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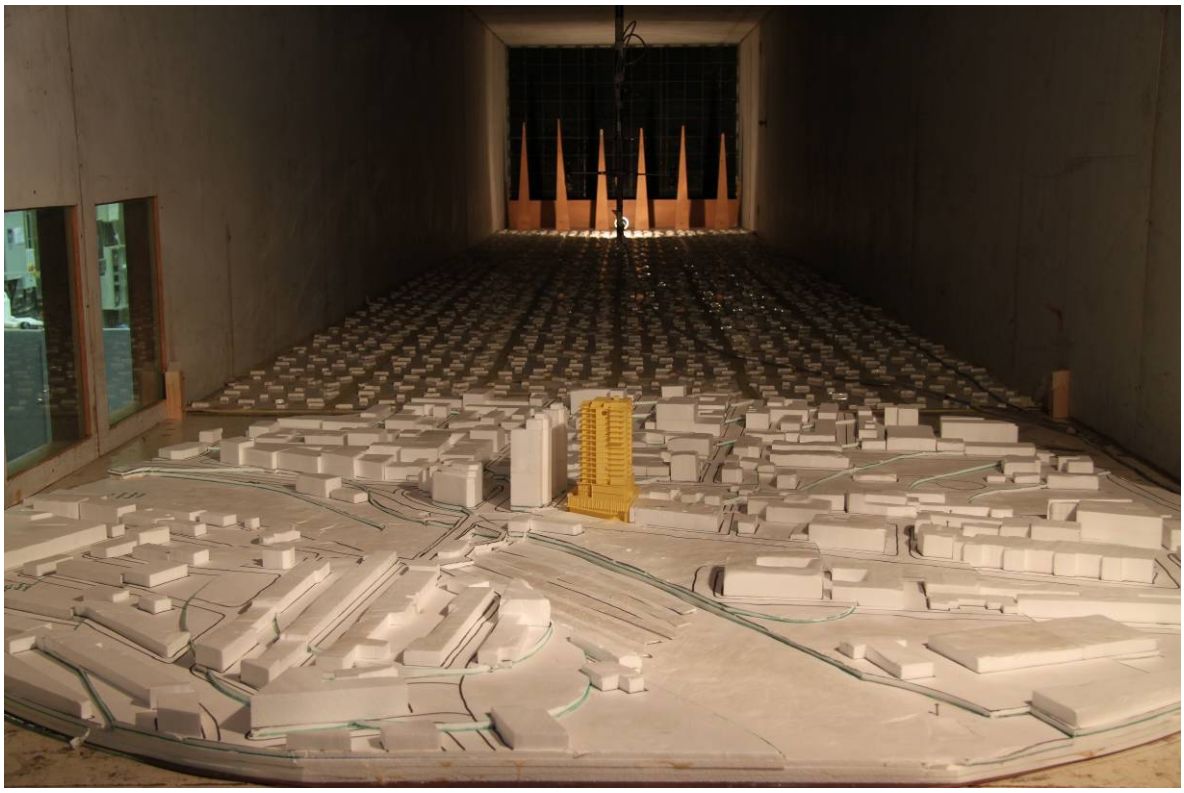

# Pedestrian Wind Environment Study

## for the proposed development at

## 157 Redfern Street, Redfern

June 25, 2009

Report Reference No. WA622-01F03(rev1)- WE Report

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## Document Control

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## Table of Contents

## 1.0 Introduction

This report presents the results of a detailed investigation into the wind environment impact in relation to the proposed development located at 157 Redfern Street, Redfern. The site is located at the corner of Gibbons and Redfern Streets, with the site being bounded by Redfern Street to the north and Gibbons Street to the east. The proposed development consists of 4 commercial and retail levels and 14 residential floors with the top level of residential level 18 having a roof terrace. It is proposed that the podium levels of the development will be used for commercial office use, and the Redfern RSL Club. The overall height of the development will be approximately 65m above the Redfern Street ground level.

Wind speed measurements were carried out using a 1:300 scale model of the proposed 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. Wind speed measurements for the ground level areas were also tested for the existing site wind conditions for comparison.

Testing was performed using Windtech's boundary layer wind tunnel facility. Peak gust and mean 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.

The results of the study indicate that the existing wind conditions along Redfern Street are particularly strong, and exceed criteria for comfortable pedestrian activity. The existing site wind conditions along Gibbons Street satisfy criteria for comfortable pedestrian activity. With the addition of the proposed development, the results of the study indicate that wind conditions along Redfern Street will be improved so that the criteria for comfortable pedestrian activity are satisfied. Wind conditions along Gibbons Street will be equivalent to the existing conditions, which are acceptable for comfortable pedestrian activity.

Wind conditions for the various outdoor terraces and balconies of the proposed development have been tested, and a set of the minimum recommended treatments have been made in this report to ensure that suitable wind conditions are achieved for all trafficable outdoor areas. The minimum recommended treatments are summarised as follows:

- 1.2m high impermeable balustrades around the north-eastern and south-western corners of the Level 3 office terrace areas, and around the south-western corner terrace of Level 5.
- 1.2m high impermeable balustrades along the perimeter of the three private terraces on the eastern aspect of Level 5, and a densely foliating row of shrubs along the northern edge of the north-eastern private terrace capable of growing to at least 1.2m high above the terrace floor slab. Note that the shrubs could be replaced by an impermeable balustrade of equivalent height if desired.

- 1.8m high impermeable privacy screens separating the three private terraces on the eastern aspect of Level 5. These can taper down to the balustrade height of 1.2m at the eastern edge if desired.
- 1.2m high impermeable balustrades around the south-western and north-eastern corner balconies on the typical levels of the tower.
- 1.2m high impermeable balustrades around the south-eastern, south-western and north-western corner terraces on Level 19.

It is expected that wind conditions to the various balconies and terraces of the proposed development can be further enhanced if impermeable balustrades are used on the perimeter of all trafficable areas, or if taller balustrades or screens are used in place of those recommended in this report. However, with the inclusion of the list of treatments above into the final design, wind conditions for all outdoor areas within and around the proposed development will be acceptable for the intended uses.

## 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 proposed 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 are presented in Figures 1a to 1e. These include photographs of the model for the existing surrounds case, and the model of the proposed development.

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

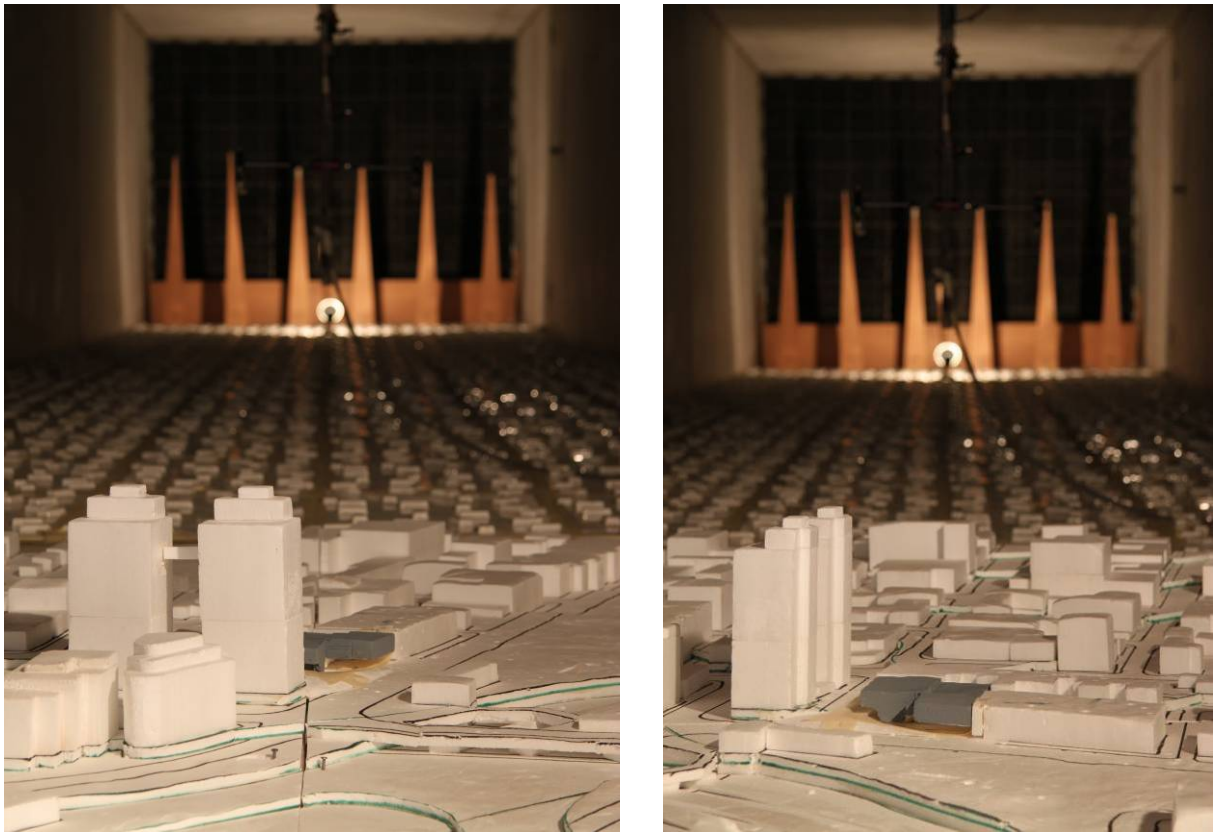

**Figure 1a: Photographs of the Wind Tunnel Model (model of the existing site, views from the north and west)**

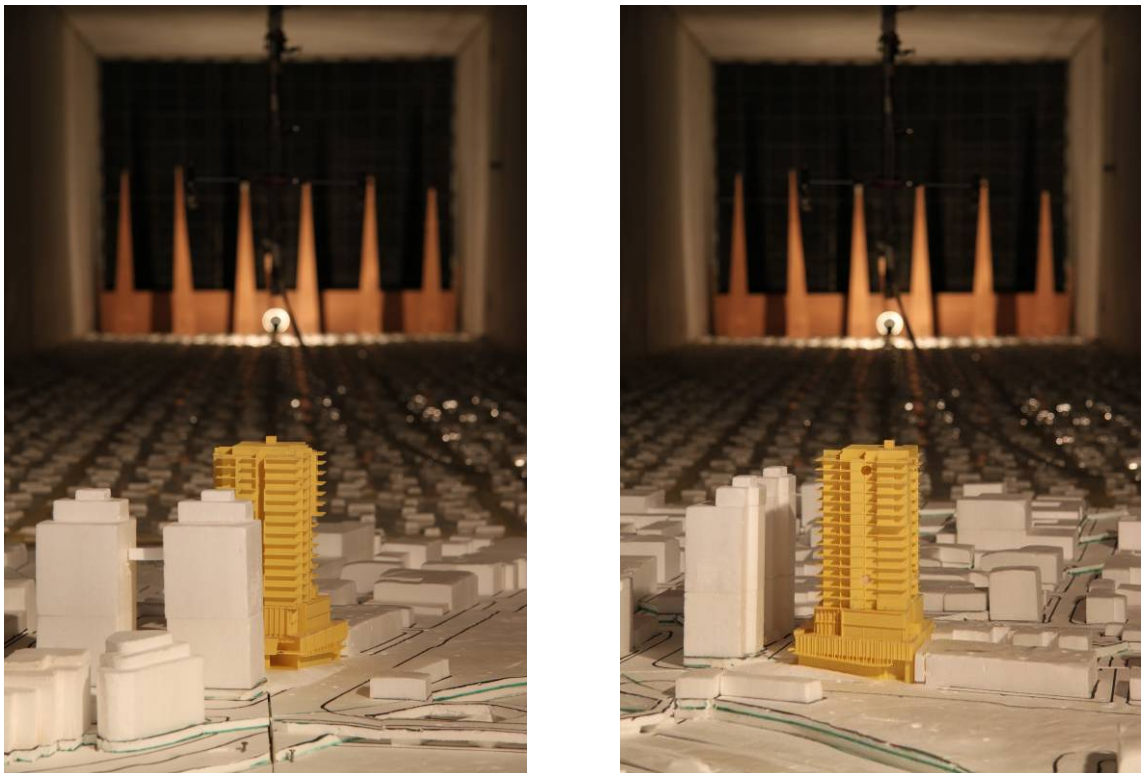

**Figure 1b: Photographs of the Wind Tunnel Model (model with the development, views from the north and west)**

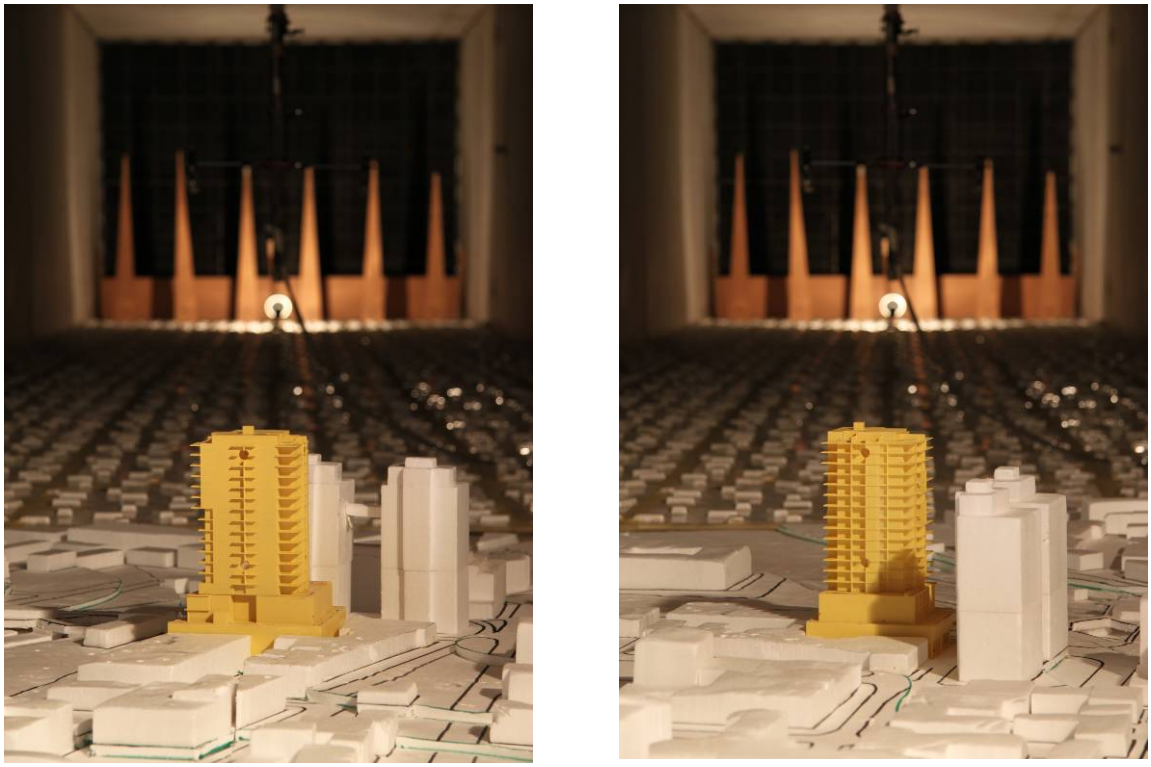

**Figure 1c: Photographs of the Wind Tunnel Model (model with the development, views from the south and east)**

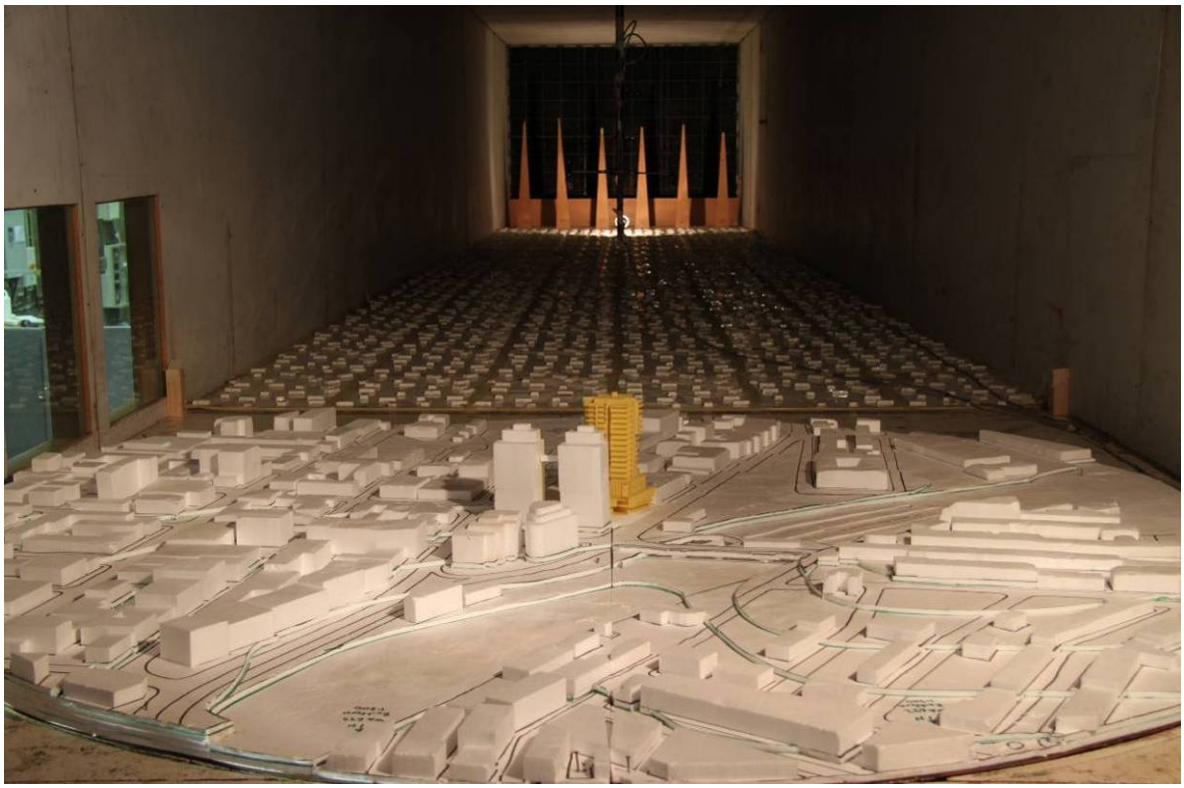

**Figure 1d: Photograph of the Wind Tunnel Model (model with the development, view from the north)**

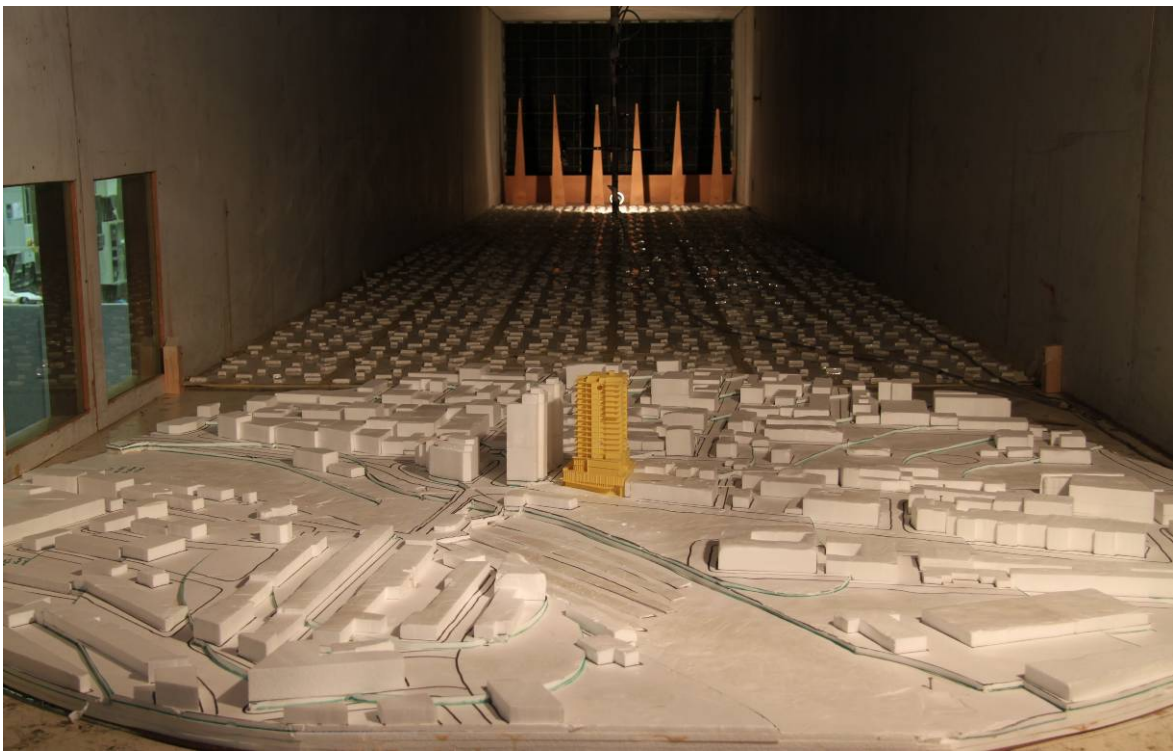

**Figure 1e: Photograph of Wind Tunnel Model (model with the development, view from the west)**

## 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 (1978) model. 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 (65m above ground for this study). Hence, for this project, the fetch length is 2.6km. 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 approaching the site from the north-north-west (from 337.5 degrees), it is assumed that the approaching wind profile at the edge of the study zone (2.6km from the site for this study) is the standard Deaves and Harris (1978) open terrain profile, since this is coming from over open terrain. The wind continues over the open terrain until, approximately 1.7km from the site, the suburban terrain begins. The wind profile begins to adapt from the open terrain profile to the suburban terrain profile. However, by the lag distance equation, at a height of 150m above ground, the profile requires approximately 3.5km 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 150m above ground, the profile is only 49% developed into the suburban wind profile from the open wind profile. At the study reference height of 65m above ground it is 100% developed into the suburban wind profile. The wind profile plot in Appendix B for wind angle 337.5 degrees shows that, by the time the wind reaches the site, the profile has already adapted to the standard suburban terrain profile for heights up to approximately the study reference height of 65m, 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 the Study Reference Height (65m), and the Corresponding Roughness Length for the Standard Deaves & Harris Profiles (1978)**

| Terrain Description | $\overline{M}_{(z,cat)}$ at BH | $M_{(z,cat)}$ at BH | Turbulence Intensity | Roughness Length (m) $z_{0,r}$ |
|---|---|---|---|---|
| Flat | 0.87 | 1.26 | 0.122 | 0.002 |
| Open | 0.79 | 1.20 | 0.144 | 0.02 |
| Suburban | 0.66 | 1.10 | 0.181 | 0.2 |
| Dense Urban | 0.48 | 0.95 | 0.257 | 2 |

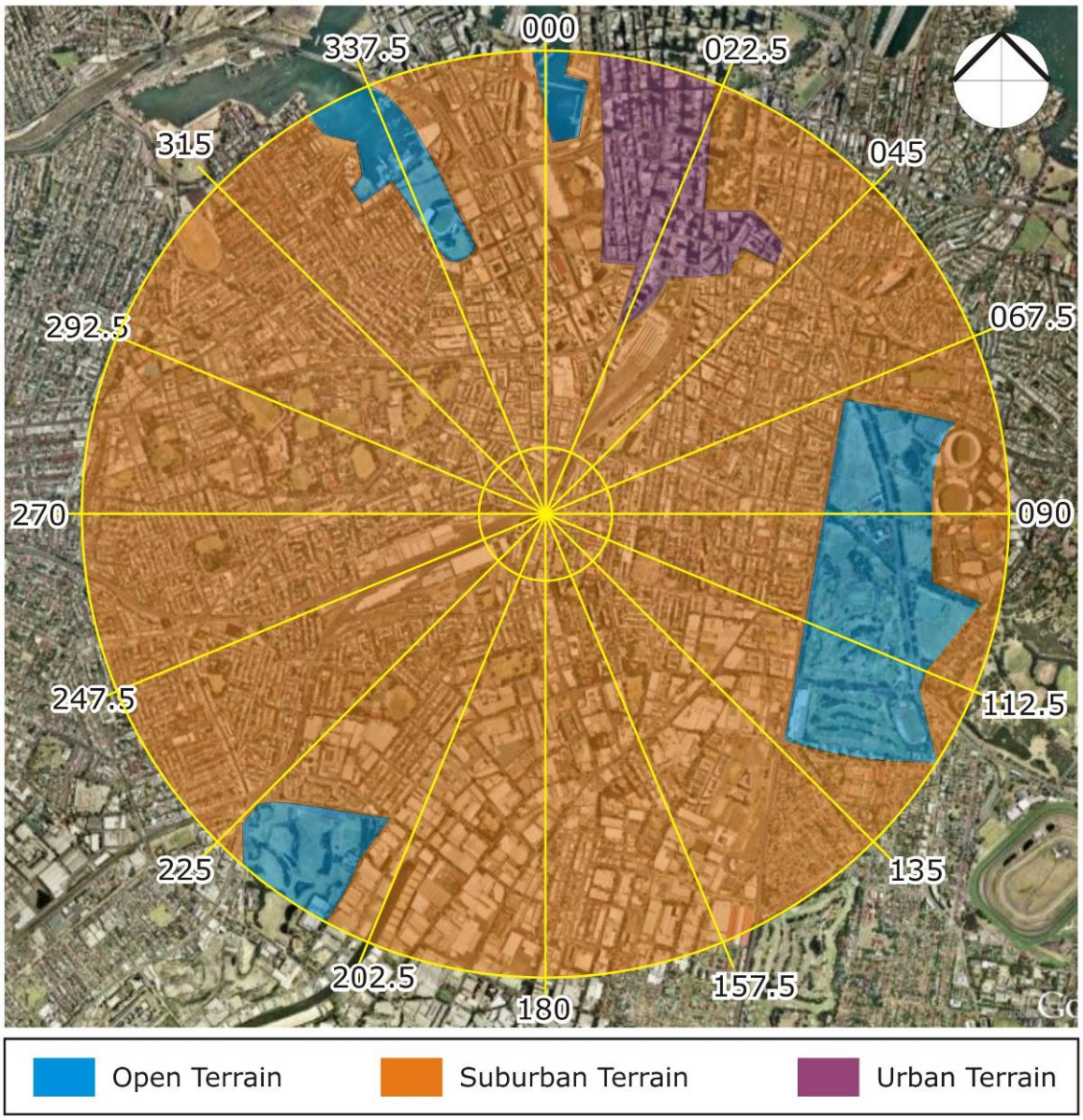


**Figure 2: Aerial Image of the Site and Surrounds – 2.6km Radius (terrain category types also indicated)**

## 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 11.3m/s. This corresponds to a velocity scale range of approximately 1:1.2 to 1:2.0 for the annual maximum peak wind speeds. Hence the sample length in the model scale of 14 seconds is equivalent to a range of approximately 35 minutes to 58 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 free stream and test-location air currents were monitored using a pair of Dantec hot wire probe anemometers. The probe support was mounted such that the probe wire was vertical 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 derived from the following relation:

$$\hat{V} = \overline{V} + g.\sigma_V$$

where g has been taken to be 3.5.

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 directional distributions of the statistical wind climate data for the Sydney region, based on 10 minute mean observations, are shown in Figure 3. This data is corrected for open terrain at 10m height above ground. The meteorological data for Sydney was measured at Kingsford Smith Airport over a period of 70 years, from 1939 to 2008.

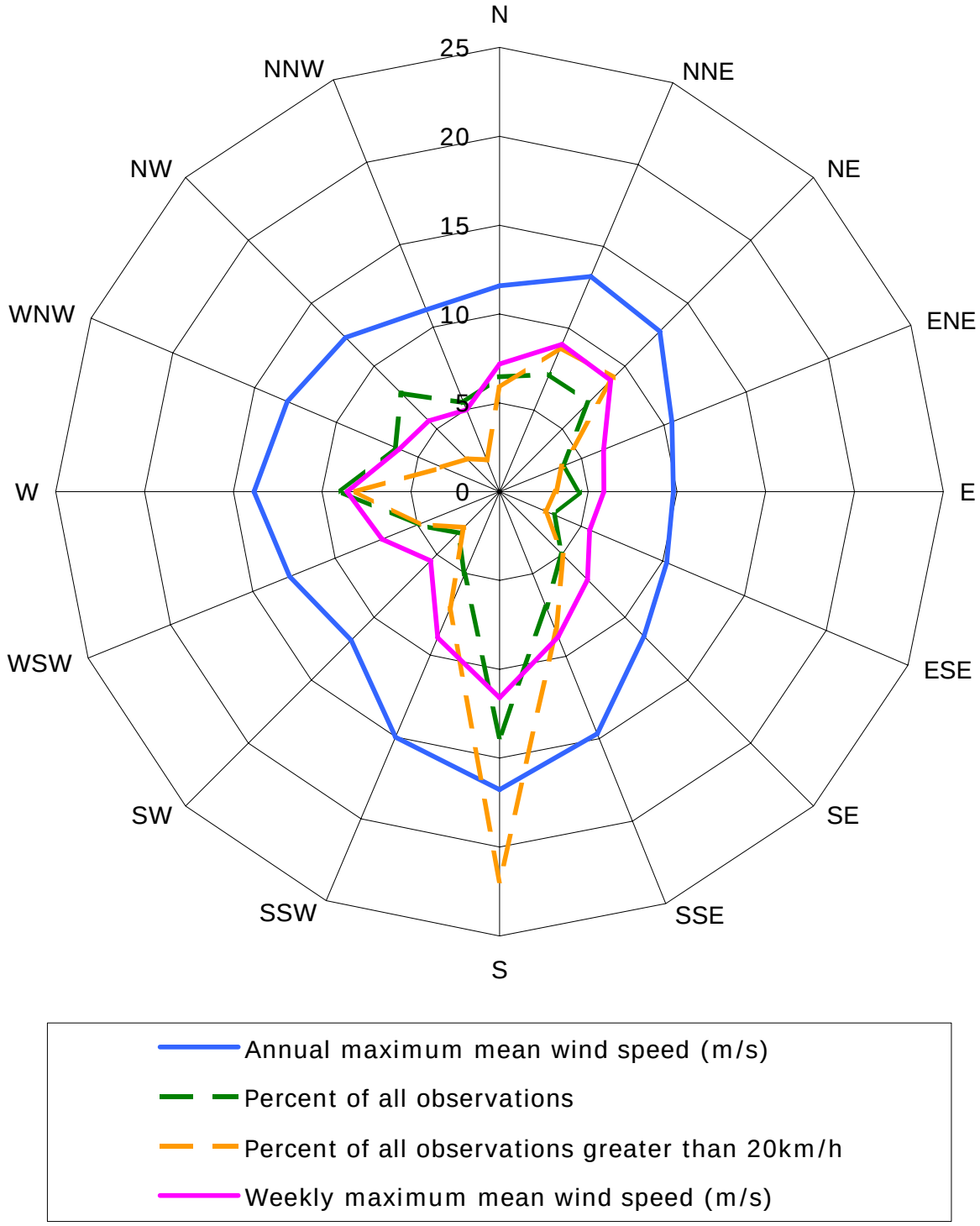


**Figure 3: Annual and Weekly Wind Speed Data for Sydney (based on 10 minute mean observations at Kingsford Smith Airport, corrected for open terrain at 10m height, from 1939 to 2008)**

## 4.0 Environmental Wind Speed Criteria

The acceptability of wind in any area is dependent upon the areas 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 2), developed by Penwarden (1975), is a modified version of the Beaufort Scale, and describes the effects of various wind intensities on people.

**Table 2: 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 3 below are based on a frequency of exceedance of once per week (a probability of exceedance of 5%).

**Table 3: Criteria by Davenport (1972)**

| Classification | Human Activities | 95 Percentile Maximum Mean (once per week) |
|---|---|---|
| Walking Fast | Acceptable for walking, main public access ways | 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 4a and 4b, below.

**Table 4a: 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 4b: 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.

**Table 5: 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 |

**Table 5: Criteria by Melbourne (1978) (continued)**

| Classification | Human Activities | Annual Maximum Gust |
|---|---|---|
| Long Exposure Activities | Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks. | 10 m/s > *u* |

## 4.4 Comparison of the Various Wind Speed Criteria

The criteria mentioned in Table 5, as well as other criteria, are compared on a probabilistic basis in Figure 4, below.

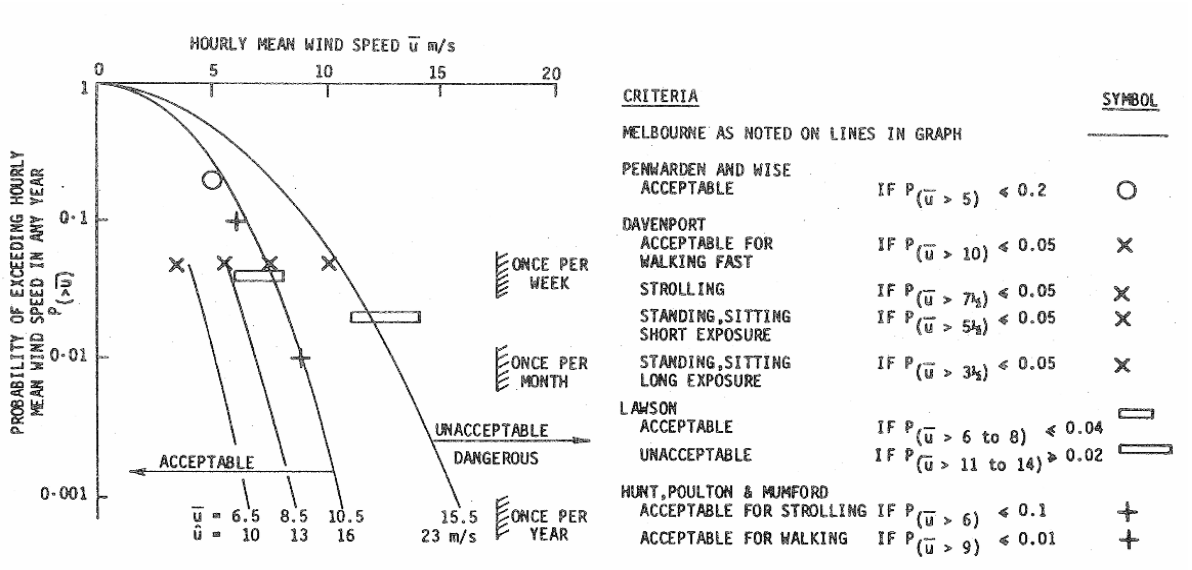


**Figure 4: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (after Melbourne, 1978)**

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.

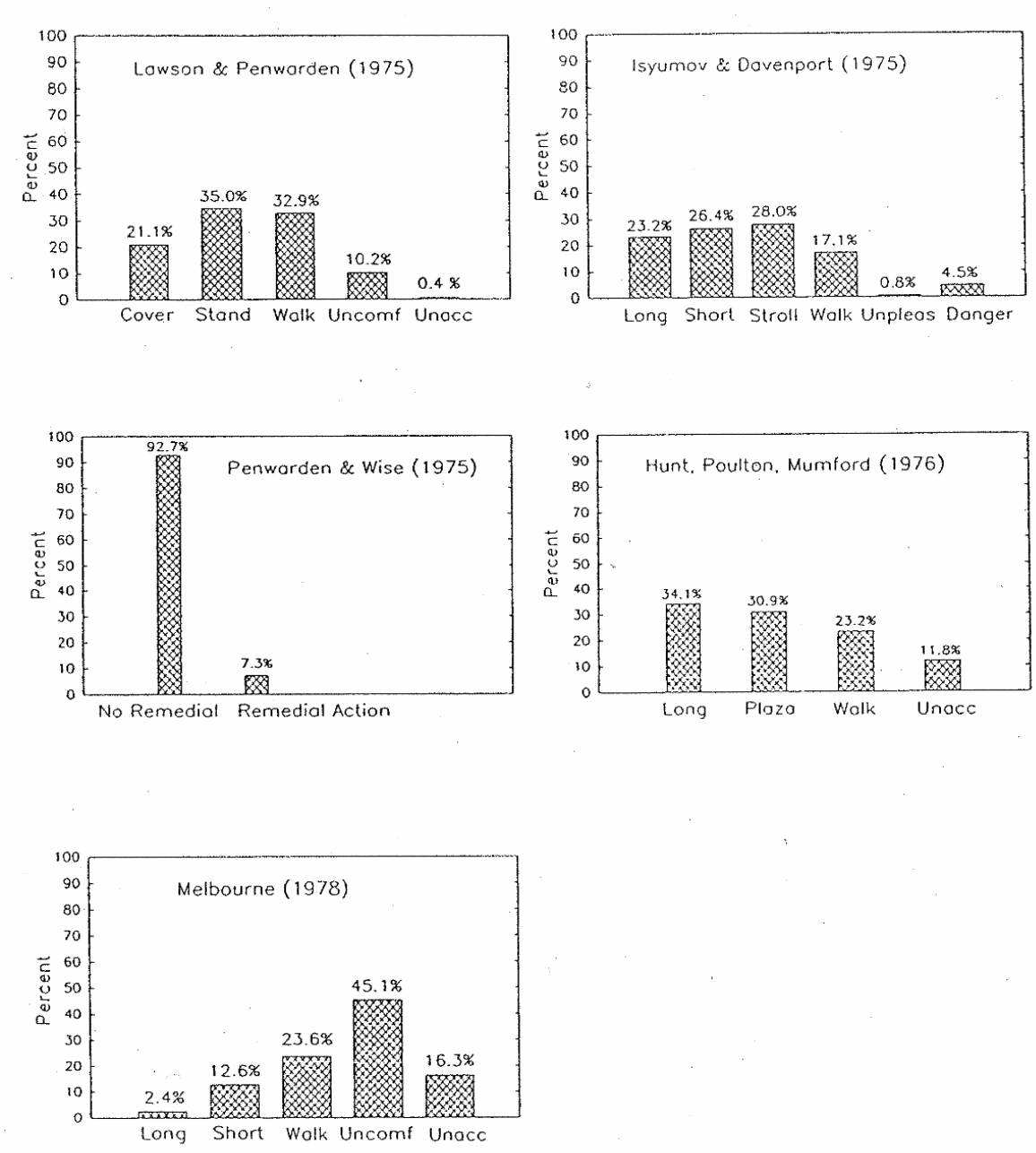


**Figure 5: Distribution of Pedestrian Wind Comfort over Five Criteria for 246 locations examined in the Wind Tunnel (after Ratcliff & Peterka, 1990)**

## 4.5 Criteria Used for This Study

This site is located within the jurisdiction of the Redfern-Waterloo Authority. No specific criteria for pedestrian wind environments have been adopted by the Authority.

We have chosen not to adopt criteria suggested by Sydney City Council, which are based on the criteria suggested by Melbourne(1978). The reasons for this are mentioned in Section 4.4 of this report. However, we have adopted the safety limit suggested by Melbourne(1978) in addition to the set of criteria mentioned below.

Our field observations carried out in conjunction with wind tunnel testing, as part of our past remedial wind environment studies tend to agree the most with the Davenport criteria described in Section 4.1 of this report, in conjunction with a Gust Equivalent Mean (GEM) wind speed (defined below).

The recommended wind comfort criteria for the various outdoor areas of the proposed development are shown in the following set of figures. Note that the Safety Limit criterion by Melbourne (1978) of 23m/s (described in Section 4.3 of this report) for annual maximum peak wind speeds is also applied to all areas.

The basic criteria for a range of outdoor activities are described as follows:

- Long Exposure: 3.5m/s for the weekly maximum GEM wind speeds
- Short Exposure: 5.5m/s for the weekly maximum GEM wind speeds
- Comfortable Walking: 7.5m/s for the weekly maximum GEM wind speeds
- Fast Walking: 10.0m/s for the weekly maximum GEM wind speeds
- Safety Limit: 23.0m/s for the annual maximum gust wind speeds

Notes:

