The Boundary Layer Wind Tunnel Laboratory

Pedestrian Level Wind Study

170-180 Columbia Street W
Waterloo, Ontario

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MAIN FINDINGS

This report describes the pedestrian-level wind study performed at the Boundary Layer Wind Tunnel Laboratory for the proposed 170-180 Columbia Street W development near the northwest corner of the intersection of Philip Street and Columbia Street W in Waterloo, ON and directly east of the N-S running LRT. A detailed discussion of the results is contained in Section 3.5. A description of the criteria used can be found in Section 3.4.

Tests were carried out for two configurations described as follows and as pictured in Figure 5:

> **Existing Site** - The existing site at 170 Columbia Street W. contains a single-storey office building and surface parking lot. The existing site at 180 Columbia Street W contains a 4-storey office building along with surface parking. An aerial view of the existing sites can be seen in Figure 2.
>
> **Proposed Site** – The proposed development consists of a 5 tower multi-unit residential development. The towers range in height from 25 to 35-storeys. An isometric view of the proposed development is shown in Figure 1.

Figure 9b indicates the 144 locations at which wind speeds were measured for the Proposed configuration, and Figure 9a the 119 locations at which wind speeds were measured for the Existing configuration. Locations 135 through 144 are located on the upper level outdoor amenity spaces of the proposed towers (Figure 9c), and Locations 1, 2, 13, 14, 16, 20, 21, 27, 47, 48, 49, 50, 54, 55, and 56 are located on ground level under the existing buildings; consequently, these locations were only tested for the Proposed configuration.

The evaluation for safety is summarized schematically in Figure 10. Comfort results for each of summer and winter seasons are summarized schematically in Figures 11 and 12. These summarize the suitability of each measurement location with respect to pedestrian-level safety or comfort. The comfort and safety categories used correspond to those summarized in Section 3.4.

Colour-coded diagrams further summarize the suitability of each measurement location with respect to pedestrian-level safety and pedestrian comfort for each tested configuration. Figure 13a presents these for safety considerations for the Existing configuration, and Figures 13b and 13c for the Proposed configuration. For comfort considerations these are presented in Figure 14a (Existing) and Figure 14b (Proposed) for the summer season, and in Figure 15a (Existing) and Figure 15b (Proposed) for the winter season. The comfort and safety categories used in these figures correspond to those summarized in section 3.4.

The introduction of a relatively high building development in an suburban environment will invariably create local wind speed-ups for some wind directions. This can be expected to be more pronounced for winds blowing around and between closely spaced multi-tower developments. With that expectation, the focus is to identify and develop strategies to make wind conditions suitable for the intended usage for negatively affected areas.

The immediate site surroundings are comprised of a typical commercial/suburban environment for all wind directions and with open parking areas. Properties along nearby Columbia Street and Philip Street are multi-storey office, with a mix of multi-unit residential buildings. Directly southwest of the site is the University of Waterloo, and Columbia Lake is about 1km to the west of the site. Beyond these areas are typical suburban residential settings. An aerial view of the existing site can be seen in Figure 2.

Existing Site

Given the suburban surroundings with some local open spaces, it is not surprising that the measured wind speeds for the Existing site are generally consistent with a typical suburban environment.

With respect to pedestrian safety, all tested locations meet the recommended criterion (see Figure 13a) in the Existing configuration.

With respect to pedestrian comfort, the classification of all areas is suitable for standing or better in the summer months (see Figure 14a). In the winter months, all but one location is suited for standing or better. The one location falling into the walking category (Location 123, see Figure 15a) in the winter is away from the proposed site and not near an entry area. As such, all locations are suited for the intended usages.

Influence of Proposed Development

The proposed development was tested without any landscaping. As a result, these results can be expected to provide somewhat conservative estimates of full-scale wind speeds, particularly in late spring through autumn months when trees have full foliage.

In general, for most directions the influence on wind speeds for measurement locations somewhat away from the proposed development (say greater than 50m) is minimal. To the north and northeast of the site the influence to wind speeds is noticed out to about 100m, particularly in winter months. Beyond these areas, the comfort categorizations largely remaining unchanged from the Existing condition.

The summer wind conditions along sidewalks see minimal change, with most tested sidewalk locations being suited for standing or better (Figure 14b), including the pathway that runs parallel to the LRT. On-site Locations 10 and 58 are expected to be suited for walking in summer months (Figure 14b); these are away from entry areas and therefore expected to be consistent with the intended usage of these areas.

All Amenity level locations (Figure 14c) are suitable for standing or sitting in the summer months. This is largely consistent with the intended usage of these areas.

In the winter season (Figure 15b), many nearby sidewalk locations along both north and south sides of Columbia Street W remain rated for standing, with a few (Locations 63, 64, 65) rated for walking; this remains consistent with recommendations for sidewalk usage. Areas to the north of the site also move into the walking category, yet remain suited for the intended usage. Other off-site locations farther to the west, south, and east of the site are minimally impacted, and rated for standing or better in the winter months.

With respect to on-site pedestrian comfort in the winter season, many locations throughout the site see an increase in the winds to walking. Locations 11, 19, 40, 42, 50, 53 and 54 are located near entryways; mitigation will be necessary to make these areas comfortable for standing or better year-round.

In the winter months Amenity Level locations 137, 139, and 141 to 144 are suitable for standing or sitting. Locations 135, 136 (Phase 01), 138 (Phase 02), and 140 (Phase 05) are suitable for walking (Figure 15c). Location 136 is near a doorway; if winter usage for these spaces is anticipated, mitigation will be required to achieve the recommended comfort criteria of standing or better.

In general, wind conditions throughout Common Outdoor Areas (between Phases 03 and 04, and south of Phases 01 and 03), and throughout the ground level Outdoor Amenity (north of Phase 02) are suitable for the intended usage.

With respect to safety, all off-site tested locations meet the recommended criterion (see Figure 13b) in the Proposed configuration. On-site ground level location 39, at the NW corner of the site, exceeds the criteria for pedestrian safety and will require mitigation.

Mitigation Strategies

In areas that are windier than desired, incorporating mitigation strategies will be required.

The areas between adjacent Towers, including some entry areas, experience wind speeds above the general recommendation for the intended usages. Porous wind screens or fencing along the western perimeter of the site or a connecting podium for the Phase 03, 04, and 05 towers may assist in reducing ground level flow throughout the development. Recessing entry areas would be beneficial to mitigate the direct impact of winds when operating doors. Densely spaced evergreen plantings or locally placed windscreens will be required to improve the winds near main entryways.

For the outdoor amenity terraces, testing was conducted modelling a 1.5m solid railing around the terrace perimeters. Increasing the perimeter railing height (to 2m or greater) would add some benefit. In addition, localized windscreens or planters with coniferous plantings along the northern, southern and western portions of all amenity spaces should be considered on amenity spaces with conditions that exceed acceptable. Examples of effective pedestrian level wind mitigation options can be seen in Figure 16. Depending on the level of comfort required, amenity features (vertical fireplaces, moderate height landscaping, windscreens, overhead trellises) may be required throughout the space.

The proposed ground level mitigation scheme, shown in Appendix C, includes strategic plantings. These measures are all positive steps at mitigating adverse winds throughout and around the site, as discussed in Section 3.8. The effectiveness of these proposed mitigation measures is to be verified through future wind tunnel tests.

1 THE WIND CLIMATE FOR THE WATERLOO REGION

1.1 Meteorological Data

The Integrated Surface Data (ISD) records are maintained by the National Climatic Data Center (NCDC), and provide a climatological database of approximately 20,000 stations around the world. The ISD contains many meteorological variables, typically recorded at intervals of 1 hour. An analysis of historical wind data from the Region of Waterloo International Airport (ISD Station 713680) was performed to develop a statistical wind climate for Kitchener/Waterloo. The historical data consists of the time period 1976 – 2022.

Based on the analysis of hourly wind records a probability distribution of wind speed and wind direction is developed and referred to as the Parent Wind Climate model. This model predicts hourly mean wind speeds at 10 m, corrected for standard open country exposure, of 20.9 m/s and 23 m/s for return periods of 10 years and 50 years, respectively.

1.2 Statistical Wind Climate Model

For the analysis of the wind tunnel data, the wind climate model is converted to a reference height of 500 m using a standard open country exposure profile. The Parent Wind Climate provides a good representation of short return period winds (return periods of 1 week to 1 year) and is used in the prediction of pedestrian-level wind speeds. The predicted hourly mean wind speeds at 10m and 500m heights are listed below for various return periods. Wind speeds at a 500m height corresponding to the Parent Wind Climate model are plotted in Figure 3 for various return periods.

	Hourly Mean Wind Speeds (km/h)	
Return Period	**10 m**	**500 m**
1 Week	38.5	70.9
1 Month	48.6	89.3
1 Year	63.4	115.9

Based on the Pedestrian Level Wind Study Terms of Reference Guide issued by the City of Waterloo, separate wind climates were developed to be used for the Comfort and Safety criteria. The development of the Safety climate utilized the complete set of historical wind data (i.e., 24 hours), while the development of the Comfort climate utilized a subset of historical wind data (i.e., between 06:00 and 23:00). The wind climate data are grouped on a two-season basis as follows:

- Summer: May through October
- Winter: November through April

The directional characteristics of winds associated with various return periods are plotted in terms of Relative Importance (%) in Figures 4a and 4b for the Safety (Annual) and Comfort (Seasonal) climates, respectively. Each wind climate model indicates that southwesterly winds are the most important.

The design probability distribution of hourly mean wind speed at 500m reference height and wind direction is shown in Appendix A. Annual and seasonal distributions are shown.

2 THE MODELLING OF THE SITE AND THE WIND

2.1 Overall Approach

The basic tool used is the Laboratory's boundary layer wind tunnel. The tunnel is designed with a very long test section, which allows extended models of upwind terrain to be placed in front of the model of the building under test. The modelling is done in more detail close to the site. The wind flow then develops characteristics which are similar to the wind over the terrain approaching the actual site. This methodology has been highly developed (see References 2 and 3) and is detailed below.

2.2 Model Design

Close-up views of the 1:400 scale model are shown in Figure 5.

Aerodynamic model components:

The models of the 170-180 Columbia Street W development model built in detail from PLA plastic.

1. A detailed proximity model of the surrounding city built in block outline from Styrofoam for a radius of approximately 500m.
2. A generic model of upstream terrain, modelled by setting appropriate heights of generic roughness blocks and by turbulence-generating spires to produce wind characteristics representative of those at the project site.

The building models and the proximity model are rotated to simulate different wind directions with the upstream terrain being changed as appropriate.

The upstream terrain was modelled using generic roughness blocks and turbulence-generating spires to produce wind characteristics representative of those at the project site. Two different terrain models were used; these are shown in Figure 6 and the azimuth ranges over which they were used are shown in Figure 7.

Testing was carried out for two (2) configurations of the surroundings, namely the Existing and Proposed. Photographs of each configuration during wind tunnel testing are shown in Figure 5.

Existing Site – The Existing site (170 Columbia St W) contains a single-storey commercial building and surface parking lot. The existing site (180 Columbia Street W) contains a 4-storey office building along with surface parking. Street level views of the site from Columbia St W can be seen in the figures below. An aerial view of the existing site can be seen in Figure 2.



Existing 170 Columbia Street W Site *Photo Credit: Google Earth*



Existing 180 Columbia Street W Site *Photo Credit: Google Earth*

Proposed Site – The Proposed development is to consist of a 5 Tower multi-unit residential development. The Towers range in height from 25 to 35-storeys. An isometric view of the proposed development is shown in Figure 1.

2.3 Characteristics of the Modelled Wind

Figure 8 presents the vertical profiles of the mean speed and of the intensity of the longitudinal component of turbulence, measured just upstream of the centre of the turntable, for the upstream terrain exposures.

The model profiles are good representations of the expected variation of full-scale wind speed and turbulence over the building height. The reference wind speed measured in the wind tunnel has been scaled such that the expected full-scale wind speeds at relevant heights above ground are achieved.

3 THE DETERMINATION OF PEDESTRIAN-LEVEL WIND SPEEDS

3.1 Overall Approach

Detailed measurements were made of pedestrian-level wind speeds at locations of interest around the project. Views of the model in the wind tunnel are shown in Figure 5 for each of the tested configurations. These wind-tunnel data were then combined with the extratropical wind climates for comfort and safety to provide statistical predictions of expected pedestrian-level wind speeds around the site.

Assessment for pedestrian safety is based on the gust wind speed predicted to occur 0.1% of time or approximately 9 hours in a year. Assessment for pedestrian comfort is based on the gust equivalent mean wind speed predicted to occur 80% of the time.

General descriptions of the testing and analysis procedure are given in Reference 1.

3.2 Model Instrumentation

Figure 9b indicates the 144 locations at which wind speeds were measured for the Proposed configuration, and Figure 9a the 119 locations at which wind speeds were measured for the Existing configuration. Locations 135 through 144 are located on the upper-level outdoor amenity spaces of the proposed towers (Figure 9c), and Locations 1, 2, 13, 14, 16, 20, 21, 27, 47, 48, 49, 50, 54, 55, and 56 are located on ground level under the existing buildings; these locations were only tested for the Proposed configuration.

Wind speed measurement locations were placed systematically along the sidewalk areas around the proposed development and on existing neighbouring pedestrian traffic routes and entrances.

Measurements were made using omni-directional pressure sensors which measure both mean and fluctuating components of the wind speed parallel to the ground at a height of about 1.5 to 2m in full scale.

3.3 Aerodynamic Data

Measurements were taken at 10° intervals for the full range of azimuths. Measured coefficients of mean and gust wind speeds at all measuring locations are presented in Appendix B as a ratio of the mean wind speed at reference height. The gust equivalent mean (GEM) wind speed is defined as the maximum of the mean wind speed or the gust wind speed divided by 1.85; the gust speed is evaluated as the mean speed + (3 x RMS speed).

The polar plots in Appendix B show the wind speed at each of the sensors, expressed as a ratio of the mean wind speed at reference height. The angular coordinate gives the direction of the approach wind, relative to true North.

The radial magnitudes and the shapes of the polar plots in Appendix B provide valuable indications of the relative magnitudes of wind speeds at different locations and their sensitivity to the direction of the approach wind.

These plots can be useful to identify important wind directions that can influence conditions at a particular location. In turn, this information can be used to inform and develop mitigation strategies.

3.4 Statistical Prediction of Pedestrian-Level Winds

The directional characteristics of the extratropical wind climate are shown in Figure 4.

The predicted wind speeds are obtained by combining the statistical wind climate model of wind speed and direction with the aerodynamic data measured in the wind tunnel. Two types of prediction are provided:

1. Wind speeds exceeded during 0.1% of the time on an annual basis.
2. Wind speeds exceeded 20% of the time on a seasonal basis.

These predictions are compared against the following specified criteria to evaluate pedestrian comfort and safety:

CRITERIA	DESCRIPTION	GEM WIND SPEED EXCEEDED 20% OF THE TIME
Comfort level 4	**Sitting**	**≤ 10 km/h**
Comfort level 3	**Standing**	**≤ 15 km/h**
Comfort level 2	**Walking**	**≤ 20 km/h**
Comfort level 1	**Uncomfortable**	**> 20 km/h**

CRITERIA	DESCRIPTION	GUST WIND SPEED EXCEEDED 0.1% OF THE TIME
Safety level	**Exceeded**	**> 90 km/h**

The comfort categories are described as follows:

- **Comfort Level 4 - Sitting:** Calm or light breezes desired at outdoor restaurants and seating areas where one can read a paper without having it blown away
- **Comfort Level 3 - Standing:** Gentle breezes suitable for main building entrances and bus stops
- **Comfort Level 2 - Walking:** Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering
- **Comfort Level 1 - Uncomfortable:** Strong winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended

The safety category is described as follows:

- **Areas which exceed the Safety Level**: Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is typically required.

These criteria are as outlined in the City of Waterloo, pedestrian level wind study Terms of Reference [Ref. 4].

3.5 Test Results and Discussion

The tested configurations include the Existing site and the Proposed development. These configurations are described in Section 2.2.

Landscaping was not modelled during wind tunnel testing. Results can therefore be expected to reflect a somewhat conservative representation of expected wind conditions around the development in areas where trees and other landscaping elements will be present.

Figure 10 compares the predicted wind speeds at the various locations for the Existing and Proposed configurations along with the criteria for pedestrian safety. Similar plots of predicted wind speeds compared to the criteria for pedestrian comfort can be found in Figures 11 and Figure 12 for summer and winter seasons, respectively.

Colour-coded diagrams are also used to summarize the suitability of each measurement location with respect to pedestrian safety and pedestrian comfort for each tested configuration. Figure 13 presents these for safety considerations for the Existing and Proposed configurations. For comfort considerations these are presented in Figures 14 and 15 for summer and winter seasons, respectively.

Results are discussed below for each of the tested configurations.

3.5.1 Existing Site Configuration

Results for the Existing configuration reflect current expected wind conditions at and around the 170-180 Columbia Street W development. This configuration is referred to as the 'Existing Site'.

With respect to pedestrian safety:

1. All tested locations meet the recommendations for pedestrian safety (see Figure 13a).

With respect to pedestrian comfort:

1. All areas are suitable for standing or better in the summer months (see Figure 14a).
2. In the winter months, most locations are typically suited for standing or better, with one location falling into the walking category (Location 123, see Figure 15a). The one location that is rated for walking in the winter is away from the proposed site and not near an entry area. As such, all locations are suited for the intended usages.

Given the suburban surroundings with some open fetches, it is not surprising that the measured wind speeds for the existing site are, in general, consistent with a typical suburban environment or marginally greater.

3.5.2 Proposed Development Configuration

Testing of the proposed development included the proposed 5-Tower multi-unit residential development at 170-180 Columbia Street W.

With respect to pedestrian safety:

1. Ground level Location 39 at the NW corner of the site exceeds the recommended safety criteria, and will require mitigation (see Figures 13b).
2. All other locations meet the criteria for pedestrian safety (see Figure 13b and 13c).

With respect to pedestrian comfort:

1. The proposed development has a moderate influence to wind speeds on and around the site; this influence is most noticeable adjacent to the site. For many directions the influence on wind speeds somewhat away from the proposed development (say greater than 50m) is minimal. Beyond these areas, the comfort categorizations largely remains unchanged from the Existing condition.
2. During the summer months (Figure 14b and 14c):
    - Wind conditions along sidewalks see minimal change in comfort classification, with all tested sidewalk locations being suited for standing or better, including the pathway that runs parallel to the LRT.
    - Locations 10 and 58 on the site property are suited for walking in summer months (Figure 14b). This is consistent with the intended usage of these areas.
    - All remaining test locations are suited for standing or better during the summer months.
3. In the winter season (Figure 15b and 15c):
    - Many nearby sidewalk locations along the north and south sides Columbia Street W remain suited for standing. The exceptions are Locations 63, 64, 65 which are rated for walking. Nonetheless, these areas remain consistent with the intended sidewalk usage.
    - Select areas to the north of the site also move into the walking category, yet remain suited for the intended usage.
    - Other off-site locations farther to the west, south, and east of the site are minimally impacted, and rated for standing or better in the winter months.

- With respect to on-site pedestrian comfort in the winter season, many locations throughout the site, and in particular areas between adjacent Towers, see an increase in the winds to walking. For locations near main entryways (Locations 11, 19, 40, 42, 50, 53 and 54), mitigation will be necessary to make them comfortable for standing or better year-round.

4. With respect to the rooftop Amenity level spaces:

   - All Amenity level locations (Figure 14c) are suitable for standing or sitting in the summer months, generally consistent with the intended usage of these areas.
   - Amenity level locations 137, 139, and 141 to 144 are suitable for standing or sitting in the winter months, while the remaining locations are rated for walking (Figure 15c).
   - Location 136 is near a doorway; if regular usage in the winter is anticipated, mitigation should will be considered to achieve a recommended comfort criteria of standing or better.

3.6 Seasonal Differences

The amount and type of activity for a given location can vary by season. For example, a terrace or outdoor amenity area may have limited or restricted usage during the winter season. Thus, in some cases it is valuable to look at the wind speeds and the corresponding classification of pedestrian comfort on a more detailed season-by-season basis.

In general, compared to annual wind speeds, wind speeds during the winter months are about 10% higher, and in the summer they are about 12% lower.

3.7 Summary Remarks

The proposed development can be expected to affect wind patterns locally in regions throughout the development site. This is consistent with the introduction of a relatively tall development to an otherwise homogeneous site with low-rise buildings. This can be expected to be more pronounced for winds blowing around and between closely spaced multi-tower developments. With that expectation, the focus is to identify and develop strategies to make wind conditions suitable for the intended usage for negatively affected areas.

With an expectation to changes in the local wind speeds, the focus should not be to return wind conditions to an ‘as-it-was’ state, but rather identify and develop strategies to make wind conditions suitable for the intended usage. For example, entry areas should have a comfort category consistent with standing activities, while sidewalks should meet the condition of being comfortable for walking.

In areas that are windier than desired, incorporating mitigation strategies will be required.

Areas between adjacent Towers experience wind speeds above the general recommendation for the intended usages, and includes some entry areas. Porous wind screens along the western perimeter of the site or a connecting podium for the Phase 03, 04, and 05 Towers may assist in reducing ground level flow throughout the development. Recessing entry areas would be beneficial to mitigate the direct impact of winds when operating doors or when exiting buildings. Densely spaced evergreen plantings or locally placed windscreens would help improve the winds near main entryways.

For the outdoor amenity terraces, testing was conducted modelling a 1.5m solid railing around the terrace perimeters. Increasing the perimeter railing height (to 2m or greater) would add some benefit. In addition, localized windscreens or planters with coniferous plantings along the northern, southern and western portions of all amenity spaces should be considered. Examples of effective pedestrian level wind mitigation options can be seen in Figure 16. Depending on the level of comfort required, amenity features (vertical fireplaces, moderate height landscaping, windscreens, overhead trellises) may be required throughout the space.

In general, summer wind conditions in Common Outdoor Areas between Phases 03 and 04, and at the south side of Phases 01 and 03 and rated for standing or better. Landscaping would only be expected to further improve on the winds in those areas. Likewise, the fencing and landscaping in

and around the Outdoor Amenity at the north side of Phase 02 will further improve on the wind conditions in that area.

