# PEDESTRIAN-LEVEL WINDS REPORT

**CPP PROJECT 15208**
**MARCH 8, 2022**

**SPRING GARDEN WEST**
Halifax, Nova Scotia

**PREPARED FOR:**
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March 8, 2022

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## EXECUTIVE SUMMARY

A wind tunnel study of the Spring Garden West development, to be located in Halifax, Nova Scotia was conducted to assess pedestrian wind comfort and safety. The proposed development is mixed use and includes two - 30 storey towers situated on a three to four storey podium in Halifax, Nova Scotia. The study was conducted in accordance with the Halifax Regional Centre Land Use By-Law to assess the pedestrian wind impact around the development site. Wind tunnel measured velocities were combined with local wind climate data to obtain the full-scale wind speeds and exceedance frequencies at the project site. The results of the study can be summarized as follows:

- During the summer, most measurement points are predicted to have wind comfort conditions rated as *standing* with a few points rated as *strolling* and *sitting* in the existing configuration. With the addition of the proposed Spring Garden West development (and future Promenade Development), wind conditions are generally expected to remain similar with wind comfort ratings at most measurement points predicted to be rated as *standing* and *strolling* with one point rated as *walking*. These predicted wind conditions are considered appropriate for the intended use of the areas around the Spring Garden West development.
- During the winter, most measurement locations around the site are generally expected to be comfortable for *walking* or *strolling* in the existing configuration, with one measurement location further south of the site predicted to be *uncomfortable*. With the addition of the Spring Garden West development (and future Promenade development) wind activity around the site are expected to increase with conditions at most locations generally rated as *walking* or *uncomfortable*. It should be noted, these predicted wind conditions are common for other similar size developments in the Halifax area during the winter season.
- All measurement locations are predicted to meet the wind safety criteria in the existing configuration. The addition of the Spring Garden West development (and future Promenade development) are expected to result in one location which marginally exceeds the safety performance standard (~1 km/h above the criteria limit).
- While the Spring Garden West development does contribute to some minor increases in wind speeds along Robie Street, it is CPP's opinion that the predicted safety exceedance at point 28 is the result of the future Promenade development and the result of winds downwashing and accelerating at the southwest corner the Promenade. It is CPP's opinion that the various conceptual mitigative strategies presented (particularly the addition of streetscaping along the Robie Street sidewalk) are expected to improve wind conditions at this location.

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# 1. INTRODUCTION

An assessment of the acceptability of the wind environment around developments can inform designers about the suitability of outdoor areas for their intended uses. Where necessary, design modifications can be made, or intervention measures added, to mitigate areas with the potential for excessive wind speeds.

The proposed Spring Garden West development is located at the corner of Spring Garden Road and Robie Street. The mixed use development includes two - 30 storey towers situated on a three to four storey podium in the heart of Halifax, Nova Scotia.

This report includes wind tunnel test procedures, test results, and a discussion of test results obtained in the CPP, Inc. Wind Engineering Laboratory.

This study was conducted in accordance with Halifax Regional Centre Land Use By-Law. All data collection was performed in accordance with the National Building Code (NBC) of Canada (2015), American Society of Civil Engineers (ASCE) Standard 7-10 (2010), the ASCE Manual of Practice Number 67 on Wind Tunnel Studies of Buildings and Structures (1999), and the ASCE Standard 49-12 on Wind Tunnel Testing of Buildings and Other Structures (2012).

## 1.1. MODEL SCALE AND CONFIGURATIONS

| *General Information* | |
|---|---|
| Model scale | 1:300 |
| Surrounding model radius (full-scale) | 1700 ft |
| Mean wind speed profile | - Open-country environment approach representative of Exposure A in NBCC<br>- Built-up environment approach representative of Exposure B in NBCC |
| *Pedestrian Comfort Study Information* | |
| Number of points | 28 |

*Testing Configuration(s)*

| | | |
|---|---|---|
| A | Existing | Site and surroundings as they currently exist (includes buildings that are under construction) |
| B | Proposed | The Spring Garden West development in addition to the adjacent future Promenade Development, as shown in Figure 3. |

### 1.2. MEASUREMENT POINTS

Wind speed measurements were made at 28 selected locations to evaluate pedestrian comfort and safety. Some measurement points were selected to determine the degree of pedestrian comfort or discomfort at locations where higher wind speeds are frequently found, such as at building corners, near entrances and on adjacent sidewalks with heavy pedestrian traffic, in open plaza areas, and on podium level amenity areas intended for recreational activity.

Wind speed and turbulence measurements were made at the model-scale equivalent of 1.5 m above the surface for 36 wind directions in 10° increments from 0° (north). Wind speeds were measured with a CPP Probe (calibratable pedestrian-level pressure probe).

The following table gives a brief description of the tested points:

| Point number(s) | Description |
|---|---|
| 6–15,32,33 | Ground-level, pedestrian points surrounding Spring Garden West. |
| 16–21,24 | Ground-level pedestrian points along Spring Garden Road. |
| 22,23,25–28 | Ground-level pedestrian points along Robie Street. |
| 29–30 | Ground-level pedestrian points along College Street. |

### 1.3. WIND CLIMATE

The measured velocity data were normalized to an approach reference wind speed and then combined with a climatological model (wind frequency and direction) derived from data measured at a standard height of 10 m at the Shearwater Airport. This data is portrayed in the wind roses in Figure 1. The arms of the wind roses point in the direction from where the wind is blowing from, the width and colour of the arm represent the wind speed, and the length of the arm indicates the percent of the time that the wind blows for that combination of speed and direction.

The meteorological information of primary interest for this evaluation is the wind frequency distribution at the project site. The Regional Centre Land Use By-Law (2018) requires that the data within the last 30 years from Shearwater Airport be used as a reference for any project site within the Halifax Regional Municipality. Sufficient length and completeness (little to no missing hourly wind data) of the wind data record is crucial for this analysis because the hourly wind measurements are binned by direction and fit to a Weibull distribution. Generally, at least 10 years of hourly wind observations are needed to achieve a good data fit. The available Shearwater Airport data include hourly and sub-hourly observations of mean and gust wind speeds from 1984-2021. After 2004, the airport observations included are during daylight hours only (06:00-18:00). During nighttime hours, wind speeds are typically slower, so the dataset from 1984-2021 would be bias towards faster wind speeds, which is not representative of the airport nor the site. Therefore, the data from 1984-2004 were used for this analysis to properly capture the wind speeds and directionality at the site.

As approaching wind directions, frequencies and magnitudes can have distinct seasonal variations (especially in regions with colder climates like Halifax) wind roses for the summer (May through October) and winter (November through April) seasons are presented. As can be seen, predominant winds from the south through southwesterly directions occur during the summer, while during the winter, winds are more predominant from the northwesterly directions. In addition, seasonally stronger winds are more often associated with the winter season and are represented by the more prevalent yellow and orange bands in the winter wind rose in Figure 1. This seasonal variation in the wind climate has been addressed in the wind comfort results presented in the contents of this report.

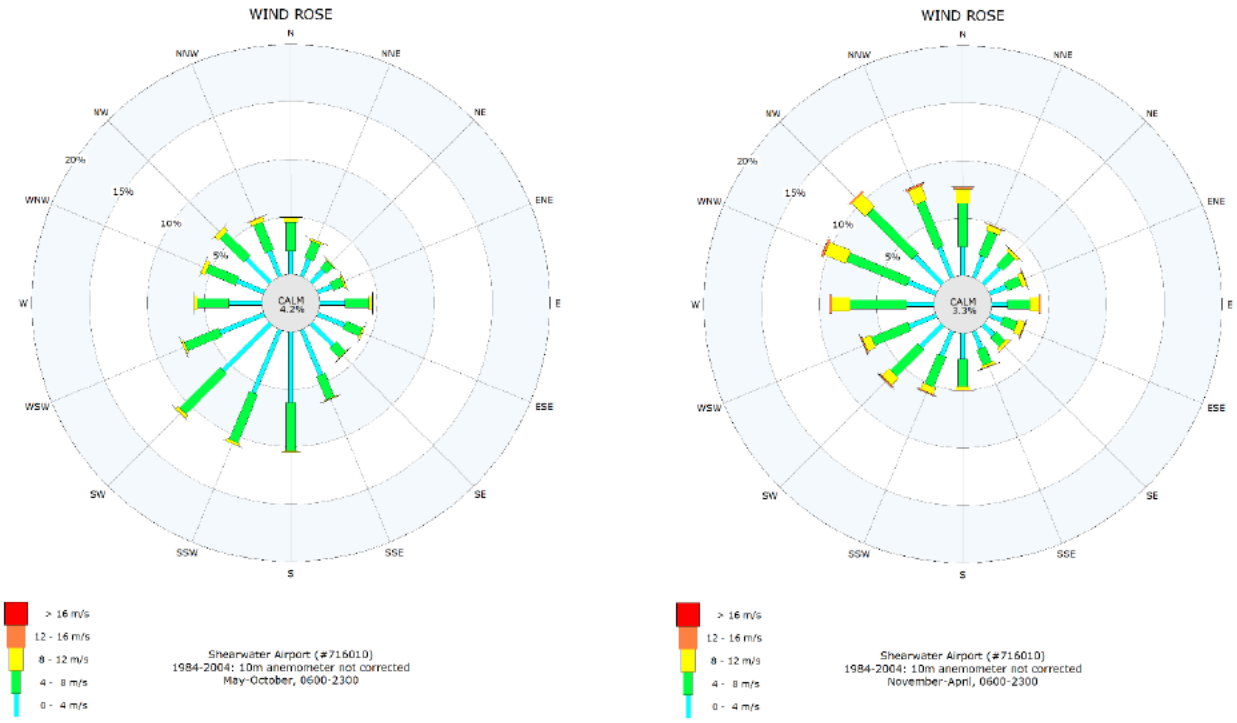


*Figure 1: Probability of occurrence of wind speed by direction – Summer (Left) and Winter (Right)*

In addition to a seasonal analysis of winds, the distribution and frequency of winds on an annual basis were also leveraged to assess the project against the City of Halifax's *"Regional Centre Land Use By-Law"* wind safety performance standards.