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

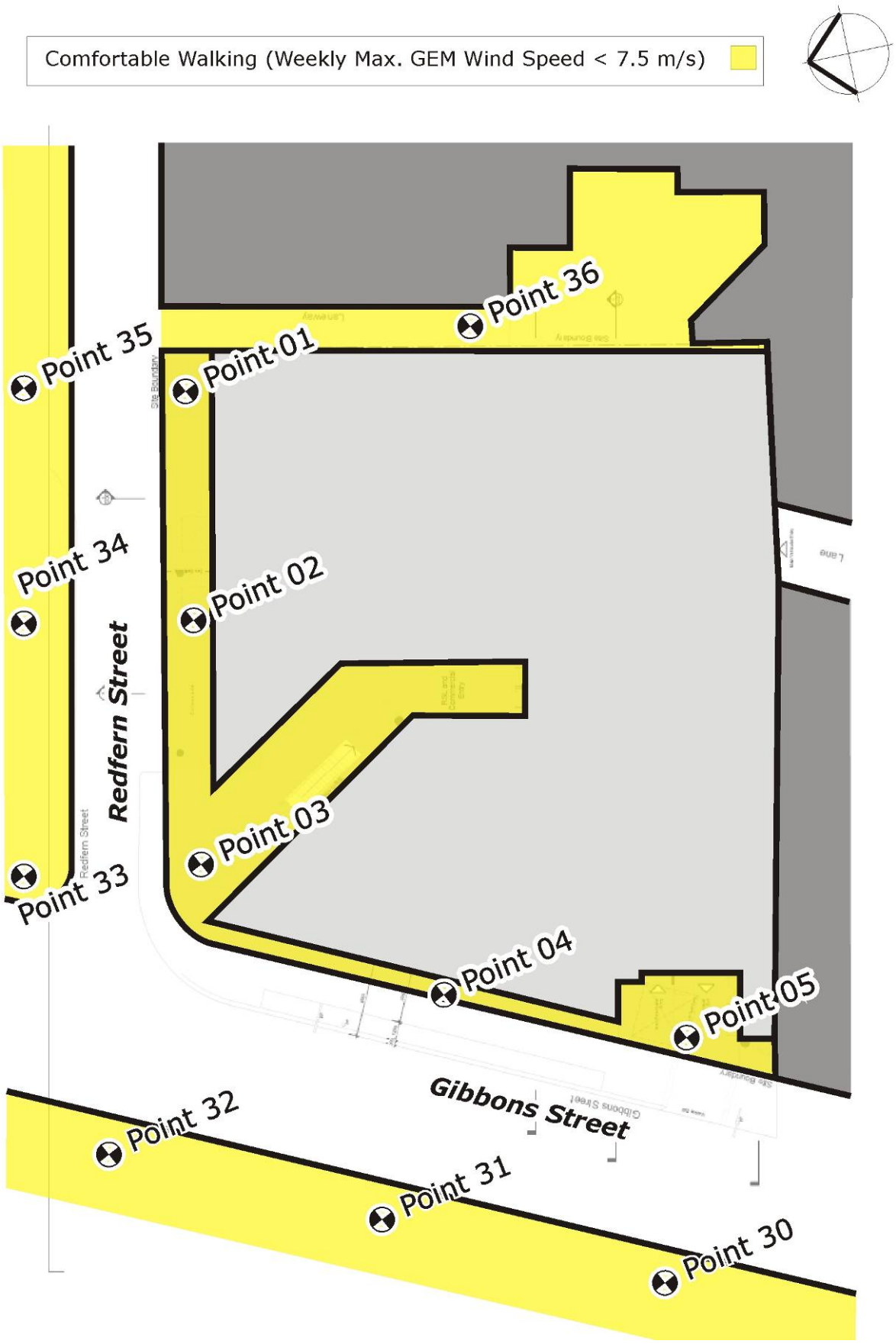


**Figure 6a: Study Point Locations & Wind Comfort Criterion Zones Ground Level**

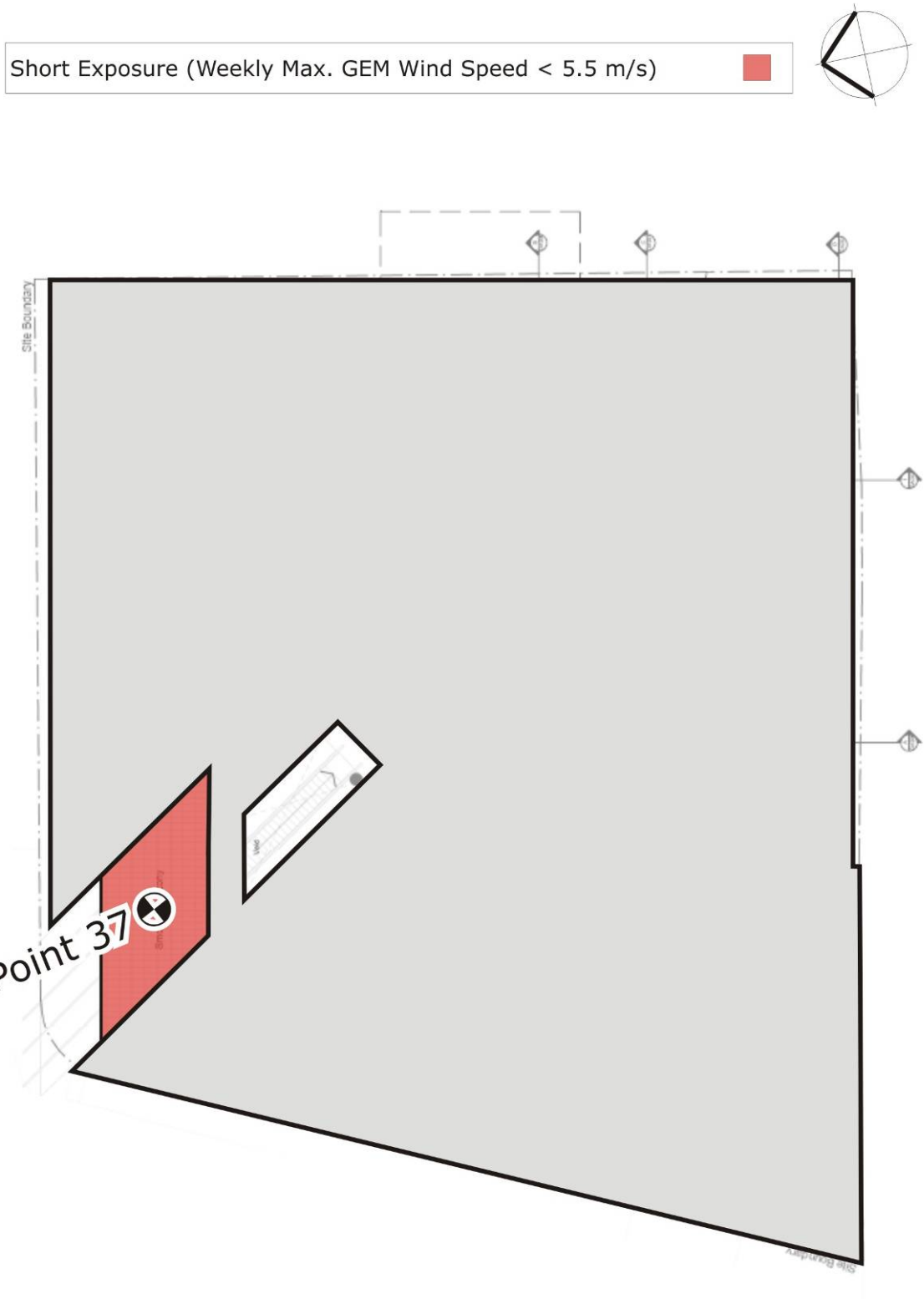


**Figure 6b: Study Point Locations & Wind Comfort Criterion Zones Level 2 (proposed RSL smoking balcony)**

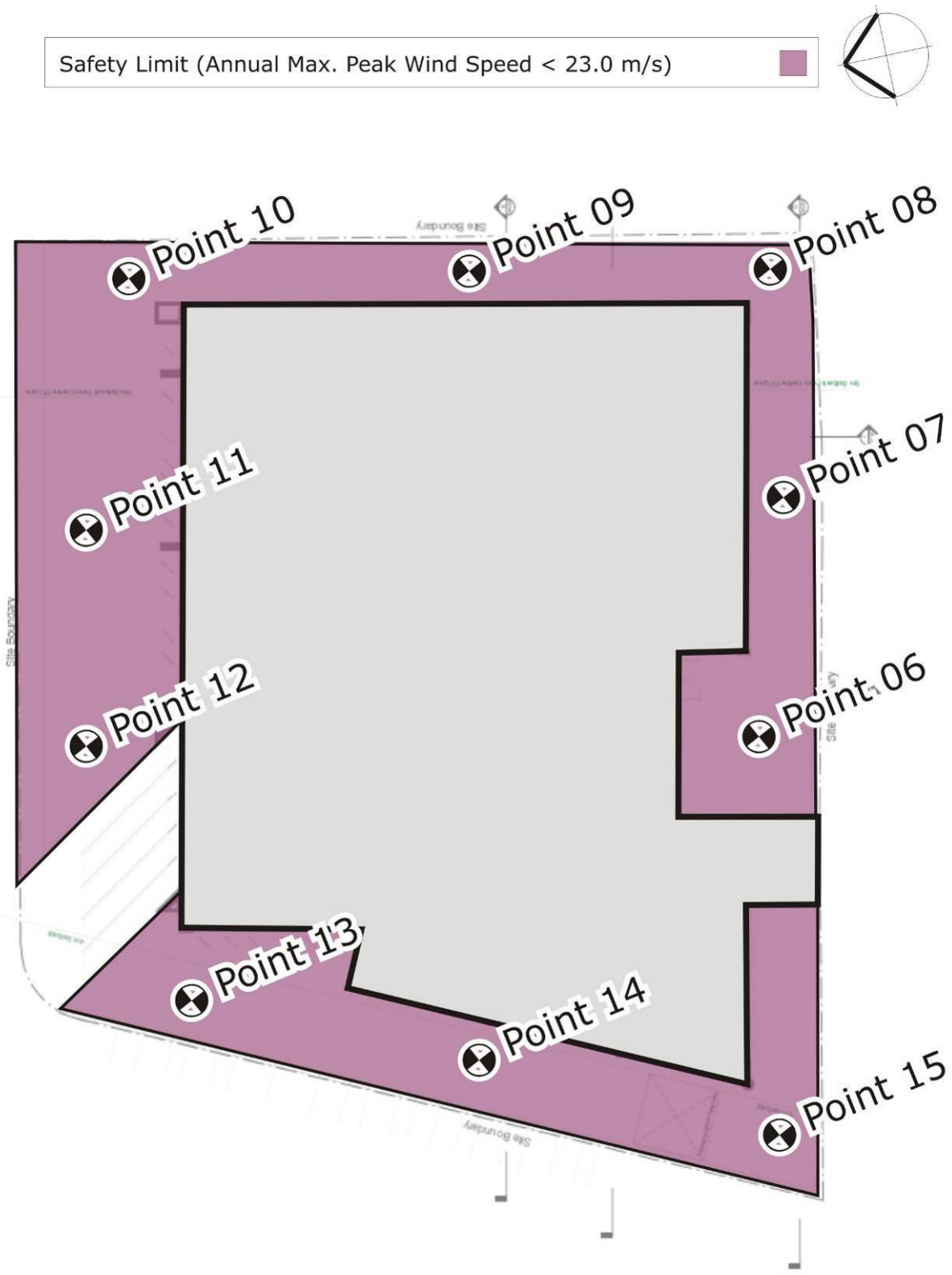


**Figure 6c: Study Point Locations & Wind Comfort Criterion Zones Level 3 (office terrace areas)**

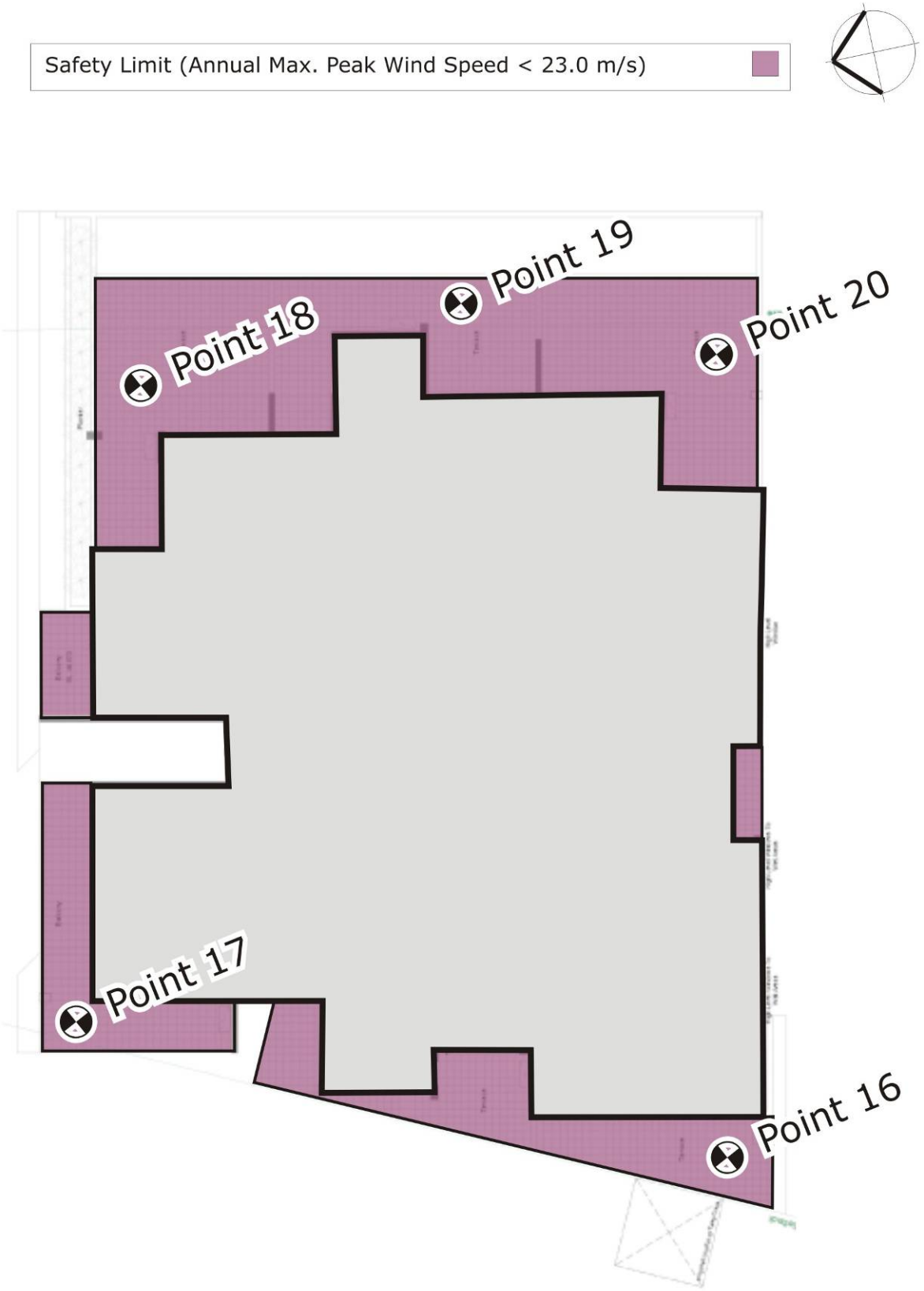


**Figure 6d: Study Point Locations & Wind Comfort Criterion Zones Level 5 Private Balconies and Terraces**

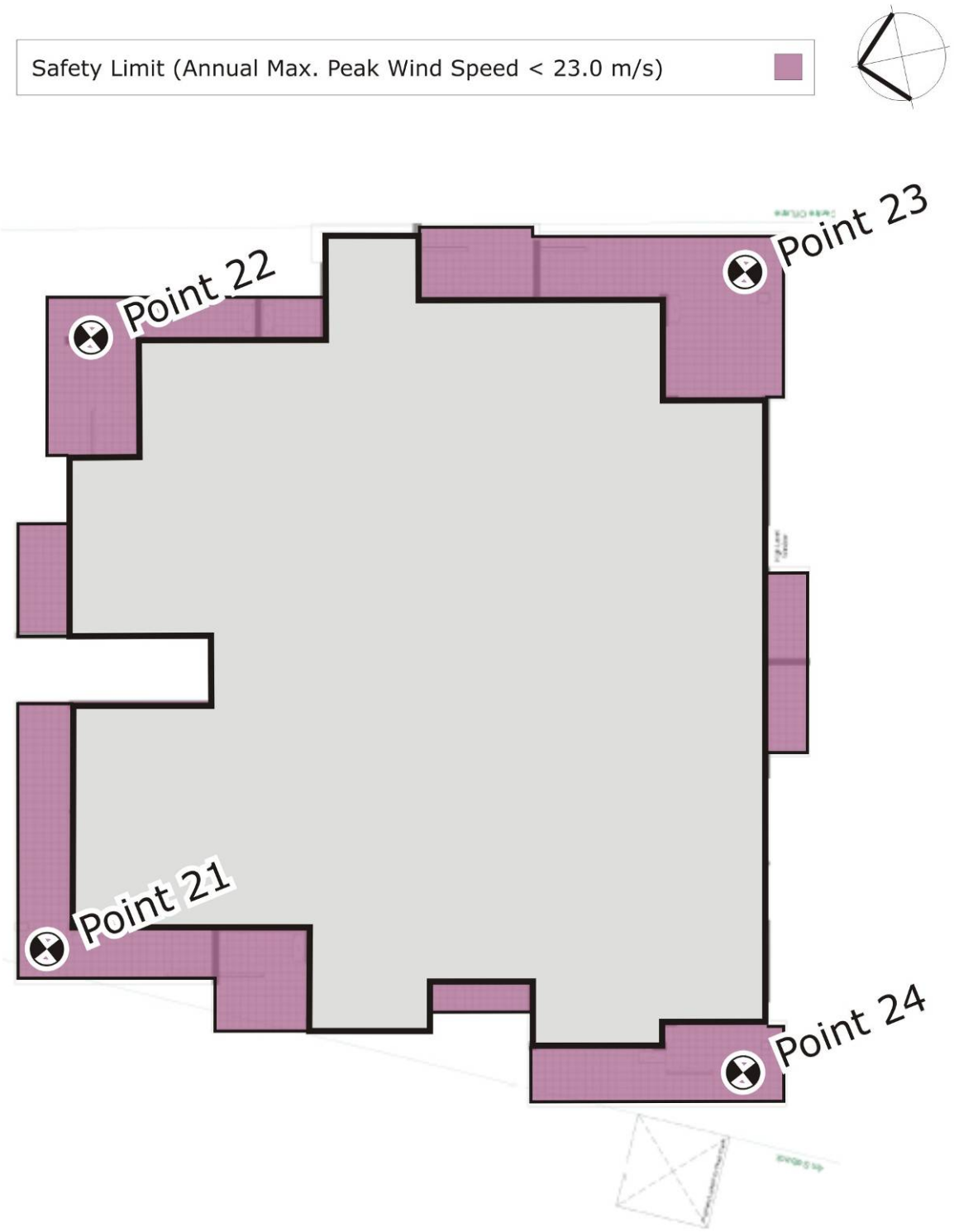


**Figure 6e: Study Point Locations & Wind Comfort Criterion Zones Private Balconies and Terraces of the Tower**

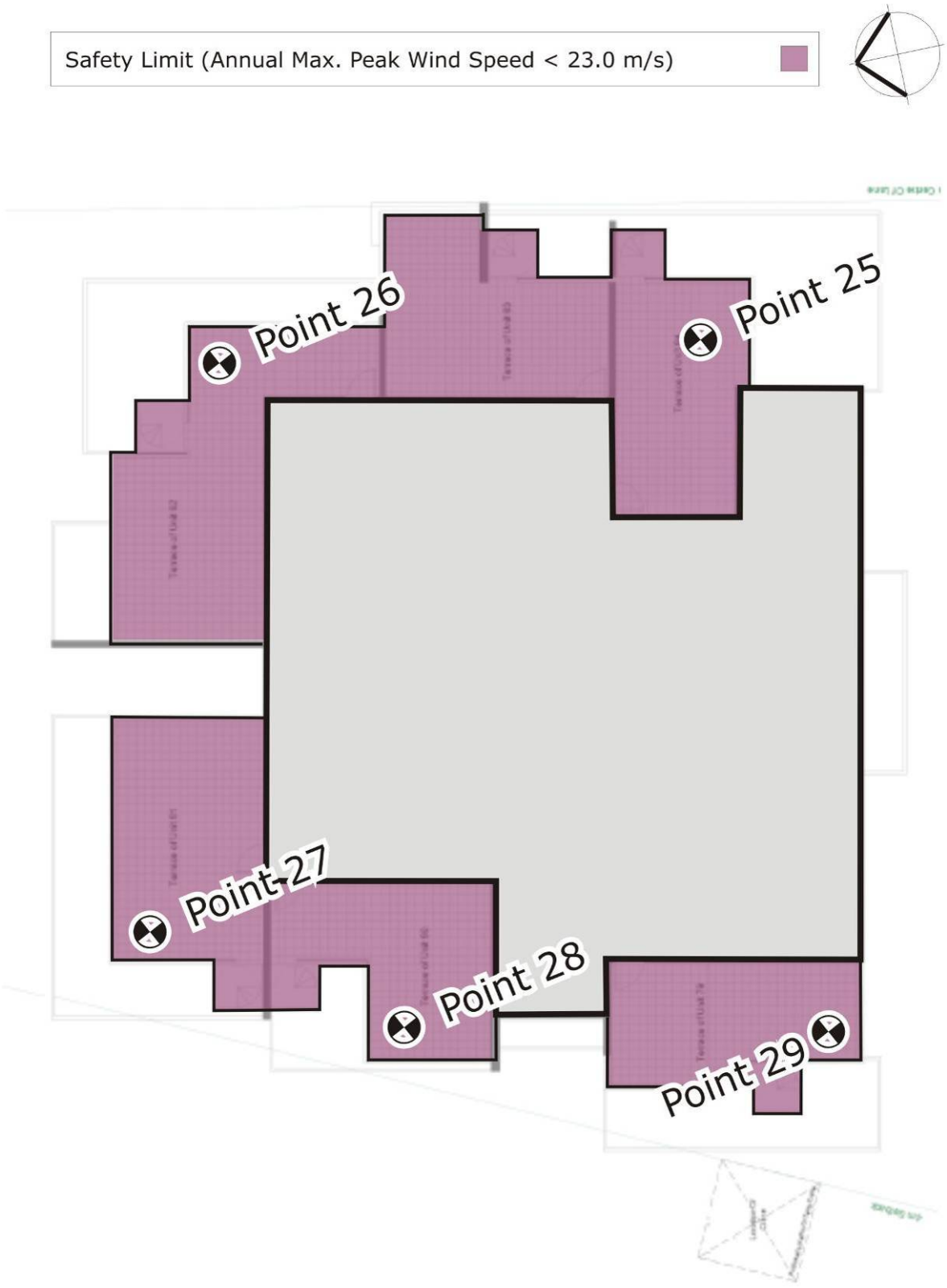


**Figure 6f: Study Point Locations & Wind Comfort Criterion Zones Level 19 (roof terrace areas)**

# 5.0 Results and Recommendations

A detailed study of wind activity within and around the various outdoor areas of the proposed development was carried out. A total of 37 study locations were selected for detailed analysis as shown in Figures 6a to 6f. These include 12 ground level test point locations and 25 study points on the various private balconies, shared and communal terraces of the proposed development.

Initially the ground level study locations surrounding the site were tested for the existing conditions. For these tests, a model of the existing building of the site was tested in the wind tunnel (shown in Figure 1a).

The model of the proposed development was then introduced and the critical outdoor locations tested. Note that the initial tests of the proposed development did not include the effect of any forms of wind ameliorating devices such as balustrades, screens, trees etc that are not indicated on the architectural drawings. For areas not achieving the appropriate wind conditions, retesting was undertaken with various forms of ameliorative treatments until an effective outcome was reached.

For the ground level areas, the measured existing wind conditions around the site are compared to the measured wind conditions with the addition of the proposed development, to determine if the proposed development has any adverse effect on the local surrounding wind conditions.

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. The results are based on the weekly maximum GEM wind speed criteria and the annual maximum peak wind speed criteria, as outlined in Section 4.5 of this report.

## 5.1 Ground Level Areas

### *The Study Points*

Test Points 1 to 5 and 30 to 36 are used to monitor the ground level wind conditions of the site. The location of each study point is summarised as follows:

- Points 1 to 3 and 33 to 35 are located along the pedestrian footpaths either side of Redfern Street.
- Points 4, 5 and 30 to 32 are located along the pedestrian footpaths either side of Gibbons Street.
- Point 36 is located in the laneway on the eastern site boundary.

The locations of these points are also shown in Figure 6a.

### *Applicable Criteria*

All ground level areas around the site are accessible by the general public and are primarily used as pedestrian thoroughfares. Hence the recommended wind comfort criterion for these types of use is the comfortable walking criterion of 7.5m/s for the weekly maximum GEM wind speeds. The appropriate wind comfort criteria for all accessible ground level areas within and around the proposed development are also indicated in Figure 6a.

Note that the safety limit of 23m/s for the annual maximum peak wind speeds should also be satisfied for all study points.

### *Results and Recommendations*

Initially the ground level study points were tested for the existing site conditions to provide a set of results for comparison. The results indicate that the existing wind conditions along either side of Redfern Street generally exceed the recommended comfortable walking criterion of 7.5m/s for the weekly maximum GEM wind speeds, and at some of the study point locations the measured wind speeds are equivalent to the safety limit of 23m/s for the annual maximum gust wind speeds. The results indicate that the existing wind conditions along either side of Gibbons Street are acceptable for general pedestrian use. The existing wind conditions in the laneway on the eastern side of the site are also acceptable for pedestrian use.

The various ground level study points were retested with the addition of the proposed development. The results indicate that there will be a significant improvement along the southern footpath of Redfern Street on the northern site boundary. The results for the remaining ground level study points around the site indicate that wind conditions will be generally equivalent to the measured existing wind conditions. Note that although there is an increase in the measured southerly winds at Point 31 with the proposed development in place, the relevant wind comfort criteria are still satisfied.

With the addition of the proposed development, the wind conditions for all ground level areas will satisfy the recommended comfortable walking criterion of 7.5m/s for the weekly maximum GEM wind speeds, and also the safety limit of 23m/s for the annual maximum gust wind speeds. Hence, with the proposed development in place, wind conditions for all ground level areas around the site will satisfy the recommended criteria.

## 5.2 Level 2 RSL Smoking Balcony

### *The Study Points*

Test Point 37 is used to monitor the wind conditions on the Level 2 RSL smoking balcony. The location of this point is also shown in Figure 6b.

### *Applicable Criteria*

The RSL smoking balcony on Level 2 is primarily to be used for short duration activities. Hence the recommended wind comfort criterion for this type of use is the short exposure criterion of 5.5m/s for the weekly maximum GEM wind speeds. This is also shown in Figure 6b.

Note that the safety limit of 23m/s for the annual maximum peak wind speeds should also be satisfied at this location.

### *Results and Recommendations*

The results of the initial tests indicate that the wind conditions at Test Point 37 will satisfy the applicable wind comfort criteria without any additional ameliorative devices. Hence wind conditions for the Level 2 smoking balcony are acceptable for the intended use.

## 5.3 Level 3 Office Private Terrace Areas

### *The Study Points*

Test Points 6 to 15 are used to monitor the wind conditions on the Level 3 private office terrace areas of the site. The locations of these points are also shown in Figure 6c.

### *Applicable Criteria*

The appropriate wind comfort criterion for private balconies and terraces is the safety limit of 23m/s for the annual maximum gust wind speeds. This is also shown in Figure 6c for the Level 3 office terrace areas.

### *Results and Recommendations*

The results of the initial tests indicate that the recommended wind comfort criteria will be exceeded at Points 10 and 15. The measured wind conditions for the remaining study point locations on this level are considered acceptable for the intended use of this area.

Study Point 10, located at the north-eastern corner of the terrace area, is exposed to strong westerly to north-westerly winds. This effect may be caused by wind from these directions being directed between the tower component of the proposed development and the neighbouring towers on the northern side of Redfern Street. This location was retested with the addition of 1.2m high impermeable balustrades around the perimeter of this corner of the terrace area, as indicated in Figure 7a. The results of the retest indicate that the impermeable balustrade will provide sufficient wind mitigation so that the safety limit criterion of 23m/s for the annual maximum gust wind speeds will be satisfied.

Study Point 13 is located at the south-western corner of the terrace area. The results indicate that this location is exposed to strong southerly winds coming over the top of the adjacent car park building to the south of the site. This area is also exposed to strong westerly winds coming around the south-western corner of the tower of the proposed development. This location was retested with the addition of 1.2m high impermeable balustrades around the perimeter of this corner of the terrace area, as indicated in Figure 7a. The results of the retest indicate that the impermeable balustrade will provide sufficient wind mitigation so that the safety limit criterion of 23m/s for the annual maximum gust wind speeds will be satisfied.

Hence it is recommended that impermeable balustrades having a minimum height of 1.2m are used around the north-eastern and south-western corners of the Level 3 private terraces. With these balustrades the wind conditions on all areas of the Level 3 private terraces will be acceptable for the intended uses. It is expected that wind conditions to the remaining areas of the terrace can be further enhanced if impermeable balustrades are used around the entire perimeter of these terraces.

## 5.4 Level 5 Private Balconies and Terraces

### *The Study Points*

Test Points 16 to 20 are used to monitor the wind conditions for the Level 5 private balcony and terrace areas. The location of these study points are also shown in Figure 6d.

### *Applicable Criteria*

The appropriate wind comfort criterion for private balconies and terraces is the safety limit of 23m/s for the annual maximum gust wind speeds. This is also shown in Figure 6d for these areas.

### *Results and Recommendations*

The results indicate that the measured wind conditions will be acceptable only at Point 17, located on the north-western corner of Level 5. Wind conditions at all of the other study point locations indicate that the safety limit criteria of 23m/s for the annual maximum gust wind speeds will be exceeded by strong southerly winds.

The study point locations where the recommended criterion was exceeded were retested with the addition of impermeable balustrades around the perimeter of the trafficable areas of each terrace. A densely foliating hedge capable of growing to at least 1.2m height above the floor slab was also added along the northern edge of the north-eastern private terrace on Level 5. The results of the retests indicate that the impermeable balustrades are effective in mitigating the adverse southerly winds affecting all of these locations. Hence it is recommended that 1.2m high impermeable balustrades and the densely foliating hedge indicated in Figure 7b be included to the proposed development to provide suitable wind conditions for the intended uses of these outdoor areas. The screens dividing the three terraces on the eastern aspect of Level 5 should be separated by impermeable privacy screens approximately 1.8m tall. These can taper down to 1.2m at the eastern edge of the terrace to meet the balustrade if desired.

Note that a 1.2m high impermeable balustrade could be used as an alternative to the densely foliating hedge.

## 5.5 Residential Apartment Private Balconies

### *The Study Points*

Test Points 21 to 24 are used to monitor the wind conditions on the various residential apartment private balconies on the typical levels of the tower. The locations of these points are also shown in Figure 6e.

### *Applicable Criteria*

The appropriate wind comfort criterion for private balconies and terraces is the safety limit of 23m/s for the annual maximum gust wind speeds. This is also shown in Figure 6e for these areas.

### *Results and Recommendations*

The results indicate that the measured wind conditions will be acceptable at Points 21 and 23, located at the north-western and south-eastern corners of the tower. Points 22 and 24 are exposed to strong southerly winds, and Point 22 is also exposed to strong north-westerly and northerly winds. The strong winds

observed at Points 22 and 24 exceed the safety limit of 23m/s for the annual maximum gust wind speeds.

Study Points 22 and 24 were retested with the addition of 1.2m high impermeable balustrades around the perimeter of the trafficable areas of the north-eastern and south-western private balconies of the tower component of the development. The results indicate that these balustrades are highly effective in mitigating the adverse winds, and hence are recommended to be implemented into the final design of the proposed development. With the addition of the impermeable balustrades as indicated in Figure 7c, wind conditions for all private balconies of the typical tower levels of the proposed development will be acceptable for their intended uses.

## 5.6 Level 19 Private Roof Terrace Areas

### *The Study Points*

Test Points 25 to 29 are used to monitor the wind conditions on the Level 19 private roof terrace areas of the development. The locations of these points are also shown in Figure 6f.

### *Applicable Criteria*

The appropriate wind comfort criterion for private balconies and terraces is the safety limit of 23m/s for the annual maximum gust wind speeds. This is also shown in Figure 6f for these areas.

### *Results and Recommendations*

The results of the initial tests indicate that only the wind conditions at Points 26 and 28 will satisfy the recommended criteria. Point 25, located at the south-eastern corner of Level 19, is exposed to strong southerly winds. Point 27, located at the north-western corner of Level 19, is exposed to strong north-westerly winds. Point 29, located at the south-western corner of Level 19, is exposed to strong south-westerly winds. The measured wind conditions at these three locations exceeded the safety limit of 23m/s for the annual maximum gust wind speeds.

Study Points 25, 27 and 29 were retested with the addition of 1.2m high impermeable balustrades around the perimeter of the trafficable areas of the terraces. The results indicate that these balustrades are highly effective in mitigating the adverse winds, and hence are recommended to be implemented into the final design of the proposed development. With the addition of the impermeable balustrades as indicated in Figure 7d, wind conditions for all of the private terraces on Level 19 of the proposed development will be acceptable for their intended uses.

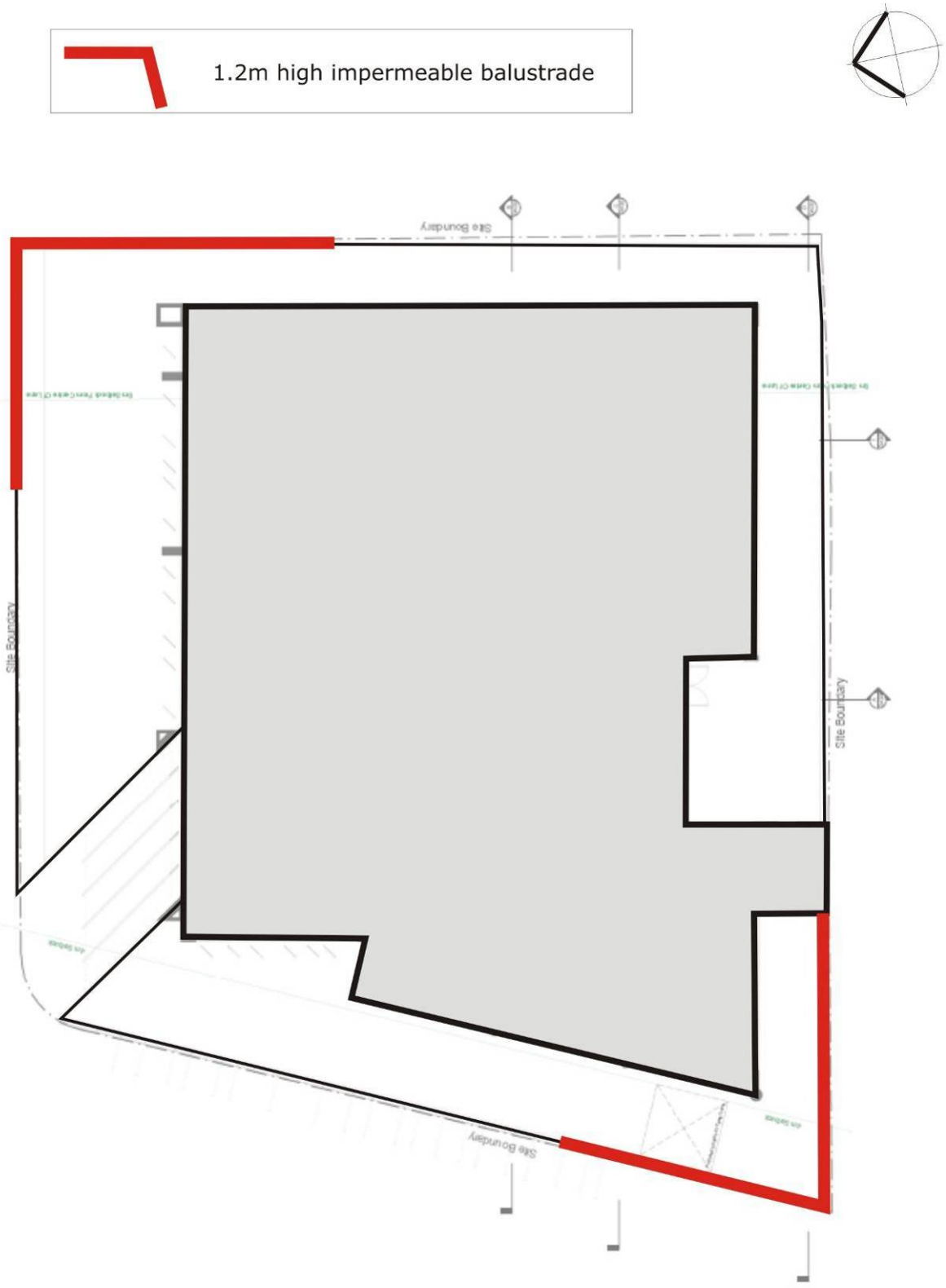


**Figure 7a: Recommended Minimum Treatments**
**Level 3 (office terrace areas)**

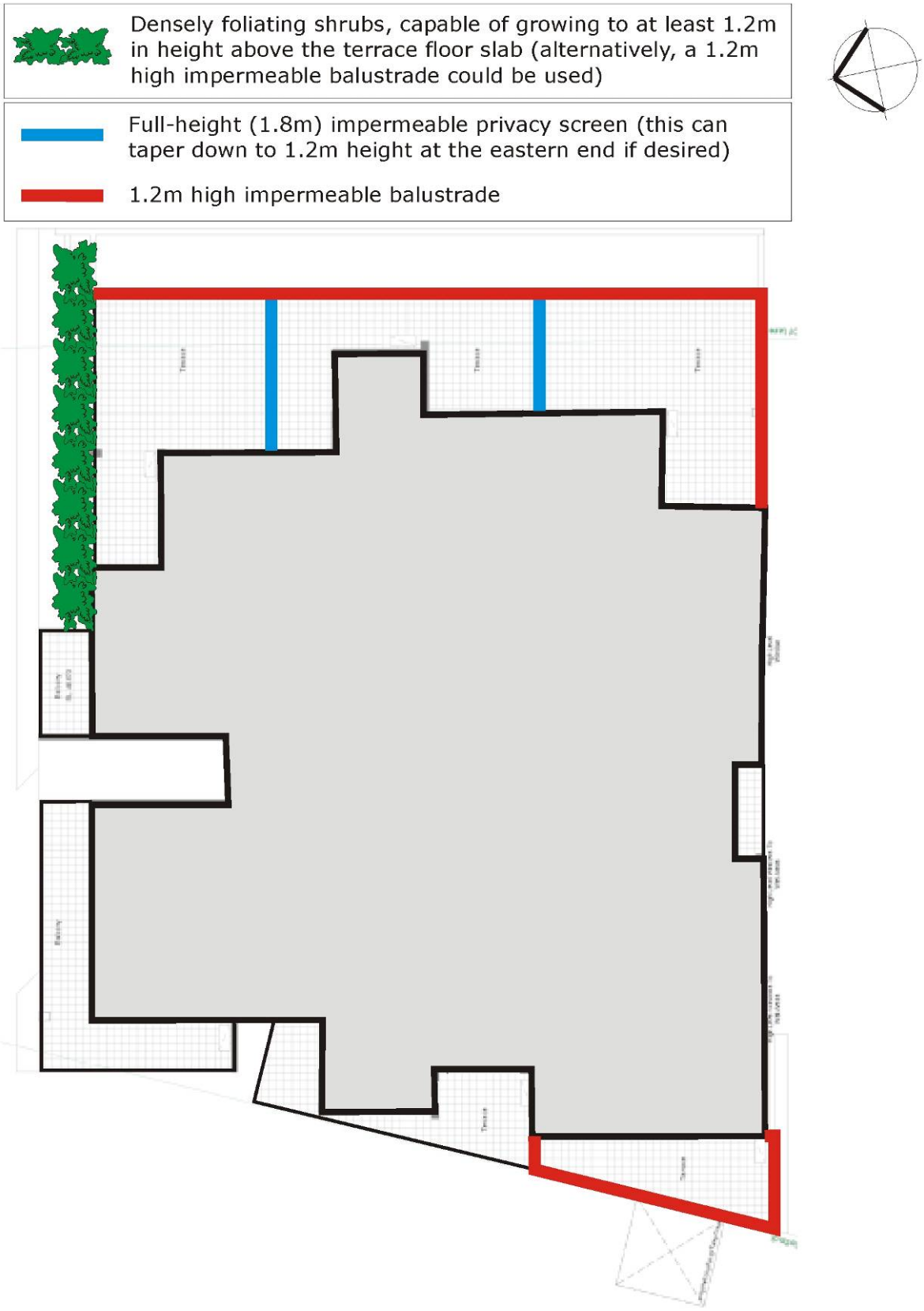


**Figure 7b: Recommended Minimum Treatments**
**Level 5 Private Terraces**

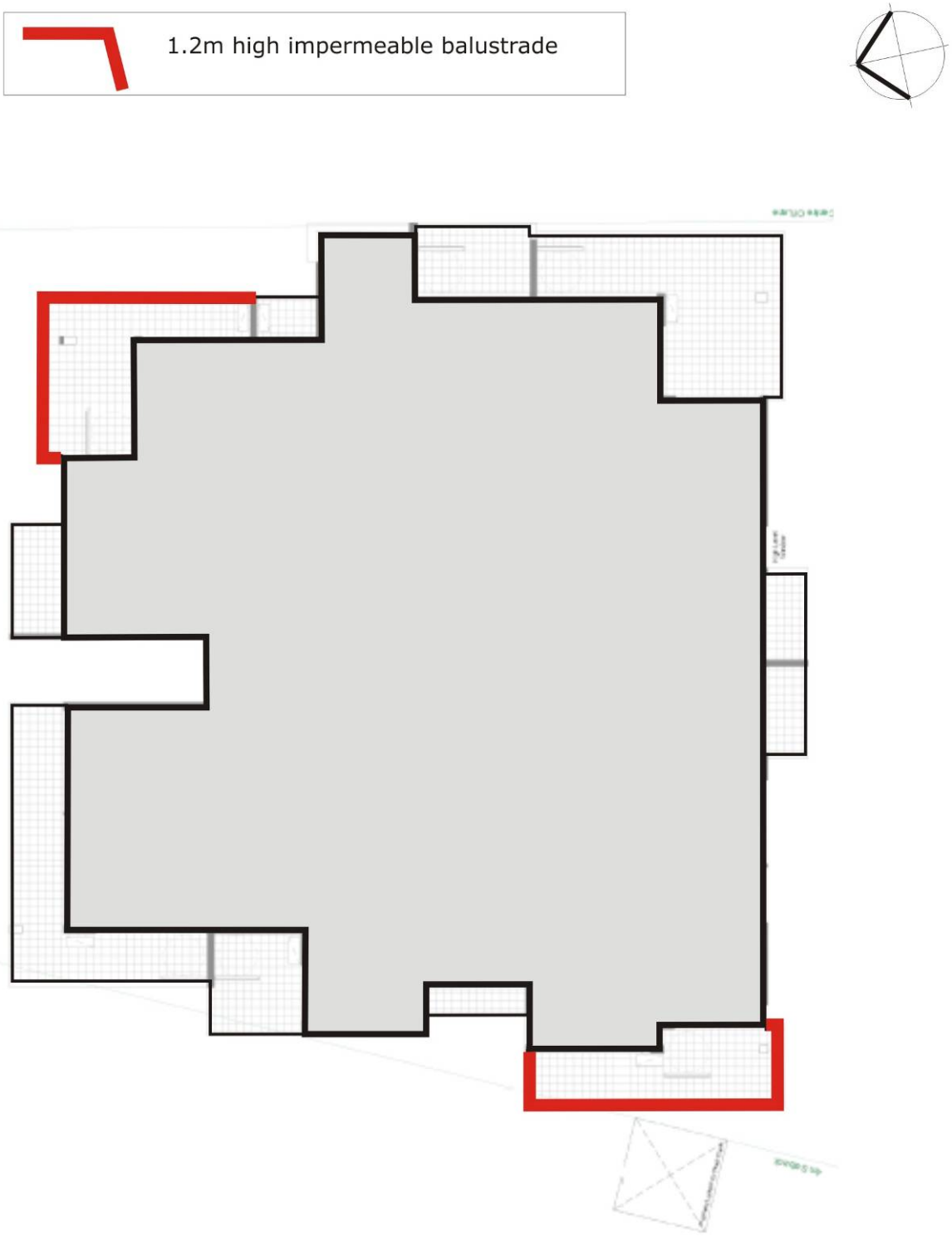


**Figure 7c: Recommended Minimum Treatments for all of the Private Balconies and Terraces of the Tower**

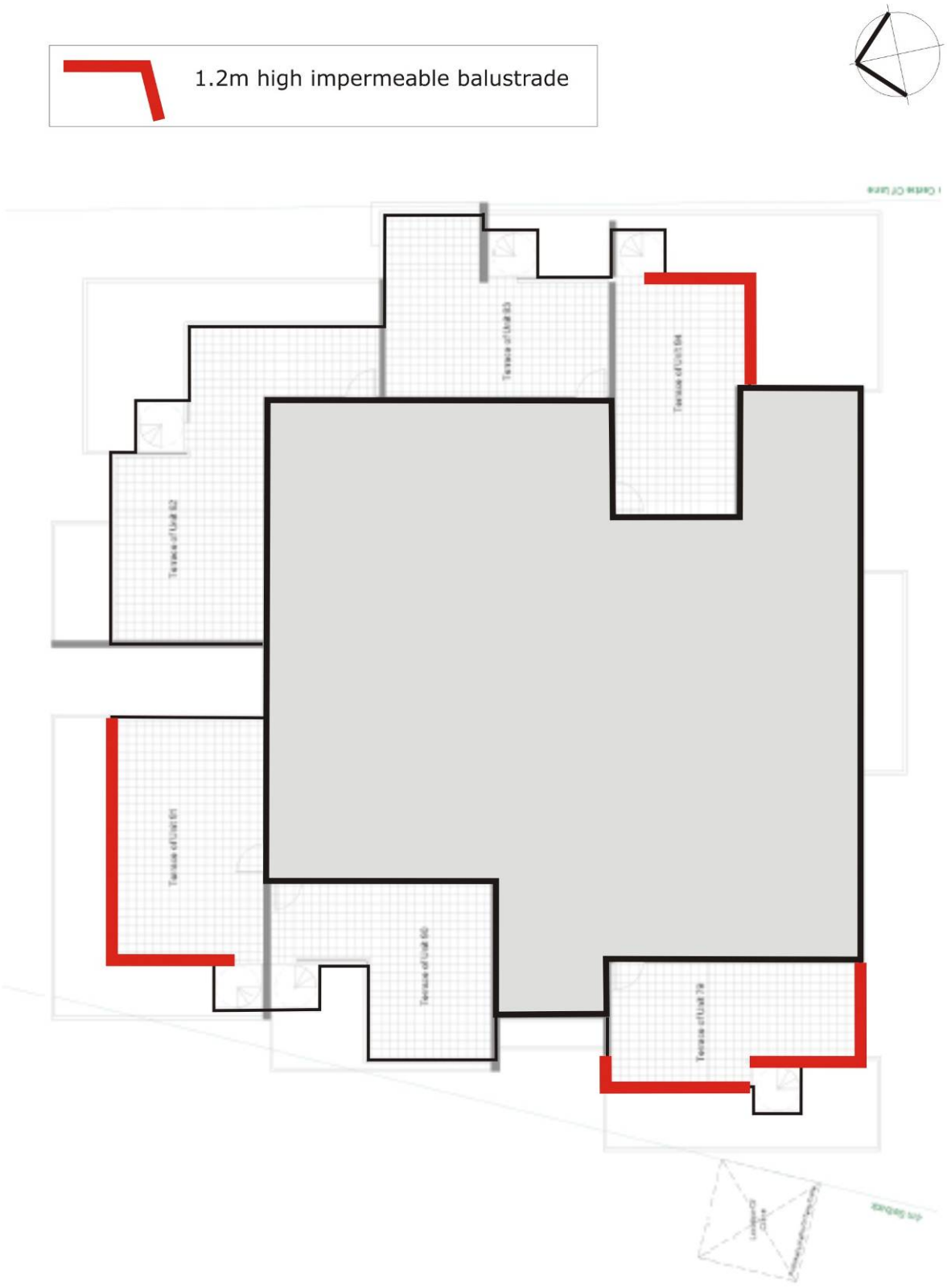


**Figure 7d: Recommended Minimum Treatments**
**Level 19 (roof terrace areas)**

## 6.0 Conclusion

A wind tunnel study has been carried out to investigate the wind environment effects pertaining to the proposed development at 157 Redfern Street, Redfern. The site is located at the corner of Gibbons and Redfern Streets, with the site being bounded by Redfern Street to the north and Gibbons Street to the east. The proposed development consists of 4 commercial and retail levels and 14 residential floors with the top level of residential level 18 having a roof terrace. It is proposed that the podium levels of the development will be used for commercial office use, and the Redfern RSL Club. The overall height of the development will be approximately 65m above the Redfern Street ground level.

Wind speed measurements were carried out using a 1:300 scale model of the proposed 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. Wind speed measurements for the ground level areas were also tested for the existing site wind conditions for comparison.

Testing was performed using Windtech's boundary layer wind tunnel facility. Peak gust and mean 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.

The results of the study indicate that the existing wind conditions along Redfern Street are particularly strong, and exceed criteria for comfortable pedestrian activity. The existing site wind conditions along Gibbons Street satisfy criteria for comfortable pedestrian activity. With the addition of the proposed development, the results of the study indicate that wind conditions along Redfern Street will be improved so that the criteria for comfortable pedestrian activity are satisfied. Wind conditions along Gibbons Street will be equivalent to the existing conditions, which are acceptable for comfortable pedestrian activity.

Wind conditions for the various outdoor terraces and balconies of the proposed development have been tested, and a set of the minimum recommended treatments have been made in this report to ensure that suitable wind conditions are achieved for all trafficable outdoor areas. The minimum recommended treatments are summarised as follows:

- 1.2m high impermeable balustrades around the north-eastern and south-western corners of the Level 3 office terrace areas, and around the south-western corner terrace of Level 5.
- 1.2m high impermeable balustrades along the perimeter of the three private terraces on the eastern aspect of Level 5, and a densely foliating row of shrubs along the northern edge of the north-eastern private terrace capable of growing to at least 1.2m high above the terrace floor slab. Note that the shrubs could be replaced by an impermeable balustrade of equivalent height if desired.
- 1.8m high impermeable privacy screens separating the three private

terraces on the eastern aspect of Level 5. These can taper down to the balustrade height of 1.2m at the eastern edge if desired.

- 1.2m high impermeable balustrades around the south-western and north-eastern corner balconies on the typical levels of the tower.
- 1.2m high impermeable balustrades around the south-eastern, south-western and north-western corner terraces on Level 19.

It is expected that wind conditions to the various balconies and terraces of the proposed development can be further enhanced if impermeable balustrades are used on the perimeter of all trafficable areas, or if taller balustrades or screens are used in place of those recommended in this report. However, with the inclusion of the list of treatments above into the final design, wind conditions for all outdoor areas within and around the proposed development will be acceptable for the intended uses.

