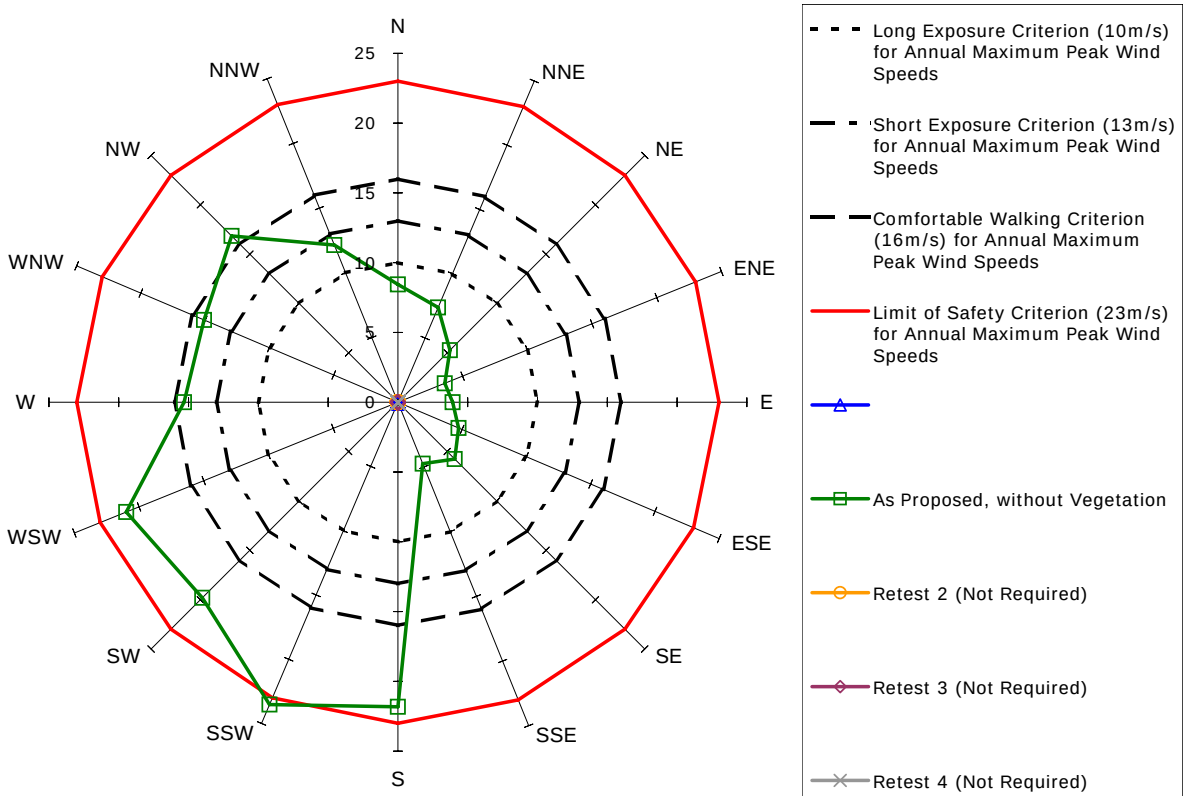


# Measured Wind Speeds at Point 45

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

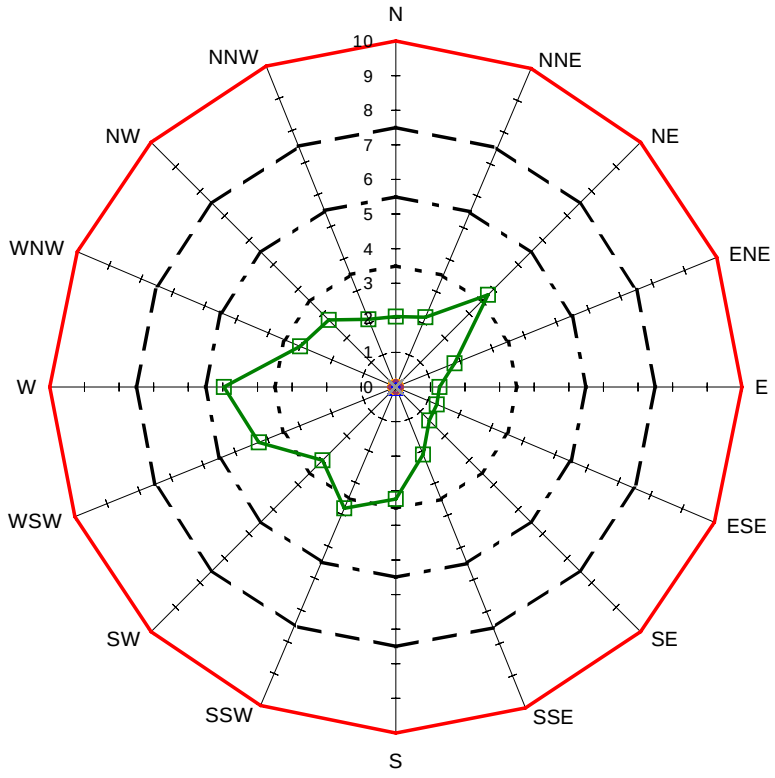



## Annual Maximum Gust Wind Speeds (m/s)



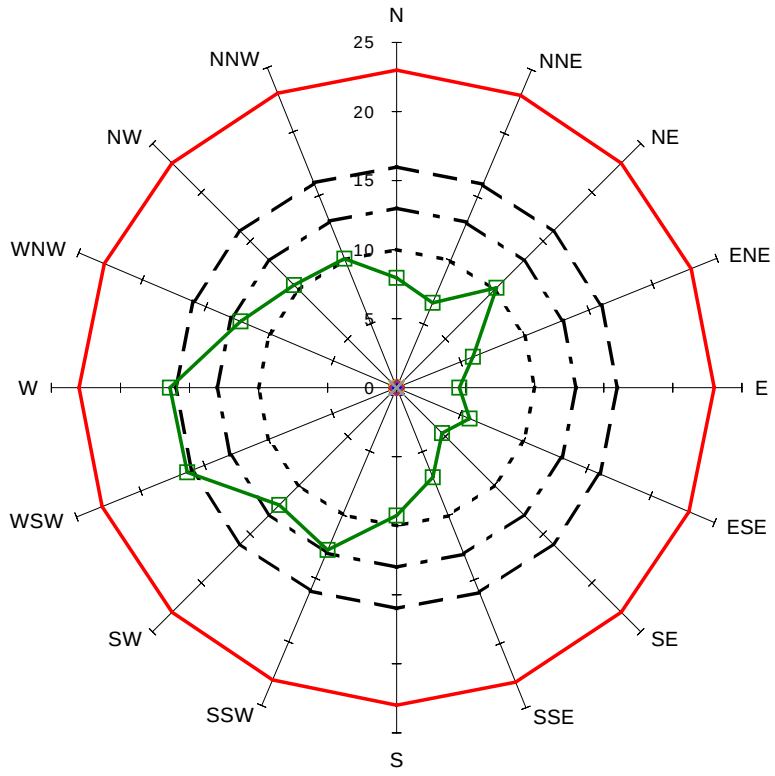
# Measured Wind Speeds at Point 46

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)




- Long Exposure Criterion (3.5m/s) for Weekly Maximum Mean (GEM) Wind Speeds
- Short Exposure Criterion (5.5m/s) for Weekly Maximum Mean (GEM) Wind Speeds
- Comfortable Walking Criterion (7.5m/s) for Weekly Maximum Mean (GEM) Wind Speeds
- Fast Walking Criterion (10m/s) for Weekly Maximum Mean (GEM) Wind Speeds
- As Proposed, without Vegetation
- Retest 2 (Not Required)
- Retest 3 (Not Required)
- Retest 4 (Not Required)

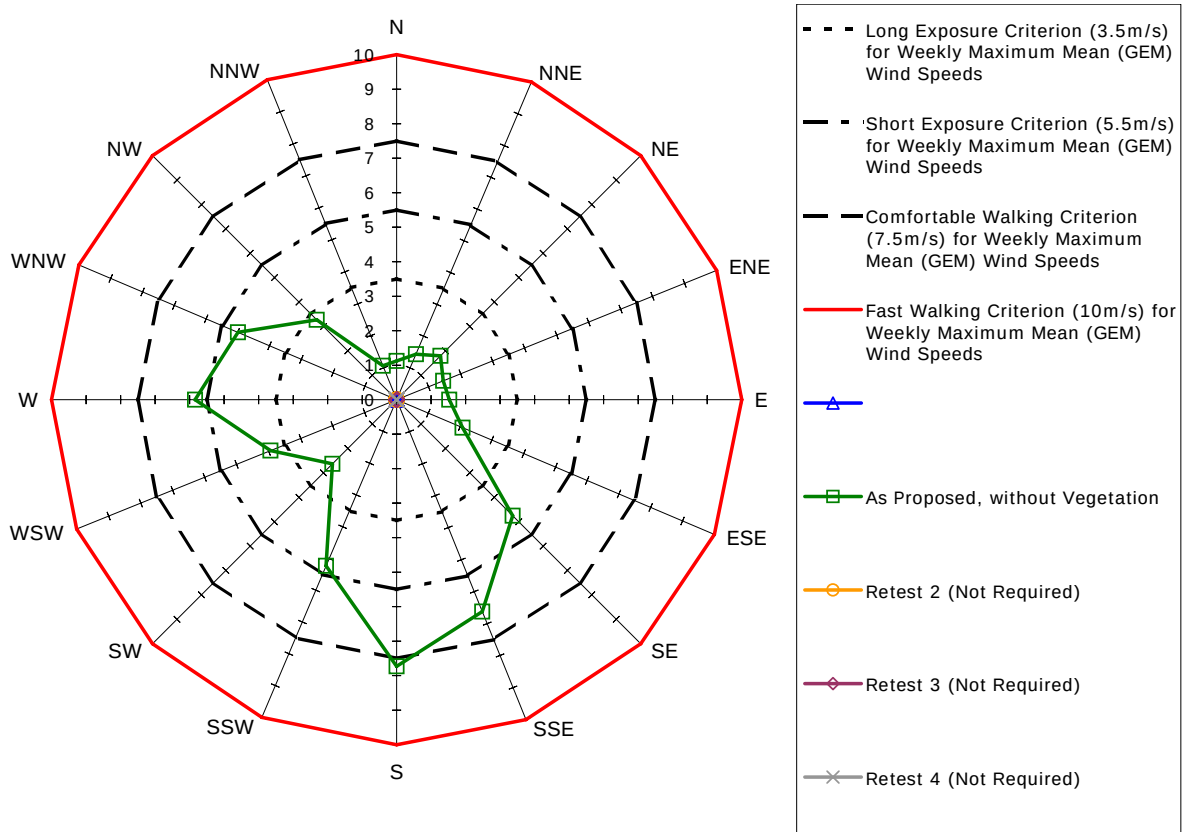
## Annual Maximum Gust Wind Speeds (m/s)



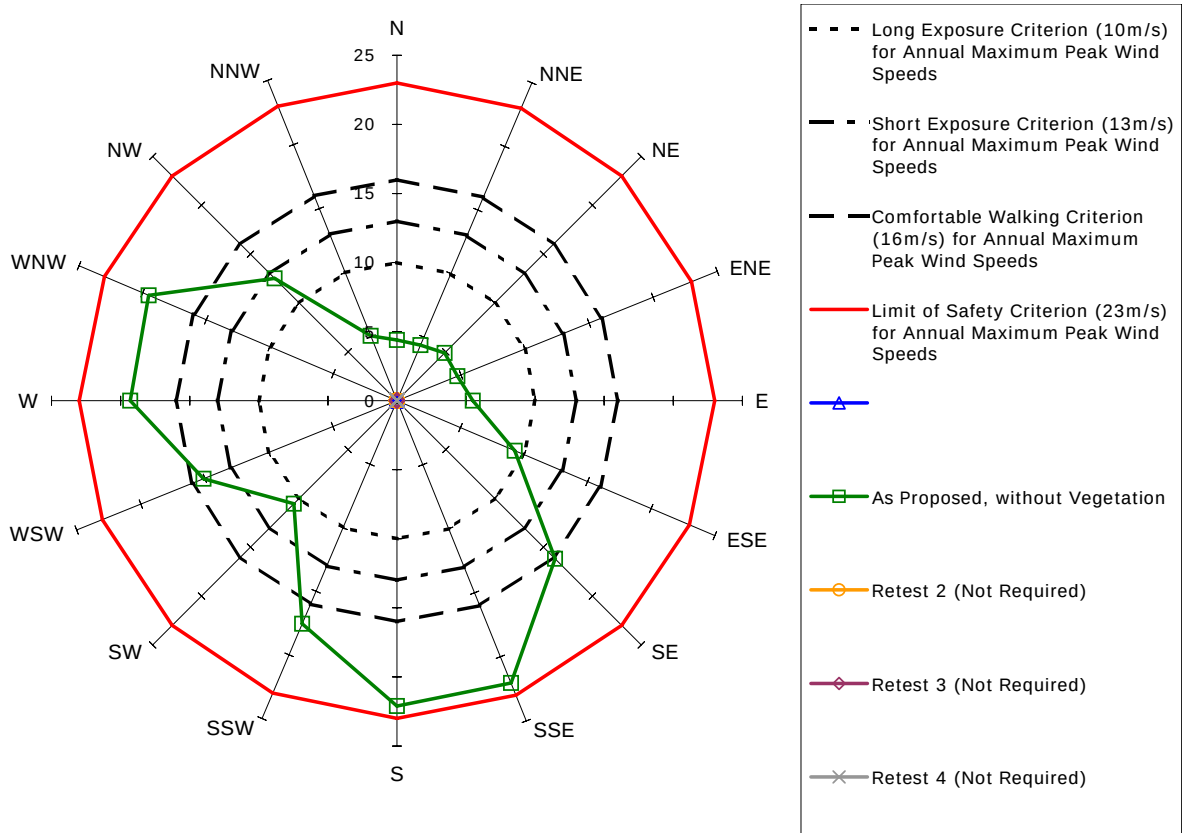

- Long Exposure Criterion (10m/s) for Annual Maximum Peak Wind Speeds
- Short Exposure Criterion (13m/s) for Annual Maximum Peak Wind Speeds
- Comfortable Walking Criterion (16m/s) for Annual Maximum Peak Wind Speeds
- Limit of Safety Criterion (23m/s) for Annual Maximum Peak Wind Speeds
- As Proposed, without Vegetation
- Retest 2 (Not Required)
- Retest 3 (Not Required)
- Retest 4 (Not Required)

