THEAKSTON ENVIRONMENTAL

Consulting Engineers • Environmental Control Specialists

REPORT

PRELIMINARY PEDESTRIAN LEVEL WIND STUDY

91 Eglinton Ave, 131 Eglinton Ave, 5055 Hurontario Street

Mississauga, Ontario

91 Eglinton Limited Partnership

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1. CONCLUSIONS AND RECOMMENDATIONS

The Residential Development proposed by 91 Eglinton Limited Partnership for the property municipally known as 91 Eglinton Ave, 131 Eglinton Ave, and 5055 Hurontario Street, in the City of Mississauga, has been assessed for environmental standards with regard to pedestrian level wind relative to comfort and safety. The pedestrian level wind and gust velocities predicted for the locations tested are within the safety criteria and most are within the comfort criteria described within the following report.

The Development involves a proposal to construct 37, 35, 25, 35, 19, and 24 storey buildings denoted Towers 1 to 6 respectively, as well as 2 Townhouse Blocks. The proposed towers include multilevel podiums and/or stepped wings of various heights with outdoor Amenity spaces atop the podiums and at-grade Public Parks at the northeast of the site. The proposed Development's residential entrances and vehicular drop-offs are accessed via Eglinton Avenue East, a future extension of Thornwood Drive, as well as private driveways dissecting the proposed Development site.

The Development is, for all intents and purposes, surrounded to prevailing windward directions by an urban/suburban mix of institutional, residential and commercial development, related open areas, and mature vegetation. These buildings and related open areas have a sympathetic relationship with the pending wind climate.

Urban development provides turbulence inducing surface roughness that can be wind friendly, while open settings afford wind the opportunity to accelerate as the wind's boundary layer profile thickens at the pedestrian level, owing to lack of surface roughness. High-rise buildings typically exacerbate wind conditions within their immediate vicinity, to varying degrees, by redirecting wind currents to the ground level and along streets and open areas. Transition zones from open to urban, and to a lesser degree suburban, settings may prove problematic, as winds exacerbated by the relatively more open settings are redirected to flow over, around, and between urban buildings.

These phenomena were observed at the site with prevailing winds that have opportunity to accelerate over the relatively open lands associated with Eglinton Avenue East, Hurontario Street, and green fields. This open setting, along with the rural, open setting of the site and relatively open lands accommodating large single storey retail buildings, and related parking, cumulatively account for the moderately windy conditions observed in the existing setting on and about the Development site. With inclusion of the proposed Development, winds that formerly flowed over the existing lands are redirected, tending to split with portions flowing over, around and down the proposed buildings' façades. At the pedestrian level, the winds redirect to travel horizontally along the buildings, around the corners and beyond, creating minor windswept areas and, on occasion, uncomfortable conditions at or near the buildings' corners and in the gaps between the buildings, and these conditions are primarily attributable to the setting, whereby the proposed Development penetrates winds that formerly flowed over the existing lands.

These phenomena result in:

- localised improvements to wind conditions along **Eglinton Avenue East**,
- similar conditions to the existing setting along the **future extension of Thornwood Drive** with minor changes to localised areas with winds from specific directions,
- conditions along the **Private Driveway** connecting with Armdale Road and the future extension of Thornwood Drive that are suitable for the intended use, most of the time,
- conditions along the **Internal Pedestrian Walkways and Public Parks** that are suitable for the intended use,
- pedestrian comfort conditions at the **Main Entrances,** that are appropriate to the intended purpose, with the exception of the northeastern Lobby Entrance to Tower 6 as well as the Main Lobby Entrance to Tower 1, that will require mitigation,
- seasonally appropriate comfort conditions at the proposed **Rooftop Amenity Spaces**, with incorporation of the recommended wind mitigation plan.

Comfort conditions expected at the proposed Development site are considered acceptable to the urban context. Mitigative features were incorporated into the proposed Development including setbacks, stepped facades, stepped podiums, parapet walls, overhangs, canopies, balconies, plantings, and others, resulting in appropriate conditions about the site. A mitigation plan is recommended for the above-mentioned entrances and Rooftop Amenity Spaces, and will be further refined at the Site Plan Approval stage. The ultimate plan will be developed in consultation, will respect wind conditions acting on the individual spaces, and incorporate mitigative design features that will result in comfort conditions appropriate to the areas' intended purpose.

Respectfully submitted,

Stephen Pollock, P. Eng. Paul Kankainen, M.A.Sc.

2. INTRODUCTION

Theakston Environmental Consulting Engineers, Fergus, Ontario, were retained by 91 Eglinton Limited Partnership to study the pedestrian level wind environment for their proposed Residential Development occupying a portion of a block of lands situated to the southeast of the future Armdale Road, northwest of Eglinton Avenue East, and northeast of Hurontario Street. The Development will be located in the City of Mississauga, with the site as depicted on the Aerial Photo in Figure 2a. The Development involves a proposal to construct 6 towers, including multilevel podiums and/or stepped wings of various heights, as well as 2 townhouse blocks in the configuration shown in Figure 2b.

Mark Liddy, P. Eng., 91 Eglinton Limited Partnership, initiated the request, and Dialog Design provided drawings. The co-operation and interest of the Client and their sponsors in all aspects of this study is gratefully acknowledged.

The specific objective of the study is to determine areas of higher than normal wind velocities induced by the shape and orientation of the proposed buildings and surroundings. The wind velocities are rated in accordance with the safety and comfort of pedestrians, notably at entrances to the buildings, sidewalks, courtyards on the property, as well as other buildings in the immediate vicinity.

In order to obtain an objective analysis of the wind conditions for the property, the wind environment was tested in two configurations. The existing configuration included existing and proposed buildings in the surrounding area. The proposed configuration included the Development's subject buildings. Mitigation procedures were assessed during these tests to determine their impact on the various wind conditions.

The laboratory techniques used in this study are established procedures that have been developed specifically for analyses of this kind. The methodology, summarized herein, describes criteria used in the determination of pedestrian level wind conditions. The facilities used by Theakston are ideal for observance of the Development at various stages of testing, and the development of wind mitigation measures, if necessary.

3. OBJECTIVES OF THE STUDY

1. To quantitatively assess, by model analyses, the pedestrian level wind environment under existing conditions and future conditions with the Development in accordance with the City of Mississauga's Terms of Reference.

2. To assess mitigative solutions.

3. To publish a Consultant's report documenting the findings and recommendations.

4. METHOD OF STUDY

4.1 General

The Theakston Environmental wind engineering facility was developed for the study of, among other sciences, the pedestrian level wind environment occurring around buildings, with focus on the safety and comfort of pedestrians. To this end, physical scale models of proposed Development sites, and immediate surroundings, are built, instrumented and tested at the facility with resulting wind speeds measured for different wind directions at various locations likely to be frequented by pedestrians. This quantitative analysis provides predictions of wind speeds for various probabilities of occurrence and for various percentages of time that are ultimately weighted relative to a historical range of wind conditions, and provided to the client.

The techniques applied to wind and other studies carried out at the facility, utilise a boundary layer wind tunnel and/or water flume (Figure 1). The testing facility has been developed for these kinds of environmental studies, and has been adapted with equipment, testing procedures and protocols, in order to provide results comparable to full scale. The Boundary Layer Wind Tunnel lends itself well to the simultaneous acquisition of large data streams while the water flume is excellent for flow visualisation.

The purpose of this Pedestrian Level Wind Study is to evaluate the pedestrian level wind speeds for a full range of wind directions. To accomplish this, the wind's mean speed boundary layer profiles are simulated and applied to a site-specific model under test, instrumented with differential pressure probes at locations of interest. During testing, pressure readings are taken over a one-hour model scale period of time, at a full-scale height of approximately 1.8m and correlated to mean and gust wind speeds, expressed as ratios of the gradient wind speed.

The mean and gust wind speeds at the forty-four (44) points tested were subsequently combined with the design probability distribution of gradient wind speed and direction, (wind statistics) recorded at Airports in the vicinity, to provide predictions of the full-scale pedestrian level wind environment. Predictions of the full-scale pedestrian level wind environment are presented as the wind speed exceeded 20% of the time, based on annual, and wind for the seasons in Figures 6a – 6e. Criterion employed by Theakston Environmental was developed by others and us and published in the attached references. The methodology has been applied to over 800 projects on this continent and abroad.

4.2 Meteorological Data

The wind climate for the Mississauga region that was used in the analysis was based on historical records of wind speed and direction measured at Pearson International Airport for the period between 1980 and 2017. The meteorological data includes hourly wind records and annual extremes. The analysis of the hourly wind records provides information to develop the statistical climate model of wind speed and direction. From this model, predicted wind speeds regardless of wind direction for various return periods can be derived. The record of annual extremes was also used to predict wind speeds at various return periods. Based on the analysis of the hourly records, the predicted hourly-mean wind speed measured at 10*m* above grade, corrected for a standard open exposure definition, is 25*m/s* for a return period of 50 years.

4.3 Statistical Wind Climate Model

For the analysis of the data, the wind climate model is converted to a reference height of 500*m* using a standard open exposure wind profile. The mean-hourly wind speed at a 500*m* reference height used for this study is 45.6*m/s* for a return period of 50 years. The corresponding 1-year return period wind speed at the 500*m* height is 36*m/s*.

The design probability distribution of mean-hourly wind speed and wind direction at reference height is shown for Pearson International Airport in Figure 5. Both annual and seasonal distributions are shown. From this it is apparent that winds can occur from any direction, however, historical data indicates the directional characteristics of strong winds are north through west to southwest and said winds are most likely to occur during the winter, spring and fall seasons.

4.4 Wind Simulation

To simulate the correct macroclimate, the upstream flow passes over conditioning features placed upstream of the model, essentially strakes and an appropriately roughened surface, as required to simulate the full-scale mean speed boundary layer approach flow profiles occurring at the site.

4.5 Pedestrian Level Wind Velocity Study

A physical model of the proposed Development and pertinent surroundings, including existing buildings, roadways, pathways, terrain and other features, was constructed to a scale of 1:500. The model is based upon information gathered during a site visit to the proposed Development site, and surrounding area. Dialog Design provided architectural drawings. City of Mississauga aerial photographs were also used in development of the model to ensure the model reasonably represents conditions at the proposed Development. The model is constructed on a circular base so that, by rotation, any range of wind directions can be assessed. Structures and features that are deemed to have an impact on the wind flows are included upwind of the scale model.

In these studies, the effects of wind were analysed using omni-directional wind velocity probes that are placed on the model and located at the usual positions of pedestrian activity. The probes measure both mean and fluctuating wind speeds at a height of approximately 1.8m. During testing, the model sample period is selected to represent 1hr of sampling time at full scale. The velocities measured by the probes are recorded by a computerized data acquisition system and combined with historical meteorological data via a post-processing program.

4.6 Pedestrian Comfort Criteria

The assignment of pedestrian comfort takes into consideration pedestrian safety and comfort attributable to mean and gust wind speeds. Gusts have a significant bearing on safety, as they can affect a person's balance, while winds flowing at or near mean velocities have a greater influence upon comfort.

Figure 6 presents results for the mean wind speed that is exceeded 20% of the time. These speeds are directly related to the pedestrian comfort at a particular point. The overall comfort rating, for existing and proposed, are depicted in Figure 7. Table 1, below, summarizes the comfort criteria used in the presentation of the results depicted in Figures 6 and 7.

Table 1: Comfort Criteria

ACTIVITY	Gust Equivalent Mean Speed Exceeded 20% of the Time		Description
COMFORT	***km/h***	***m/s*** (used in Fig. 6)	
Sitting	0-10	0-2.8	Calm or light breezes desired for outdoor restaurants and seating areas where one can read a paper without having it blown away.
Standing	0-15	0-4.2	Gentle breezes suitable for main building entrances and bus stops.
Walking	0-20	0-5.6	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering.
Uncomfortable	>20	>5.6	Strong winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended.

The activities are described as suitable for Sitting, Standing, Walking, or Uncomfortable, depending on average wind speed exceeded 20% of the time. For a point to be rated as suitable for Sitting, for example, the wind conditions must not exceed 10*km/h* (2.8*m/s*), more than 20% of the time. Thus, in the plots (Figure 6), the upper limit of each bar ends within the range described by the comfort category. For sitting, the rating would include conditions ranging from calm up to wind speeds that would rustle tree leaves or wave flags slightly, as presented in the Beaufort Scale included in the Appendices. As the name infers, the category is recommended for outdoor space where people might sit for extended periods.

The Standing category is slightly more tolerant of wind, including wind speeds from calm up to 15*km/h* (4.2*m/s*). In this situation, the wind would rustle tree leaves and, on occasion, move smaller branches while flags flap. This category would be suitable for locations where people might sit for short periods or stand in relative comfort. The Walking category includes wind speeds from calm up to 20*km/h* (5.6*m/s*). These winds would set tree limbs in motion, lift leaves, litter and dust, and the locations are suitable for activity areas. The Uncomfortable category covers a broad range of wind conditions that are generally a nuisance for most activities, including wind speeds above 20*km/h* (15.6*m/s*).

In Figure 6, the probe locations are listed along the bottom of the chart; beneath the graphical representation of the Mean Wind Speed exceeded 20% of the time. Along the right edge of the plot the comfort categories are shown. The background of the plot is lightly shaded in colours corresponding to the categories shown in Table 1. Each category represents a 5*km/h* (or more) interval. The location is rated as suitable for Sitting, Standing, Walking, or Uncomfortable, if the bar extends into the corresponding interval.

The charts represent the average person's response to wind force annually and for four seasons. Effects such as wind chill and humidex (based on perception) are not considered. Also clothing is not considered, since clothing and perceived comfort varies greatly among the population. There are many variables that contribute to a person's perception of the wind environment beyond the seasonal variations presented. While people are generally more tolerant of wind during the summer months, than during the winter, due to the wind cooling effect, people become acclimatized to a particular wind environment. Persons dwelling near the shore of an ocean, large lake or open field are more tolerant of wind than someone residing in a sheltered wind environment.

4.7 Pedestrian Safety Criteria

Safety criteria are also included in the analysis to ensure that strong winds do not cause a loss of balance to individuals occupying the area. The safety criteria are based on wind speeds exceeded nine times per year as shown in Table 2.

Both the Comfort and Safety Criteria are based on those developed at the Allan G. Davenport Wind Engineering Group Boundary Layer Wind Tunnel Laboratory, located on the campus of The University of Western Ontario. The comfort criteria were subsequently revised for the Mississauga Urban Design Terms of Reference for Wind Comfort and Safety Studies, in consultation with RWDI and more closely respects the Lawson criteria.

Table 2: Safety Criteria

ACTIVITY	**Mean Wind Speed Exceeded 9 times per year**		**Description**
SAFETY	***km/h***	***m/s*** (used in Fig. 8)	
All-Weather	0-90	0-25	Acceptable gust speeds that will not adversely affect a pedestrian's balance and footing.
Exceeding All-Weather	>90	>25	Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is typically required.

4.8 Pedestrian Comfort Criteria – Seasonal Variation

The level of comfort perceived by an individual is highly dependent on seasonal variations of climate. Perceived comfort is also specific to each individual, and depends on the clothing choices. The comfort criterion that is being used averages the results across the general population to remove effects of individuals and clothing choices, however, seasonal effects are important. For instance, a terrace or outdoor amenity space may have limited use during the winter season, but require acceptable comfort during the summer.

The comfort of a site is based on the "annual" results of the study, Figures 6a and 7a and 7b. In cases where seasonal comfort is important, results have been included for the seasons; winter, spring, summer, and fall (see Figures 6b to 6e and Figures 7c to 7j).

When compared to the annual average wind speed, winter winds are about 12.5% higher and summer winds are about 16% lower.

5. RESULTS

5.1 Study Site and Test Conditions

<u>Proposed Development</u>

The Development occupies a portion of a block lands situated to the northeast of the intersection of Hurontario Street with Eglinton Avenue East in the City of Mississauga. The subject site was occupied by a one storey residential dwelling, and several farming related structures that are to be removed. The development is phased, however, the analysis is based upon the ultimate configuration.

The first phase occupies the east portion of the Development site, and involves construction of Lot A, which is comprised of a 25 storey tower, denoted Tower 3, as well as two 3 storey townhouse blocks. The tower is situated in the southwest corner of the lot, steps down to 6 storeys to the east, and has a 3 and 12 storey wing extending to the north. Outdoor amenity spaces are proposed on the podium rooftops at the 4^{th} and 13^{th} levels. A private driveway connects with the extension of Thornwood Drive to the north of the building and loops under the podium through a 3 storey breezeway, providing access to the tower's main entrances. The two 3 storey townhouse blocks are located to the northeast of the tower, with a proposed Public Park to the north.