3.8 Comments to Landscape Plan

The proposed ground level landscape scheme is shown in Appendix C. The inclusion of landscape is considered a positive measure that will be beneficial at mitigating winds and/or inhibiting pedestrians from accessing windier areas. More specifically, these measures include:

- A wood barrier fence along the west side of the property and wrapping around the southwest corner of the site for wind mitigation.
- Extensive landscaping included in areas around building corners and along streets, most notably near Locations 39 and 58. Landscape includes plantings to deter pedestrian traffic at windy areas at building corners, and evergreen trees/shrubs to deter access at select areas and act as wind breaks.
- Extensive plantings in the outdoor amenity space to the north of Building 2 will improve wind conditions locally, helping to keep winds aloft.
- Tree plantings (deciduous and coniferous) will be beneficial in mitigating winds at the Common Outdoor Area between Phase 03 and Phase 04. Likewise, landscape plans for Common Outdoor Areas at the south side of Phases 01 and 03 would only be expected to further improve on the local wind in those areas.
- Fencing and landscape plans for the area in and around the Outdoor Amenity at the north side of Phase 02 will further improve on the wind conditions in that area.

The effectiveness of any proposed mitigation, including size and extent of the different features, are to be best verified through future wind tunnel tests.

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FIGURES

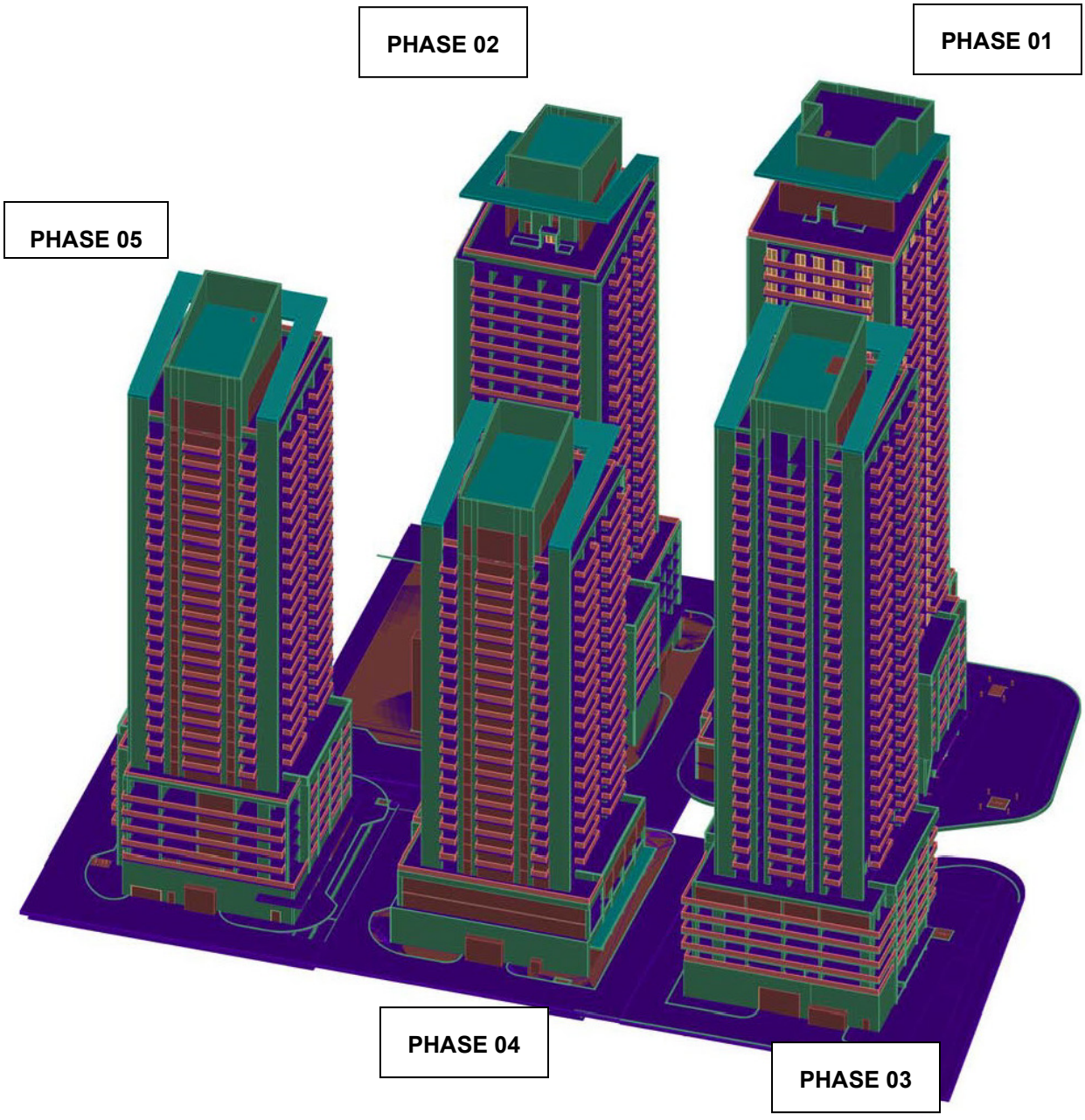


FIGURE 1 SOUTHWEST ISOMETRIC VIEW OF THE PROPOSED DEVELOPMENT



Photo Credit: Google

FIGURE 2 AERIAL VIEW OF EXISTING SITE LOCATION

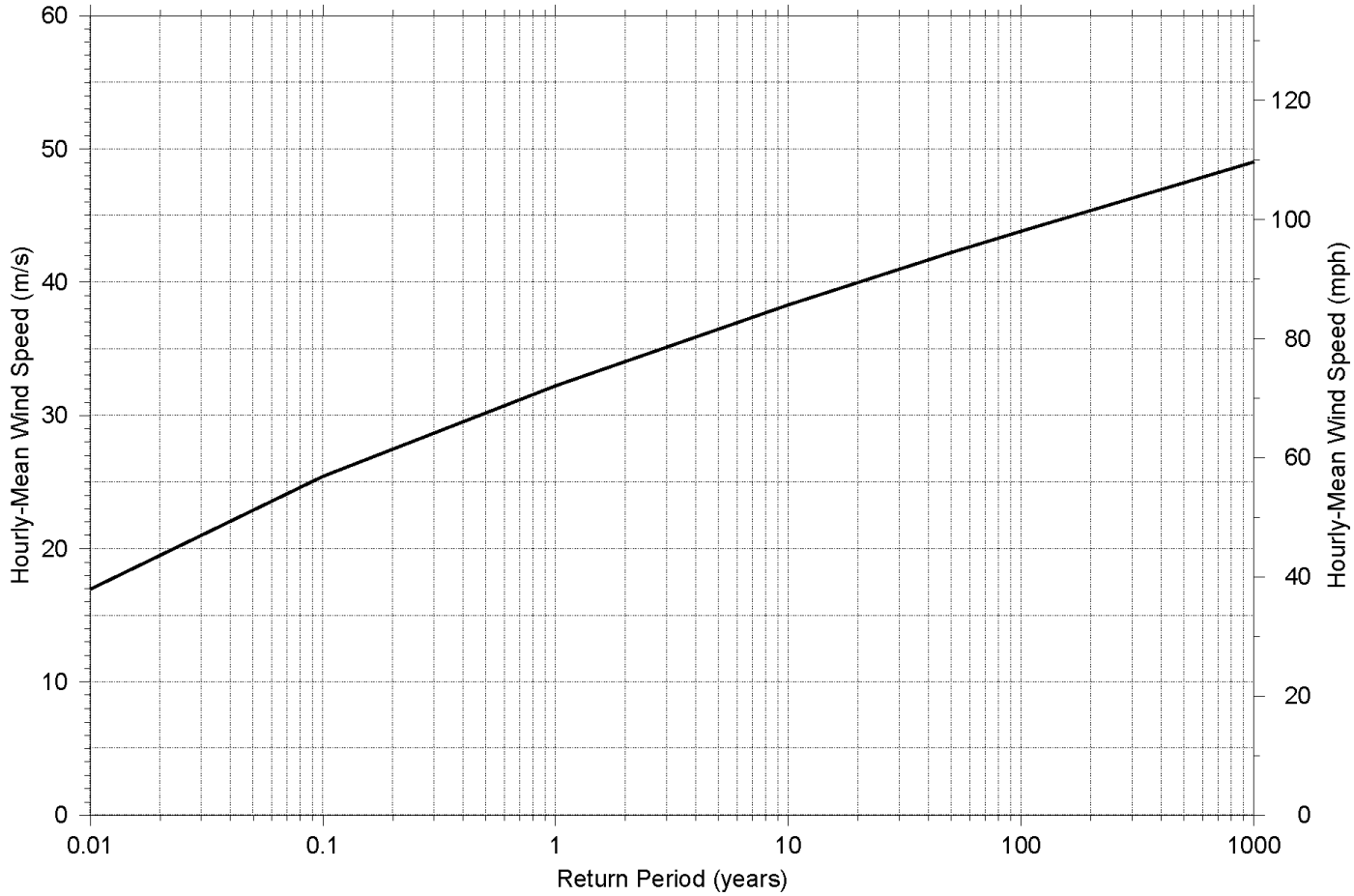


FIGURE 3 PREDICTED ANNUAL EXTREME REFERENCE WIND SPEEDS AT 500m HEIGHT FOR VARIOUS RETURN PERIODS

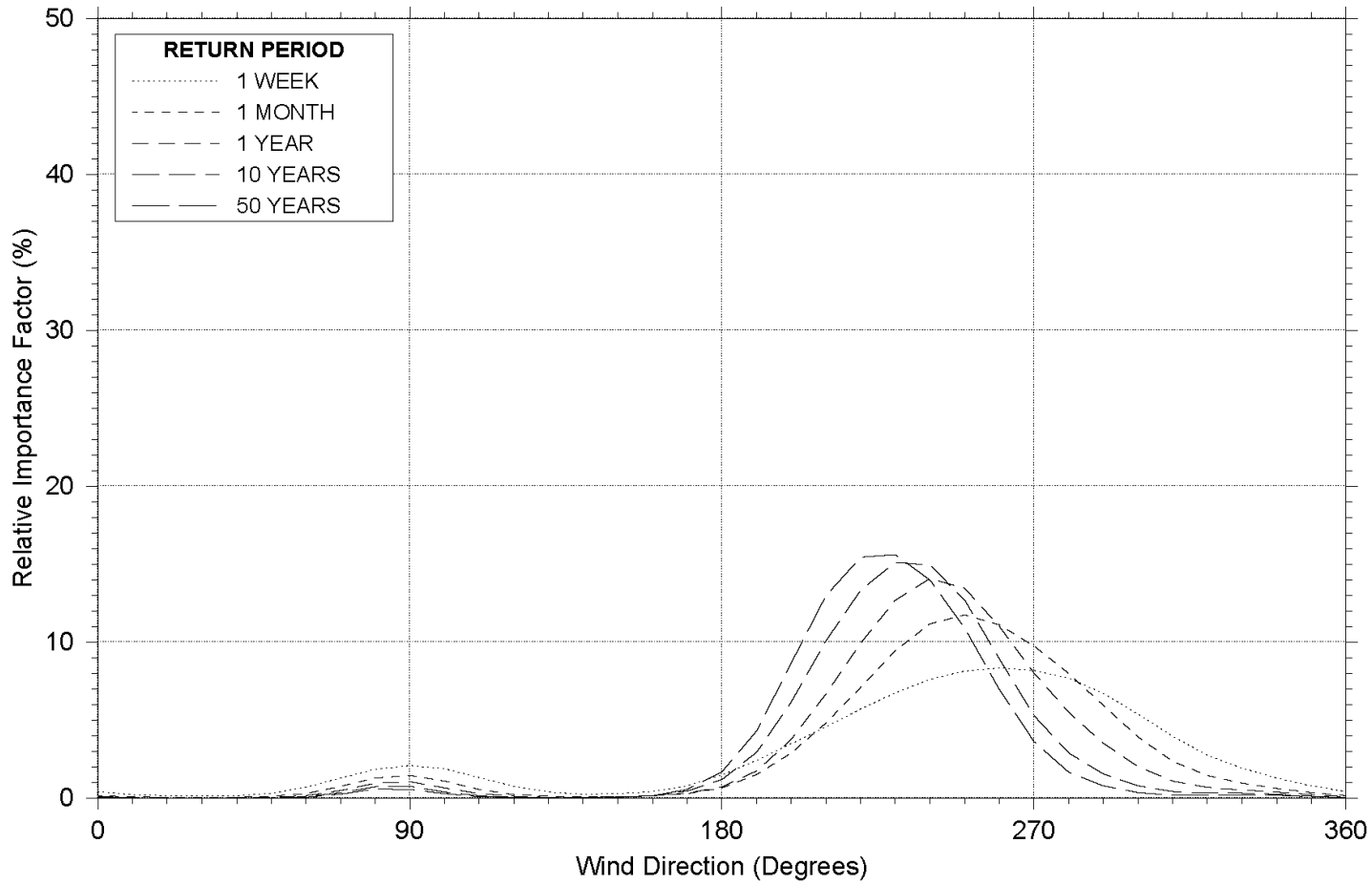


FIGURE 4a RELATIVE IMPORTANCE OF AZIMUTHAL SECTOR TO THE PROBABILITY OF EXCEEDING VARIOUS RETURN-PERIOD WIND SPEEDS - ANNUAL

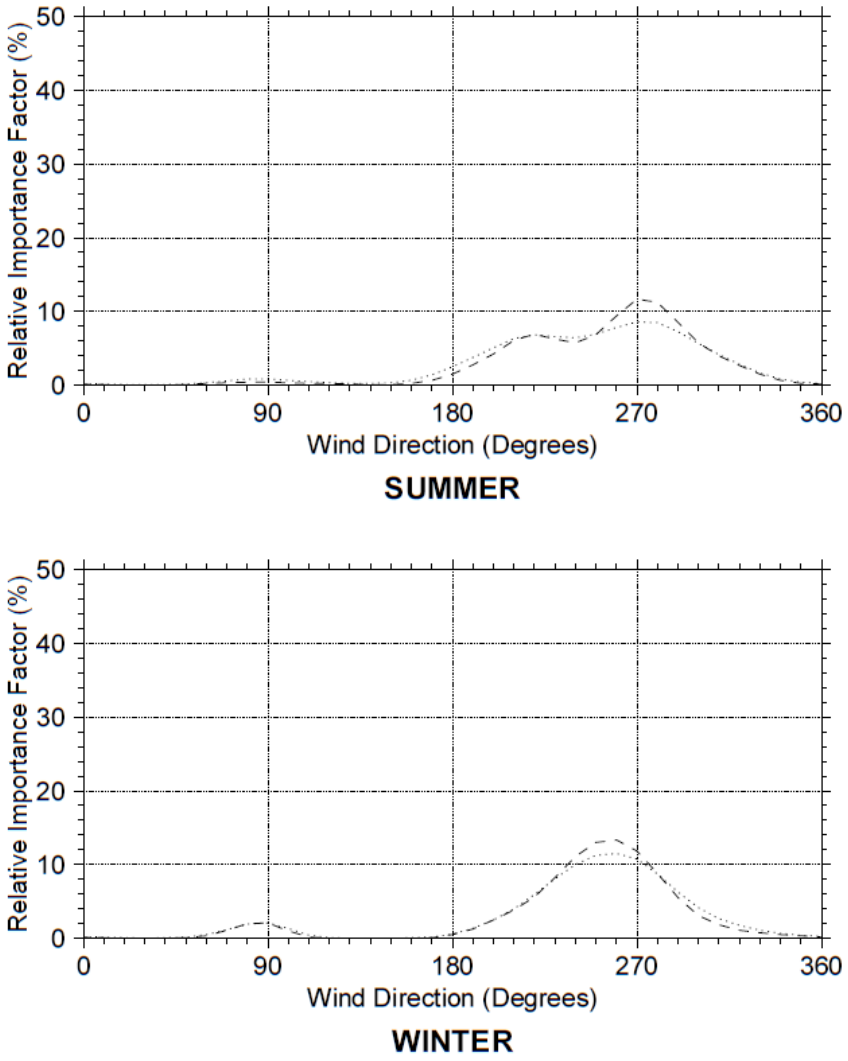


FIGURE 4b RELATIVE IMPORTANCE OF AZIMUTHAL SECTOR TO THE PROBABILITY OF EXCEEDING VARIOUS RETURN-PERIOD WIND SPEEDS - SEASONAL