Unlike the seasonal breakdown of winds shown in the summer and winter wind roses, which have been filtered between the hours of 6:00 to 23:00 (inclusive), the annual wind rose portrayed in Figure 2 accounts for all hours (0:00 to 23:00 (inclusive)). Echoing the frequency and directionality of the winds during the summer and winter seasons, winds for the area are predominant from the southwesterly and northwesterly directions on an annual basis.

All climate data were adjusted to the site location using an analytical method to account for the exposure of the project site for each direction. The combination of the wind tunnel data and climatological data produces a cumulative probability distribution of wind speed for the site at each pedestrian measurement location which are then evaluated against the applicable pedestrian wind comfort and safety performance standards for the region.

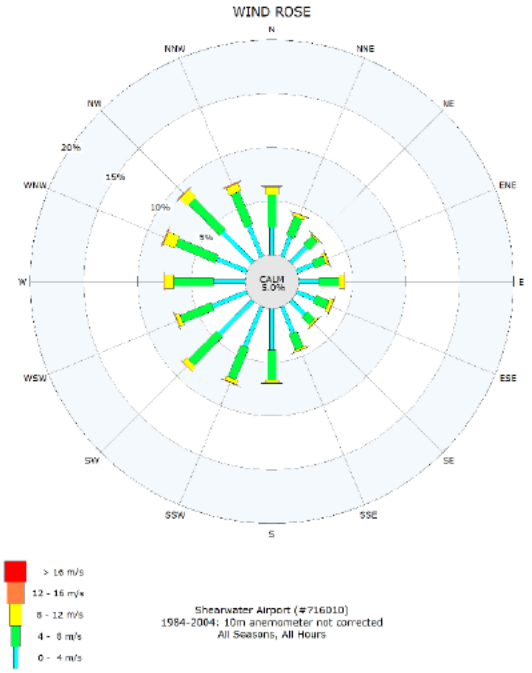


*Figure 2: Probability of occurrence of wind speed by direction – Annual*

## 2. PEDESTRIAN-LEVEL WIND RATINGS – HALIFAX PERFORMANCE STANDARDS

The Spring Garden Road project is taller than 20m, is located in the city of Halifax and has therefore been evaluated in accordance with "*Appendix 1: Pedestrian Wind Impact Assessment Protocol and Performance Standards*" in the "*Regional Centre Land Use By-Law*" published by the City of Halifax:

> *"When an application is made for a new building or an addition to an existing building higher than 20.0 metres, a pedestrian wind impact assessment shall be conducted."*

CPP's evaluation of the development was conducted through detailed quantitative wind tunnel testing where wind speed ratios were acquired, combined with the local climate data to produce the predicted wind speeds, and then compared to the published Halifax wind comfort and safety performance standards. These performance standards are divided into separate categories of comfort and safety. The comfort criteria allow planners to assess the usability, with respect to the wind environment, of different locations for various purposes, such as for long-duration activities (e.g., sitting at an outdoor café) or strolling on walkways. The safety criteria help to identify locations where wind speeds may be potentially hazardous to pedestrians.

Comfort ratings are based on an equivalent wind speed ($U_{Equiv}$) (the larger of the mean wind speed ($U_{Mean}$) or the gust-equivalent mean (GEM) wind speed ($U_{GEM}$) which is equal to the gust wind speed divided by 1.85) that is exceeded seasonally 20% of the time. The wind comfort categories and criteria are defined as follows:

| Comfort Category | $U_{Equiv}$ (1,2) | Description |
|---|---|---|
| Sitting | ≤ 10 km/h | Calm or light breezes suitable for outdoor restaurant uses, seating areas, and other amenities. |
| Standing | ≤ 14 km/h | Gentle breezes suitable for main building entrances and bus stops where pedestrians may linger. |
| Strolling | ≤ 17 km/h | Moderate winds appropriate for window shopping and strolling along a downtown street, or park. |
| Walking | ≤ 20 km/h | Relatively high speeds that can be tolerated if one's objective is to walk, run, or cycle. |
| Uncomfortable | > 20 km/h | Strong winds unacceptable for all pedestrian activities; wind mitigation is typically required. |

***Notes:***

*(1) $U_{Equiv} = Max\ (U_{Mean}, U_{Gust} / 1.85)$*

*(2) $U_{Equiv}$ speeds are based on a seasonal exceedance of 20% between the hours of 6:00 to 23:00 (inclusive). Hours from 0:00 – 5:00 (inclusive) are excluded from the wind comfort analysis because nighttime usage of outdoor spaces is anticipated to be limited during these hours.*

The perception of wind speeds within these comfort categories can vary by individual, so opinions regarding the local wind environment should be taken into account when evaluating the Halifax wind comfort performance standards.

Safety ratings are based on gust wind speeds ($U_{Gust}$) that are exceeded annually 0.1% of the time and can be summarized as follows:

| Safety Performance Standard | $U_{Gust}$ (1) | Description |
|---|---|---|
| O Pass | ≤ 90 km/h | Meets wind safety performance standards. |
| O Fail | > 90 km/h | Excessive wind speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is required. |

***Notes:***

(1) *$U_{Gust}$ speeds are based on an annual exceedance of 0.1% between the hours of 0:00 to 23:00 (inclusive).*

Note that the ratings of 'Uncomfortable' and 'Safety' are the words of the published wind requirements and may not apply directly to any particular project. High wind areas are certainly not unacceptable all the time, just on windier days. The word uncomfortable, in our understanding, refers to acceptability of the site by pedestrians for typical pedestrian use; i.e., on the windiest days, pedestrians will not find the areas 'acceptable' regardless of the regular intended use, and will tend to avoid such areas if possible. Failure of the safety criterion, as we understand it, indicates some unspecified potential for causing injury to a less stable individual who might be blown over. The likelihood of such an event is not well described in literature and is likely to be strongly affected by individual differences, presence of water, blowing dust or particulates, and other variables in addition to the wind speed.

## 3. DISCUSSION OF RESULTS

Figure 4a through 4f contain colour-coded markers (see Section 2) indicating the safety and comfort ratings for each of the measurement locations. Figure 5a through 5c illustrate where each location falls within the range of wind speeds ascribed to each comfort and safety rating for both the existing and proposed configurations. For example, Figure 5a shows that Point 14 just slightly exceeds the *sitting* comfort rating limit for the existing configuration, while that same point slightly exceeds the *standing* comfort rating limit for the proposed configuration. Tables 1 and 2 list the resulting wind speed at each pedestrian point location for the comfort and safety criteria, respectively. Figure 6 shows the wind tunnel layout with the surrounding buildings and pedestrian point numbering.

In general, wind conditions comfortable for *sitting* and *standing* are considered appropriate for areas such as entrances or dining spaces where pedestrians will be apt to gather for longer durations, while wind conditions comfortable for *strolling* and *walking* are more appropriate for sidewalks where pedestrians are actively in transit. Locations rated as *uncomfortable* are generally less suitable for most pedestrian activities in most cityscapes and wind control solutions are often sought. Whether mitigation is needed at a location depends upon the intended pedestrian usage of the location.

Since perception of the wind environment varies from person to person and by location, local knowledge of the wind environment at the project location must inform the decision regarding wind reduction measures. The perception of wind speeds within these comfort categories can vary by individual, so opinions regarding the local wind environment should be considered when evaluating the ratings.

### 3.1. WIND COMFORT RESULTS – SUMMER SEASON

In the existing configuration, none of the measured points are predicted to have an *uncomfortable* comfort rating. Most measurement points are predicted to have wind comfort conditions rated as *standing* with a few points rated as *strolling* and *sitting*.

With the addition of the proposed Spring Garden West development (and future Promenade Development), wind conditions are generally expected to remain similar with wind comfort ratings at most measurement points predicted to be rated as *standing* and *strolling* with one point rated as *walking*. These predicted wind conditions are considered appropriate for the intended use of the areas around the Spring Garden West development. A summary of the total number of locations within each of the comfort ratings for each configuration in the summer season is provided below:

| Comfort Category | Existing Config number of occurrences | Proposed Config number of occurrences | Change from Existing to Proposed Config |
|---|---|---|---|
| Sitting | 4 | 3 | -1 |
| Standing | 19 | 10 | -9 |
| Strolling | 4 | 14 | +10 |
| Walking | 0 | 1 | +1 |
| Uncomfortable | 0 | 0 | 0 |

### 3.2. WIND COMFORT RESULTS – WINTER SEASON

As seasonally stronger winds are more prevalent during the winter, the predicted wind comfort conditions in the vicinity of the project site for both the existing and project site are expected to be lessened comparatively to the summer wind conditions.

For the existing configuration, most measurement locations around the site are generally expected to be comfortable for walking or strolling. One measurement location further south of the site is predicted to be *uncomfortable*.

For the proposed configuration, the addition of the Spring Garden West development (and future Promenade development) are expected to result in wind conditions around the site which are generally rated as *walking* or *uncomfortable*. It should be noted, these predicted wind conditions are common for other similar size developments in the Halifax area during the winter season. A summary of the total number of locations within each of the comfort ratings for each configuration in the winter season is provided below:

| Comfort Category | Existing Config number of occurrences | Proposed Config number of occurrences | Change from Existing to Proposed Config |
|---|---|---|---|
| Sitting | 1 | 1 | 0 |
| Standing | 4 | 1 | -3 |
| Strolling | 13 | 3 | -10 |
| Walking | 8 | 13 | +5 |
| Uncomfortable | 1 | 10 | +9 |

Most of the predicted *uncomfortable* wind conditions are predicted to occur at the northwest corner of the Spring Garden West development and along the Robie Street sidewalks. Of note, the proposed configuration not only includes the Spring Garden West project but also the Promenade development as directed by the Halifax Regional Municipality (HRM). Both developments are contributing to the anticipated increased wind speeds in the vicinity. In addition, the wind tunnel model did not include existing landscape vegetation and mature deciduous trees along Spring Garden Road, Robie Street or within Balcom Park immediately to the west. The results may therefore be considered as representing worst-case conditions. While the inclusion of landscaping in the wind tunnel model may result in localized reductions to wind speeds at some measurement locations, landscaping (especially in colder climates like Halifax) often lose their foliage during the colder months, rendering them less effective as a form of wind control.