The second phase occupies the northwest portion of the Development site, and involves construction of Lot B, which is comprised of a 24 storey tower, denoted Tower 6. The tower is situated in the southwest corner of the lot and has a surrounding 2, 3, 6, and 8 storey podium that extends to the east. Outdoor amenity space is proposed on the podium rooftop at the 9th level, and passive outdoor space is proposed for the 3rd level. A private driveway off Armdale Road penetrates the podium with a 2 storey breezeway. The building's main entrances are located on either side of the breezeway along the north façade of the building. A proposed Public Park is situated to the east of the building, extending to Thornwood Drive.

The third phase occupies the southwest portion of the Development site, and involves construction of Lot C. The third phase is comprised of 4 towers connected via multilevel podiums in a square-style configuration. Tower 1 is 37 storeys in height and is located in the southwest corner of the lot, Tower 2 is 35 storeys in height and located in the southeast corner of the lot, Tower 4 is 35 storeys in height and is located in the northwest corner of the lot, and Tower 5 is 19 storeys in height is located in the northeast corner of the lot. Six storey podiums connect the towers to the south, east, and west. A central 3 storey podium with a sunken 2 storey component connects all 4 towers. Outdoor amenity space is proposed for the 7th level, atop the southern and western connective podiums. A rooftop passive outdoor space is proposed at the 3rd level atop the sunken portion of the central podium. A 2 storey internal courtyard is accessed from an extension of the private driveway to the north, penetrating the connective podium between Towers 4 and 5. A pedestrian walkway also penetrates the connective podium between Towers 1 and 2 to the south, providing access to the internal courtyard from Eglinton Avenue East. The entrances to Towers 1 and 2 are proposed at the southwest and southeast corners of the buildings, respectively, along Eglinton Avenue East. The entrances to Towers 4 and 5 are accessed from the west and east sides of the internal courtyard, respectively.

The configuration of the proposed buildings and associated Public Parks and Amenity Spaces is shown in Figure 2b. The Development, located in the City of Mississauga, is depicted in the Aerial Photo in Figure 2a. Note: Mississauga's street orientation is relative to the Lake Ontario Shoreline resulting in east/west orientated streets in the subject area being offset by approximately 50 degrees north.

Surrounding Area

The most noteworthy urban buildings in the immediate surroundings, by proximity, are the proposed Pinnacle Development comprised of 8 buildings ranging in height from 30 to 50 storeys, occupying lands to the west of the intersection of Eglinton Avenue West and Hurontario Street. Earlier phases of the Pinnacle Development are complete, subsequent phases are under construction, approved, or seeking approval. To the west of the site is the future 5081 Hurontario Street Development comprised of three towers that are 21, 27, and

33 storeys in height. Also to the west of the site, north of the 5081 Hurontario Street development, is the 8 Nahani Way development site proposed to include a 33 storey residential tower with 2 storey townhomes planned along the northeasterly side of the site, fronting the balance of Nahani Way and the future Belbin Street. To the southeast and east of the above-mentioned Pinnacle Development, also proposed along Hurontario Street, Summit Eglinton Inc. plans to build Townhouses and Semi Detached Units on lands along the northwest and northeast extremities of the site, removed from Hurontario Street, with high-rise to the southeast and southwest with the latter fronting Hurontario Street. To the southeast of Eglinton Avenue West, and southwest of Hurontario Street lay several large residential buildings that are well spaced with parking, green space and Cooksville Creek related lands with townhomes and lower density residential farther to the southwest along Eglinton Avenue West.

Macroclimate

For the proposed Development, the upstream wind flow during testing was conditioned to simulate an atmospheric boundary layer passing over urban/suburban terrain. The terrain within the site's immediate vicinity was incorporated into the proximity model. Historical meteorological data recorded from the Toronto Pearson International Airport was used in this analysis. For studies in the City of Mississauga, the data is presented annually and for four seasons and the resulting wind roses are presented as mean velocity and percent frequency in Figure 5. The mean velocities presented in the wind roses are measured at an elevation of 10*m*. Thus, representative ground level velocities at a height of 2*m*, for an urban macroclimate, are 52% of the mean values indicated on the wind rose, (for suburban and rural macroclimates the values are 63% and 78% respectively). The macroclimate for this area is dependent upon wind direction and varies with direction between suburban and urban.

Winter (November 16 to March 31) has the highest mean velocities of the seasons with prevailing winds from the north and west, with significant components from north through west to southwest as indicated in Figure 5b. Summer (June 16 to September 15) has the lowest mean wind velocities of the seasons with prevailing winds from north through west to southerly as indicated in Figure 5d. Spring and Fall winds tend to be more moderate and emanate from the north through west to southwest. Reported pedestrian comfort ratings generally pertain to annual conditions, unless stated otherwise.

5.2 Pedestrian Level Wind Velocity Study

On the site model, forty-four (44) wind velocity measurement probes were located around the proposed Development, activity areas, and surrounds, to determine conditions related to comfort and safety. Figure 4 depicts probe locations at which pedestrian level wind velocity measurements were taken in the existing and proposed scenarios. For the existing setting, the subject buildings were removed and the "existing" site model retested with the existing building.

Measurements of pedestrian level mean and gust wind speeds at the various locations shown were taken over a period of time equivalent to one hour of measurements at full-scale. The mean ground level wind velocity measured is presented as a ratio of gradient wind speed, in the plots of Figure B of the Appendices, for each point in the existing and proposed scenarios. These relative wind speeds are presented as polar plots in which the radial distance for a particular wind direction represents the wind speed at the location for that wind direction, expressed as a ratio of the corresponding wind speed at gradient height. They do not assist in assessing wind comfort conditions until the probability distribution gradient wind speed and direction is applied.

The design probability distribution gradient wind speed and direction, taken from historical meteorological data for the area (see Figure 5) was combined with pedestrian level mean and gust wind speeds measured at each point to provide predictions of the percentage of time a point will be comfortable for a given activity. These predictions of mean and maximum or "gust" wind speeds are provided on an annual and seasonal basis in Figures 6a-6e.

The ratings for a given location are conservative by design, and those ratings that are Uncomfortable, when close to a transition between Walking and Uncomfortable, will not pose a problem from a pedestrian comfort point of view. When the existing surroundings and proposed buildings' fine massing details and actual landscaping are taken into consideration, the results tend toward a more comfortable site than quantitative testing alone would indicate.

Venturi action, scour action, downwash and other factors, as discussed in the Appendix on wind flow phenomena, can be associated with large buildings, depending on their orientation and configuration. These serve to increase wind velocities. Open areas within a heavily developed area may also encounter high wind velocities. Consequently, wind force effects are common in heavily built-up areas. The Development site is open to an urban/suburban setting to prevailing and remaining compass points with winds flowing over and between buildings. As such, the surroundings can be expected to influence wind at the site to varying degrees. It should be noted that the probes are positioned at points typically subject to windy conditions in an urban environment in order to determine the worst-case scenario.

5.3 Review of Probe Results

The probe results, as follows, were clustered into groups comprised of Public Street Conditions, Private Driveway Conditions, Internal Walkway Conditions, Public Park

Conditions, Pedestrian Entrance Conditions, and Rooftop Amenity Area Conditions. The measurement locations are depicted in Figure 4 and are listed in Figures 6a through 6e, annually and for the seasons, for the existing and proposed configurations. The results are also graphically depicted for the existing and proposed configurations in Figures 7a – 7j. The following discusses anticipated wind conditions and suitability for the points' intended use.

5.3.1 Public Street Conditions

Eglinton Avenue East

Probes 1 through 6 were located along Eglinton Avenue East within the zone of influence of the proposed Development. Of these probe locations, all indicate annual wind conditions that are suitable for standing in the existing setting, with the exception of probe 1, that is suitable for sitting. The relatively consistent ratings are partially attributed to westerly through northwesterly winds that approach from over the currently open development site, the lack of turbulence inducing roughness affording winds opportunity to approach the pedestrian level and smoothen. The predominately suburban setting to the east through north to near west of the site introduces roughness to the wind's approach flow, moderating the winds upon approach. The ratings can also be partially attributed to winds approaching in approximate alignment with the street, the open approach of the street, related boulevards, and low-rise commercial buildings affording winds approaching from the southwesterly portion of the prevailing wind climate opportunity to approach the pedestrian level and similarly smoothen upon approach.

With inclusion of the proposed Development, probe locations 3, 5, and 6 realised an improvement, sufficient to change annual comfort categories from standing to sitting. Probe 2 similarly improved, but remained suitable for standing. The improvements realised can be attributed to the proposed development presenting increased blockage to winds, resulting in the observed leeward effect, however, the realignment of winds associated with insertion of tall buildings into a suburban/urban setting invariably causes a realignment of winds that can result in localised windier conditions. Points 1 and 4 realised increased wind effects sufficient to change annual comfort ratings from sitting to standing, and standing to walking, respectively, but the areas remain suitable for the intended purpose.

From the mean ground level wind velocity presented as a ratio of gradient wind speed, in the plots of Figure B in the Appendix, it is apparent that many of these points realise either no change or an improvement to the existing setting with inclusion of the proposed Development for specific wind directions, however, there are directions from which the wind is exacerbated. Should that direction coincide with dominant wind directions, as indicated in Figure 5's wind roses, relatively more windy conditions can be expected. As such, the relatively more windy conditions predicted at probe locations 1 and 4, situated to the southwest of the Development at the intersection of Thornwood Dr. and Eglinton

Avenue East, respectively, result from winds that formerly flowed over the open lands of the existing site being redirected to flow along the buildings, around the corners, and beyond, however, the areas remain suitable to the intended purpose year round.

The above-mentioned, considered in concert with massing features and landscaping that were too fine to be incorporated into the site and surroundings, and urban intensification of the surroundings will result in further improvement. During the winter months, windier conditions are predicted, however, the street remains comfortable and suitable for the intended use. All points are suitable for standing, or better, with the exception of Point 4 which will be suitable for walking during the spring, and activities requiring longer exposure times during the summer.

Eglinton Avenue East remains within the pedestrian level wind velocity safety criteria as All-Weather Areas, as described in Section 4.7 and depicted in Figure 9.

Future Thornwood Drive Extension
Probes 10 to 14 were located along the future extension of Thornwood Drive. In the existing setting, said points are suitable for standing year-round, with more comfortable conditions, suitable for sitting at most points, predicted through the summer months. The comfortable conditions can be attributed to the neighbouring townhouse developments introducing roughness to the wind's approach flow, moderating the winds as they approach the proposed Development site.

With inclusion of the proposed Development a realignment of winds will occur, resulting in windier conditions being realised with winds emanating from specific directions, and more comfortable conditions with winds from others. However, the net result of the altered wind flow patterns only changes the annual comfort ratings for points 11 and 12, from standing to sitting and walking, respectively. From the Appendix Figure B Wind Radar Plots, it is apparent that with inclusion of the proposed Development, the extension of Thornwood Drive is susceptible to winds emanating from the northwest and southeast. These winds are in approximate alignment with the street and will be redirected to flow around building corners and between towers, resulting in the windier conditions realised in some locations.

During the winter months there is a greater propensity for stronger winds from specific directions, and should these directions coincide with an area sensitive to wind from a particular direction, windier, less comfortable conditions will prevail. As a result, in addition to point 12, points 10 and 14, situated proximate to building corners, also become suitable for walking. The street is predicted comfortable for the intended use, however, urban intensification of lands to the west can reasonably be expected to moderate westerly winds upon approach, likely resulting in more comfortable conditions.

The future extension of Thornwood Drive remains within the pedestrian level wind velocity safety criteria as All-Weather Areas, as described in Section 4.7 and depicted in Figure 9.

Armdale Road
Probes 21, 22, 17, and 13 were situated along Armdale Road, to the northwest of the proposed Development site. The road realises comfortable conditions in the existing setting, annually suitable for standing.

With inclusion of the proposed Development, dominant winds from the west through north will be redirected to flow down and along the north façade of Tower 6. The resulting increase in wind along Armdale Road is insufficient to change the annual ratings, with the exception of probe 21, located at the western corner of Tower 6, that becomes suitable for walking. Windier conditions will be realised through the winter months, resulting in probe 17, located at the northern corner of Tower 6, to also become suitable for walking.

The street is predicted comfortable for the intended use, and urban intensification of lands to the west can reasonably be expected to moderate westerly winds upon approach, likely resulting in more comfortable conditions. Armdale Road remains within the pedestrian level wind velocity safety criteria as an All-Weather Area.

5.3.2 Private Driveway Conditions

Probes 18 to 21 were placed along the sidewalk adjacent to the Private Driveway connecting with Armdale Road and the future extension of Thornwood Drive, providing access to Lots B and C. Similar to the points described above, the area is predicted annually suitable for standing in the existing configuration. With inclusion of the proposed Development, the driveway is predicted to experience relatively windy conditions proximate to the corners of the proposed towers, with locations 19, 20, and 21 becoming suitable for walking annually. Location 20 is predicted uncomfortable through the winter months, on the occasion of strong westerly through southwesterly winds, however, it is close to the transition to walking, and as such will be comfortable for walking with consideration of fine design elements, landscaping, and future urban intensification of the surroundings. Probe 18, adjacent to the proposed Public Park A, is well sheltered from dominant winds by the proposed Development and as such realises comfortable conditions, suitable for sitting annually.

The sidewalks along the private driveway are susceptible to winds flowing around the buildings and along the driveway between, however the areas remain suitable for the intended purpose. Consideration of fine design elements too fine to include in the massing model will result in more comfortable conditions than those predicted. The private driveway also remains within the pedestrian level wind velocity safety criteria as an All-Weather Area.

5.3.3 Internal Walkway Conditions

Probes 7 and 8 were situated along a pedestrian walkway adjacent to the proposed Townhouse Blocks. The walkway is well sheltered from the majority of the wind climate, and as such will realise comfortable conditions, suitable for sitting annually.

Probes 17 and 18 were located along a pedestrian walkway to the west of the proposed Public Park A, adjacent to Tower 6's six storey podium. The walkway is also well sheltered by the proposed Development and neighbouring buildings, resulting in conditions suitable for standing at the north end and sitting at the south end. The walkway will experience slightly windier conditions in the winter months, suitable for walking and standing, respectively, but remains suitable for the intended use.

Probe 25 was located along the pedestrian walkway in the 2-storey breezeway between Towers 1 and 2, providing access to Lot C's internal courtyard area. The walkway is susceptible to winds emanating from the east through south accelerating as they flow through the breezeway, however, winds from the east to south are not historically frequent or strong. This results in relatively windy conditions, suitable for walking year-round, which is appropriate for the intended use. Urban intensification of the surrounds to windward directions, as well as fine design and landscape elements, will result in more comfortable conditions through the breezeway.

The walkways are rated as suitable for the intended uses, and will experience more comfortable conditions with consideration of design elements and landscaping that were too fine to incorporate into the massing model. The walkways fall within the pedestrian level wind velocity safety criteria as All-Weather Areas.

5.3.4 Public Park Conditions

Probe 16 was placed centrally within the proposed Public Park A. Park A is well protected from the majority of the wind climate by the proposed Development and neighbouring townhouse blocks to the north, resulting in comfortable conditions, suitable for sitting year-round.

Probe 9 was placed within the proposed Public Park B at the north end of the site. Park B is also well protected by the proposed Development and neighbouring buildings, and will experience conditions suitable for sitting in the summer and fall, and standing through the remainder of the year.

While the areas are predicted comfortable and suitable for the intended use, the comfort conditions are expected to further improve through incorporation of appropriate Public Park landscape plans that will most appropriately be addressed in the future. The proposed Public Parks fall within the pedestrian level wind velocity safety criteria as All-Weather Areas.

5.3.5 Pedestrian Entrance Conditions

Lot A

Probes 28 and 29 were located at the Main Residential Lobby Entrances for Tower 3 along the Private Driveway penetrating the 12 storey podium. Winds emanating from the northeast through east will accelerate through the breezeway resulting in windy conditions on occurrence of said winds, however, as indicated on the Figure 5 Wind Roses, winds from these directions are uncommon. The entrances are rated as suitable for standing annually, with probe 28 experiencing conditions rated for walking in the winter months, however the rating is near the transition to standing and with consideration of fine design and landscape elements, and the proposed vestibule, the entrance will be suitable for standing year-round.

Lot B

Probes 22 and 23 were placed at the residential lobby entrances to Tower 6, respectively fronting Armdale Road and the Private Driveway on the west and east facades of the breezeway. Probe 22, situated at the entrance fronting Armdale Road on the west side of the breezeway, is exposed to winds emanating from the southwest, flowing along the façade of the building, but will realise comfortable conditions, suitable for standing annually. Probe 23, situated at the entrance fronting the Private Driveway on the east side of the breezeway, is exposed to more dominant winds, and will experience windier conditions. Winds emanating from the northwest through southwest that are redirected to flow around the corners of the building and through the breezeway, result in conditions suitable for walking, annually, and uncomfortable at times through the winter months. The proposed vestibules will assist in mitigating winds at these entrances; however it is preferable to locate entrances away from corners or gaps between buildings. Additional mitigation will be required in order to achieve conditions suitable for the intended use at the eastern entrance.