# Measured Wind Speeds at Point 47

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

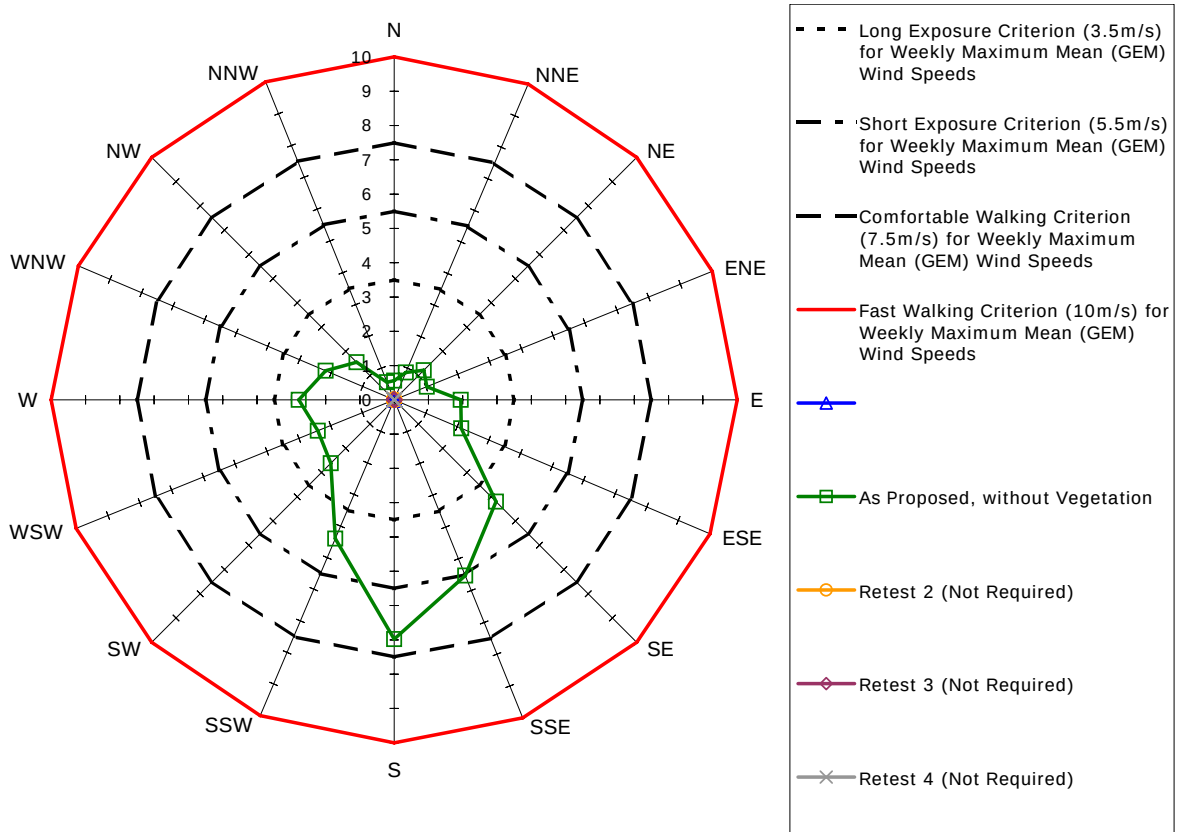



## Annual Maximum Gust Wind Speeds (m/s)

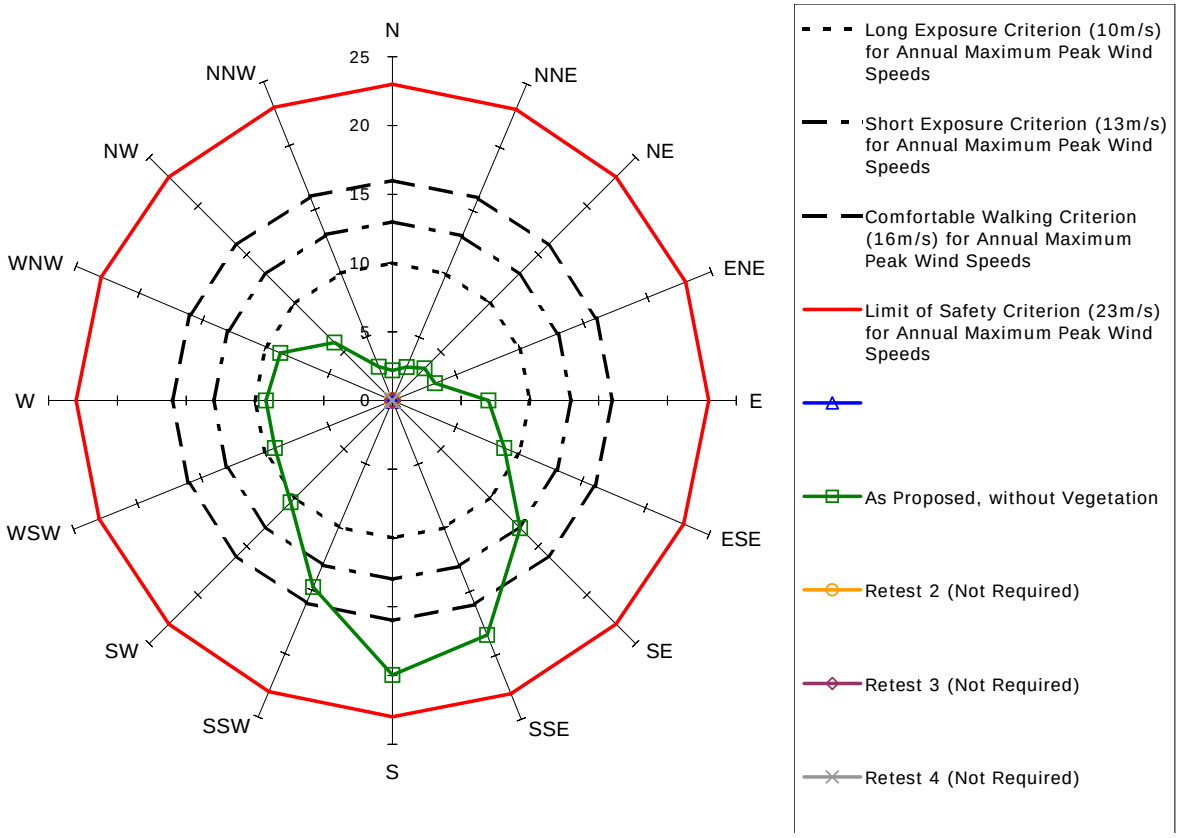


# Measured Wind Speeds at Point 48

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

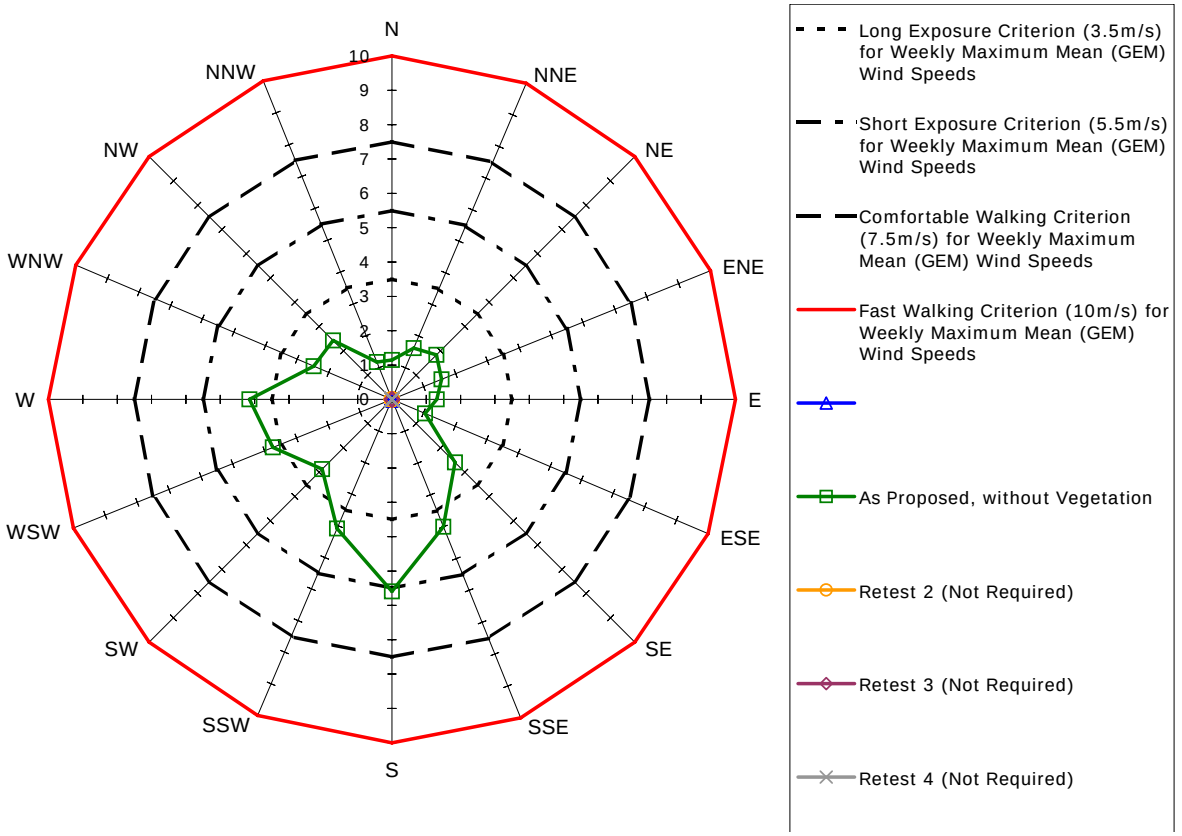



## Annual Maximum Gust Wind Speeds (m/s)

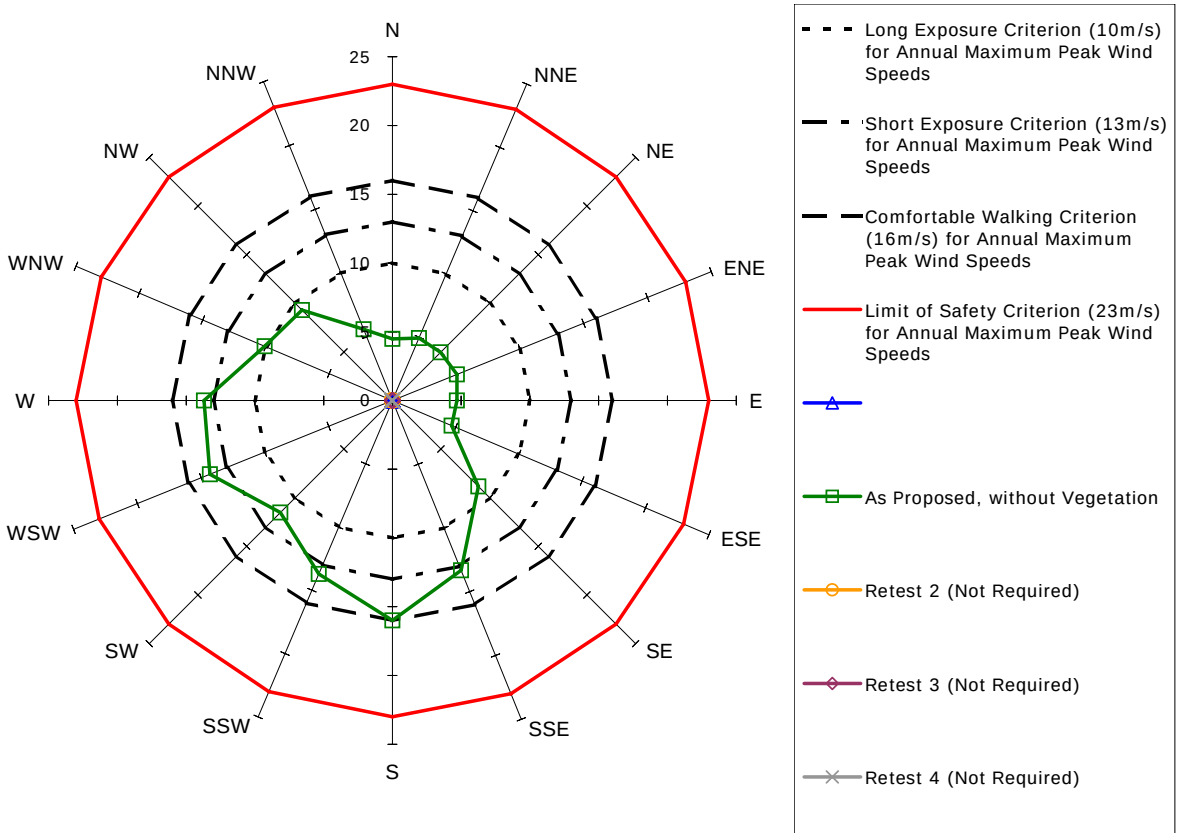


# Measured Wind Speeds at Point 49

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

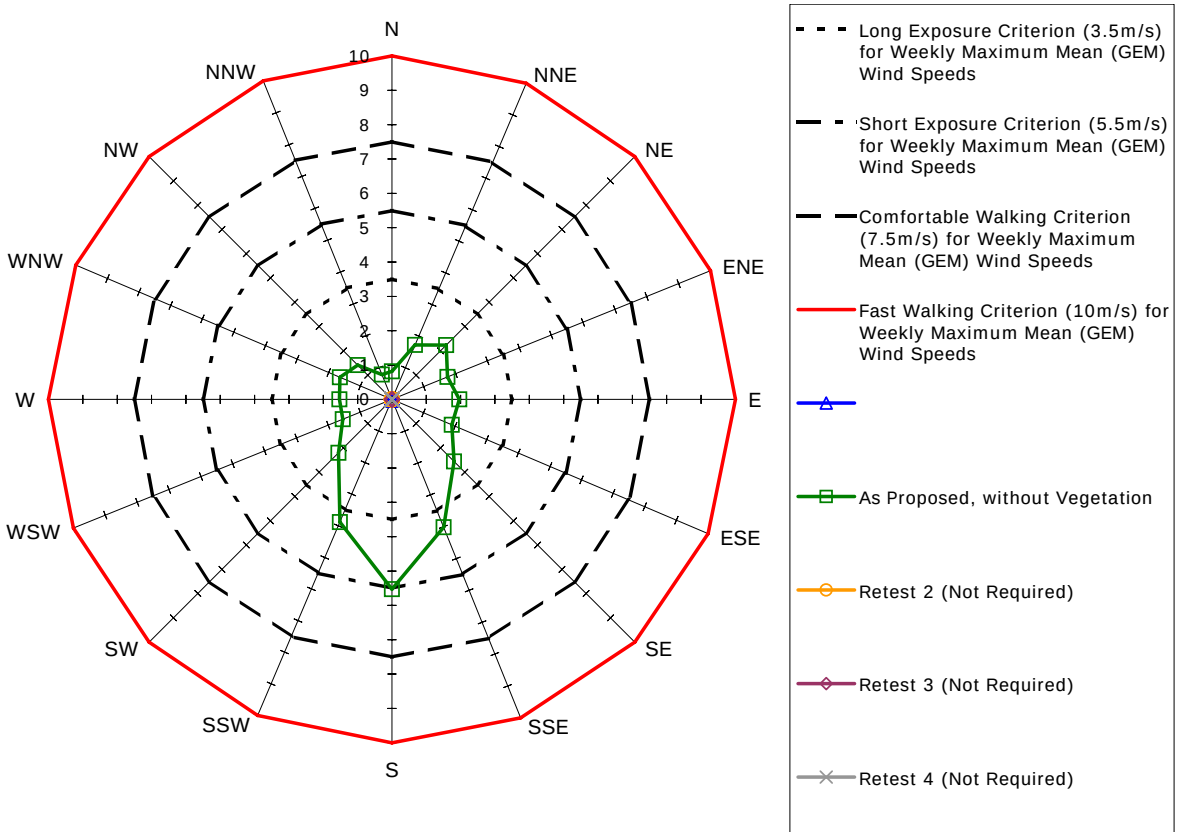



## Annual Maximum Gust Wind Speeds (m/s)

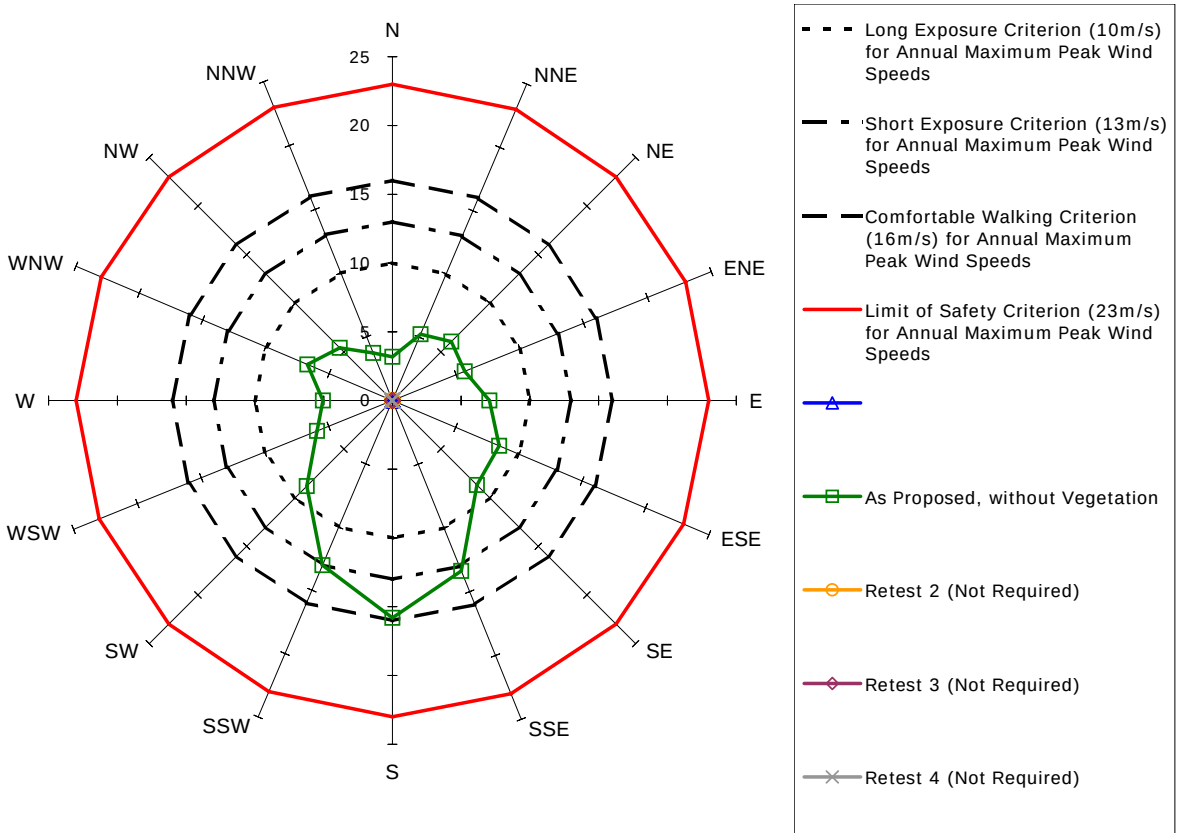