CPP presented typical wind/building interaction principle in a preliminary meeting to discuss wind mitigation measures which were integrated into the Spring Garden development. Beyond the HRM required podium step-backs, these mitigation measures included the recessed and canopy protected entries, continuous perimeter podium planter covered with a canopied colonnade, volume enclosure of a portion of the podium terrace between the towers, and balcony and bay tower projections.

While the anticipated winter wind conditions are common for the Halifax area and similar to the wind conditions associated with developments of similar size, wind conditions could be further improved through the

implementation of additional architectural and landscaping wind control measures. Feasible wind mitigation measures were discussed with the architects and the developer of the Spring Garden West development whom are intent on providing a comfortable and safe wind environment around the development for pedestrians. Some of the proposed wind control measures may include the following:

- Glass wind breaks (2.5m tall, 2m wide) at the ends of the exterior seating area along the west façade of the development;
- Dense vegetation in planter boxes under the portico facing Robie Street; and,
- Wind breaks (2.5m tall) along Spring Garden Road at retail and residential tower entries in the form of vertical perforated signage features.

Furthermore, the developer will seek to agree with the Halifax Regional Municipality (HRM) for streetscape improvements along the wide street verges including, but not limited, evergreen planters with trees, benches, street art and bus shelters etc. The cumulative effect of these aforementioned mitigation measures are expected to reduce the strength of approaching northwesterly and southwesterly winds and therefore improve wind conditions in the immediate vicinity of the project.

Points 6 and 12 are representative of the entrances to the two residential towers at the Spring Garden Road and Robbie Street, respectively. In the summer they are both rated as *strolling* and in the winter, they are rated at *uncomfortable*. The windier conditions are due to westerly and northwesterly winds flowing along the Spring Garden Street and Robie Street, and further accelerate around the building corner. Test points along the Robie Street and Spring Garden Road shop front sidewalks generally drop one comfort level with the proposed building. This can be expected as these building frontages are directly exposed to the northwest winds from across the intersection from low scale residential neighborhood. Points 10, 11,12 along Robie Street and 7 on Spring Garden Road are within 1 to 2 km/hr of the *walking* comfort category. Point 6 is not on the sidewalk but is representative of wind conditions at the recessed overhang entry of the east tower and would be expected to benefit from wind mitigation measures along the retail frontage. While the design of these entrances include positive design features like overhead canopies and being recessed / notched, winds will be less calm as a pedestrian moves further away from the entrance. It is CPP's opinion that increasing the projection of the canopies would provide a fairly marginal improvement to wind speeds, but including more localized vegetation, shrubbery and planters would provide more benefit in breaking up the winds.

### 3.3. WIND SAFETY RESULTS

All measurement locations are predicted to meet the wind safety criteria in the existing configuration. The addition of the Spring Garden West development (and future Promenade development) are expected to result in one (1) location at the corner of Robie and College streets (point 28 on figure 4f) that marginally exceeds the safety performance standard. The exceedance at this location is 1.3% above the wind gust speed threshold with a wind speed of 91.2 km/h (1.2 km/h above the wind speed threshold of 90 km/h) for a frequency of 0.195% (approximately 8 hours above the allowable exceedance limit of 9 hours). This probability of exceedance is the cumulative effect of multiple gust / storm events that are statistically expected to occur at this location and are due to a combination of winds from the west-southwesterly through west northwesterly directions. It is CPP's opinion that most of the winds would occur during the winter when seasonally stronger winds are more prevalent. While the Spring Garden West development does contribute to some minor increases in wind speeds

[illegible] safety exceedance at point [illegible]

Promenade development and the result of winds downwashing and accelerating at the southwest corner the Promenade. It is CPP's opinion that the various conceptual mitigative strategies discussed within the report (particularly the addition of streetscaping along the Robie Street sidewalk) are expected to improve wind conditions at this location.

## REFERENCES

American Society of Civil Engineers (1999), Wind Tunnel Studies of Buildings and Structures (ASCE Manual of Practice Number 67).

American Society of Civil Engineers (2010), Minimum Design Loads for Buildings and Other Structures (ASCE 7–10).

American Society of Civil Engineers (2012), Wind Tunnel Testing for Buildings and Other Structures (ASCE 49-12).

# FIGURES

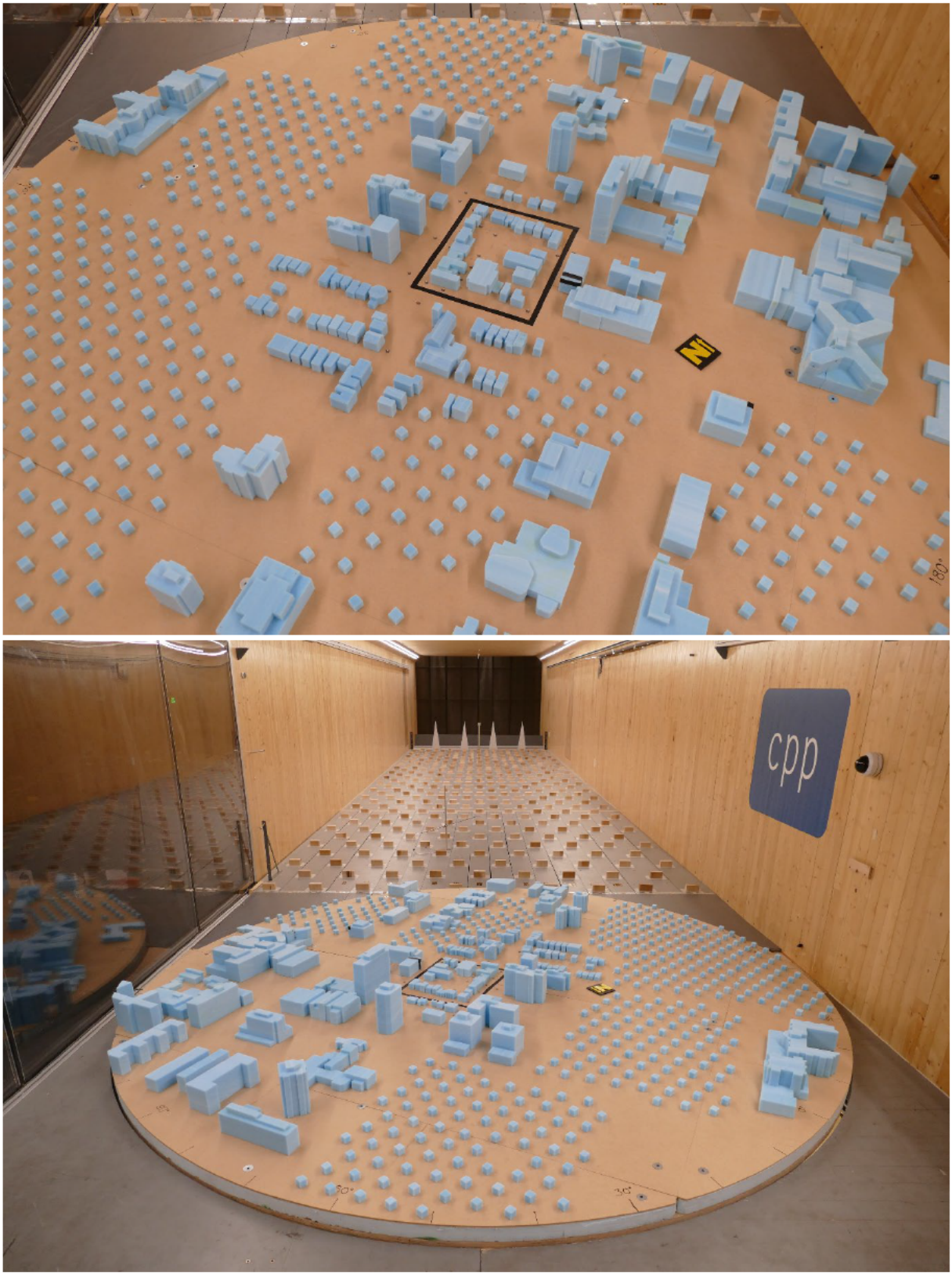


*Figure 3a: Photographs of the completed model in the wind tunnel – Existing Configuration.*