Lot C

Probes 24 and 15 were located along Eglinton Avenue East, at the south and east corners of Lot C, representing the main entrances to the Residential Lobbies of Towers 1 and 2, respectively. The Main Residential Entrance for Tower 1 is located at the south corner of the proposed Development, and as such is exposed to winds emanating from the east and west, flowing along the building facades and around the corner, resulting in conditions suitable for walking annually. The entrance is predicted uncomfortable at times through the winter months, however it is close to the transition to walking, and as such will be comfortable for walking with consideration of fine design elements, landscaping, and future urban intensification of the surroundings. It is preferable to locate entrances away from building corners, and additional mitigation will be required in order to achieve conditions suitable for the intended use at the entrance.

The Main Residential Entrance for Tower 2 is rated suitable for standing annually. The entrance realises windier conditions through the spring and winter months, rated for walking, however the point is at the transition to standing, and with consideration of fine design elements and landscape features, will be suitable for standing year-round.

The Main Residential Entrances for Towers 4 and 5 are located on the west and east sides of the internal courtyard, and represented by probes 26 and 27, respectively. The entrances are isolated from the wind climate, within the internal courtyard, and as such are predicted comfortable and suitable for sitting year-round.

Wind conditions comfortable for standing are preferable at building entrances, while conditions suitable for walking are suitable for sidewalks. Conditions at the proposed main residential entrances and related walkways are considered comfortable and suitable to the intended purpose, with the above noted exceptions. Consideration of the proposed vestibules and existing and proposed surface roughness features too fine to incorporate into the massing model will further improve the comfort ratings. The proposed Development's Main Residential Entrances fall within the pedestrian level wind velocity safety criteria as All-Weather Areas.

5.3.6 Rooftop Outdoor Amenity Areas

Outdoor Amenity Areas and Passive Outdoor Spaces are proposed situated atop the podiums and/or between the towers at probe locations 30 through 44, as indicated in Figures 2b and 4. Many of the spaces will be susceptible to winds from specific directions being deflected to flow down, around and where applicable, through the gaps between the towers, resulting in windy, though not inordinate wind conditions.

Lot A

An Outdoor Amenity Space is proposed atop the 3 storey podium adjacent to the north façade of Tower 3, represented by probe 30. The space is predicted suitable for standing in the summer and walking in the shoulder seasons. The space is relatively exposed to large portions of the wind climate and would benefit from a mitigation plan including 1.8m high wind screens about the perimeter of the space, as well as trellises situated above seating areas, and other mitigative features situated to windward directions. Incorporation of the recommended mitigation plan will result in comfortable conditions that are seasonally suitable for the intended use.

Outdoor Amenity Space is also proposed atop Tower 3's 12 storey podium, represented by probes 31 and 32. The space is rated as suitable for sitting and standing, respectively, in the summer and fall, and standing through the remaining months. The space would benefit from 1.8m high wind screens about the west and north facades of the space, as well as trellises situated above seating areas, in order to achieve conditions suitable for longer exposure times.

Lot B

A Passive Outdoor Space is proposed atop Tower 6's 2 storey podium, represented by probe 33. The area is protected by the adjacent upper podium levels to the majority of the wind climate and as such will experience comfortable conditions, suitable for sitting year-round.

Outdoor Amenity Space is proposed atop the 8 storey podium, to the northeast of Tower 6, as represented by probes 34 and 35. The space is predicted suitable for standing, or better, through the summer and shoulder months. The area will experience windier conditions on the occasion of winds emanating from the northwest through southwest, and as such would benefit from 1.8m high wind screens about the western corner of the space, adjacent to the tower. Incorporation of the recommended mitigation plan will result in comfortable conditions that are seasonally suitable for the intended use.

Lot C

Passive Outdoor Space is proposed atop the central, sunken 2 storey podium, represented by probes 36 and 37. The space is predicted suitable for sitting in the summer, and standing, or better, through the shoulder months. Large portions of the wind climate will flow up and over the adjacent upper podium levels, and ultimately above the space, however, winds from specific directions will reattach with the pedestrian level at portions of the 3rd level, resulting in windier conditions from these directions. A mitigation plan incorporating trellises over seating areas as well as plantings situated about the space will provide roughness to winds and result in conditions suitable for longer exposure times further into the shoulder seasons.

Probes 38 through 44 were situated about the Outdoor Amenity Space proposed atop the 6 storey podium. Probes 38 and 39 are located on the portion of the Amenity Space between Towers 1 and 4, and are rated as suitable for standing, or better, through the summer and shoulder seasons. This portion of the space is well protected by the proposed Development to the north through east to south, however it is susceptible to winds emanating from the west through south and would benefit from a mitigation plan including 1.8m high wind screens about the southwest façade.

Probes 40 and 41 were situated along the southern portion of the Amenity Space, beneath Tower 1's overhang. Location 40, to the south, is well sheltered and as such is suitable for sitting through the summer and shoulder seasons. Probe 41 was predicted suitable for standing through the shoulder seasons, however the point is near the transition and can be considered suitable for sitting, seasonally, considering massing details that were too fine to incorporate into the model.

Probes 42 and 43 were situated on the portion of the Amenity Space between Towers 1 and 2. Probe 42 is located proximate to Tower 1 and is protected from much of the wind climate, however, it will be exposed to winds emanating from the southeast, which seldom occur. This results in conditions proximate to Tower 1 that are suitable for standing through the summer and shoulder months. Probe 43 is located proximate to Tower 2 and is susceptible to winds flowing around the corners of Lot C's towers and over the area, resulting in windy conditions. The portion of the space proximate to Tower 2 is predicted to be uncomfortable and will require mitigation to achieve seasonally comfortable conditions. Wind screens, 1.8m in height, are recommended along the northern façade of the space between Towers 1 and 2, as well as trellises above seating areas, and other mitigative features situated to windward directions. Incorporation of the recommended mitigation plan will result in comfortable conditions that are seasonally suitable for the intended use.

Probe 44 is situated along the northeastern portion of the Amenity Space, beneath Tower 2's overhang. This area of the Amenity Space is well sheltered and as such is suitable for sitting through the summer and shoulder seasons and comfortable for the intended use.

The analysis was conducted without the subject and neighbouring buildings' fine design features or existing and proposed hard and soft landscape features in place. As such, we reasonably expect prevailing pedestrian comfort conditions will be better than those predicted. A mitigation plan, as recommended above, is required for the some of the amenity spaces, if activities requiring longer exposure times are desired. This might be accomplished with a landscaping plan for the rooftop amenity spaces that includes appropriately engineered windscreens, railings, trellises, coarse vegetation, recessed seating, and others, which considered cumulatively, will further improve wind conditions in the residential amenity areas, making them suitable to the intended purpose.

The recommended mitigation plans for the rooftop amenity spaces will be further analysed and implemented at the Site Plan Approval stage. The ultimate plan will be developed in consultation, will respect wind conditions acting on the individual spaces, and incorporate mitigative design features that will result in comfort conditions appropriate to the areas' intended purpose.

The proposed Development's Rooftop Amenity Spaces and Passive Outdoor Spaces fall within the pedestrian level wind velocity safety criteria as All-Weather Areas.

Summary

The observed wind velocity and flow patterns at the Development are largely influenced by approach wind characteristics that are dictated by the urban/suburban mix of residential and commercial development, related open areas, and mature vegetation mitigating the wind, to different degrees, on approach. Historical weather data indicates that strong winds of a mean wind speed greater than 30 km/h occur approximately 13 percent of the time during the winter months and 4 percent of the time during the summer. Once the subject site is developed, ground level winds at several locations will improve, with occasional localized areas of higher pedestrian level winds. The relationship between surface roughness and wind is discussed in the Appendix and shown graphically in Figure A of the same section.

Consideration of existing and proposed building features too fine to incorporate into the massing model, along with recommended mitigation through the implementation of the landscape plan further addressed at the Site Plan Approval stage, will improve the predicted comfort ratings beyond those reported herein, resulting in conditions suitable for the intended use.

As such, the site is predicted comfortable under normal wind conditions annually; however, under high ambient winter wind conditions with winds emanating from specific directions, several localized areas adjacent to building corners, may be windy from time to time, but the area remains within safety criteria and appropriate to the intended purpose. The consideration of proposed surface roughness will result in conditions more comfortable than those reported herein.

A mitigation plan is required for the northeastern Lobby Entrance to Tower 6 as well as the Main Lobby Entrance to Tower 1 in order to achieve suitable conditions. A mitigation plan is also recommended for various Rooftop Amenity Spaces, including perimeter wind screens, trellises, and others, and will be examined further at the Site Plan Approval stage. The ultimate plan will be developed in consultation, will respect wind conditions acting on the individual spaces, and incorporate mitigative design features that will result in comfort conditions appropriate to the areas' intended purpose. The proposed Development is predicted to realise wind conditions suitable to the context.

6. FIGURES:

Figure 1: Laboratory Testing Facility

Figure 2a: Site Aerial Photo

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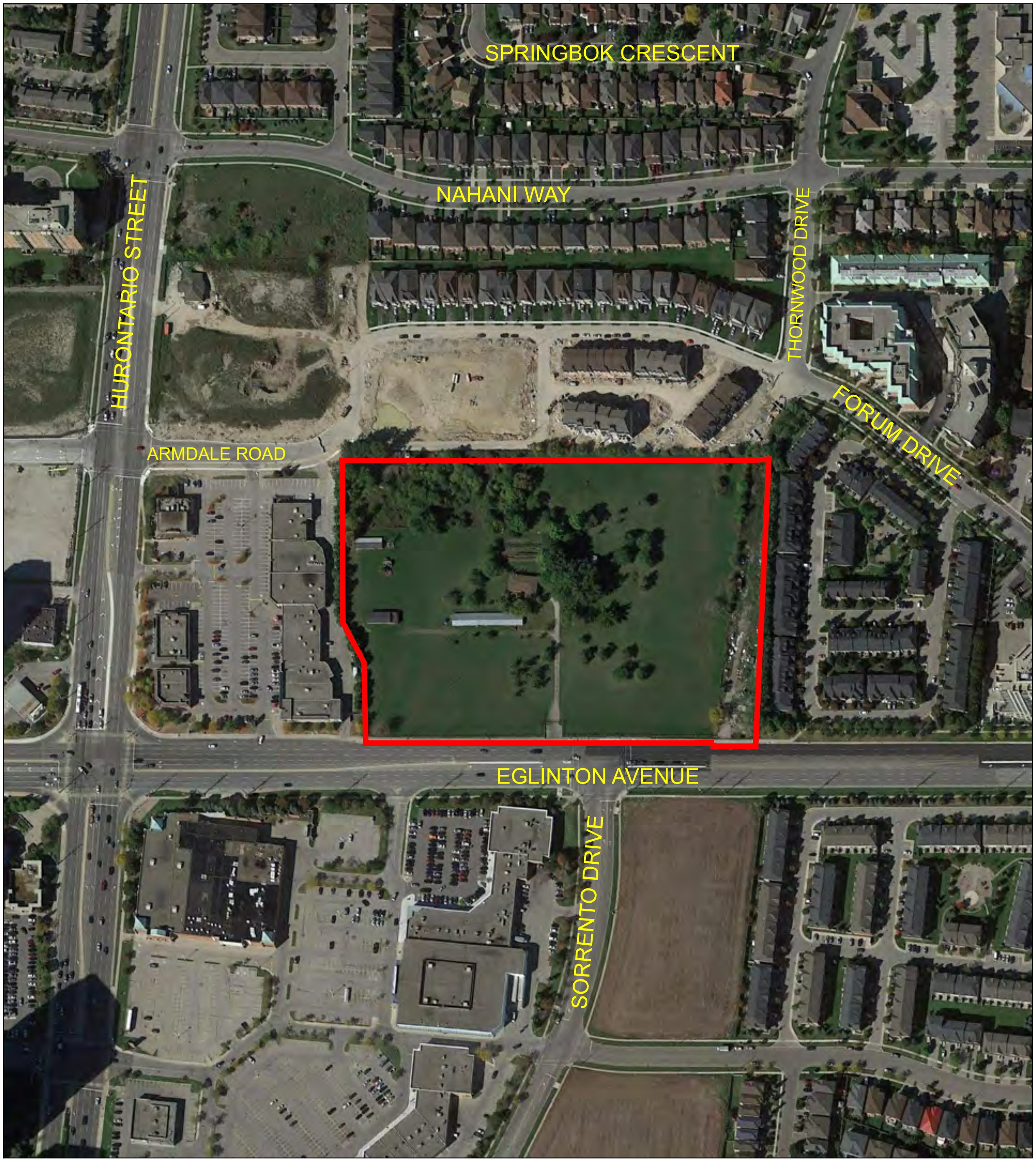


FIGURE 1

AERIAL CONTEXT PLAN

91 EGLINTON AVENUE &
5055 HURONTARIO STREET, ON

Subject Property

N

Scale NTS
May 28, 2019

GSAI
Glen Schnarr & Associates Inc.

Figure 2b: Site Plan

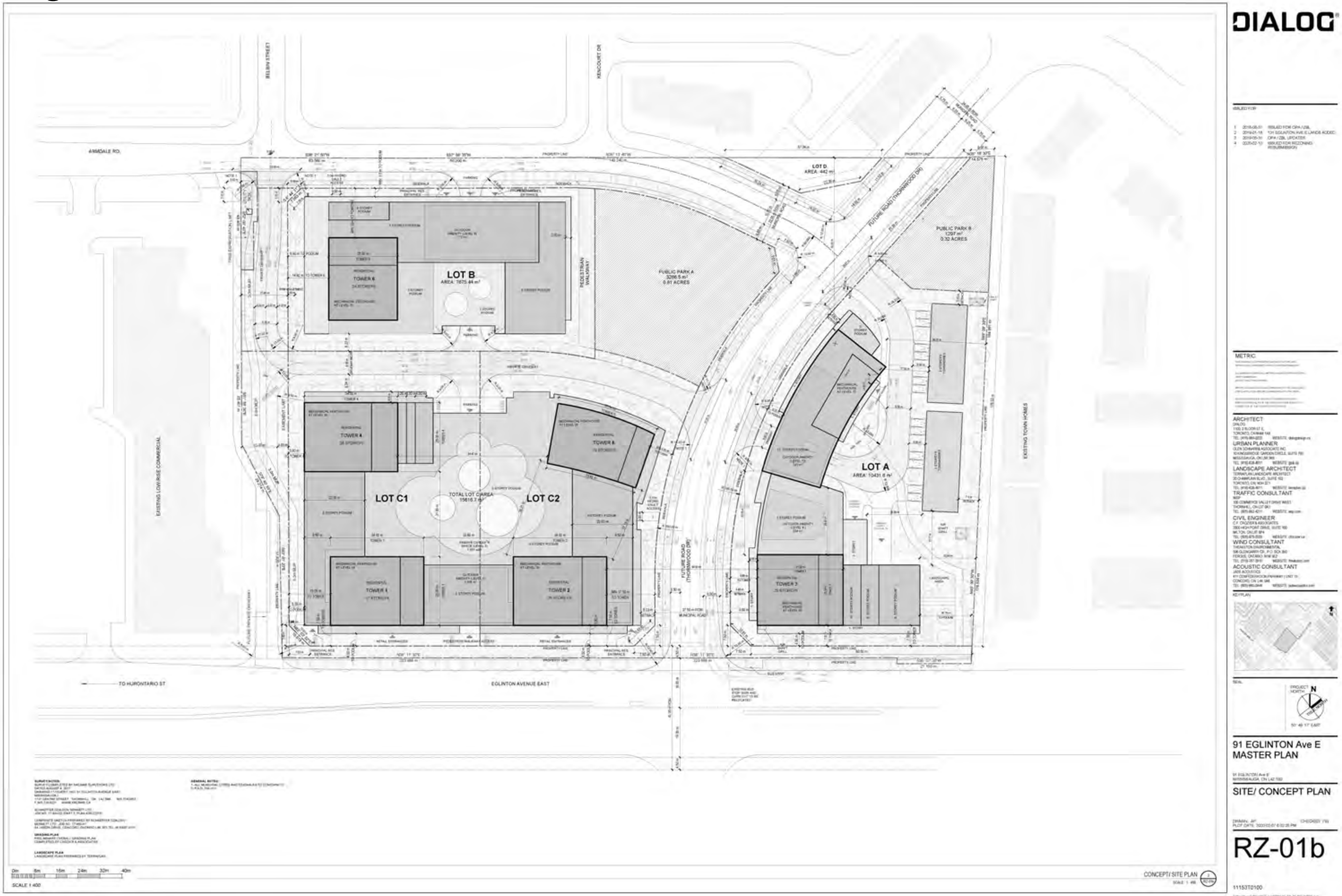
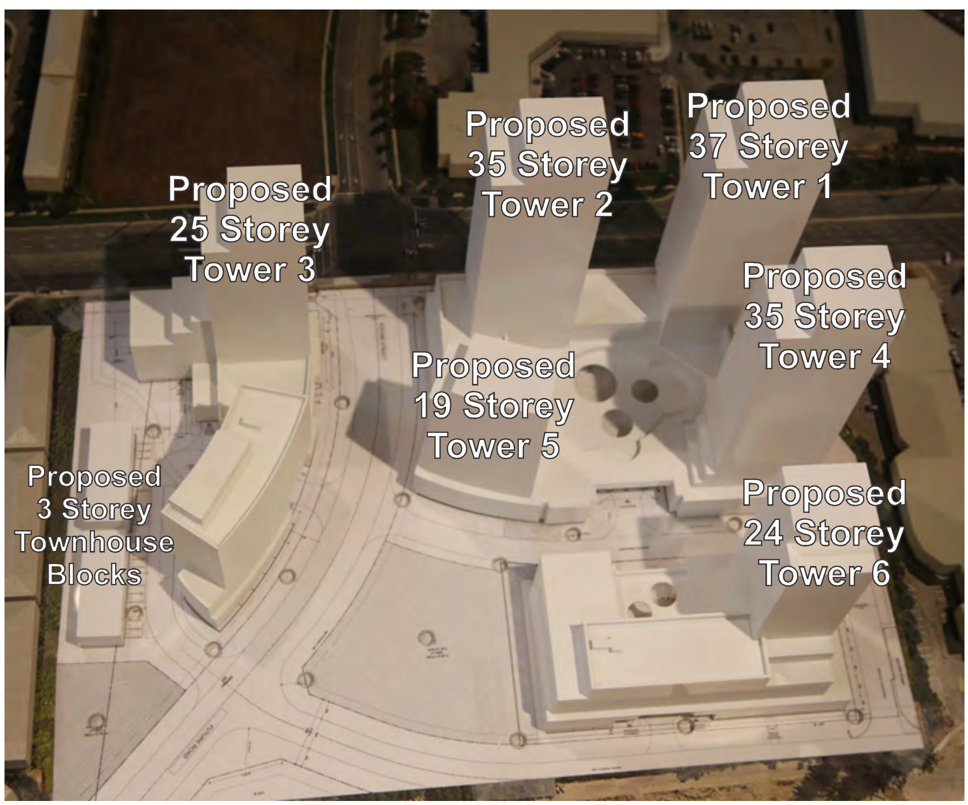


Figure 3: 1:500 Scale model of test site

a) Overall view of model - Proposed Site



b) Close-up view of model - Proposed Site

Figure 4: Location plan for pedestrian level wind velocity measurements.