# Measured Wind Speeds at Point 50

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

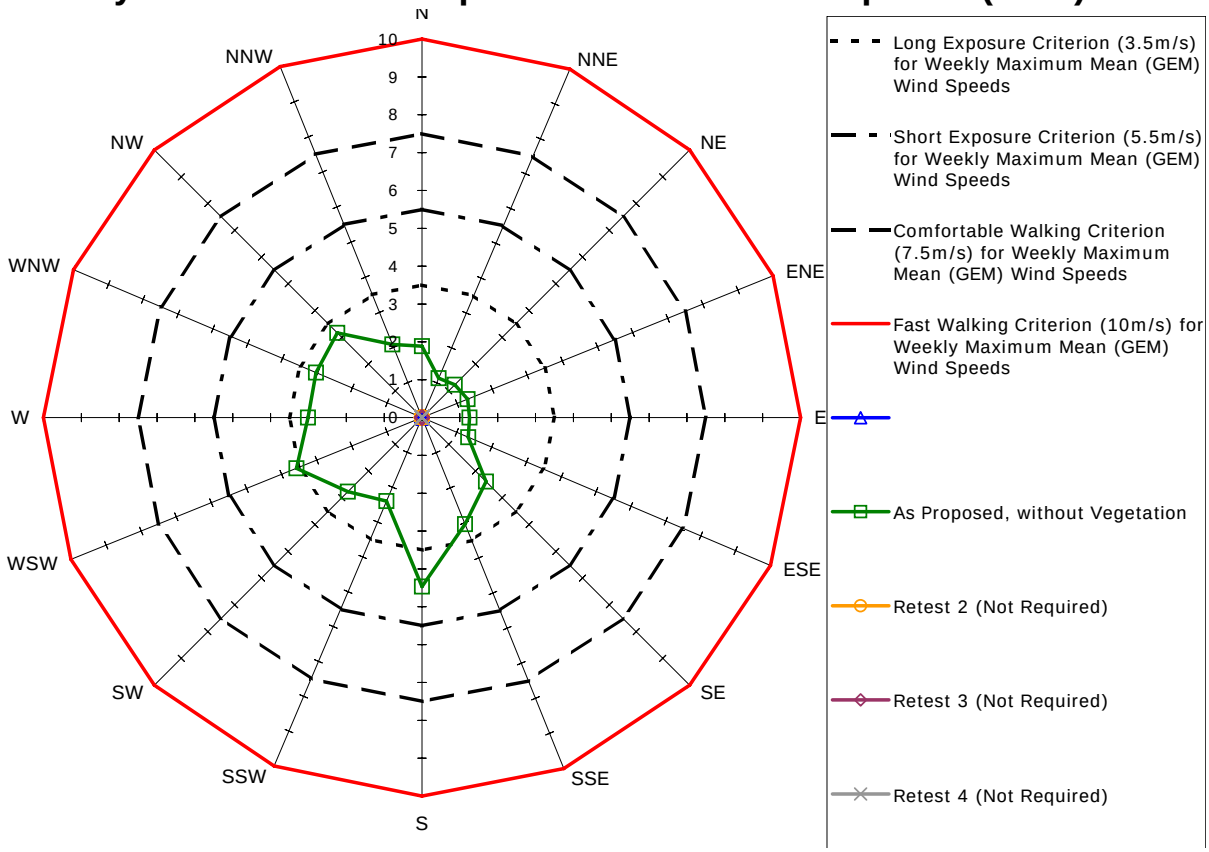



## Annual Maximum Gust Wind Speeds (m/s)

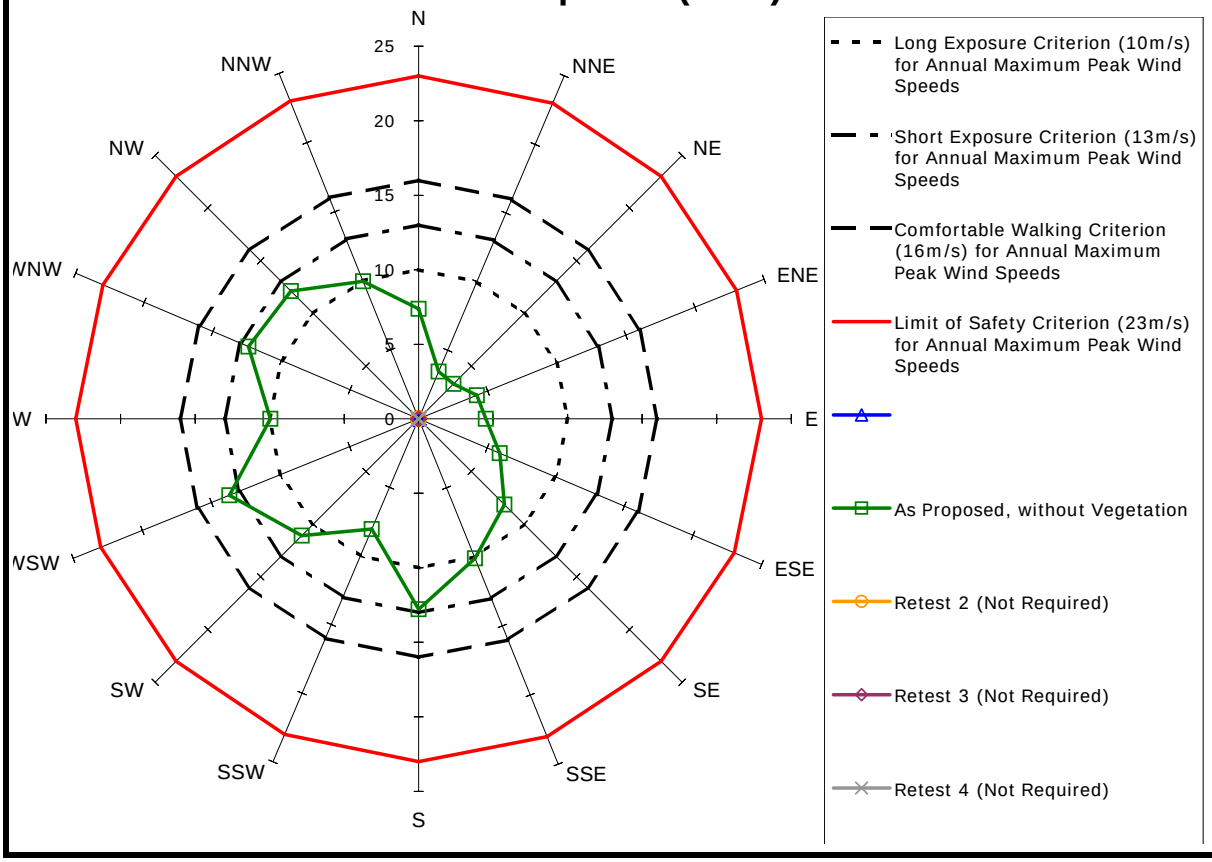


# Measured Wind Speeds at Point 51

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

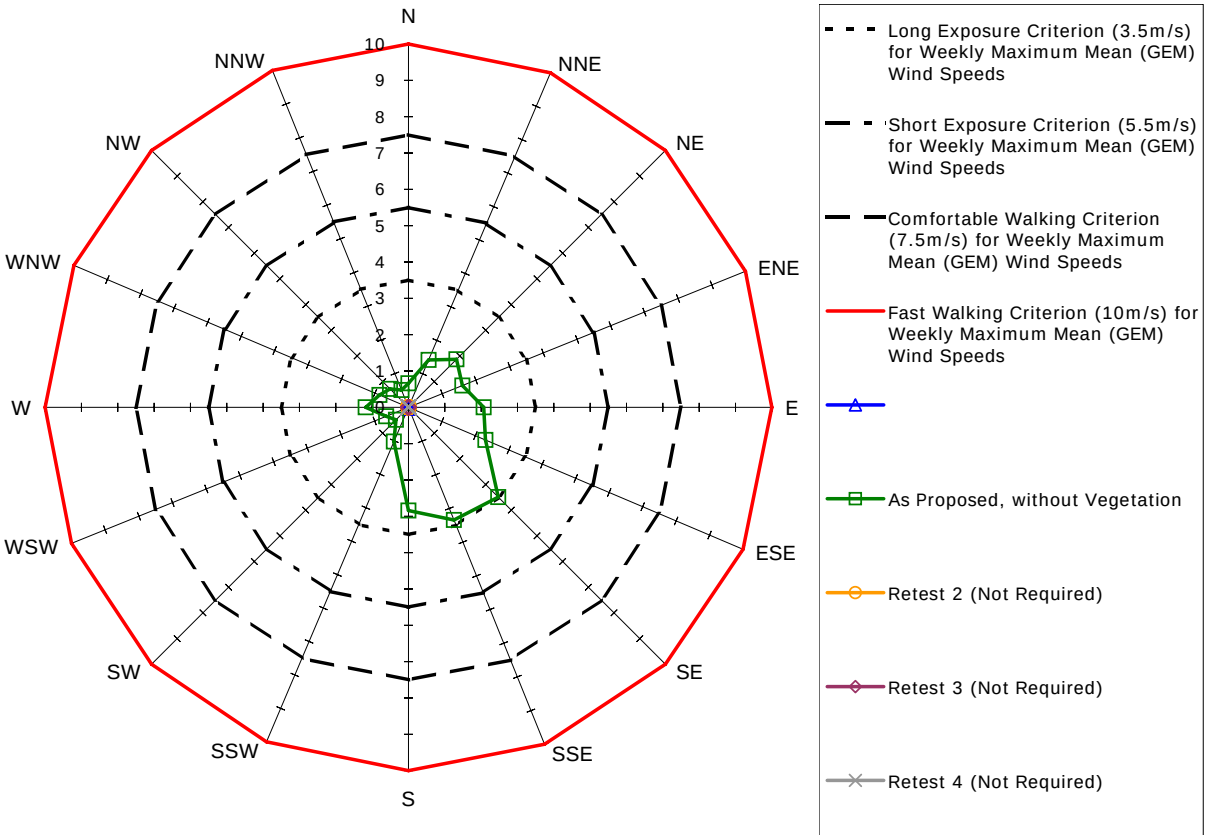



## Annual Maximum Gust Wind Speeds (m/s)

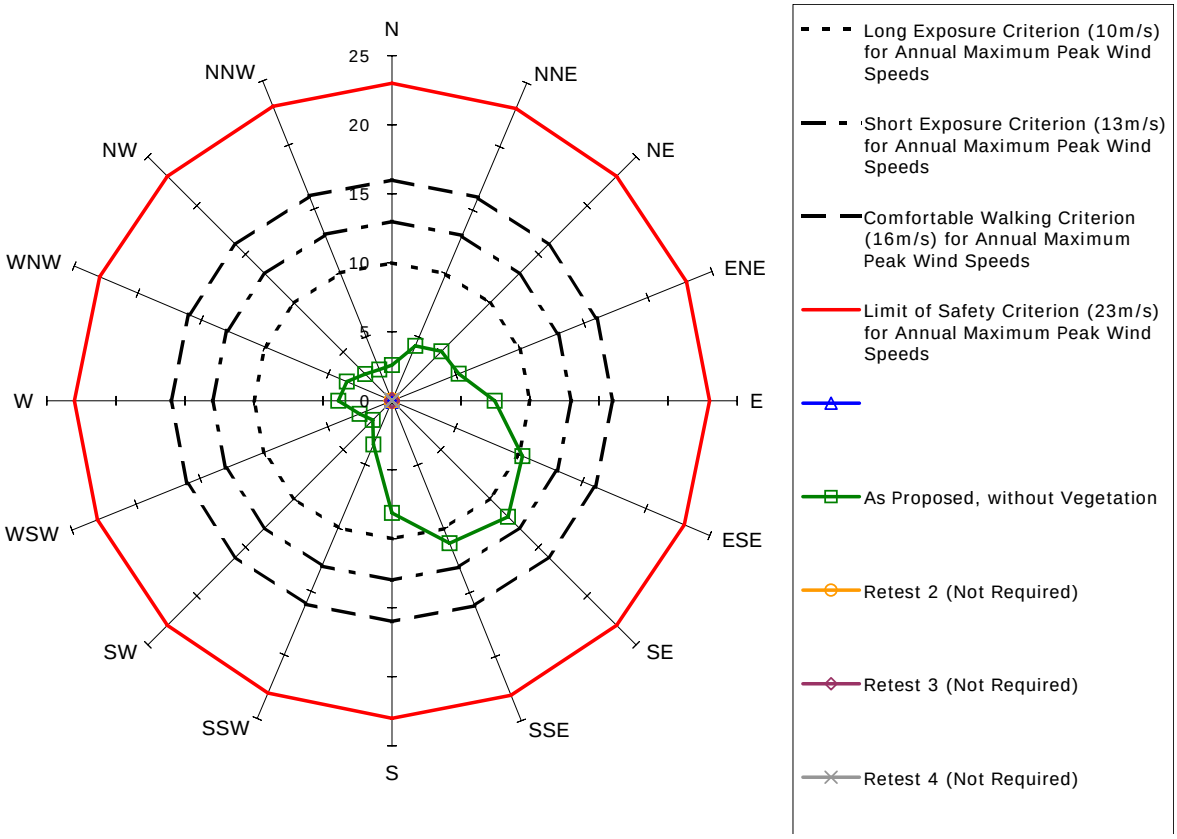


# Measured Wind Speeds at Point 52

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

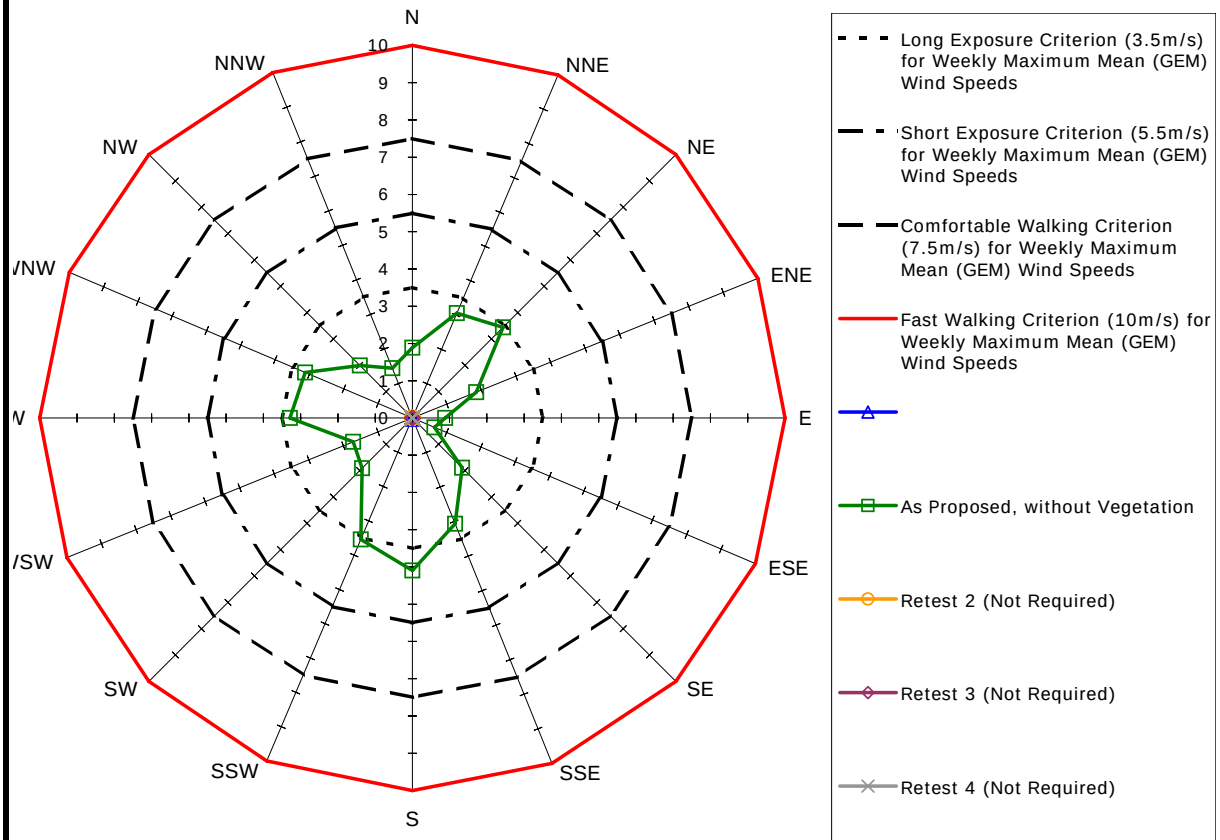