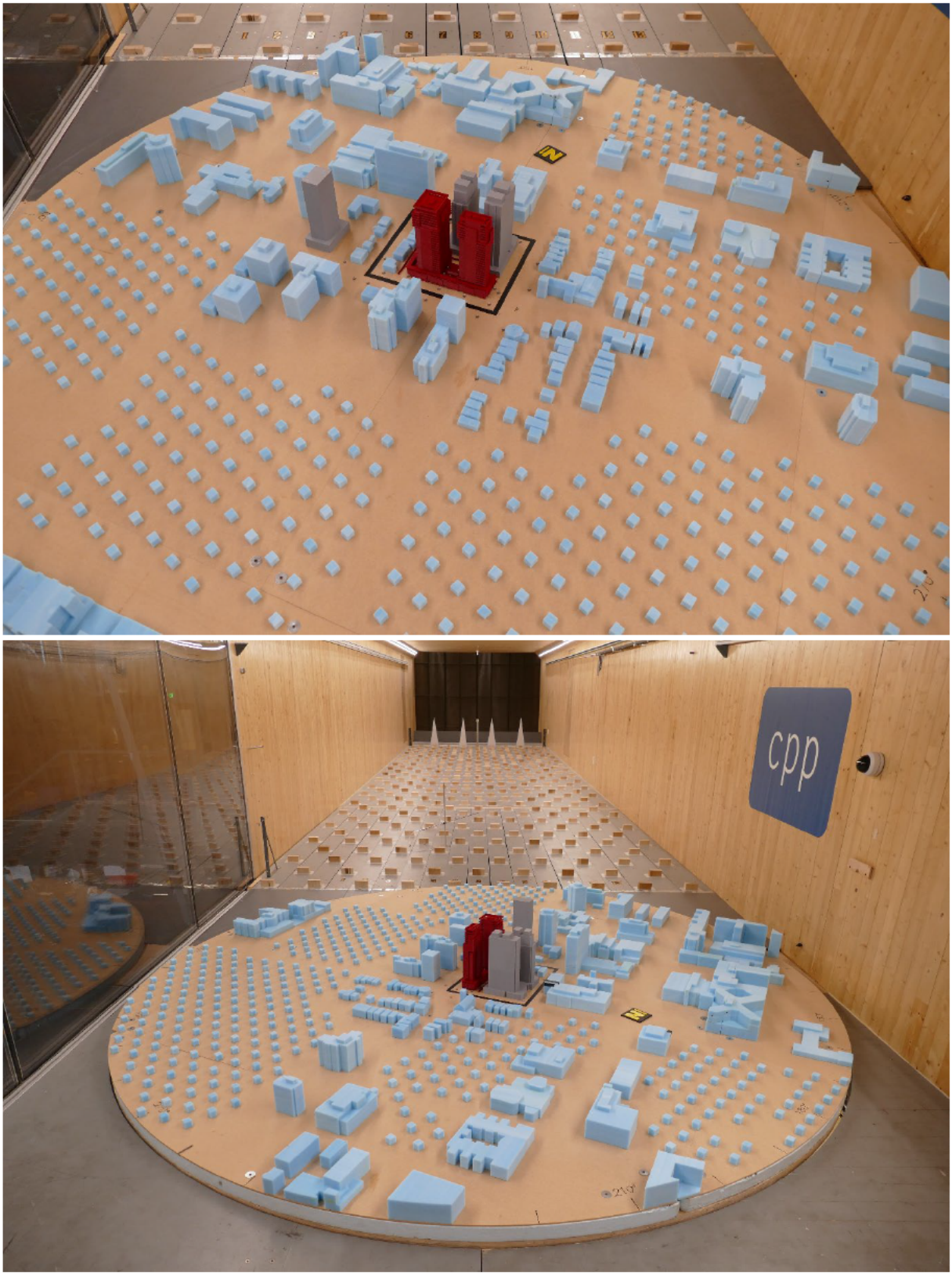


*Figure 3b: Photographs of the completed model in the wind tunnel – Proposed Configuration.*

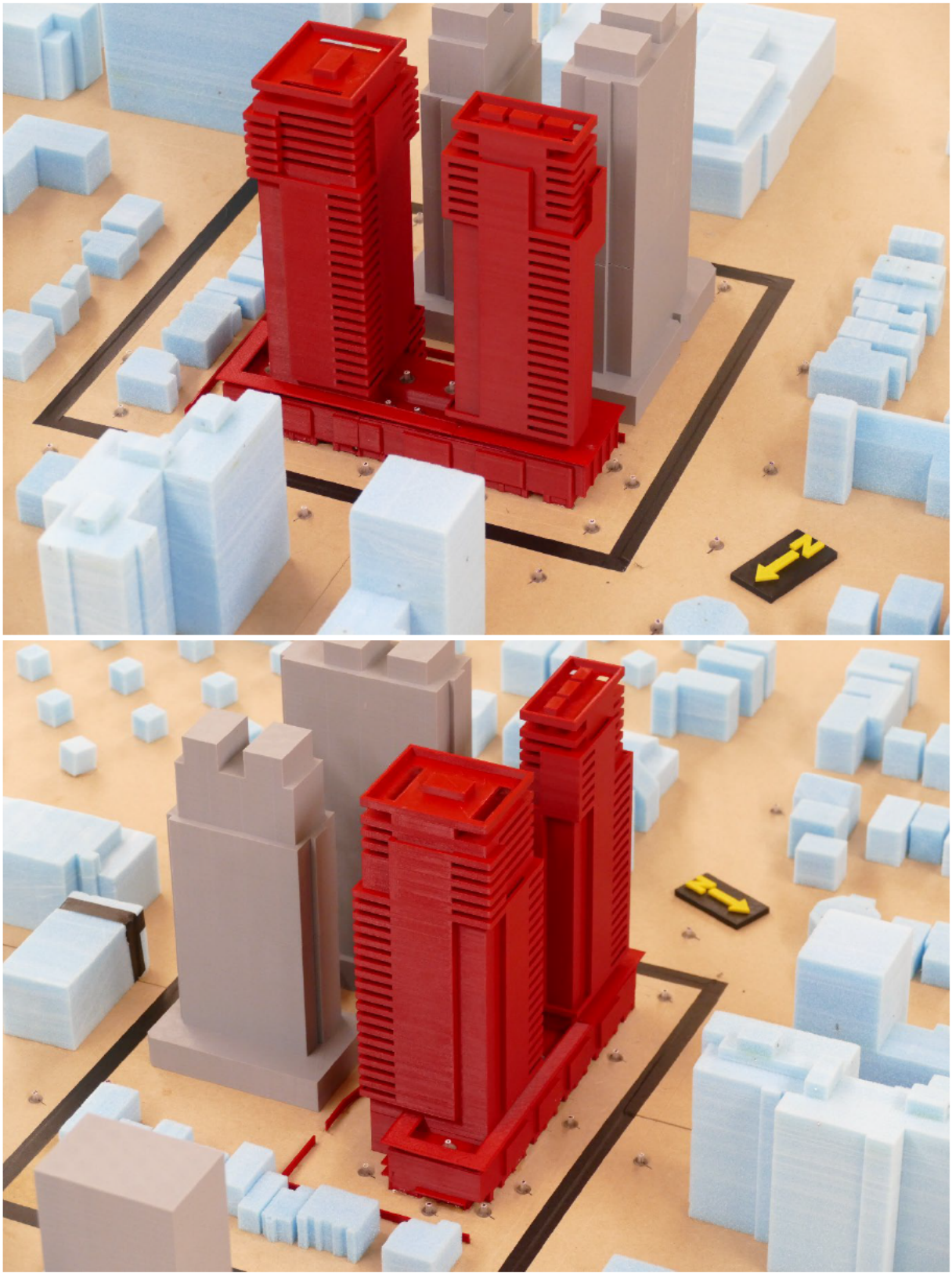


*Figure 3c: Photographs of the completed model in the wind tunnel – Close-up views of the spring garden west model.*

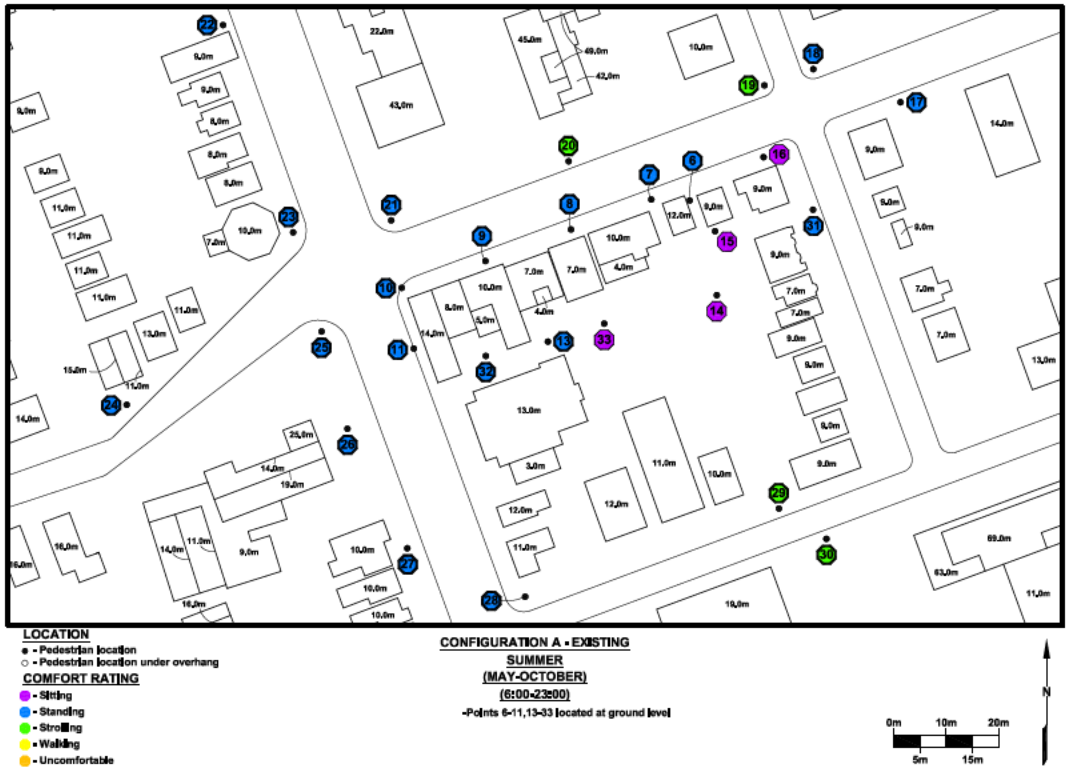


*Figure 4a: Pedestrian wind speed measurement points with comfort ratings – Existing Configuration – Summer*