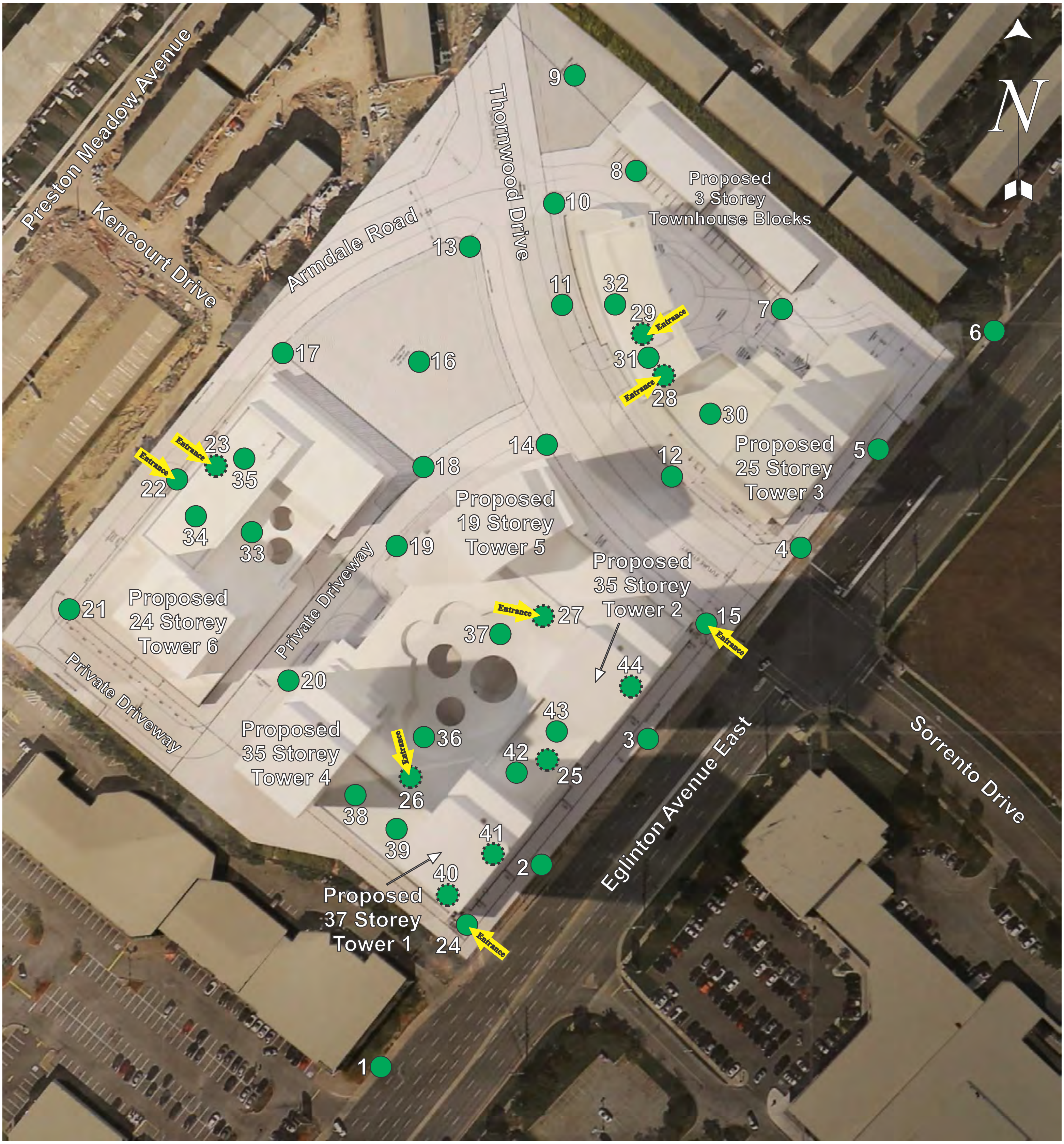


Figure 5a: Annual Wind Rose - Pearson International Airport.

Historical Directional Distribution of Winds (@ 10*m* height)
(1980 - 2017)

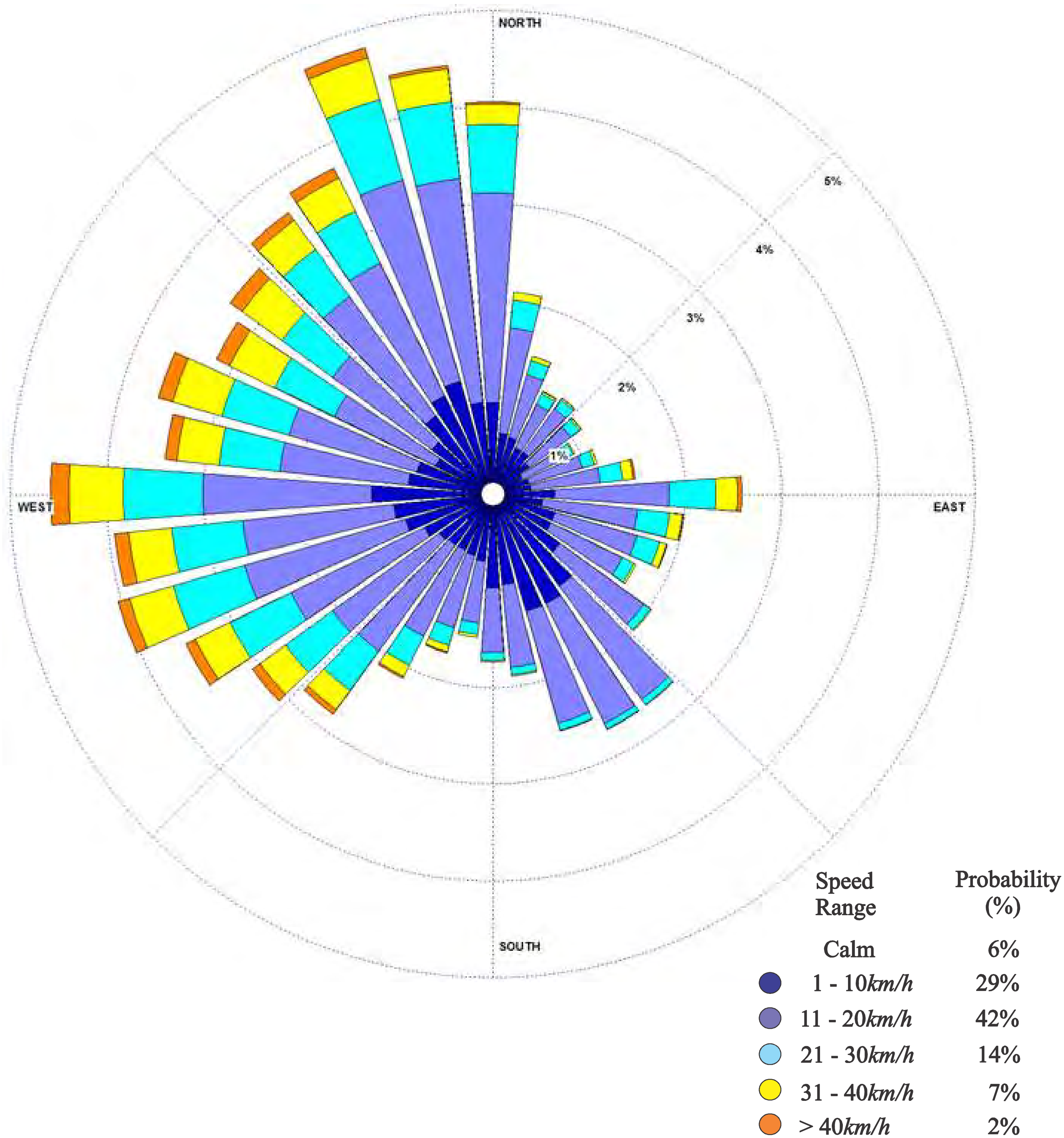
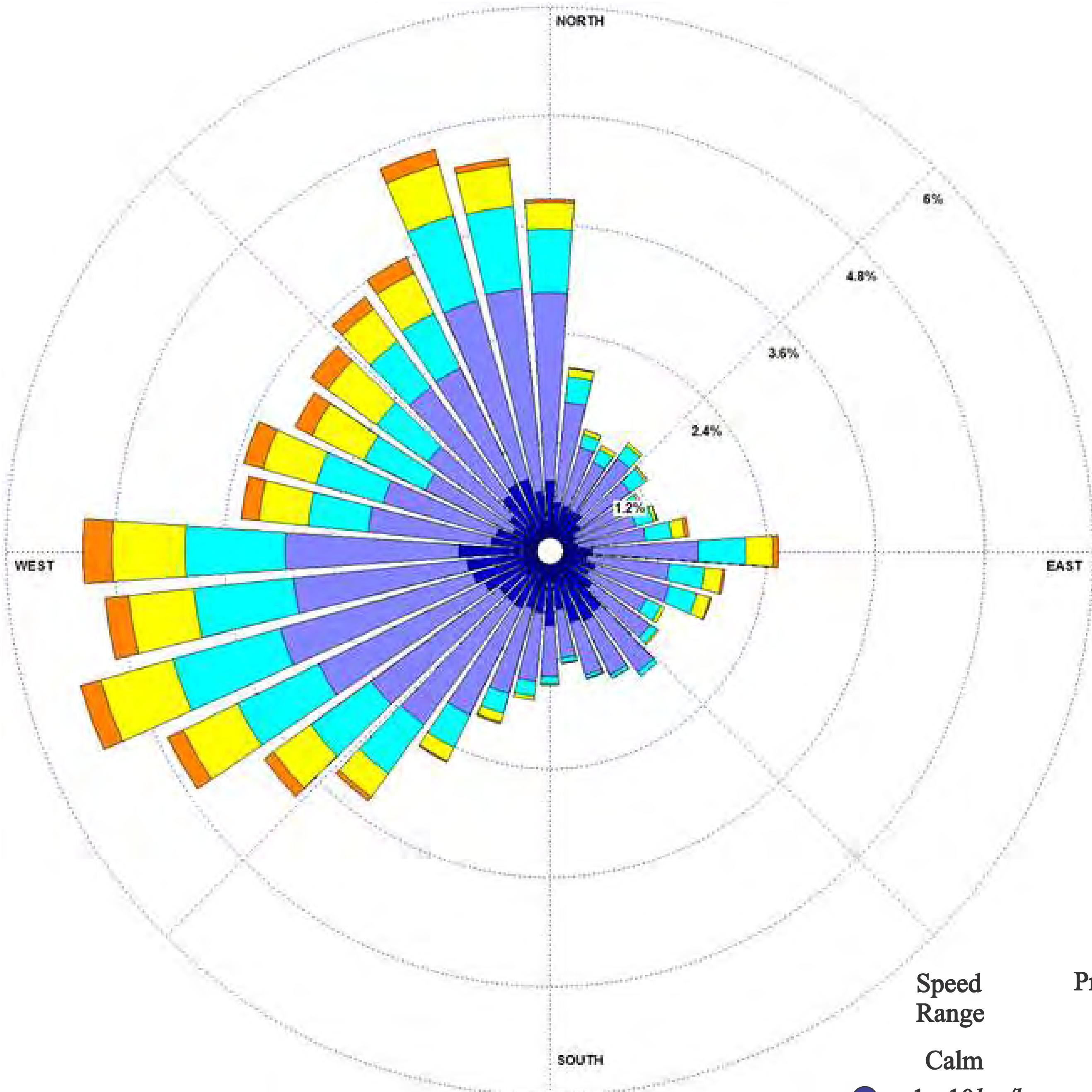


Figure 5b: Winter Wind Rose - Pearson International Airport.

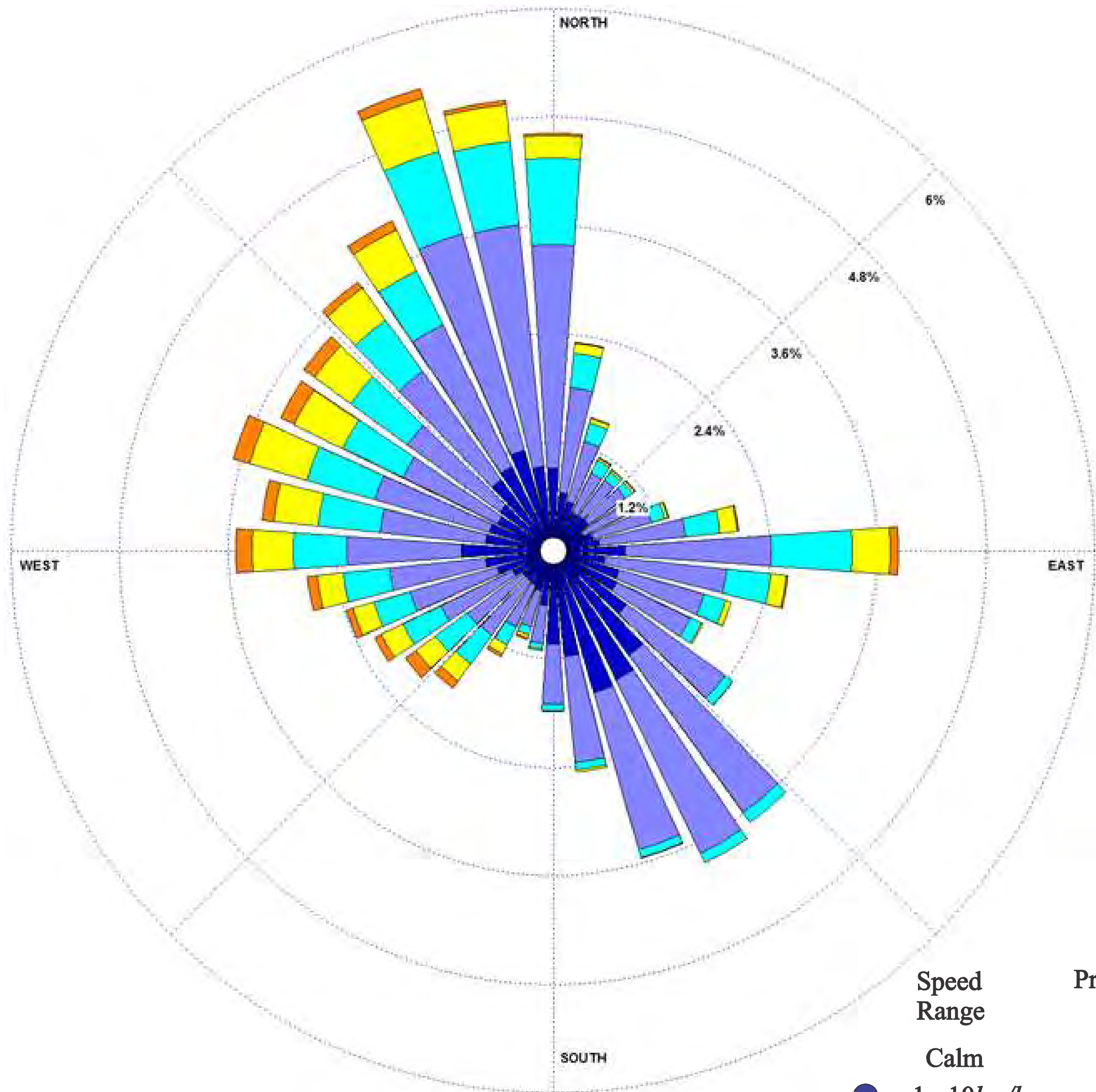
Historical Directional Distribution of Winds (@ 10*m* height)
November 16 through March 31 (1980 - 2017)



Speed Range	Probability (%)
Calm	5%
1 - 10*km/h*	23%
11 - 20*km/h*	42%
21 - 30*km/h*	17%
31 - 40*km/h*	10%
> 40*km/h*	3%

Figure 5c: Spring Wind Rose - Pearson International Airport.