## Annual Maximum Gust Wind Speeds (m/s)

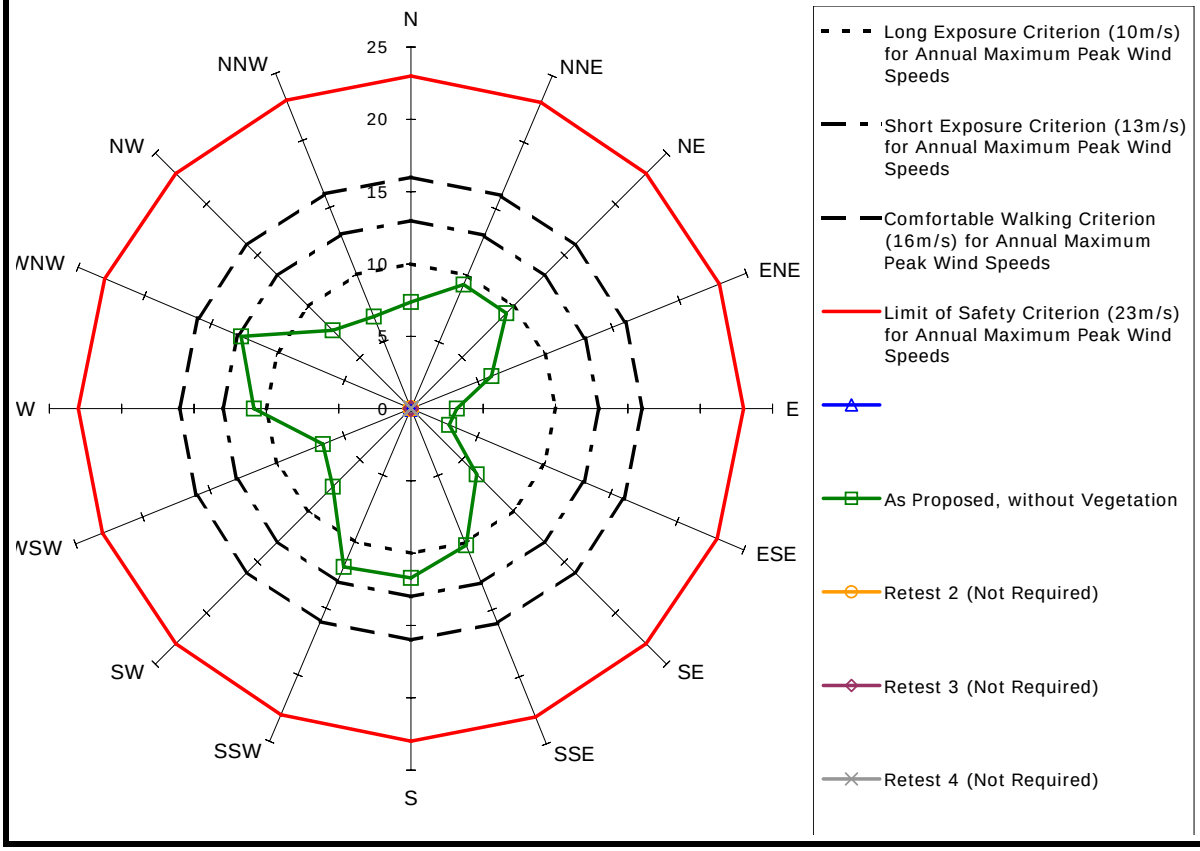


# Measured Wind Speeds at Point 53

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

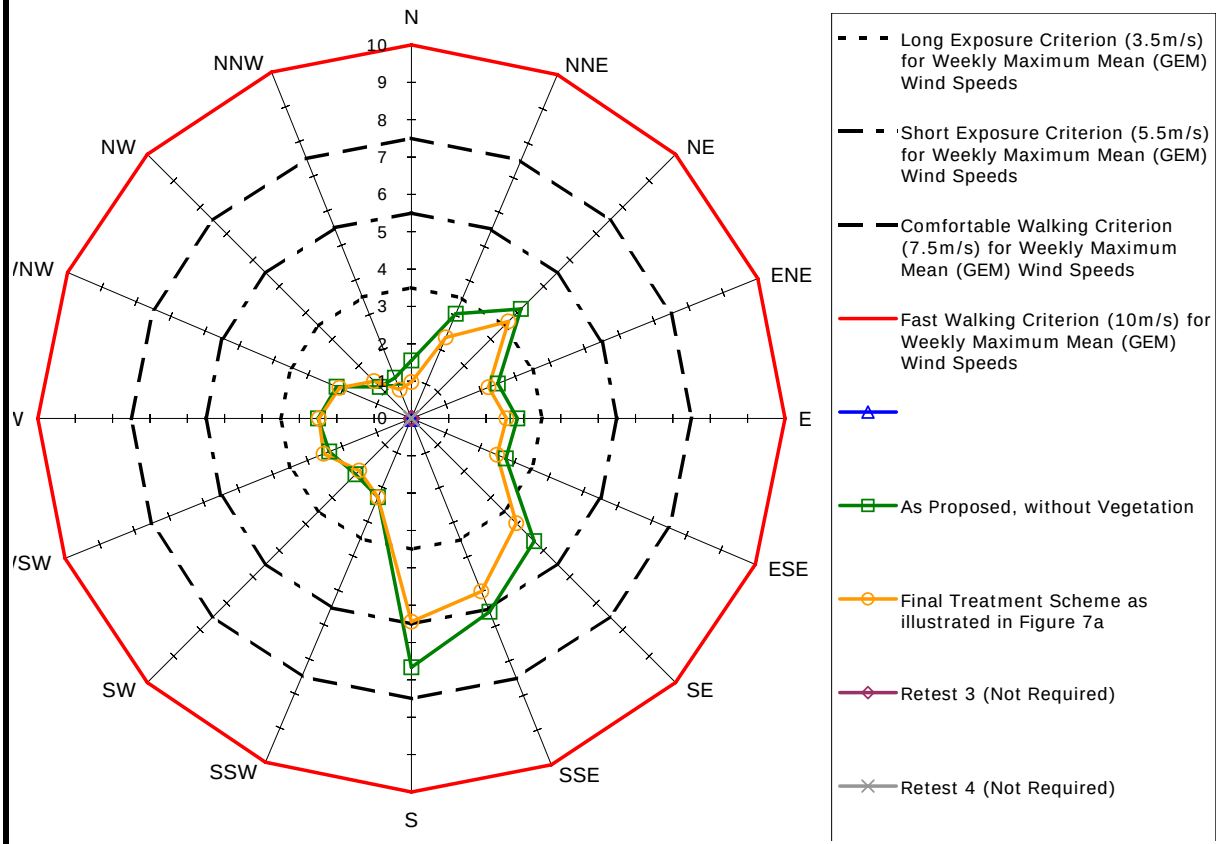



## Annual Maximum Gust Wind Speeds (m/s)

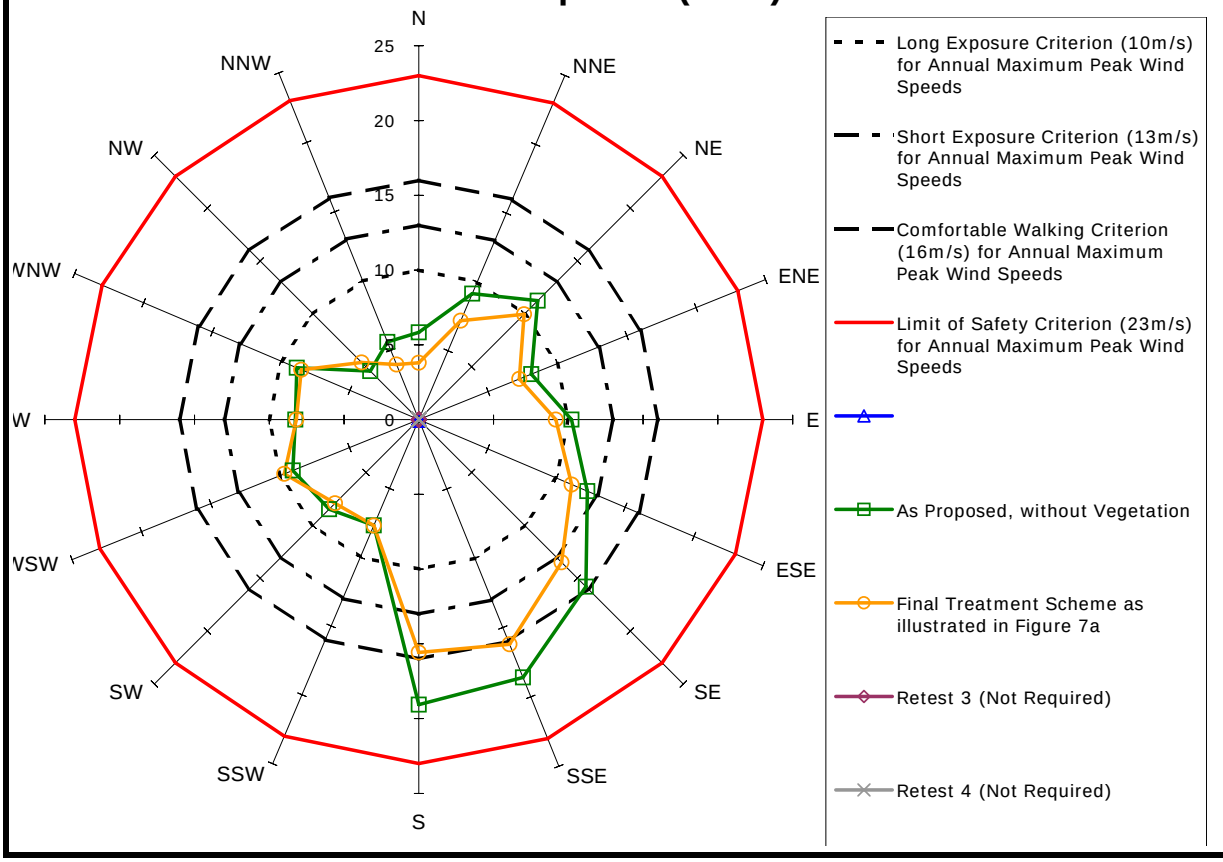


# Measured Wind Speeds at Point 54

## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

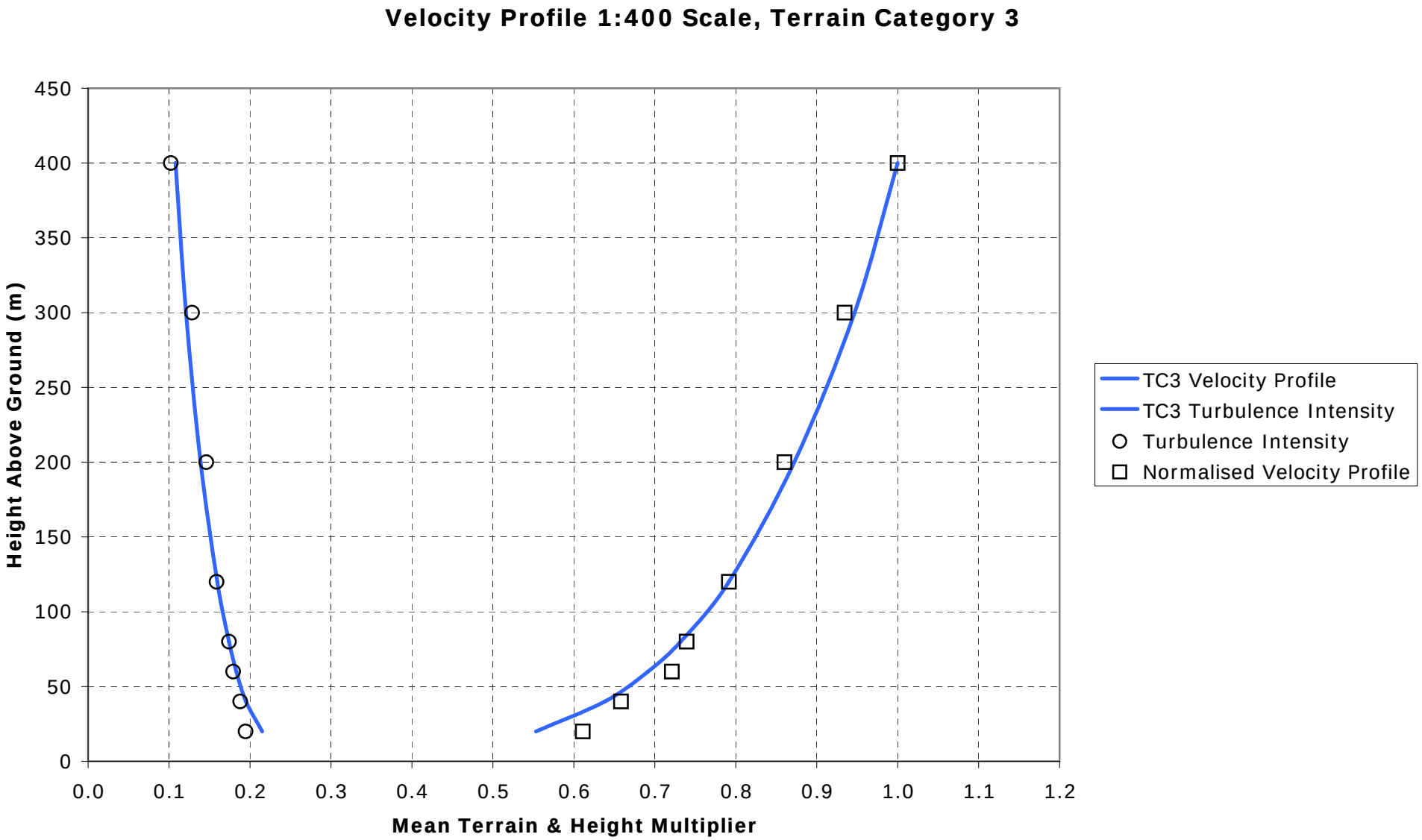


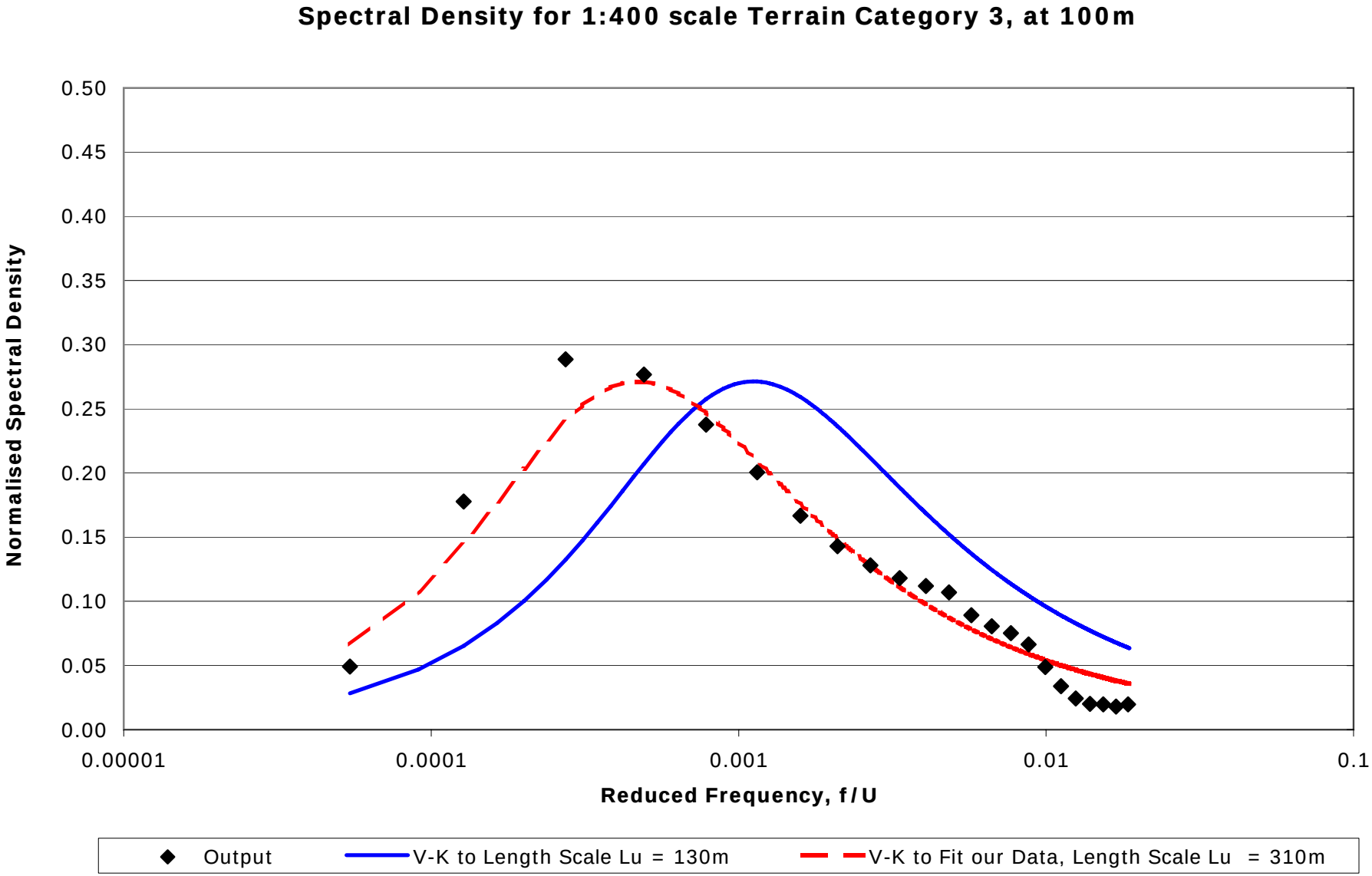

## Annual Maximum Gust Wind Speeds (m/s)

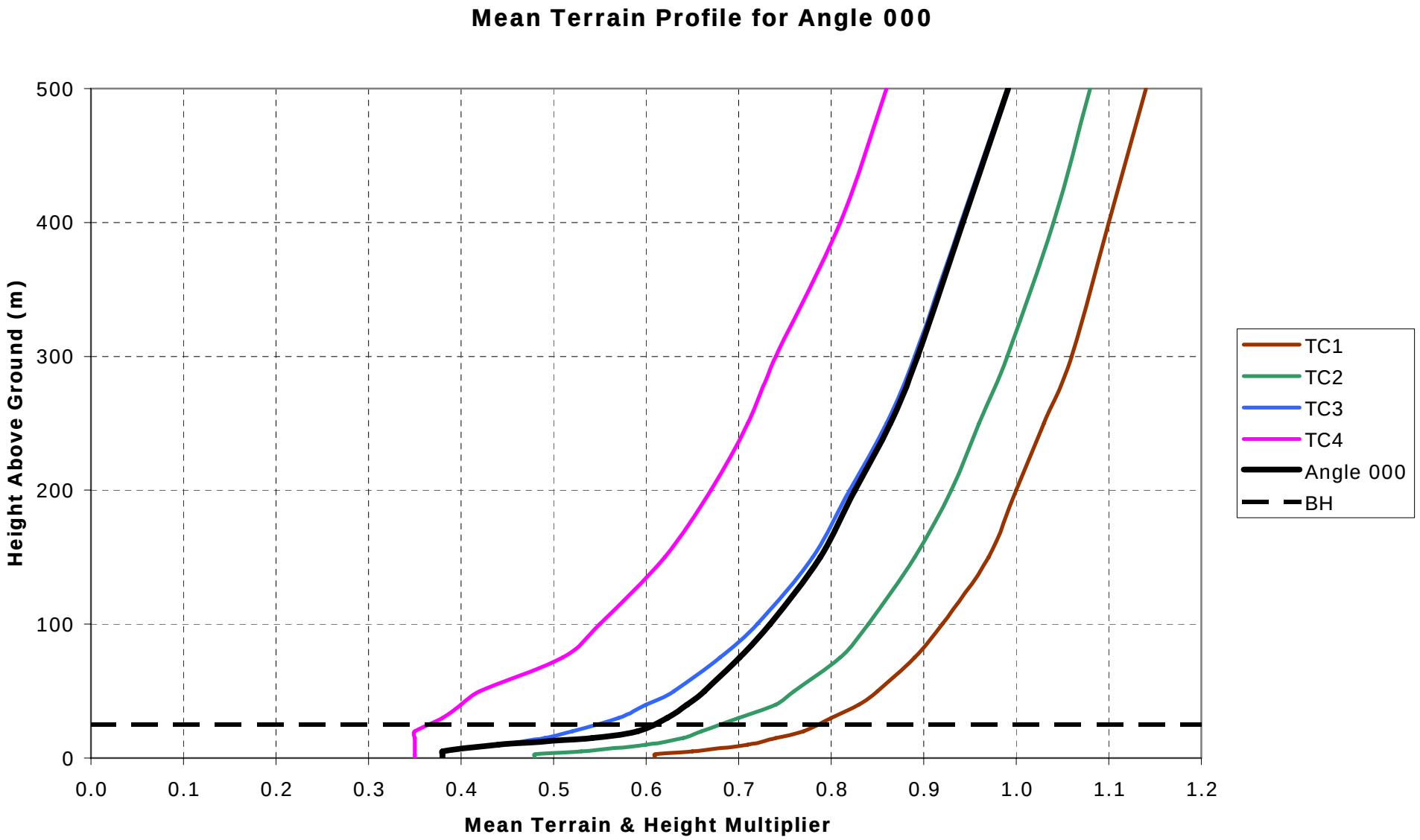


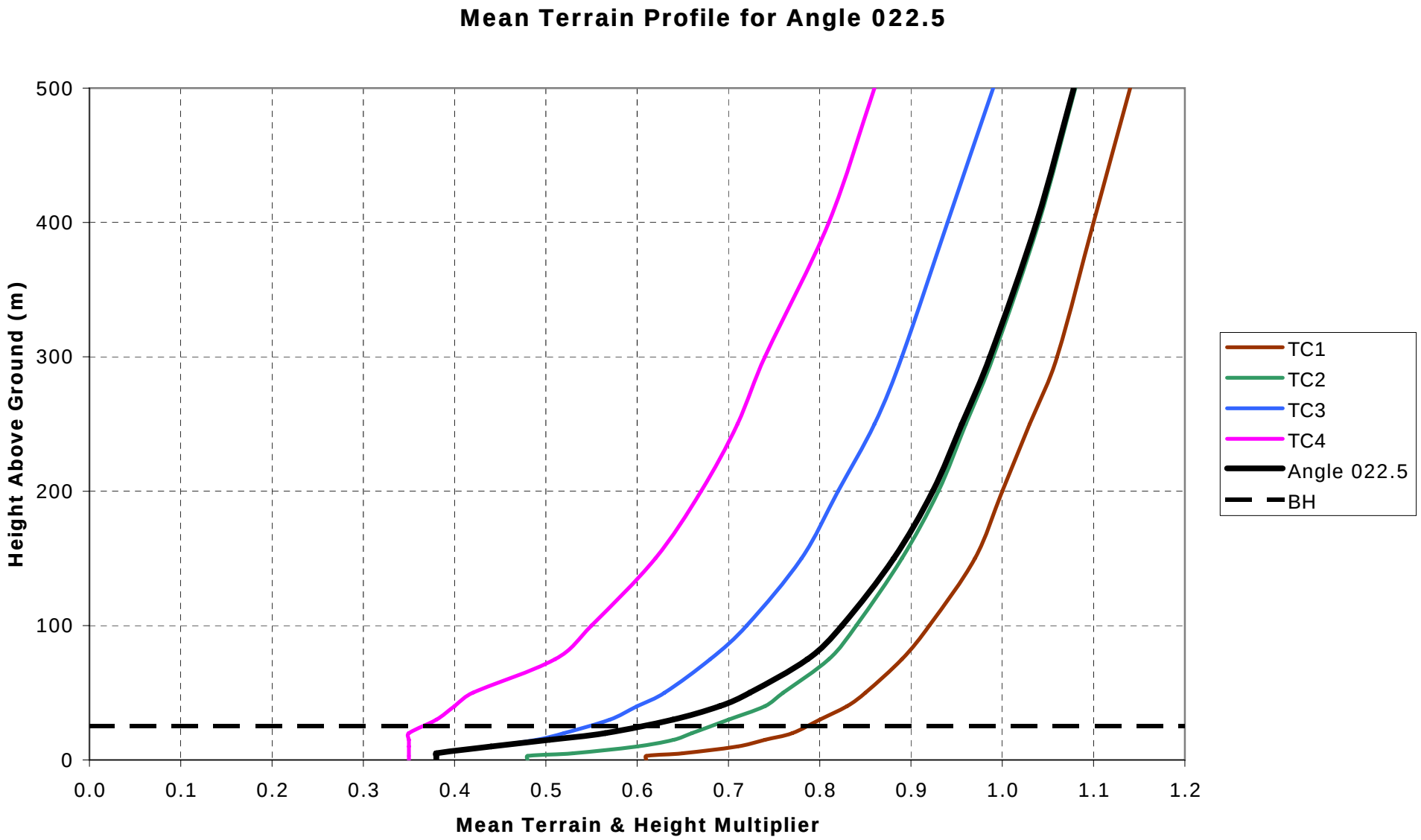
# Appendix B

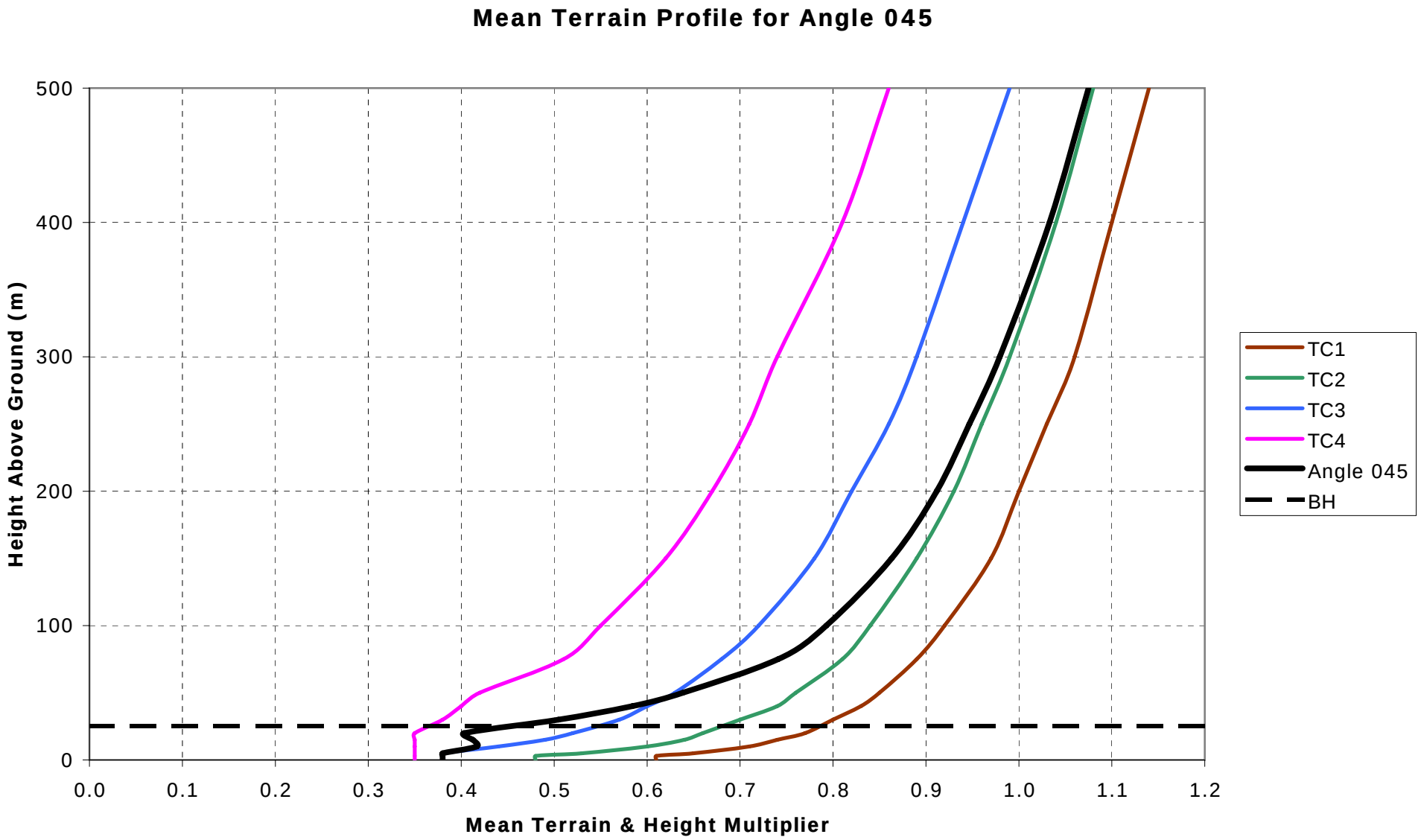