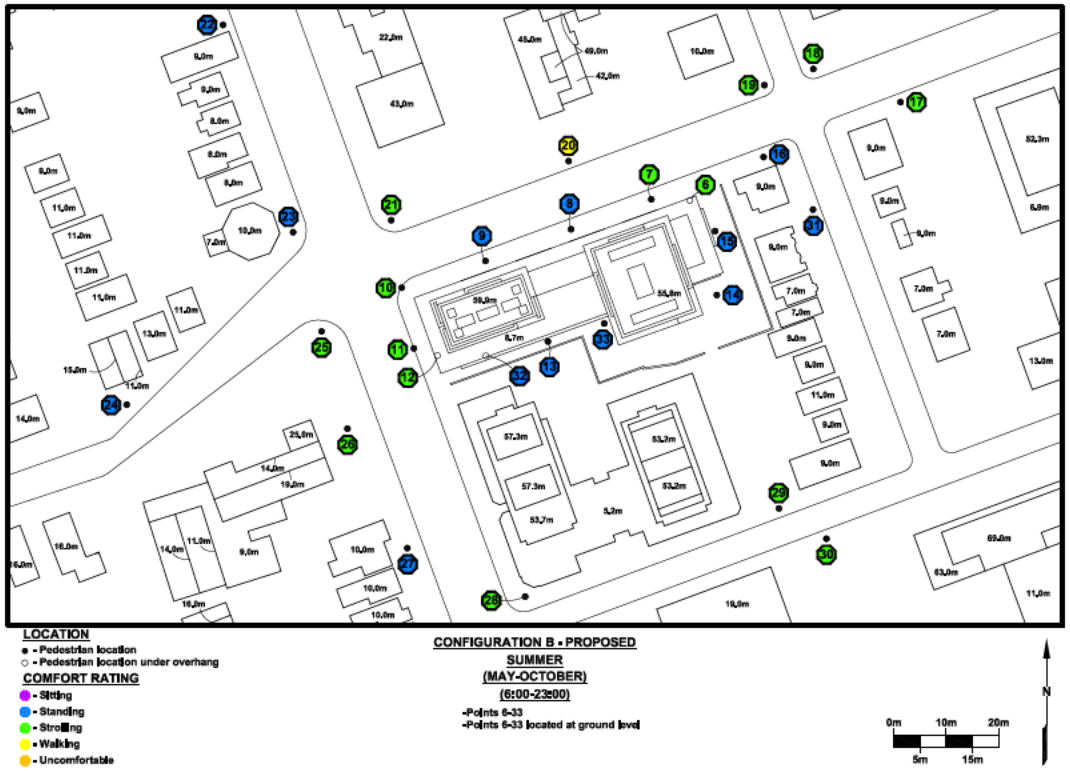


*Figure 4b: Pedestrian wind speed measurement points with comfort ratings – Proposed Configuration –*

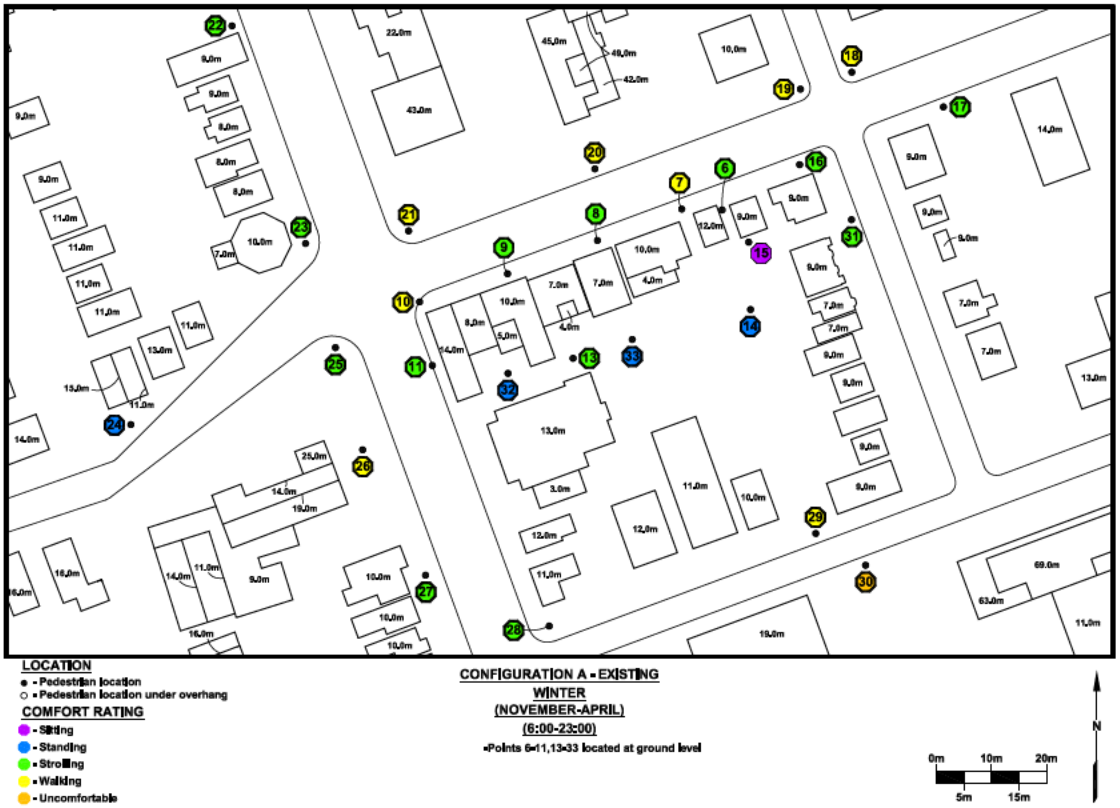


*Figure 4c: Pedestrian wind speed measurement points with comfort ratings – Existing Configuration – Winter*