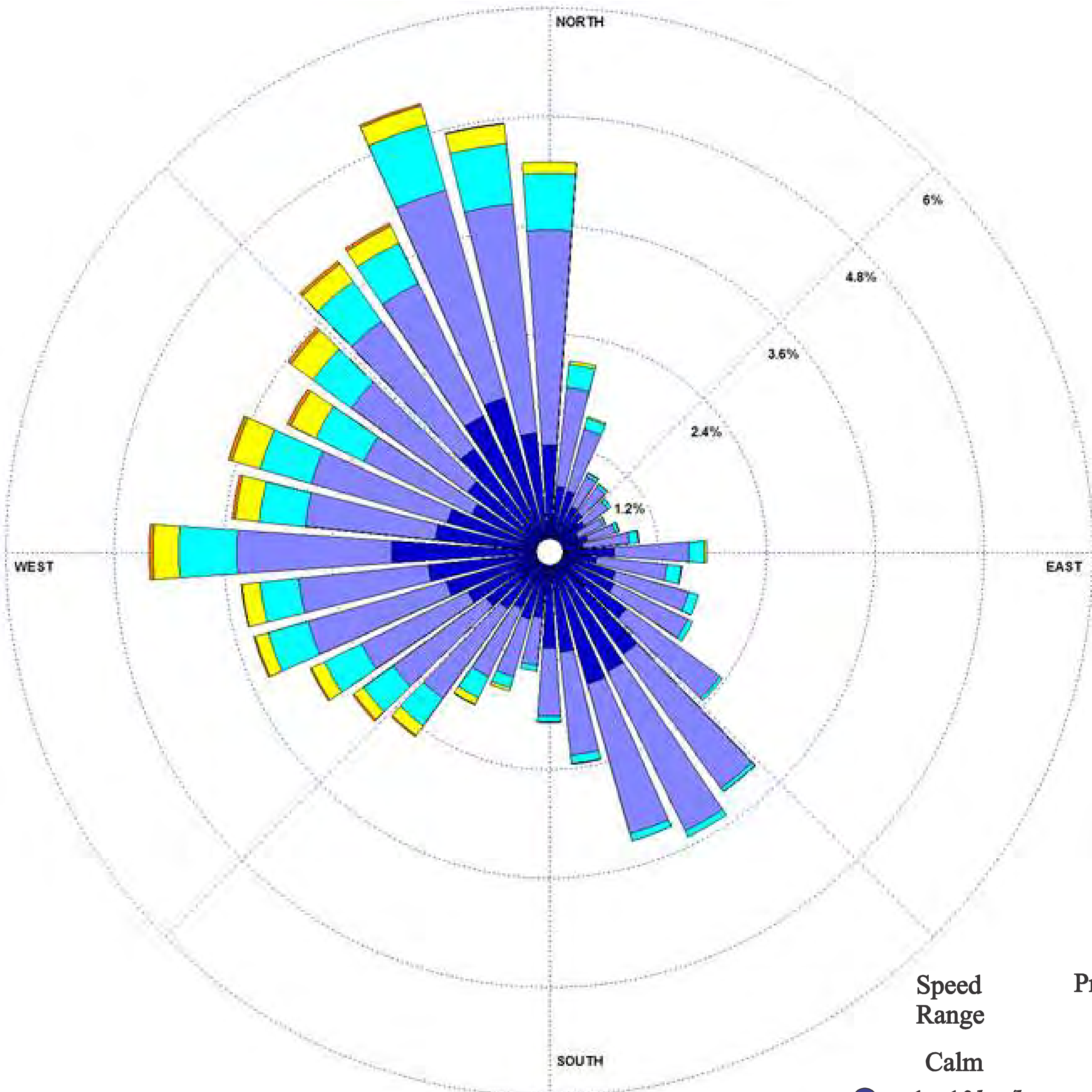
Historical Directional Distribution of Winds (@ 10*m* height)
April 1 through June 15 (1980 - 2017)



Speed Range	Probability (%)
Calm	6%
1 - 10*km/h*	28%
11 - 20*km/h*	42%
21 - 30*km/h*	14%
31 - 40*km/h*	8%
> 40*km/h*	2%

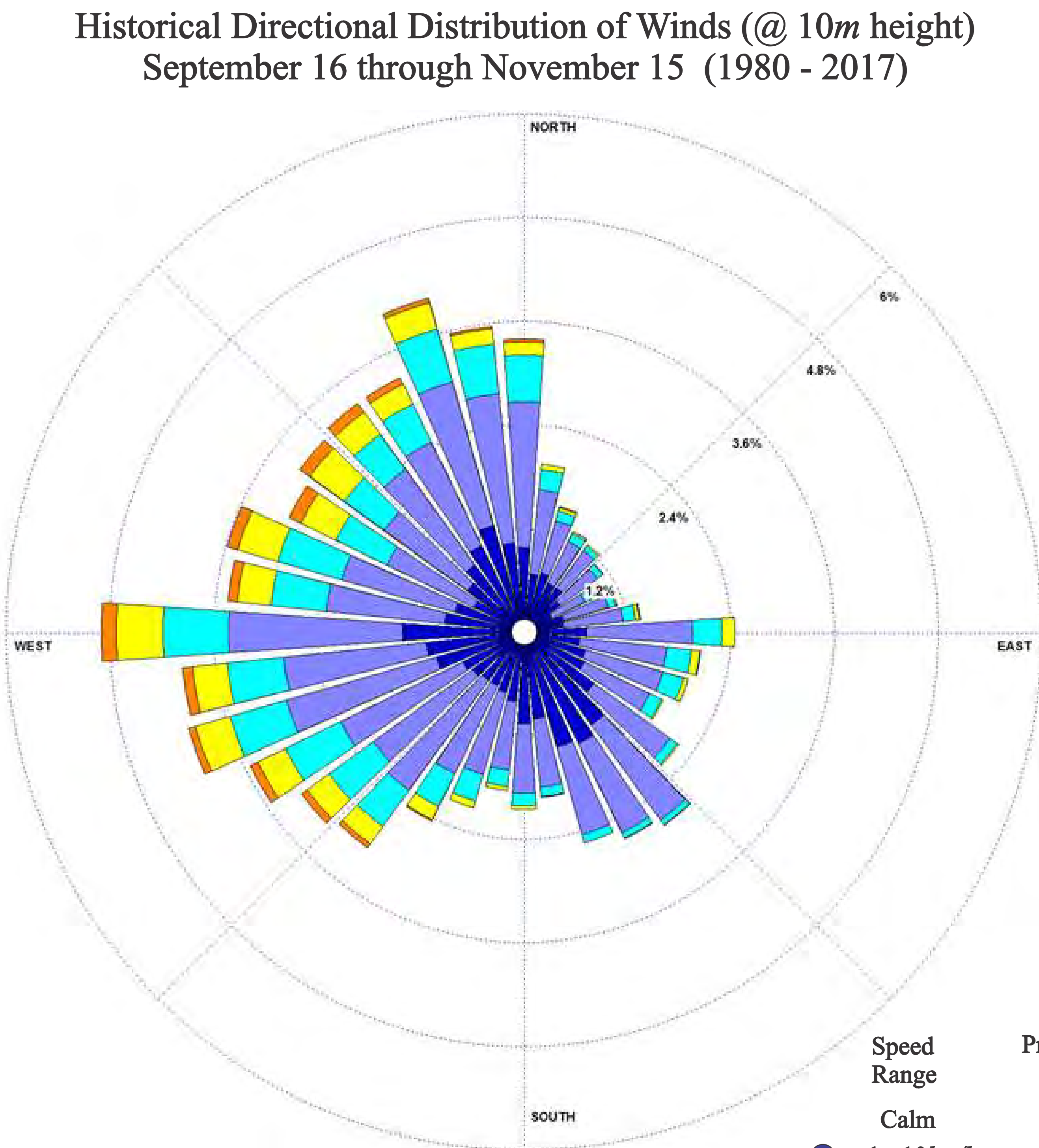
Figure 5d: Summer Wind Rose - Pearson International Airport.

Historical Directional Distribution of Winds (@ 10*m* height)
June 16 through September 15 (1980 - 2017)



Speed Range	Probability (%)
Calm	7%
1 - 10*km/h*	36%
11 - 20*km/h*	43%
21 - 30*km/h*	10%
31 - 40*km/h*	4%
> 40*km/h*	<1%

Figure 5e: Fall Wind Rose - Pearson International Airport.



Speed Range	Probability (%)
Calm	7%
1 - 10*km/h*	31%
11 - 20*km/h*	41%
21 - 30*km/h*	13%
31 - 40*km/h*	6%
> 40*km/h*	2%

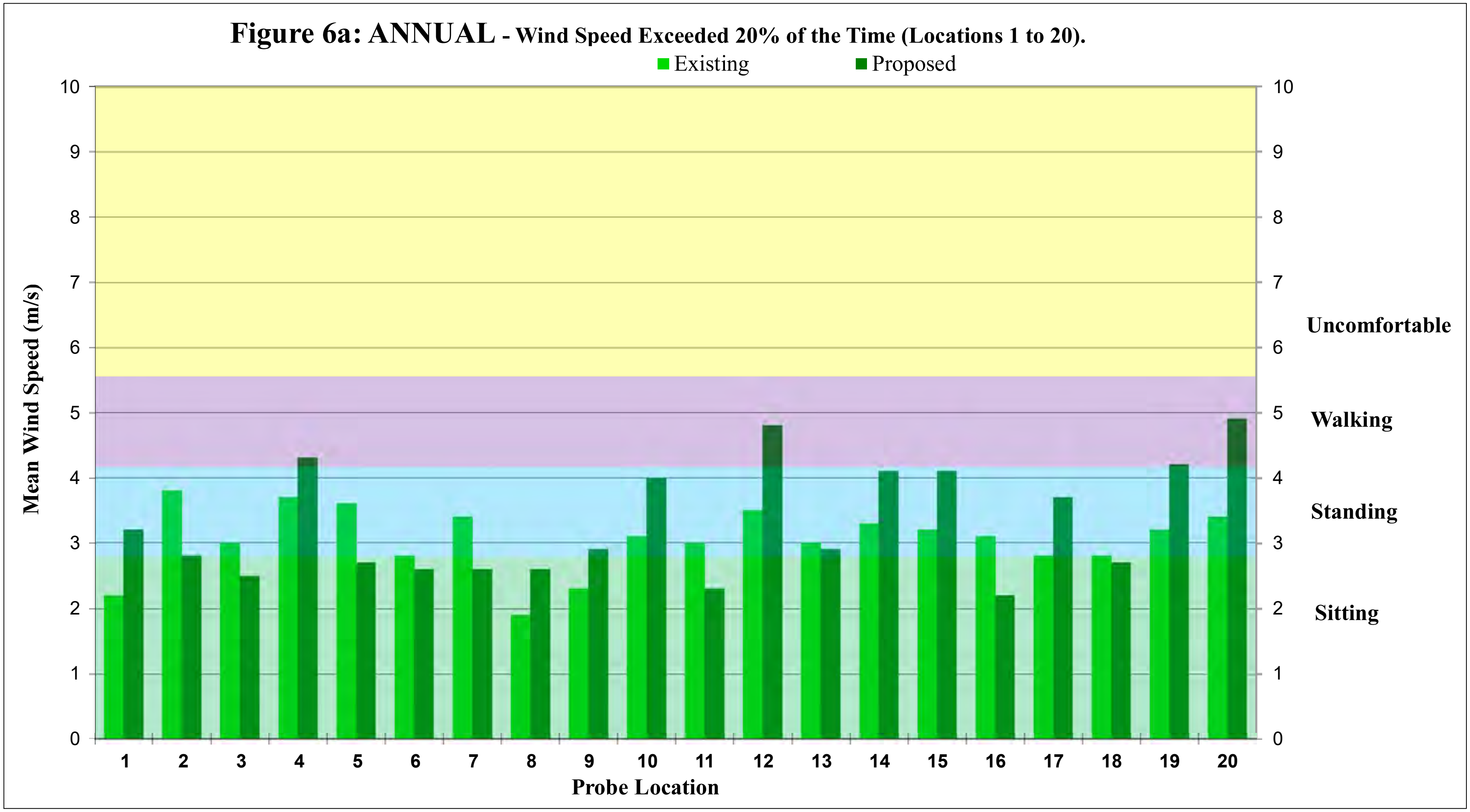


Figure 6a: ANNUAL - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting

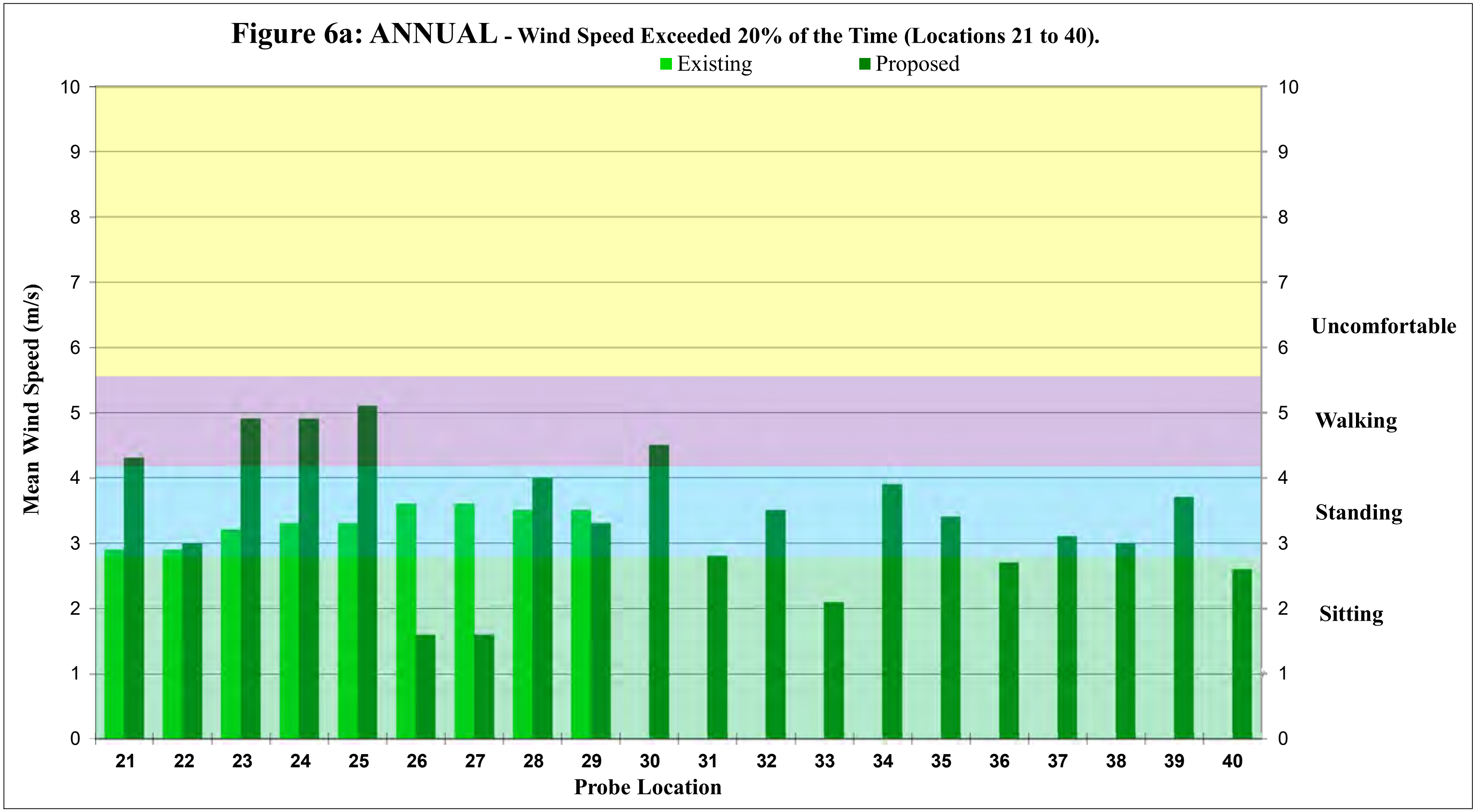


Figure 6a: ANNUAL - Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (m/s)
0
1
2
3
4
5
6
7
8
9
10
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location
Uncomfortable
Walking
Standing
Sitting