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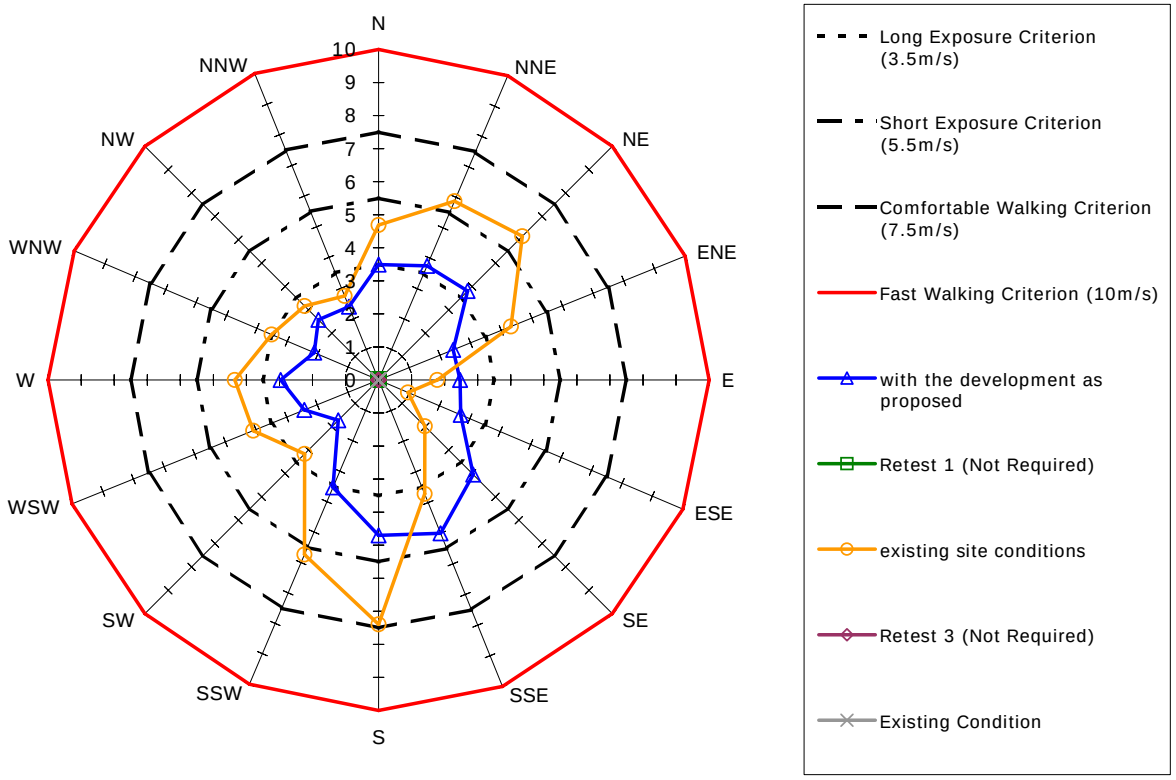
# Appendix A

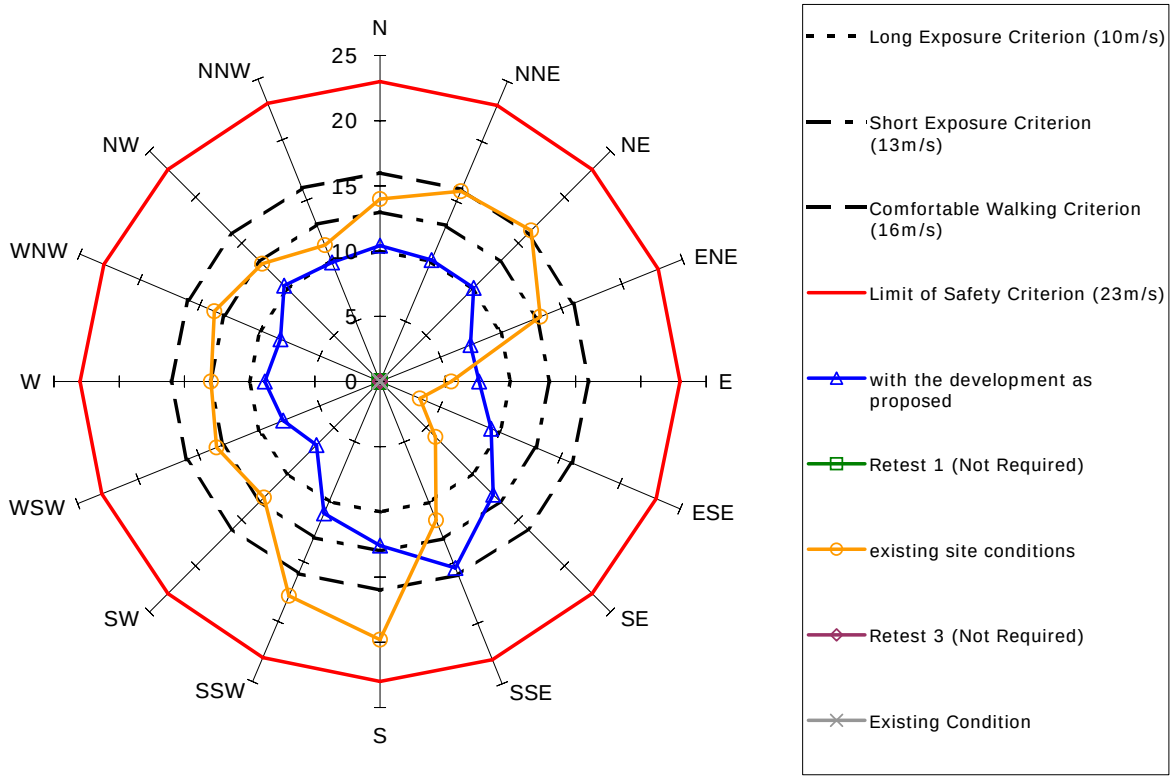
Plots of Wind Tunnel Results

# Measured Wind Speeds at Point 01

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

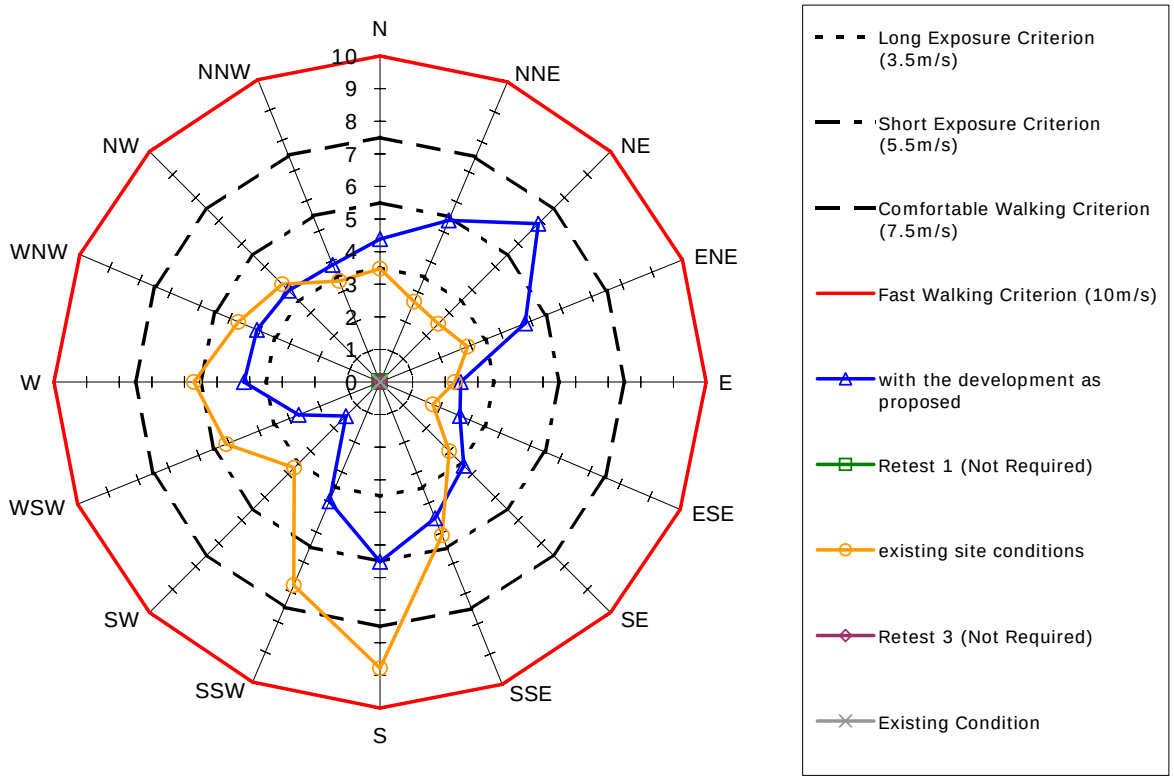



## Annual Maximum Gust Wind Speeds (m/s)

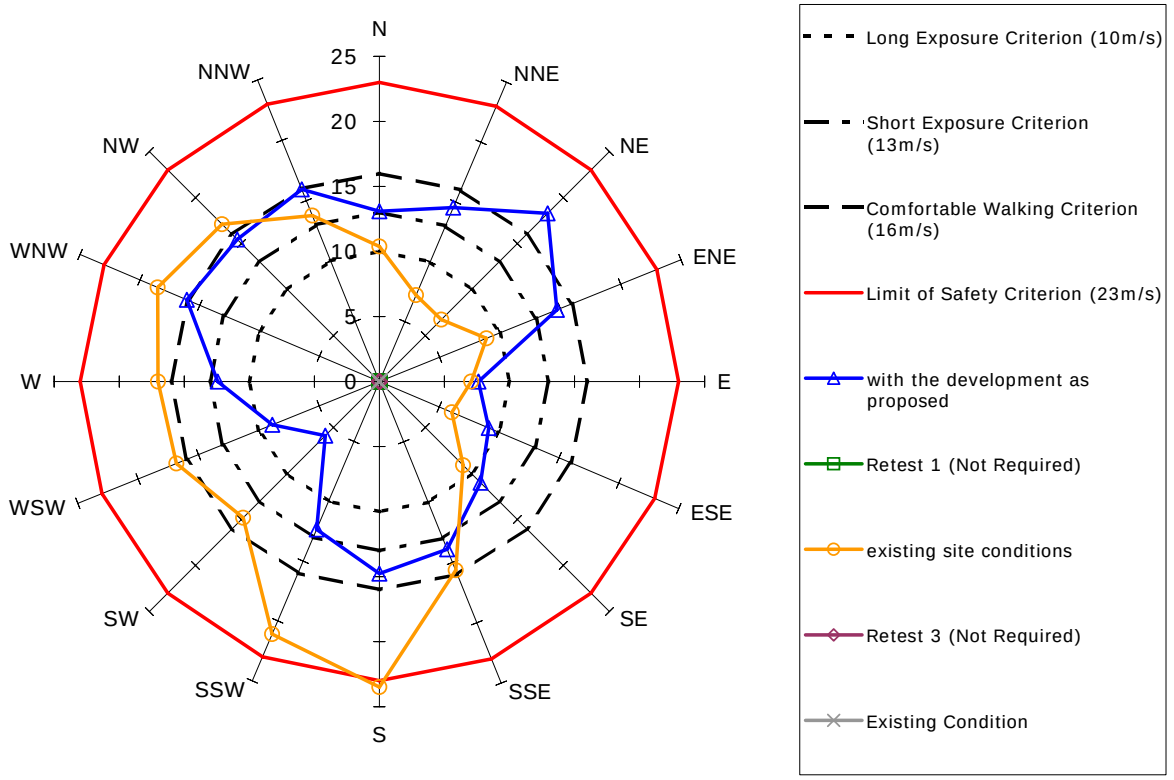


# Measured Wind Speeds at Point 02

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

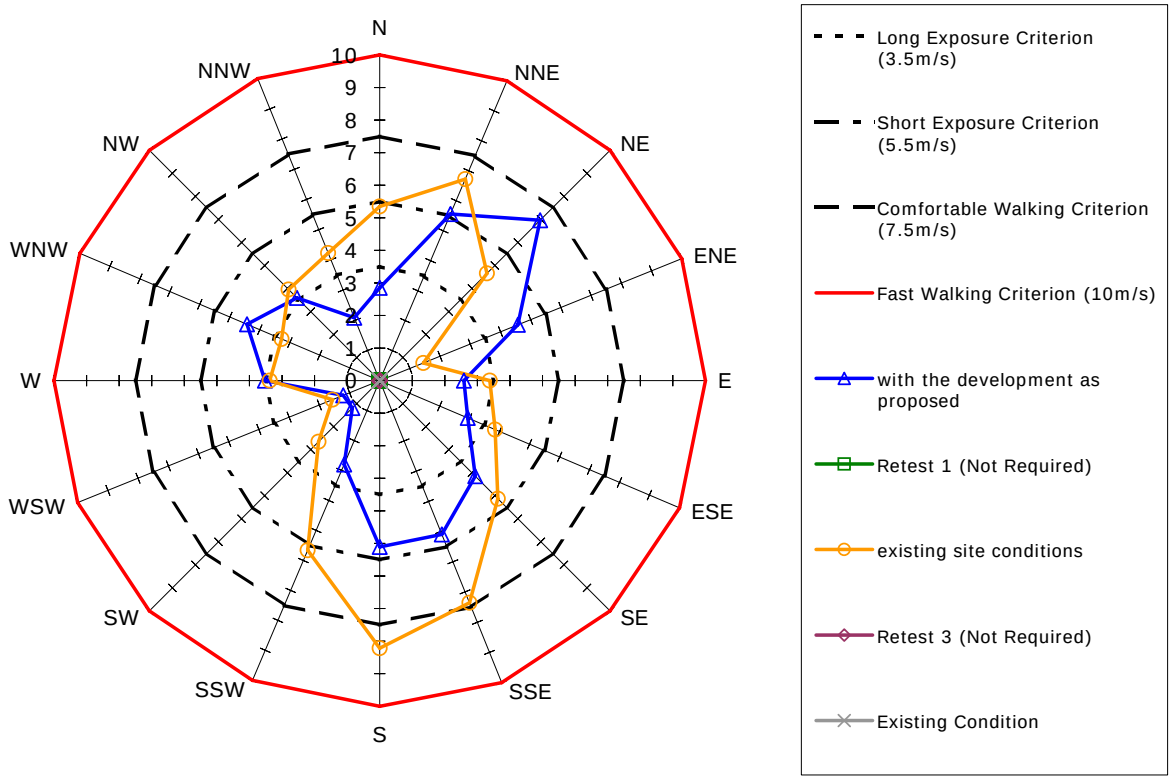



## Annual Maximum Gust Wind Speeds (m/s)

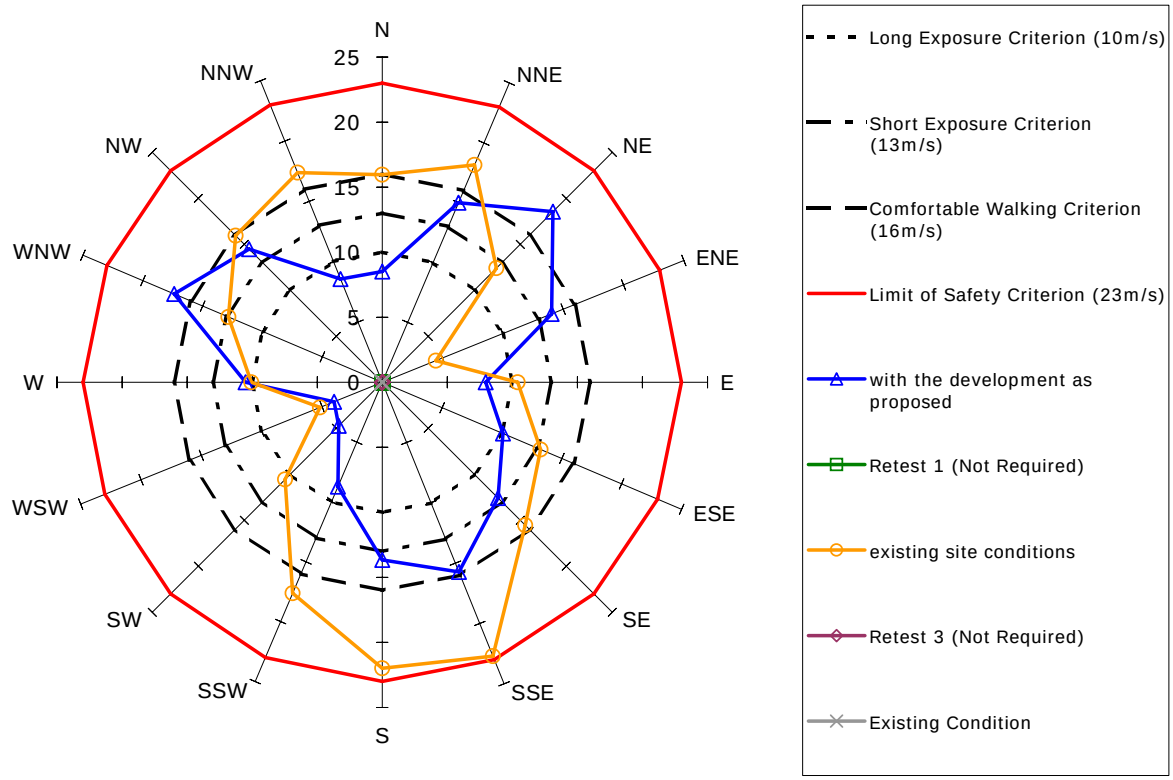


# Measured Wind Speeds at Point 03

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

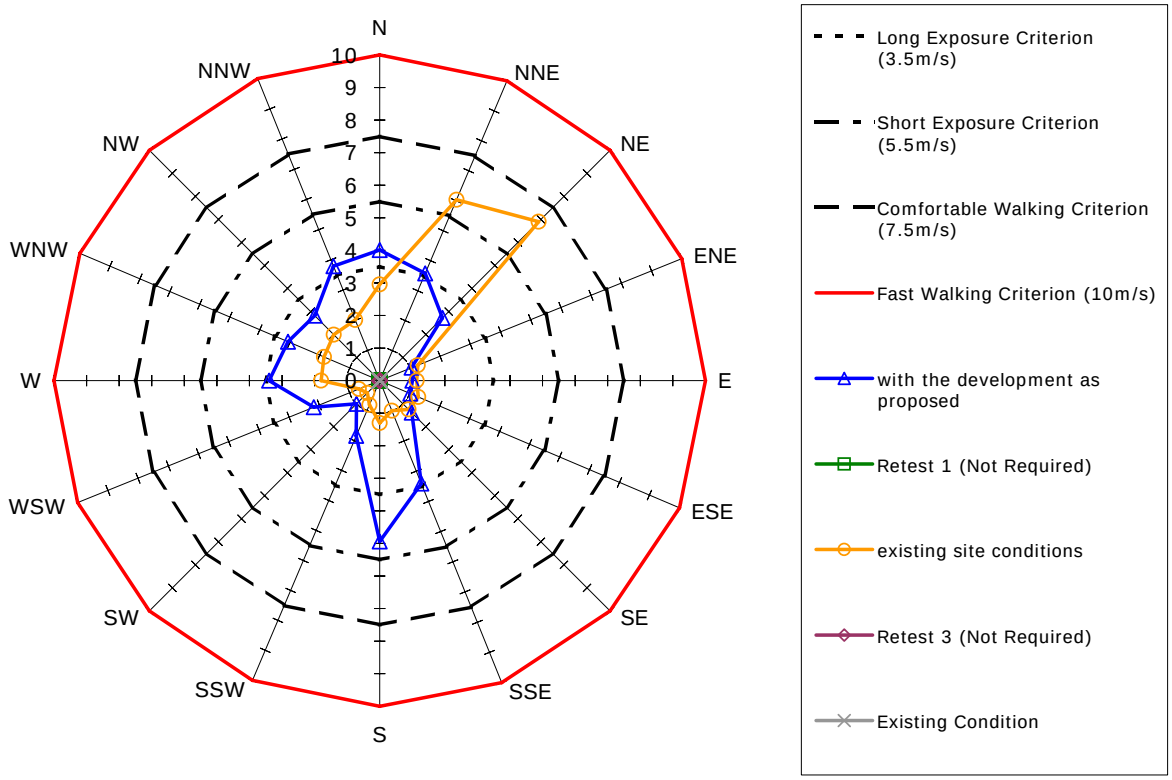



## Annual Maximum Gust Wind Speeds (m/s)

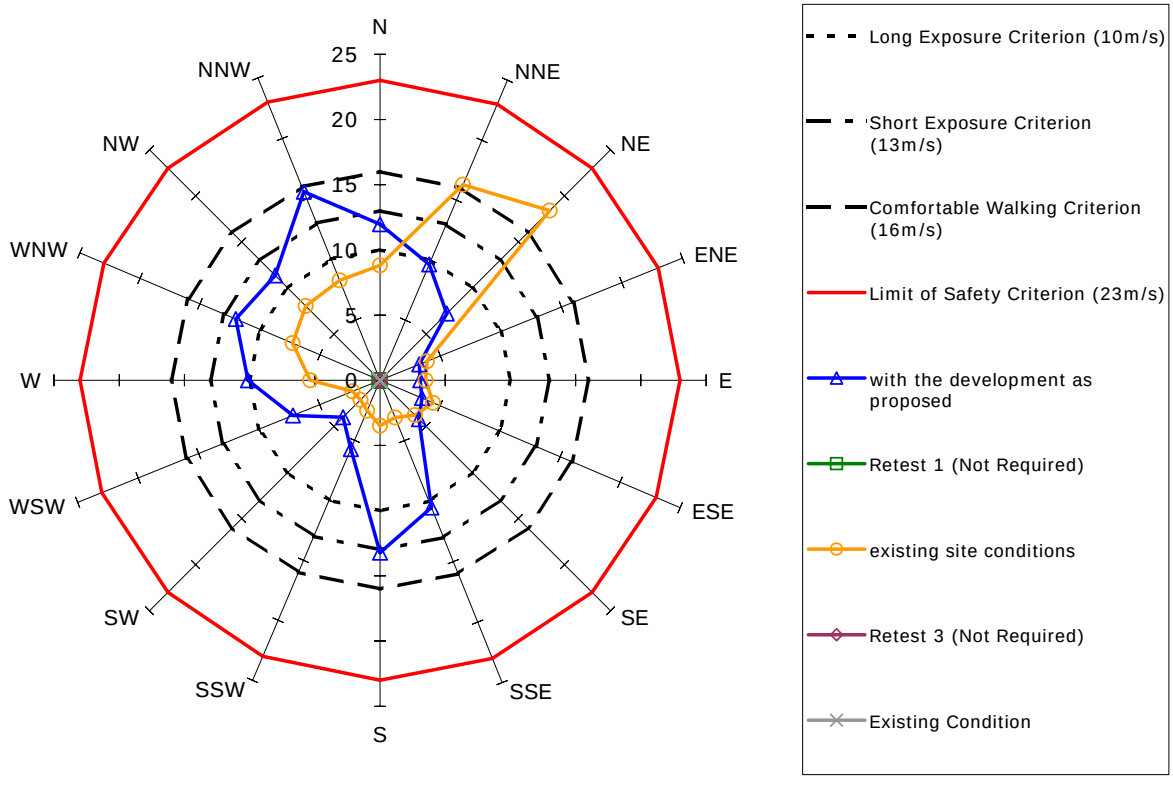


# Measured Wind Speeds at Point 04

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




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



# Measured Wind Speeds at Point 05

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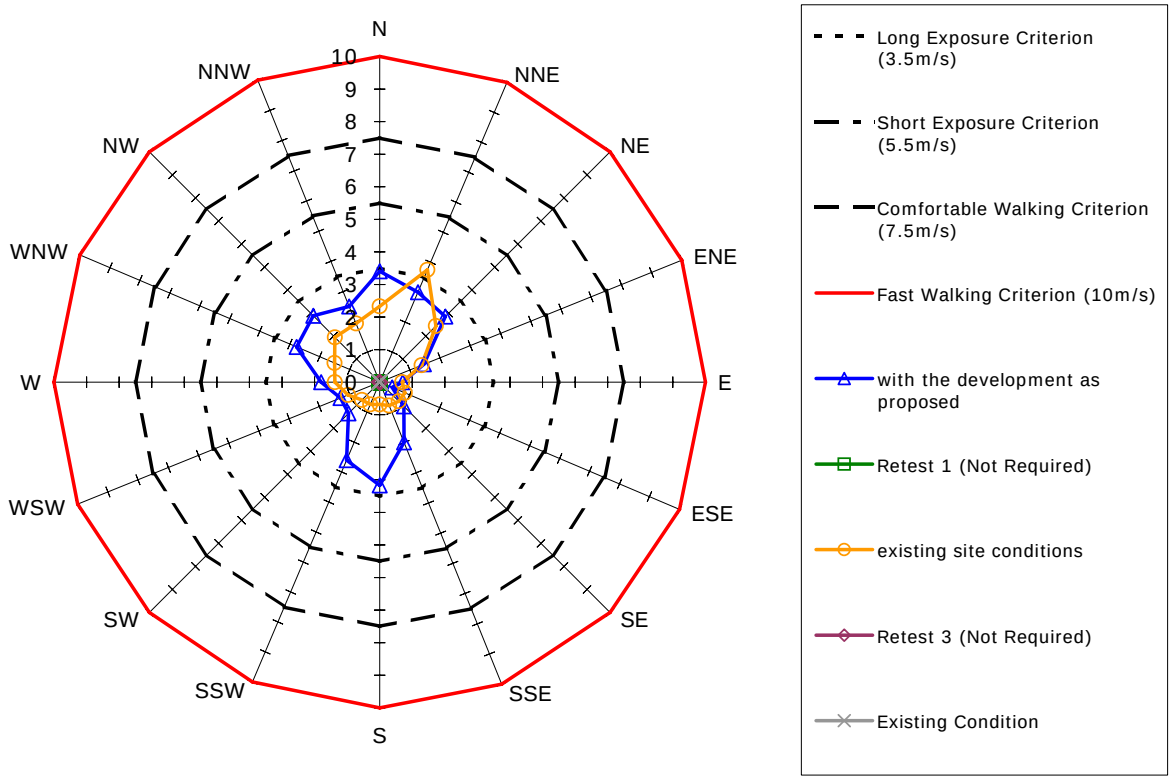


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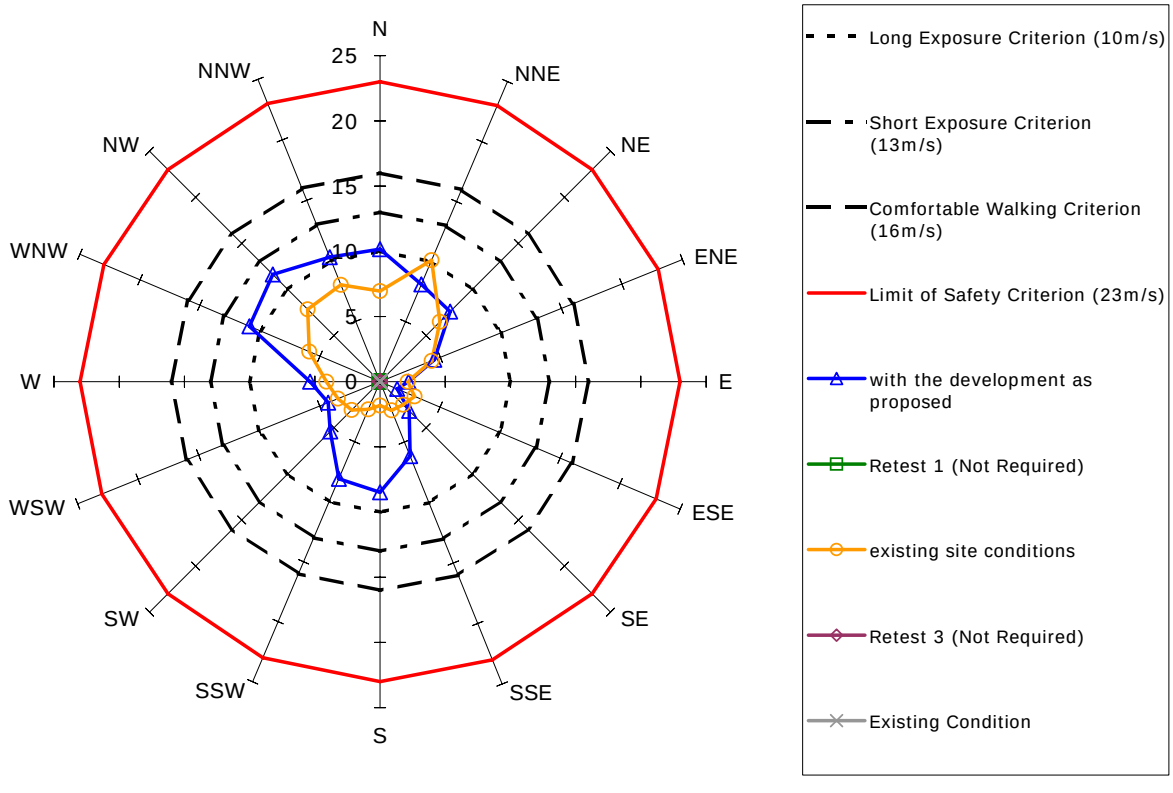
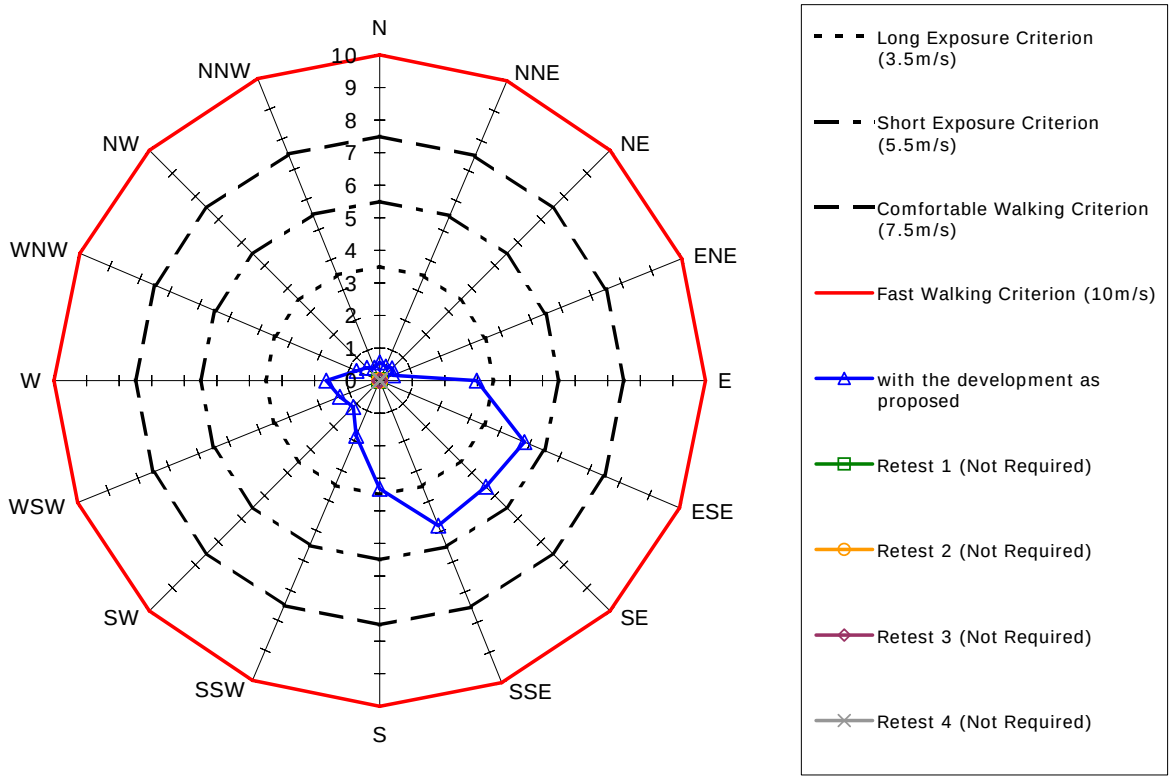
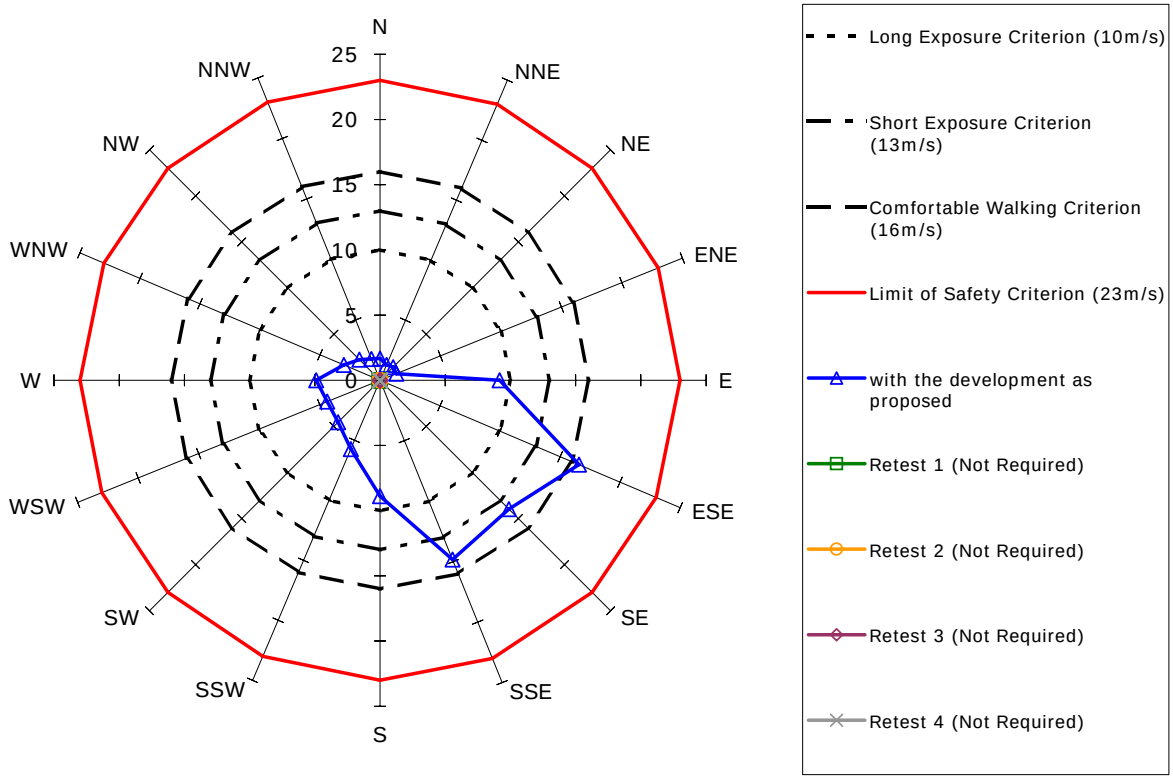


# Measured Wind Speeds at Point 06

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

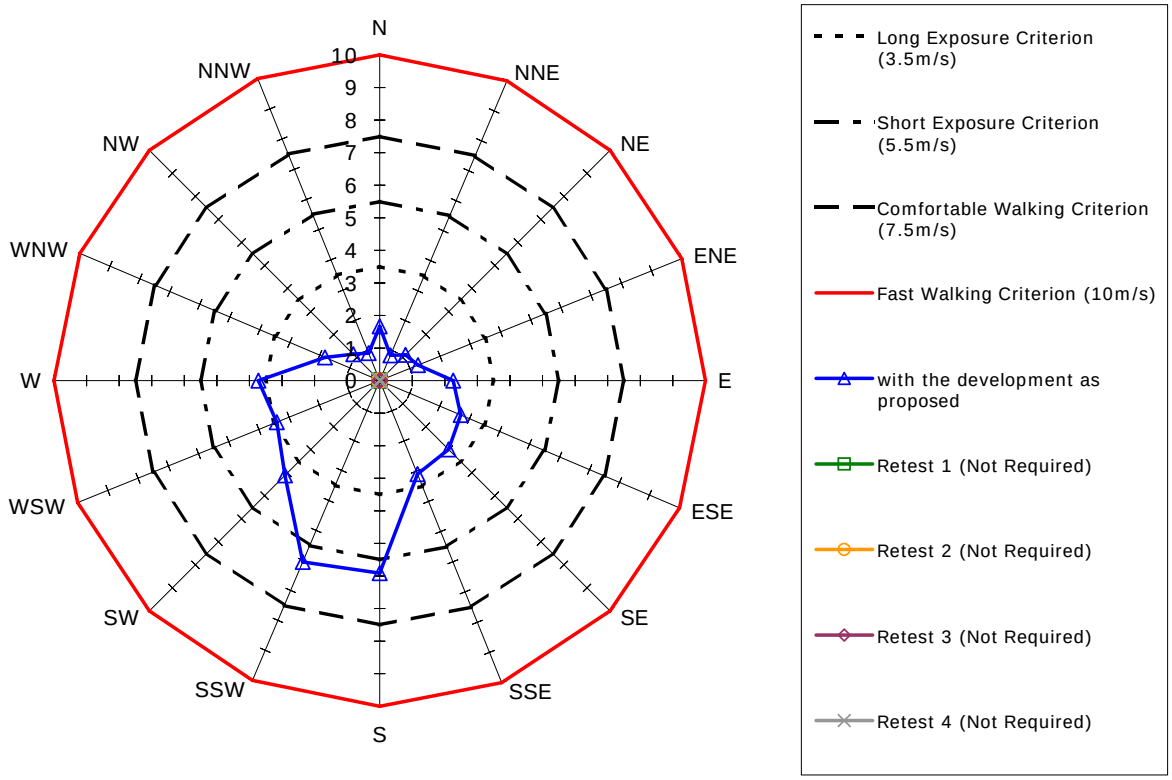



## Annual Maximum Gust Wind Speeds (m/s)

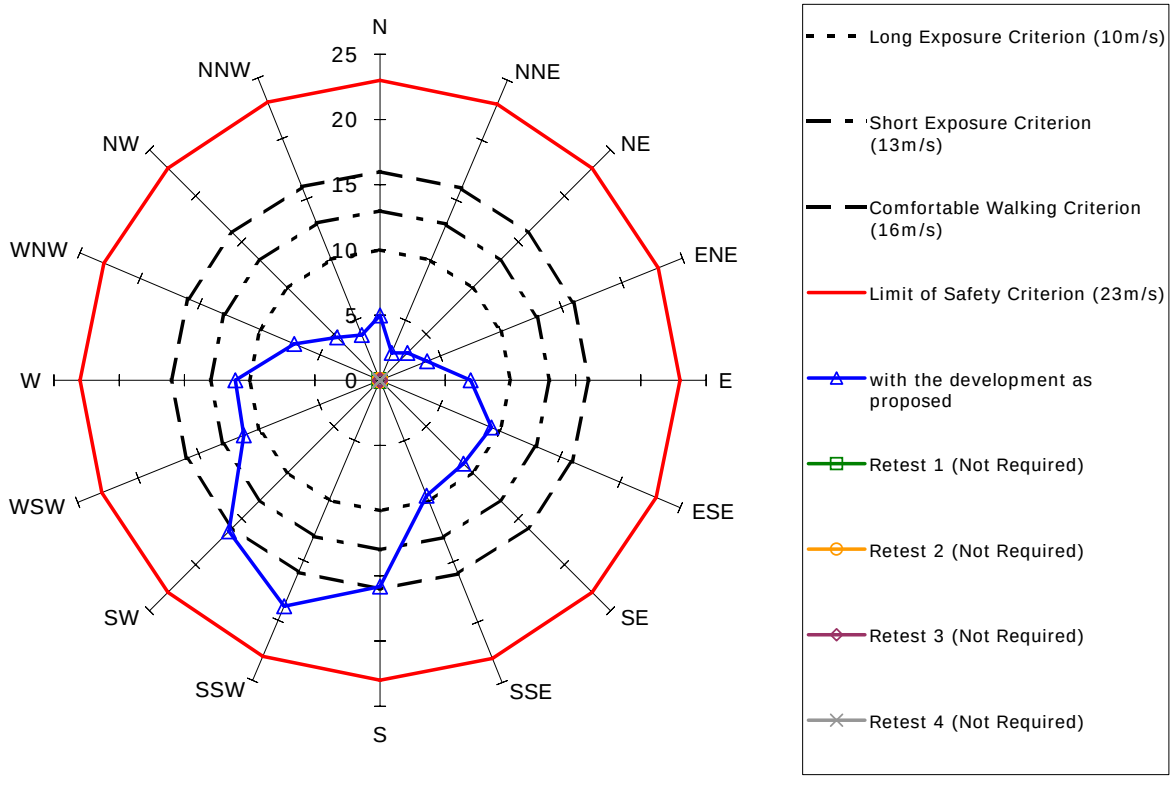


# Measured Wind Speeds at Point 07

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




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



# Measured Wind Speeds at Point 08

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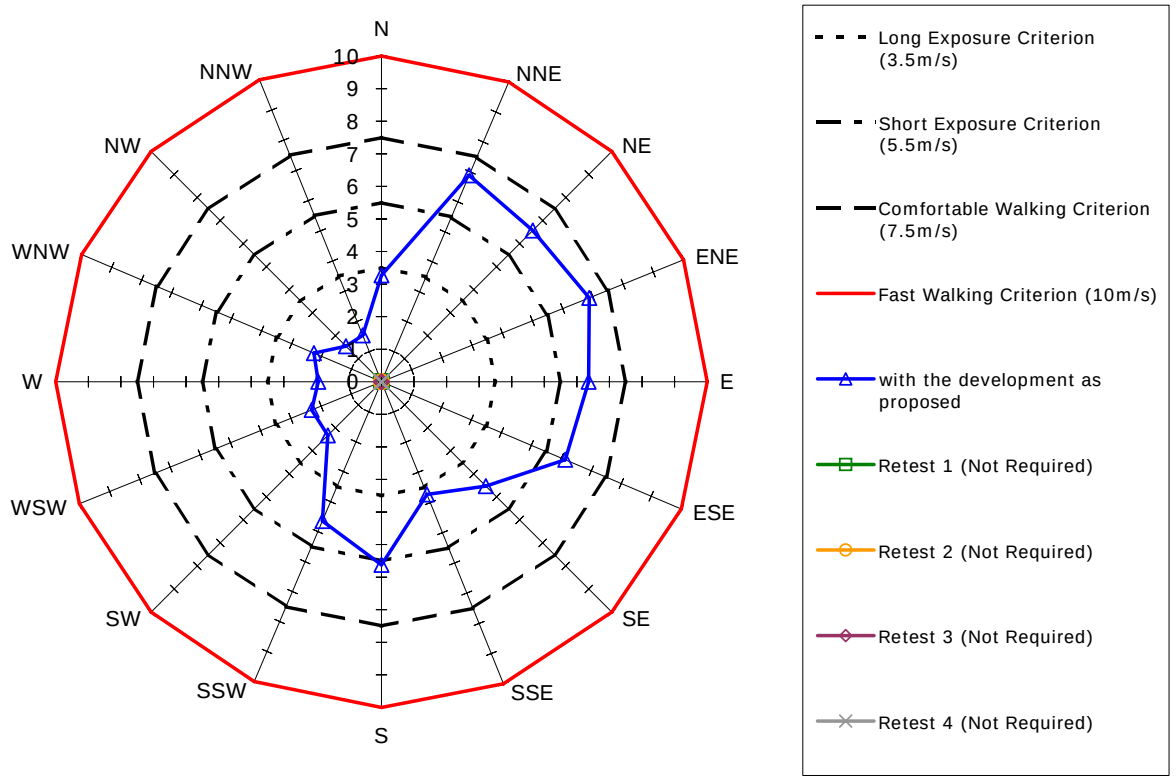


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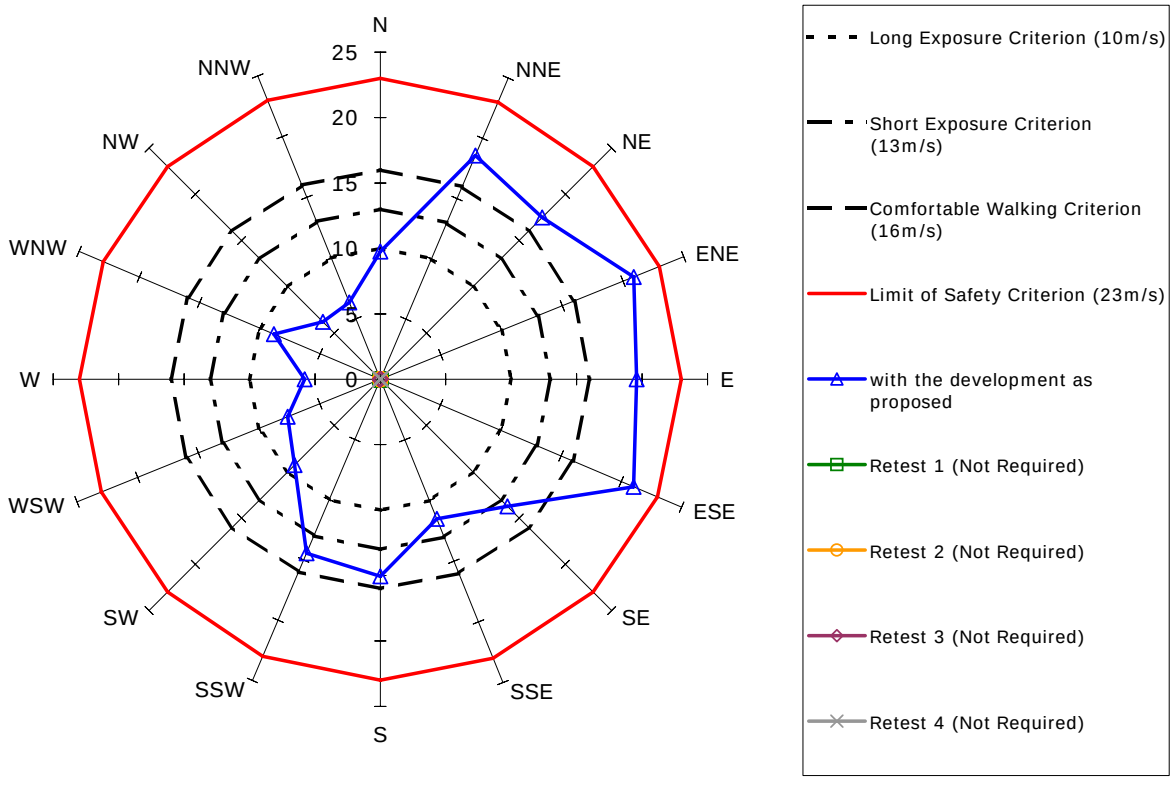

# Measured Wind Speeds at Point 09

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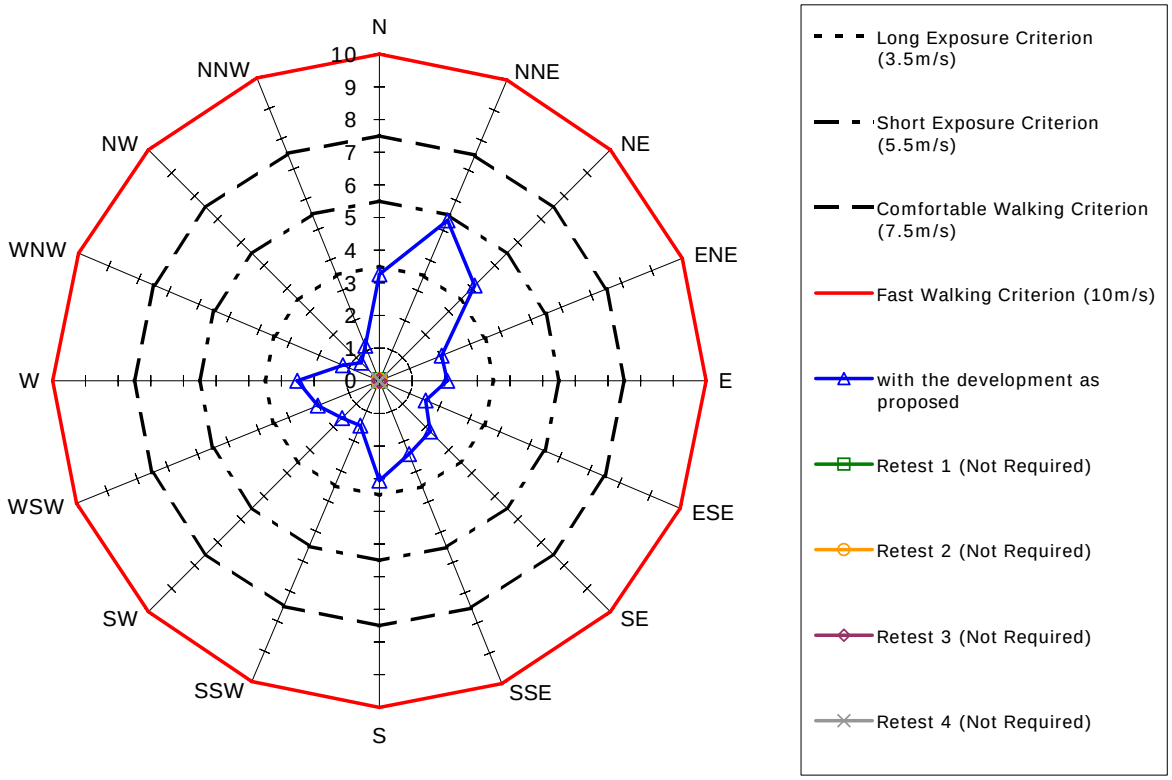