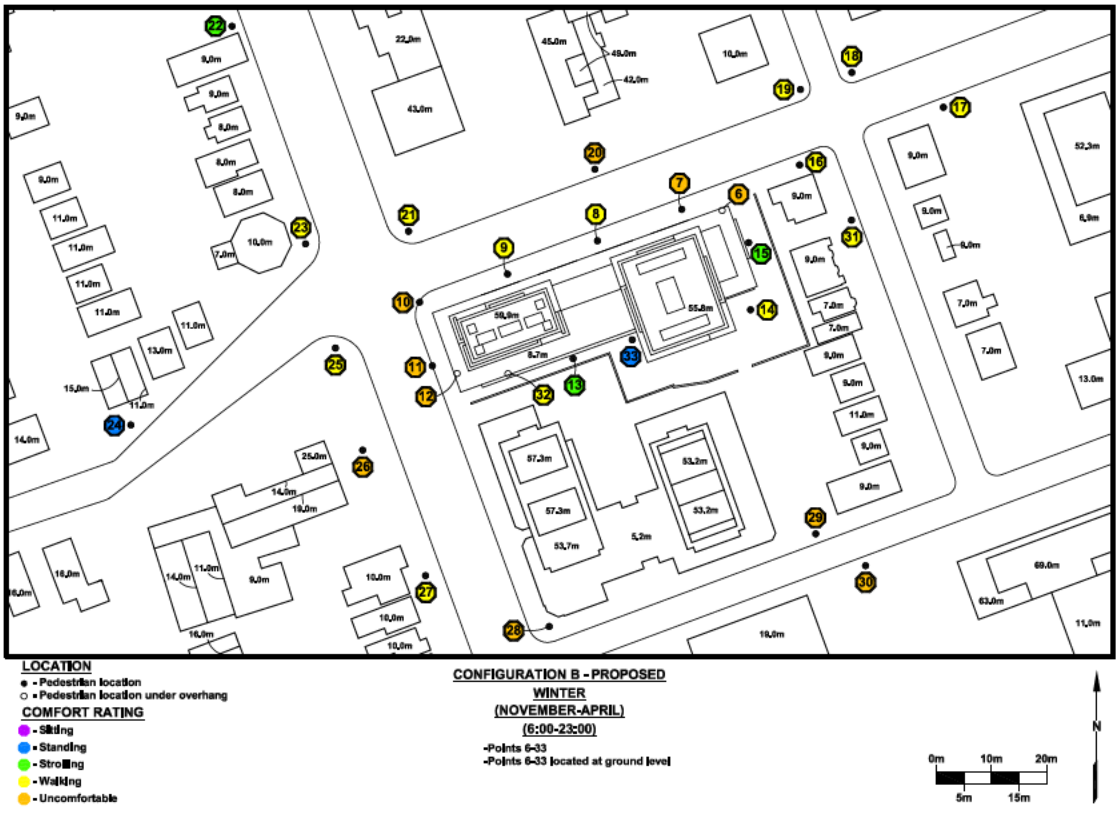


*Figure 4c: Pedestrian wind speed measurement points with comfort ratings*

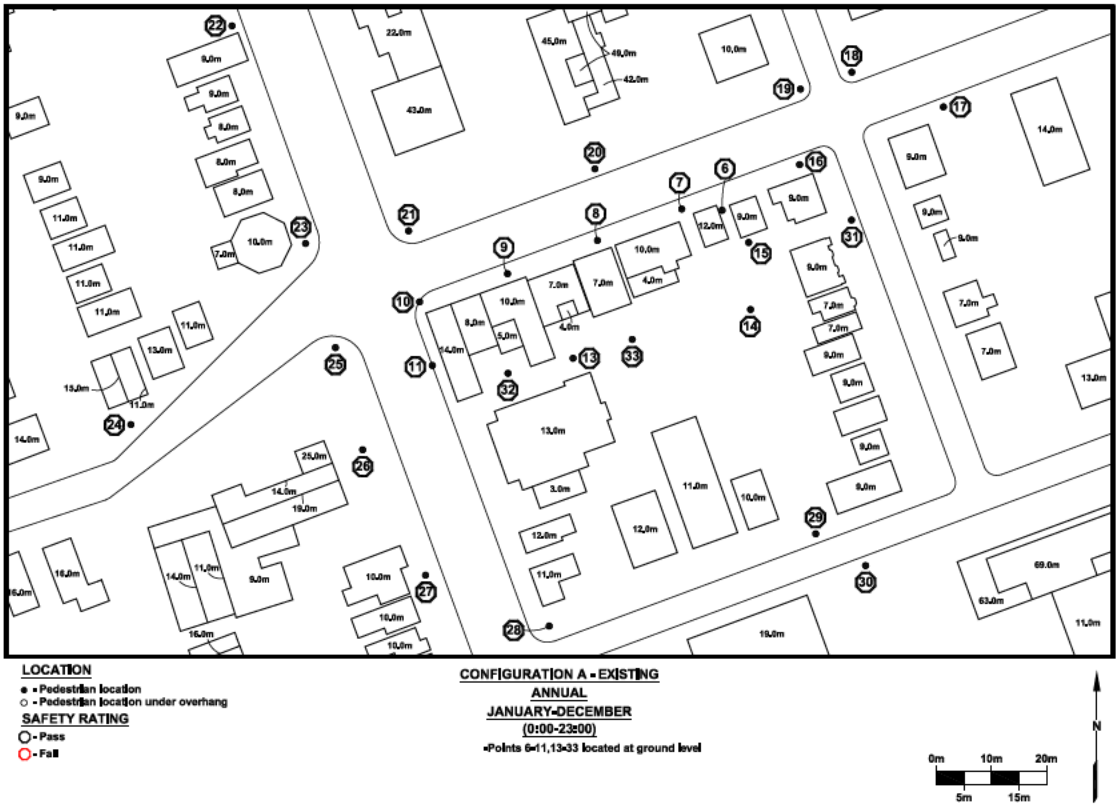


*Figure 4e: Pedestrian wind speed measurement points with safety ratings – Existing Configuration – Annual*

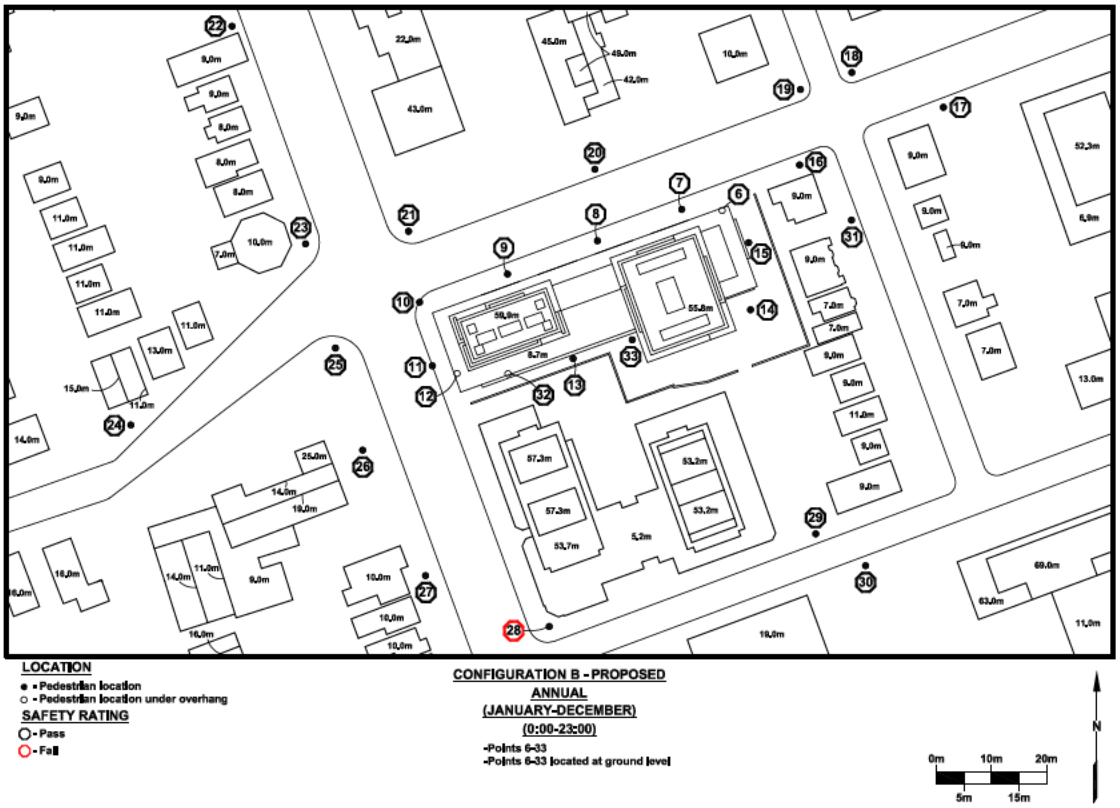


*Figure 4f: Pedestrian wind speed measurement points with safety ratings – Proposed Configuration – Annual*