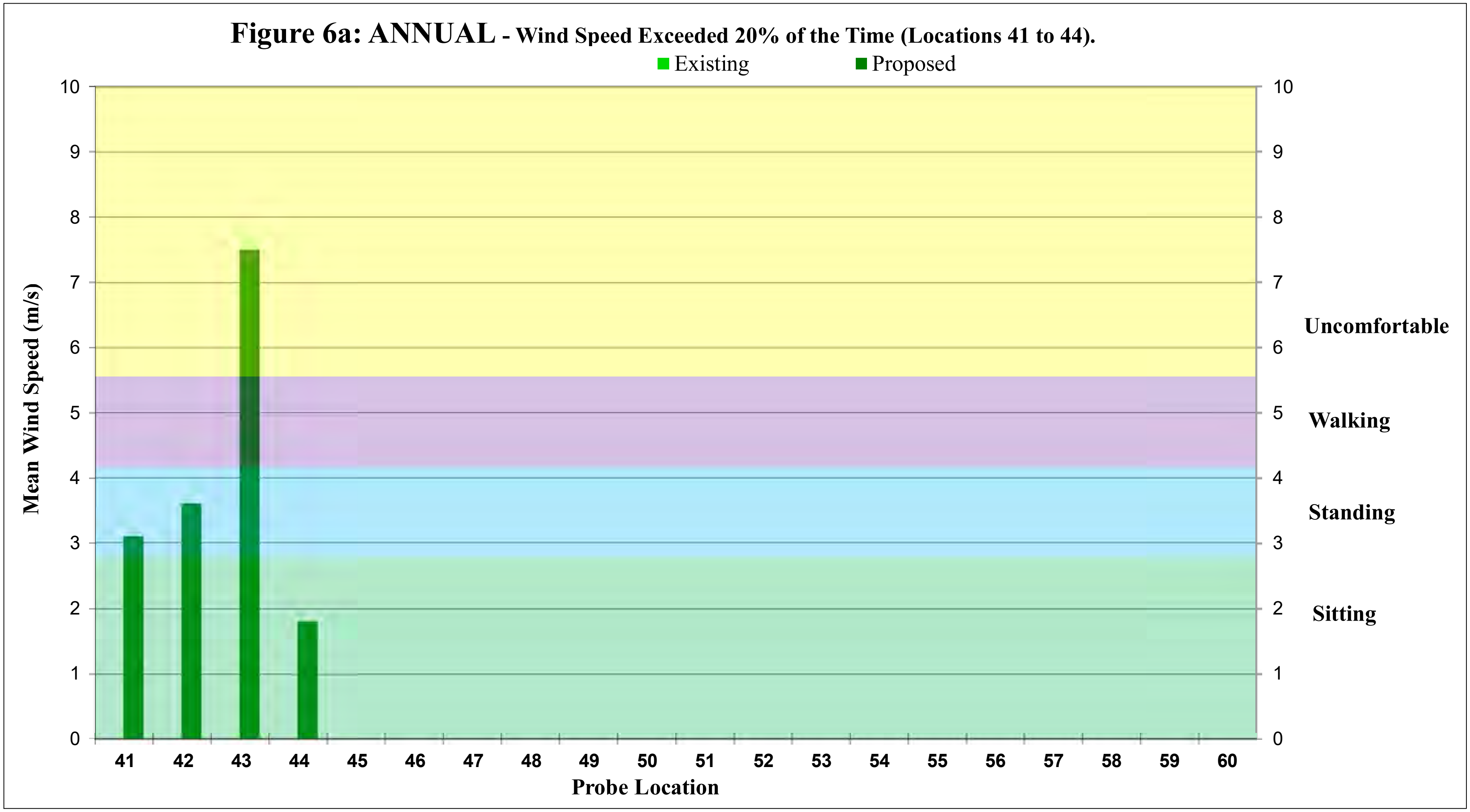


Figure 6a: ANNUAL - Wind Speed Exceeded 20% of the Time (Locations 41 to 44).
Existing
Proposed
Mean Wind Speed (m/s)
0
1
2
3
4
5
6
7
8
9
10
Uncomfortable
Walking
Standing
Sitting
41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
Probe Location

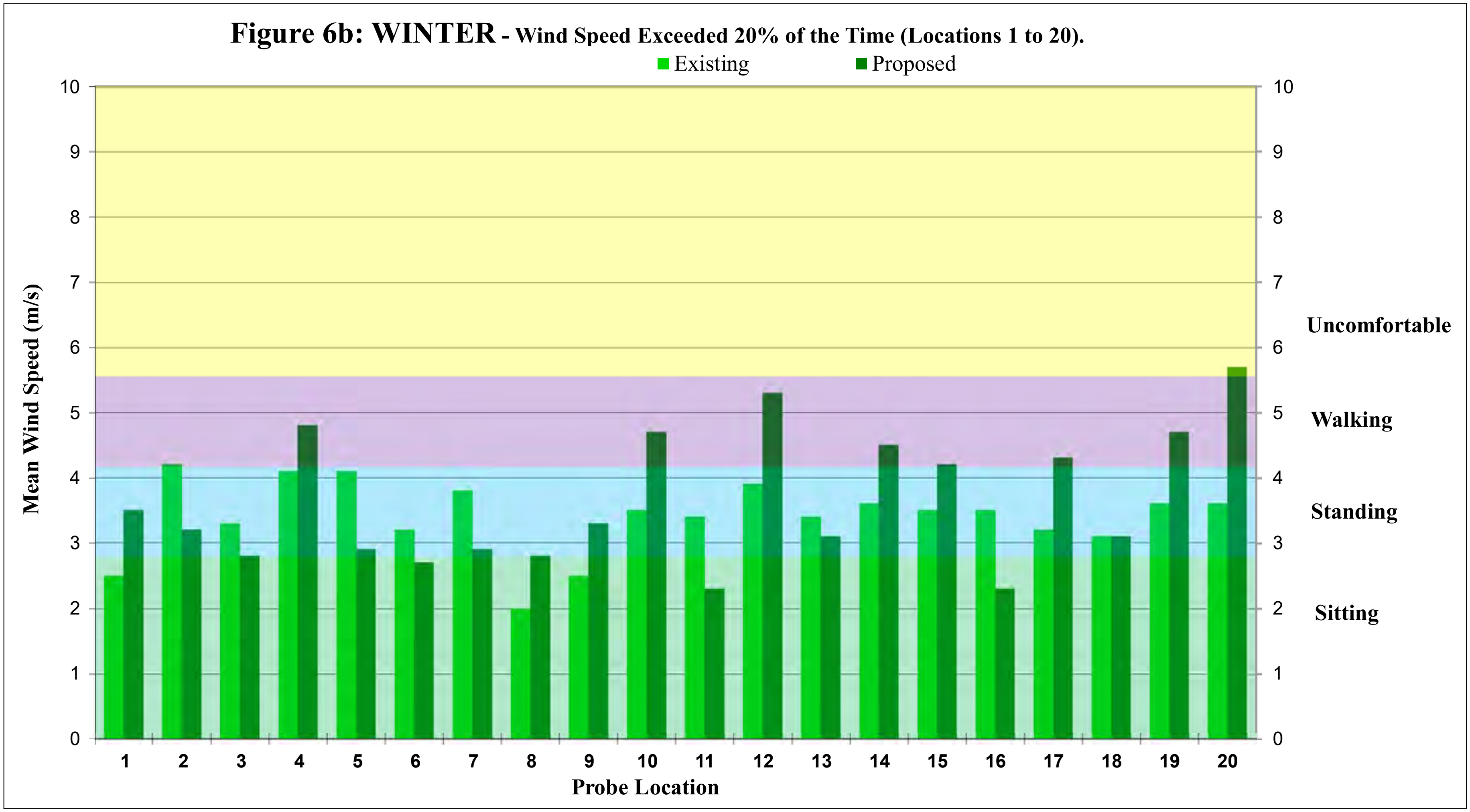


Figure 6b: WINTER - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
0
1
2
3
4
5
6
7
8
9
10
Uncomfortable
Walking
Standing
Sitting
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Probe Location

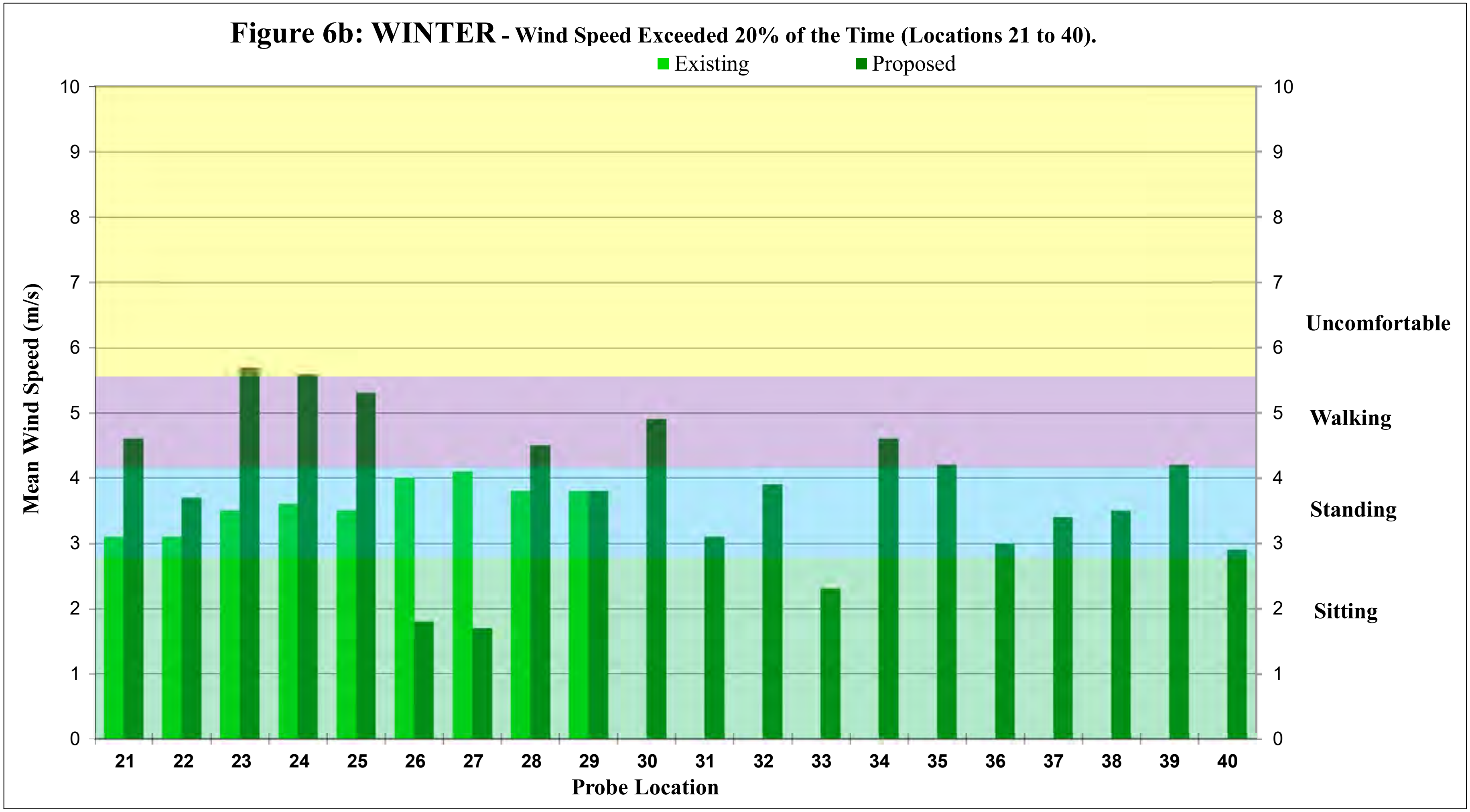


Figure 6b: WINTER - Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
1
2
3
4
5
6
7
8
9
10
21
22
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39
40

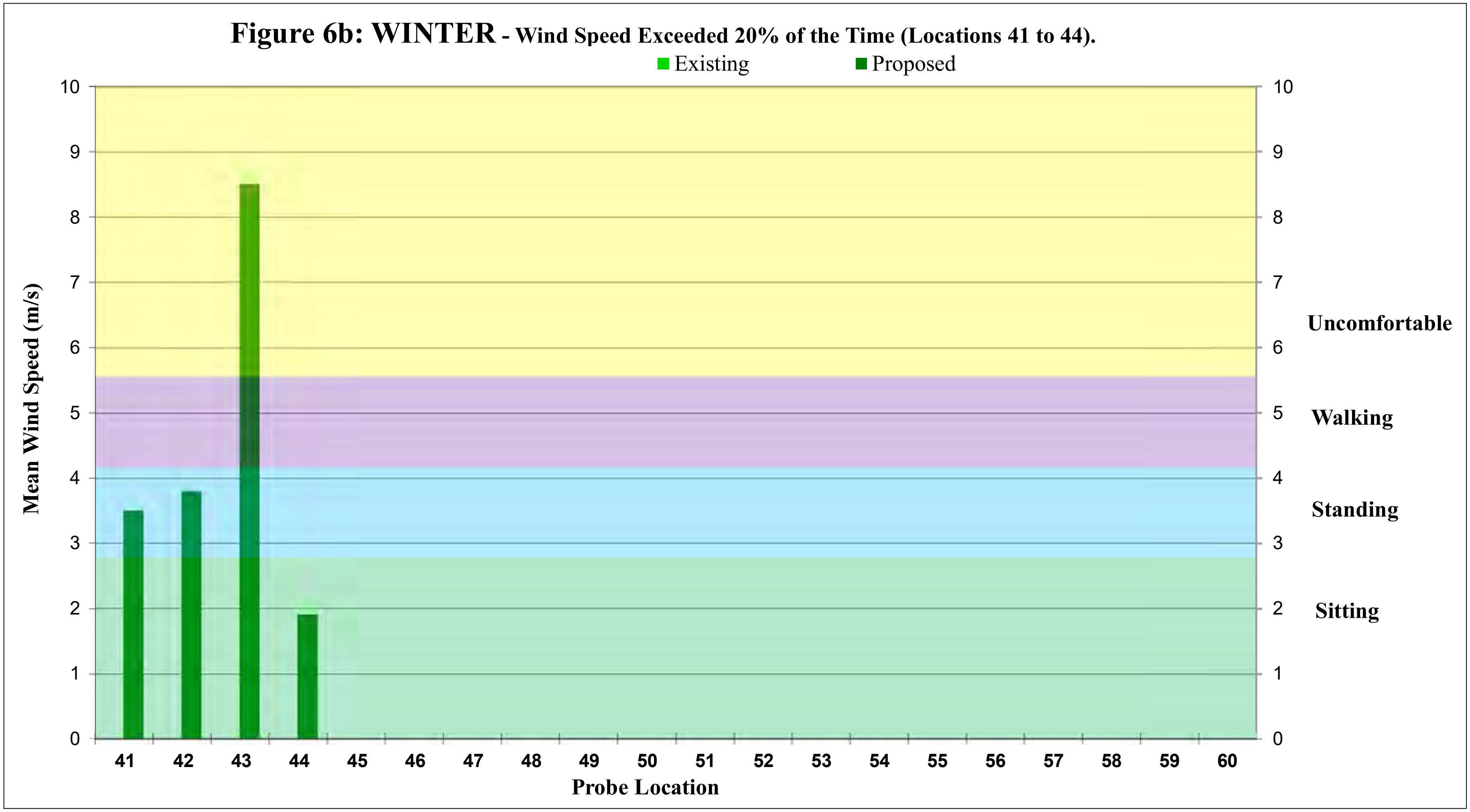


Figure 6b: WINTER - Wind Speed Exceeded 20% of the Time (Locations 41 to 44).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
0
1
2
3
4
5
6
7
8
9
10
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Uncomfortable
Walking
Standing
Sitting