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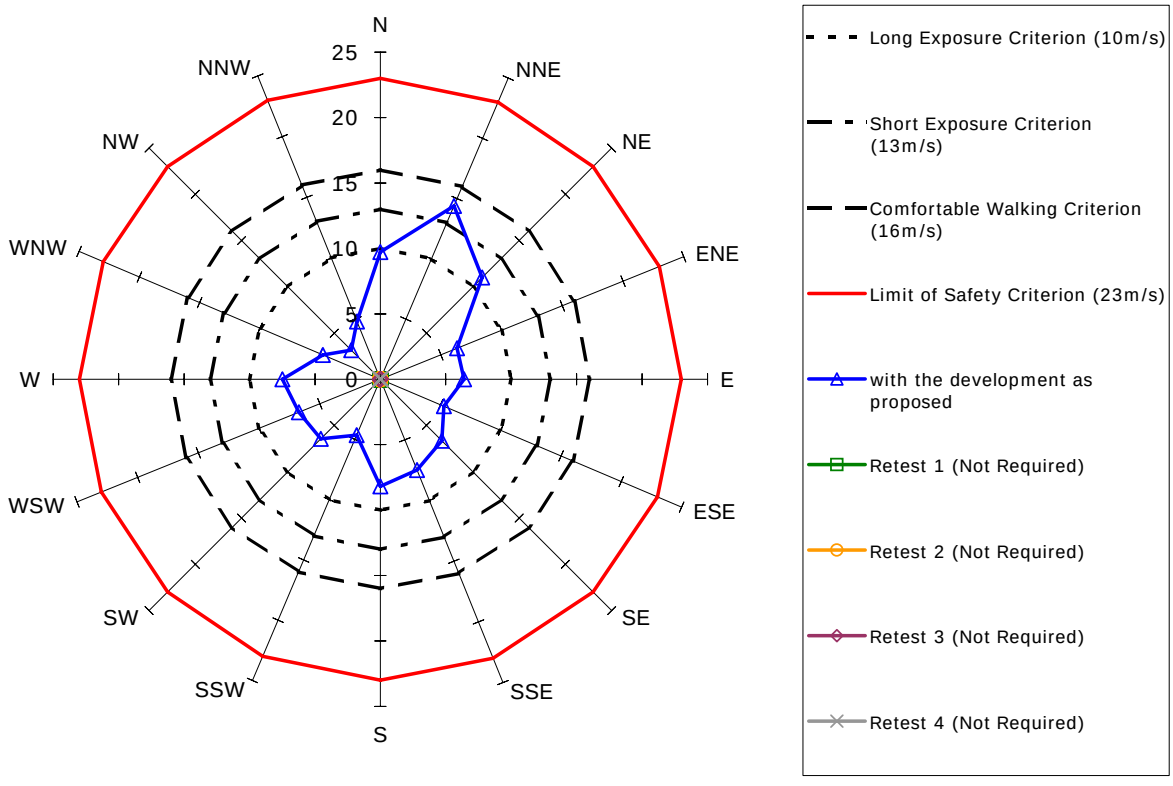

# Measured Wind Speeds at Point 10

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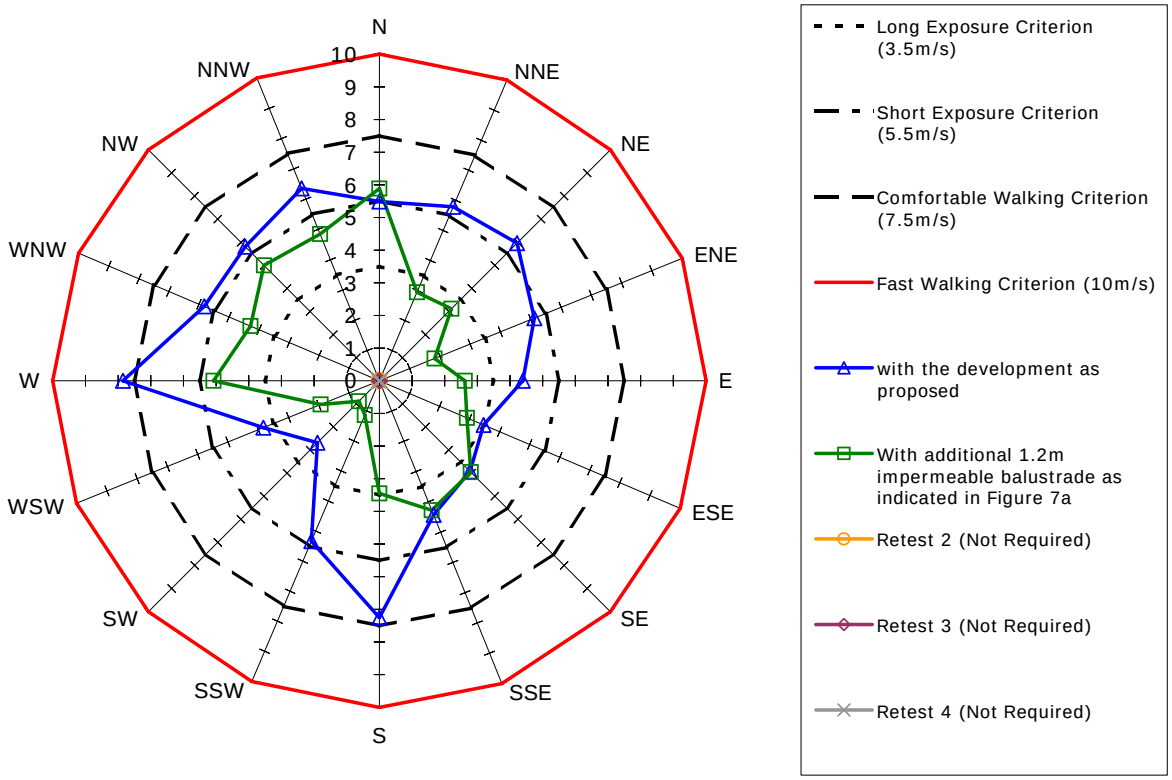


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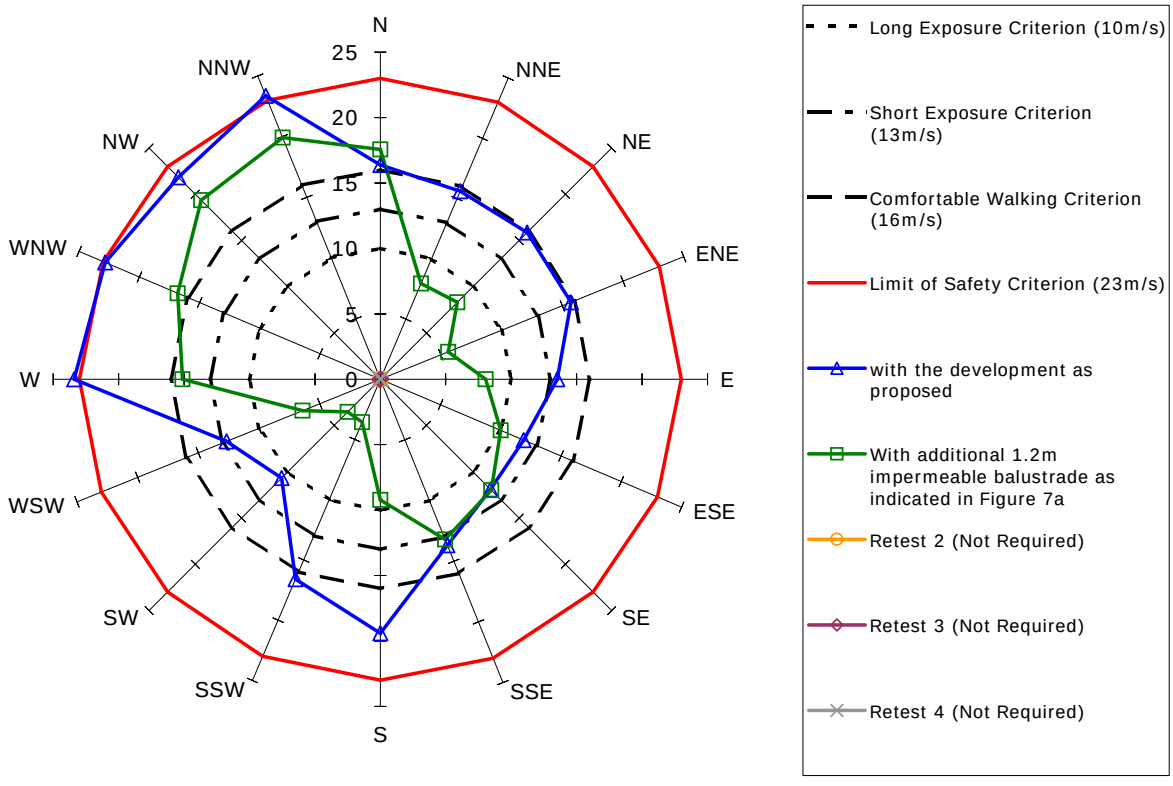

# Measured Wind Speeds at Point 11

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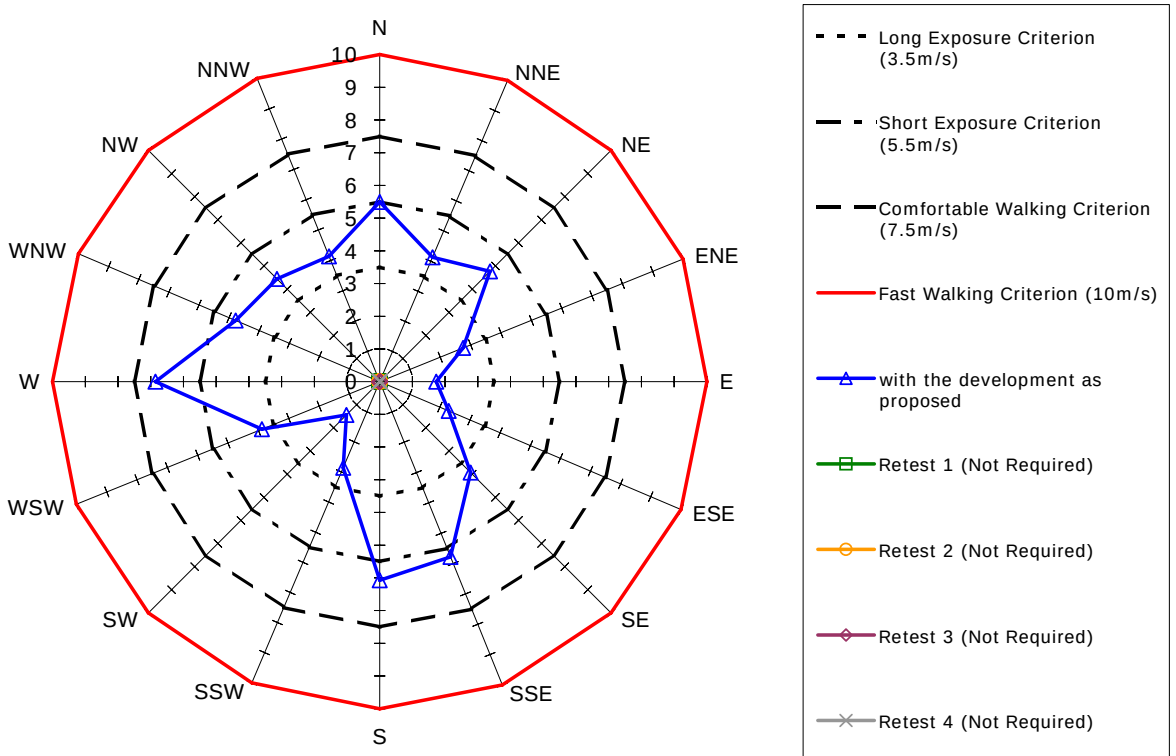
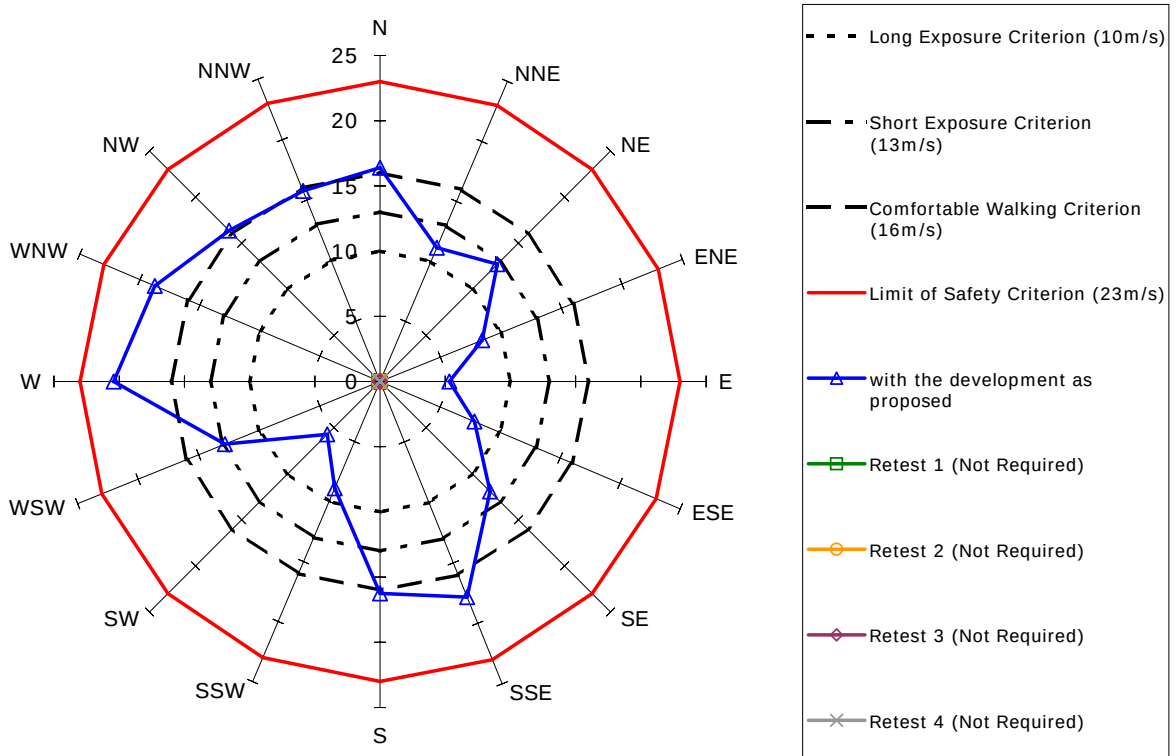



## Annual Maximum Gust Wind Speeds (m/s)



# Measured Wind Speeds at Point 12

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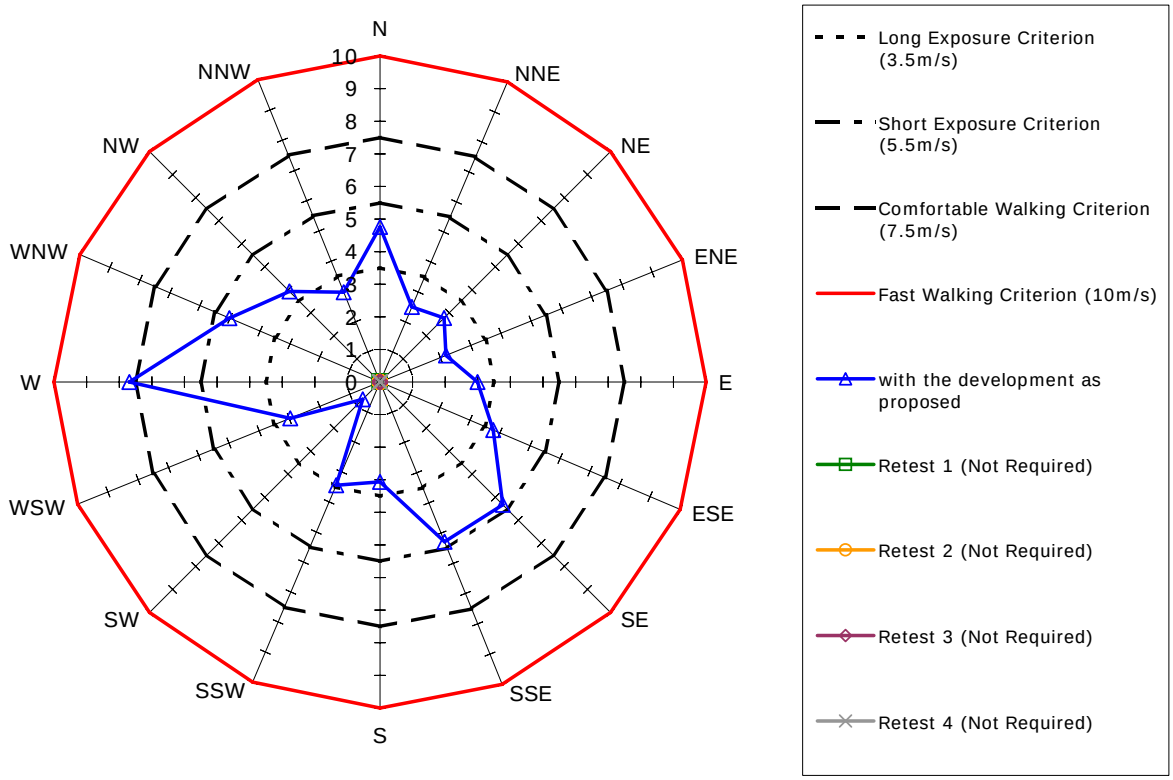
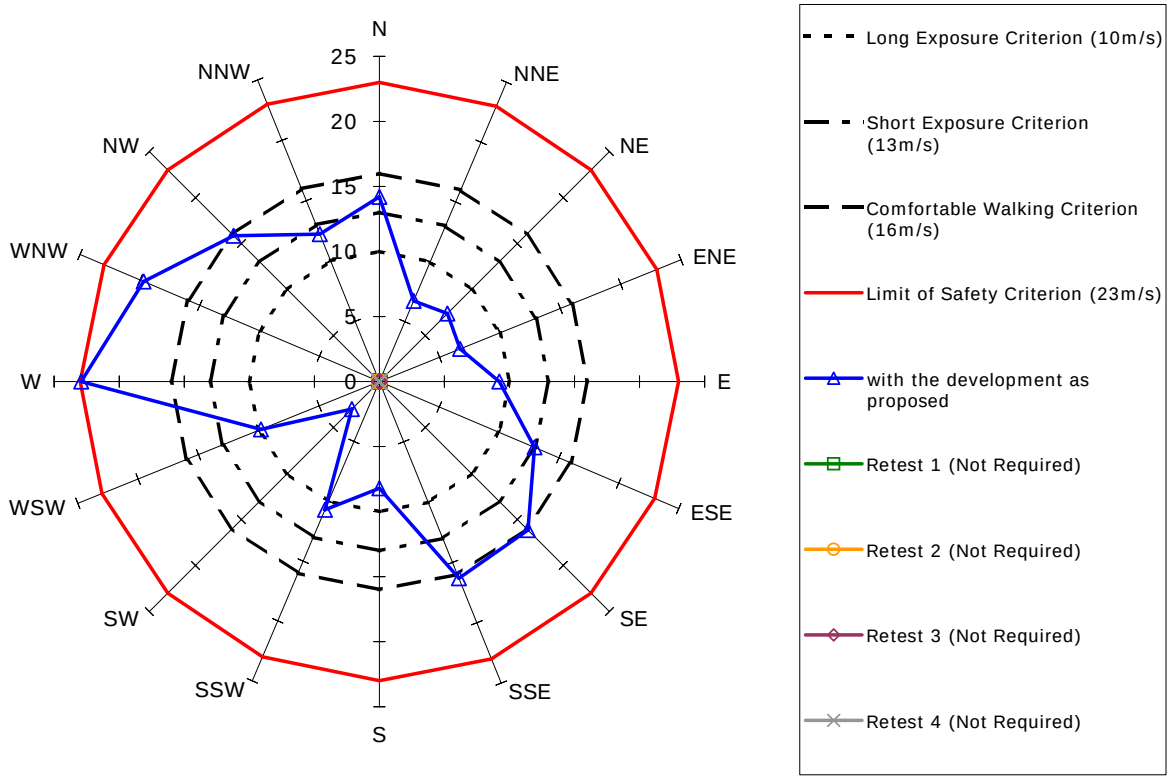



## Annual Maximum Gust Wind Speeds (m/s)



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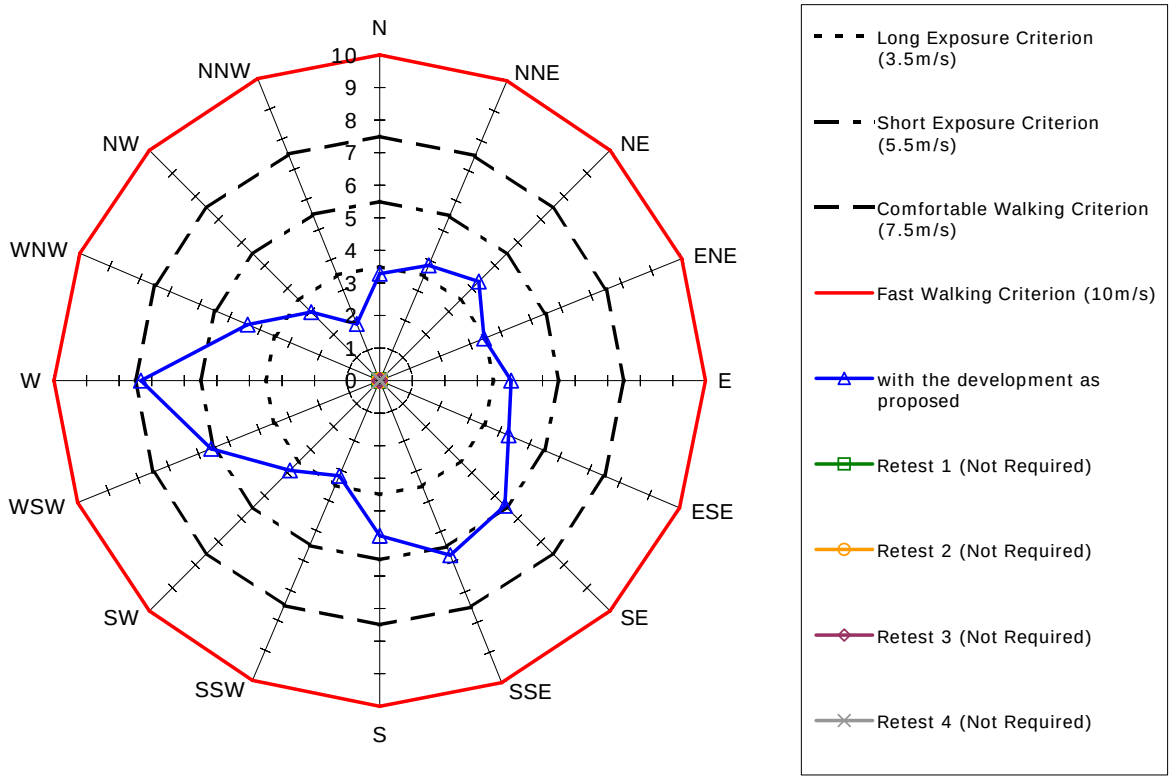
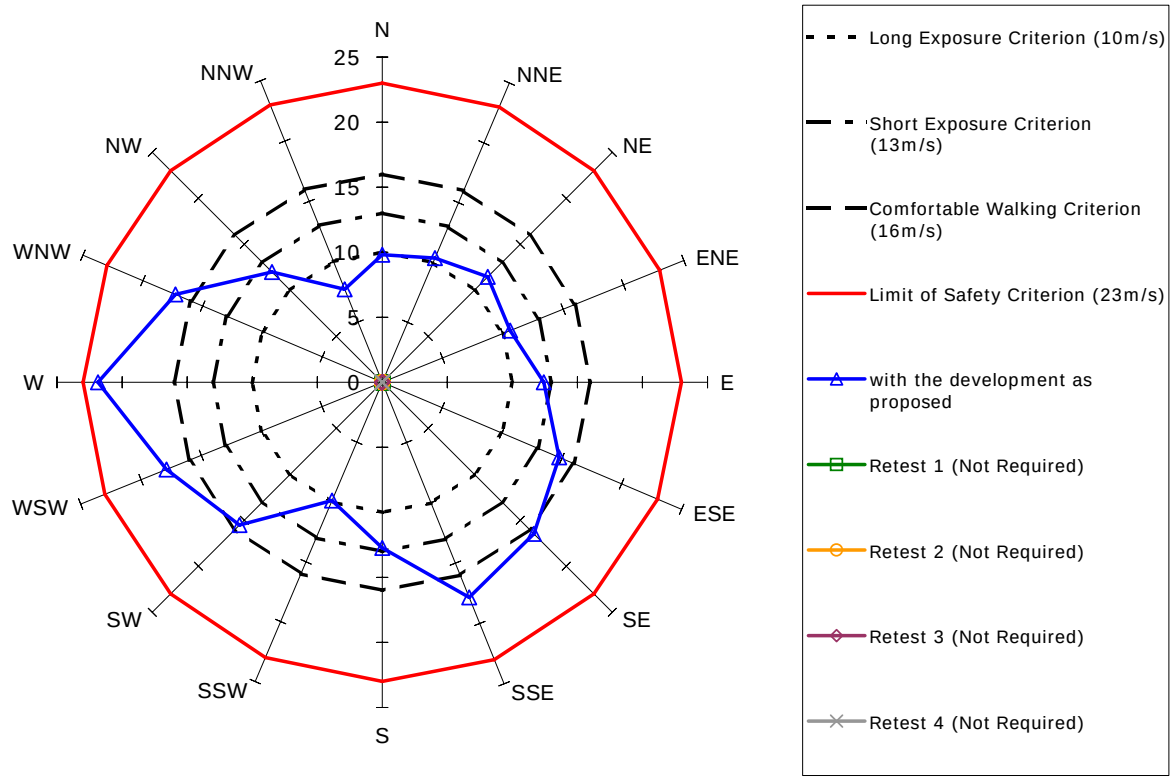
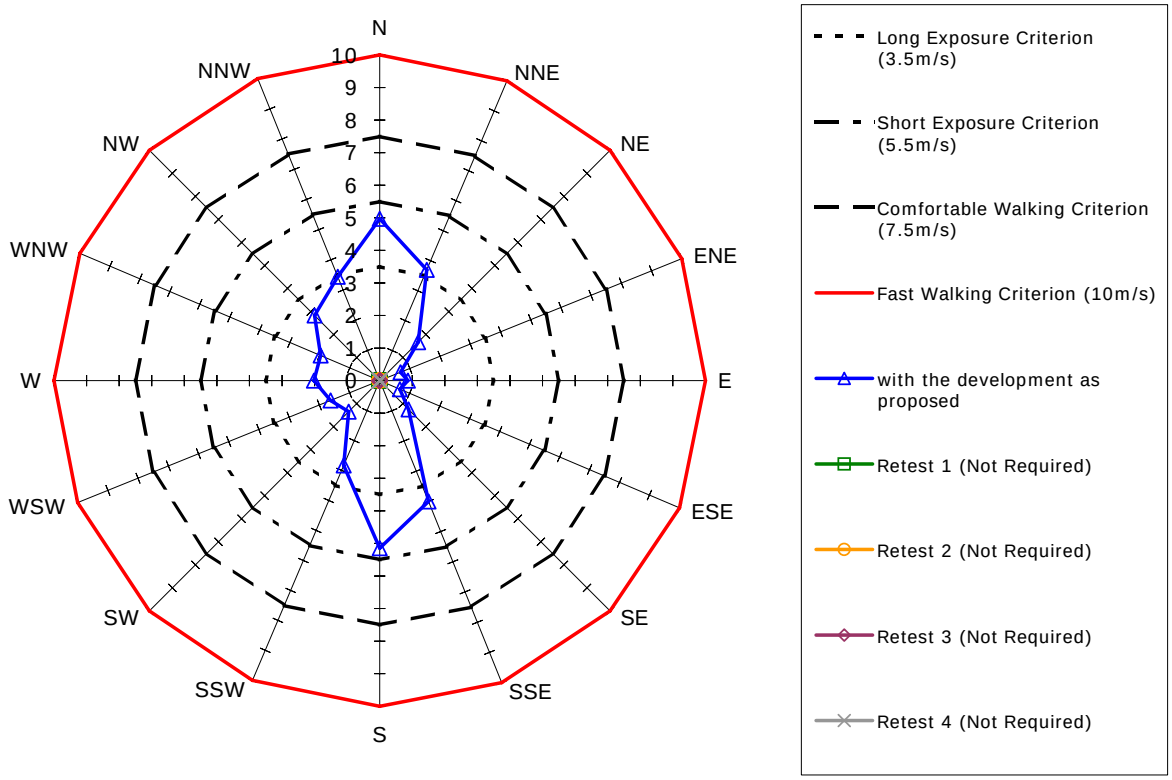