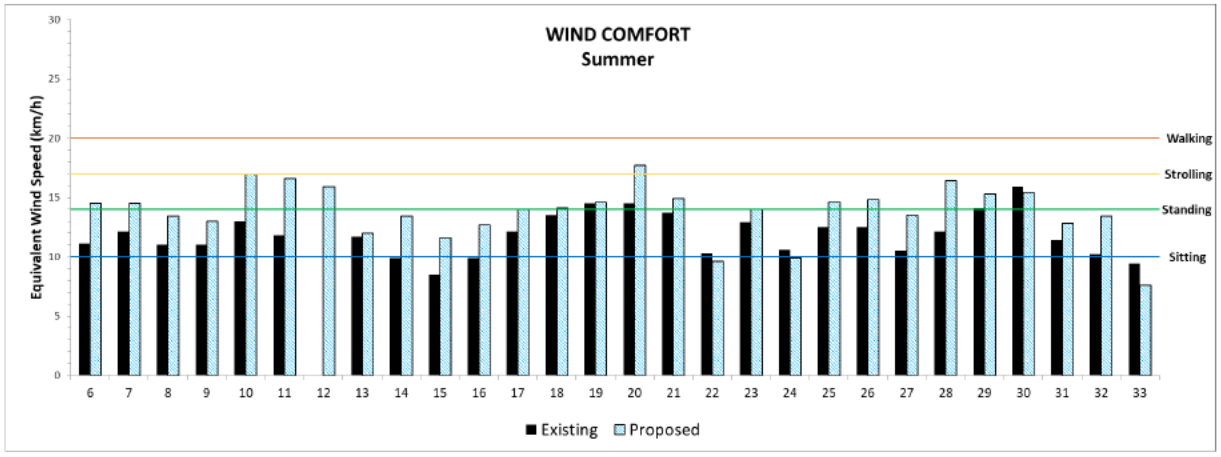


*Figure 5a: Comparison of Comfort Wind Speeds – Summer*

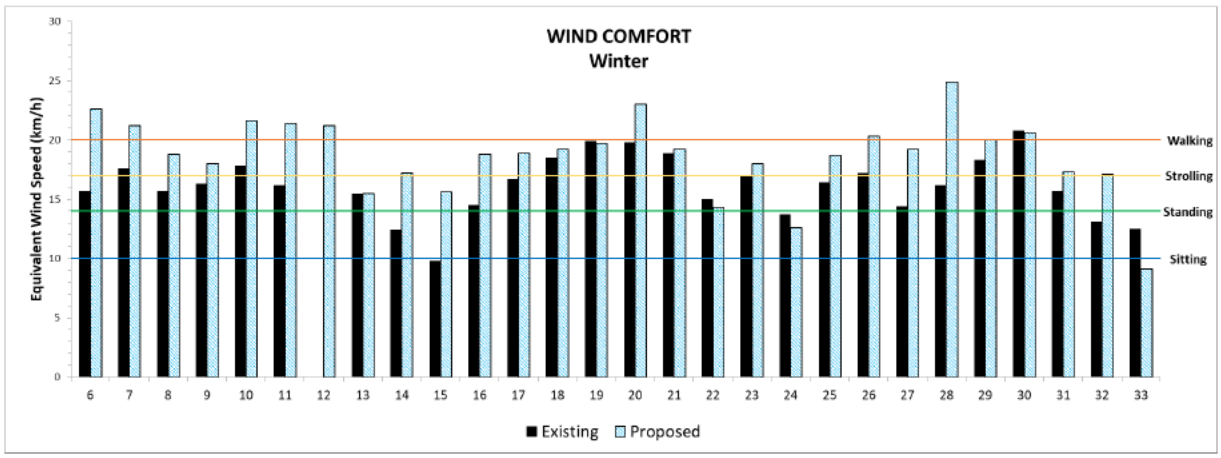


*Figure 5b: Comparison of Comfort Wind Speeds – Winter*

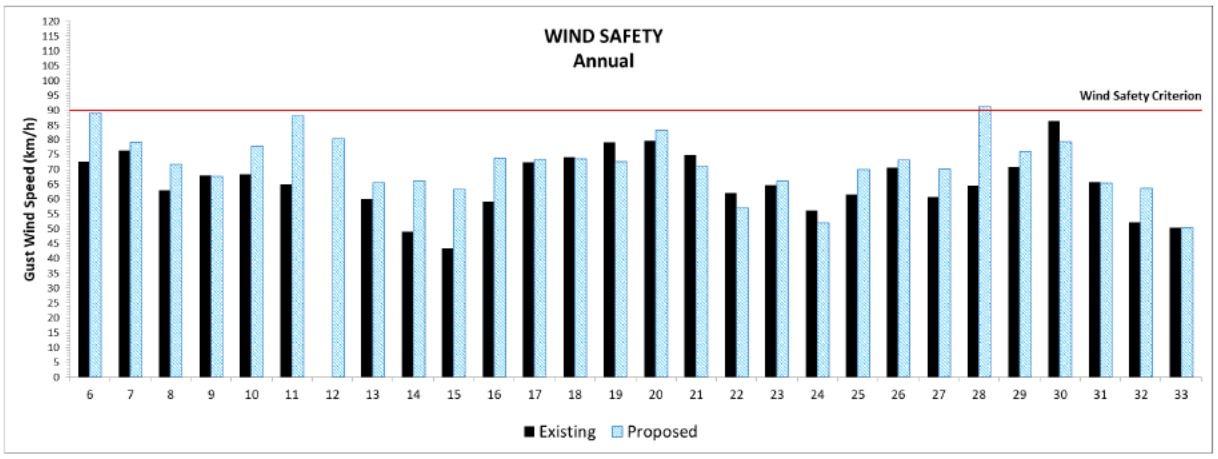


*Figure 5c: Comparison of Safety Wind Speeds – Annual*

*Table 1. Pedestrian Wind Comfort Results*

| # | Season | Configuration | Speed (km/h) | Rating |
|---|---|---|---|---|
| 6 | Summer | Existing | 11.1 | Standing |
| | | Proposed | 14.5 | Strolling |
| | Winter | Existing | 15.7 | Strolling |
| | | Proposed | 22.6 | Uncomfortable |
| 7 | Summer | Existing | 12.1 | Standing |
| | | Proposed | 14.5 | Strolling |
| | Winter | Existing | 17.6 | Walking |
| | | Proposed | 21.2 | Uncomfortable |
| 8 | Summer | Existing | 11.0 | Standing |
| | | Proposed | 13.4 | Standing |
| | Winter | Existing | 15.7 | Strolling |
| | | Proposed | 18.8 | Walking |
| 9 | Summer | Existing | 11.0 | Standing |
| | | Proposed | 13.0 | Standing |
| | Winter | Existing | 16.3 | Walking |
| | | Proposed | 18.0 | Walking |
| 10 | Summer | Existing | 13.0 | Strolling |
| | | Proposed | 17.0 | Strolling |
| | Winter | Existing | 17.8 | Walking |
| | | Proposed | 21.6 | Uncomfortable |
| 11 | Summer | Existing | 11.8 | Standing |
| | | Proposed | 16.6 | Strolling |
| | Winter | Existing | 16.2 | Walking |
| | | Proposed | 21.4 | Uncomfortable |
| 12 | Summer | Existing | - | - |
| | | Proposed | 15.9 | Strolling |
| | Winter | Existing | - | - |
| | | Proposed | 21.2 | Uncomfortable |
| 13 | Summer | Existing | 11.7 | Standing |
| | | Proposed | 12.0 | Standing |
| | Winter | Existing | 15.5 | Strolling |
| | | Proposed | 15.5 | Strolling |
| 14 | Summer | Existing | 9.9 | Standing |
| | | Proposed | 13.4 | Standing |
| | Winter | Existing | 12.4 | Standing |
| | | Proposed | 17.2 | Walking |
| 15 | Summer | Existing | 8.5 | Sitting |
| | | Proposed | 11.6 | Standing |
| | Winter | Existing | 9.8 | Standing |
| | | Proposed | 15.6 | Strolling |
| 16 | Summer | Existing | 9.9 | Standing |
| | | Proposed | 12.7 | Standing |
| | Winter | Existing | 14.5 | Strolling |
| | | Proposed | 18.8 | Walking |
| 17 | Summer | Existing | 12.1 | Standing |
| | | Proposed | 14.0 | Strolling |
| | Winter | Existing | 16.7 | Walking |
| | | Proposed | 18.9 | Walking |
| 18 | Summer | Existing | 13.5 | Strolling |
| | | Proposed | 14.1 | Strolling |
| | Winter | Existing | 18.5 | Walking |
| | | Proposed | 19.2 | Walking |
| 19 | Summer | Existing | 14.5 | Strolling |
| | | Proposed | 14.6 | Strolling |
| | Winter | Existing | 19.9 | Uncomfortable |
| | | Proposed | 19.7 | Walking |
| 20 | Summer | Existing | 14.5 | Strolling |
| | | Proposed | 17.7 | Walking |
| | Winter | Existing | 19.8 | Uncomfortable |
| | | Proposed | 23.0 | Uncomfortable |
| 21 | Summer | Existing | 13.7 | Strolling |
| | | Proposed | 14.9 | Strolling |
| | Winter | Existing | 18.9 | Uncomfortable |
| | | Proposed | 19.2 | Walking |

| Season | Months | Hours |
|---|---|---|
| Summer | May – October | 6:00 – 23:00 |
| Winter | November - April | 6:00 – 23:00 |

| Rating | Sitting | Standing | Strolling | Walking | Uncomfortable |
|---|---|---|---|---|---|
| *Speed (km/h) | ≤ 10 | ≤ 14 | ≤ 17 | ≤ 20 | > 20 |
| Exceedance Limit (%) | ≤ 80% | ≤ 80% | ≤ 80% | ≤ 80% | > 20% |

*Speed = Max (Mean, Gust / 1.85)

*Table 1. Pedestrian Wind Comfort Results*

| # | Season | Configuration | Speed (km/h) | Rating |
|---|---|---|---|---|
| **22** | Summer | Existing | 10.3 | Standing |
| | | Proposed | 9.6 | Sitting |
| | Winter | Existing | 15.0 | Strolling |
| | | Proposed | 14.3 | Strolling |
| **23** | Summer | Existing | 12.9 | Strolling |
| | | Proposed | 14.0 | Standing |
| | Winter | Existing | 17.0 | Walking |
| | | Proposed | 18.0 | Walking |
| **24** | Summer | Existing | 10.6 | Standing |
| | | Proposed | 9.9 | Sitting |
| | Winter | Existing | 13.7 | Strolling |
| | | Proposed | 12.6 | Standing |
| **25** | Summer | Existing | 12.5 | Standing |
| | | Proposed | 14.6 | Strolling |
| | Winter | Existing | 16.4 | Walking |
| | | Proposed | 18.7 | Walking |
| **26** | Summer | Existing | 12.5 | Standing |
| | | Proposed | 14.8 | Strolling |
| | Winter | Existing | 17.2 | Walking |
| | | Proposed | 20.3 | Uncomfortable |
| **27** | Summer | Existing | 10.5 | Standing |
| | | Proposed | 13.5 | Standing |
| | Winter | Existing | 14.4 | Strolling |
| | | Proposed | 19.2 | Walking |
| **28** | Summer | Existing | 12.1 | Standing |
| | | Proposed | 16.4 | Strolling |
| | Winter | Existing | 16.2 | Walking |
| | | Proposed | 24.9 | Uncomfortable |

| # | Season | Configuration | Speed (km/h) | Rating |
|---|---|---|---|---|
| **29** | Summer | Existing | 14.1 | Strolling |
| | | Proposed | 15.3 | Strolling |
| | Winter | Existing | 18.3 | Walking |
| | | Proposed | 20.0 | Uncomfortable |
| **30** | Summer | Existing | 15.9 | Walking |
| | | Proposed | 15.4 | Strolling |
| | Winter | Existing | 20.8 | Uncomfortable |
| | | Proposed | 20.6 | Uncomfortable |
| **31** | Summer | Existing | 11.4 | Standing |
| | | Proposed | 12.8 | Standing |
| | Winter | Existing | 15.7 | Strolling |
| | | Proposed | 17.3 | Walking |
| **32** | Summer | Existing | 10.2 | Standing |
| | | Proposed | 13.4 | Standing |
| | Winter | Existing | 13.1 | Strolling |
| | | Proposed | 17.1 | Walking |
| **33** | Summer | Existing | 9.4 | Standing |
| | | Proposed | 7.6 | Sitting |
| | Winter | Existing | 12.5 | Standing |
| | | Proposed | 9.1 | Sitting |

| Season | Months | Hours |
|---|---|---|
| Summer | May – October | 6:00 – 23:00 |
| Winter | November - April | 6:00 – 23:00 |

| Rating | Sitting | Standing | Strolling | Walking | Uncomfortable |
|---|---|---|---|---|---|
| *Speed (km/h) | ≤ 10 | ≤ 14 | ≤ 17 | ≤ 20 | > 20 |
| Exceedance Limit (%) | ≤ 80% | ≤ 80% | ≤ 80% | ≤ 80% | > 20% |