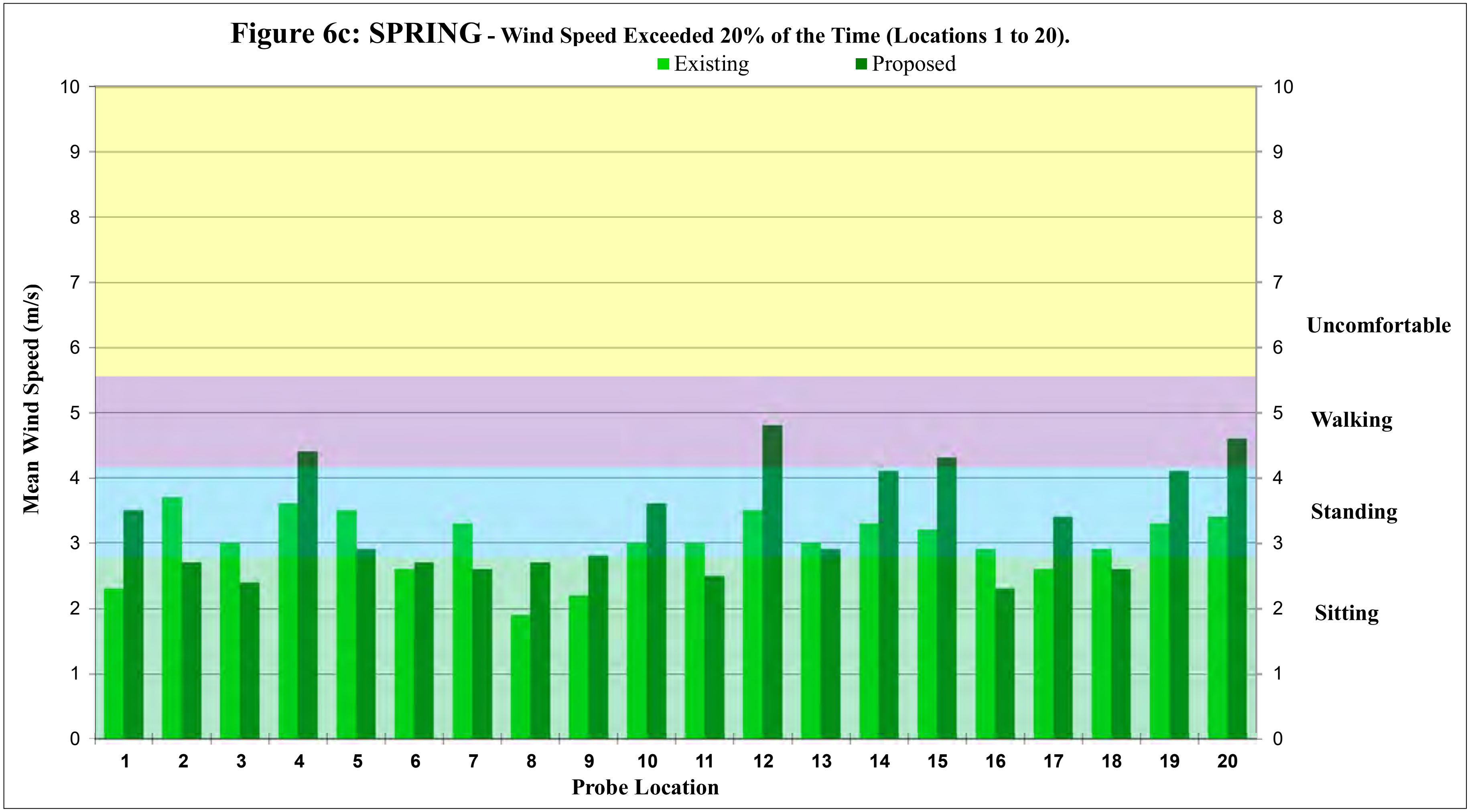


Figure 6c: SPRING - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting

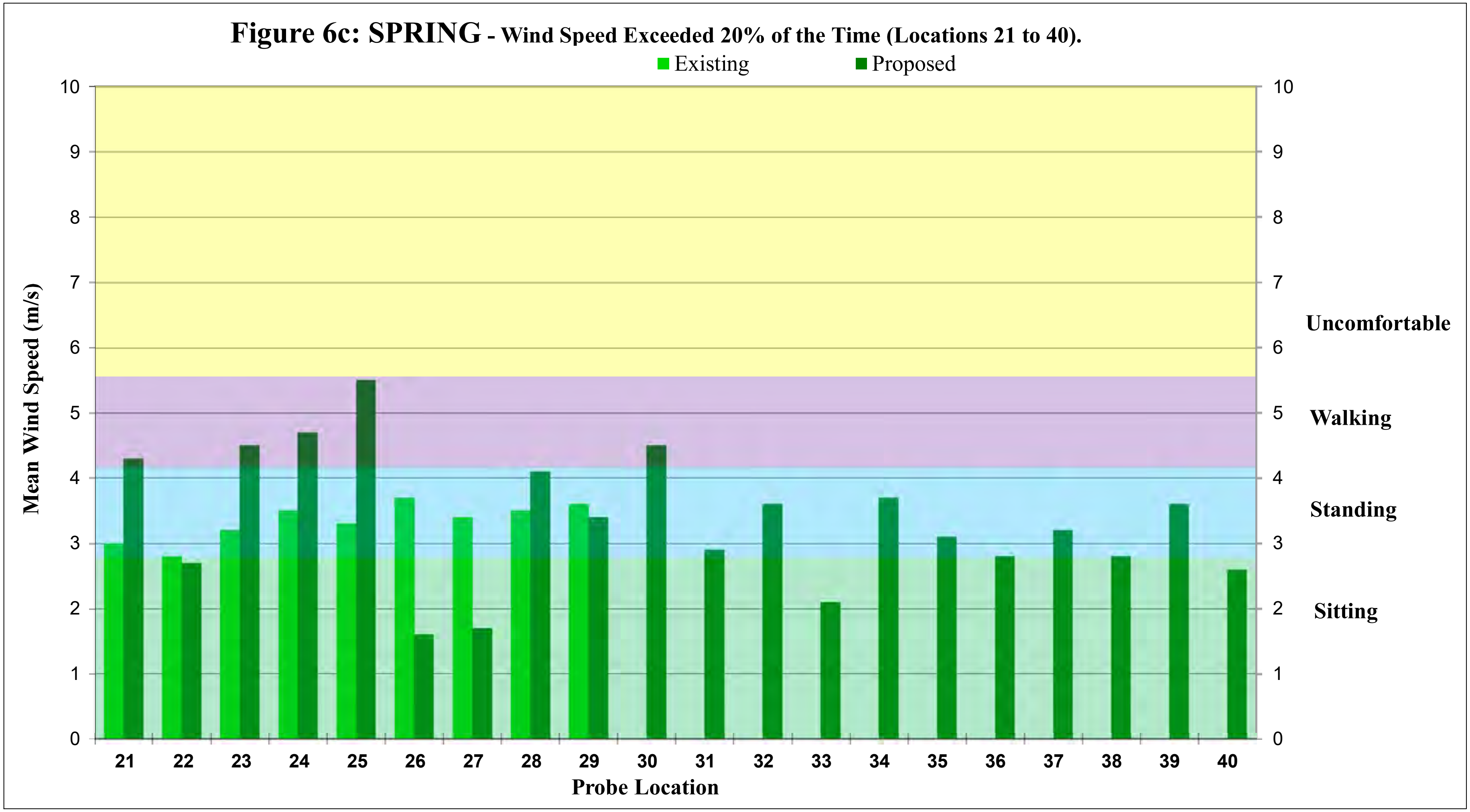
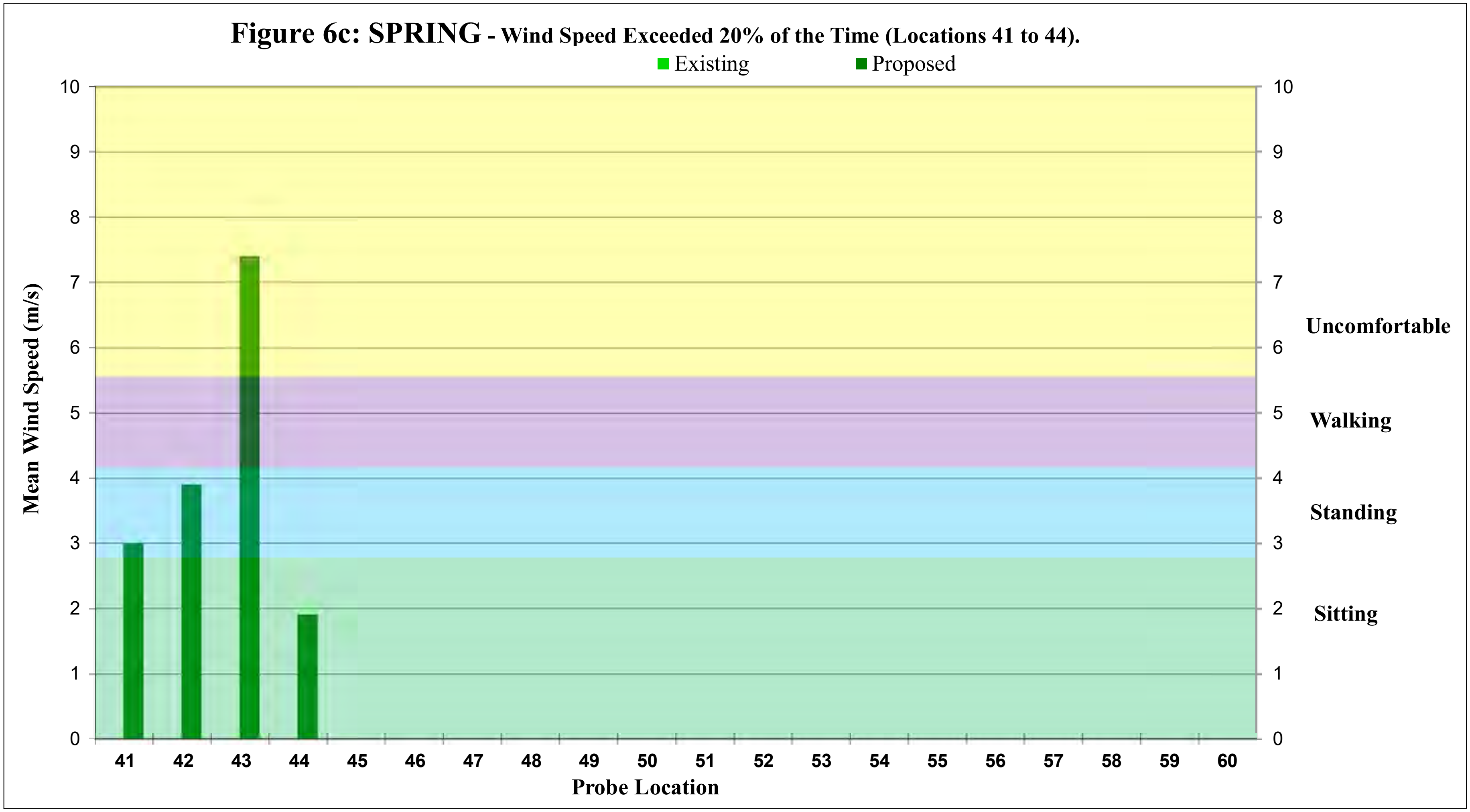


Figure 6c: SPRING - Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting



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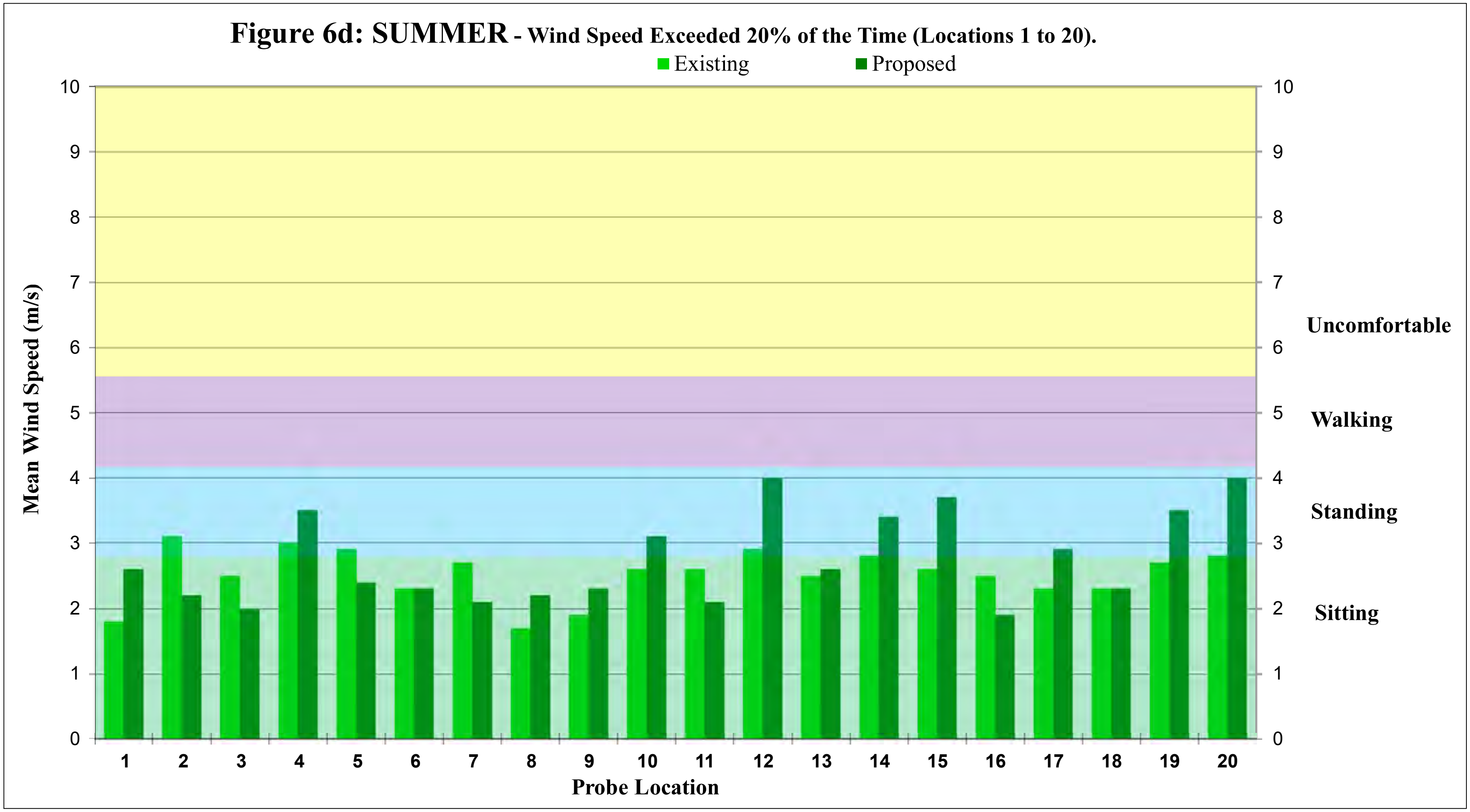
Figure 6d: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
1
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8
9
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