## Annual Maximum Gust Wind Speeds (m/s)

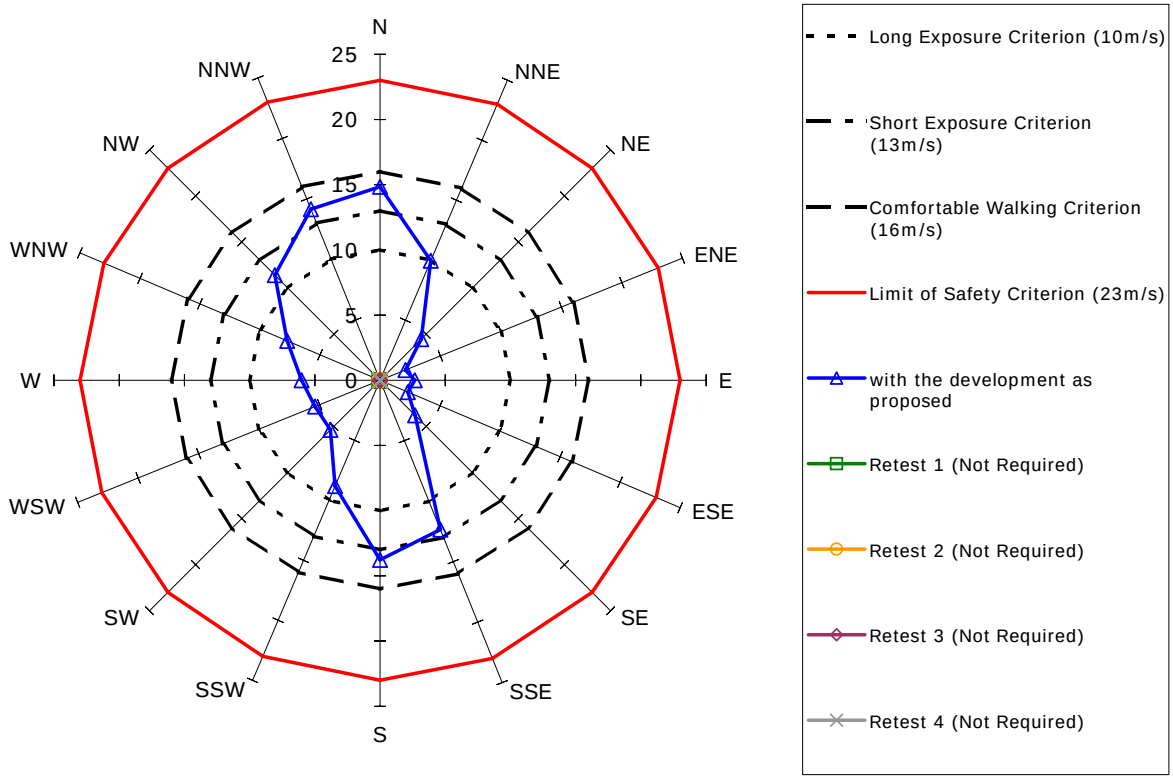


# Measured Wind Speeds at Point 14

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

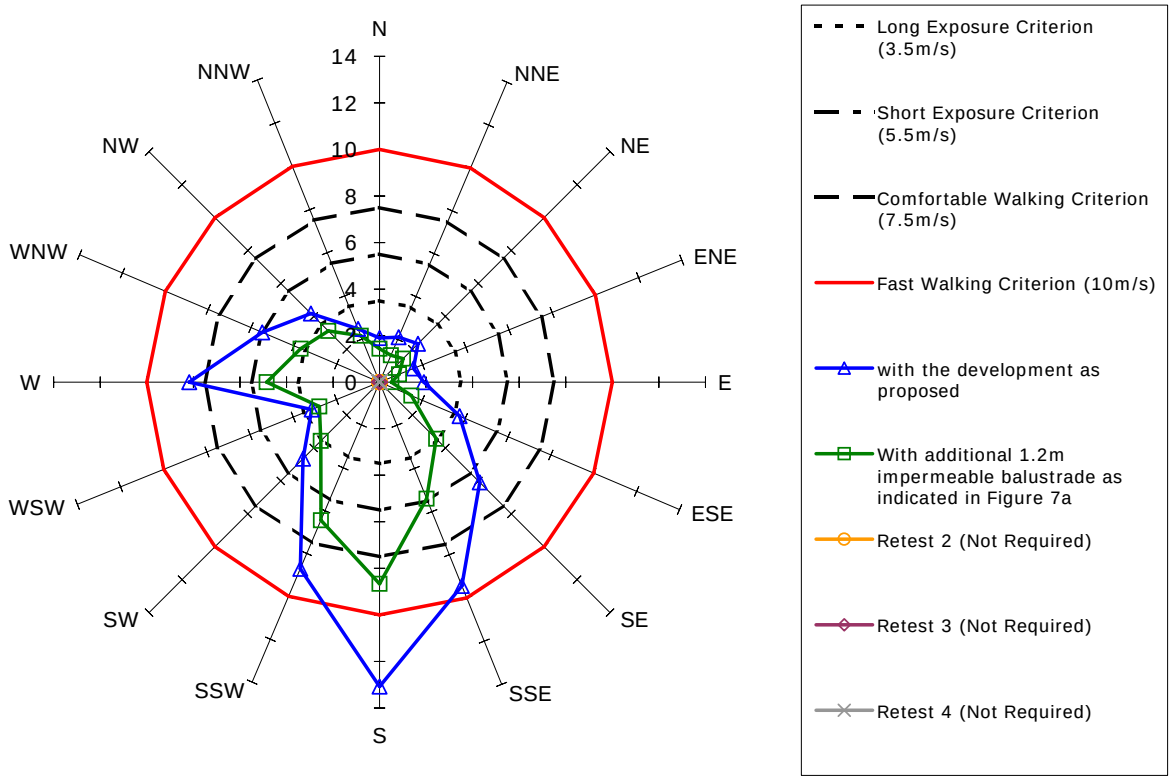



## Annual Maximum Gust Wind Speeds (m/s)

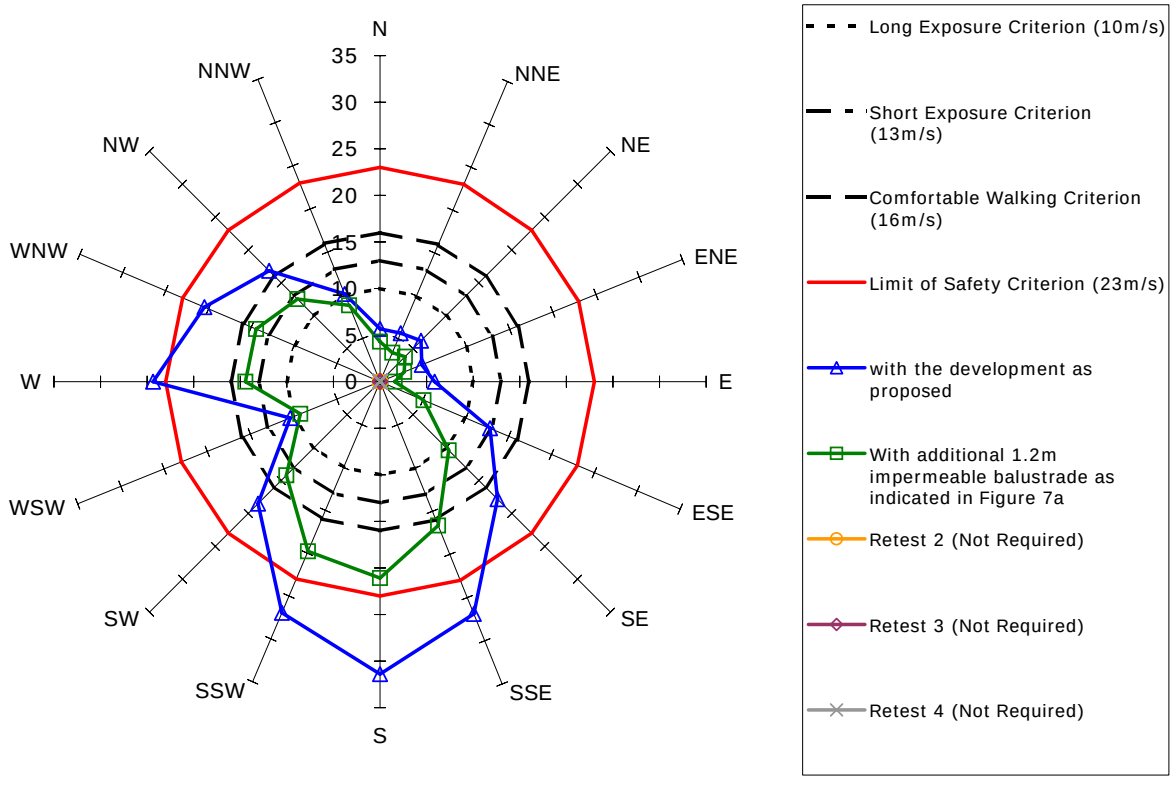


# Measured Wind Speeds at Point 15

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

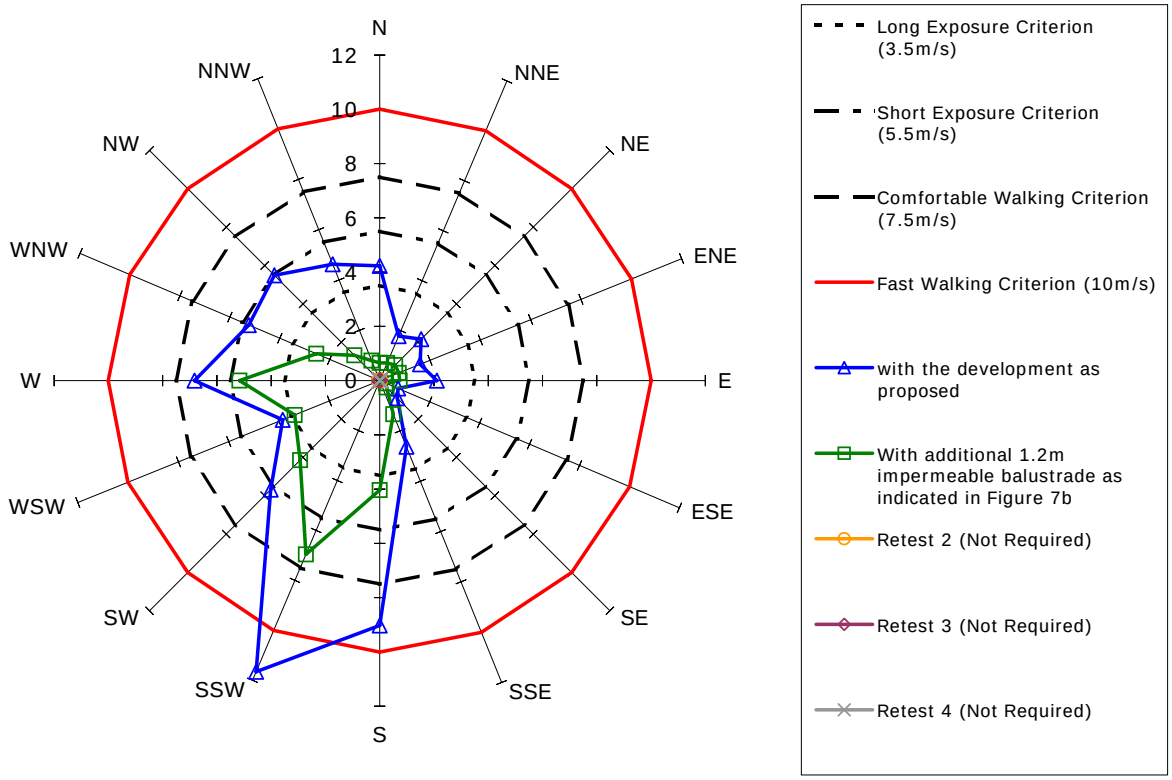



## Annual Maximum Gust Wind Speeds (m/s)

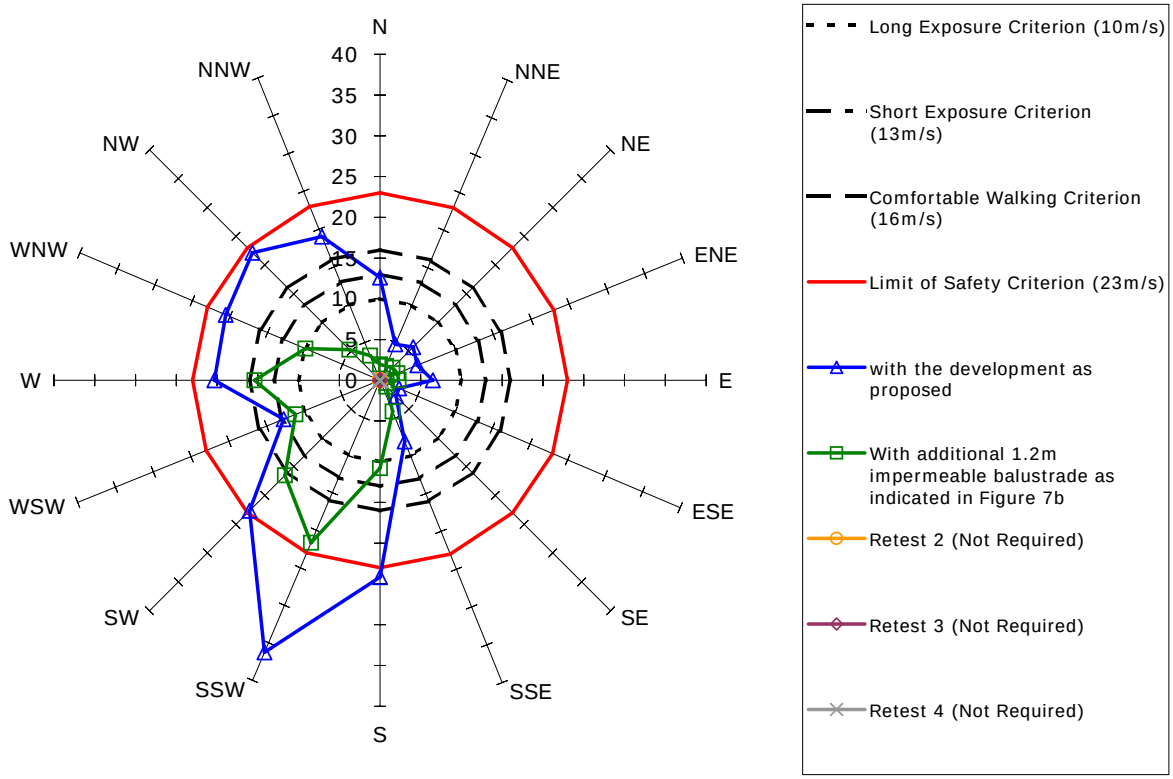


# Measured Wind Speeds at Point 16

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

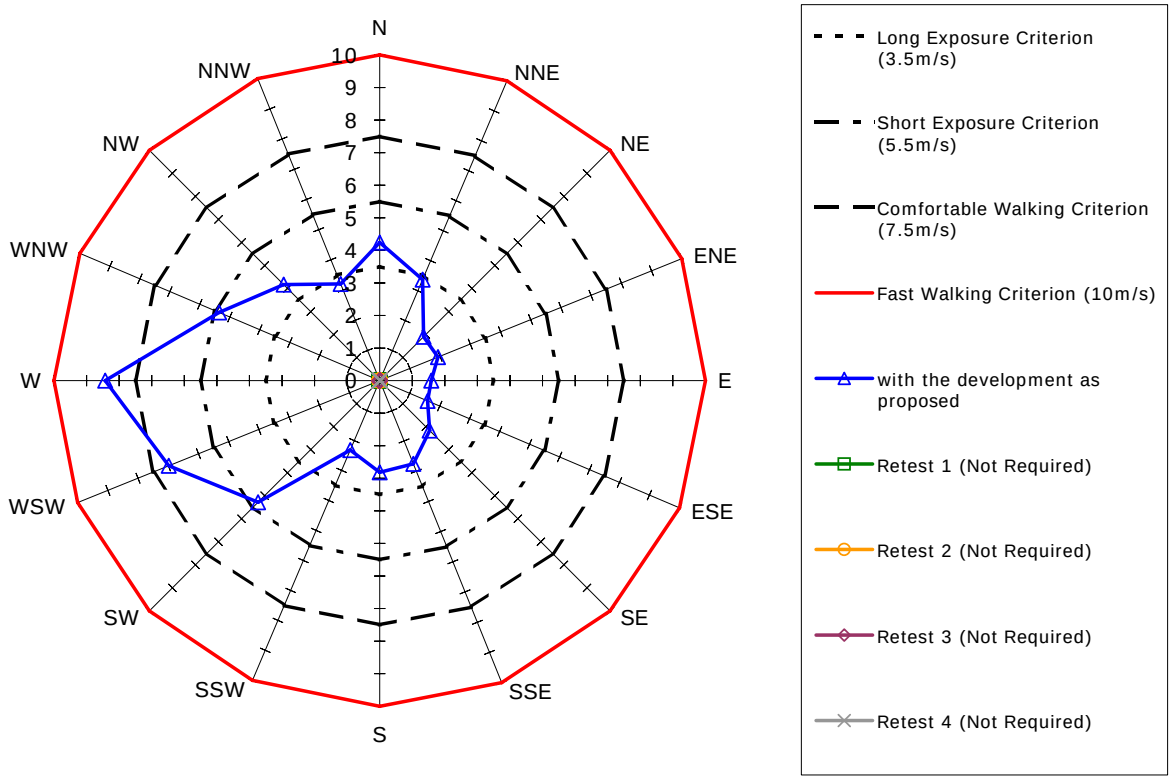



## Annual Maximum Gust Wind Speeds (m/s)

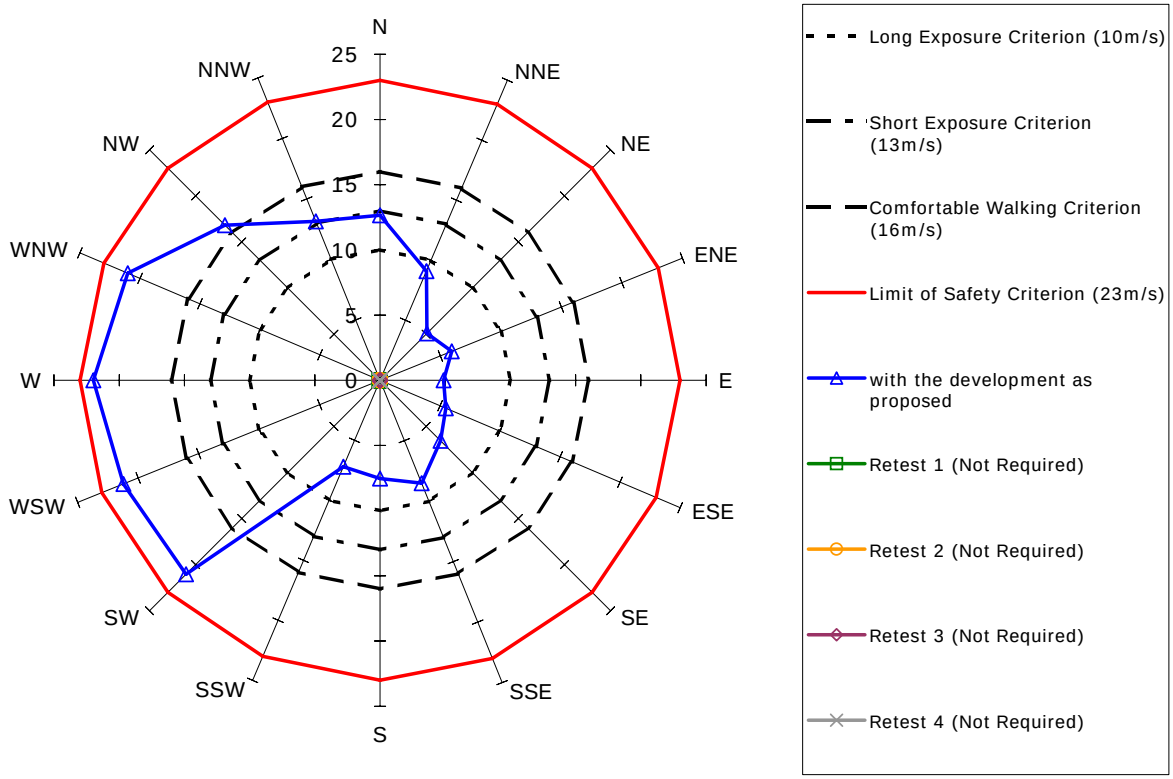


# Measured Wind Speeds at Point 17

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

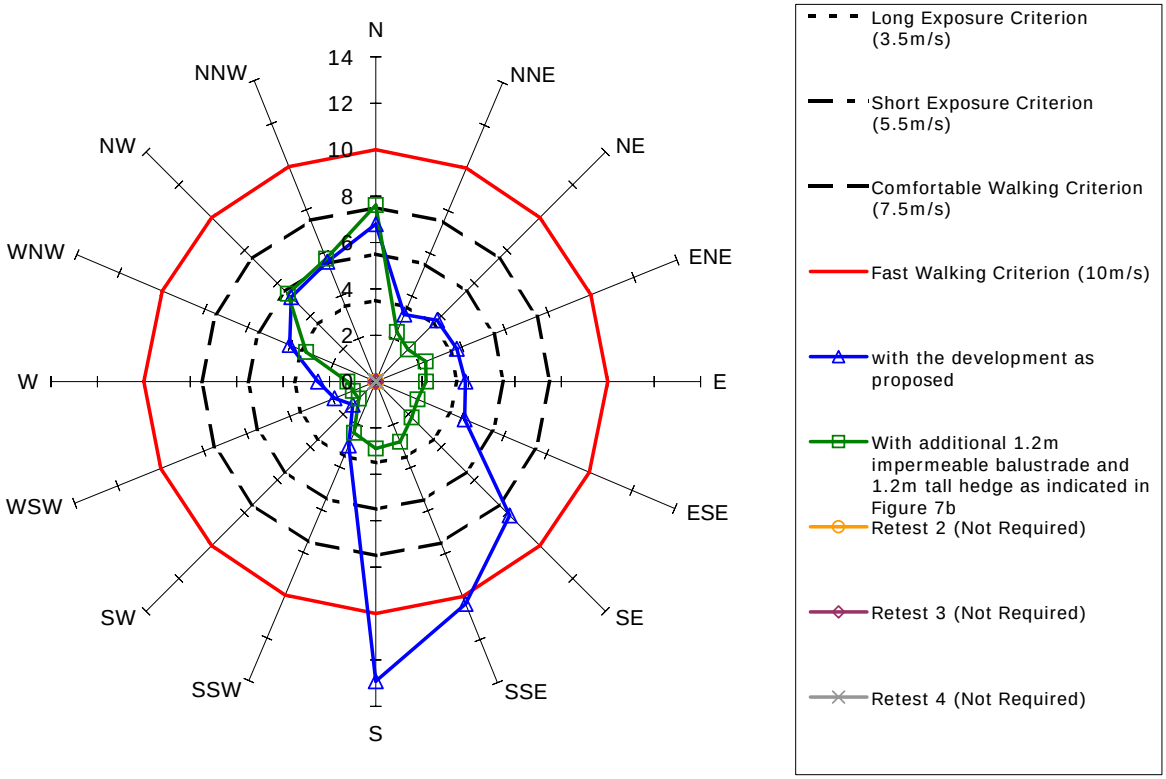



## Annual Maximum Gust Wind Speeds (m/s)

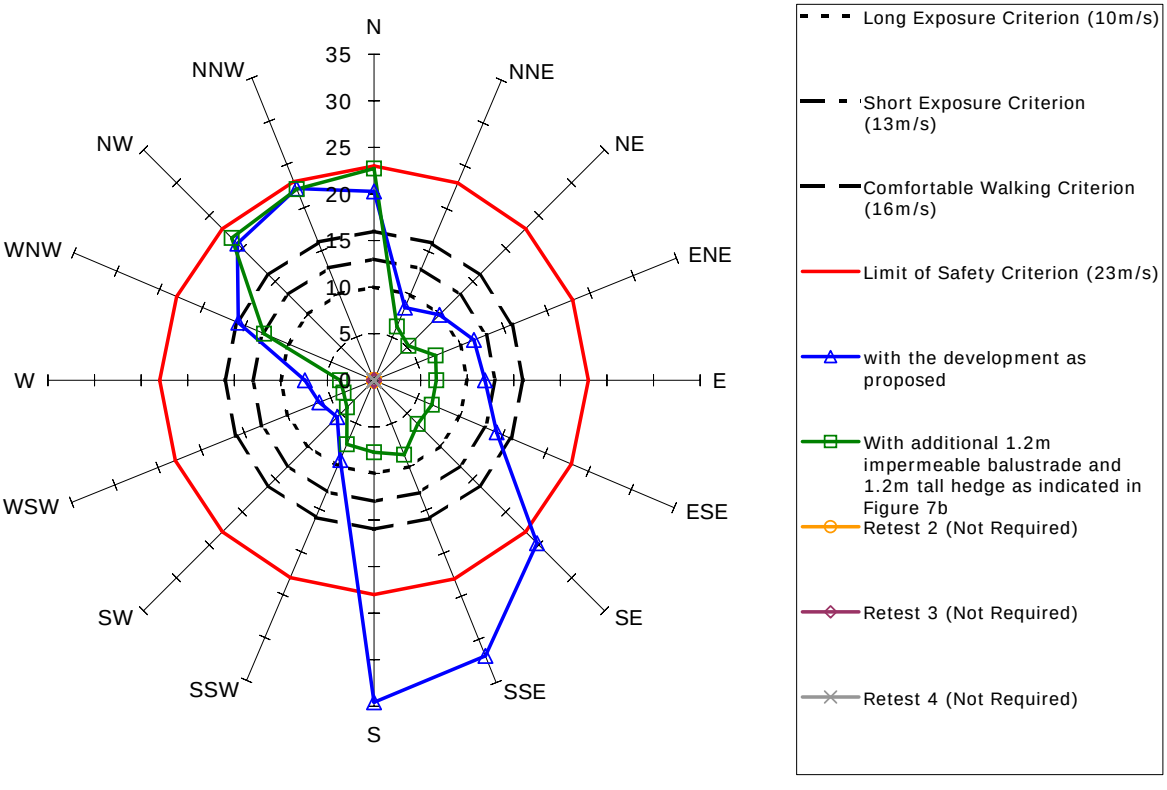


# Measured Wind Speeds at Point 18

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

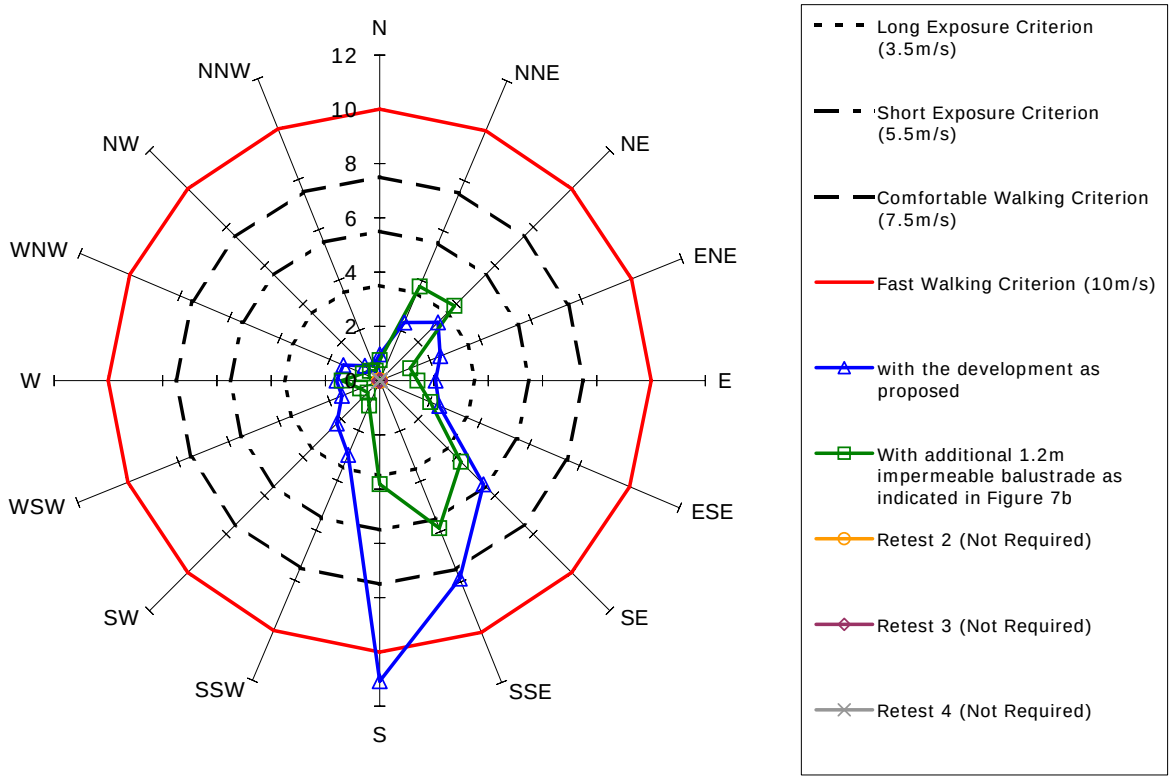



## Annual Maximum Gust Wind Speeds (m/s)

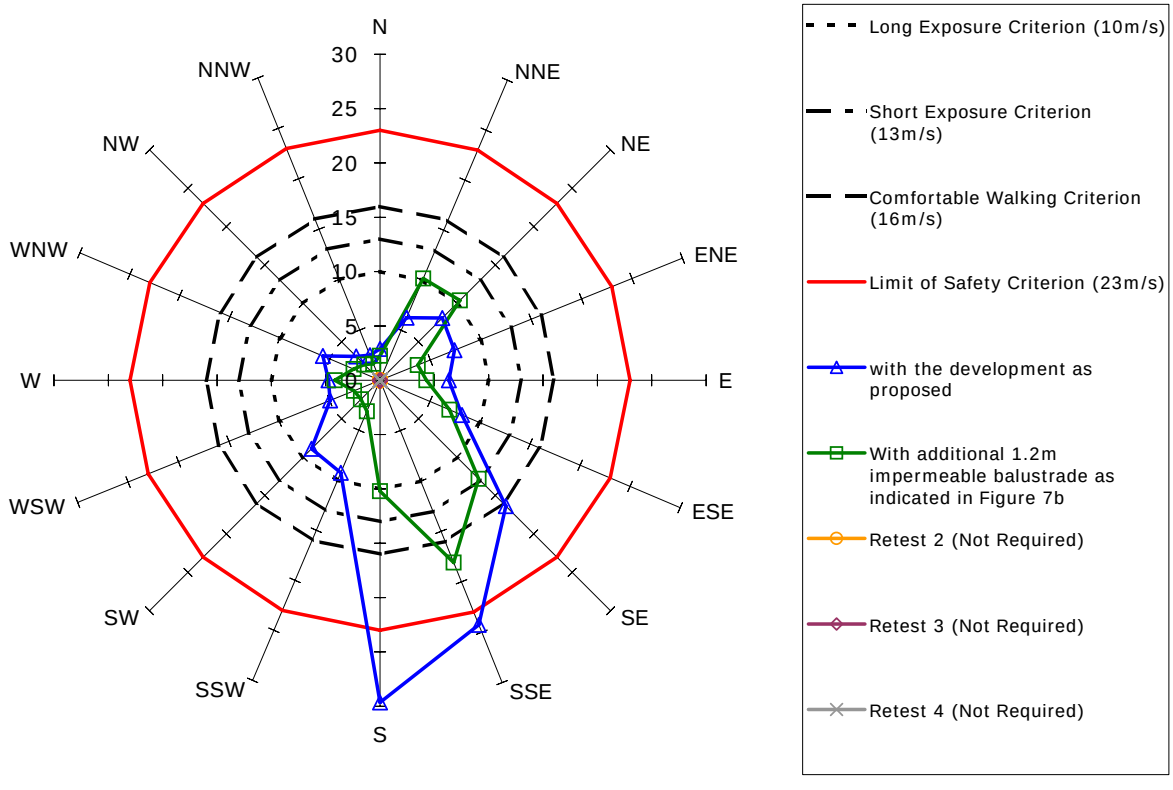


# Measured Wind Speeds at Point 19

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

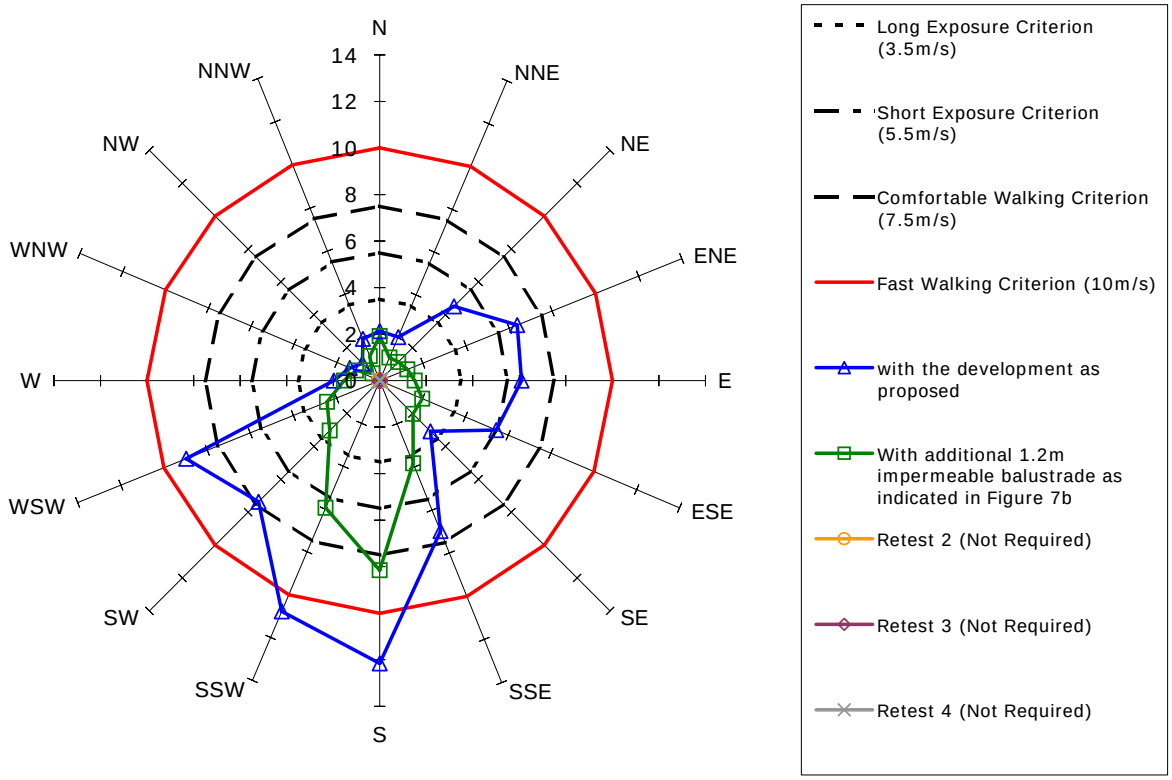



## Annual Maximum Gust Wind Speeds (m/s)

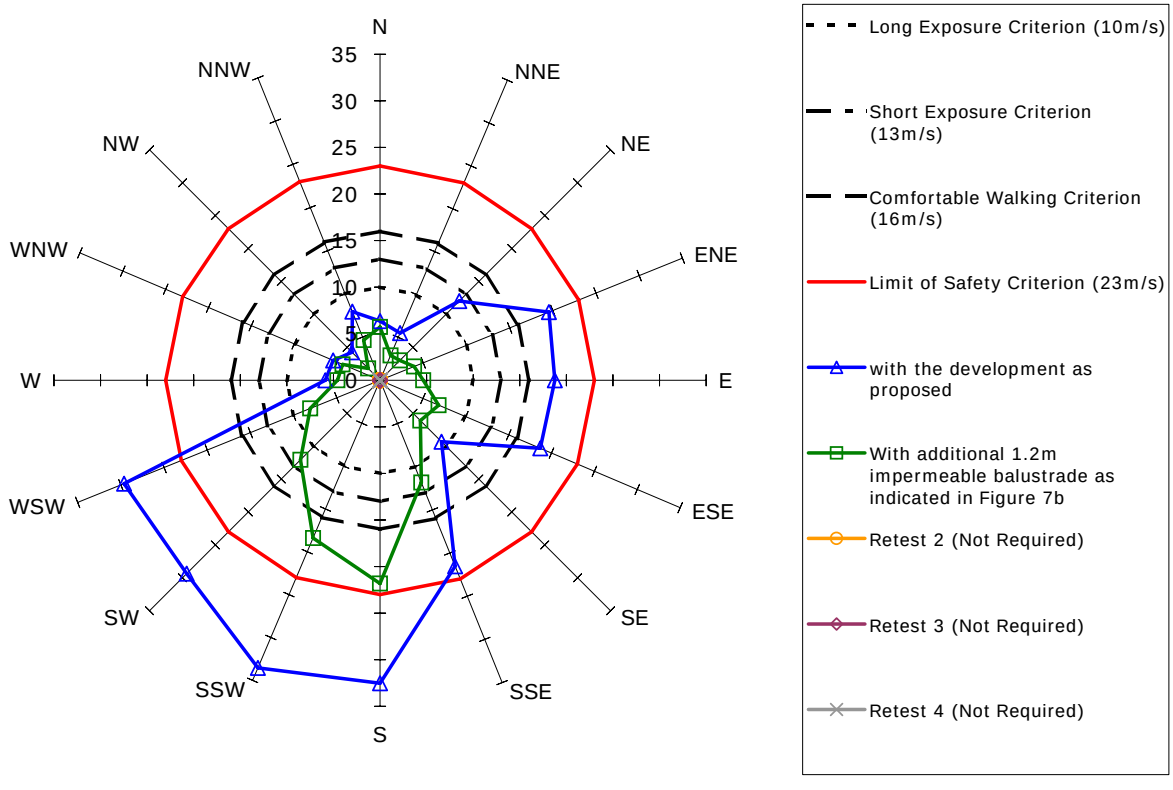


# Measured Wind Speeds at Point 20

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

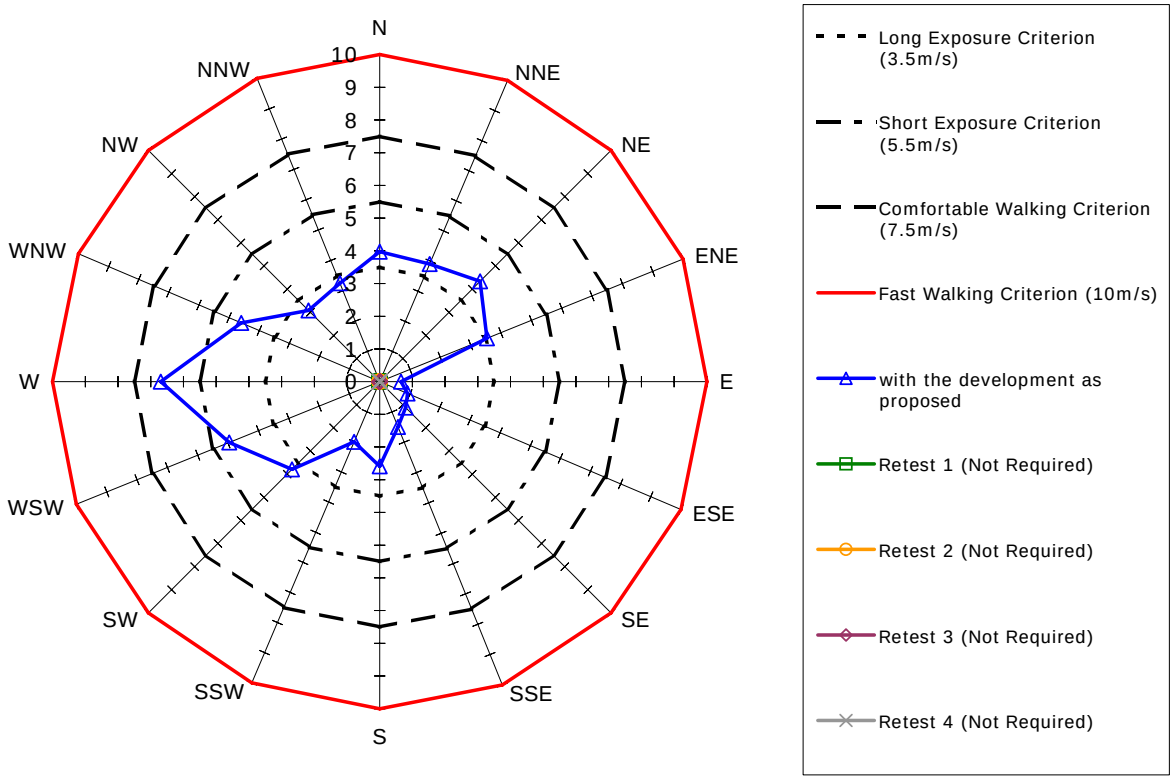



## Annual Maximum Gust Wind Speeds (m/s)

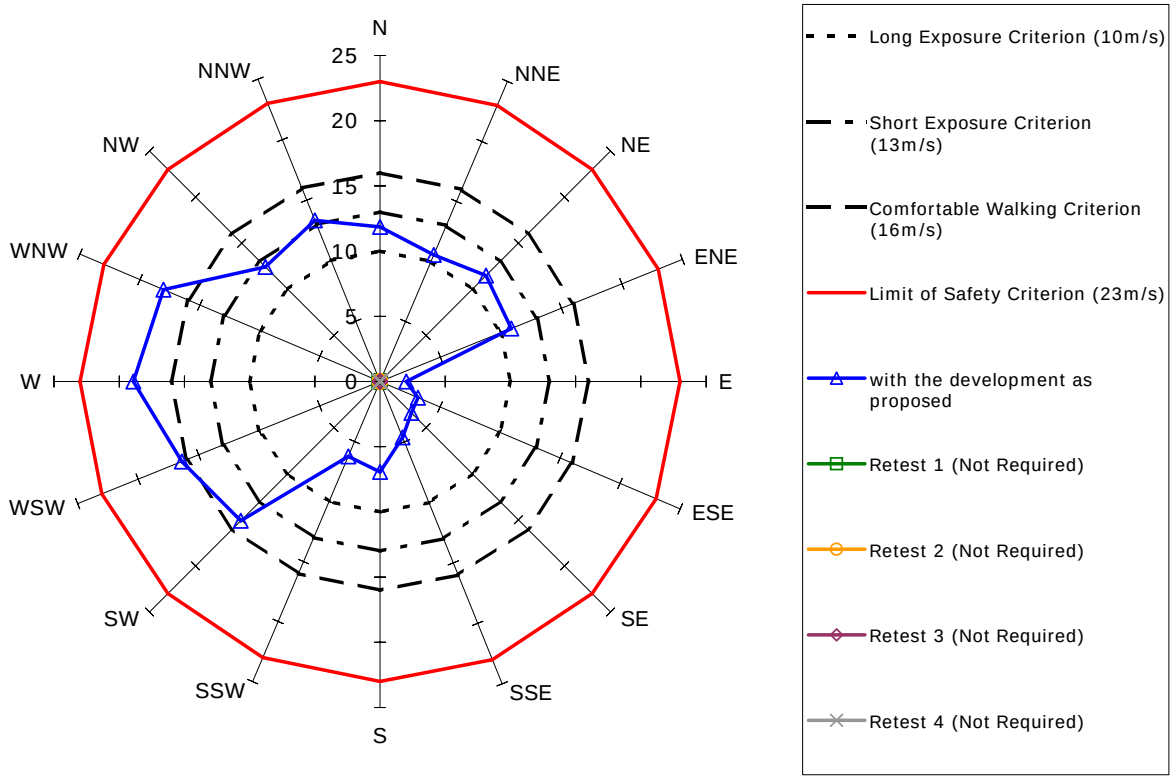


# Measured Wind Speeds at Point 21

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