Wind Tunnel Boundary Layer Profile

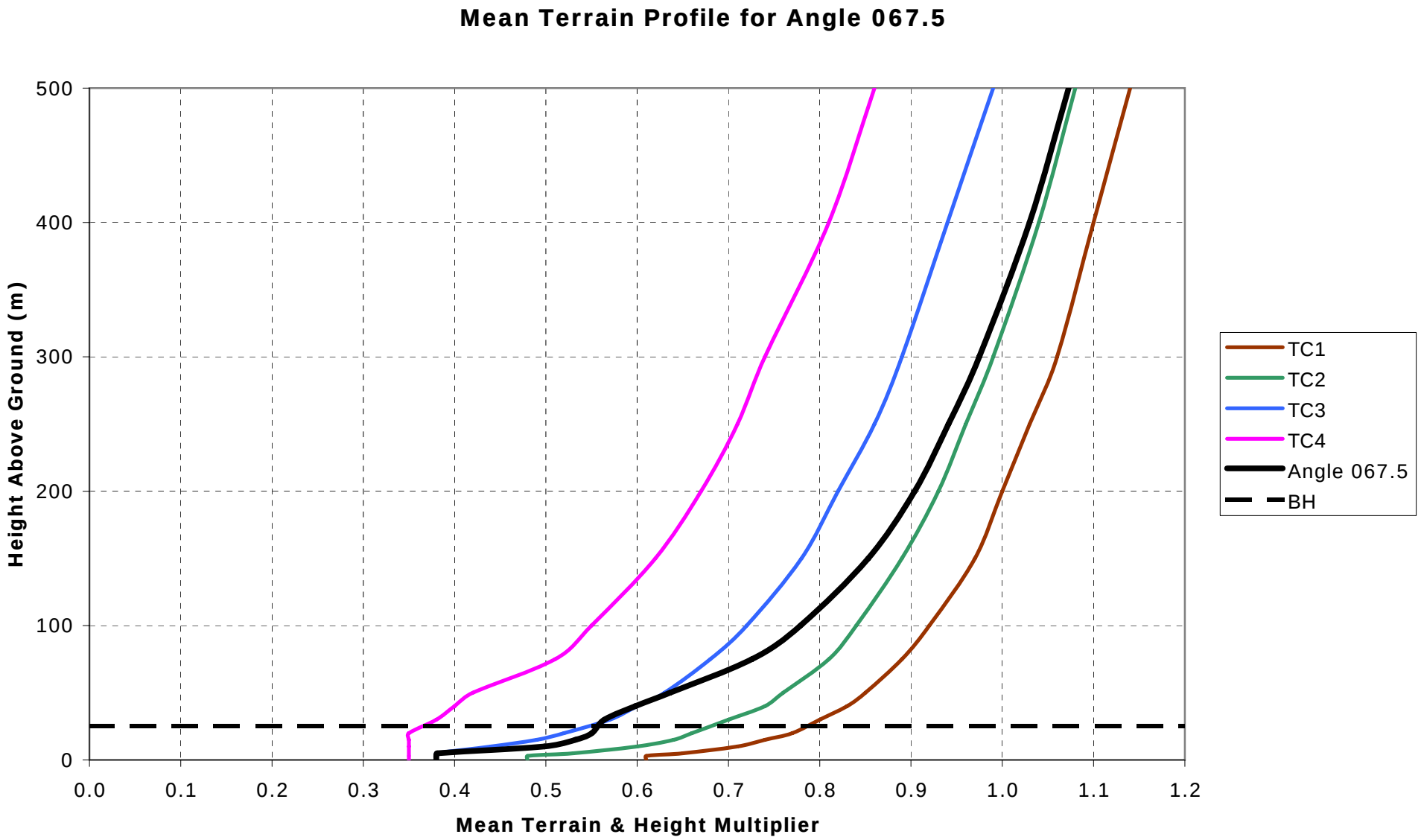

Velocity Profile 1:400 Scale, Terrain Category 3
Height Above Ground (m)
450
400
350
300
250
200
150
100
50
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC3 Velocity Profile
TC3 Turbulence Intensity
Turbulence Intensity
Normalised Velocity Profile

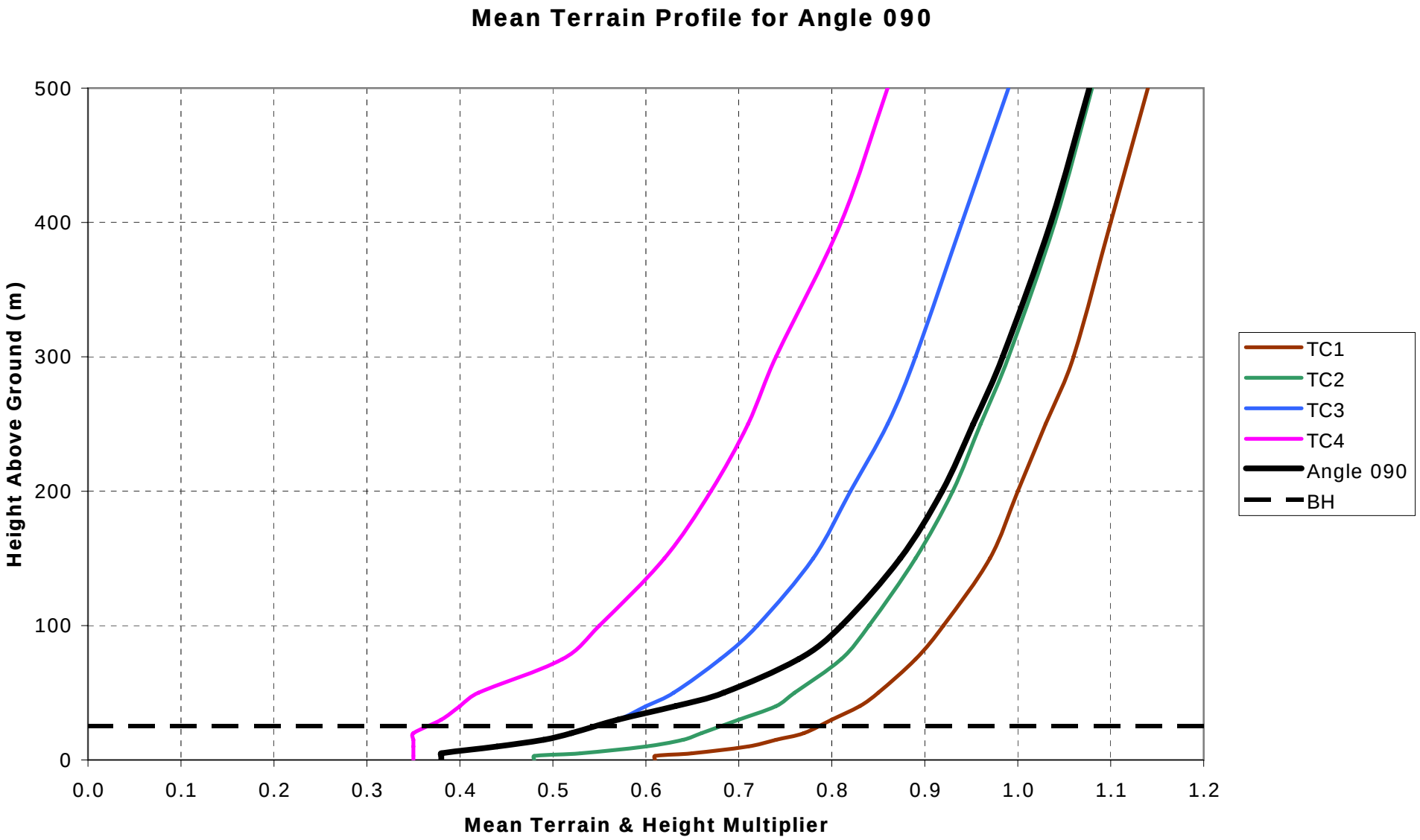

Spectral Density for 1:400 scale Terrain Category 3, at 100m
Normalised Spectral Density
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00001
0.0001
0.001
0.01
0.1
Reduced Frequency, f/U
Output
V-K to Length Scale Lu = 130m
V-K to Fit our Data, Length Scale Lu = 310m