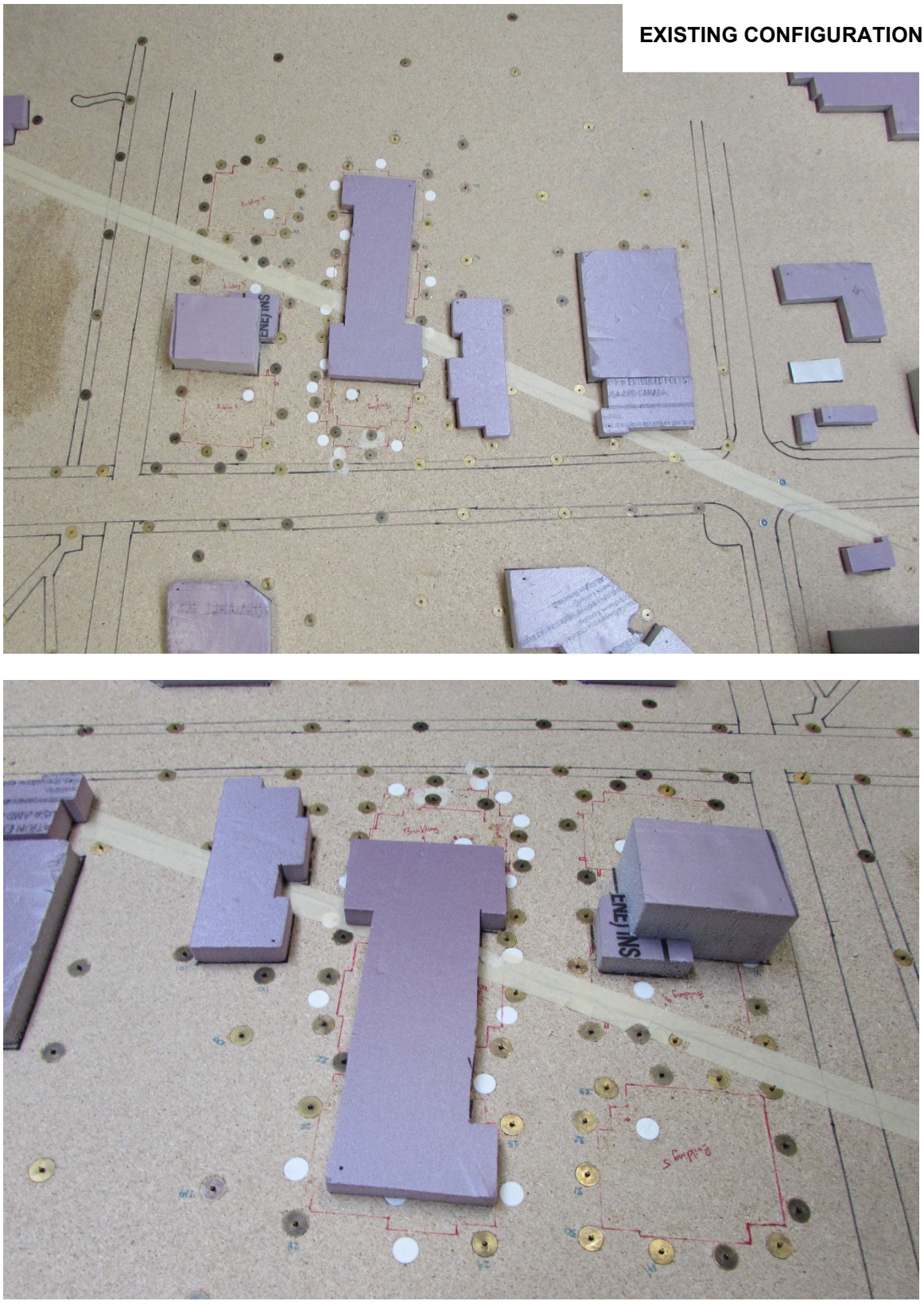


FIGURE 5a CLOSE UP VIEWS OF THE PEDESTRIAN LEVEL WIND SPEED MODELS FOR 'EXISTING' CONFIGURATION

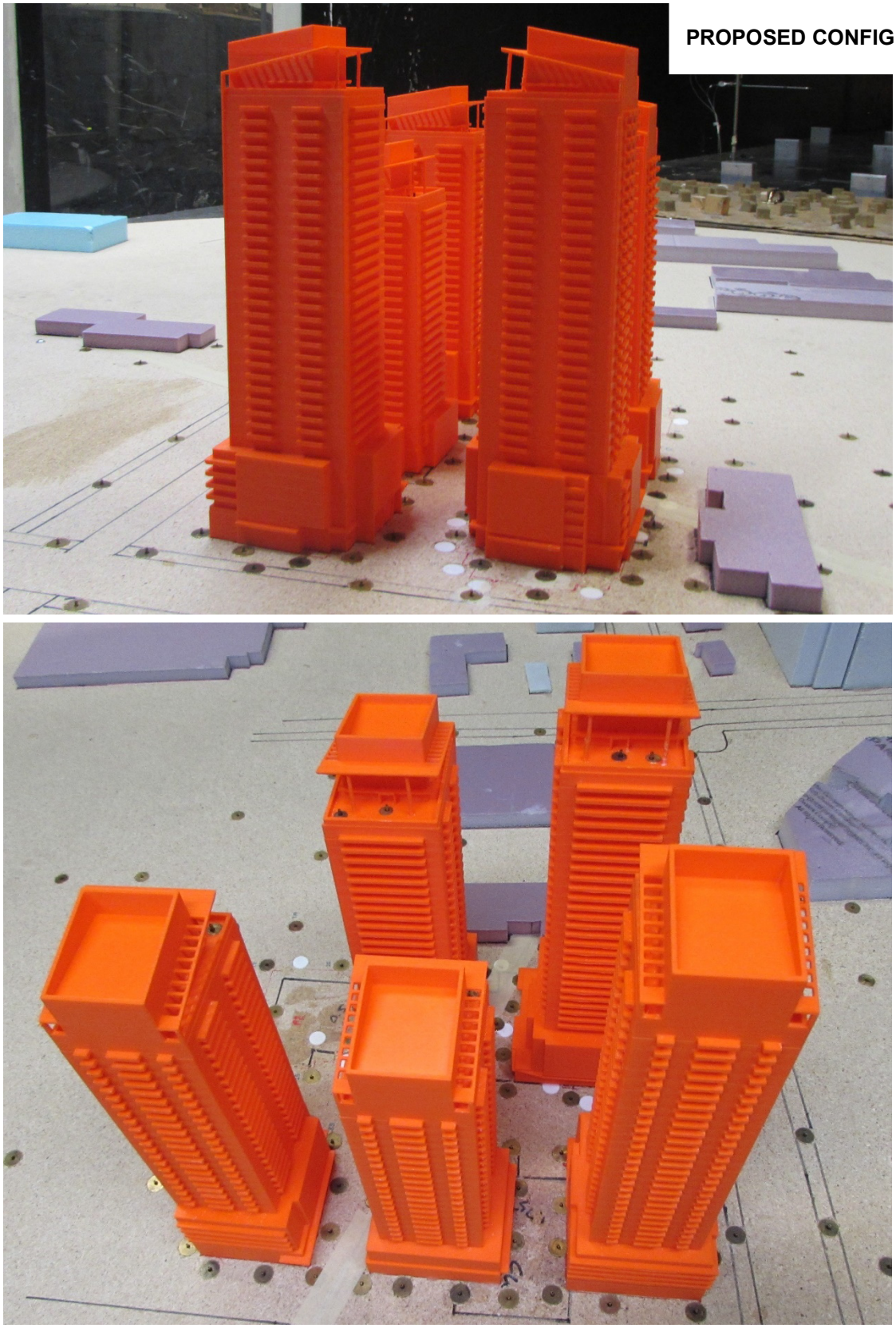
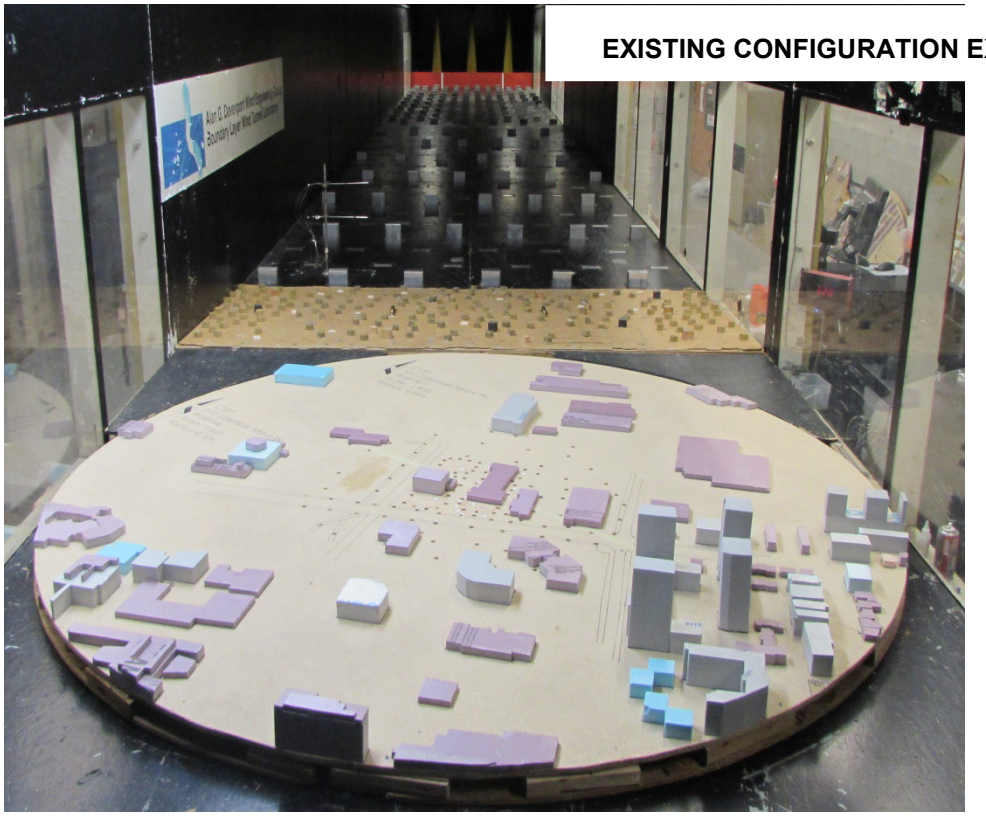
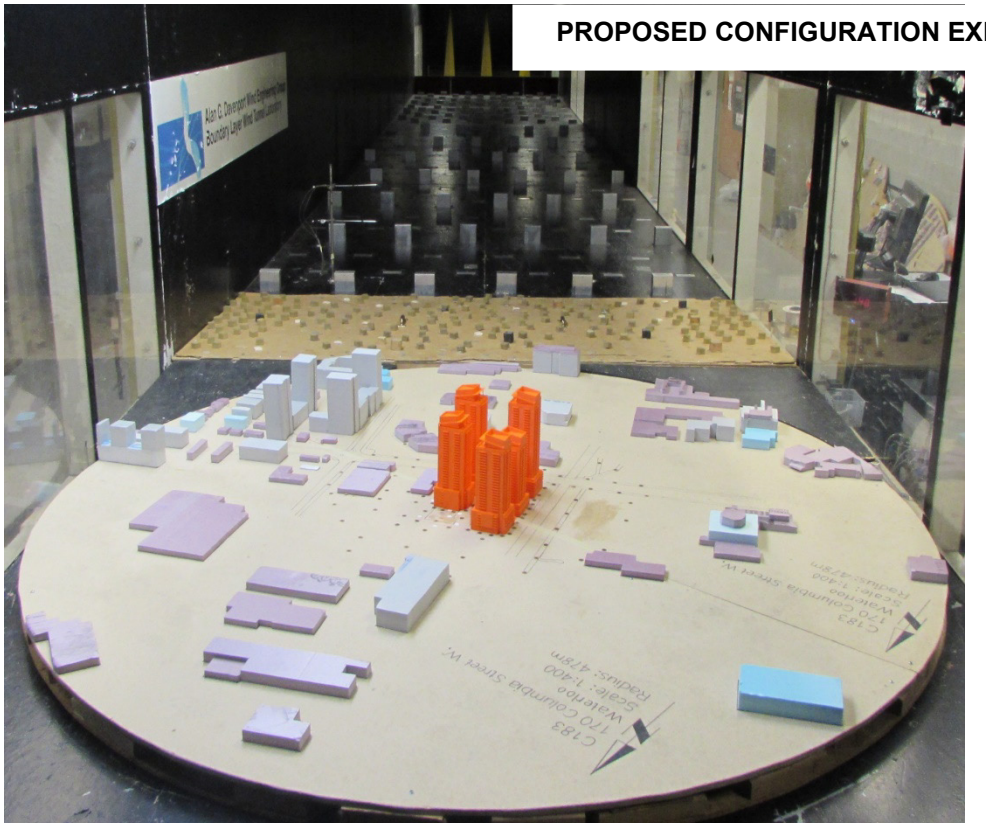


FIGURE 5b CLOSE UP VIEWS OF THE PEDESTRIAN LEVEL WIND SPEED MODELS FOR 'PROPOSED' CONFIGURATION



EXISTING CONFIGURATION EXPOSURE 1



PROPOSED CONFIGURATION EXPOSURE 2

FIGURE 6 PHOTOGRAPHS OF THE MODEL IN THE WIND TUNNEL SHOWING THE UPSTREAM TERRAIN MODEL (EXPOSURES) USED



FIGURE 7 AZIMUTH RANGES OVER WHICH THE UPSTREAM TERRAIN MODELS WERE USED

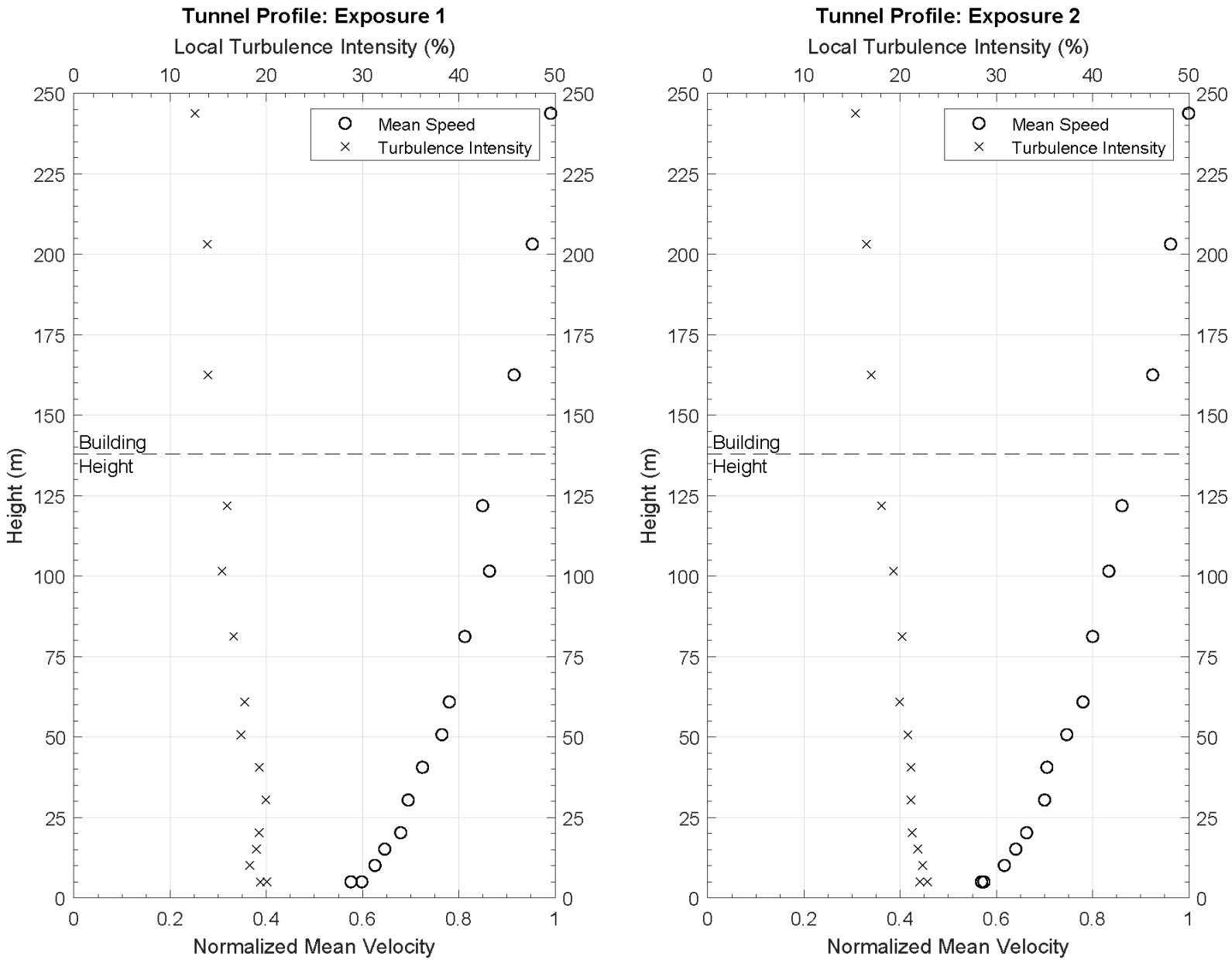


FIGURE 8 VERTICAL PROFILES OF MEAN WIND SPEED AND LONGITUDINAL TURBULENCE INTENSITY MEASURED JUST UPSTREAM OF THE PROXIMITY MODEL.