**Speed = Max (Mean, Gust / 1.85)*

*Table 2. Pedestrian Wind Safety Results*

| # | Season | Configuration | Speed (km/h) | Rating |
|---|---|---|---|---|
| 6 | Annual | Existing | 72.6 | Pass |
| | | Proposed | 89.1 | Pass |
| 7 | Annual | Existing | 76.3 | Pass |
| | | Proposed | 79.1 | Pass |
| 8 | Annual | Existing | 63.0 | Pass |
| | | Proposed | 71.7 | Pass |
| 9 | Annual | Existing | 67.9 | Pass |
| | | Proposed | 67.6 | Pass |
| 10 | Annual | Existing | 68.4 | Pass |
| | | Proposed | 77.8 | Pass |
| 11 | Annual | Existing | 65.0 | Pass |
| | | Proposed | 88.1 | Pass |
| 12 | Annual | Existing | - | - |
| | | Proposed | 80.5 | Pass |
| 13 | Annual | Existing | 60.0 | Pass |
| | | Proposed | 65.6 | Pass |
| 14 | Annual | Existing | 49.0 | Pass |
| | | Proposed | 66.2 | Pass |
| 15 | Annual | Existing | 43.5 | Pass |
| | | Proposed | 63.4 | Pass |
| 16 | Annual | Existing | 59.0 | Pass |
| | | Proposed | 73.7 | Pass |
| 17 | Annual | Existing | 72.4 | Pass |
| | | Proposed | 73.3 | Pass |
| 18 | Annual | Existing | 74.1 | Pass |
| | | Proposed | 73.6 | Pass |
| 19 | Annual | Existing | 79.1 | Pass |
| | | Proposed | 72.7 | Pass |
| 20 | Annual | Existing | 79.6 | Pass |
| | | Proposed | 83.2 | Pass |
| 21 | Annual | Existing | 74.9 | Pass |
| | | Proposed | 71.2 | Pass |
| 22 | Annual | Existing | 62.1 | Pass |
| | | Proposed | 57.0 | Pass |
| 23 | Annual | Existing | 64.7 | Pass |
| | | Proposed | 66.2 | Pass |
| 24 | Annual | Existing | 56.2 | Pass |
| | | Proposed | 52.0 | Pass |
| 25 | Annual | Existing | 61.5 | Pass |
| | | Proposed | 70.1 | Pass |
| 26 | Annual | Existing | 70.5 | Pass |
| | | Proposed | 73.1 | Pass |
| 27 | Annual | Existing | 60.8 | Pass |
| | | Proposed | 70.3 | Pass |
| 28 | Annual | Existing | 64.5 | Pass |
| | | Proposed | 91.2 | Fail |
| 29 | Annual | Existing | 70.8 | Pass |
| | | Proposed | 76.0 | Pass |
| 30 | Annual | Existing | 86.3 | Pass |
| | | Proposed | 79.3 | Pass |
| 31 | Annual | Existing | 65.7 | Pass |
| | | Proposed | 65.4 | Pass |
| 32 | Annual | Existing | 52.3 | Pass |
| | | Proposed | 63.8 | Pass |
| 33 | Annual | Existing | 50.3 | Pass |
| | | Proposed | 50.4 | Pass |

| Season | Months | Hours |
|---|---|---|
| Annual | January- December | 0:00 – 23:00 |

| Rating | Pass | Fail |
|---|---|---|
| *Speed (km/h) | ≤ 90 | > 90 |
| Exceedance Limit (%) | ≤ 0.1% | > 0.1% |

*Speed = Max (Mean, Gust / 1.85)

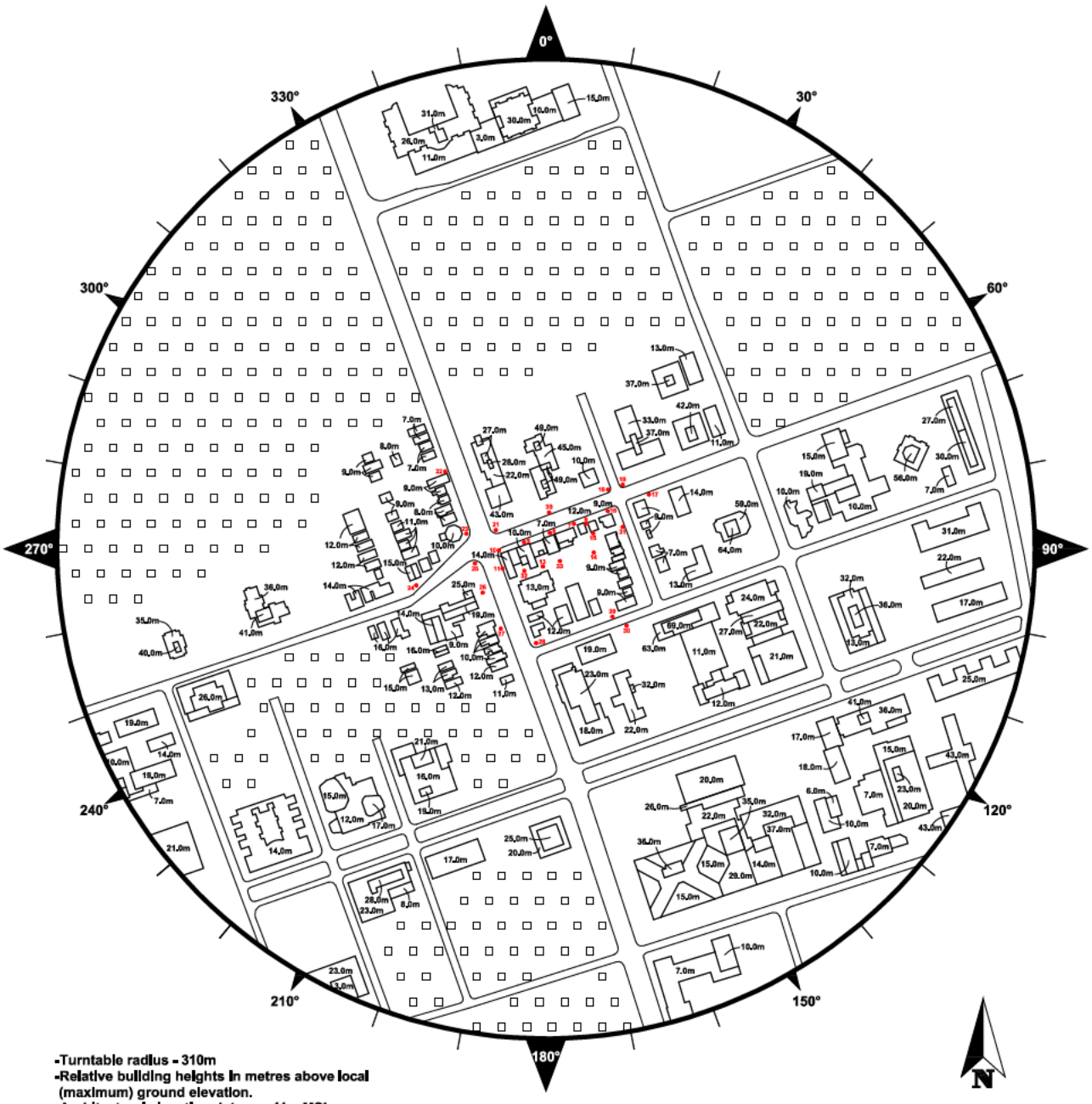


*Figure 6a: Existing Configuration Wind Tunnel Layout*

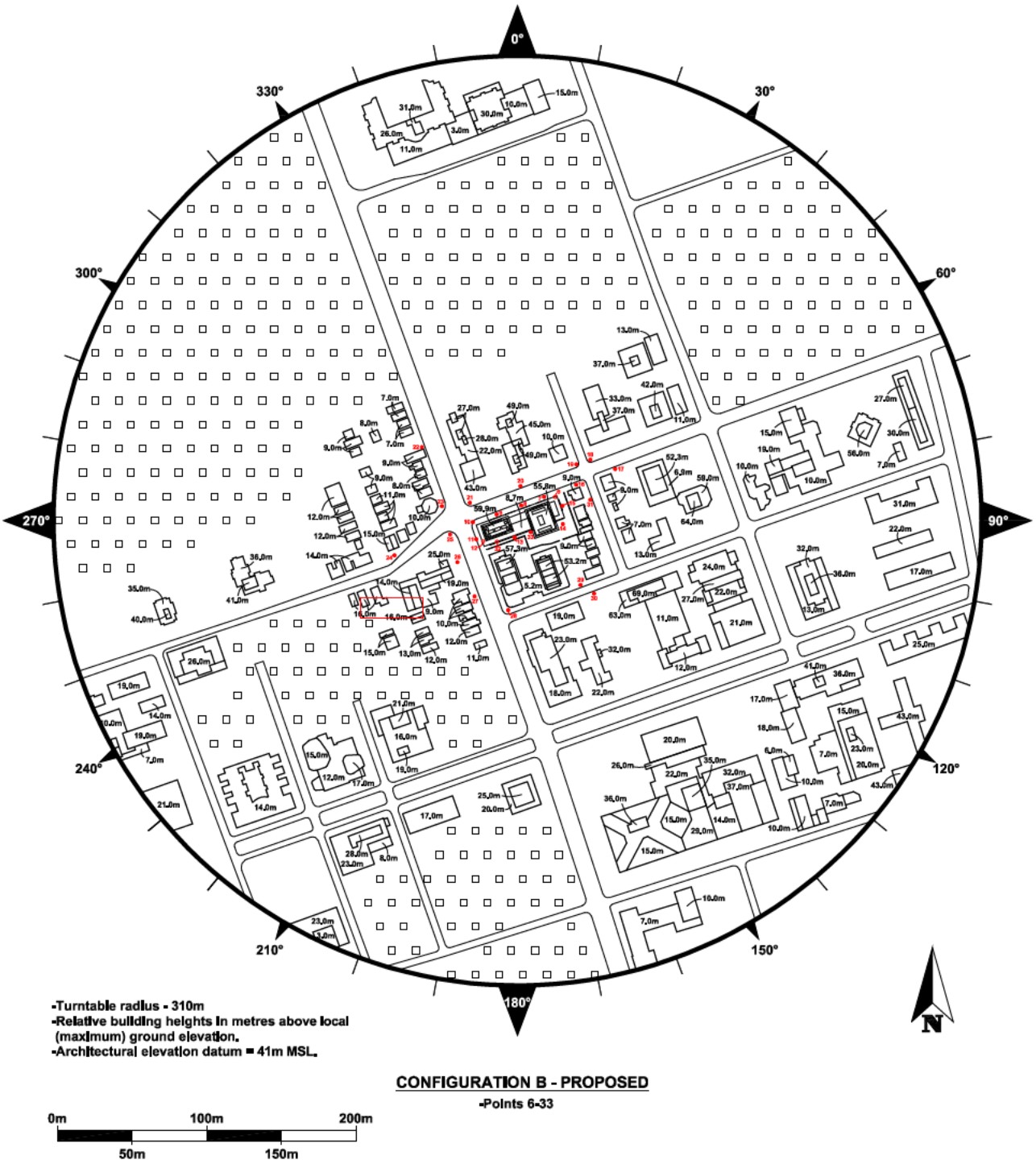


*Figure 6b: Proposed Configuration Wind Tunnel Layout.*