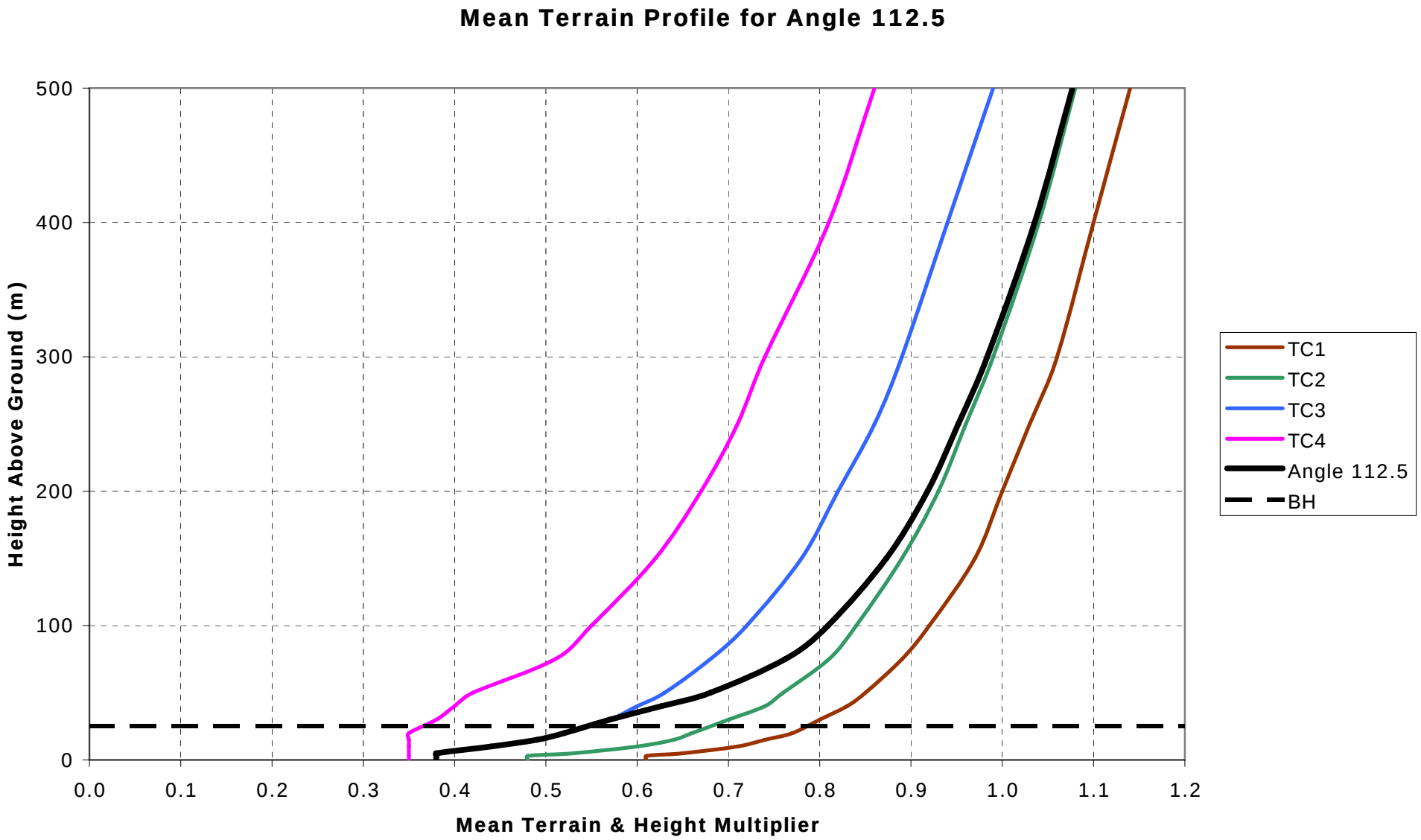

Mean Terrain Profile for Angle 000
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 000
BH

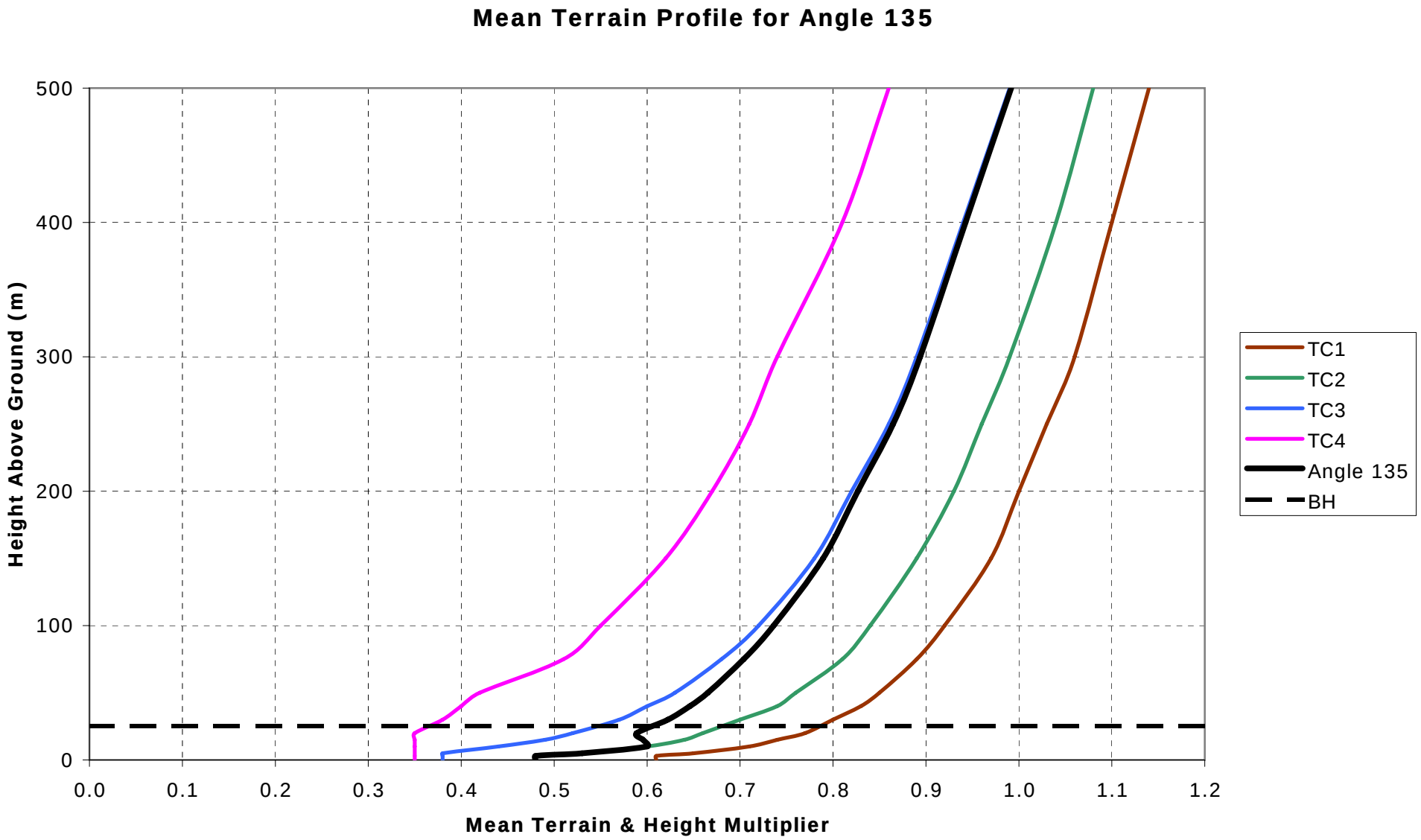

Mean Terrain Profile for Angle 022.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 022.5
BH

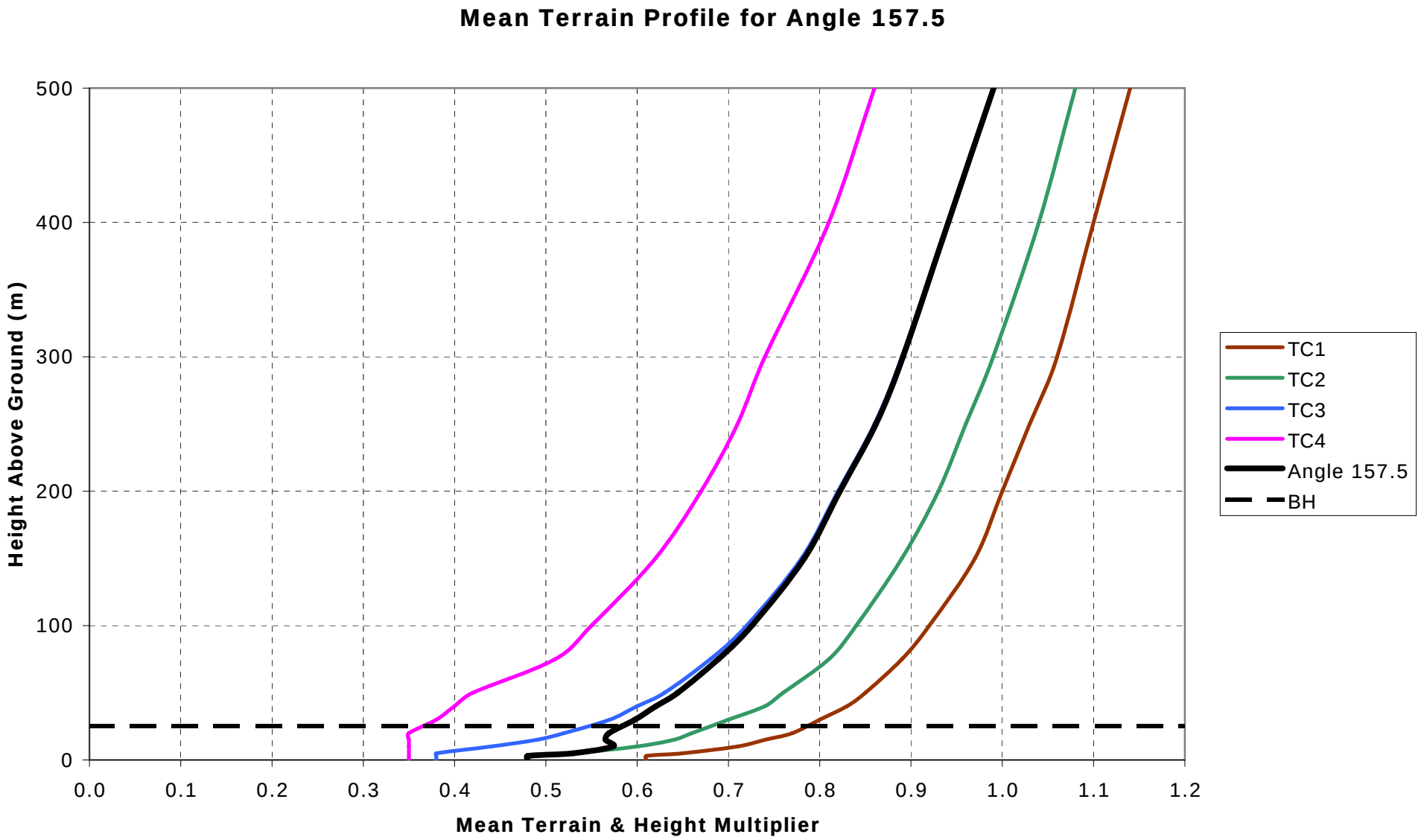

Mean Terrain Profile for Angle 045
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 045
BH

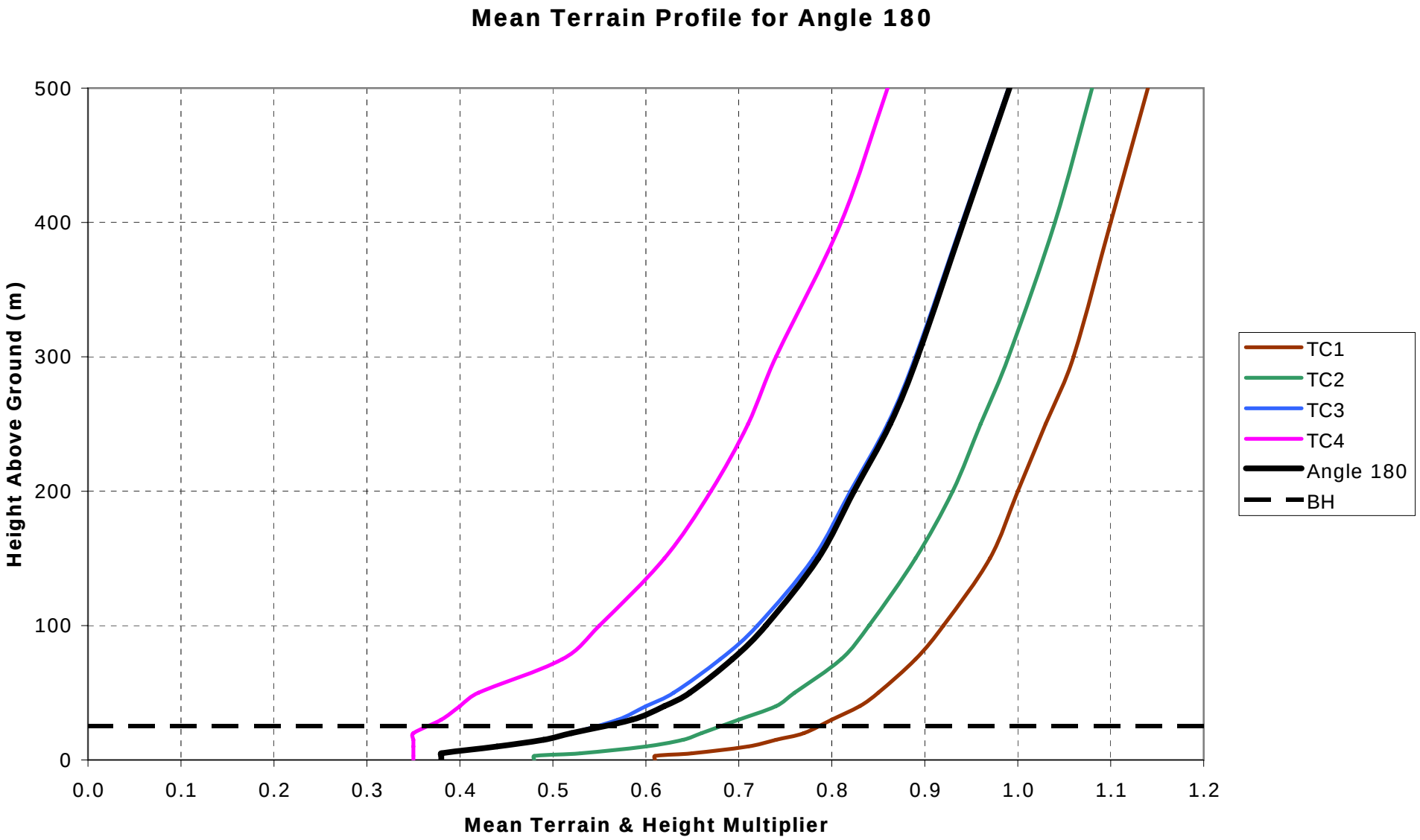

Mean Terrain Profile for Angle 067.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 067.5
BH

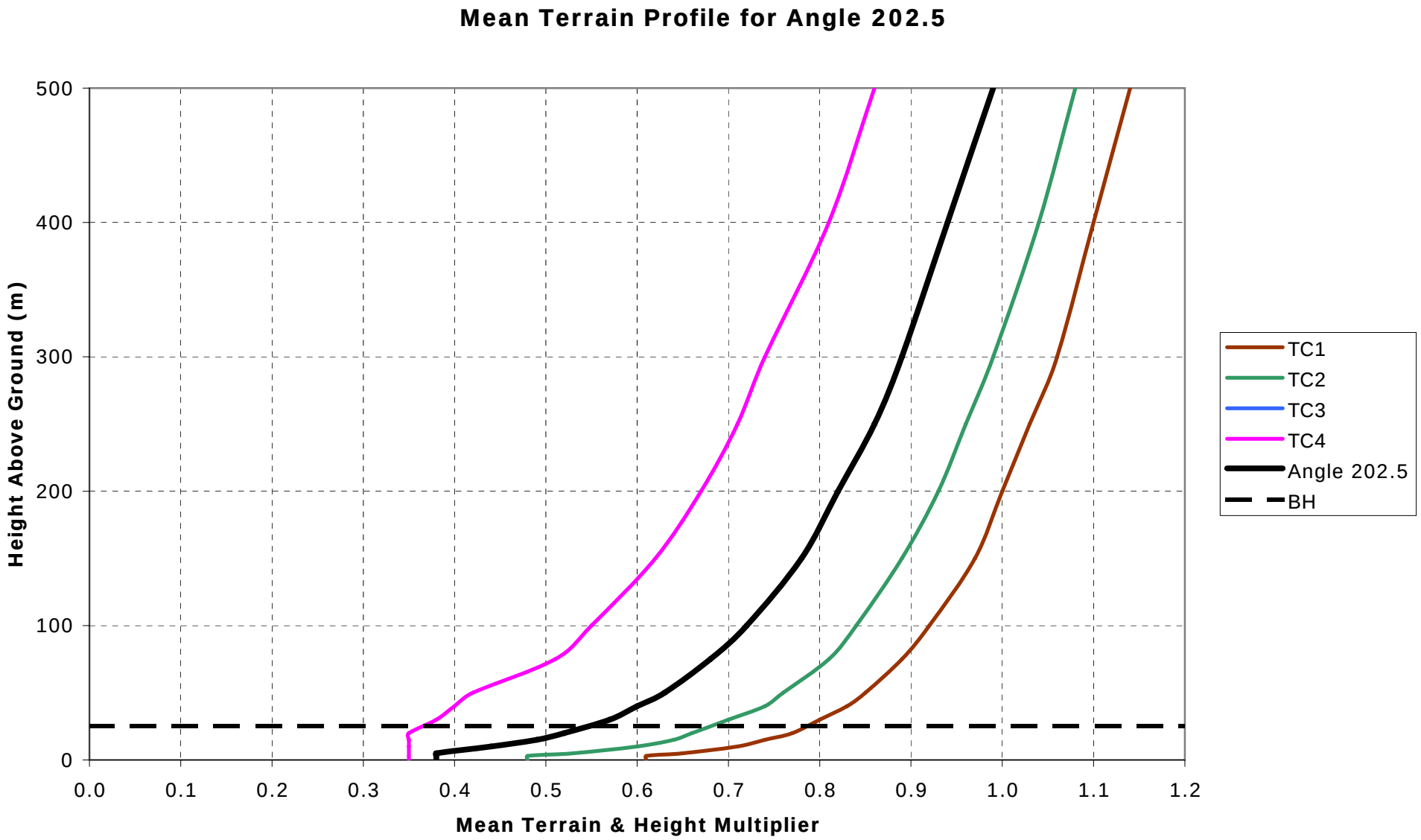

Mean Terrain Profile for Angle 090
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 090
BH