FIGURE 9a MEASUREMENT LOCATIONS FOR PEDESTRIAN-LEVEL WIND SPEEDS – EXISTING SITE



FIGURE 9b MEASUREMENT LOCATIONS FOR PEDESTRIAN-LEVEL WIND SPEEDS – PROPOSED DEVELOPMENT – GROUND LEVEL

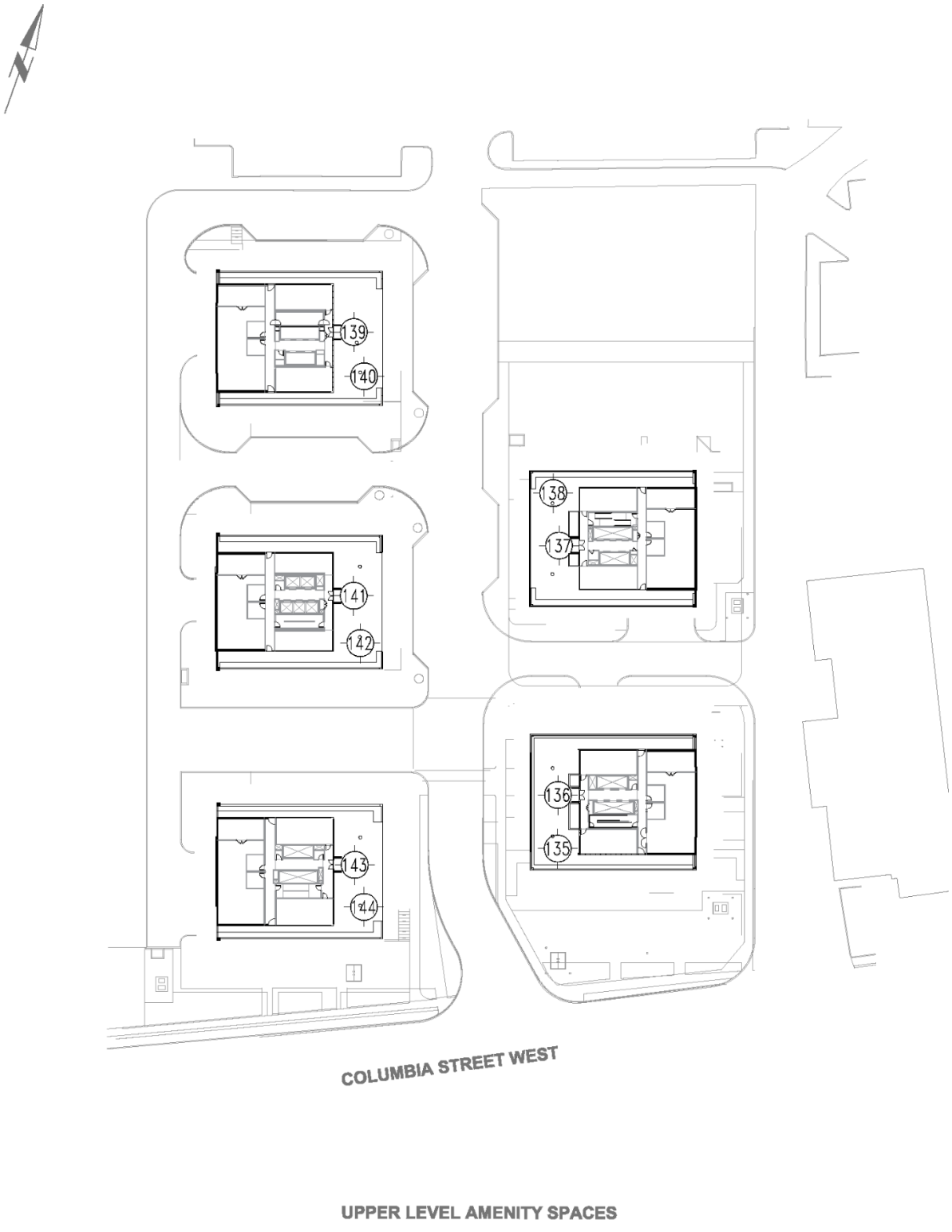


FIGURE 9c MEASUREMENT LOCATIONS FOR PEDESTRIAN-LEVEL WIND SPEEDS – PROPOSED DEVELOPMENT – AMENITY LEVELS



FIGURE 10a PREDICTED WIND SPEEDS COMPARED WITH CRITERIA FOR PEDESTRIAN SAFETY



FIGURE 10b PREDICTED WIND SPEEDS COMPARED WITH CRITERIA FOR PEDESTRIAN SAFETY

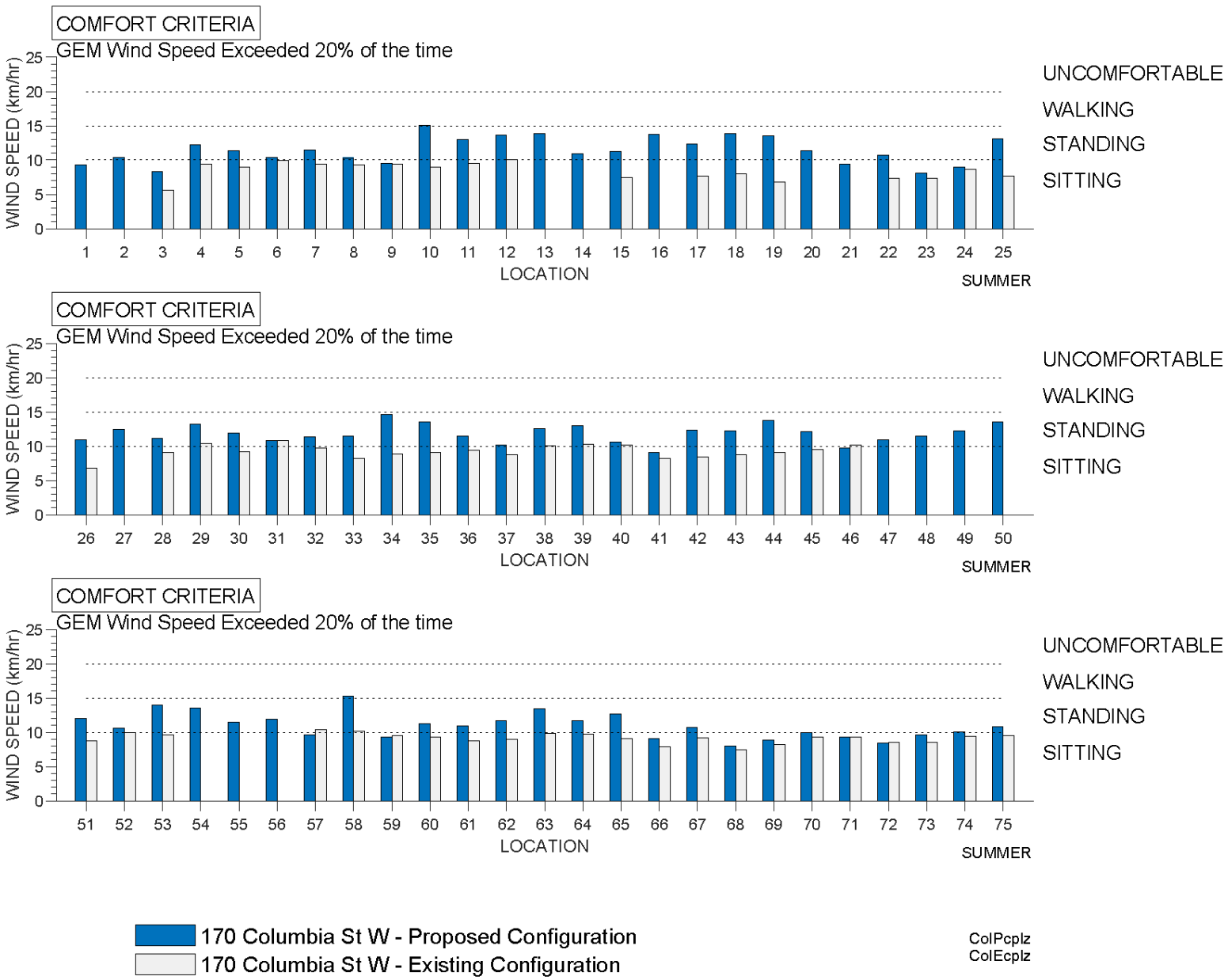


FIGURE 11a PREDICTED WIND SPEEDS COMPARED WITH CRITERIA FOR PEDESTRIAN COMFORT – SUMMER

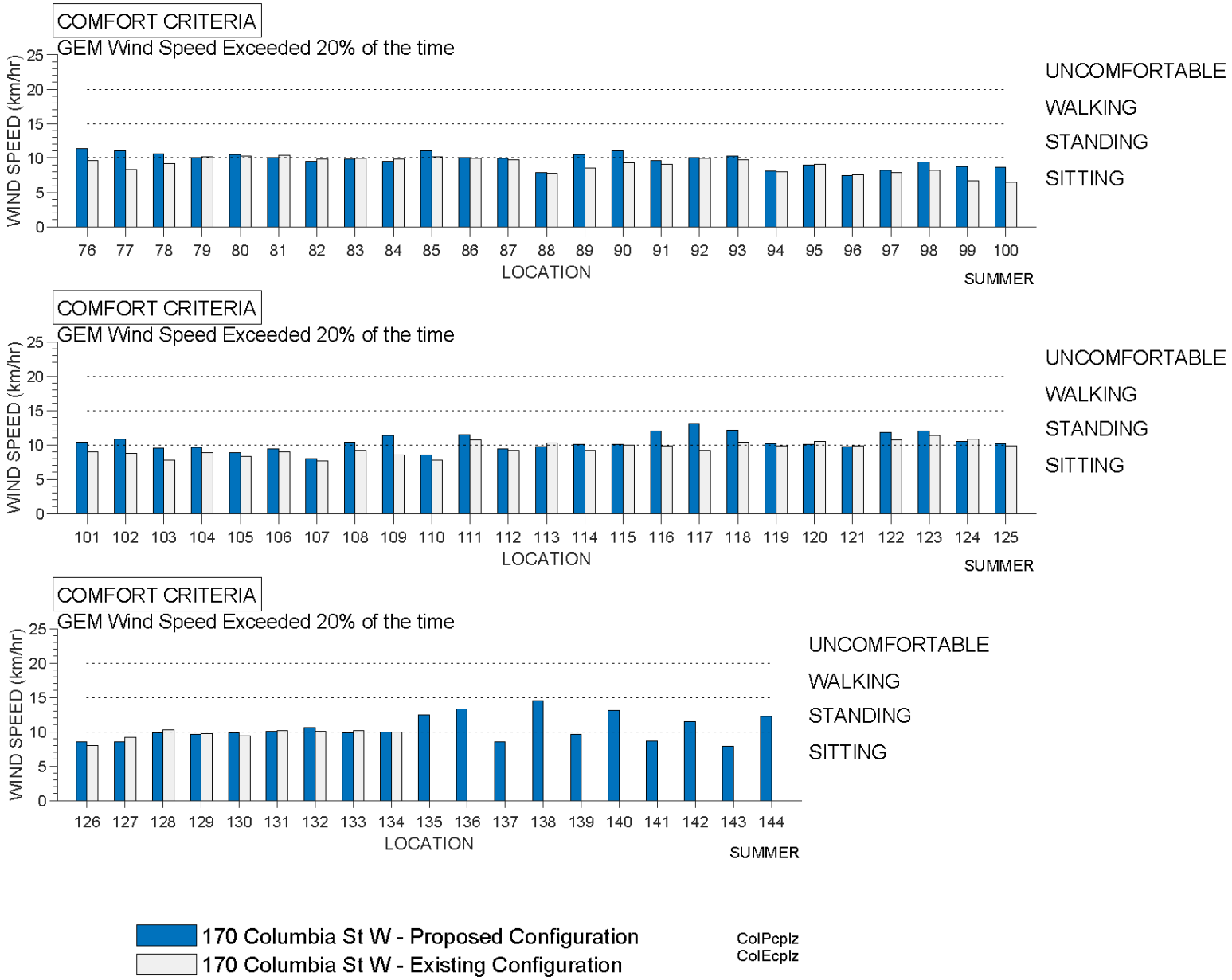


FIGURE 11b PREDICTED WIND SPEEDS COMPARED WITH CRITERIA FOR PEDESTRIAN COMFORT – SUMMER



FIGURE 12a PREDICTED WIND SPEEDS COMPARED WITH CRITERIA FOR PEDESTRIAN COMFORT – WINTER



FIGURE 12b PREDICTED WIND SPEEDS COMPARED WITH CRITERIA FOR PEDESTRIAN COMFORT – WINTER

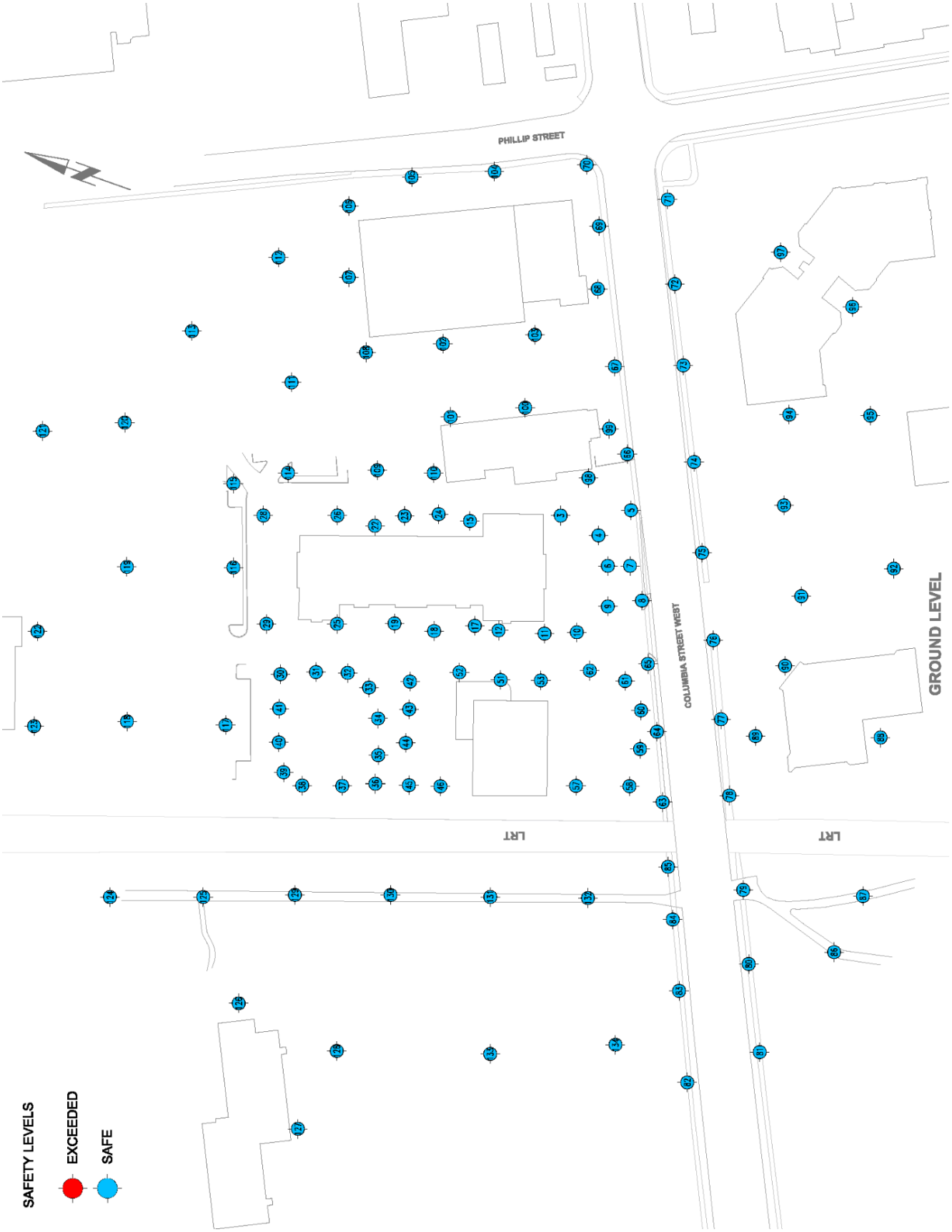


FIGURE 13a SUMMARY OF PREDICTED SAFETY LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – EXISTING SITE



FIGURE 13b SUMMARY OF PREDICTED SAFETY LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – PROPOSED DEVELOPMENT GROUND LEVEL

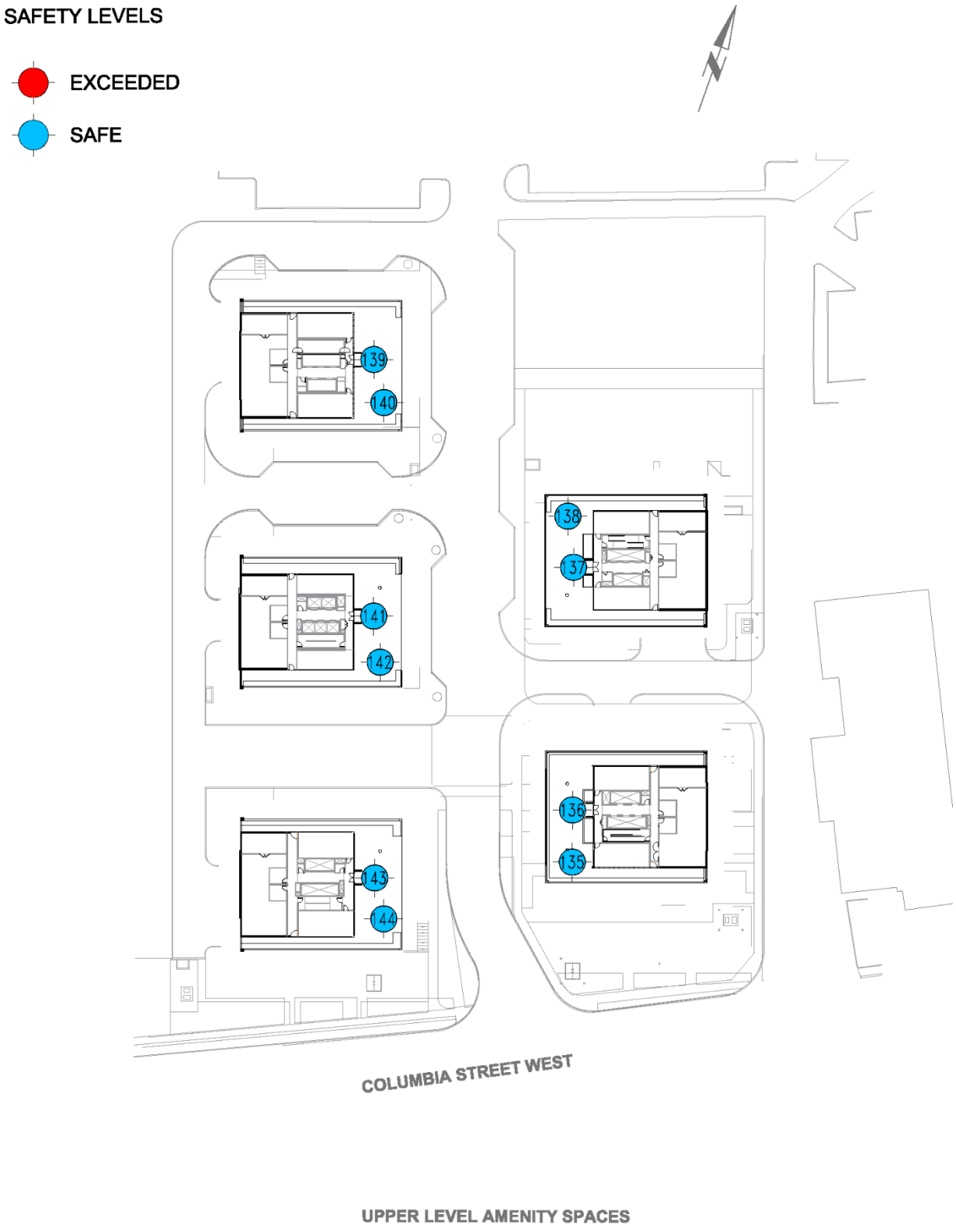


FIGURE 13c SUMMARY OF PREDICTED SAFETY LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – PROPOSED DEVELOPMENT AMENITY LEVELS

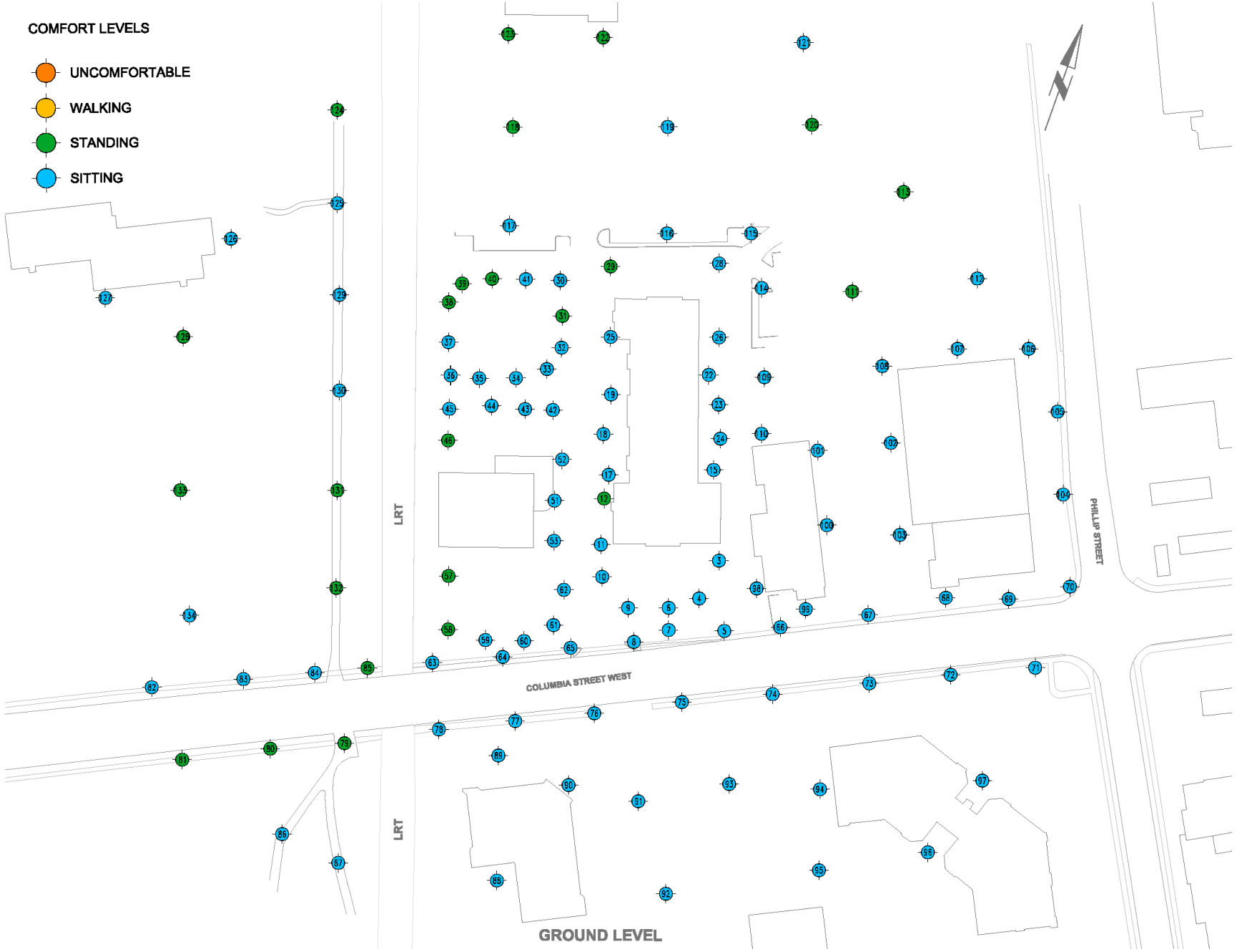


FIGURE 14a SUMMARY OF PREDICTED COMFORT LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – EXISTING SITE - SUMMER



FIGURE 14b SUMMARY OF PREDICTED COMFORT LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – PROPOSED DEVELOPMENT - SUMMER

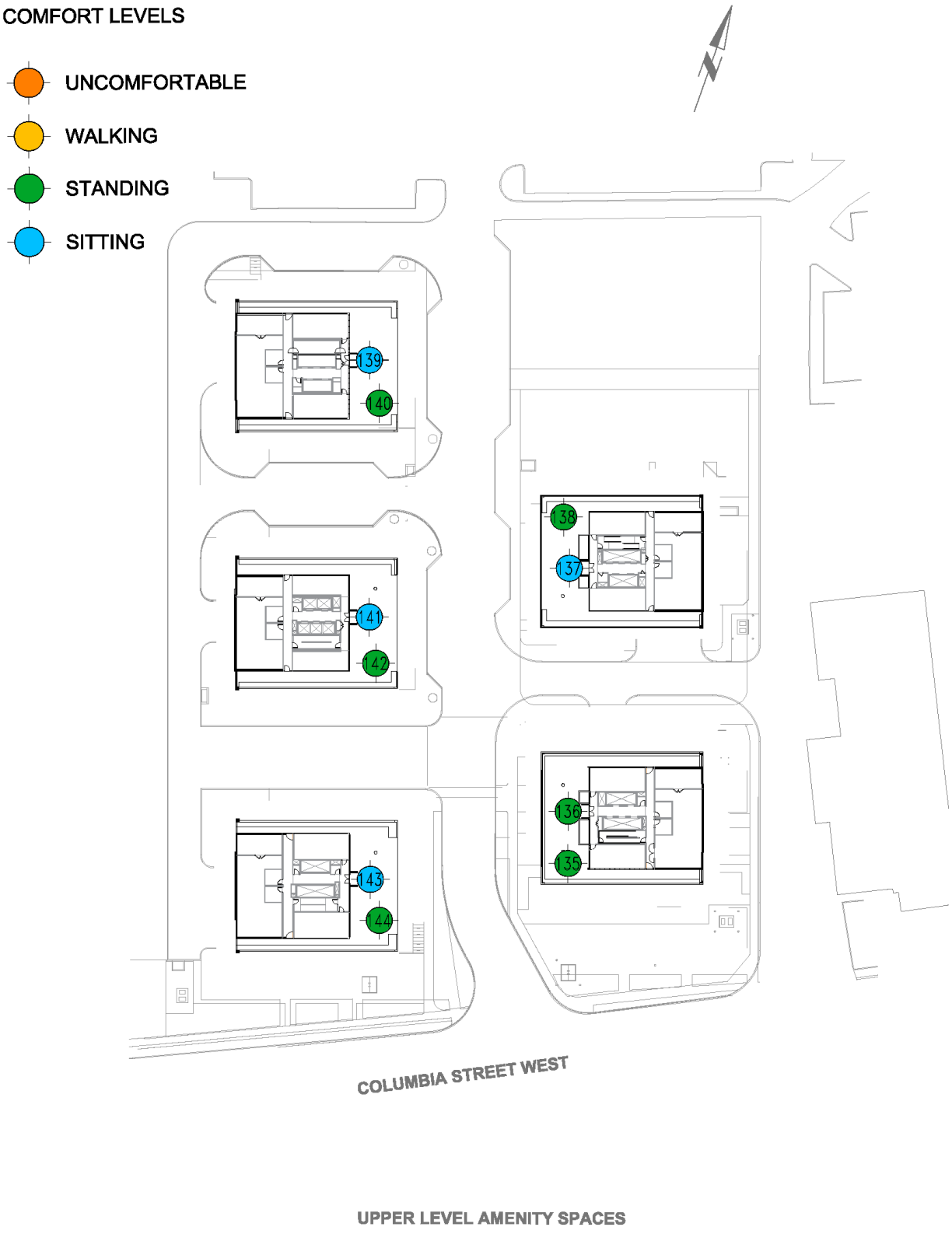


FIGURE 14c SUMMARY OF PREDICTED COMFORT LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – PROPOSED DEVELOPMENT AMENITY LEVELS – SUMMER

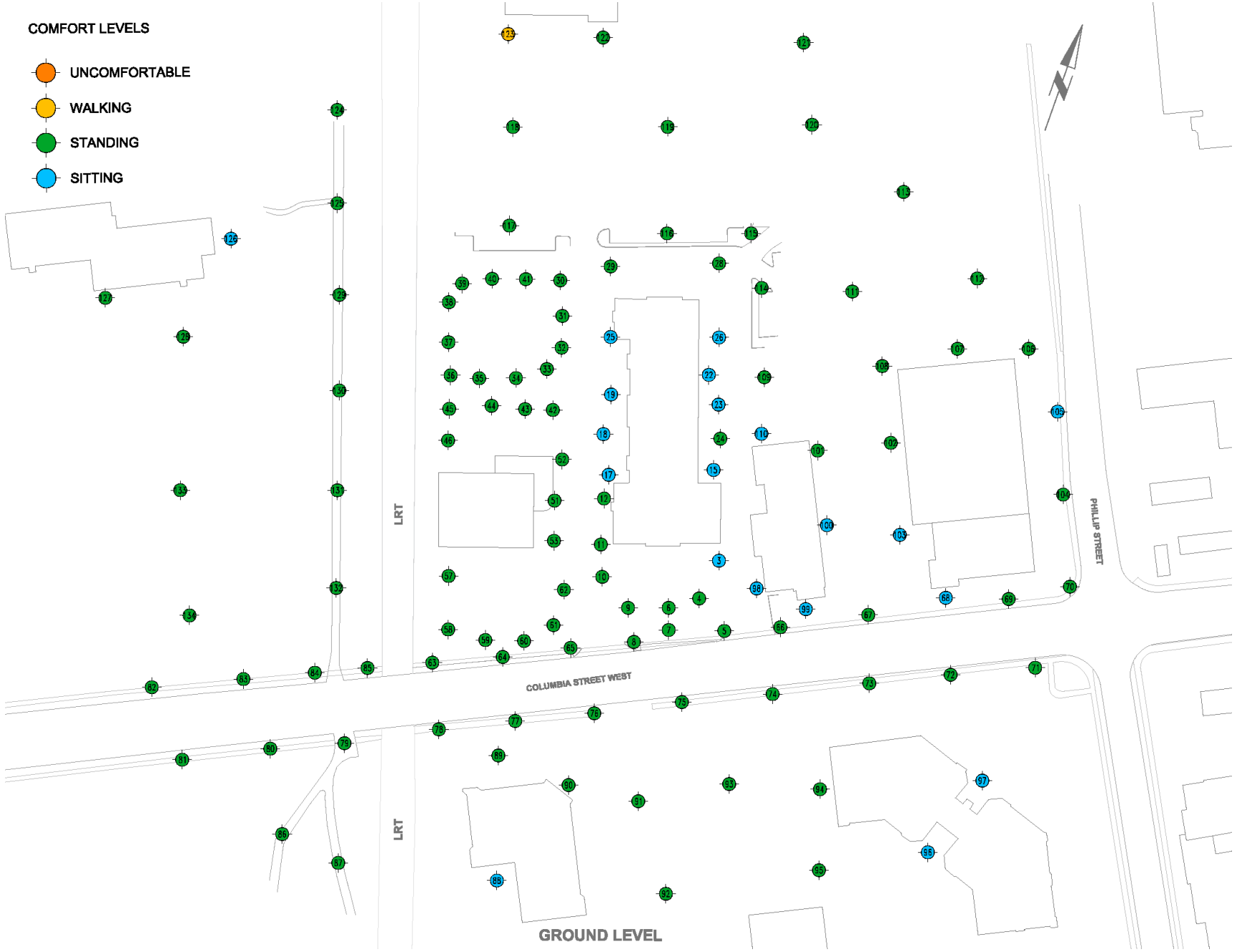


FIGURE 15a SUMMARY OF PREDICTED <u>COMFORT</u> LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – EXISTING SITE - WINTER