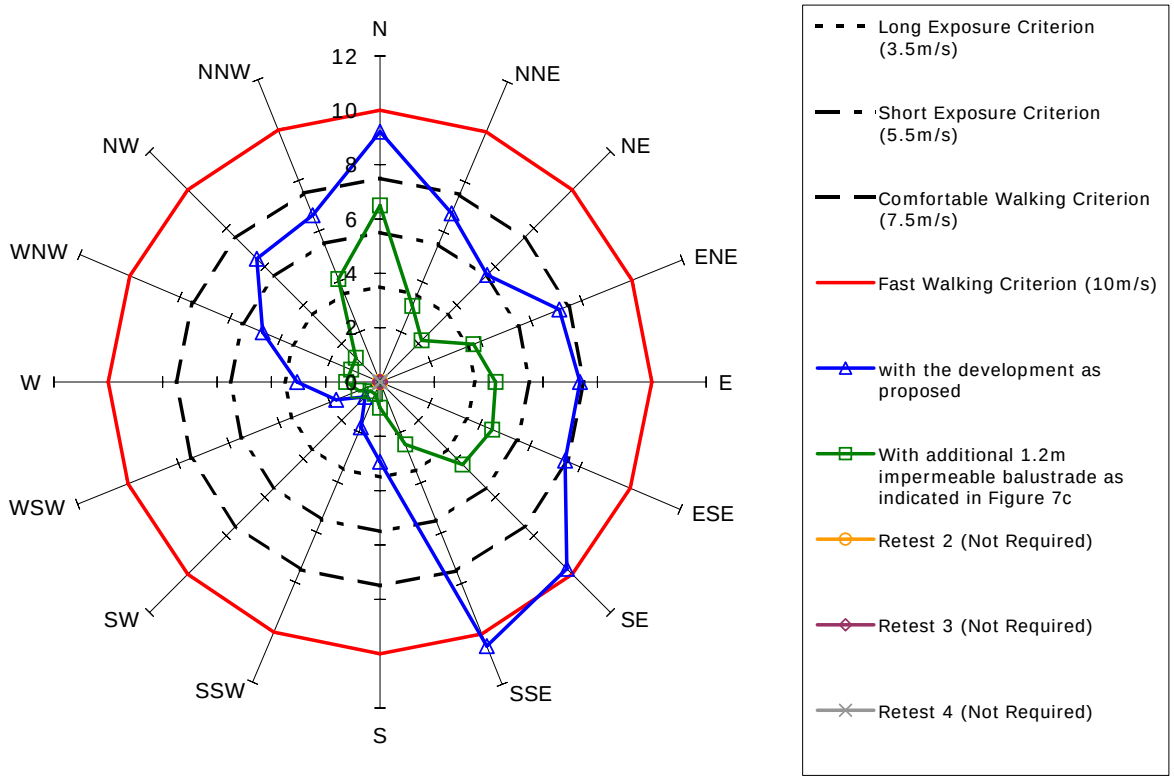



## Annual Maximum Gust Wind Speeds (m/s)

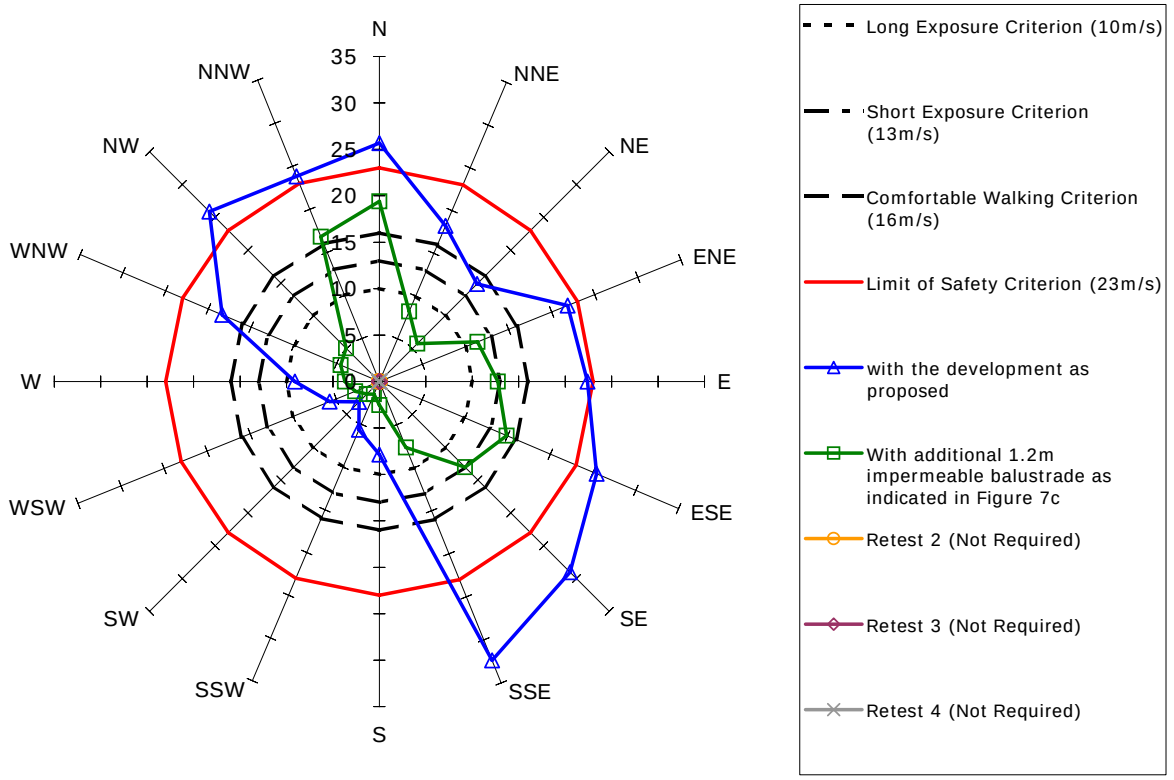


# Measured Wind Speeds at Point 22

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

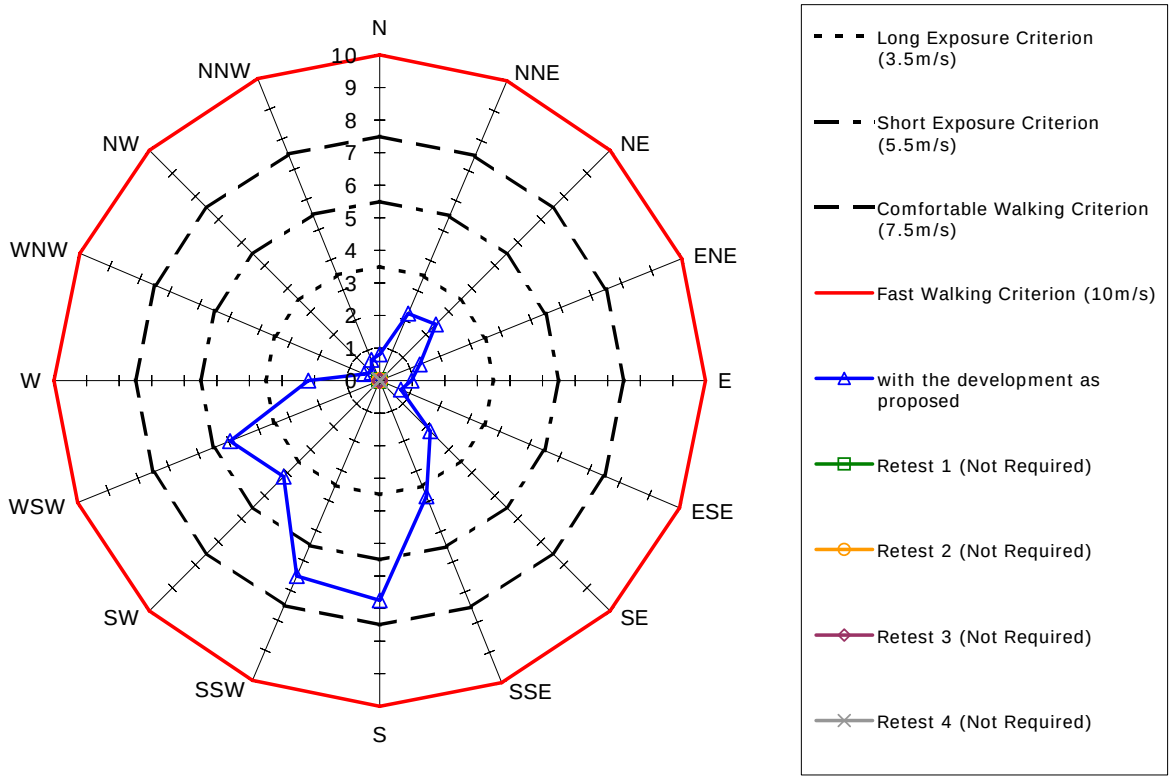



## Annual Maximum Gust Wind Speeds (m/s)

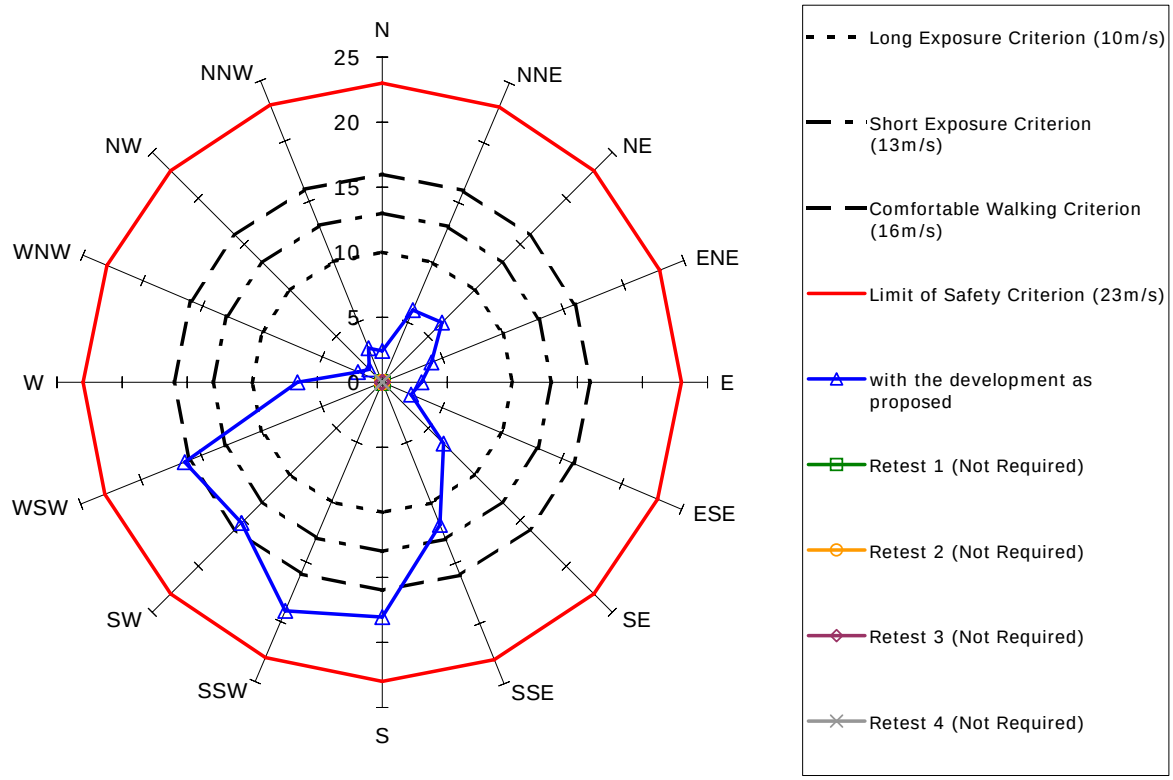


# Measured Wind Speeds at Point 23

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

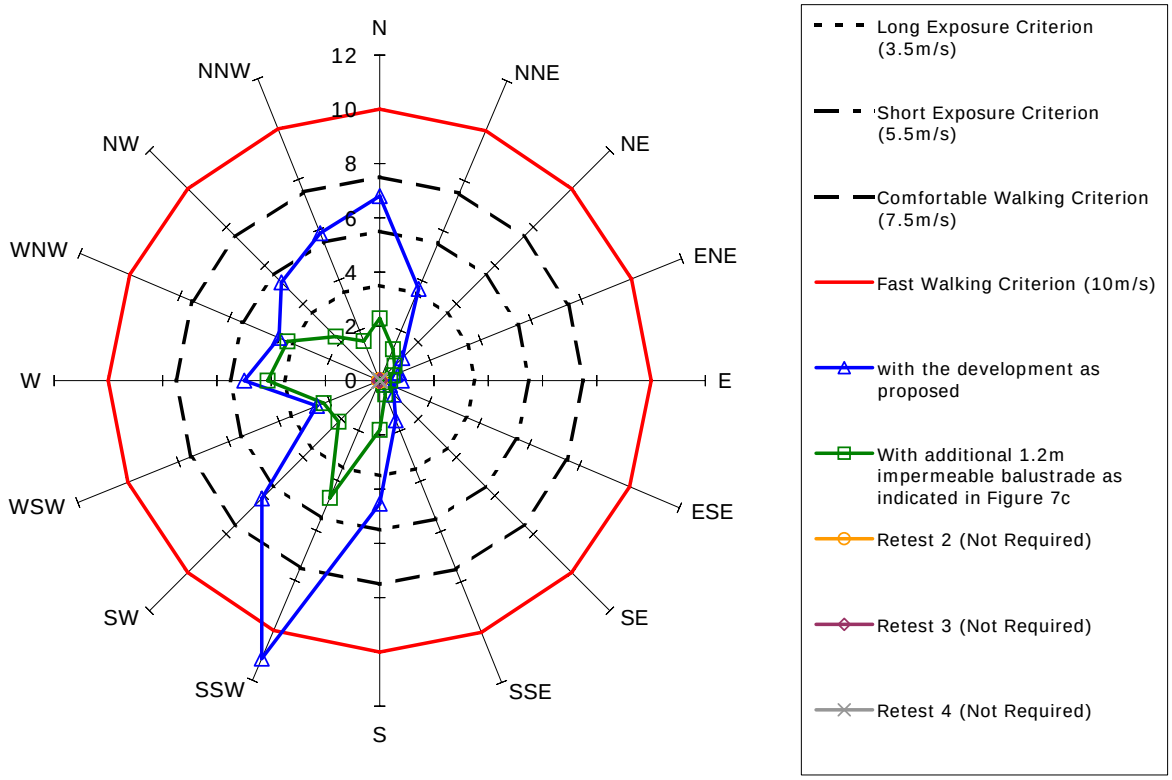



## Annual Maximum Gust Wind Speeds (m/s)

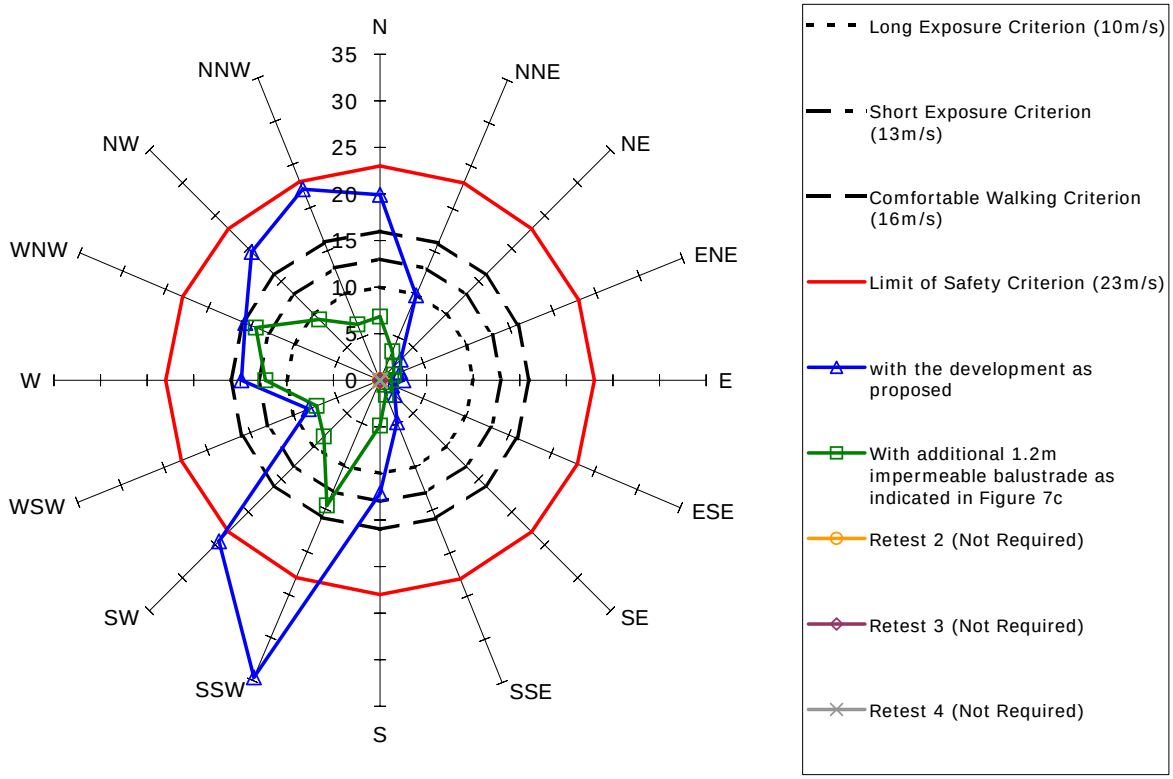


# Measured Wind Speeds at Point 24

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

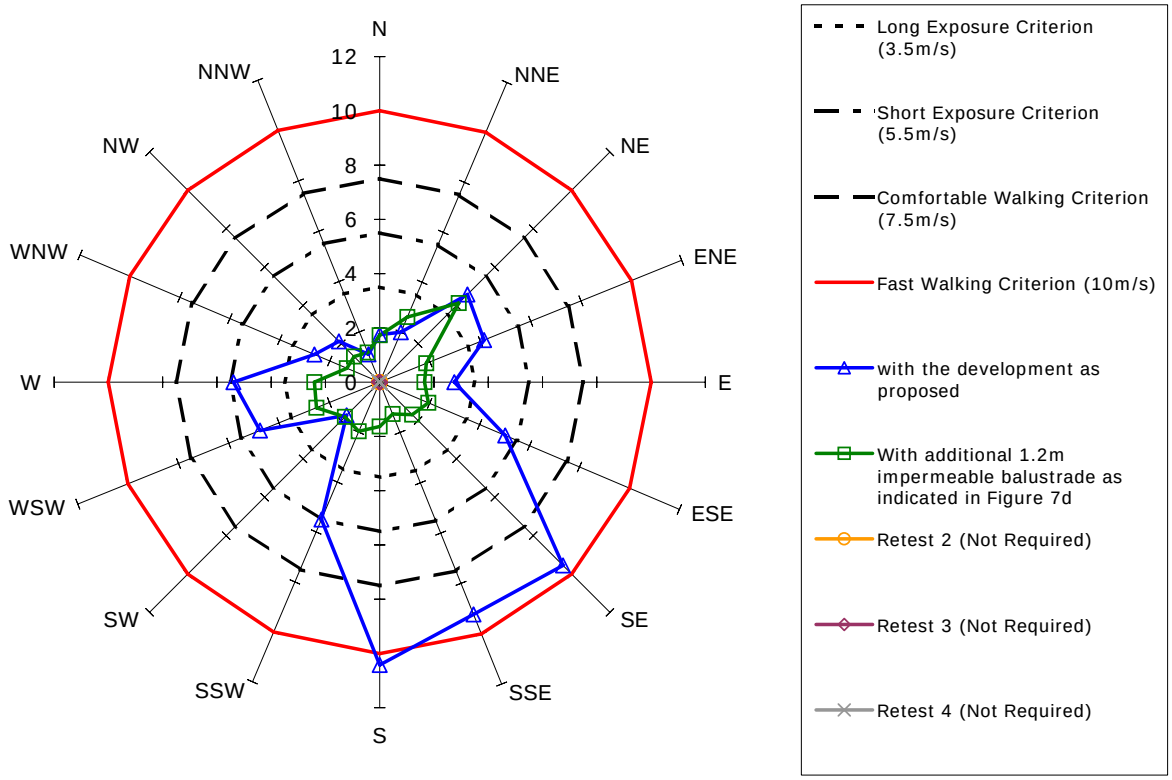



## Annual Maximum Gust Wind Speeds (m/s)

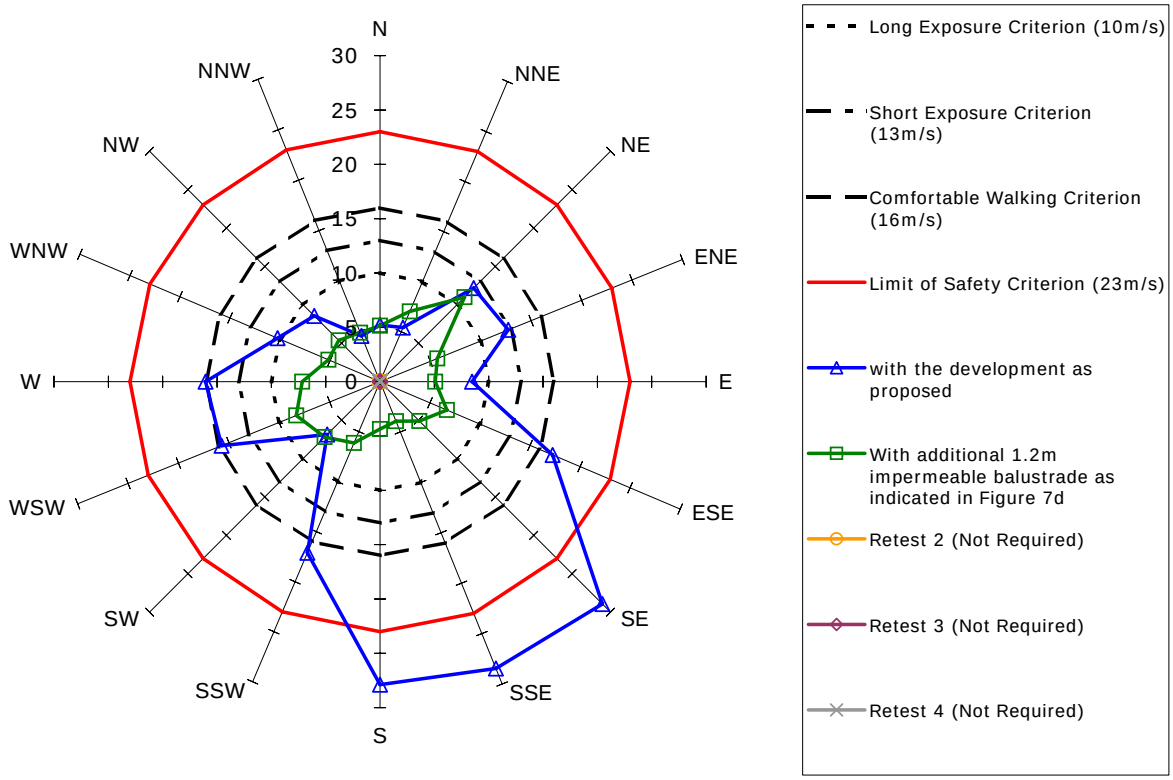


# Measured Wind Speeds at Point 25

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

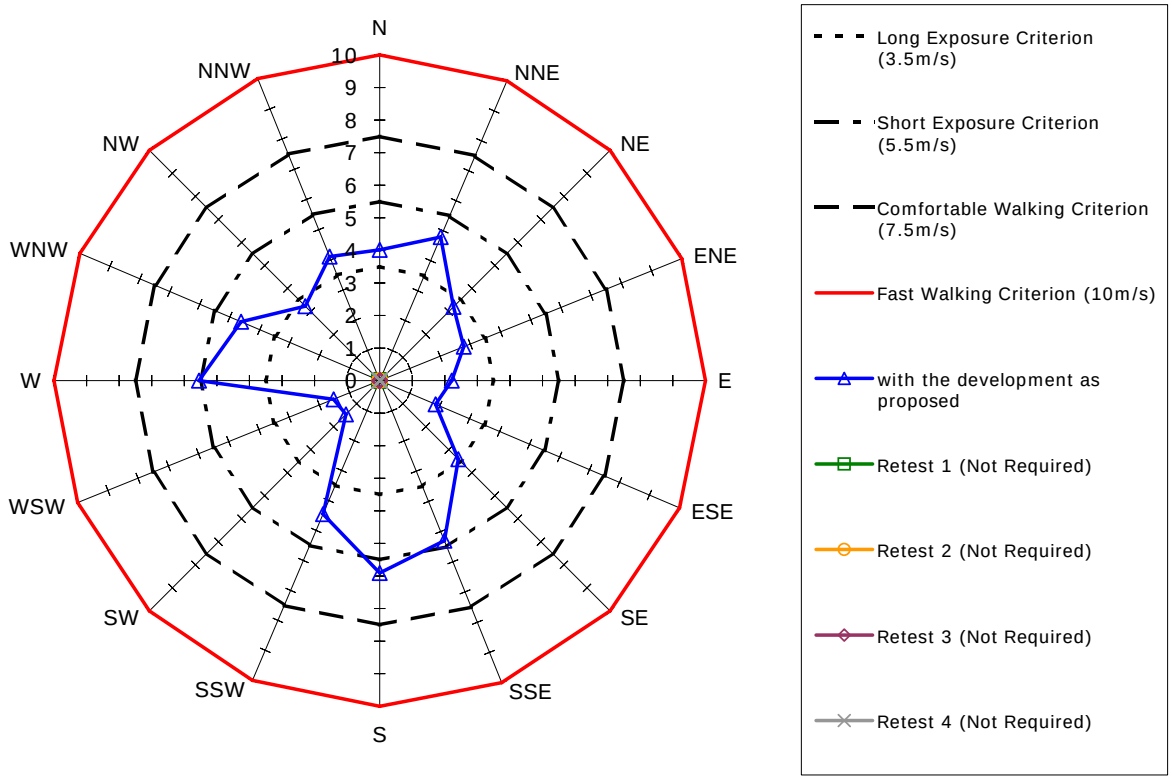



## Annual Maximum Gust Wind Speeds (m/s)

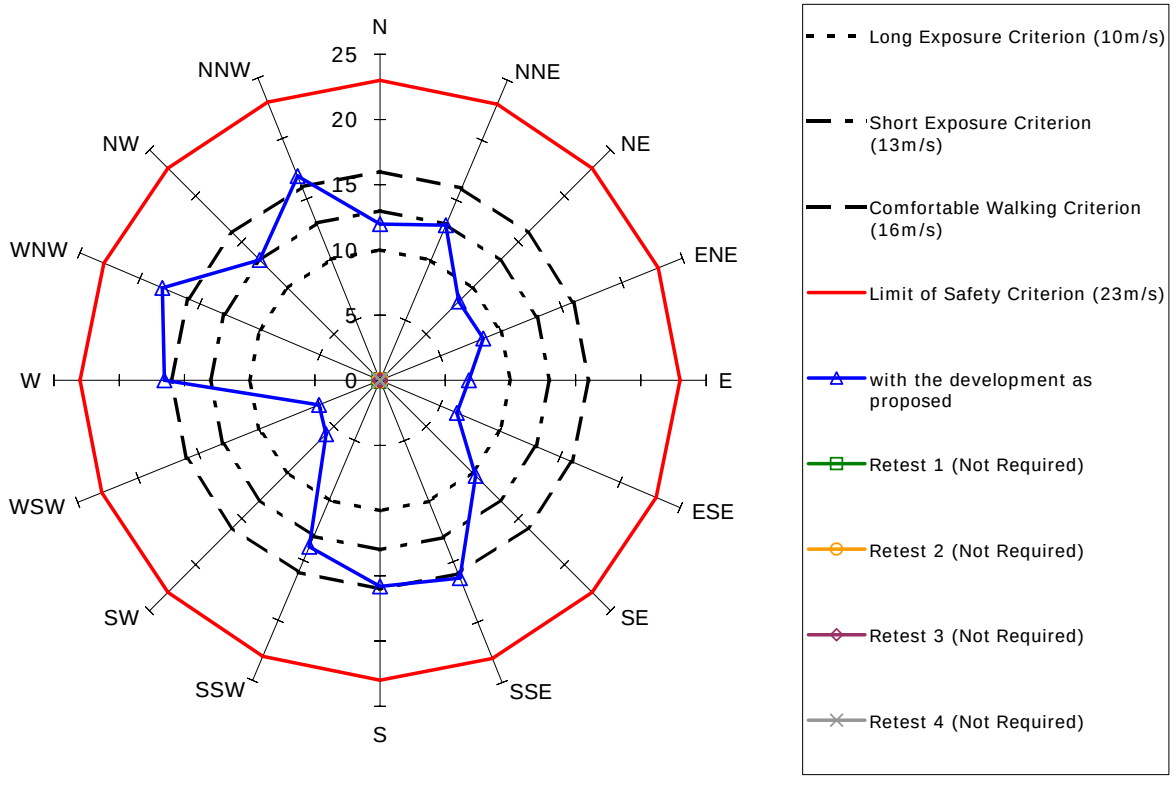


# Measured Wind Speeds at Point 26

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

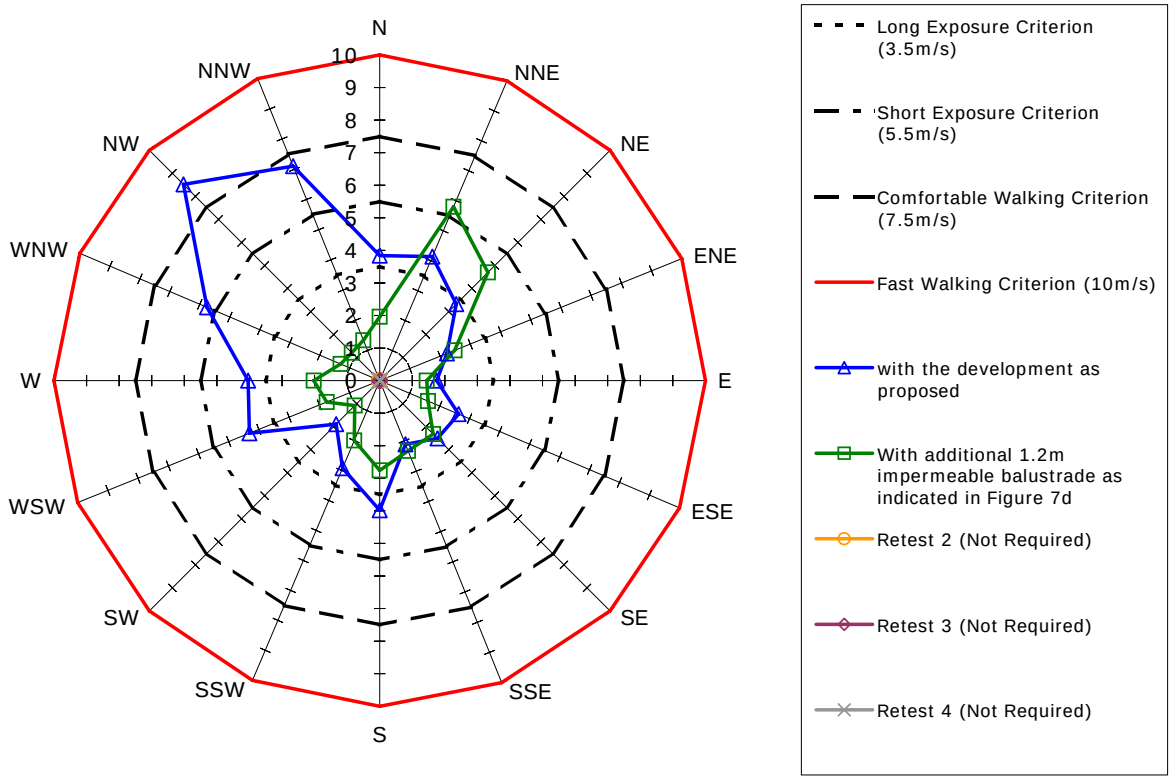



## Annual Maximum Gust Wind Speeds (m/s)

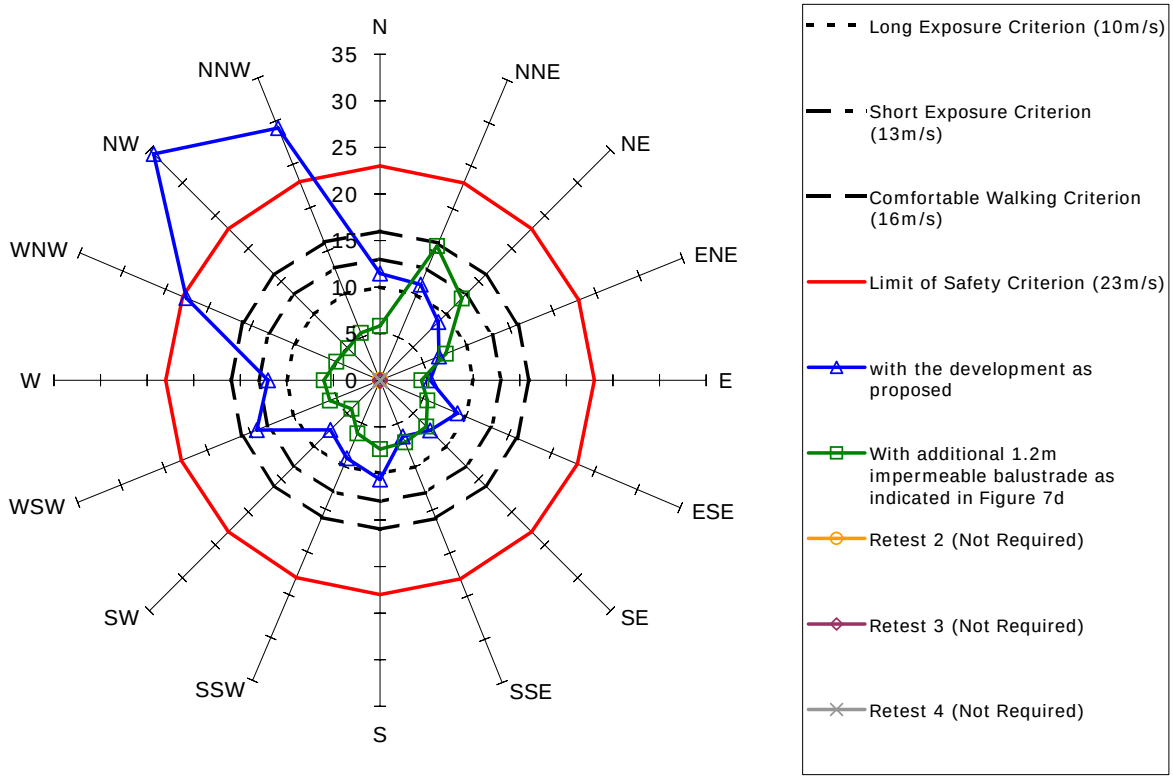


# Measured Wind Speeds at Point 27

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

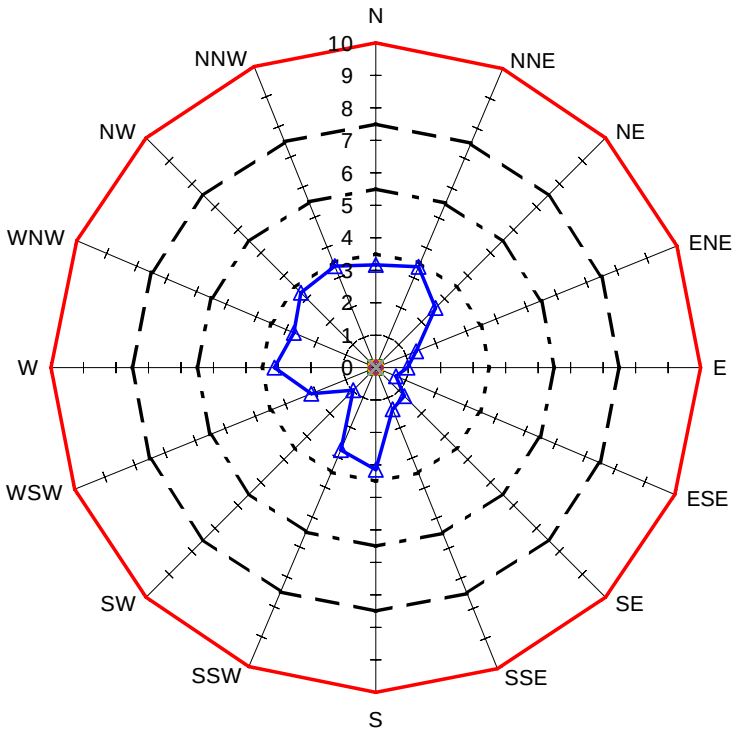


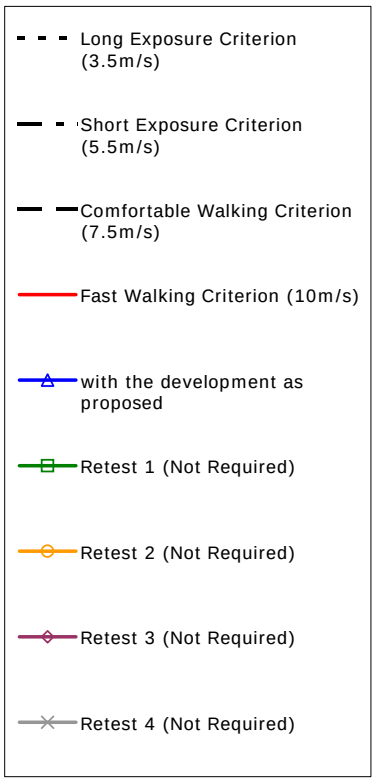

## Annual Maximum Gust Wind Speeds (m/s)



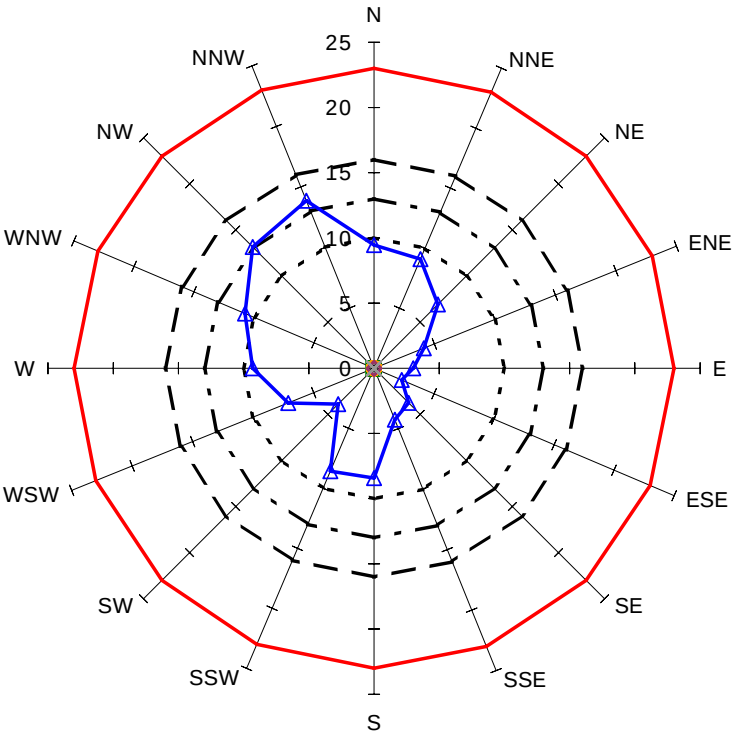
# Measured Wind Speeds at Point 28

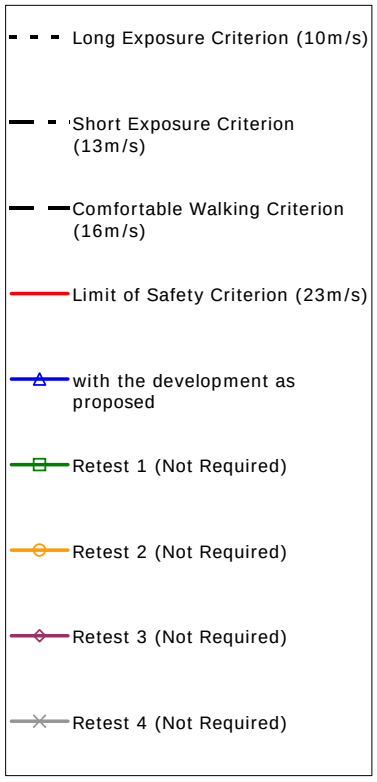
## Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)