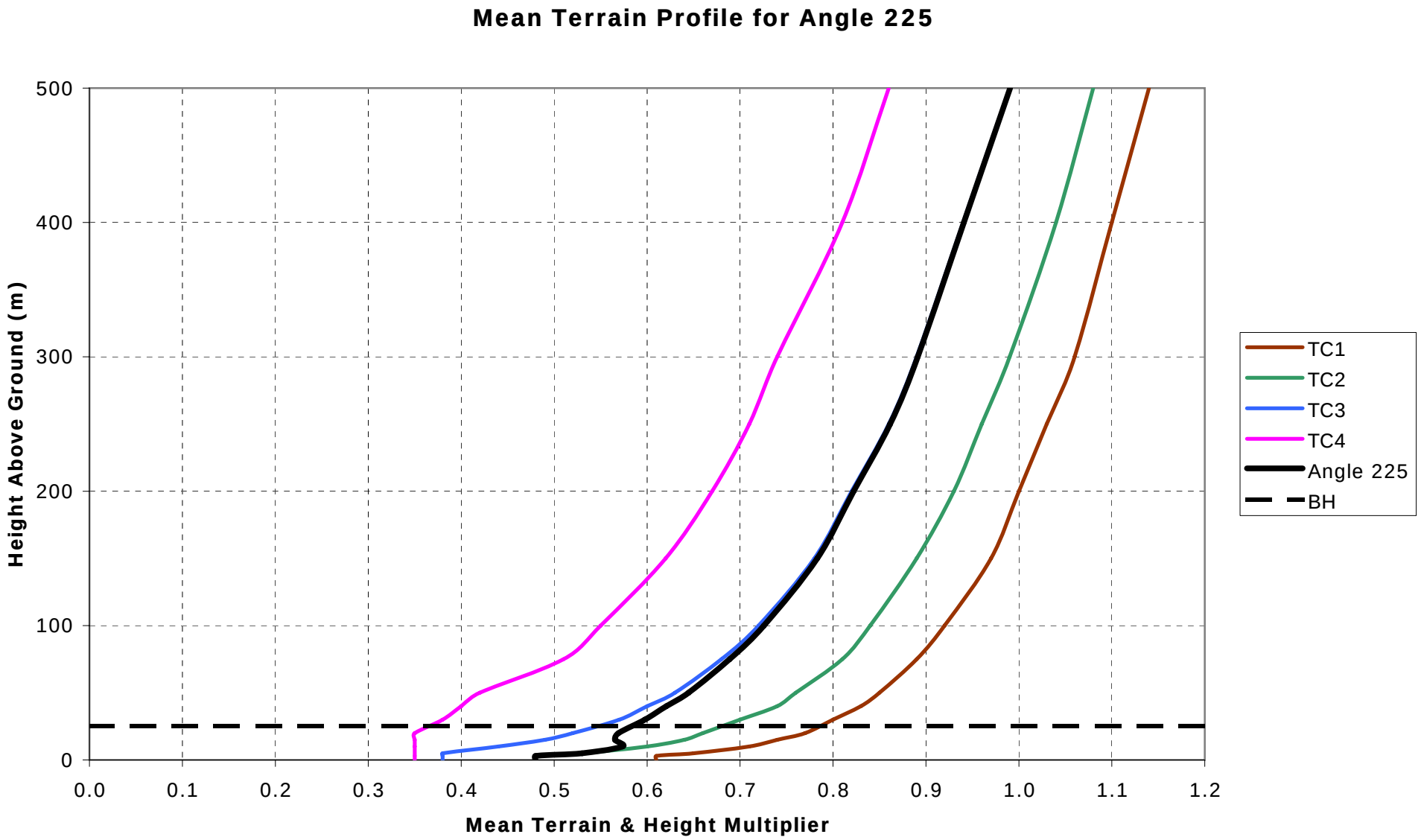

Mean Terrain Profile for Angle 112.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 112.5
BH

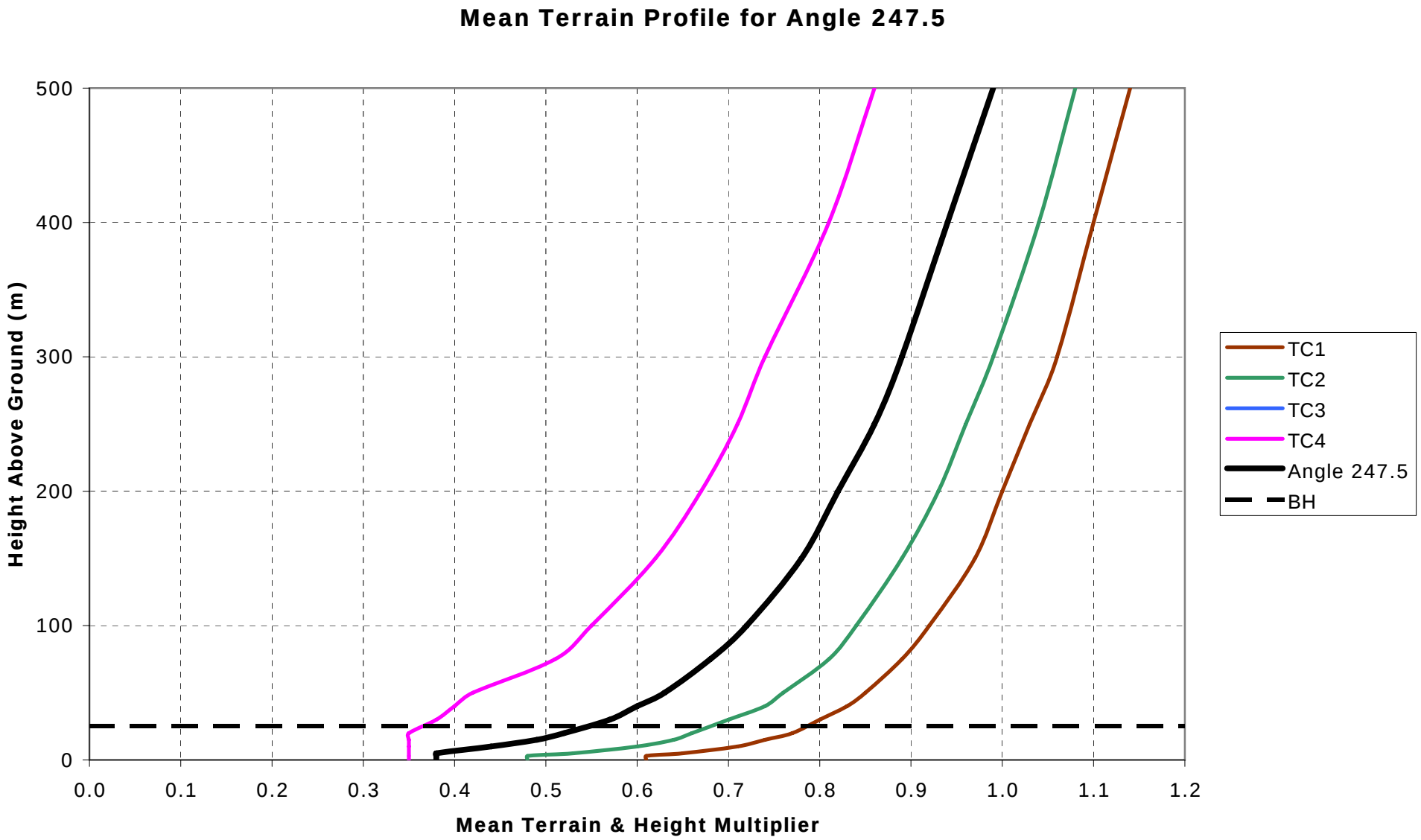

Mean Terrain Profile for Angle 135
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 135
BH

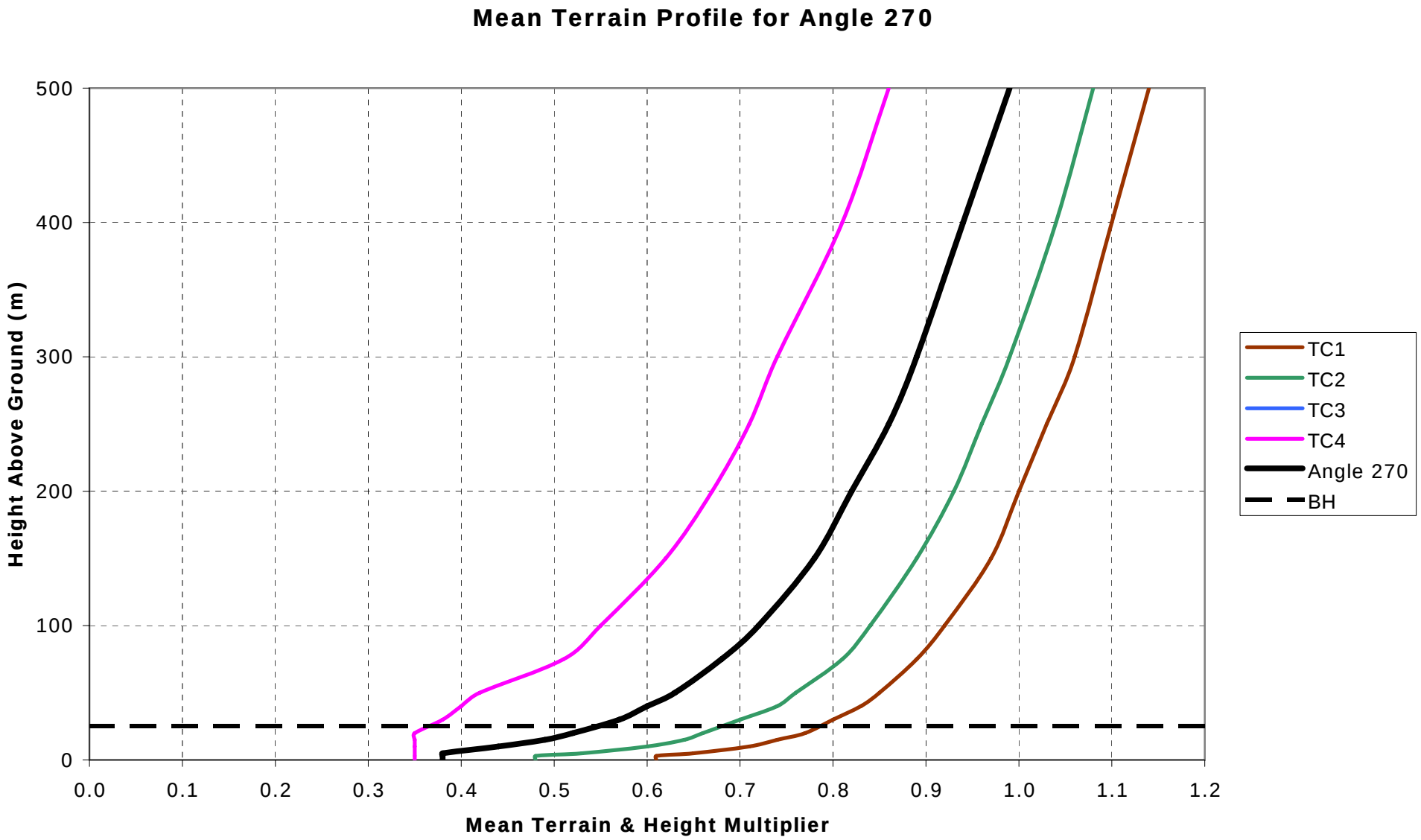

Mean Terrain Profile for Angle 157.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 157.5
BH

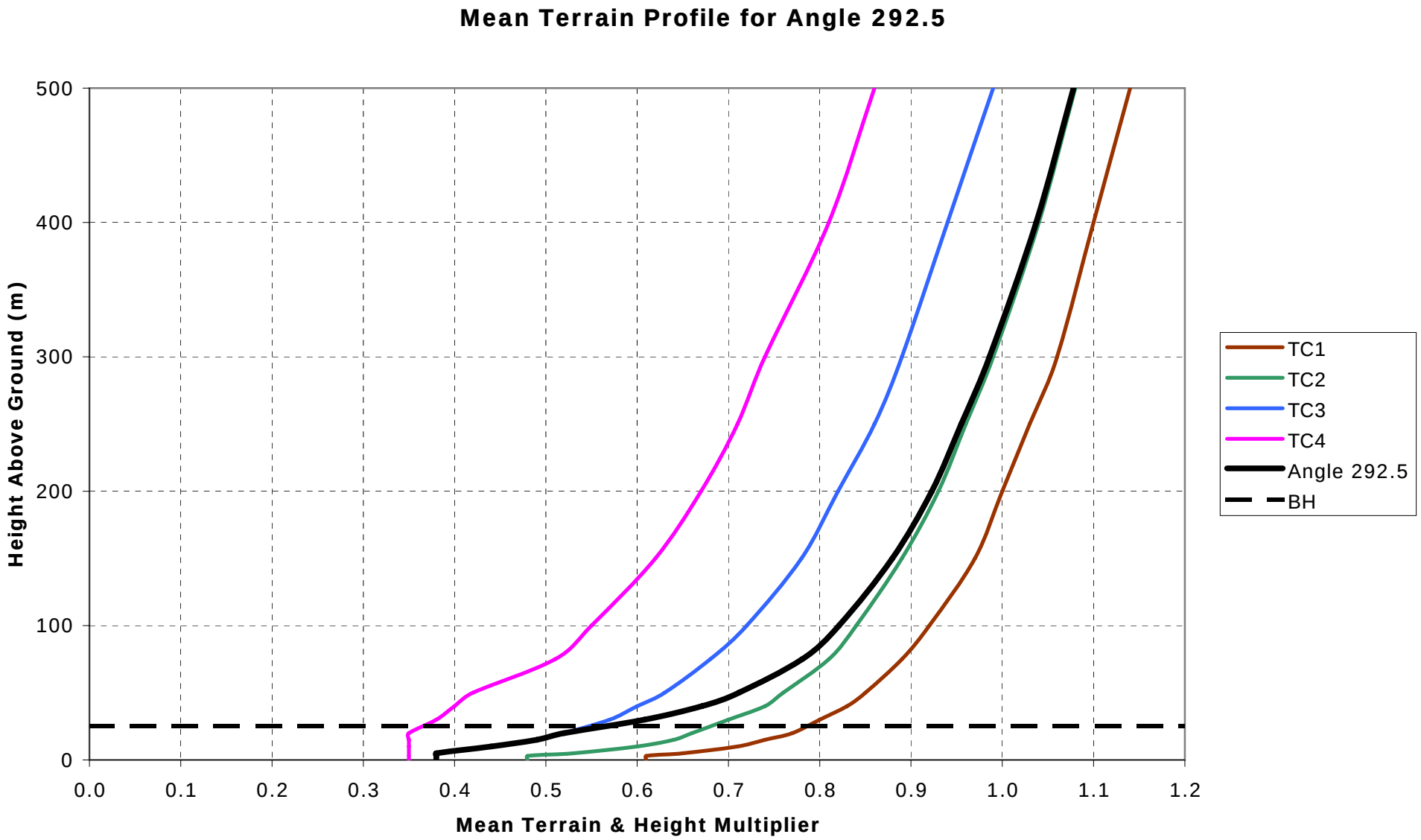

Mean Terrain Profile for Angle 180
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 180
BH