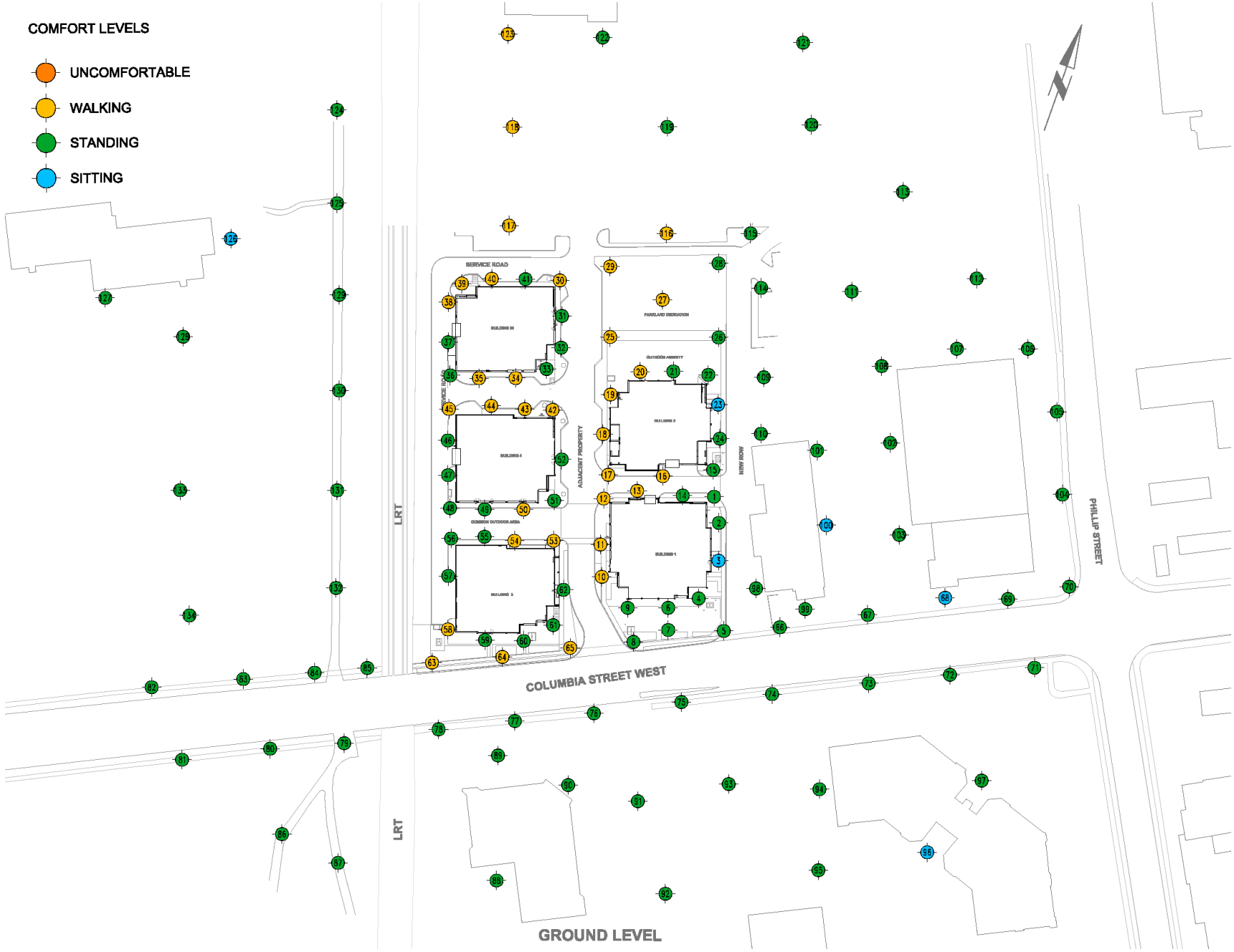


FIGURE 15b SUMMARY OF PREDICTED COMFORT LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – PROPOSED DEVELOPMENT – WINTER

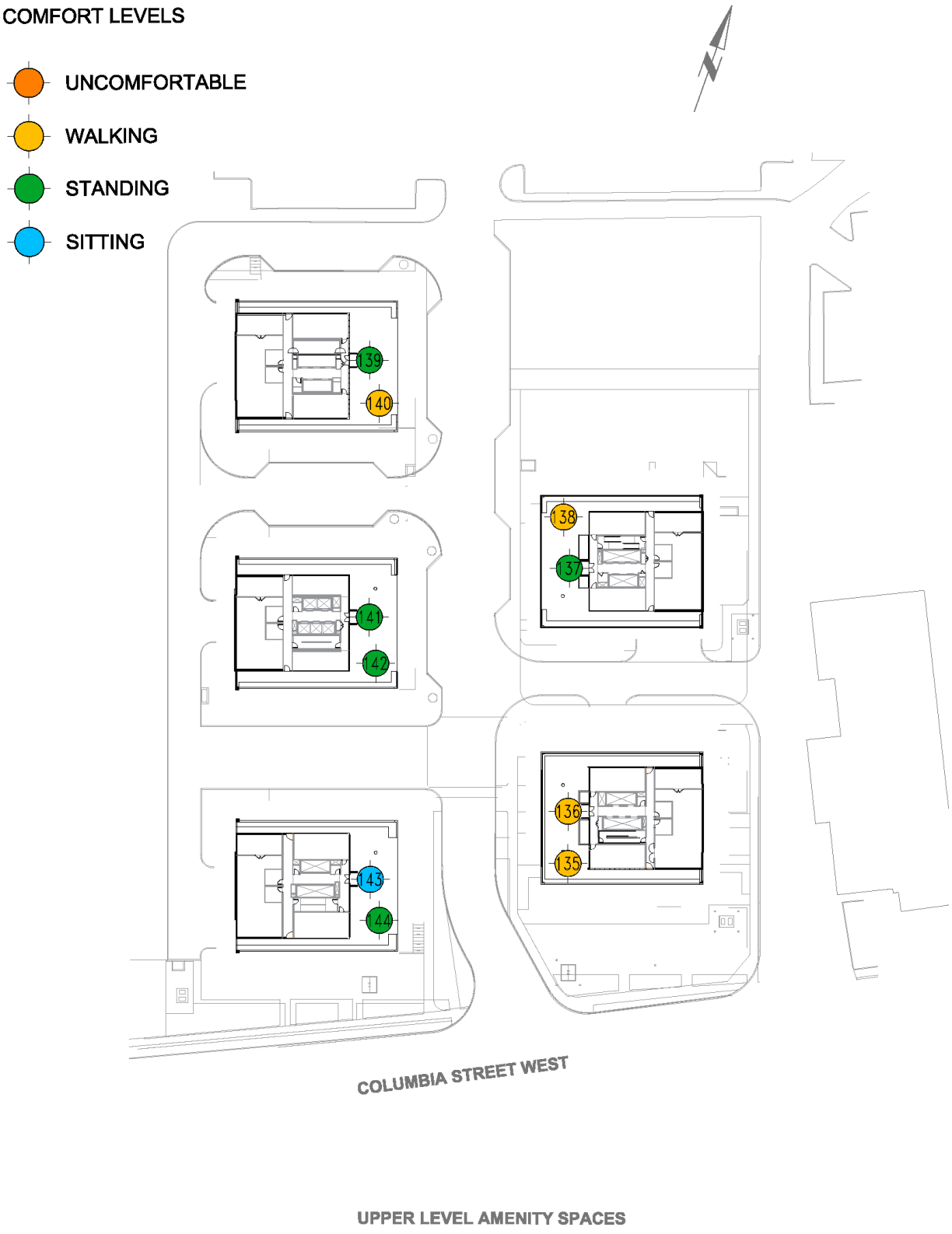


FIGURE 15c SUMMARY OF PREDICTED COMFORT LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – PROPOSED DEVELOPMENT AMENITY LEVELS – WINTER







FIGURE 16 EXAMPLES OF VARIOUS MITIGATION OPTIONS FOR THE OUTDOOR AMENITY AREAS

APPENDIX A

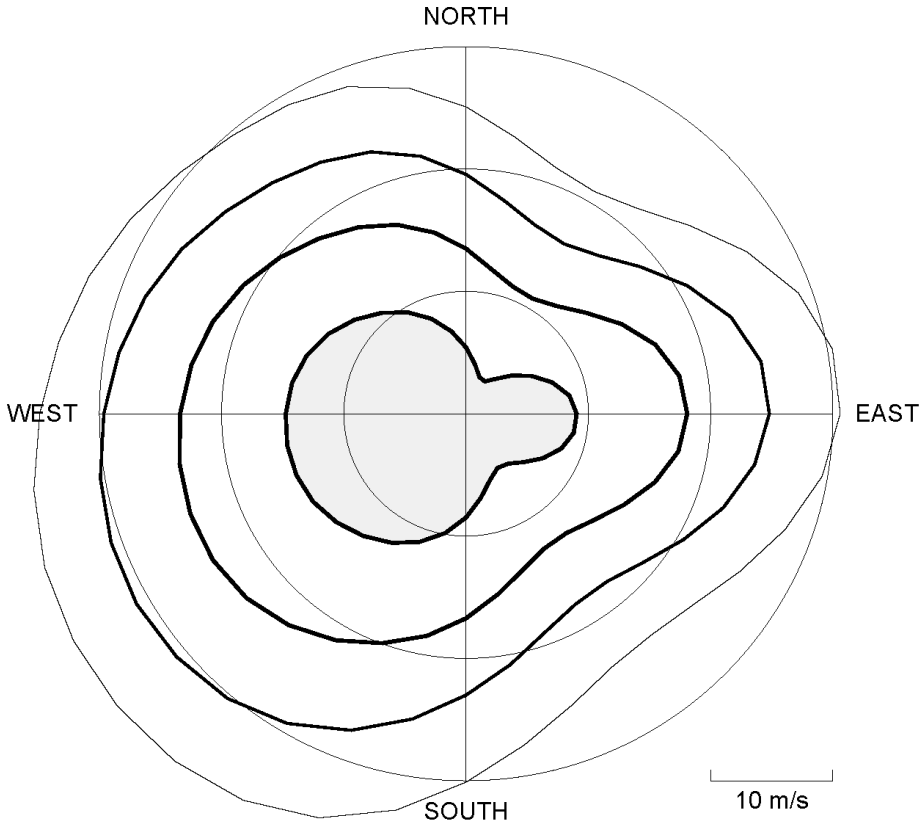
PROBABILITY DISTRIBUTIONS OF WIND SPEED AND DIRECTION

In the plots, the radial distance represents the wind speed at a reference height of 500 m in standard open country exposure. Contours are plotted for four probability levels: the innermost contour is for a probability level of 0.01 or 1% of the time. The other contours represent 0.1%, 0.01% and 0.001% of the time. Thus, the more-common winds are represented by the inner contours and the more-rare winds by the outer contours.

These plots have been derived using data at 16 compass directions, which were interpolated to every 10°. Thus, a point on the innermost contour would represent the wind speed that is exceeded 1% of the time within a 10° sector centred on that wind direction.

To determine the probability of exceeding a particular wind speed at a particular direction, interpolate between the contour levels. For example, to determine the probability of exceeding 20 m/s from the west, find the point on the plot corresponding to this speed and direction. In this case (for 20 m/s at 270°), the probability of exceeding 20 m/s from the west falls between the 1% and 0.1% contours and is approximately 0.35%.

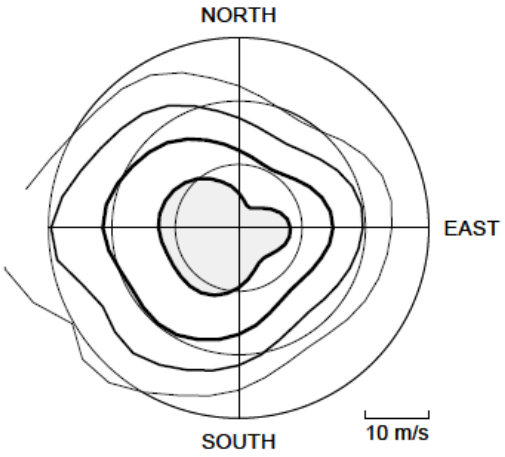
The probability of a particular wind speed being exceeded regardless of direction can be obtained by summing the probabilities of exceeding that wind speed at every 10° over the full 360° azimuth range.



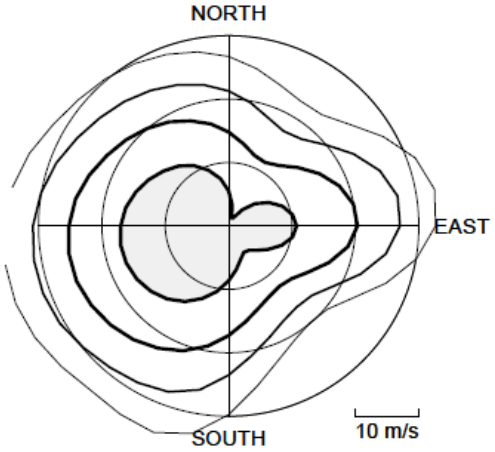
ANNUAL

A point on the innermost contour represents the wind speed exceeded
1% of the time within a 10 degree sector centred on that direction.
Other contours represent probability levels of:
0.1%, 0.01% and 0.001% respectively.

Waterloo, ON (ISH 713680)



SUMMER



WINTER

A point on the innermost contour represents the wind speed exceeded 1% of the time within a 10 degree sector centred on that direction. Other contours represent probability levels of: 0.1%, 0.01% and 0.001% respectively.

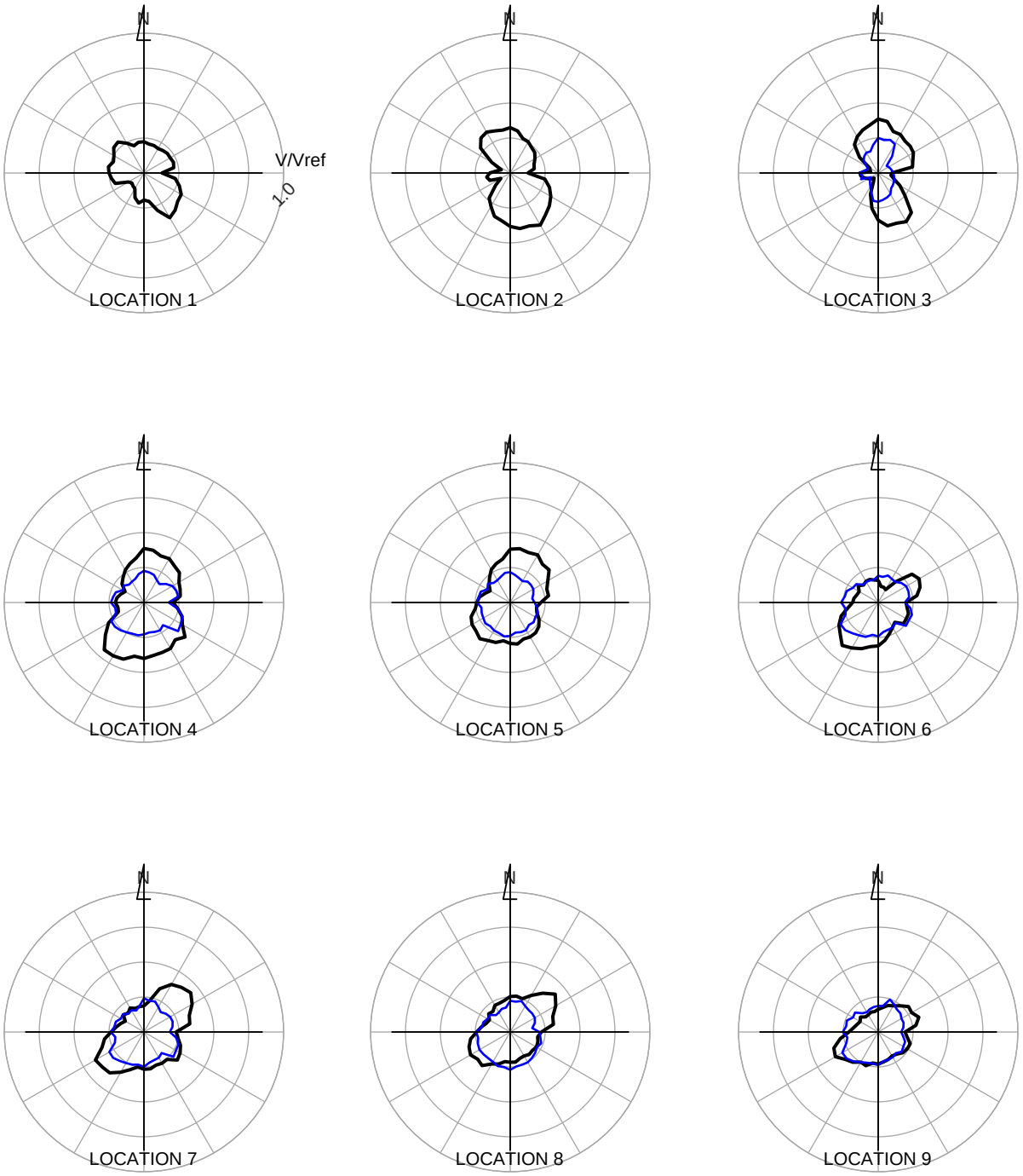
Waterloo, ON (ISH 713680)

APPENDIX B

POLAR PLOTS OF SPEED COEFFICIENTS

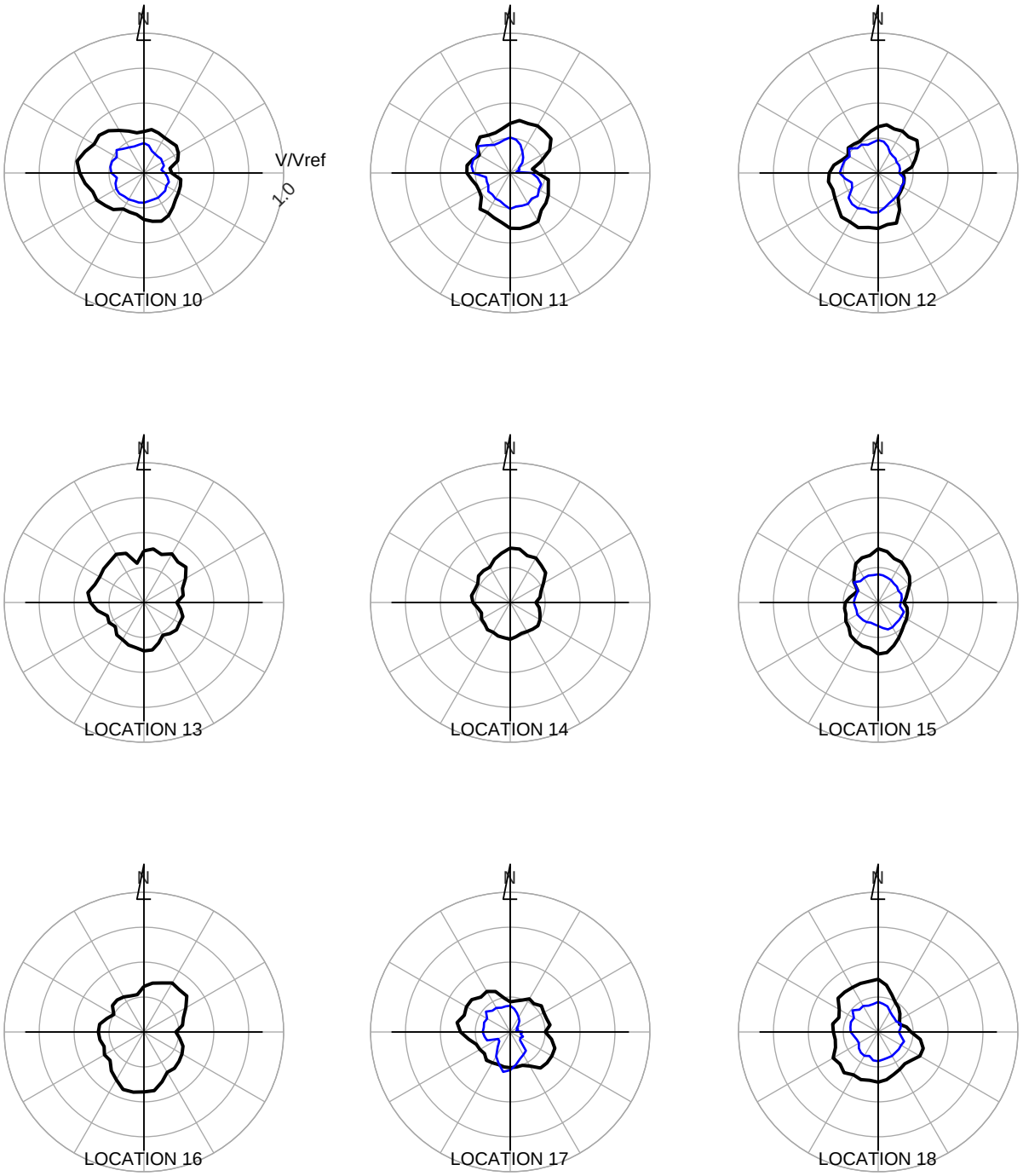
Speed ratios are the speed at the probe height divided by the speed at reference height (see Figure 3).

The azimuth indicated refers to the direction of the oncoming reference-height wind flow, measured from true North. Surface wind directions may vary considerably from these.