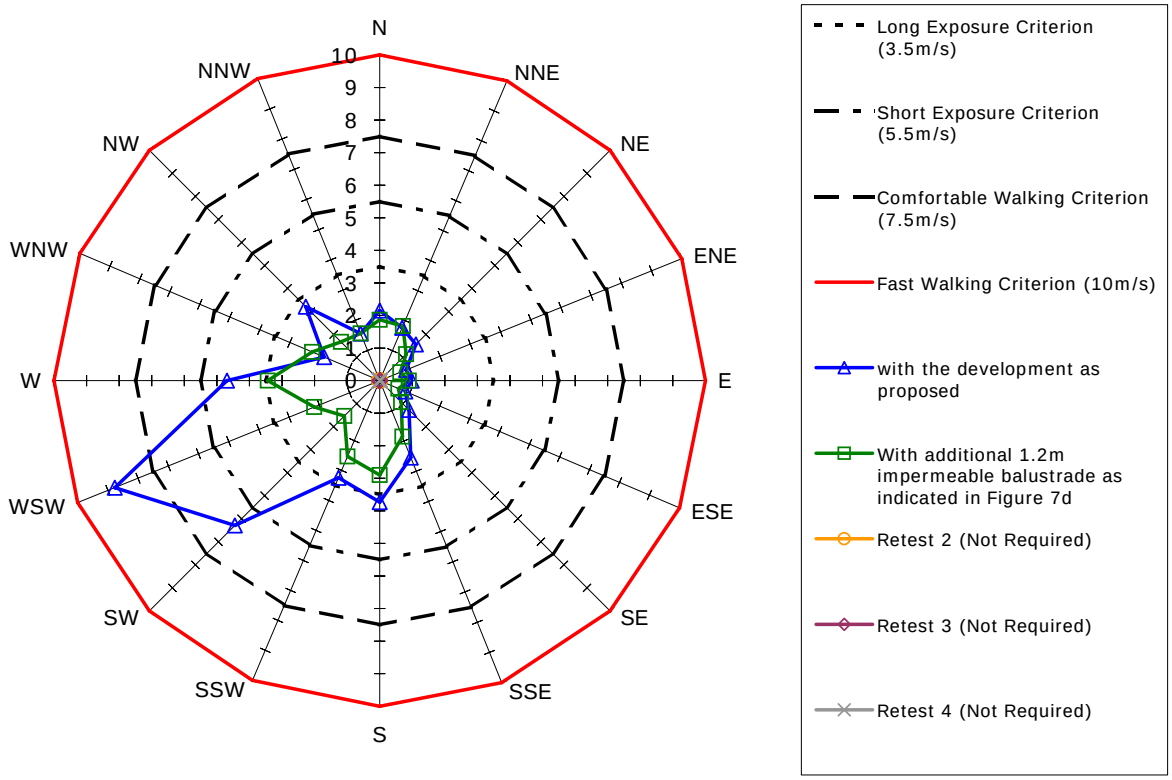

## Annual Maximum Gust Wind Speeds (m/s)



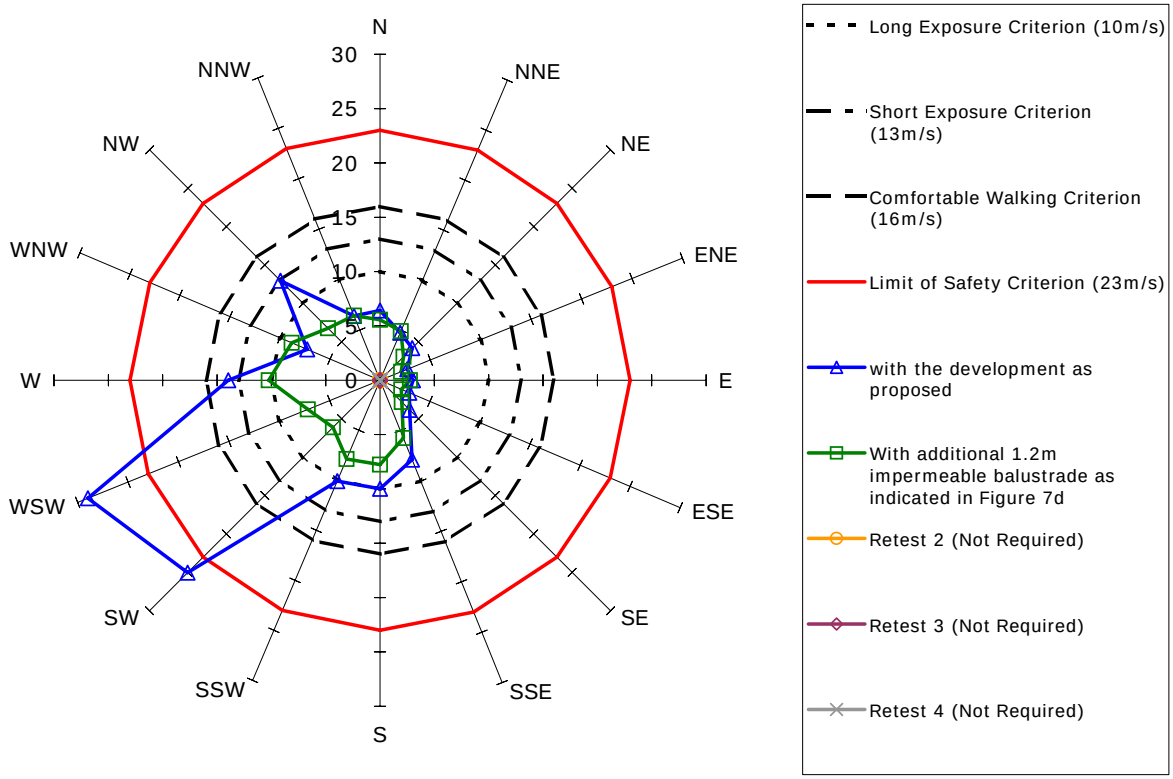



# Measured Wind Speeds at Point 29

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

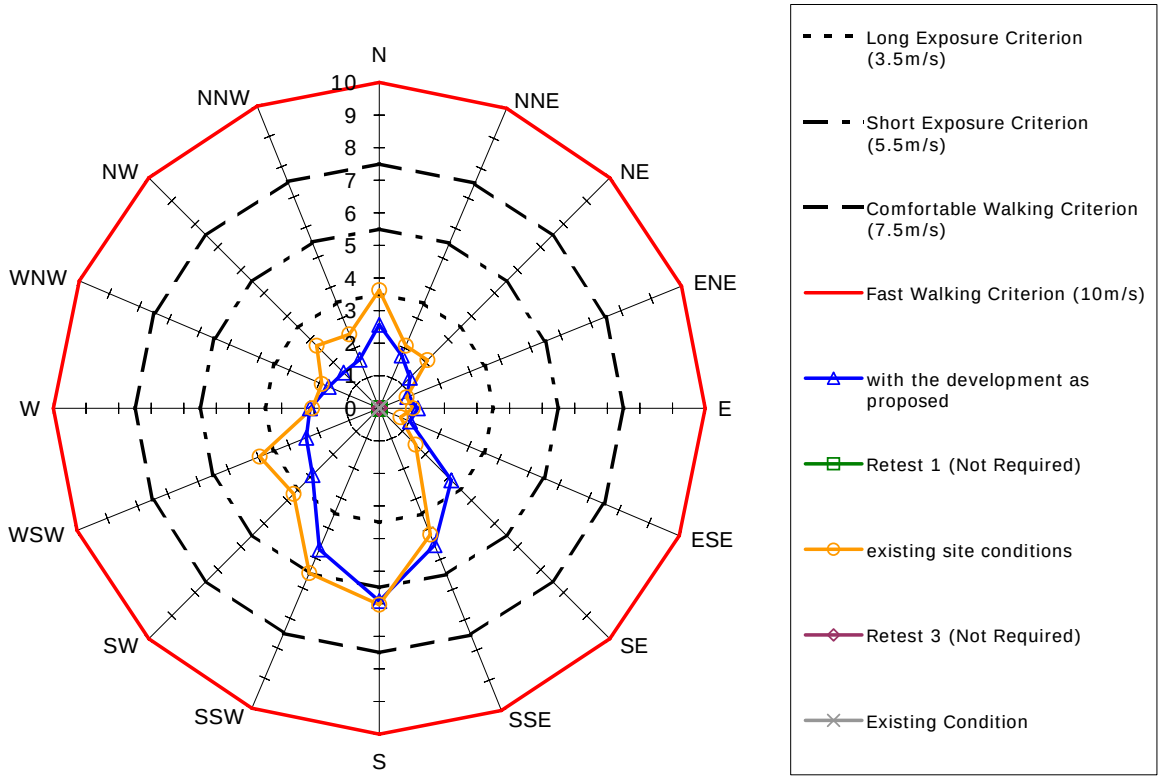



## Annual Maximum Gust Wind Speeds (m/s)

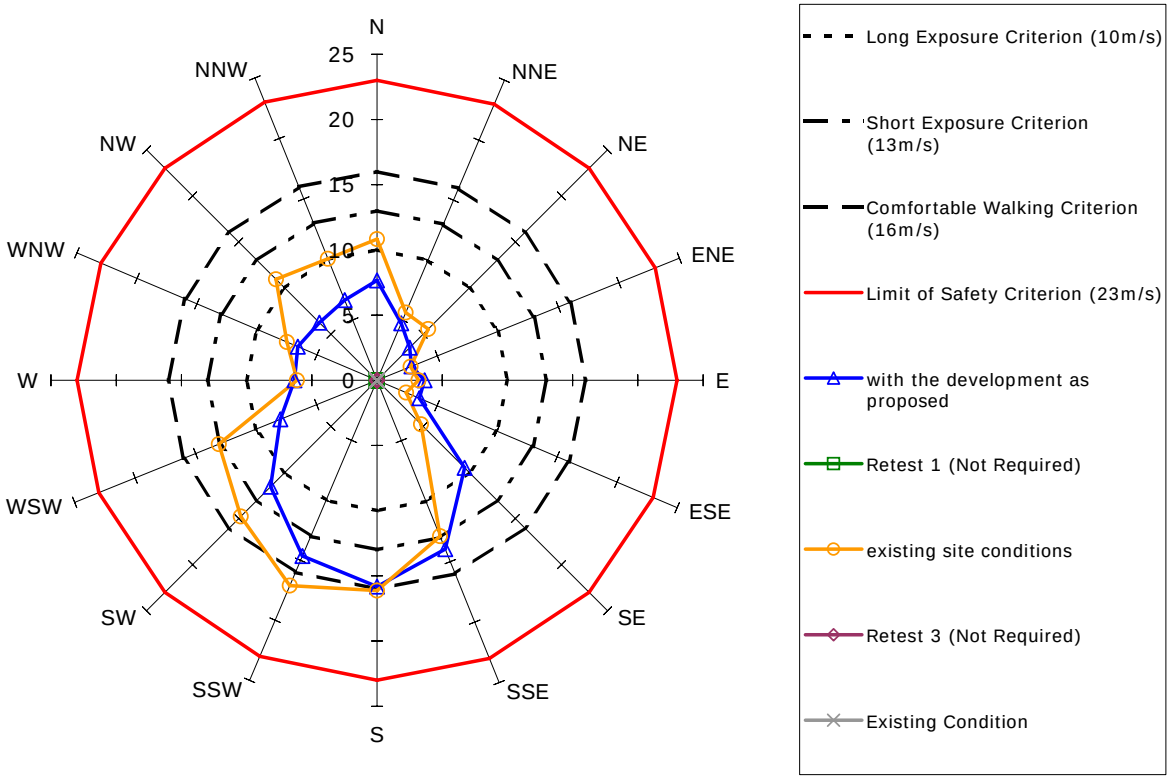


# Measured Wind Speeds at Point 30

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

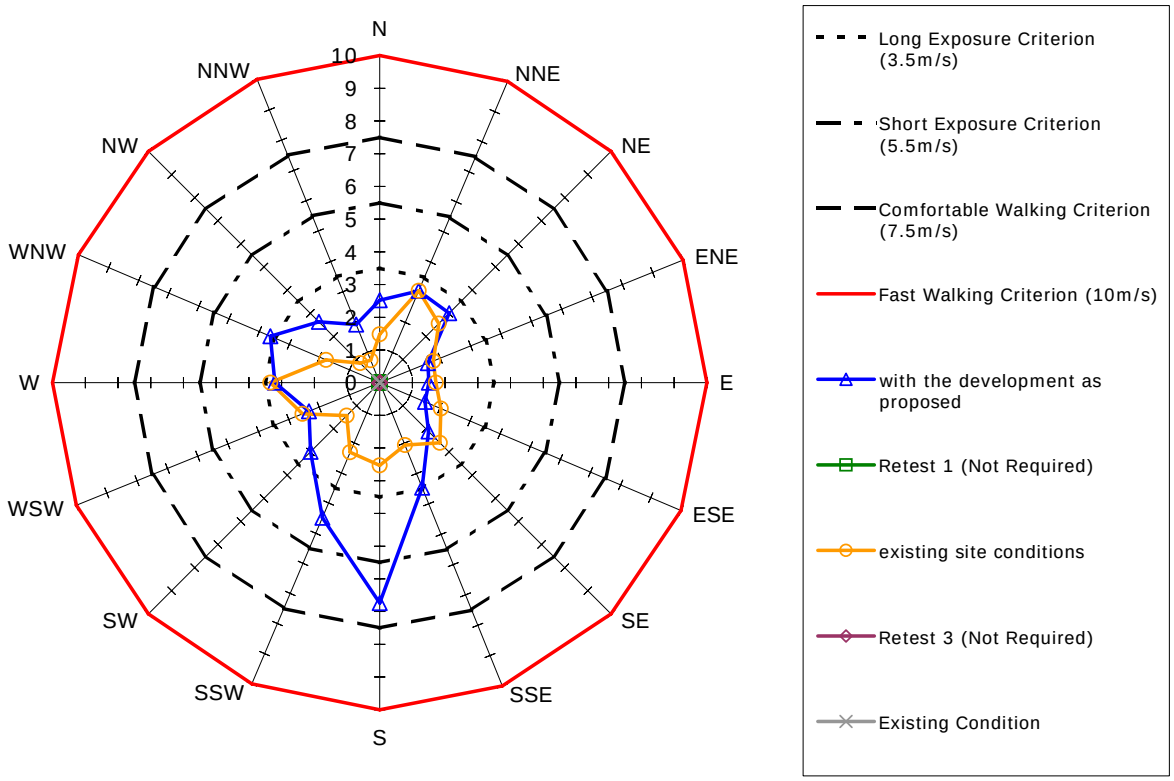



## Annual Maximum Gust Wind Speeds (m/s)

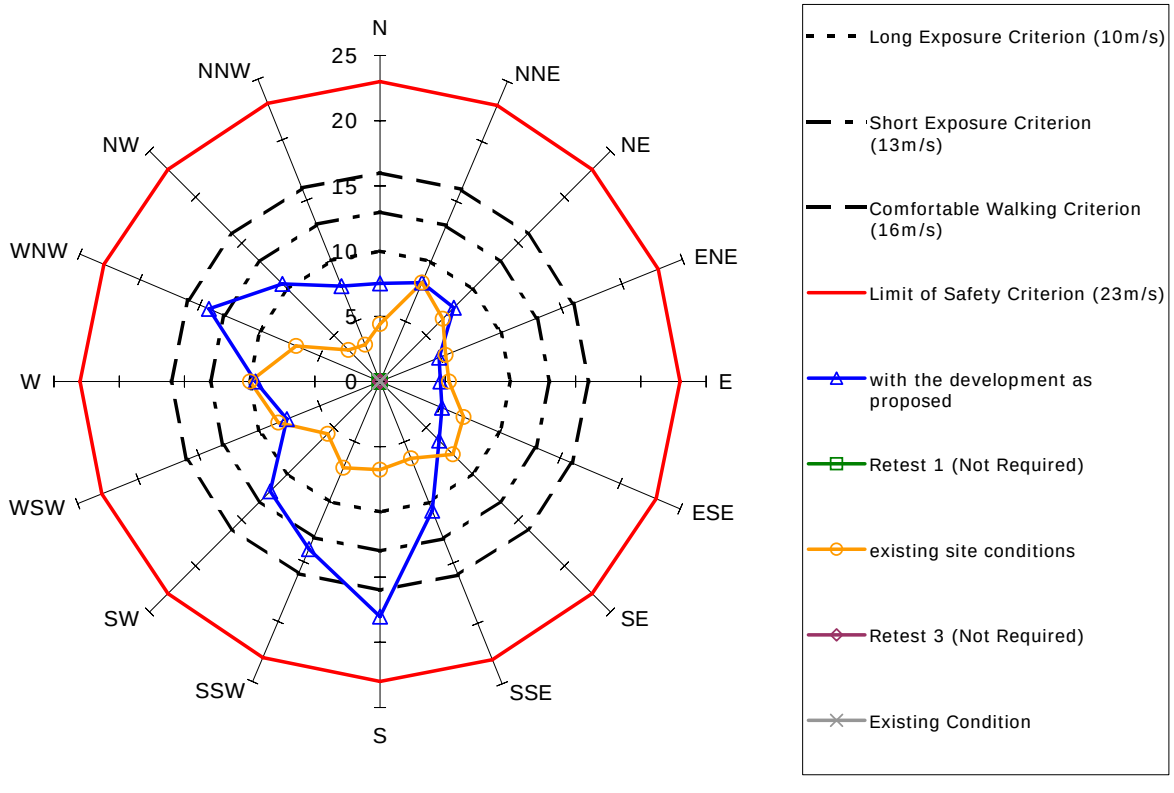


# Measured Wind Speeds at Point 31

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

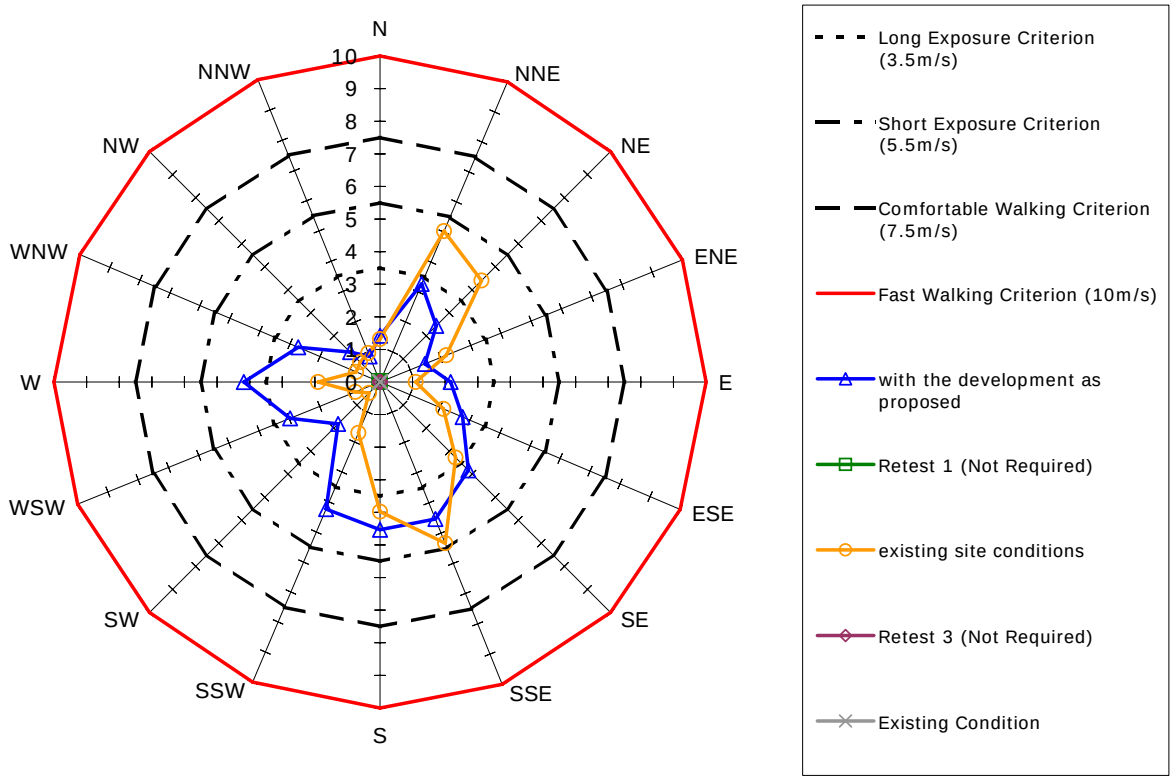



## Annual Maximum Gust Wind Speeds (m/s)

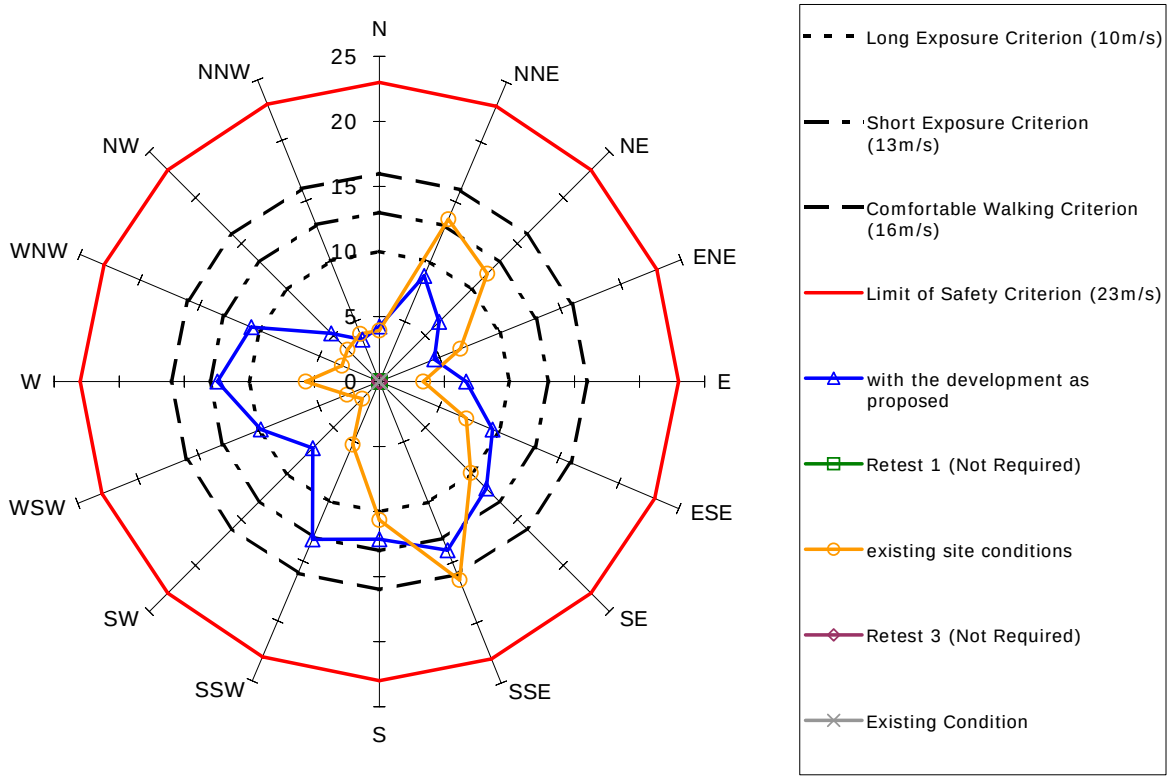


# Measured Wind Speeds at Point 32

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

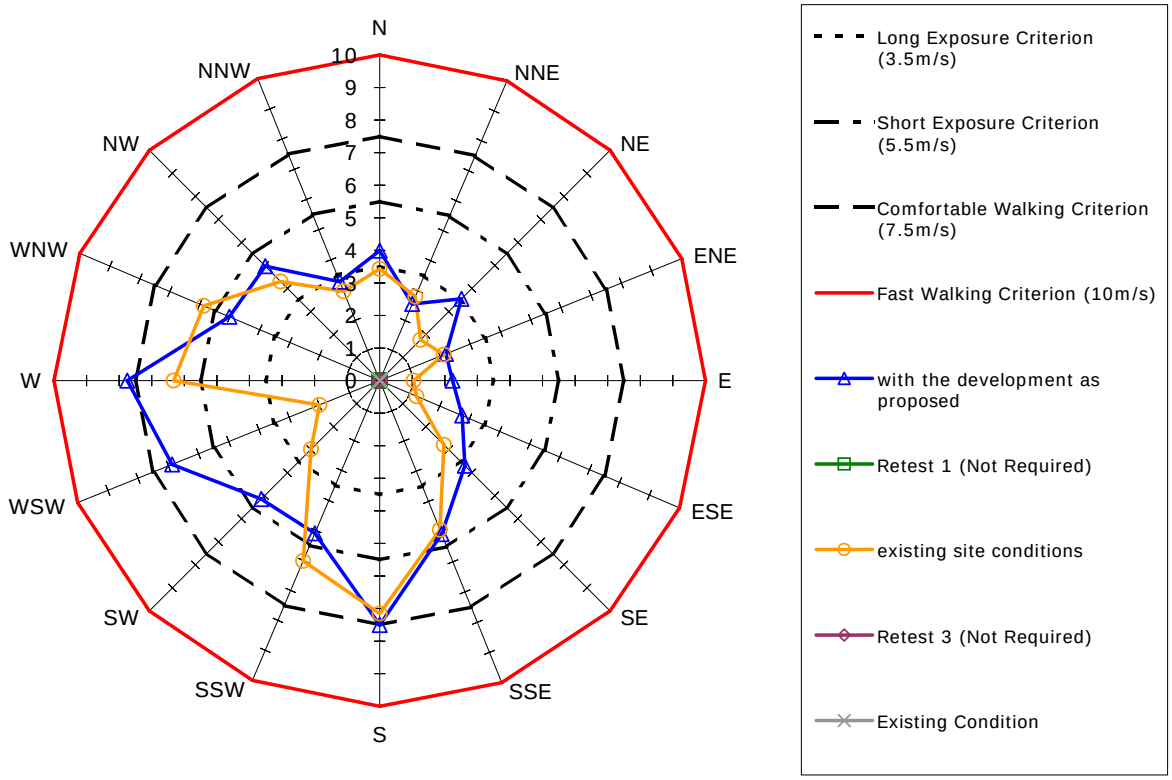



## Annual Maximum Gust Wind Speeds (m/s)

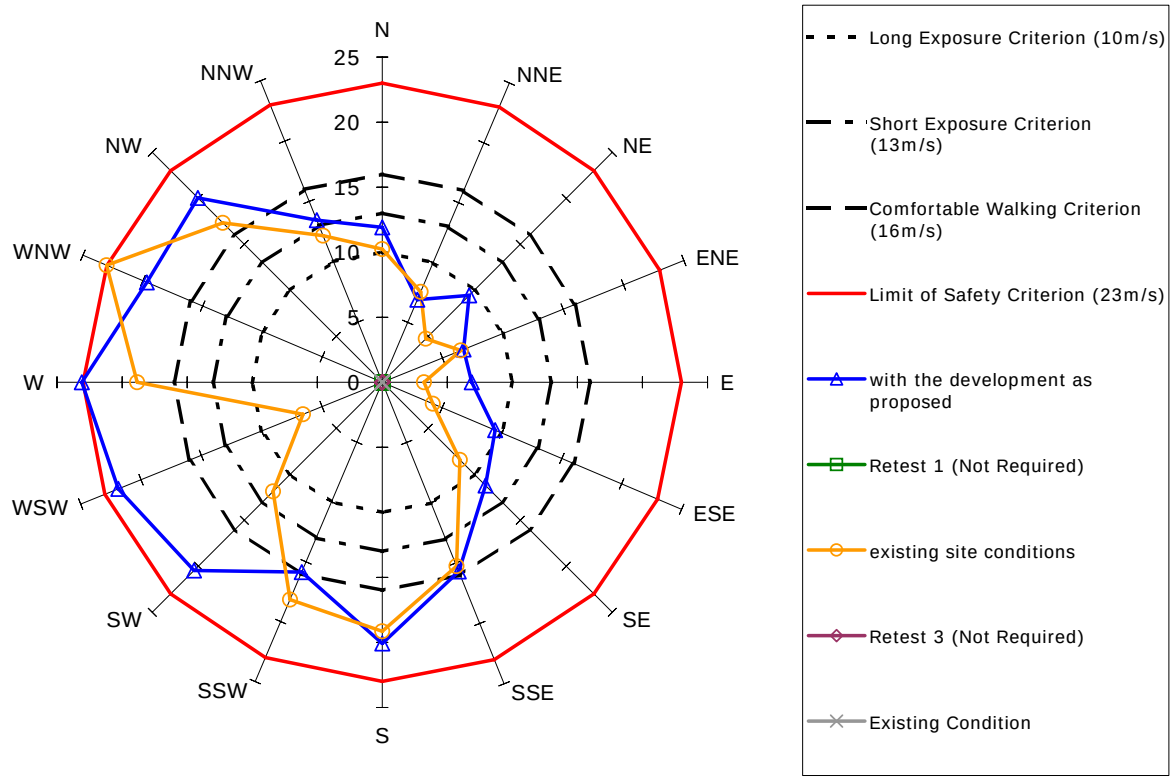


# Measured Wind Speeds at Point 33

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

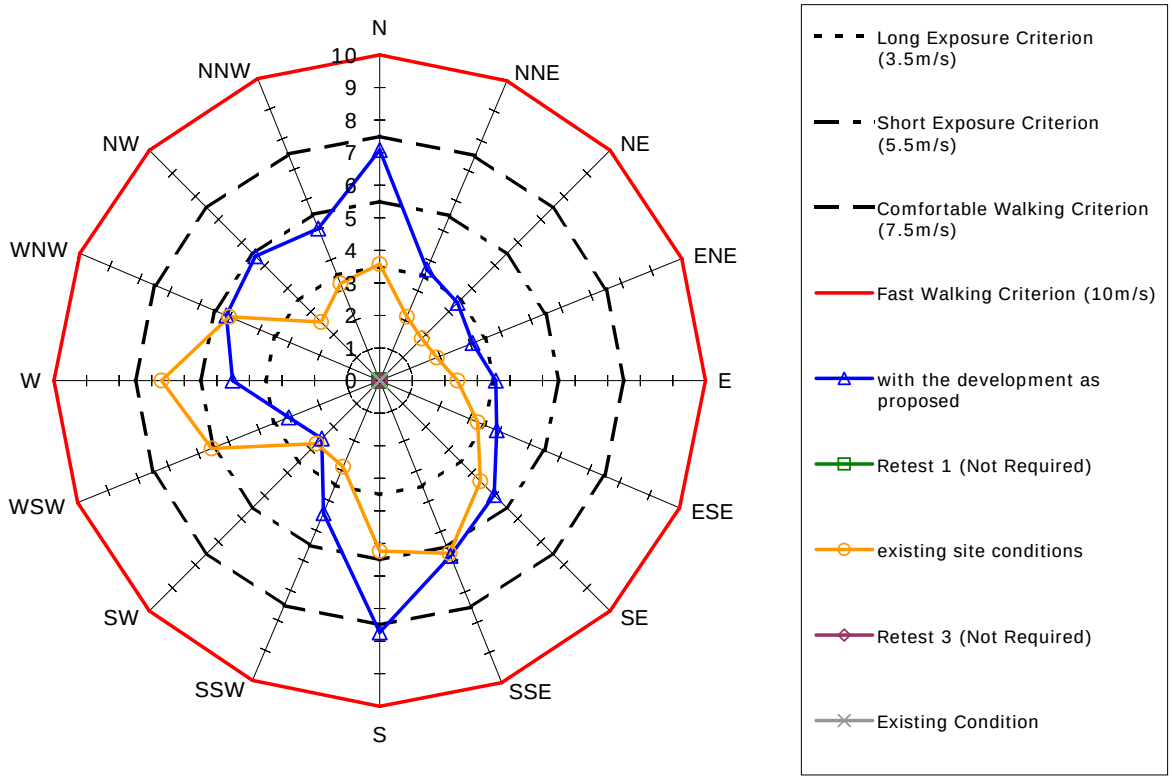



## Annual Maximum Gust Wind Speeds (m/s)

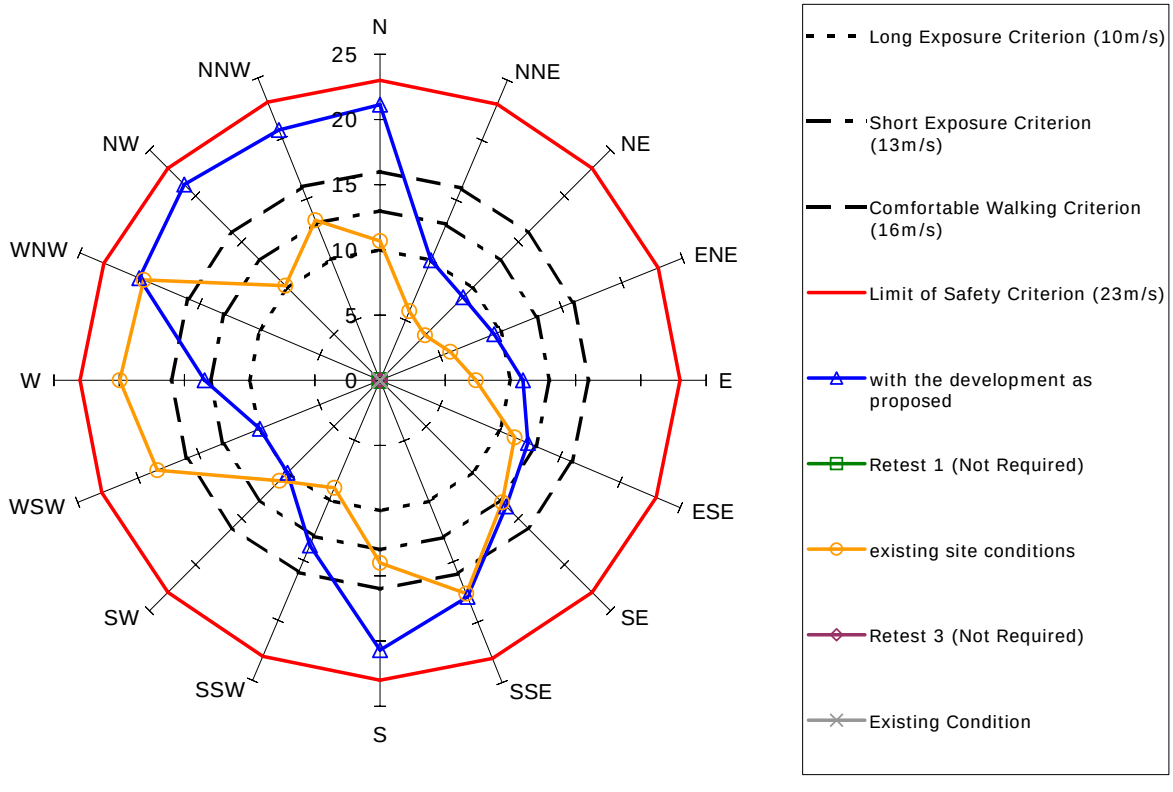


# Measured Wind Speeds at Point 34

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

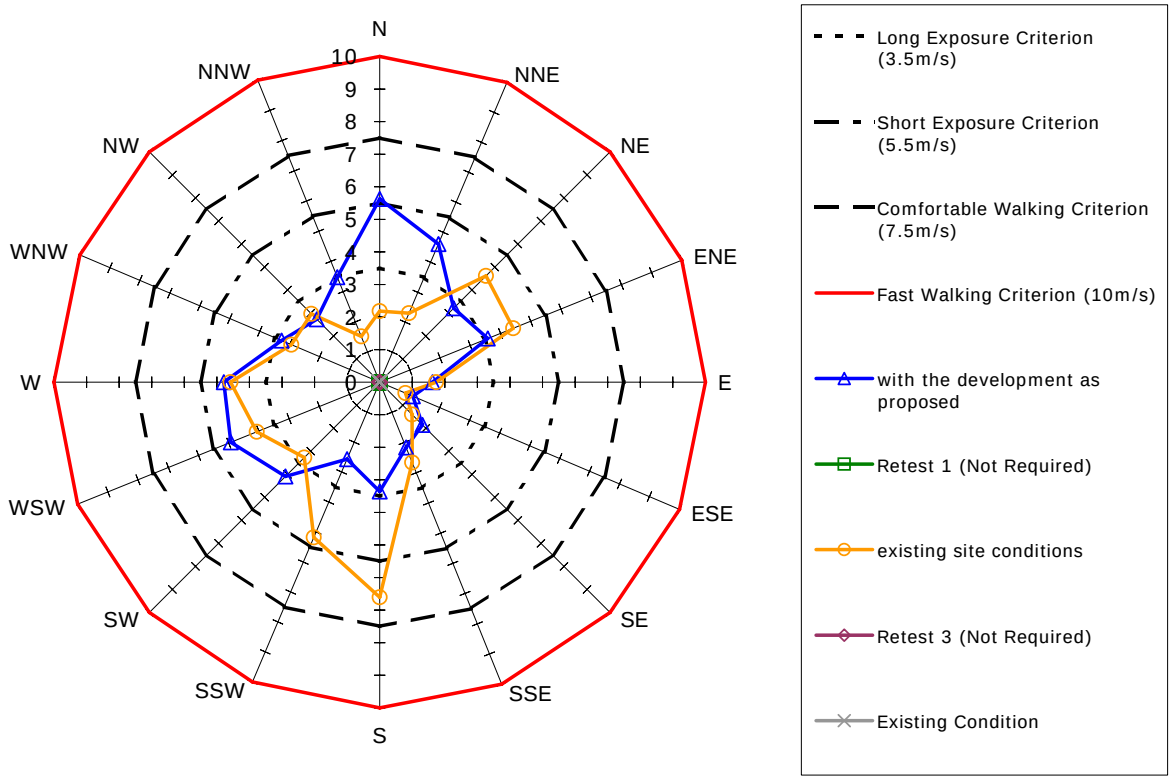



## Annual Maximum Gust Wind Speeds (m/s)

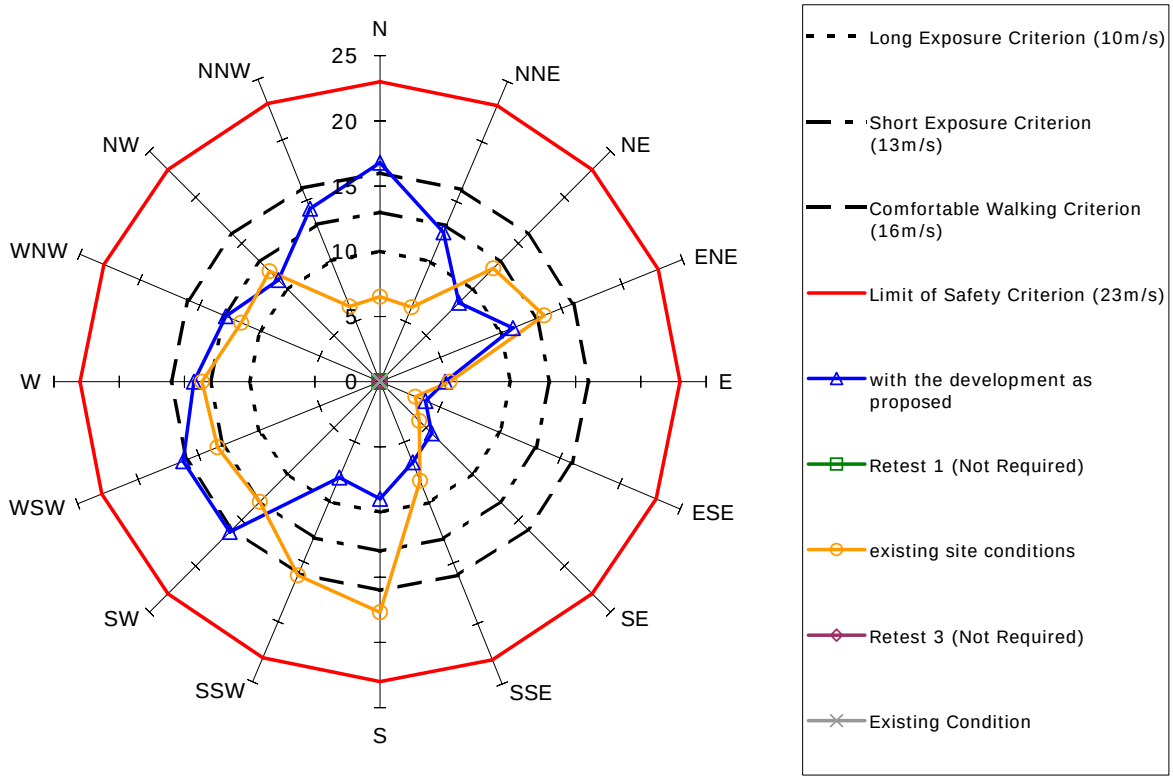


# Measured Wind Speeds at Point 35

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

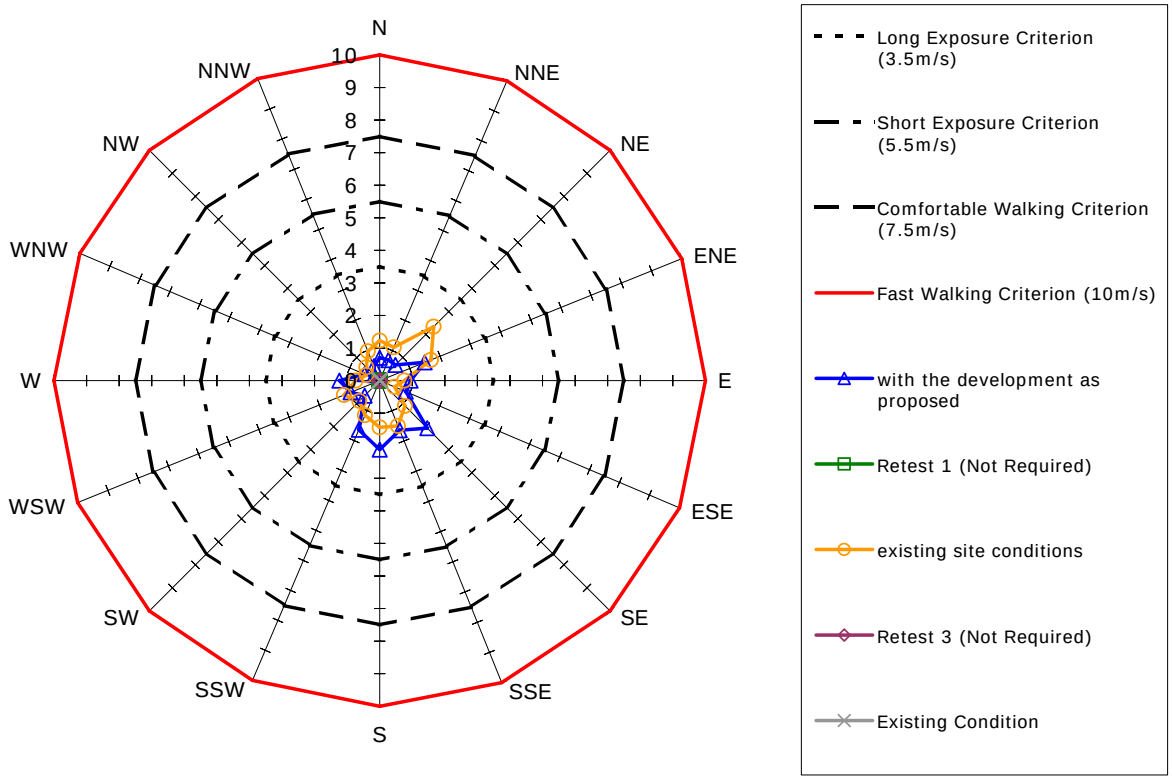



## Annual Maximum Gust Wind Speeds (m/s)

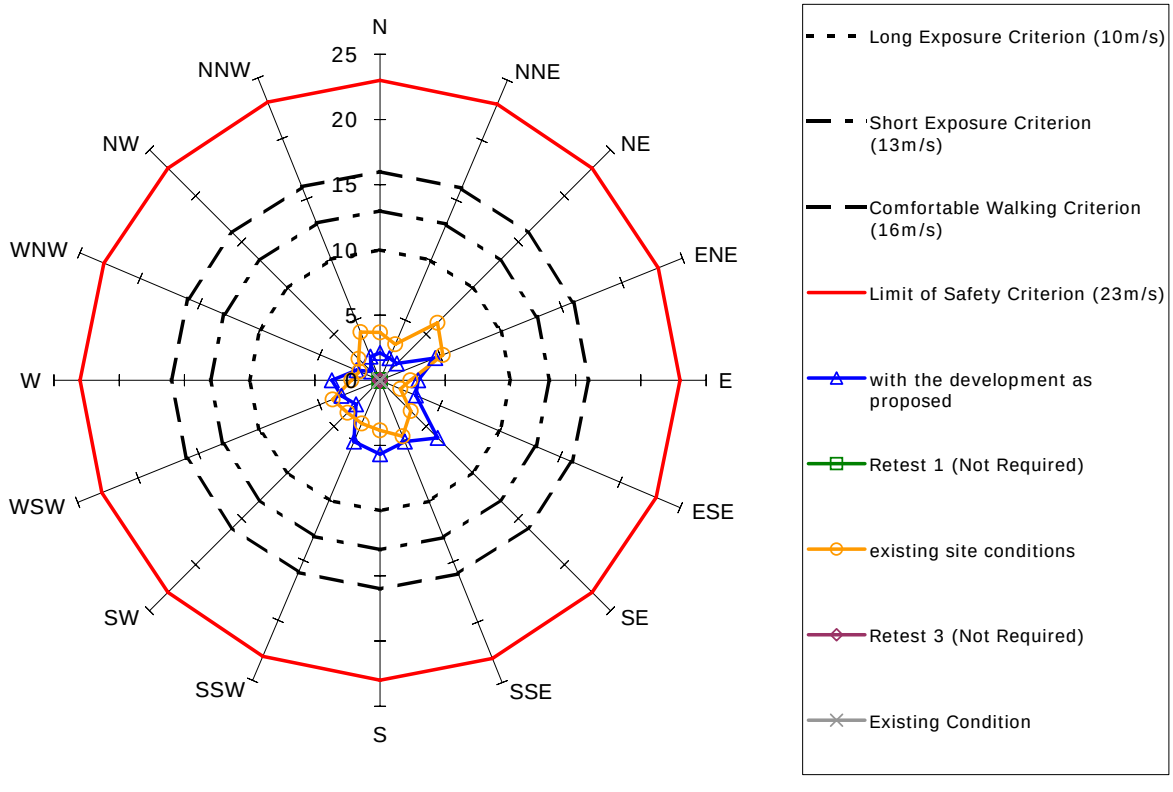


# Measured Wind Speeds at Point 36

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

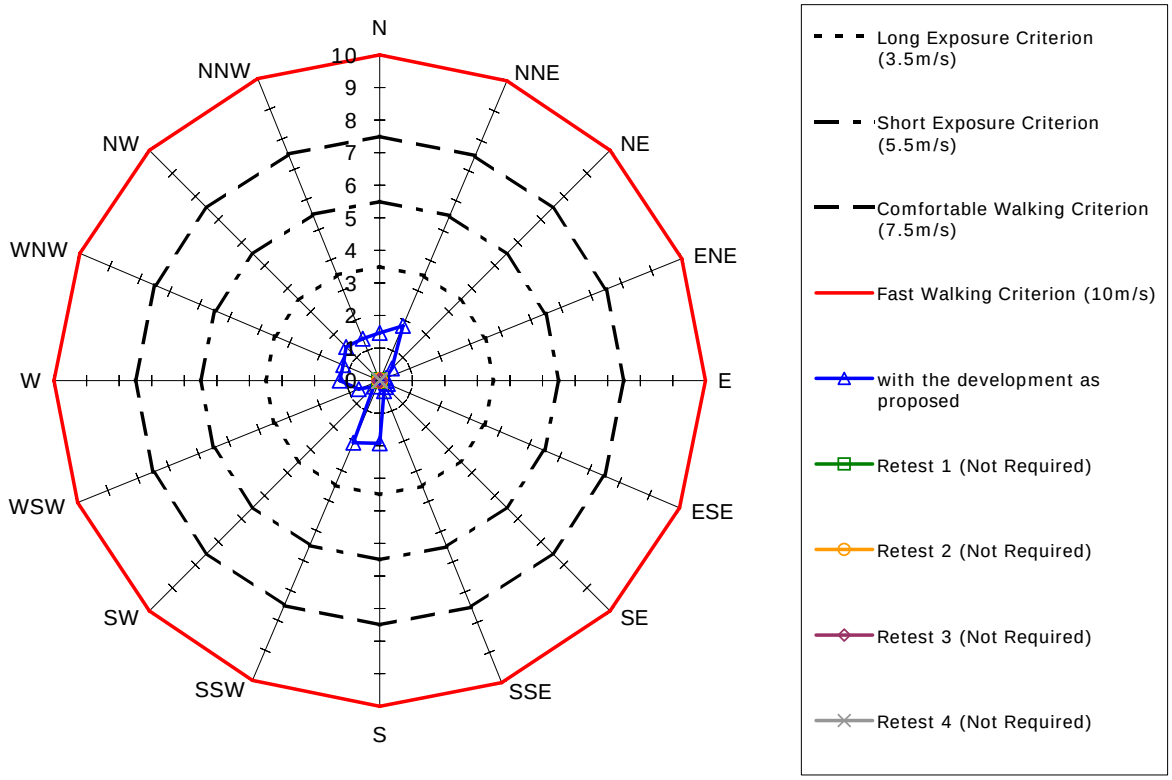



## Annual Maximum Gust Wind Speeds (m/s)

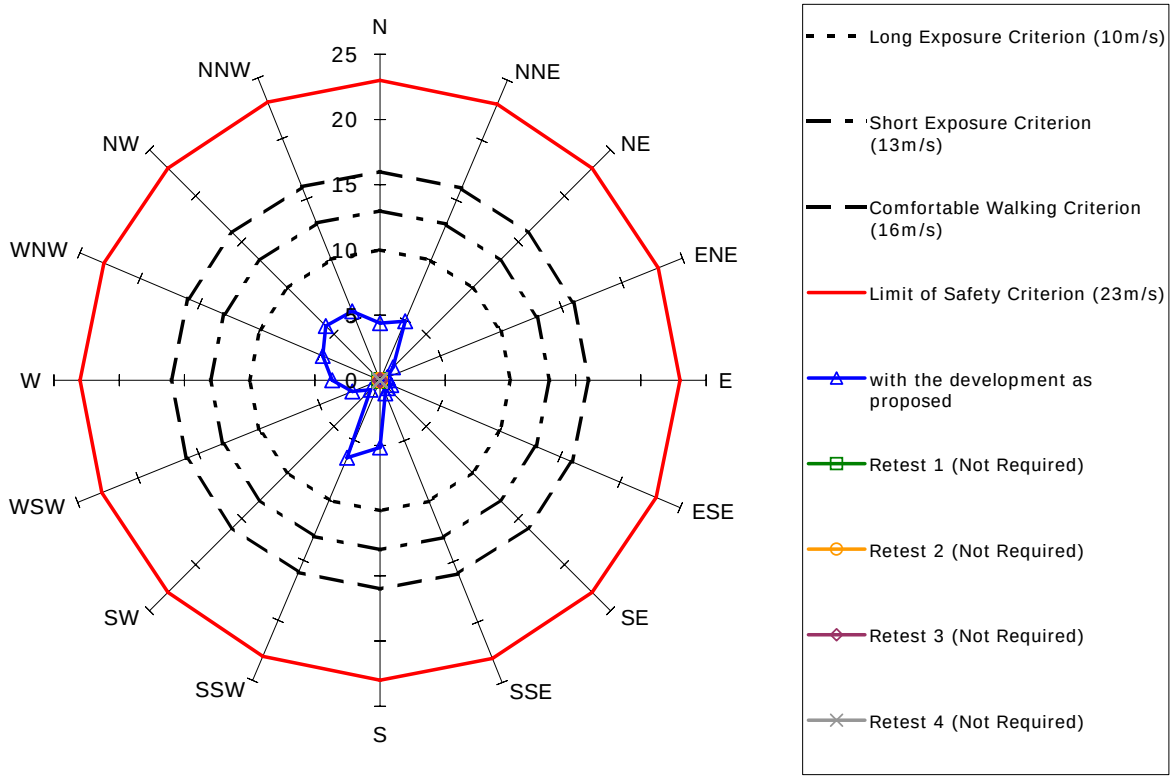


# Measured Wind Speeds at Point 37

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

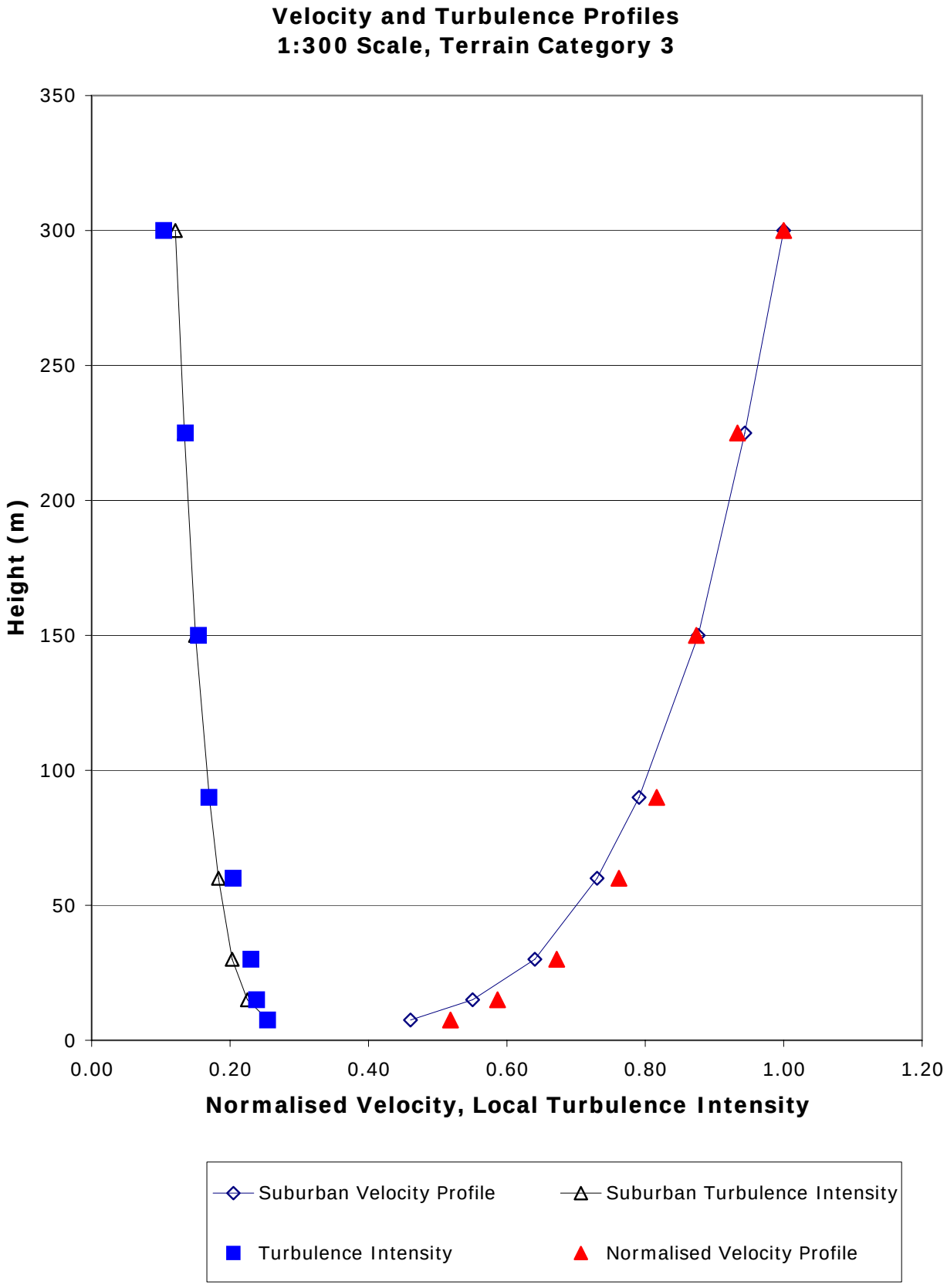


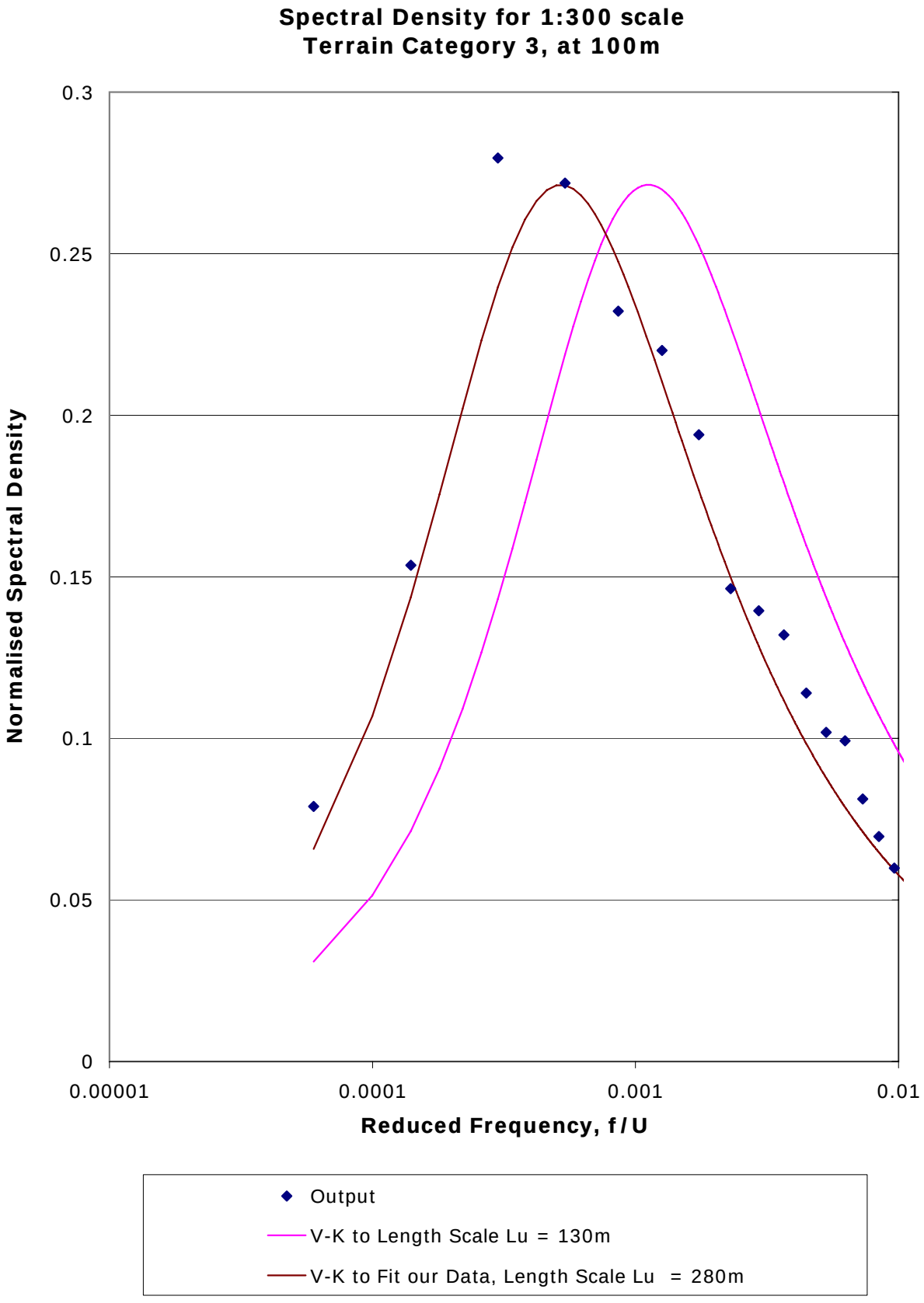

## Annual Maximum Gust Wind Speeds (m/s)

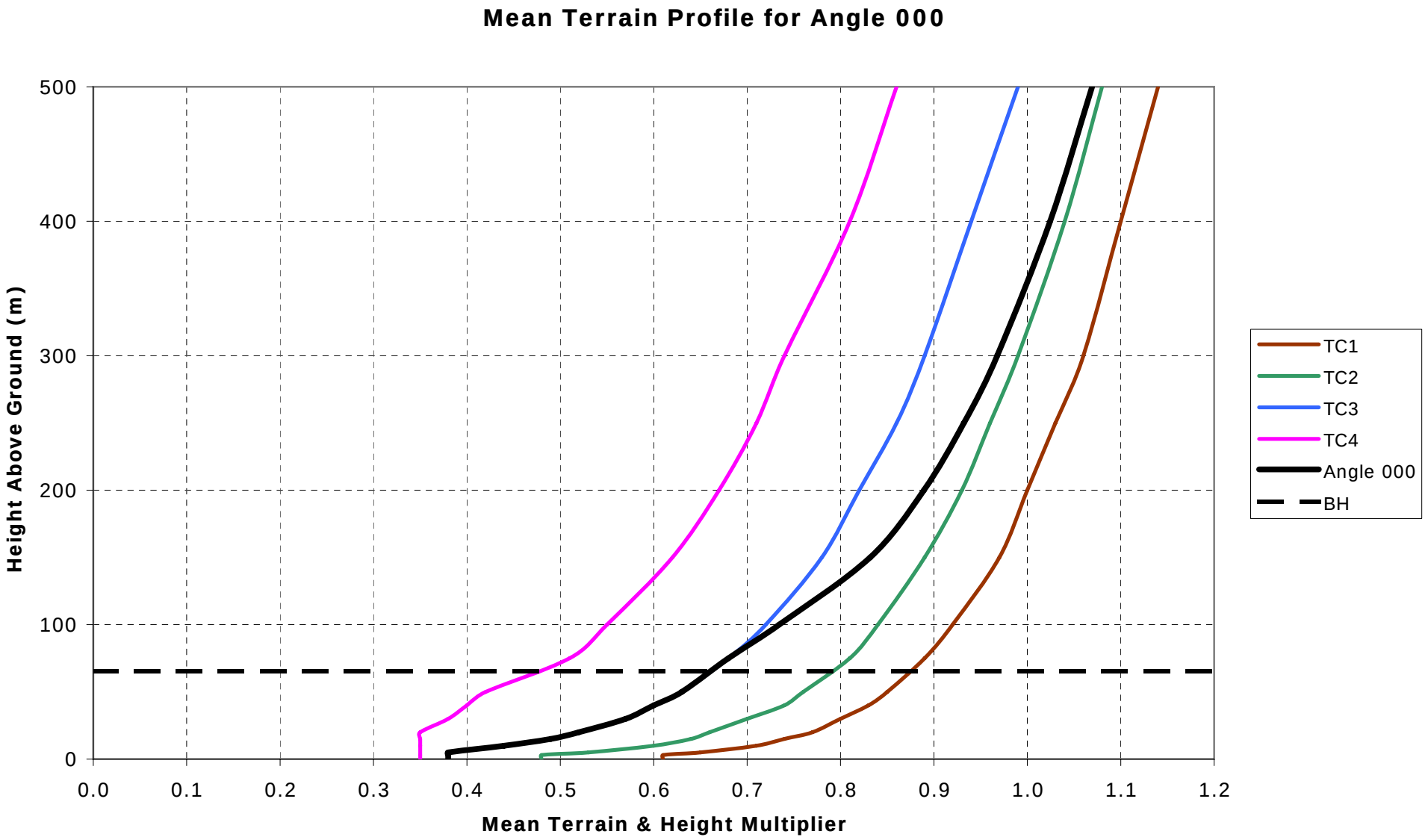


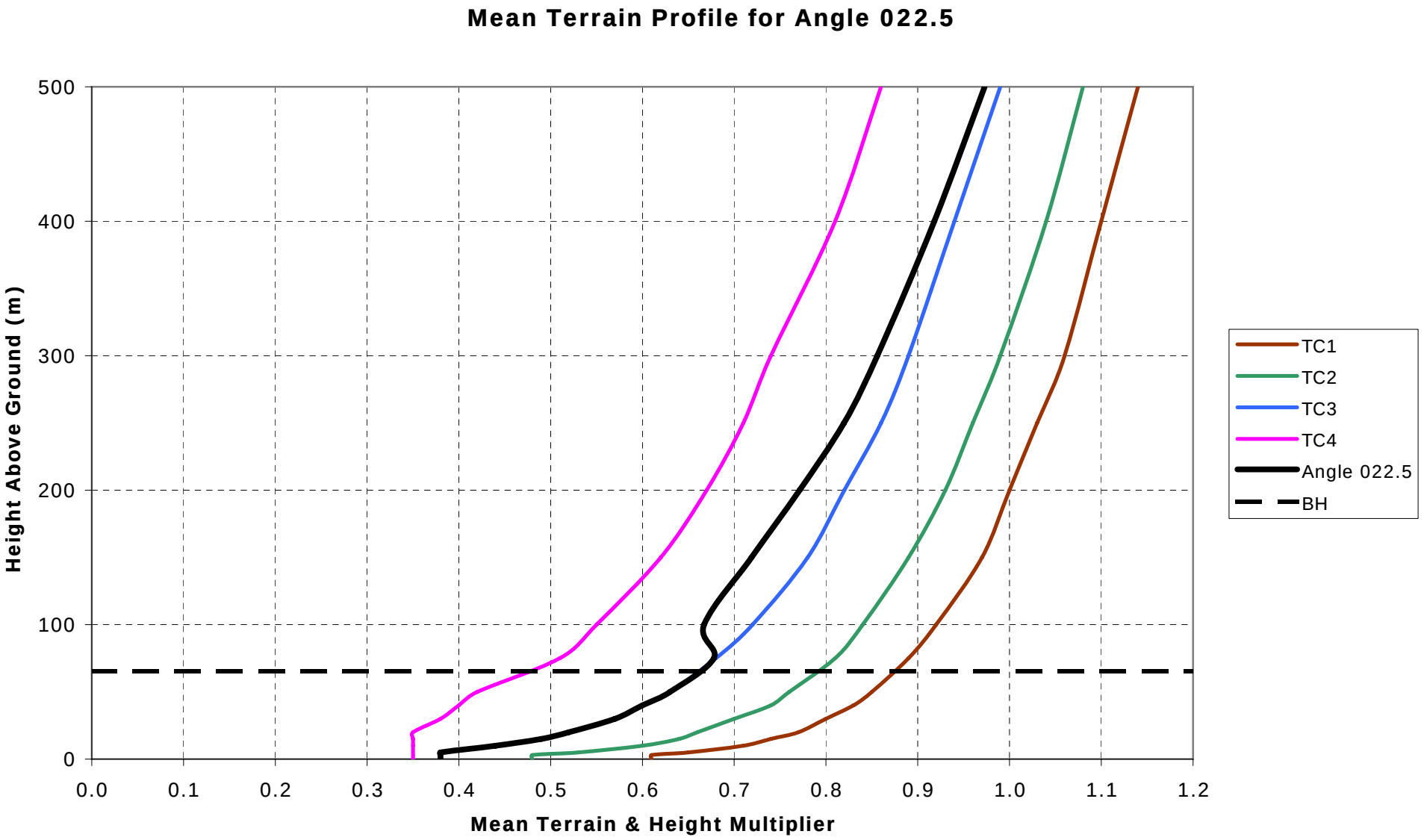
# Appendix B

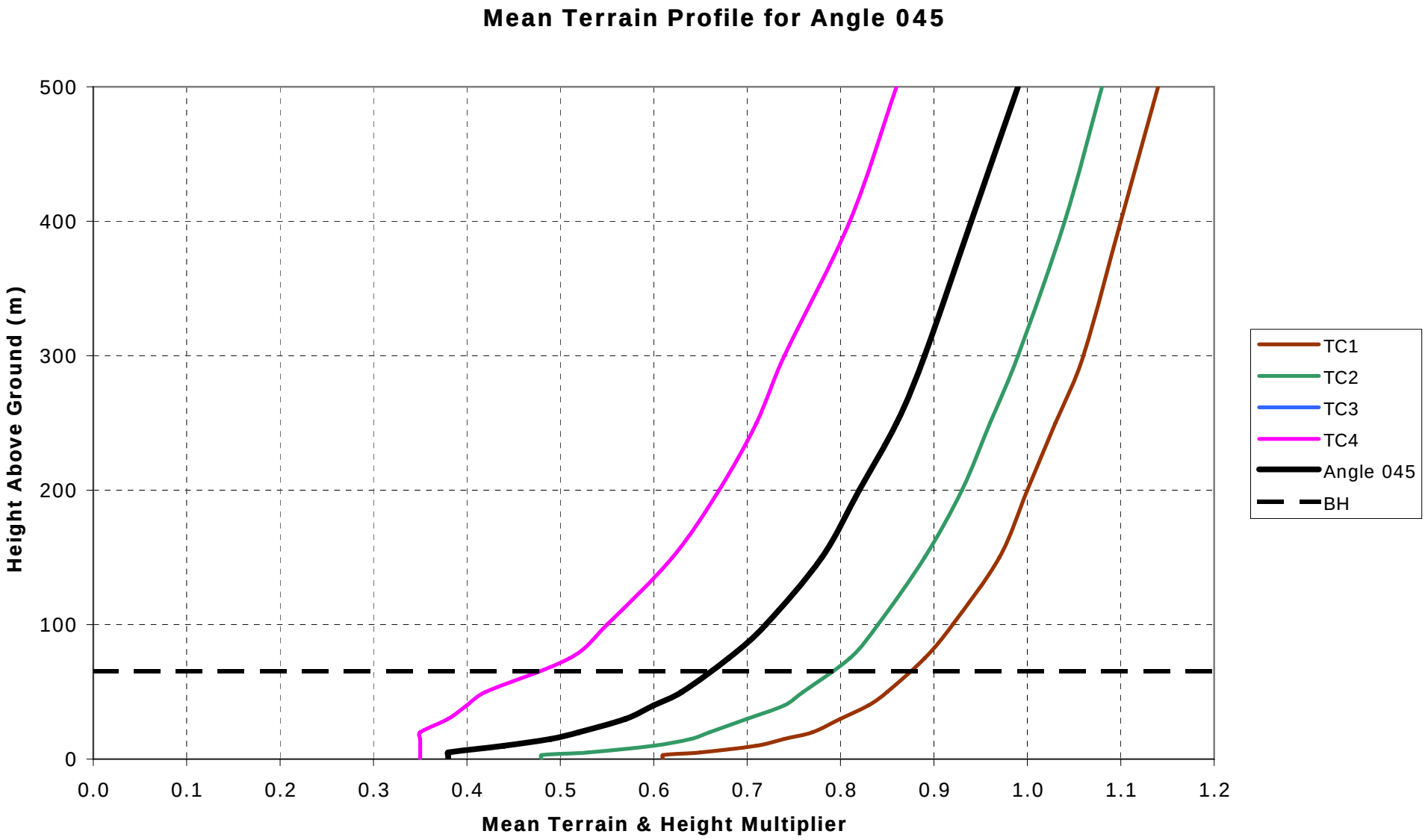
Wind Tunnel Boundary Layer Profiles

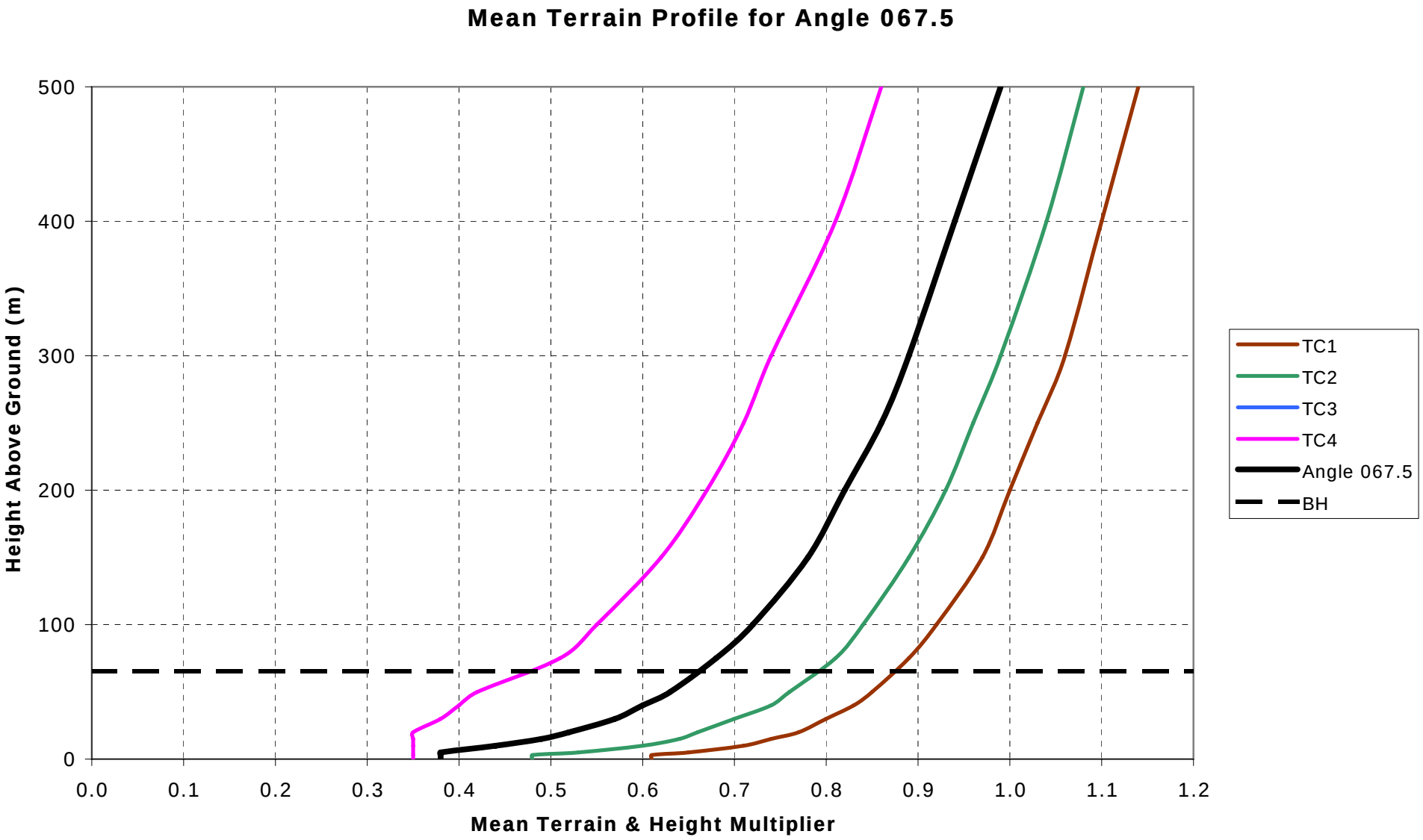

Velocity and Turbulence Profiles
1:300 Scale, Terrain Category 3
Height (m)
350
300
250
200
150
100
50
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
Normalised Velocity, Local Turbulence Intensity
Suburban Velocity Profile
Suburban Turbulence Intensity
Turbulence Intensity
Normalised Velocity Profile