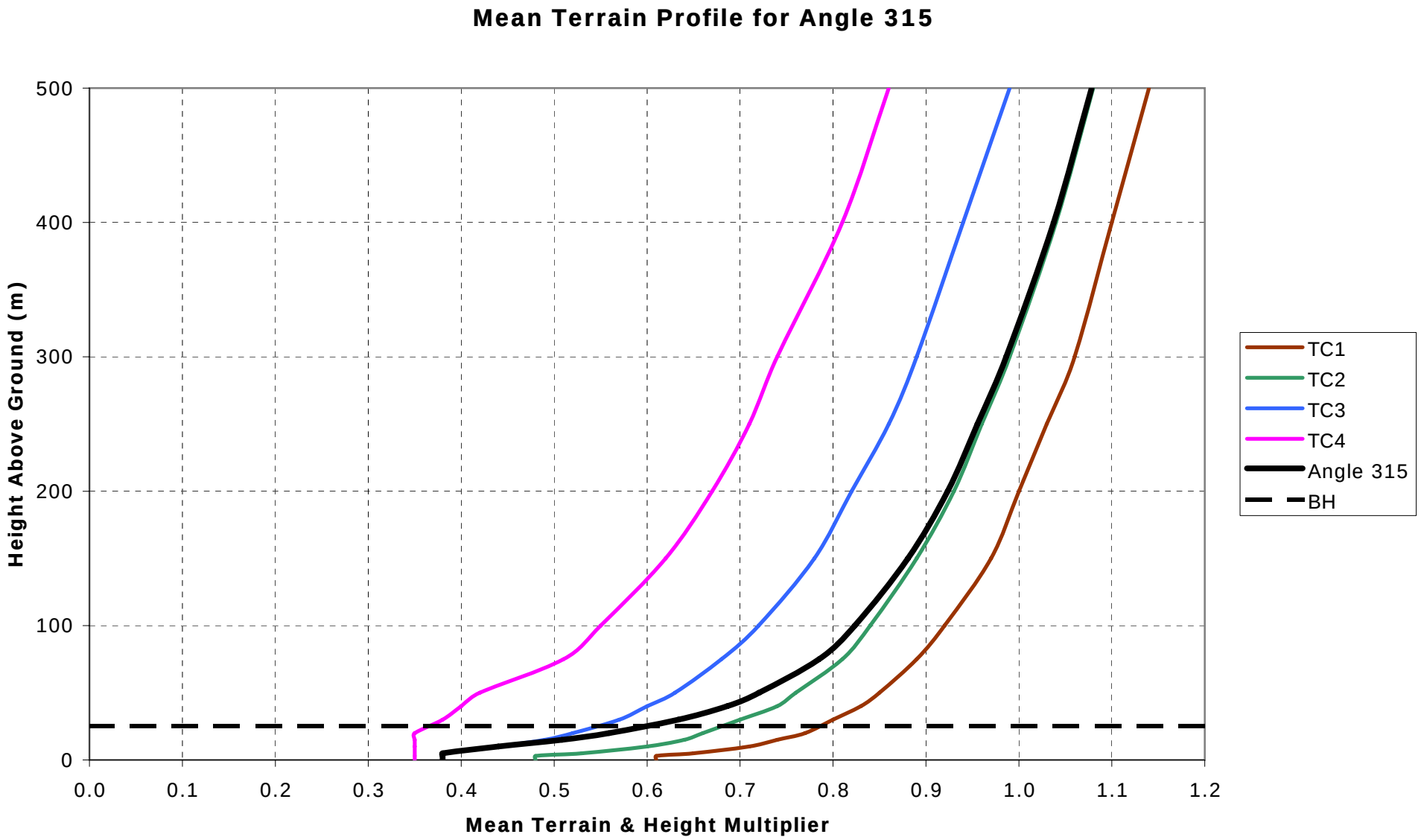

Mean Terrain Profile for Angle 202.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 202.5
BH

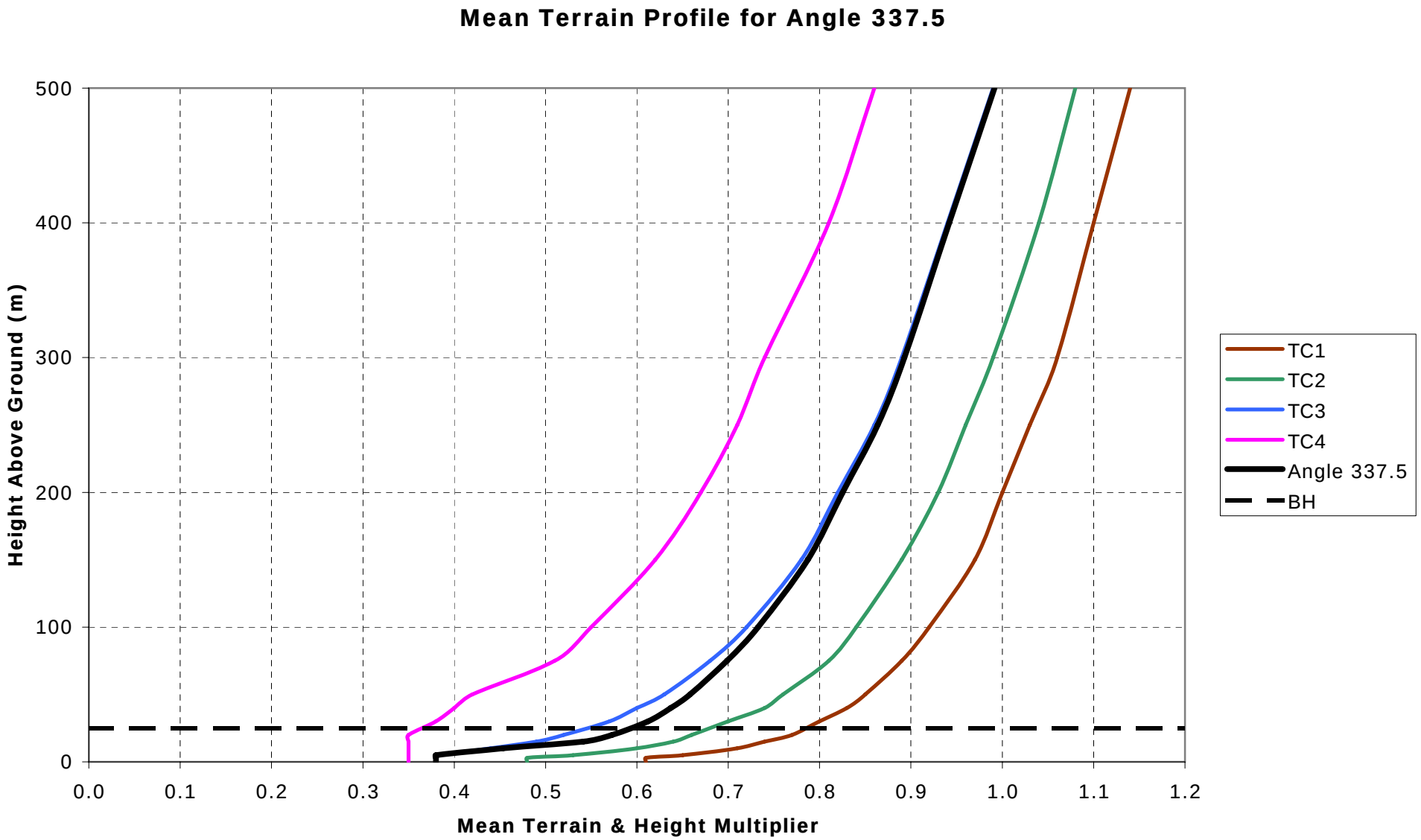

Mean Terrain Profile for Angle 225
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 225
BH


Mean Terrain Profile for Angle 247.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 247.5
BH


Mean Terrain Profile for Angle 270
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 270
BH


Mean Terrain Profile for Angle 292.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 292.5
BH


Mean Terrain Profile for Angle 315
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 315
BH


Mean Terrain Profile for Angle 337.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 337.5
BH

# Appendix C

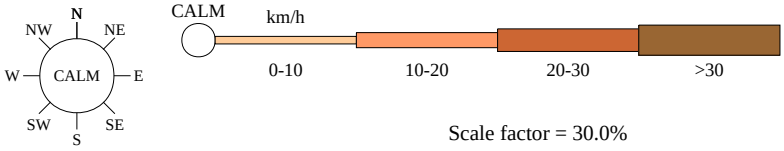
Wind Roses for the Sydney Region

Sydney Airport, 1939-2000

# WIND FREQUENCY ANALYSIS (in km/h)

**SYDNEY AIRPORT AMO STATION NUMBER 066037**

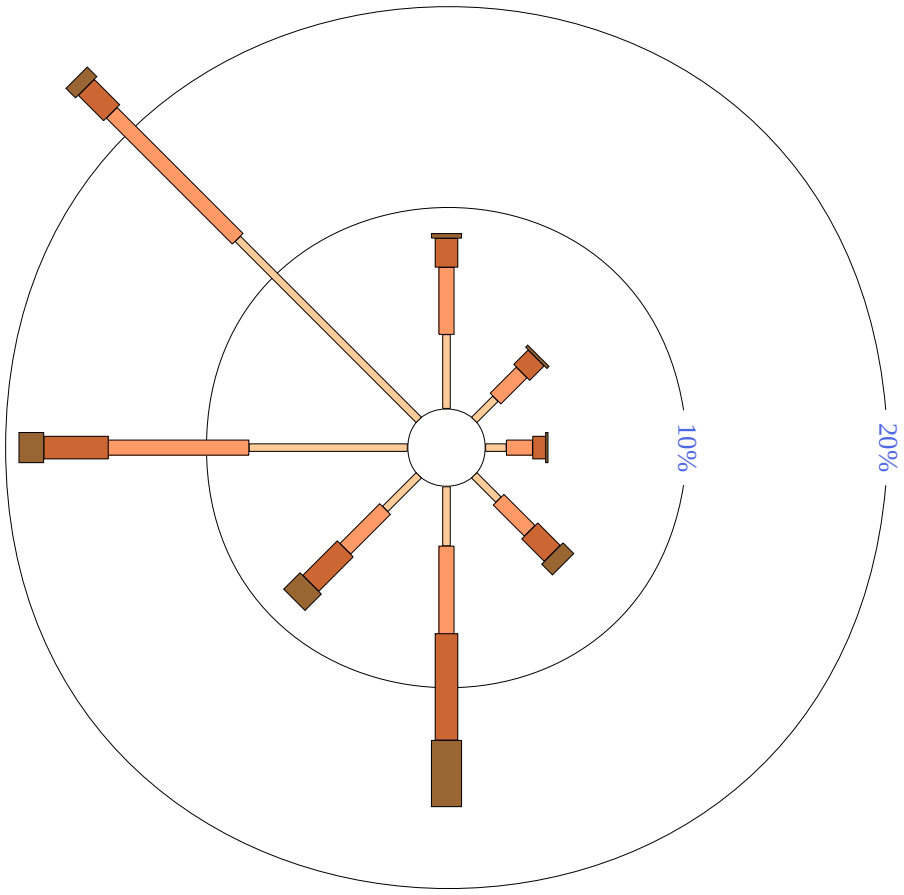
**Latitude: -33.94 ° Longitude: 151.17 °**




Scale factor = 30.0%

9 am
23333 Total Observations (1939 to 2004)

Calm 10%




Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
An observed wind speed which falls precisely on the boundary between two divisions (eg 10km/h) will be included in the lower range (eg 1-10 km/h). Only quality controlled data have been used.

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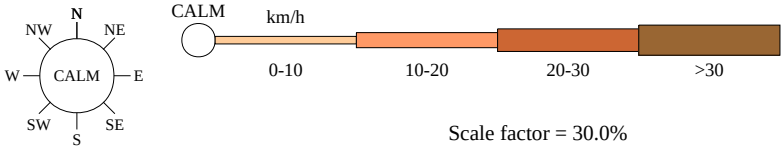
# WIND FREQUENCY ANALYSIS (in km/h)

**SYDNEY AIRPORT AMO STATION NUMBER 066037**

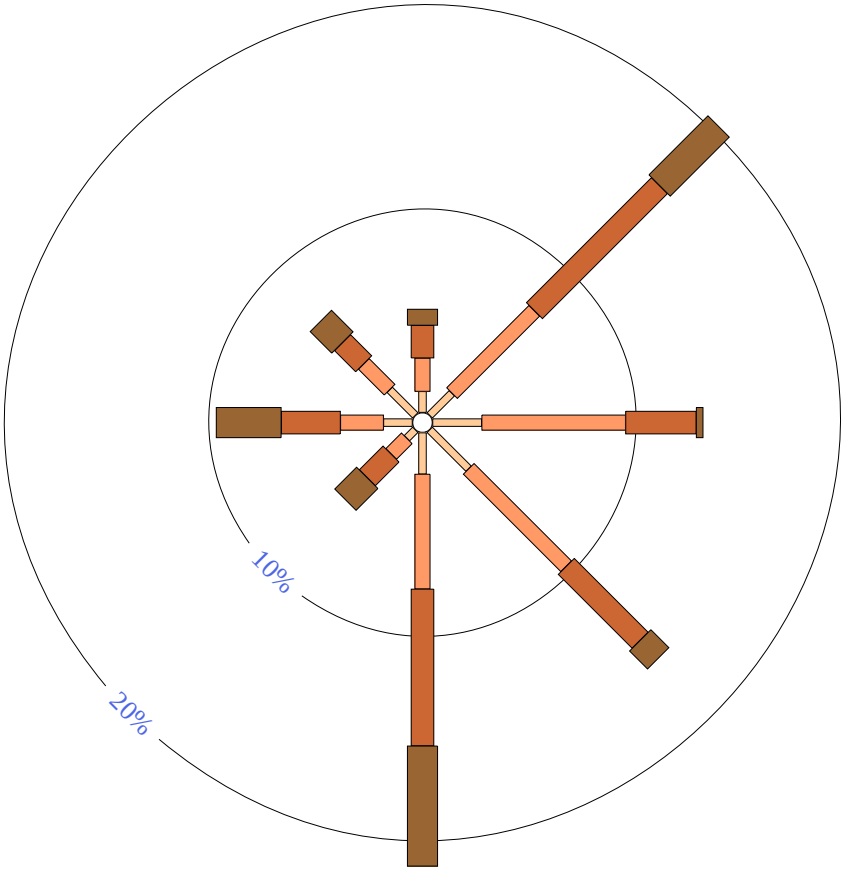
**Latitude: -33.94 ° Longitude: 151.17 °**




Scale factor = 30.0%

3 pm
23407 Total Observations (1939 to 2004)

Calm 2%




Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
An observed wind speed which falls precisely on the boundary between two divisions (eg 10km/h) will be included in the lower range (eg 1-10 km/h). Only quality controlled data have been used.

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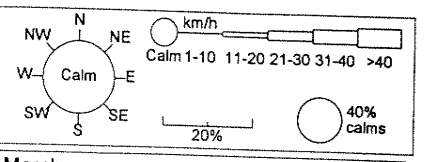
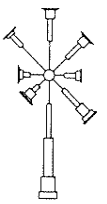
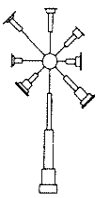
Site Number 066037 • Locality: SYDNEY AIRPORT • Opened Jan 1929 • Still Open
Latitude 33°56'28"S • Longitude 151°10'21"E • Elevation 6m



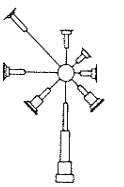

9 am January 1933 observations



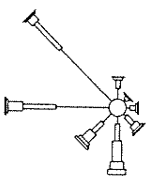
9 am February 1755 observations



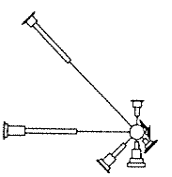
9 am March 1922 observations



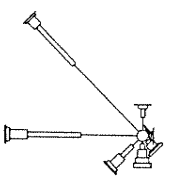
9 am April 1834 observations



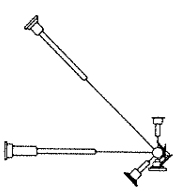
9 am May 1866 observations



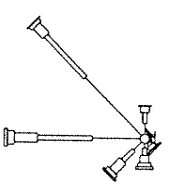
9 am June 1806 observations



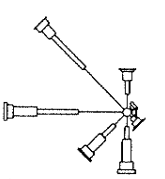
9 am July 1873 observations



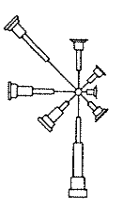
9 am August 1876 observations



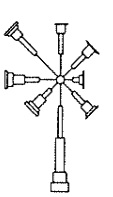
9 am September 1814 observations



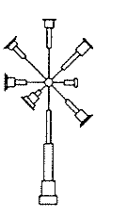
9 am October 1901 observations



9 am November 1835 observations



9 am December 1906 observations



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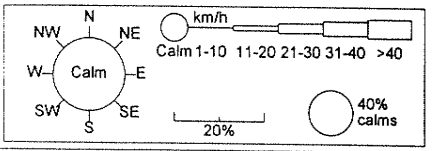
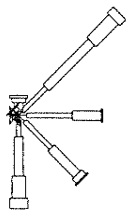
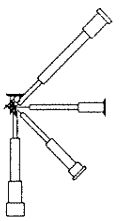


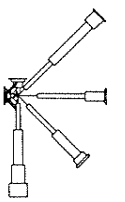

3 pm January 1939 observations



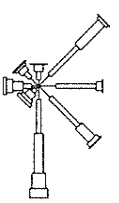
3 pm February 1771 observations



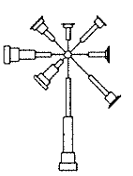
3 pm March 1925 observations



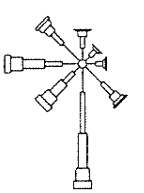
3 pm April 1832 observations



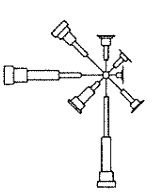
3 pm May 1877 observations



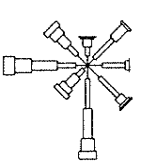
3 pm June 1821 observations



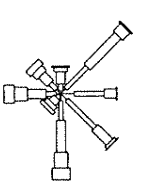
3 pm July 1882 observations



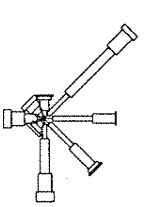
3 pm August 1882 observations



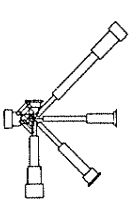
3 pm September 1811 observations



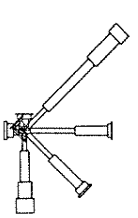
3 pm October 1904 observations



3 pm November 1839 observations



3 pm December 1906 observations



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