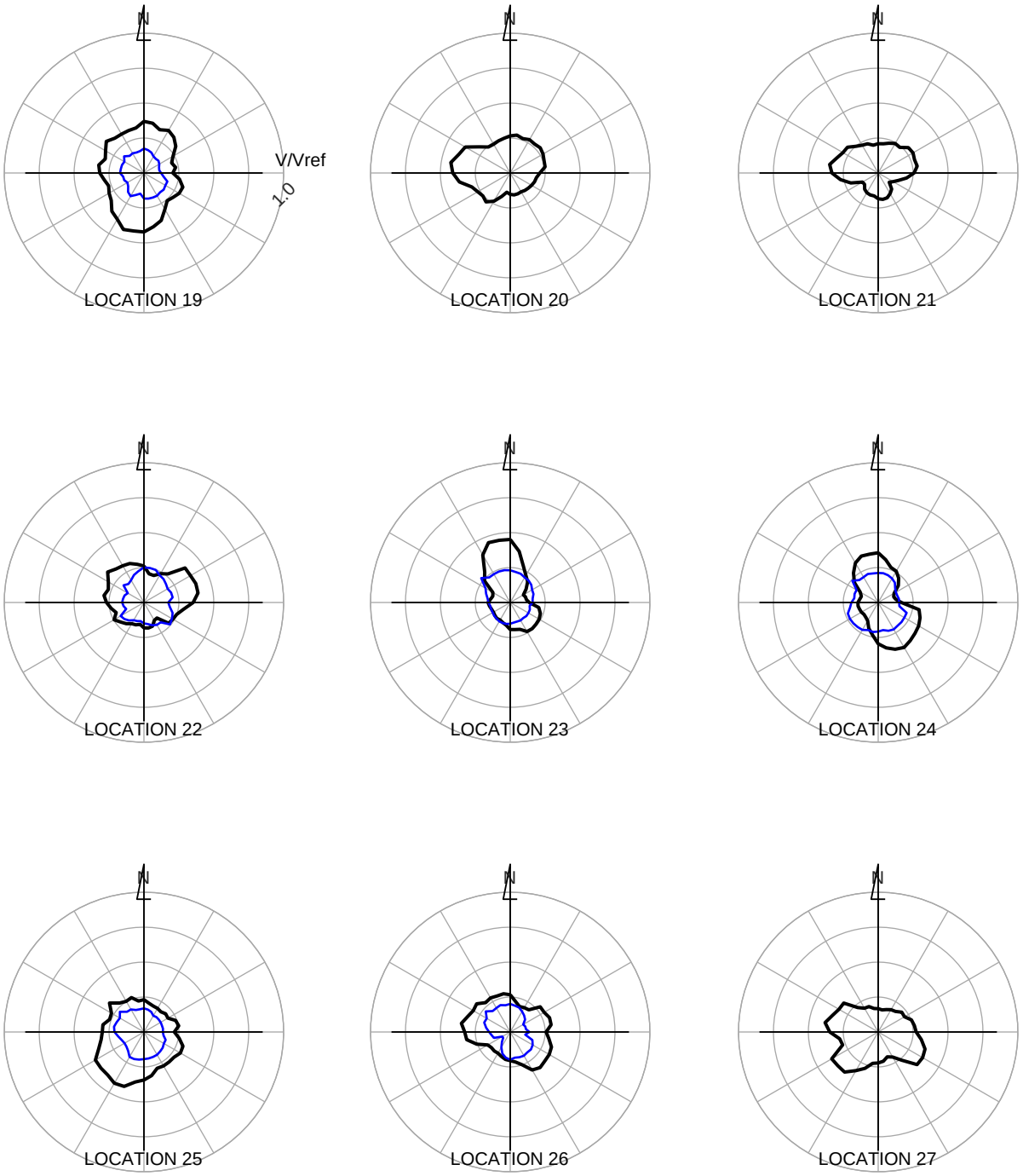
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



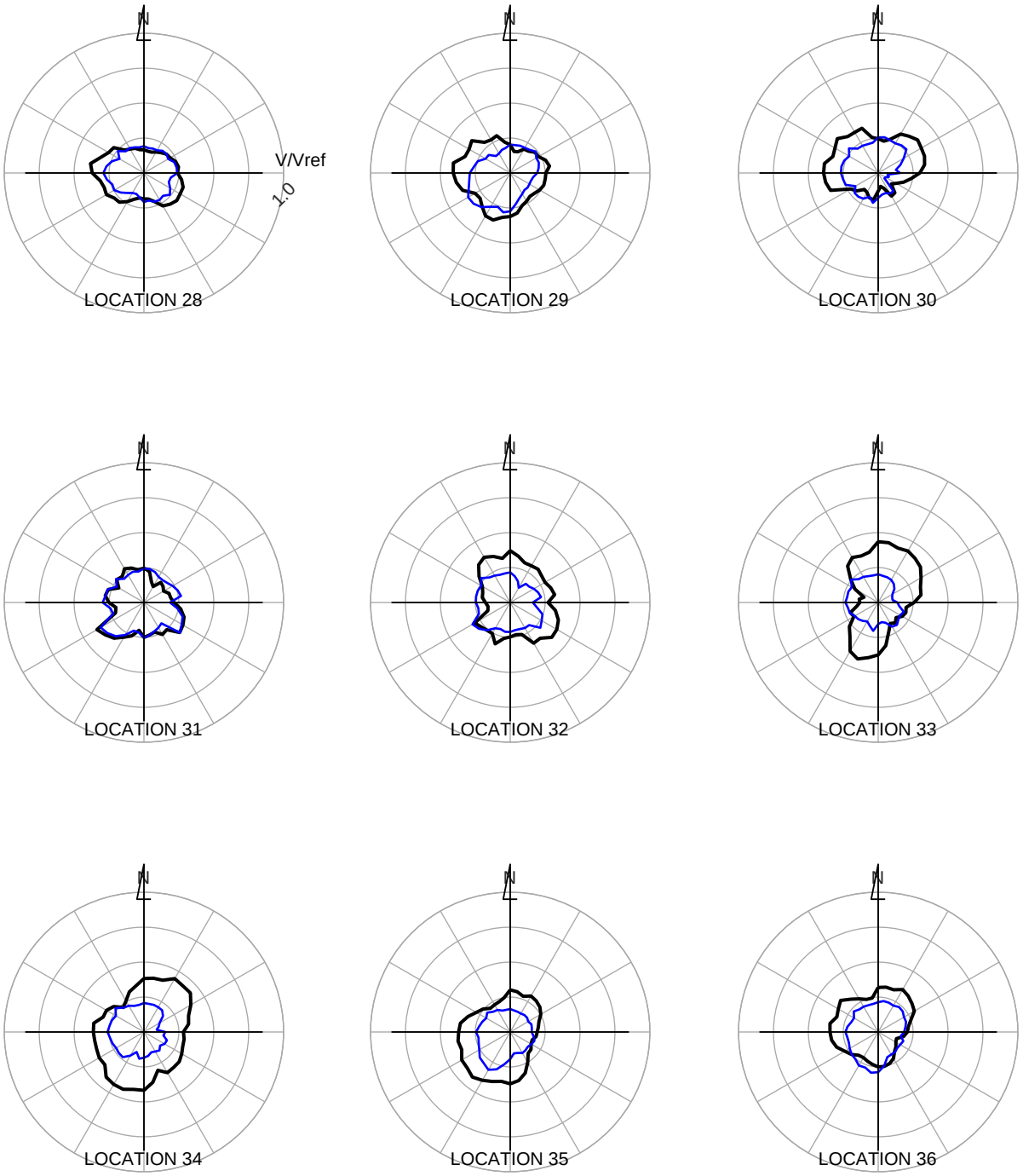
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



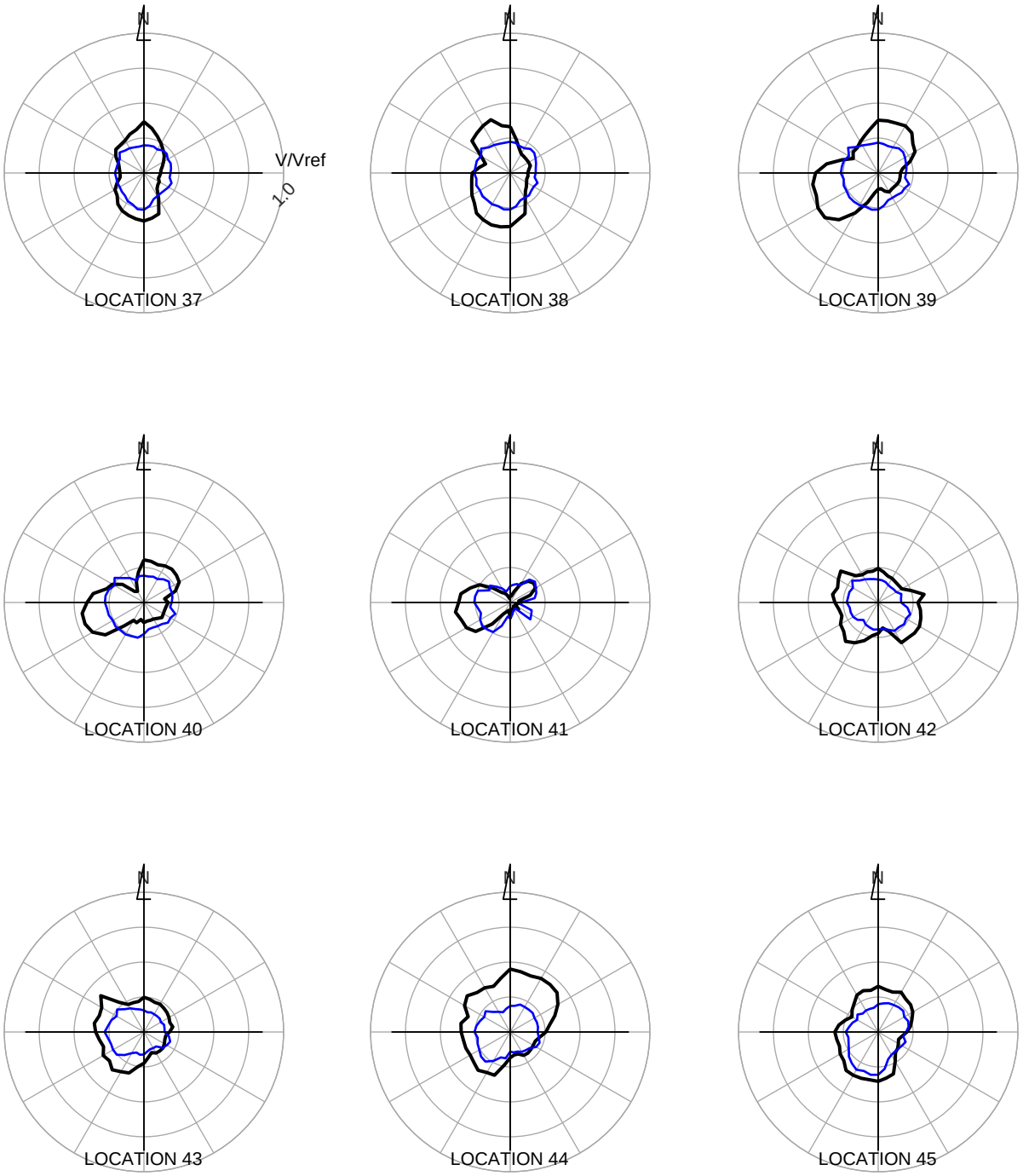
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



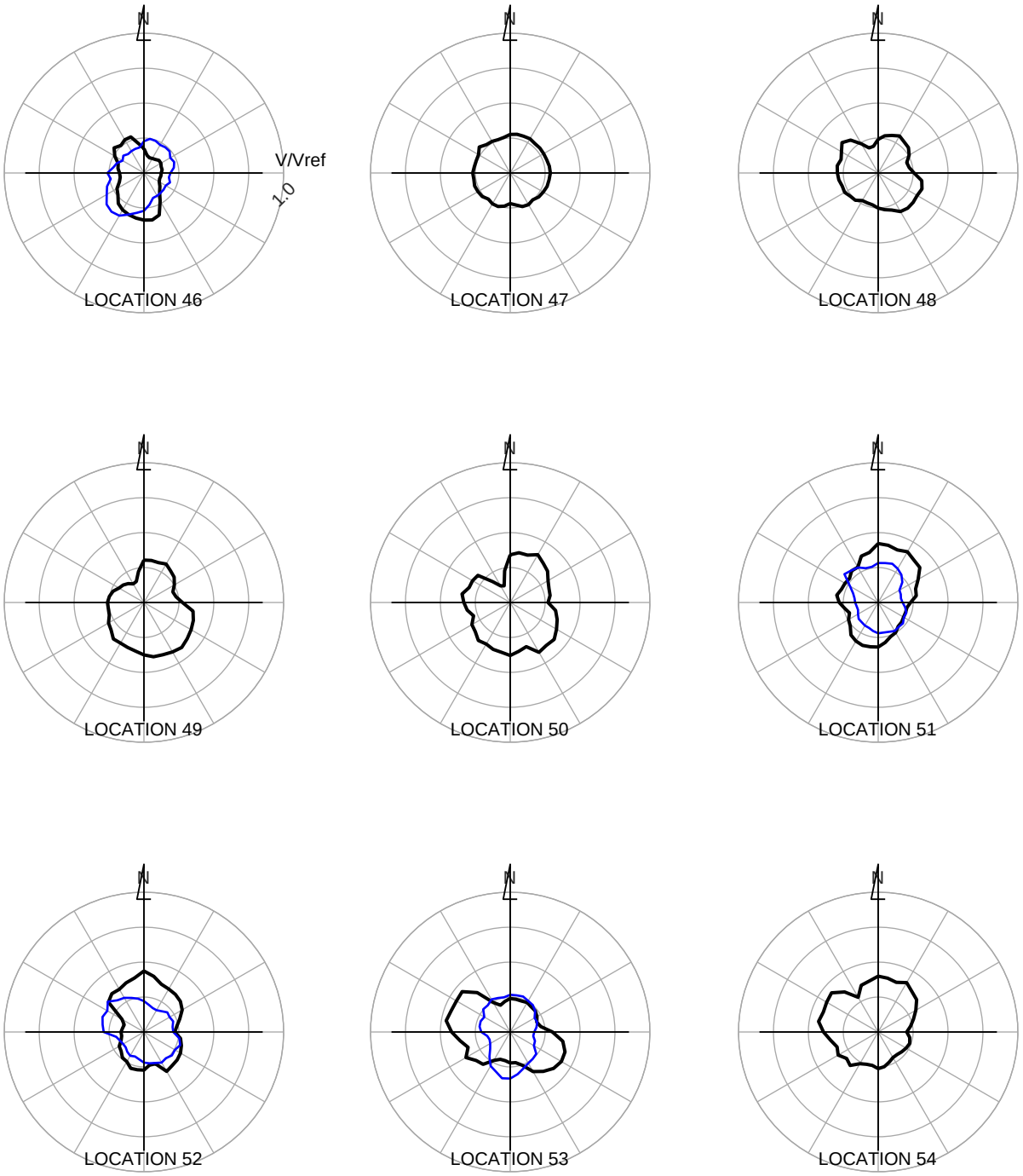
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



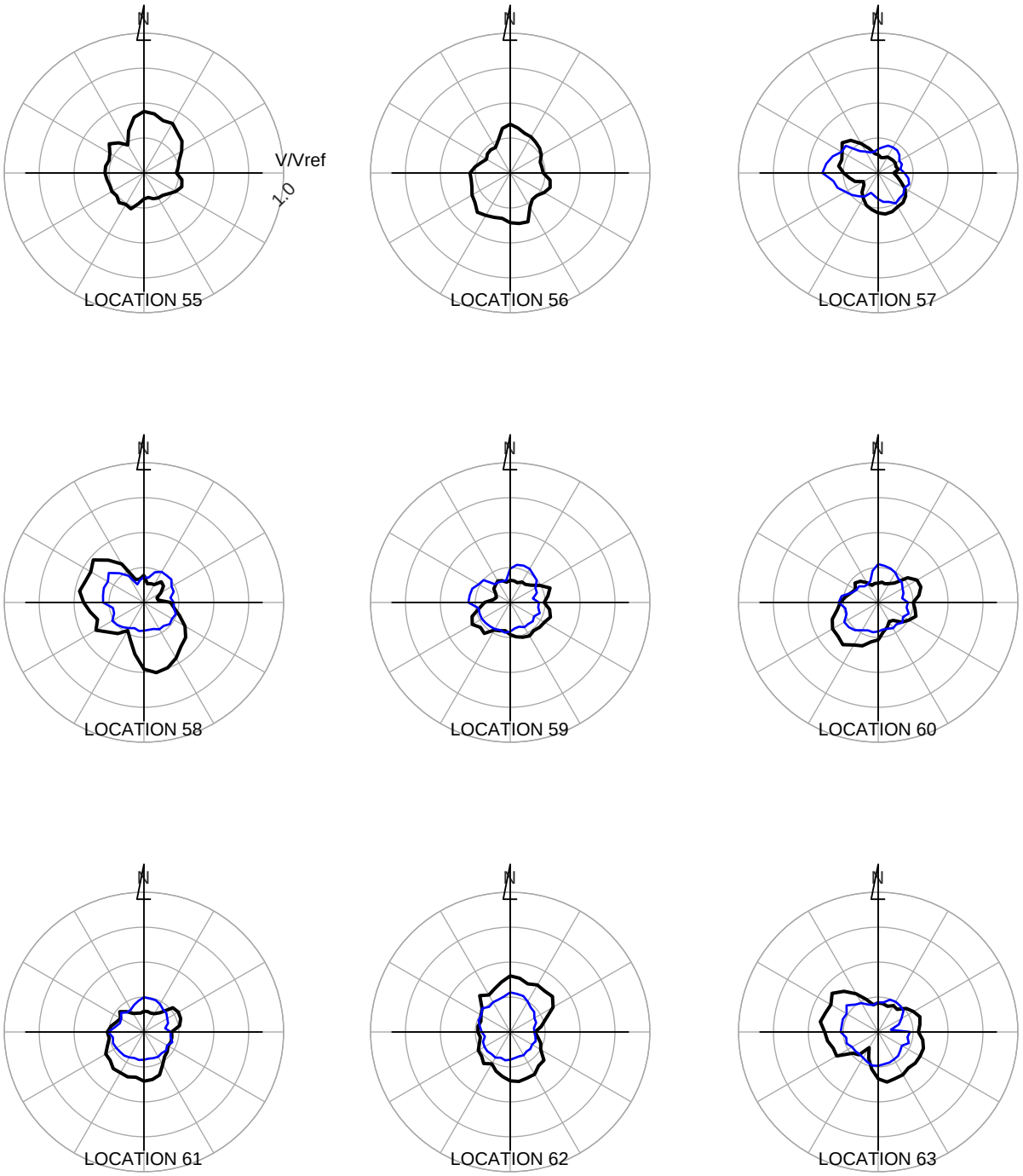
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



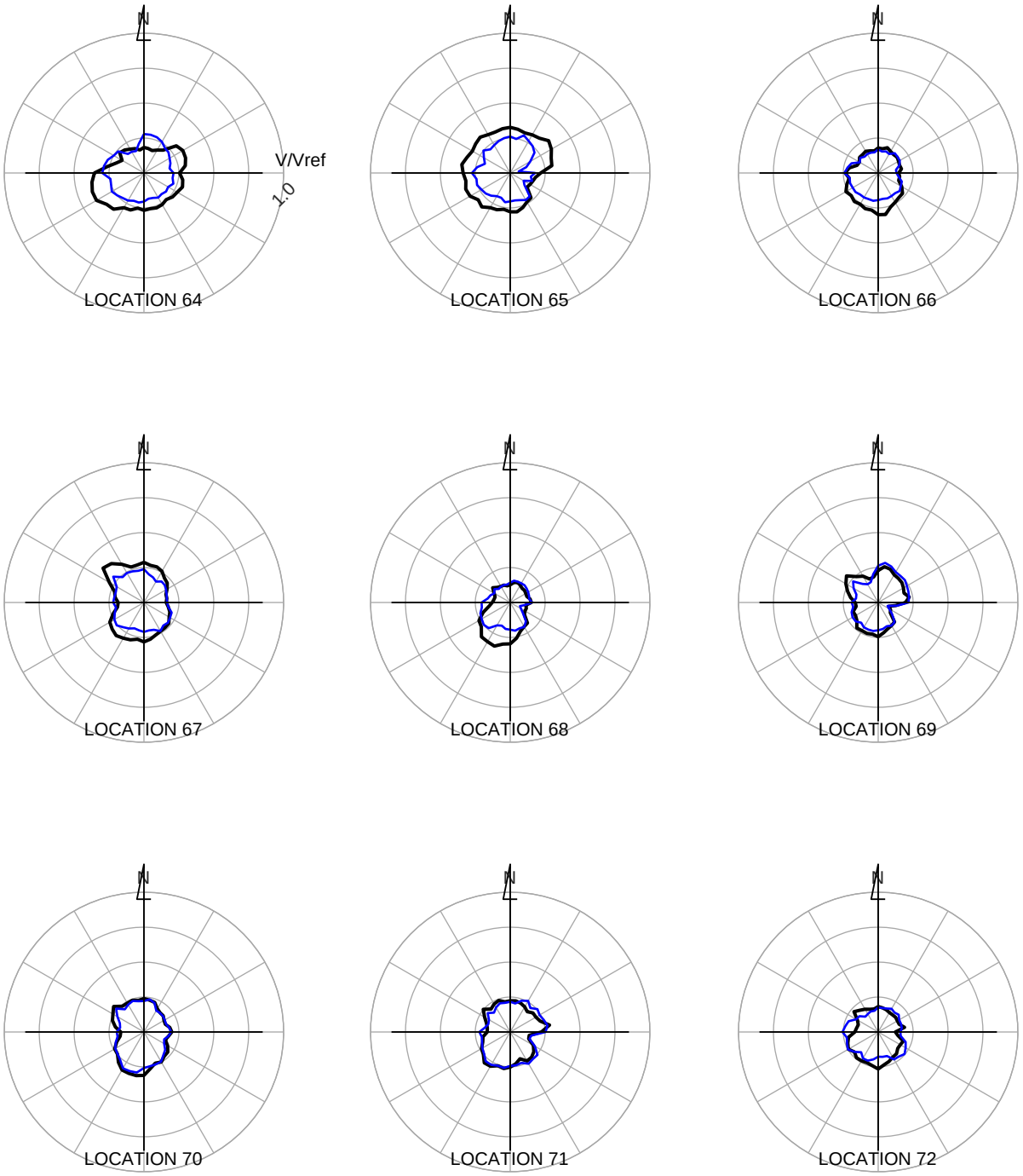
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



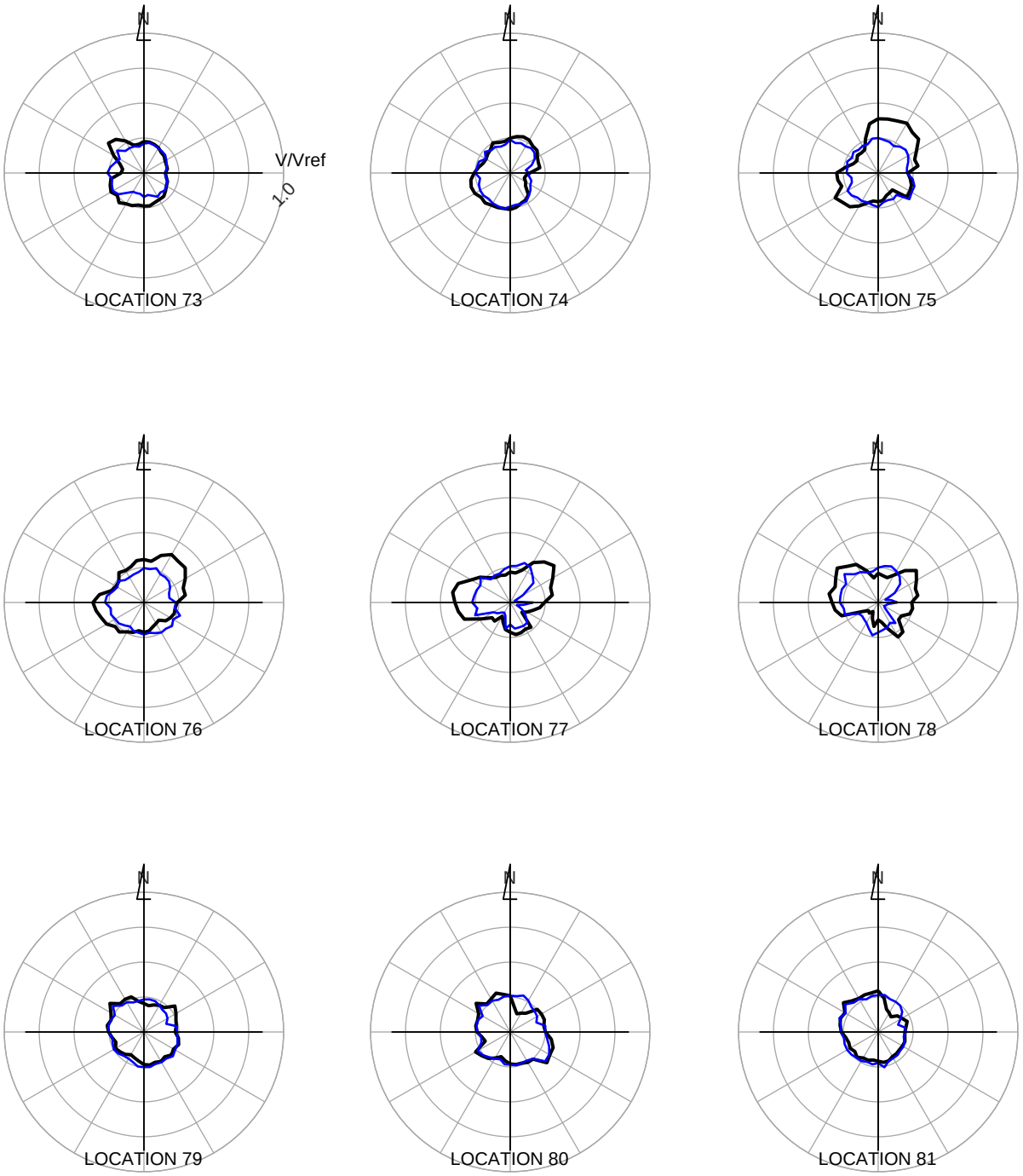
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