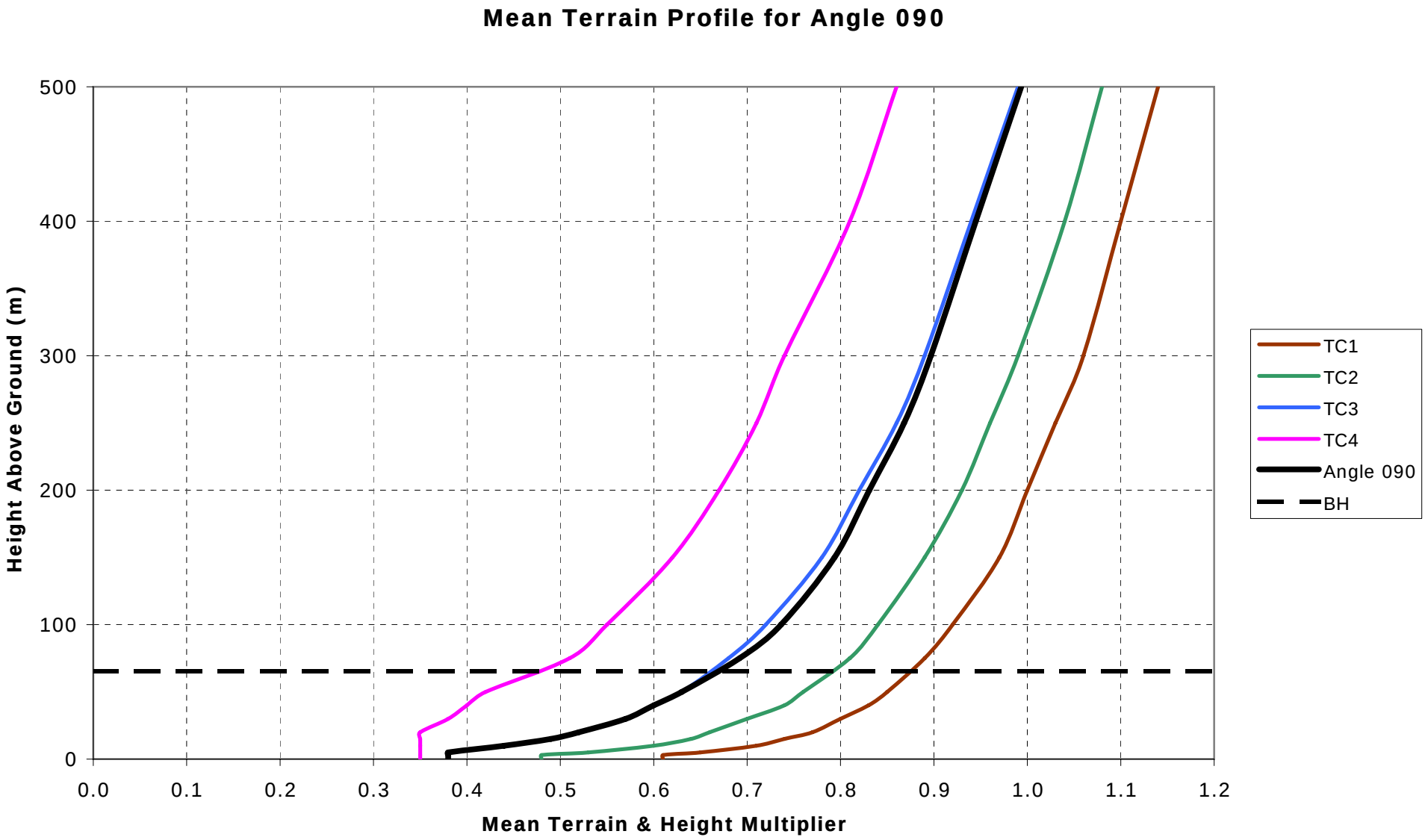

Spectral Density for 1:300 scale
Terrain Category 3, at 100m
Normalised Spectral Density
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00001
0.0001
0.001
0.01
Reduced Frequency, f/U
Output
V-K to Length Scale Lu = 130m
V-K to Fit our Data, Length Scale Lu = 280m

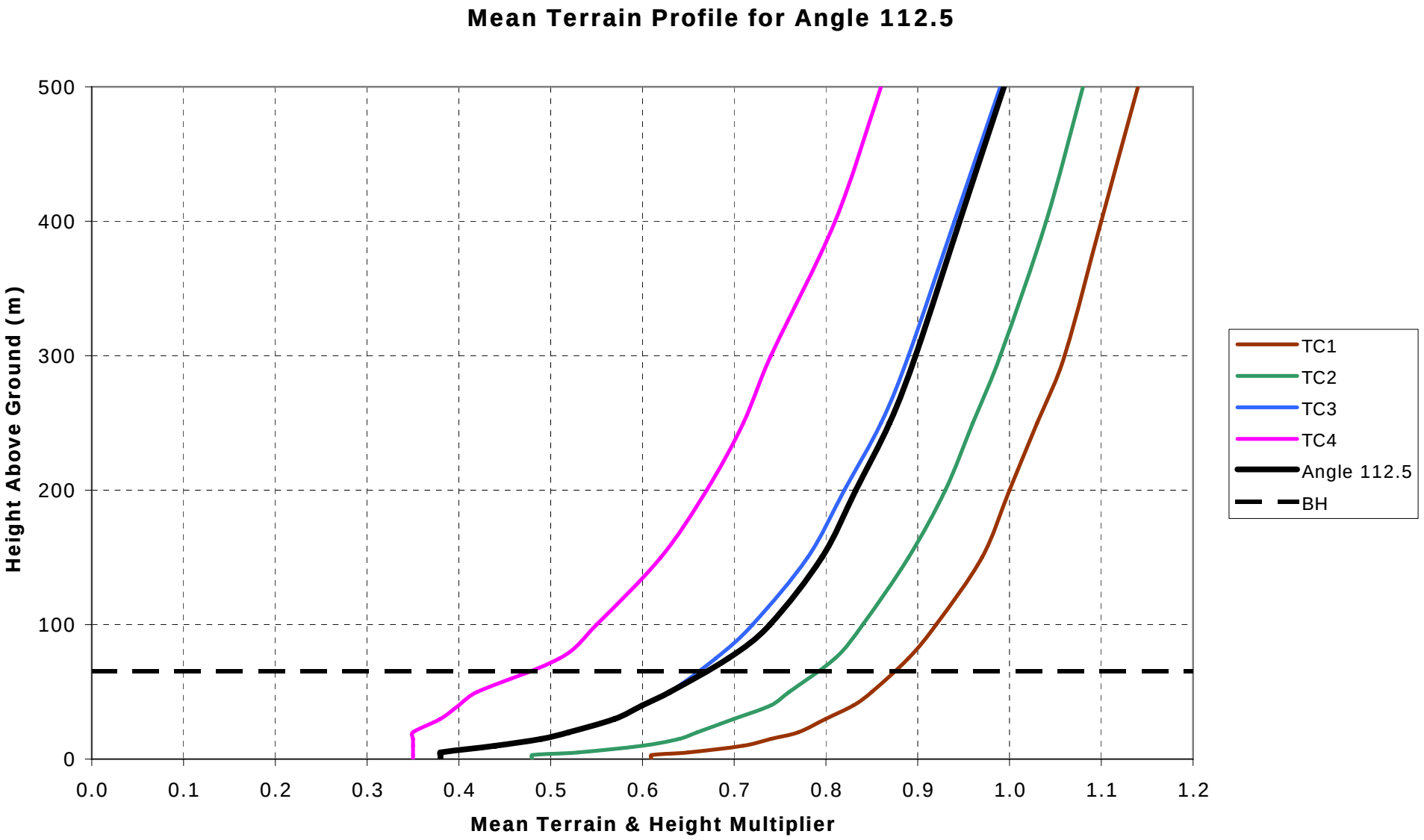

Mean Terrain Profile for Angle 000
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 000
BH

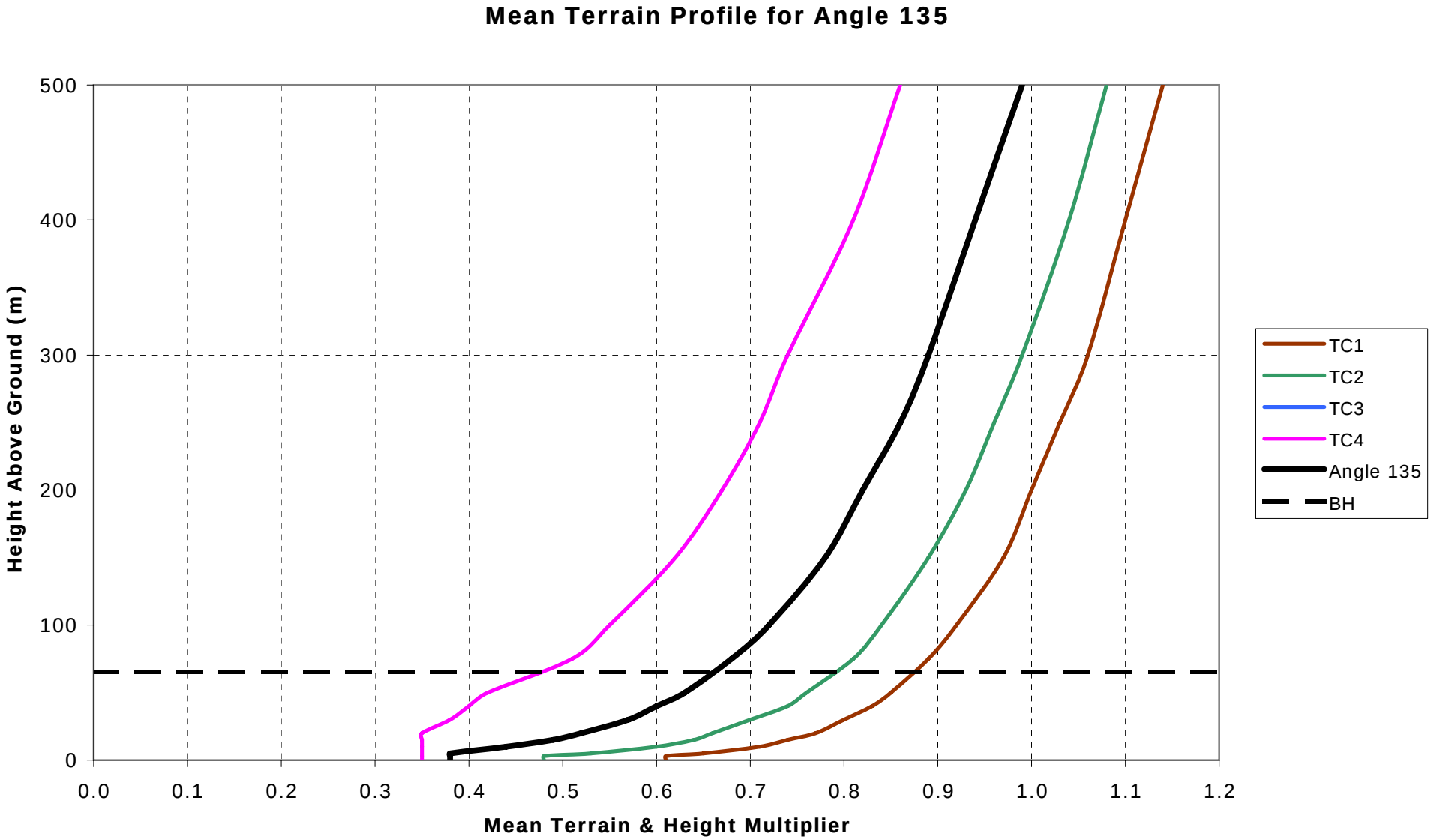

Mean Terrain Profile for Angle 022.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 022.5
BH

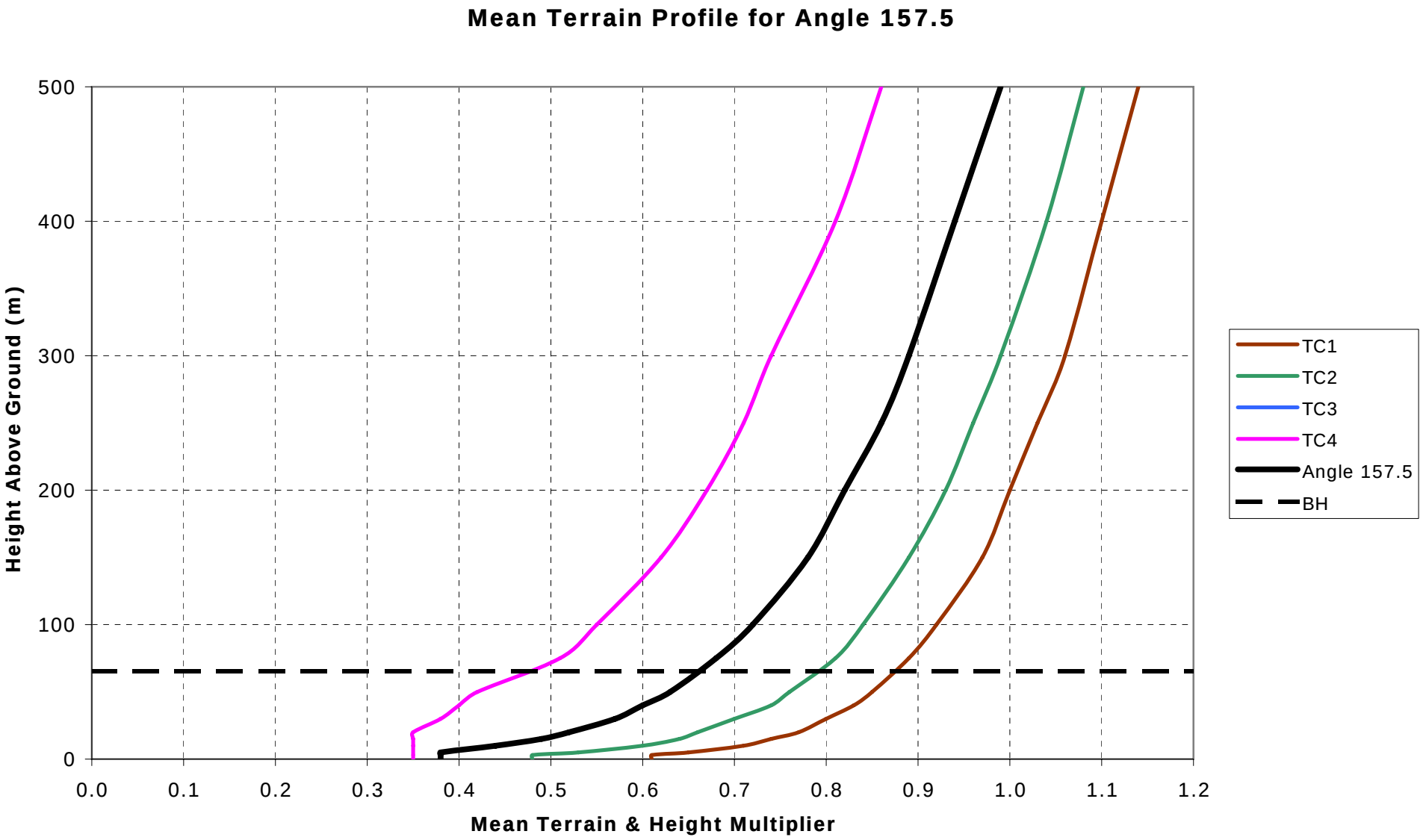

Mean Terrain Profile for Angle 045
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 045
BH

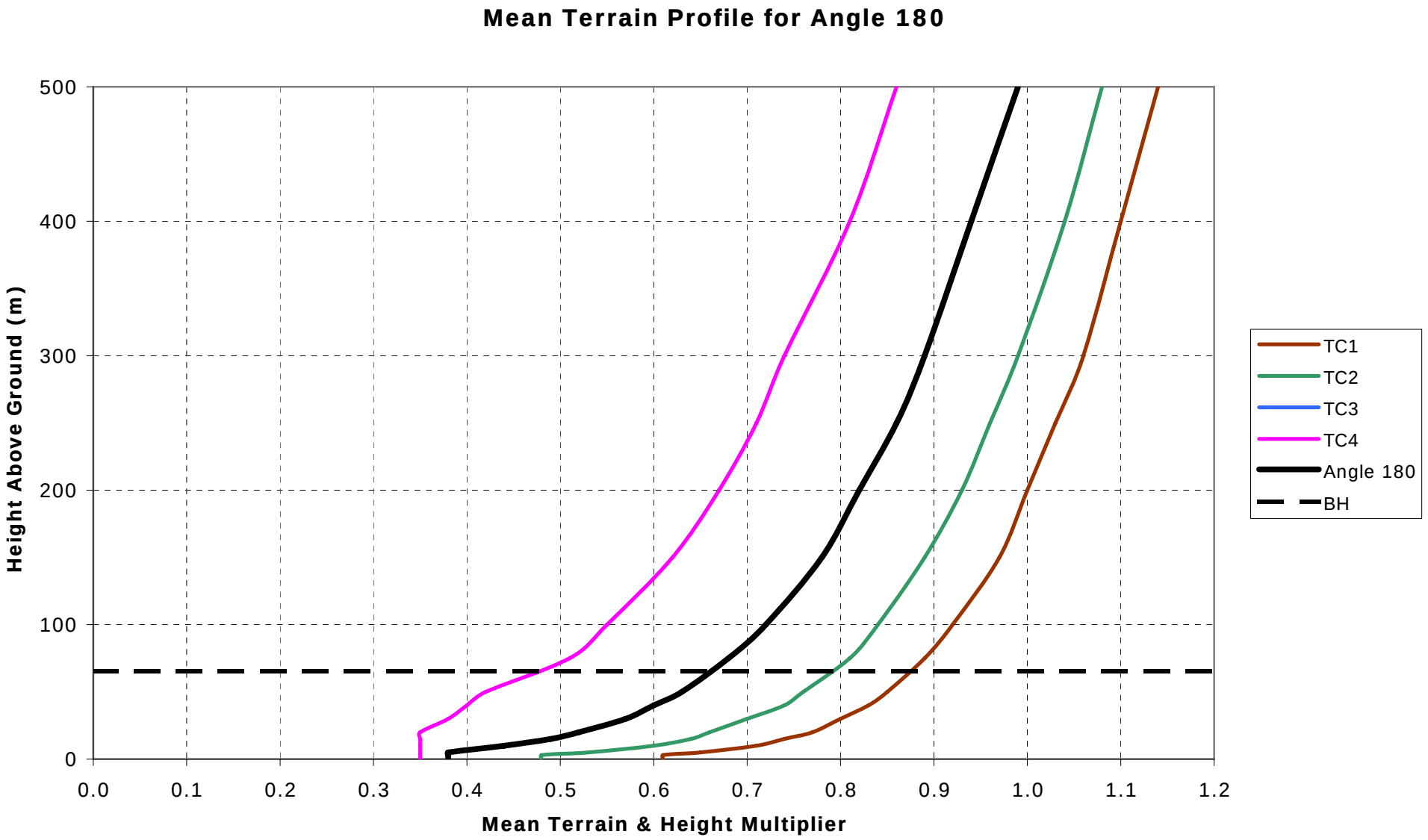

Mean Terrain Profile for Angle 067.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 067.5
BH

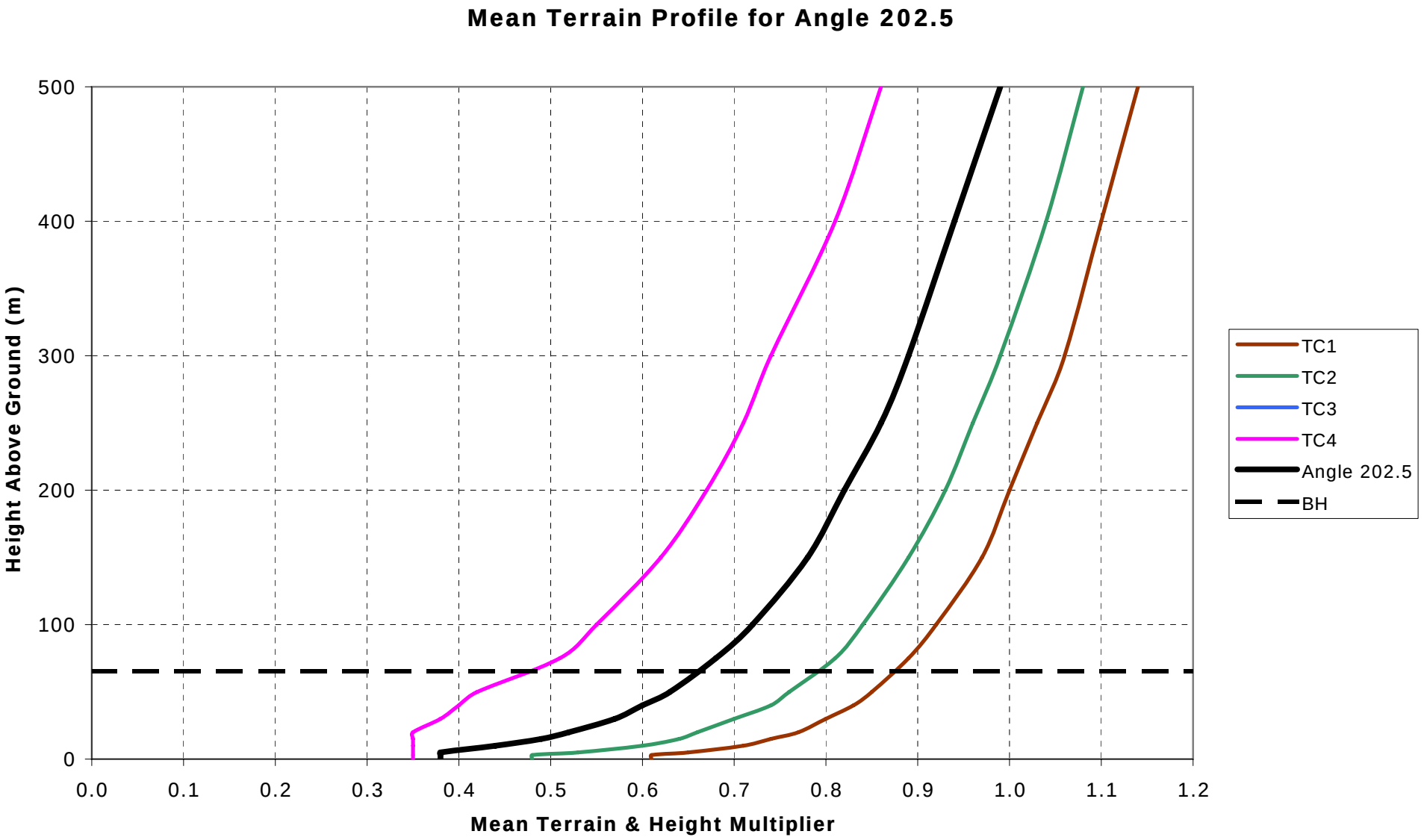

Mean Terrain Profile for Angle 090
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 090
BH

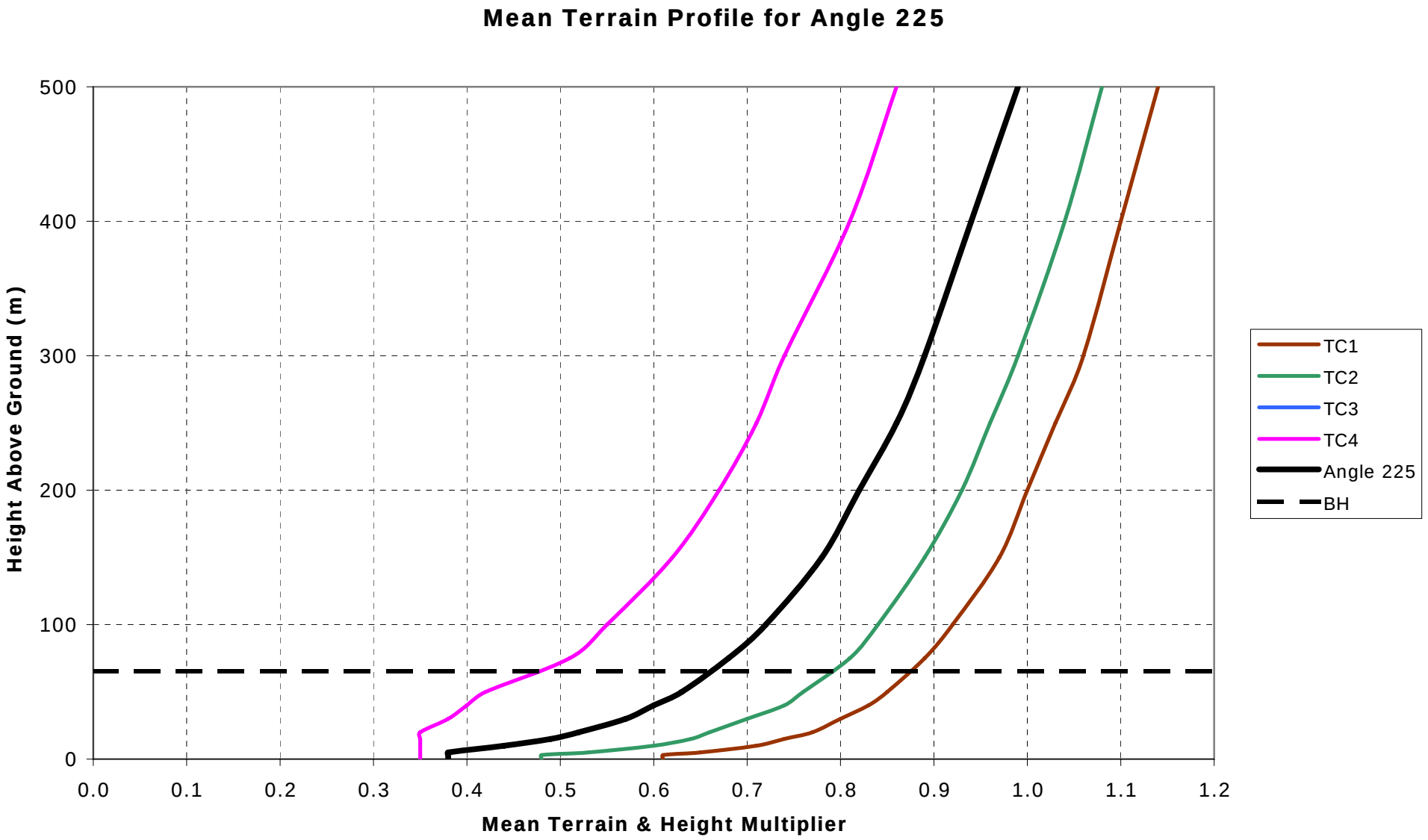

Mean Terrain Profile for Angle 112.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 112.5
BH

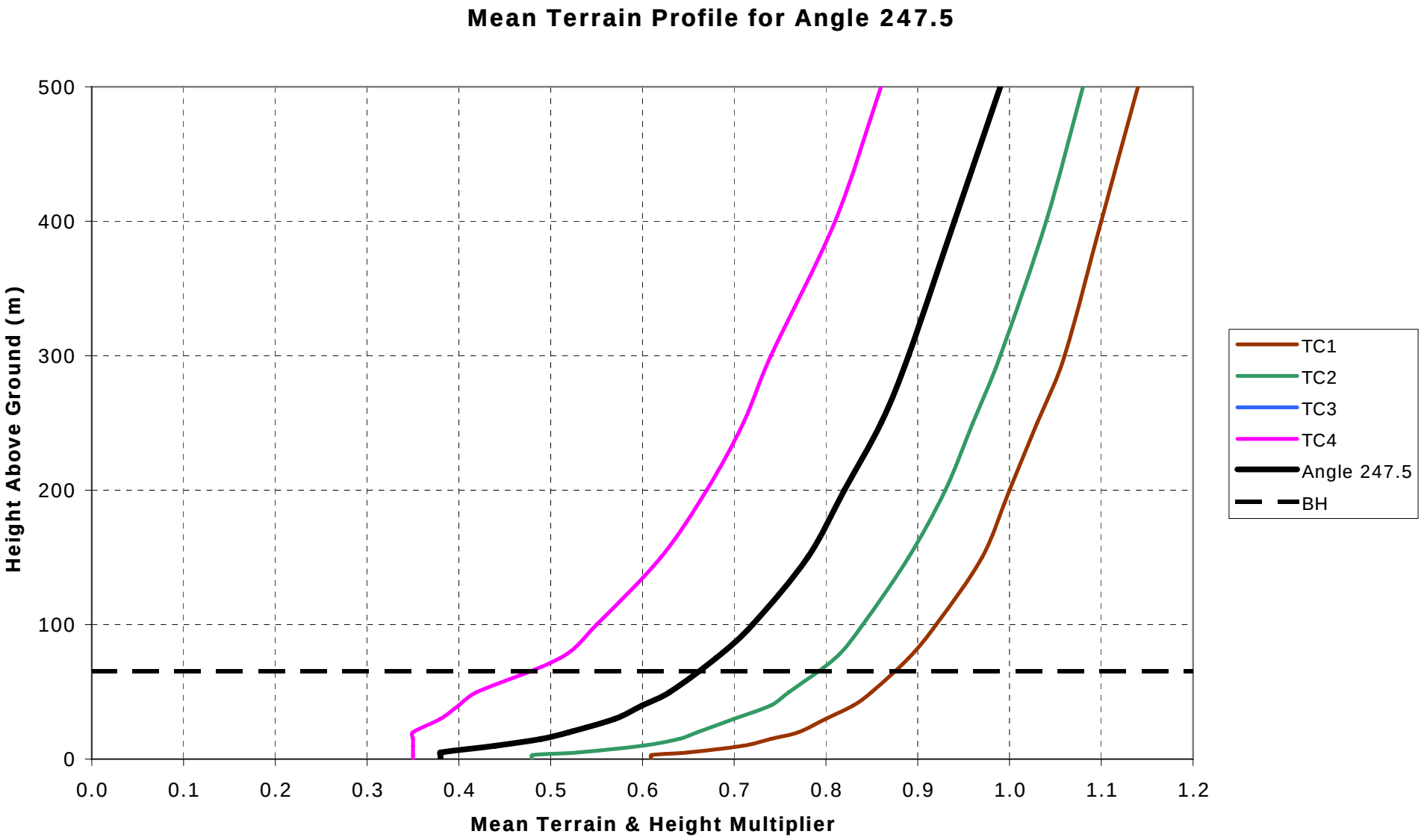

Mean Terrain Profile for Angle 135
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 135
BH

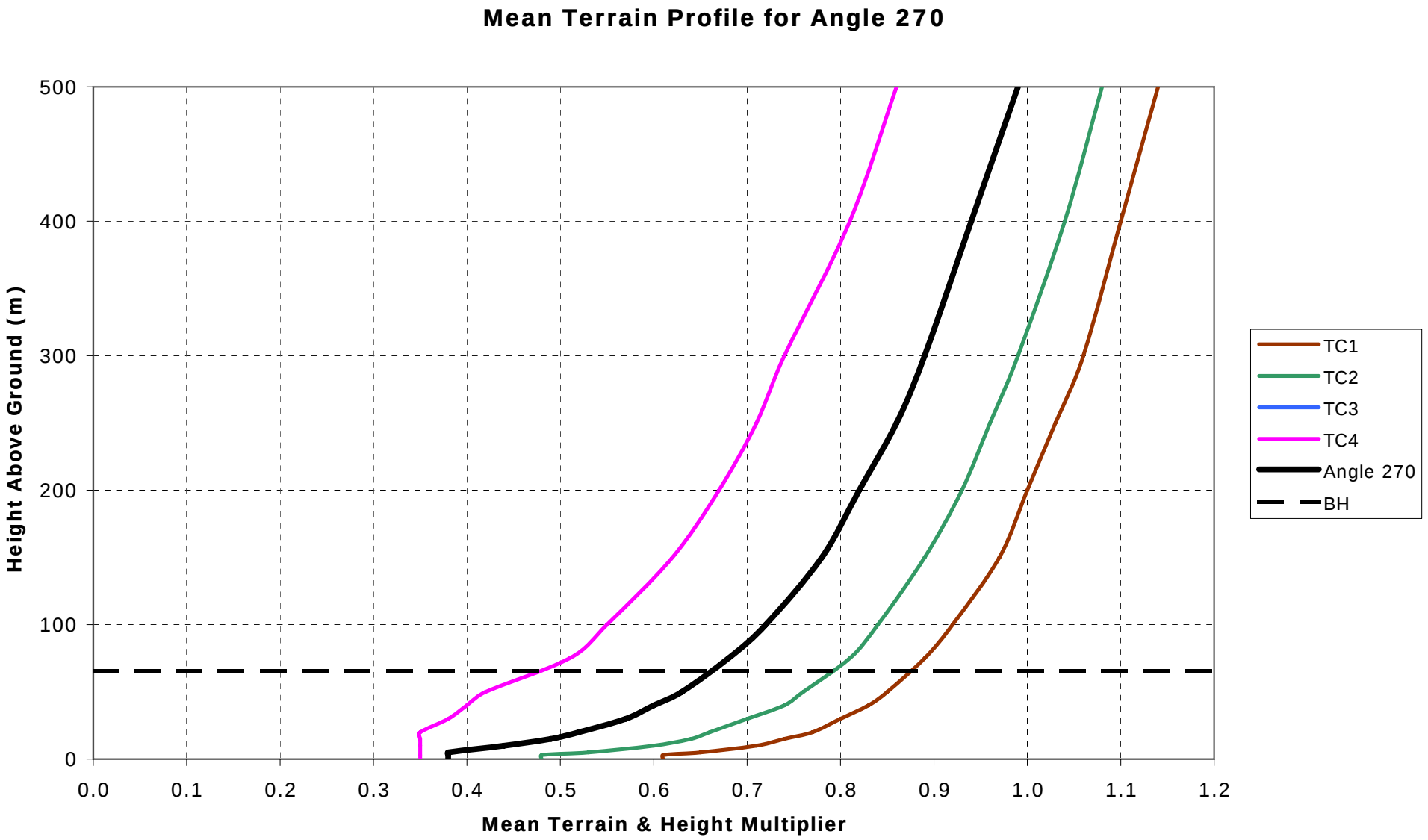

Mean Terrain Profile for Angle 157.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 157.5
BH

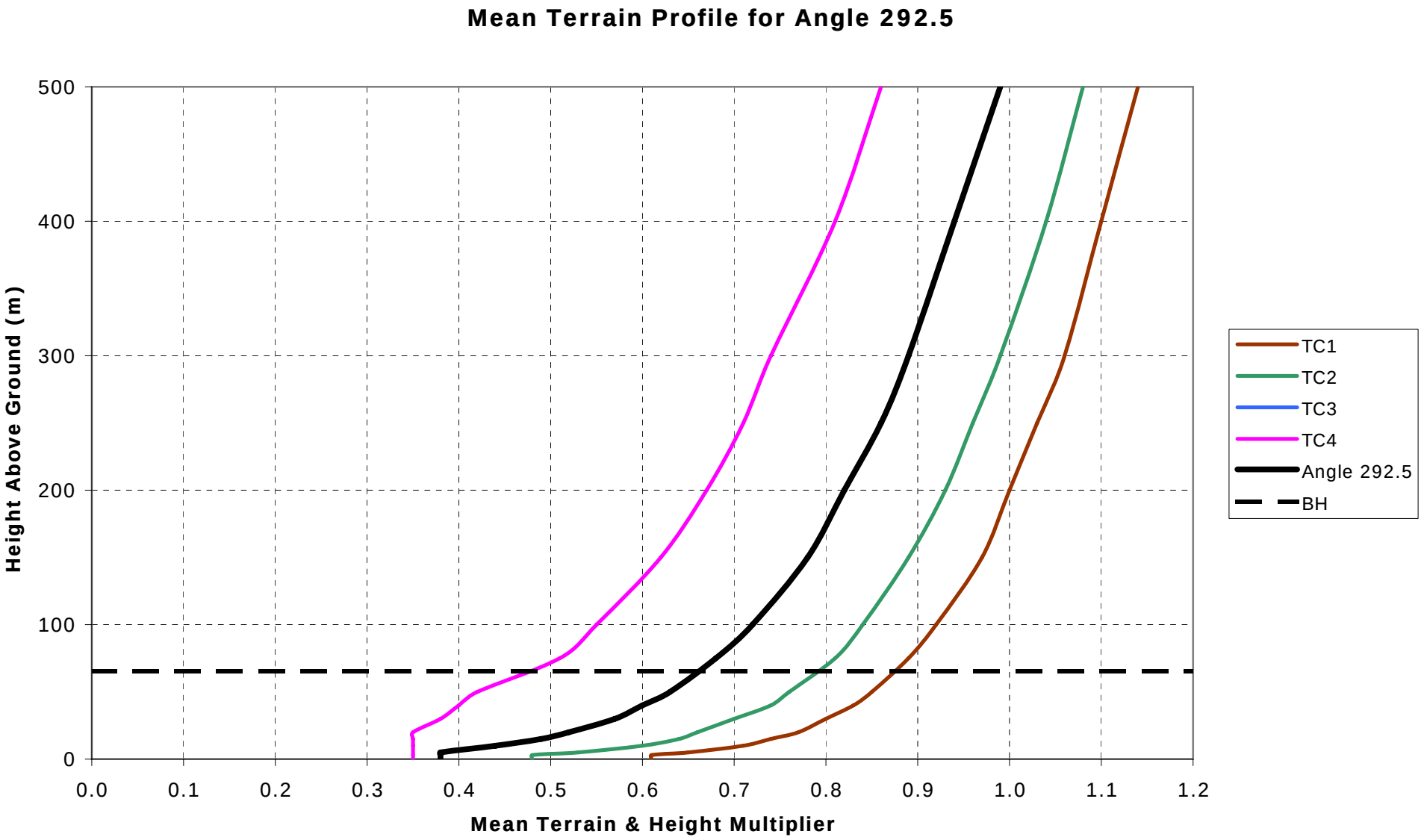

Mean Terrain Profile for Angle 180
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 180
BH

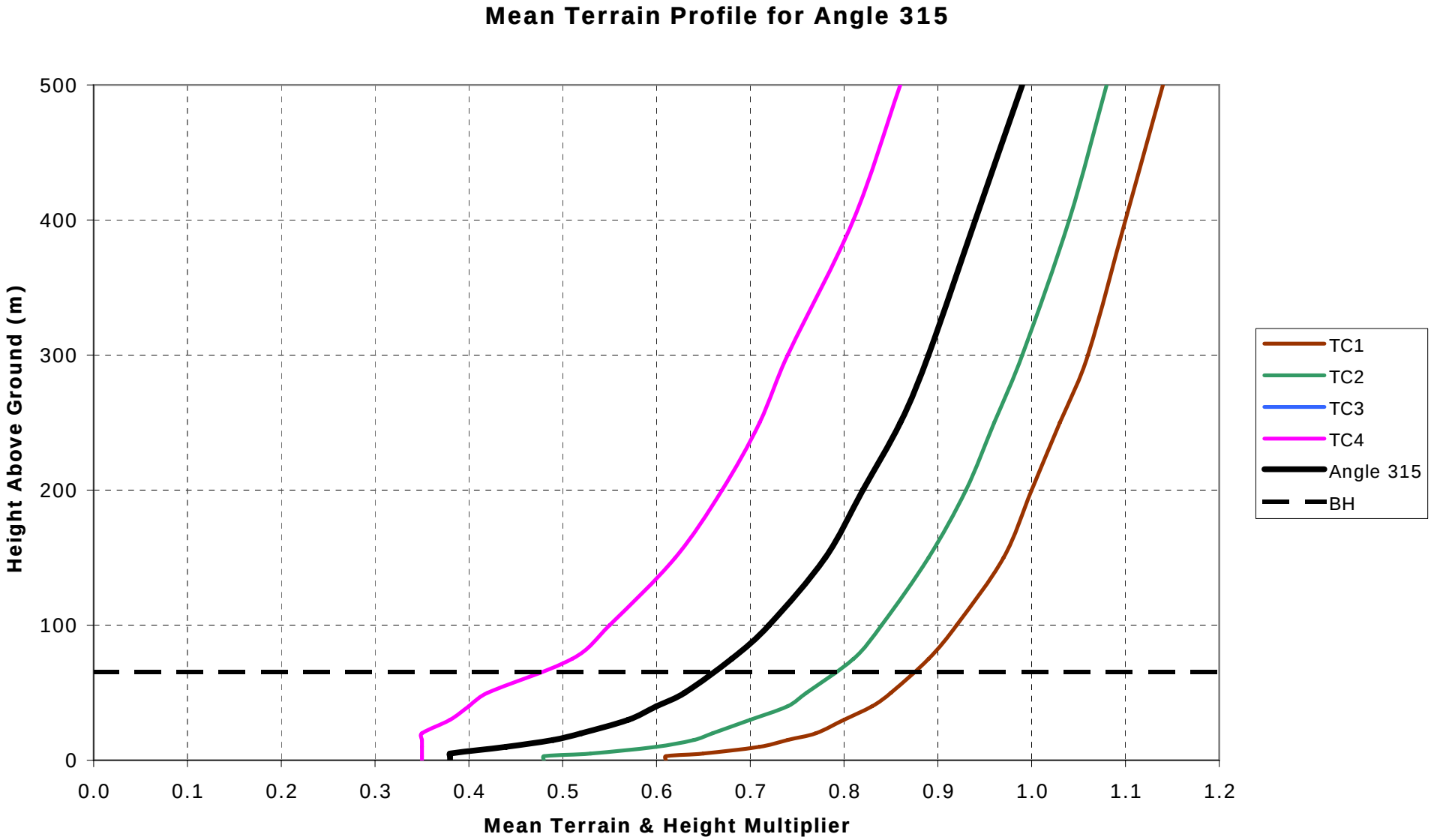

Mean Terrain Profile for Angle 202.5
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 202.5
BH

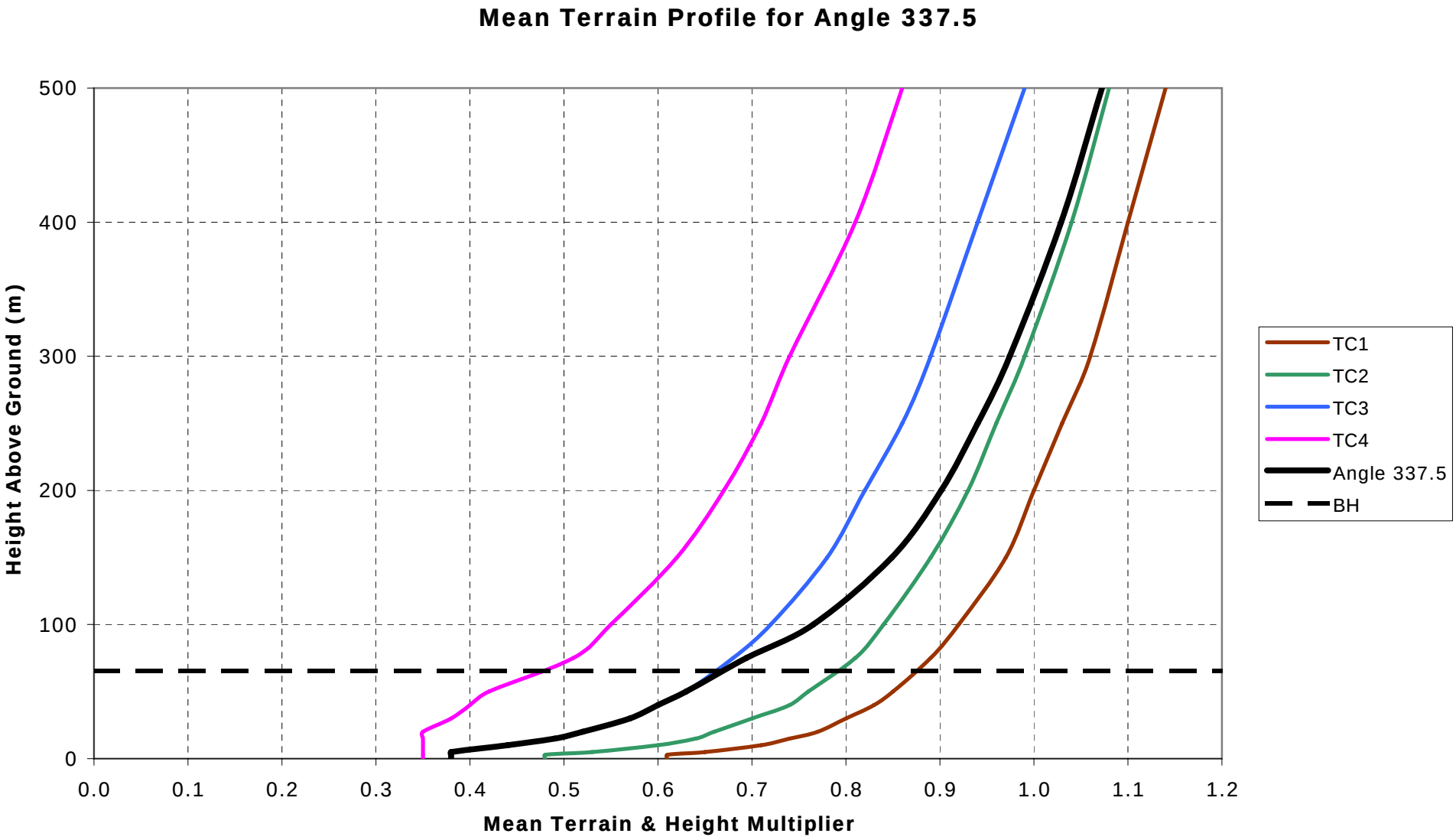

Mean Terrain Profile for Angle 225
Height Above Ground (m)
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Mean Terrain & Height Multiplier
TC1
TC2
TC3
TC4
Angle 225
BH


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