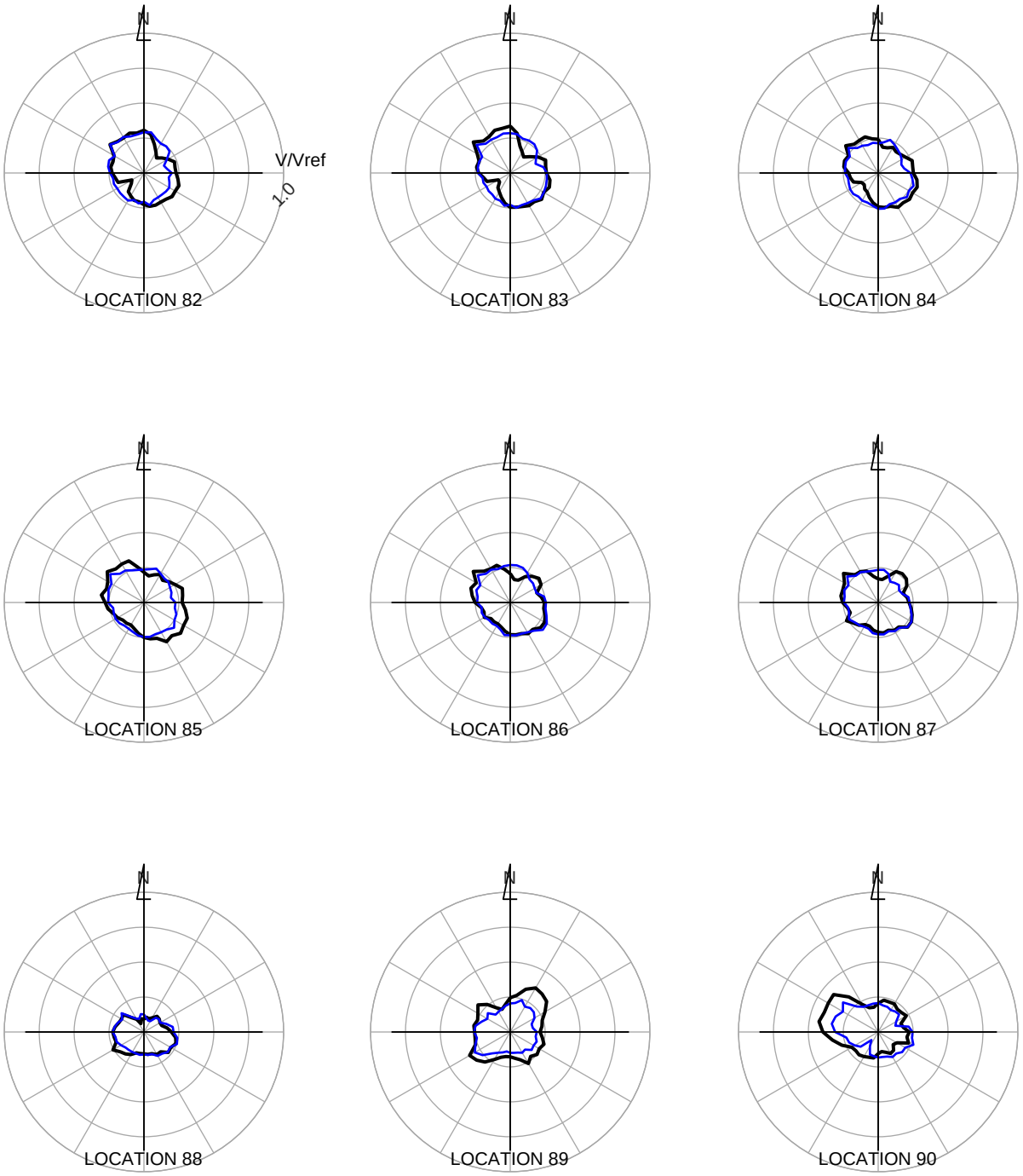
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



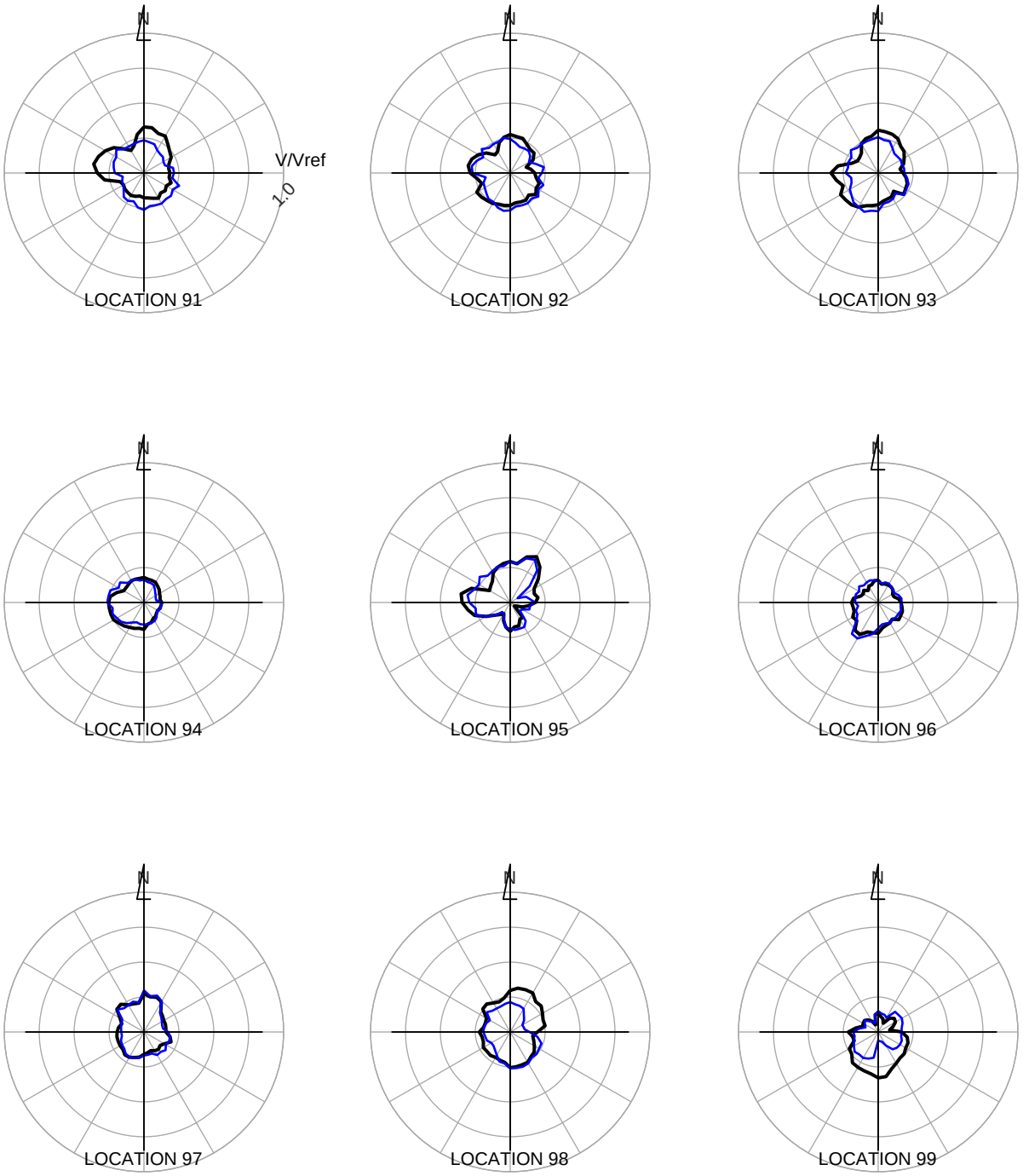
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



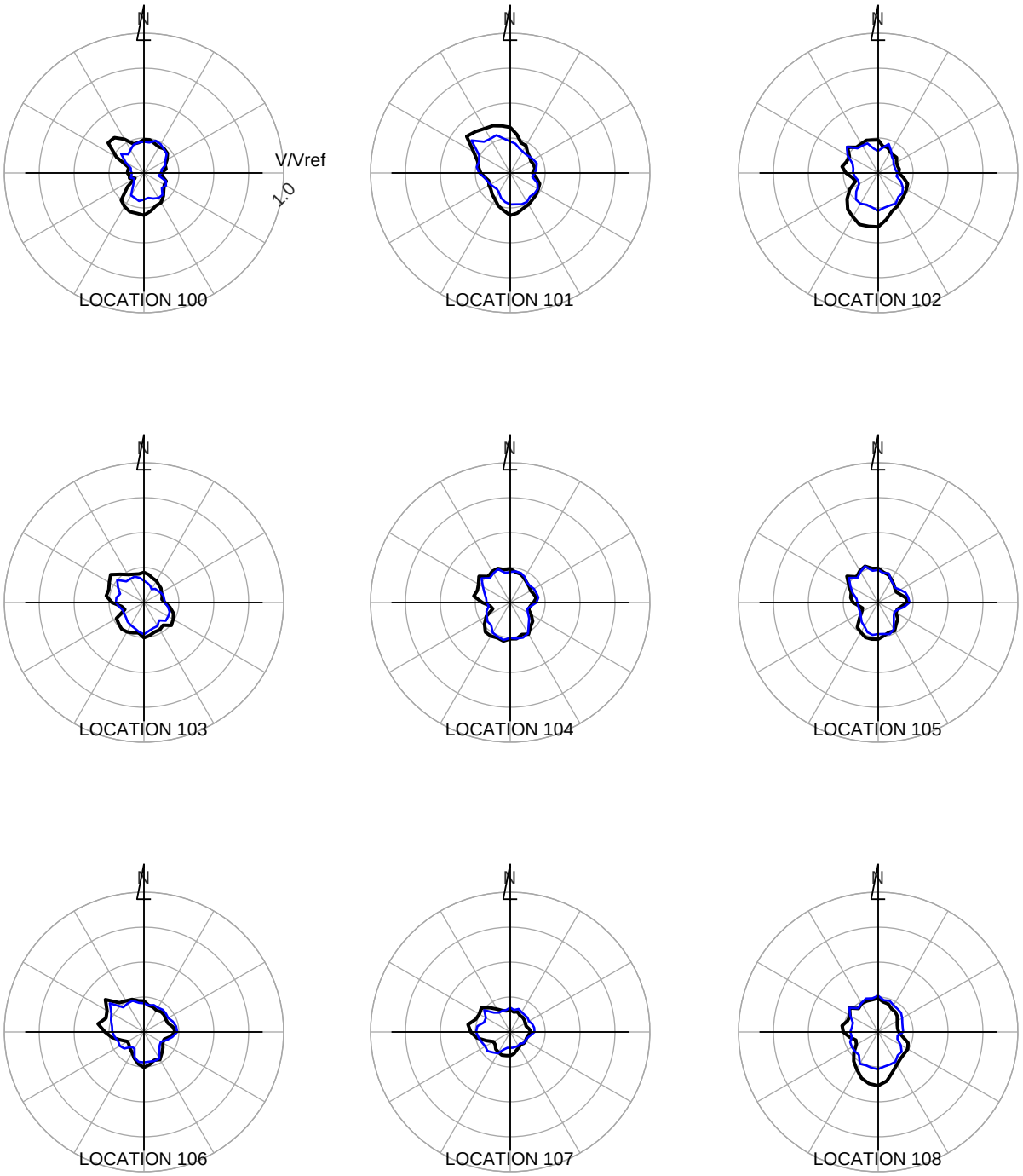
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



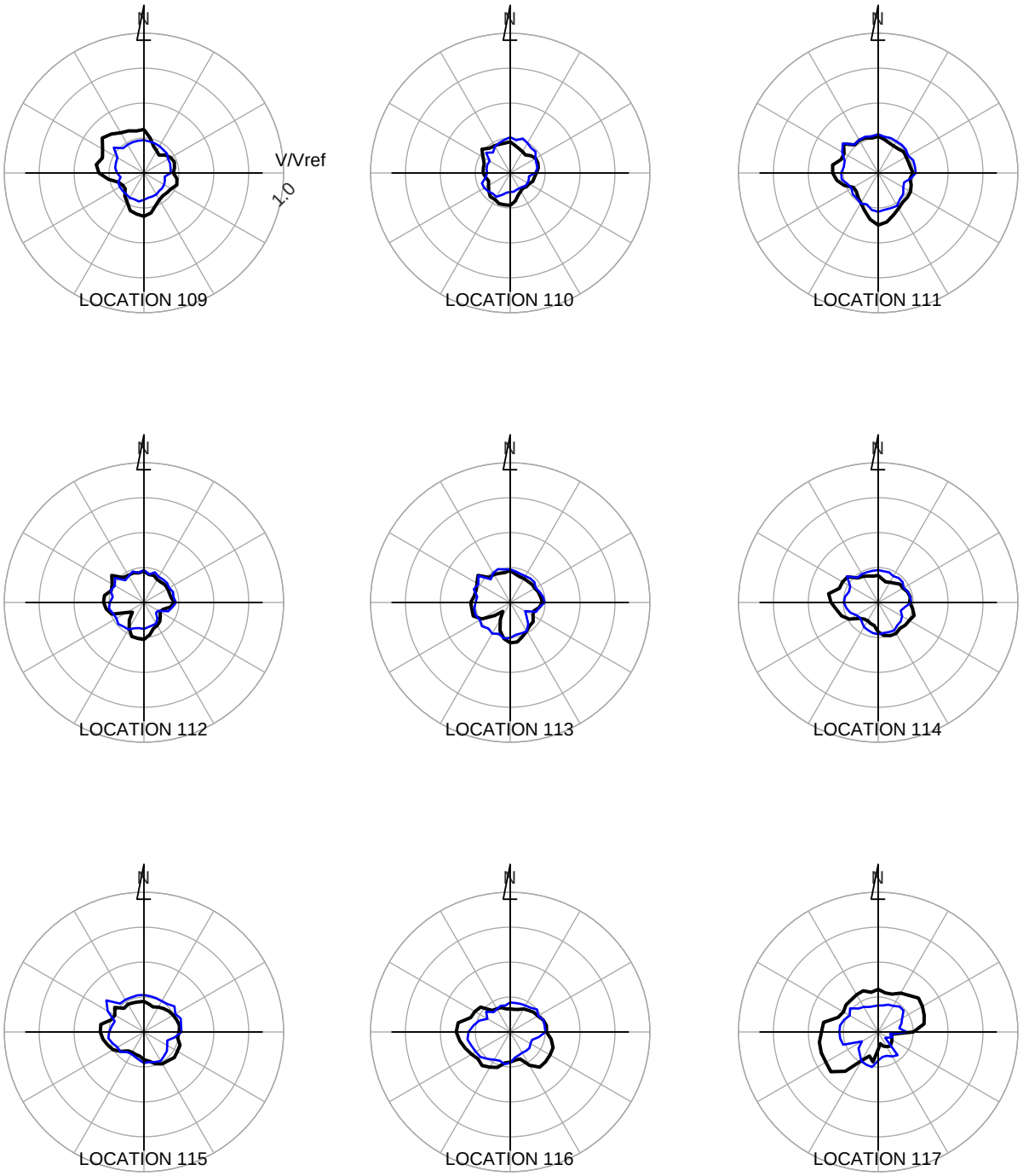
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



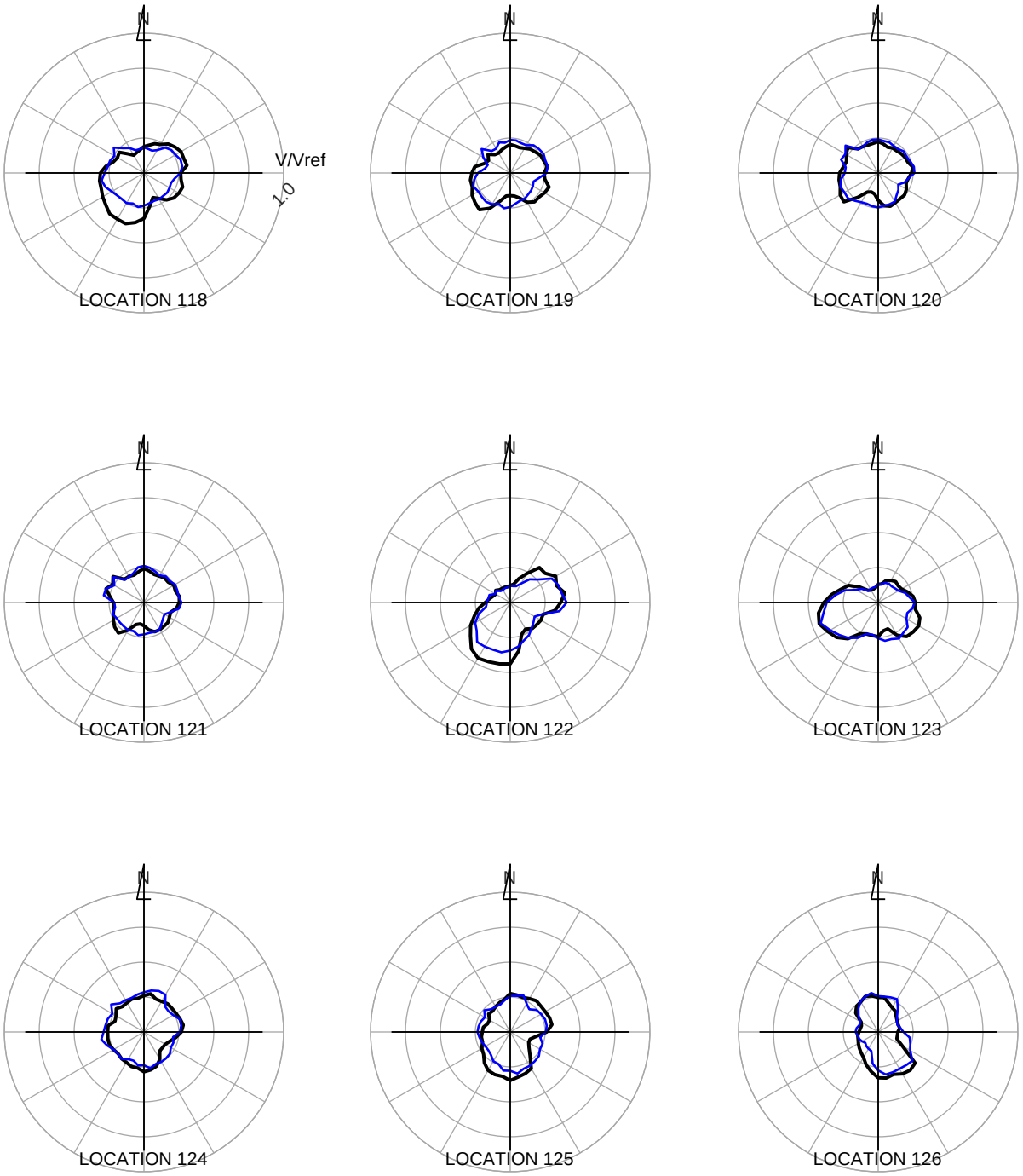
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



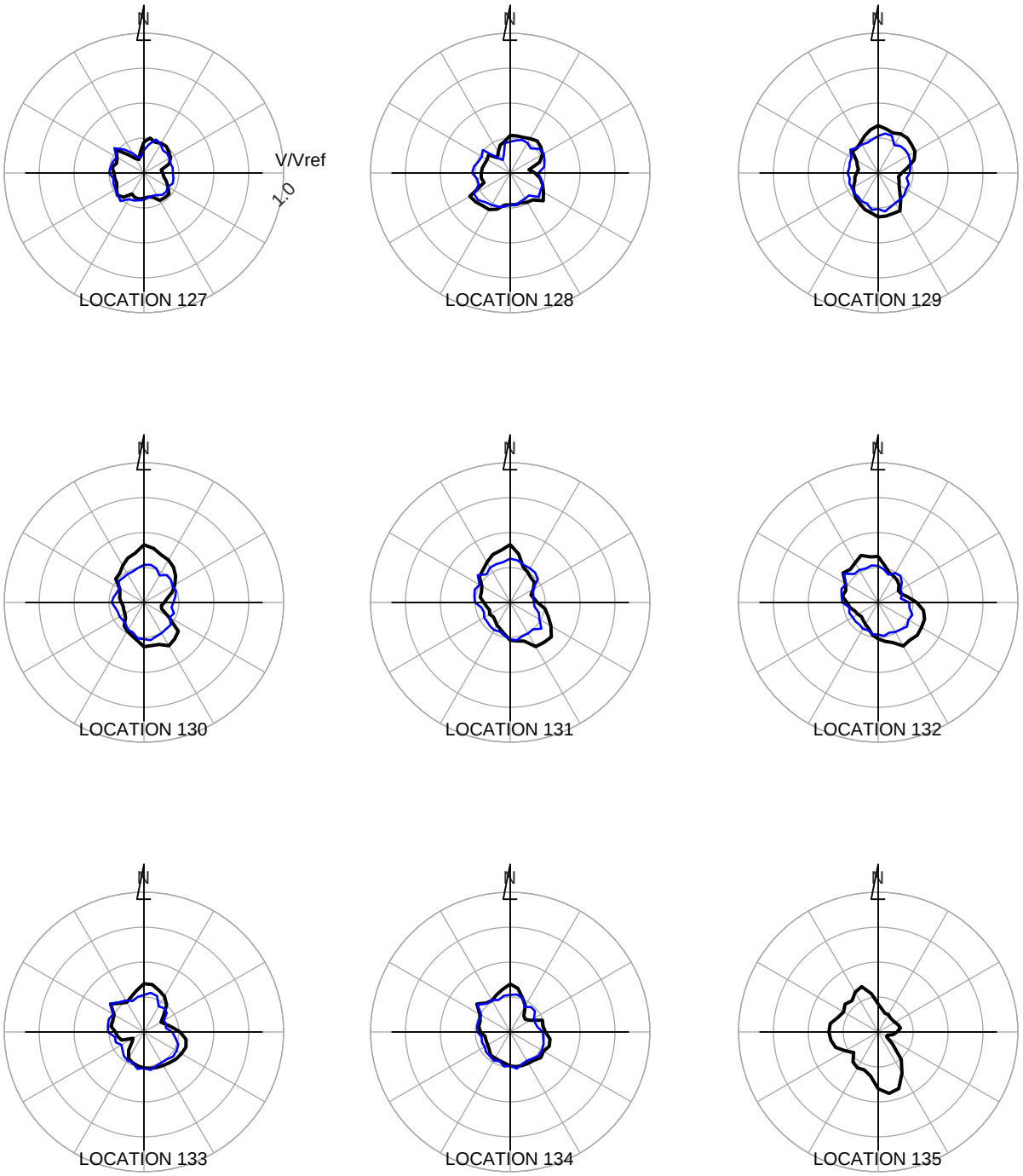
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

170 Columbia St W - Existing Configuration ColEcplz/GEMean



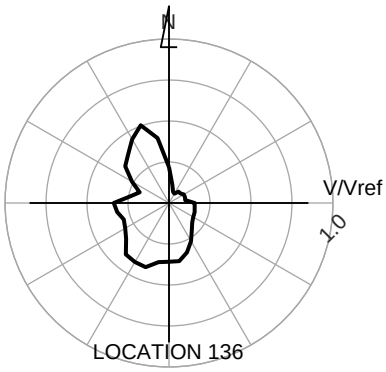
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

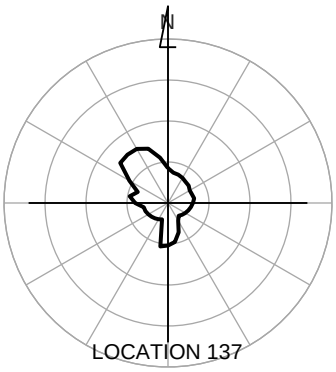
170 Columbia St W - Existing Configuration ColEcplz/GEMean

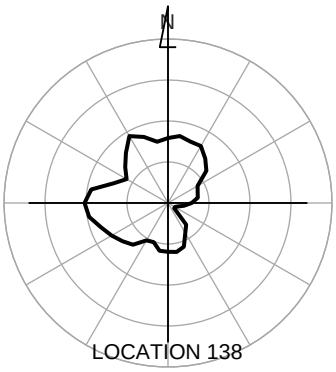


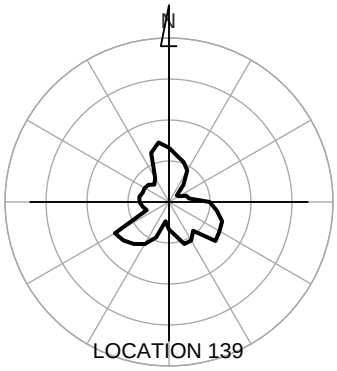
170 Columbia St W - Proposed Configuration ColPcplz/GEMean

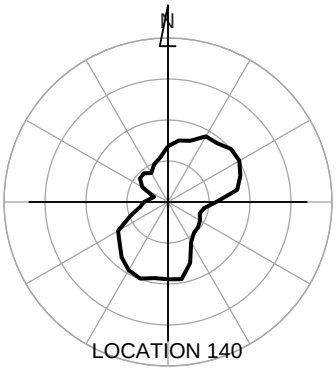
170 Columbia St W - Existing Configuration ColEcplz/GEMean

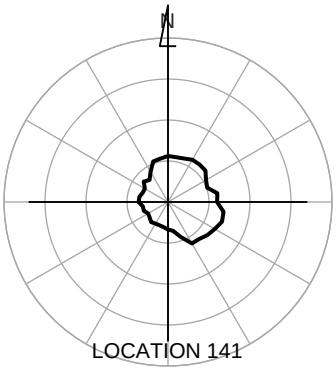


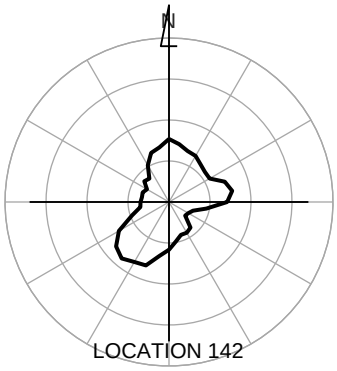


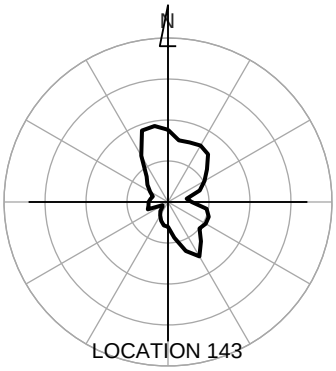


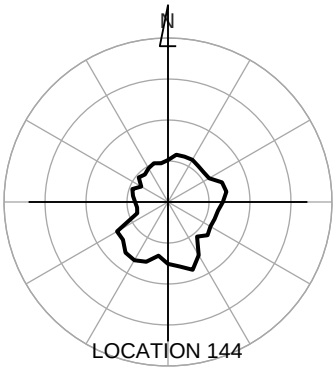












170 Columbia St W - Proposed Configuration ColPcplz/GEMean

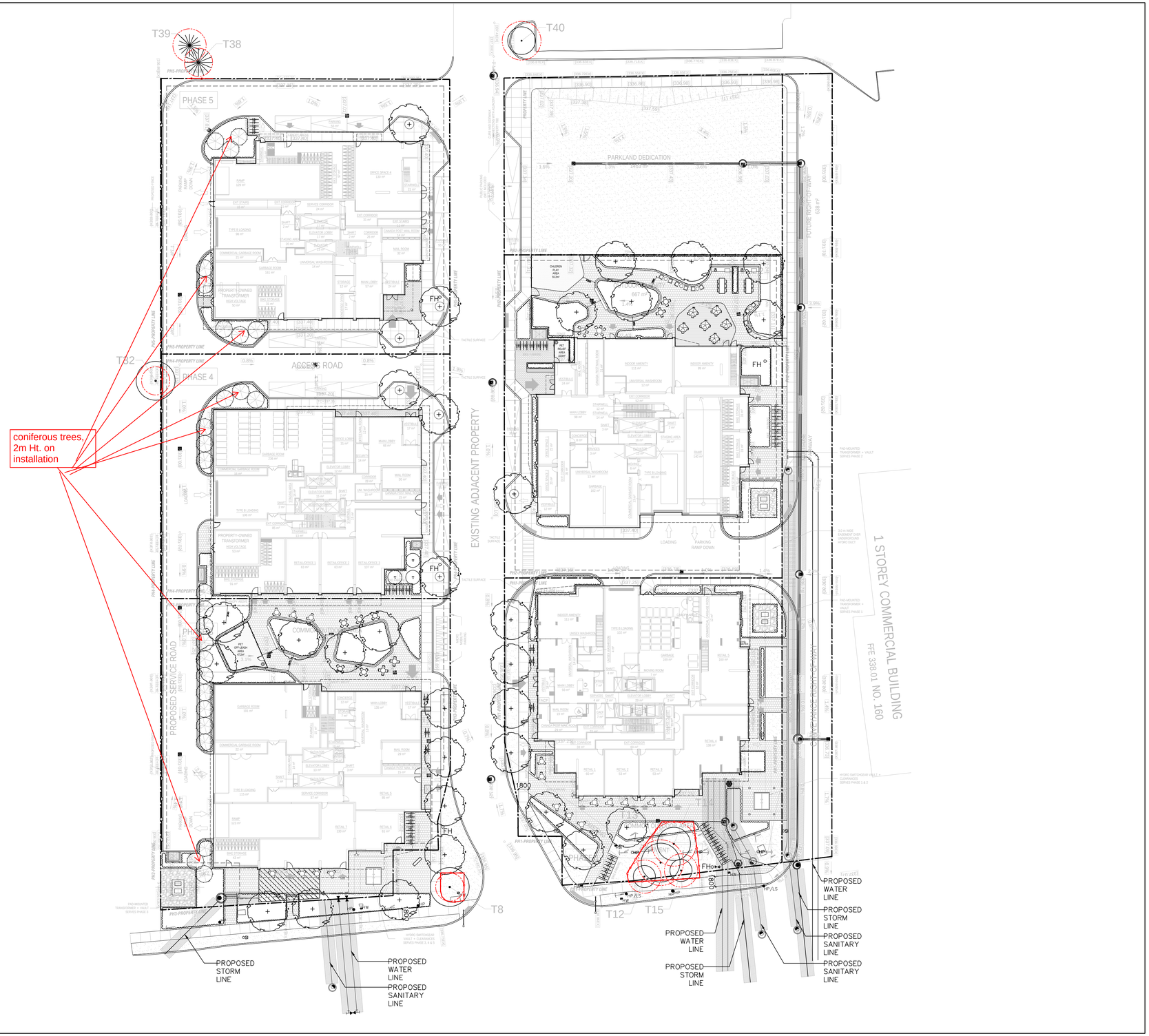
170 Columbia St W - Existing Configuration ColEcplz/GEMean

APPENDIX C

PROPOSED LANDSCAPING PLANS

Drawing includes:

1. Sheet RZL1 - Landscape Plan



1 RZL1 LANDSCAPE PLAN

1:350

GENERAL NOTES:

- ARCHITECTURAL INFORMATION PROVIDED BY: aaa architects
- SURVEY INFORMATION PROVIDED BY: WalterFedy
- EXISTING UTILITY INFORMATION PROVIDED BY WalterFedy
- GRADING INFORMATION PROVIDED BY: WalterFedy
- ALL LANDSCAPE FURNITURE SHOWN IS FOR DESIGN CONCEPT ONLY
- PROPOSED LIGHT LOCATION ON SITE SUBJECT TO PHOTOMETRIC STUDY
- ALL EXISTING MUNICIPAL SIGNAGE TO BE REINSTATED
- TREE LOCATIONS ON PUBLIC PROPERTY SUBJECT TO REVIEW AND APPROVAL BY UNDERGROUND UTILITY COMPANIES.
- ROOT DEFLECTOR TO BE USED WHERE ROOT BALL OF TREES ON PUBLIC PROPERTY ARE WITHIN 1.2m OF UNDERGROUND UTILITIES.
- PLANTING ON PRIVATE PROPERTY TO BE PROVIDED WITH A WATER EFFICIENT FULLY AUTOMATIC IRRIGATION SYSTEM USING STORMWATER HARVESTING. PLANTING WITHIN THE RIGHT OF WAY TO BE WATERED WITH A WATER EFFICIENT FULLY AUTOMATIC IRRIGATION SYSTEM
- ALL LIGHTING TO BE DARK SKY COMPLIANT
- GRATE POROSITY NOT TOO EXCEED 20x20mm OR 10x100mm

LEGEND

- HIGH BRANCHING, DECIDUOUS, SHADE TREES
- EXISTING TREES TO BE PRESERVED
- TREE PROTECTION HOARDING
- PROPOSED PLANTING
- PROPERTY LINE
- EXTENT OF UNDERGROUND BUILDING ABOVE
- CONCRETE PAVING/ SIDEWALK; SRI>29
- UNIT PAVING; SRI>29
- SOD
- TACTILE INDICATOR STRIP
- BIKE RINGS
- MOVEABLE TABLE AND CHAIRS
- FH — FIRE HYDRANT
- UNDERGROUND UTILITY OFFSET ZONE
- HP/LS — EXISTING HYDRO POLE WITH LIGHT STANDARD
- HW — EXISTING HANDWELL
- OSI — SIGN

0m 1m 5m 10m

N



Key Plan n.t.s.

Notes:

1. Do not scale the drawings.
2. The contractor shall check and verify all dimensions and conditions on the project and immediately report any discrepancies to the consultant before proceeding with the work.
3. The contractor is to be aware of all existing and proposed services and utilities. The contractor shall have all underground services and utility lines staked by each agency having jurisdiction prior to commencing work.

No.	Issued	YY-MM-DD
3.	Re-Issued for Rezoning	26-07-31
2.	Re-Issued for Rezoning	25-01-23
1.	Issued for Rezoning	25-04-17

This drawing is to be used for the following purpose: Not to be used for construction unless signed by the landscape architect.

Project: 170 Columbia Street West

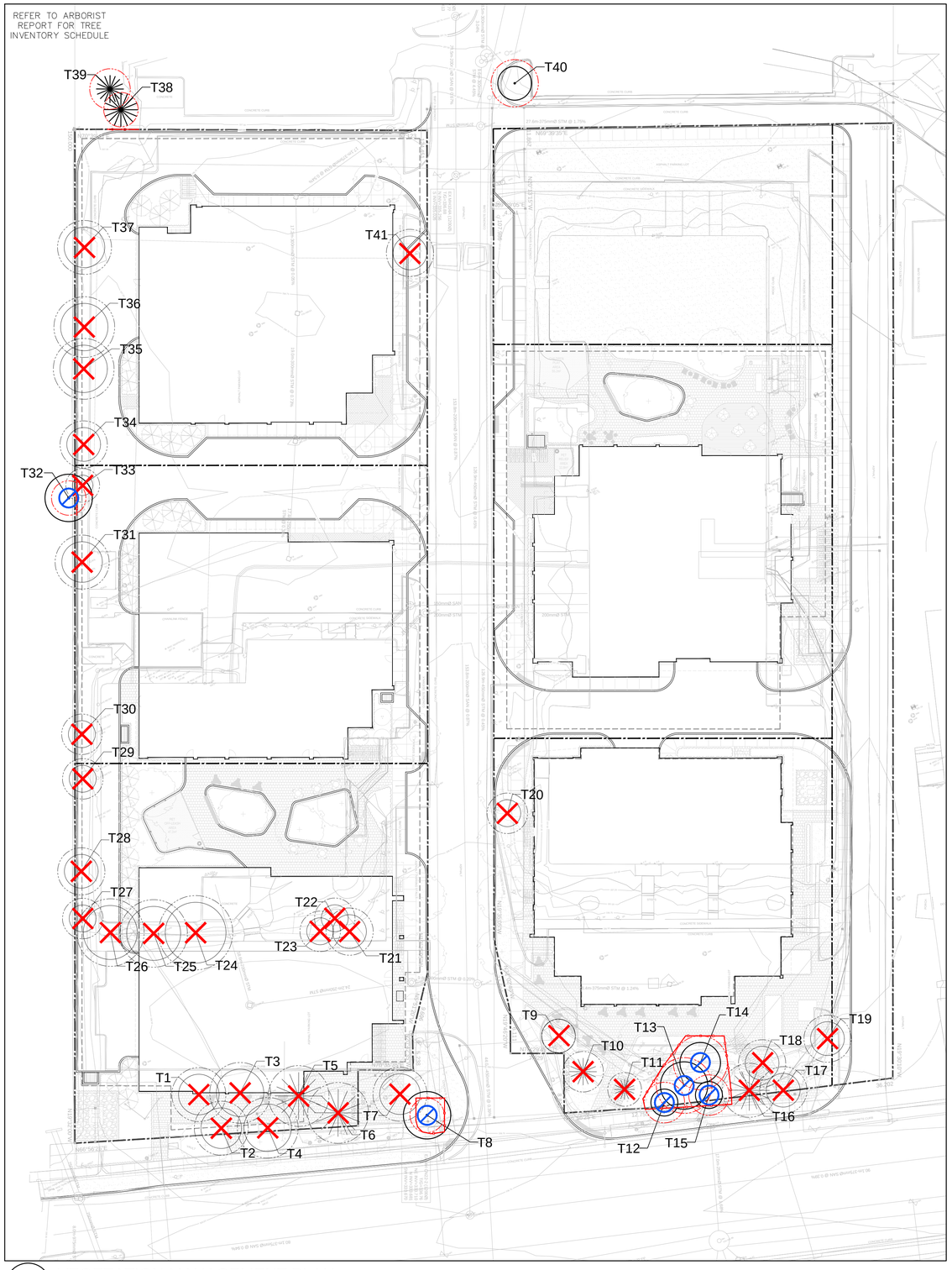
Prepared for: IN8 Developments

Location: 170 Columbia Street W Waterloo, Ontario

NAK DS Inc.
a Division of NAK Design Strategies
213 Sterling Road
Suite 211
Toronto, Ontario
M6R 2B2

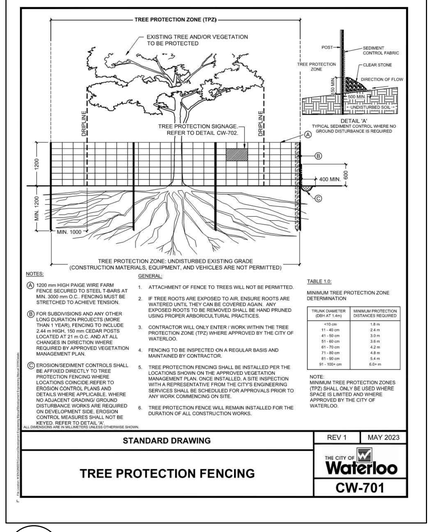
Drawing Title: LANDSCAPE PLAN

Date: March 2025
Scale: As Shown
Drawn: AG
Checked: PDF
Project No: 2740
Drawing No: RZL1

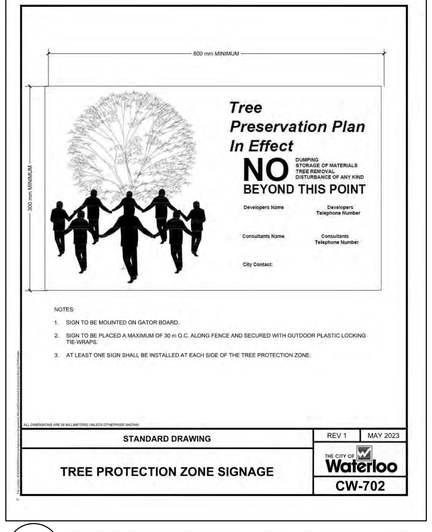


1 VMP1 VEGETATION MANAGEMENT PLAN 1:350

1. All existing vegetation located on site, and on adjacent properties within 6m of the property line (both private and public) have been identified on the VMP.
2. The Location of all trees and property boundaries have been accurately located/represented on this plan. Tree ownership determination has been based on accurate tree locations, field review and property boundary information.
3. No vegetation removals may occur from the site until the issuance of the building permit. Where no building permit is required, tree removals may not occur until the time of final site plan approval (inclusive of engineering approvals).
4. All tree clearing shall be in accordance with the federal Migratory Birds Convention Act, 1994, and the provincial Endangered Species Act, 2007. Clearing activities shall be completed in accordance with all recommended bird nesting windows and the protection of Species at Risk habitat.
5. Tree Protection Fencing (TPF) shall be certified by the Consultant to be in compliance with the approved Vegetation Management Plan. Upon receipt of TPF certification and a satisfactory site inspection by an Engineering Services Landscape Representative, final approval shall be granted by City Staff prior to the commencement of any work or vegetation removals.
6. Tree preservation fence will remain installed for the duration of construction.
7. Any trees identified to be preserved that are impacted by development (further to the approved VMP plan) will be replaced with the same species or an approved alternate, to the satisfaction of the City of Waterloo, at a minimum of 70 mm caliper size for deciduous trees and a minimum 250 cm height for coniferous trees.
8. Any root and branch pruning of existing vegetation to be preserved on site shall be in conformance with current ANSI A300 Standards.
9. Every effort to preserve and protect vegetation located on adjacent properties will be undertaken during construction/site works
10. Approvals as granted by the City of Waterloo through the Site Plan approval process do not supersede any civil or common law property rights. It is the applicant/Owner's responsibility to:
a. determine ownership and coordinate and obtain approvals of:
i. Any removal of a shared boundary tree or tree located on adjacent property;
ii. Any injury to a shared boundary tree or tree located on adjacent property;
iii. Encroachment and access requirements;
b. resolve any property disputes;
c. and ensure compliance with all applicable laws.
11. Where impact/injury to preserved shared boundary trees or trees on adjacent properties has been identified the applicant agrees to provide an assessment of the impact to the long-term health of each tree, to be prepared by a qualified expert (i.e. Certified Arborist).
12. The City recommends that the Owner obtain written owner acknowledgement and approval of the required work and potential impacts where potential injury has been identified within the TPZ.
13. All trees located on shared property boundaries or on adjacent properties that are proposed to be removed (as identified on this plan or in the accompanying arborist report) will have Owner approval documented through a signed Letter of Understanding for each property to be provided prior to Site Plan Approval.



2 VMP1 TREE PROTECTION FENCING



3 VMP1 TREE PROTECTION ZONE SIGNAGE

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LEGEND

- T1 / T10 — TREE HOARDING PROTECTION; EXISTING TREES TO BE RETAINED
- TREES TO BE PRESERVED WITH IMPACT
- TREES TO BE REMOVED
- PROPERTY LINE
- PROPOSED BUILDING
- CURB
- EXTENT OF UNDERGROUND GARAGE



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Project: 170 Columbia Street West

Prepared for: IN8 Developments

Location: 170 Columbia Street W
Waterloo, Ontario

NAK DS Inc.
a Division of NAK Design Strategies
213 Sterling Road
Suite 211
Toronto, Ontario
M6R 2B2

ASSOCIATION OF LANDSCAPE DESIGNERS ONTARIO — SILVANO TARDELLI — MEMBER — OALA

Drawing Title: VEGETATION MANAGEMENT PLAN

0m 1m 5m 10m

Date: March 2025
Scale: As Shown
Drawn: AG
Checked: PDF
Project No: 2740
Drawing No: VMP1