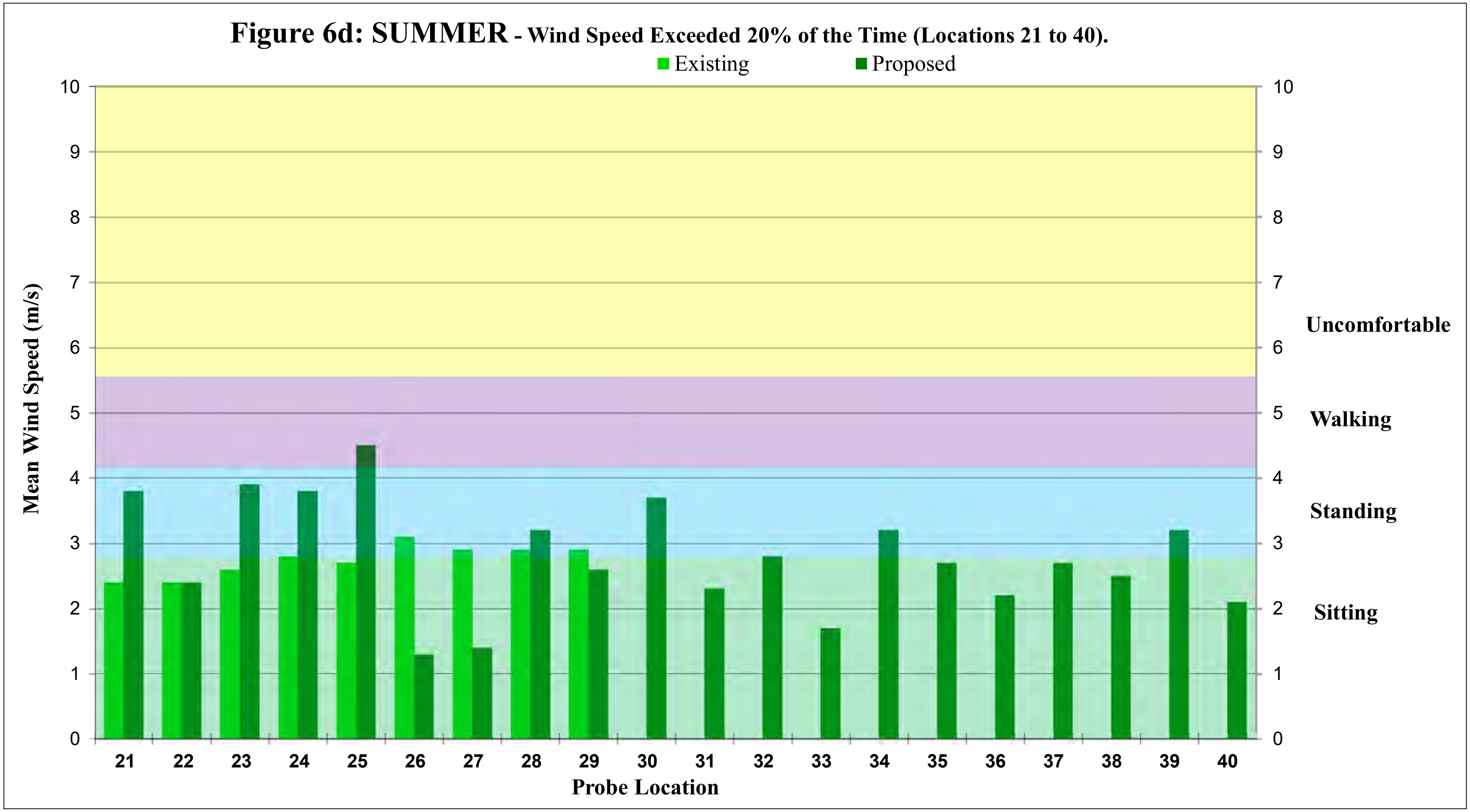
Figure 6d: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
1
2
3
4
5
6
7
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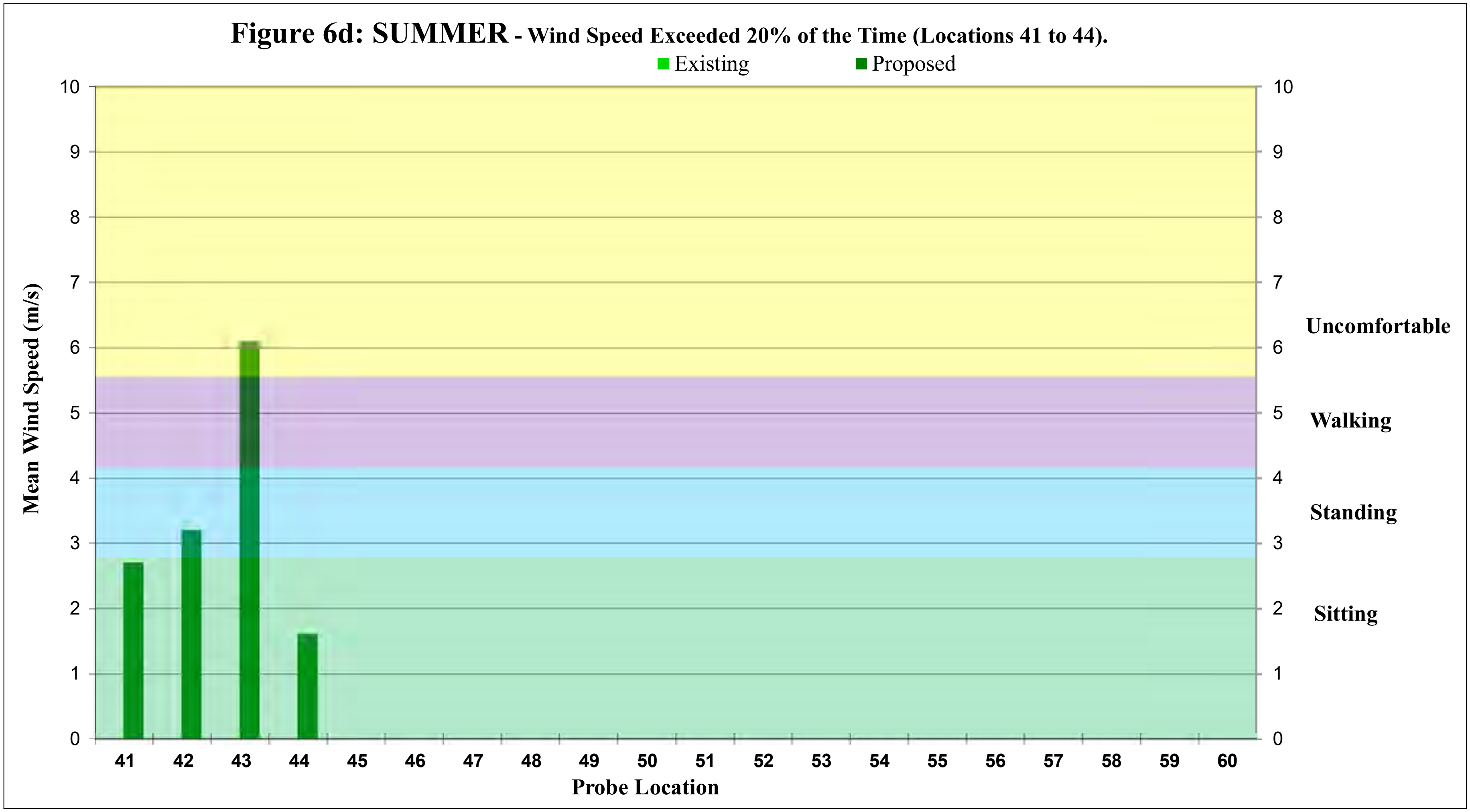
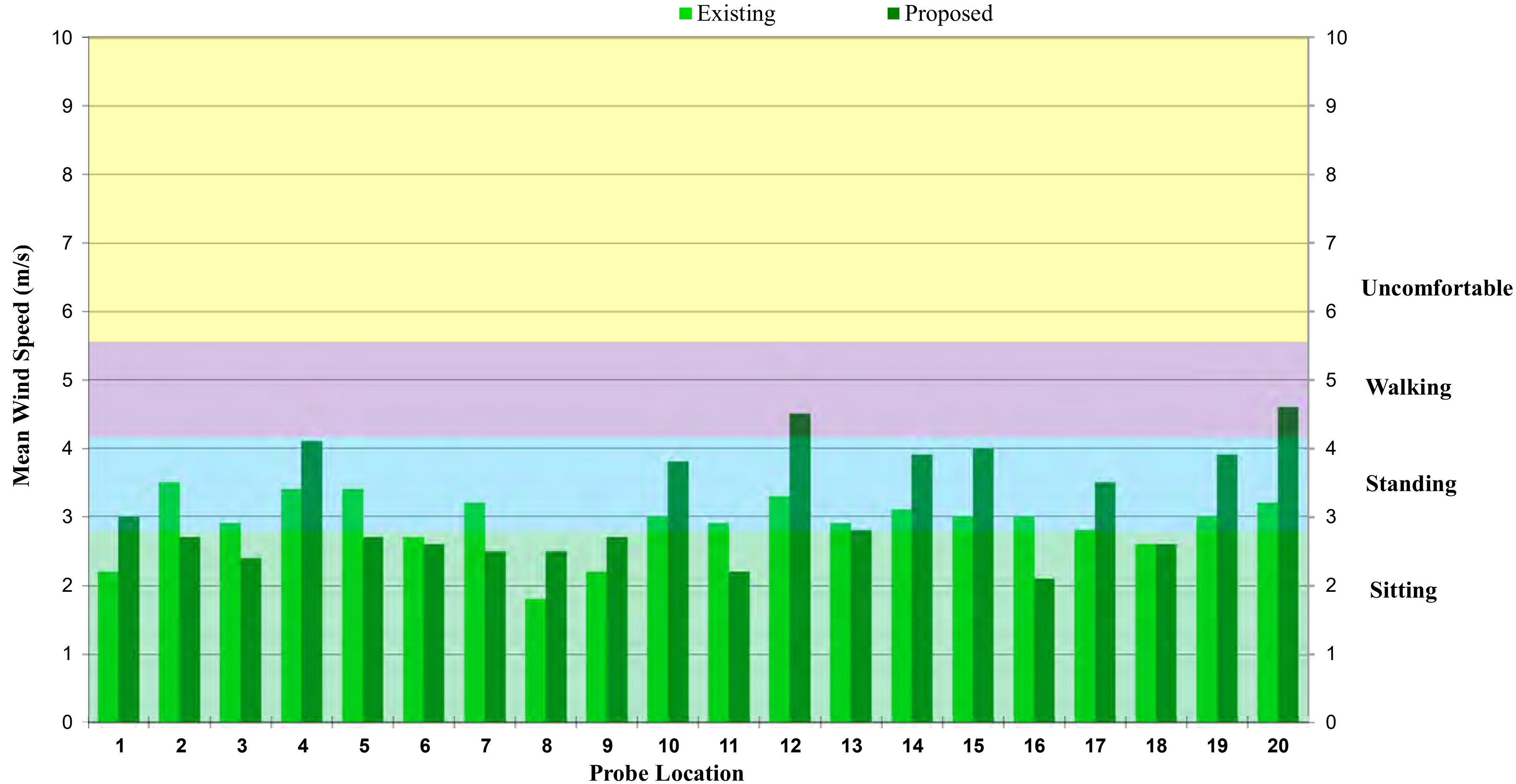
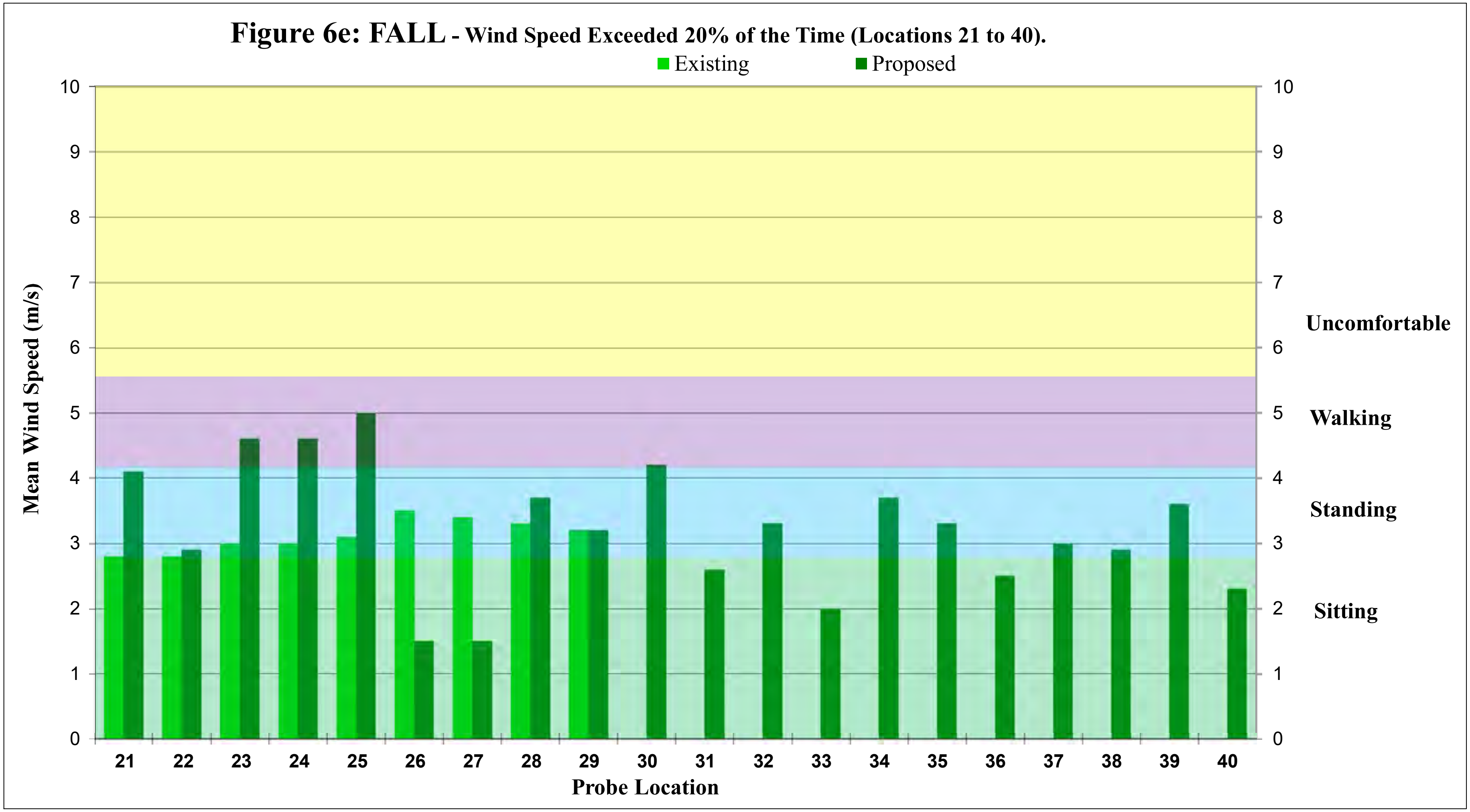


Figure 6d: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 41 to 44).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting

Figure 6e: FALL - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).





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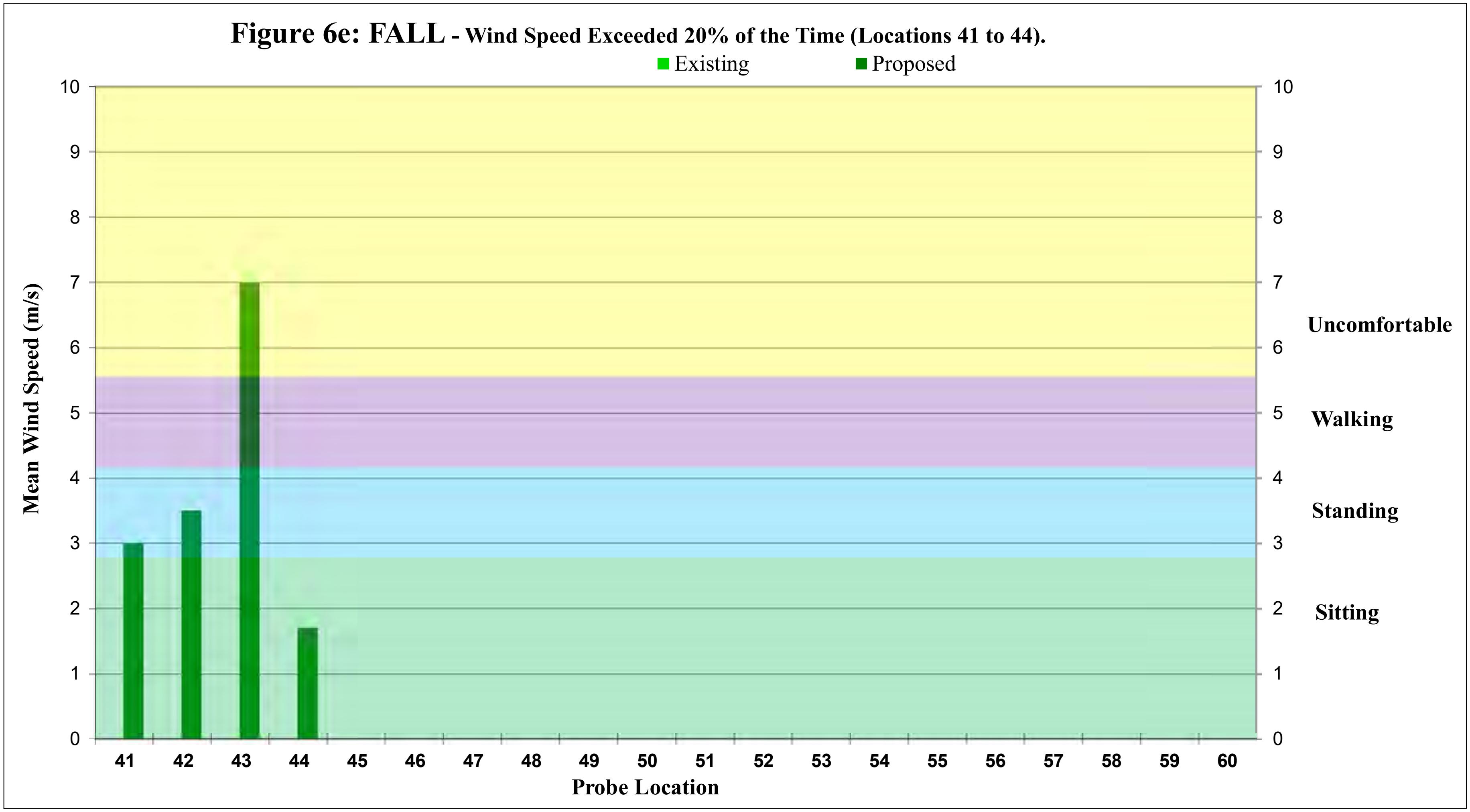

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Figure 7a: Pedestrian level wind velocity comfort categories.

Comfort Categories - Annual - Existing

Sitting Standing Walking Uncomfortable

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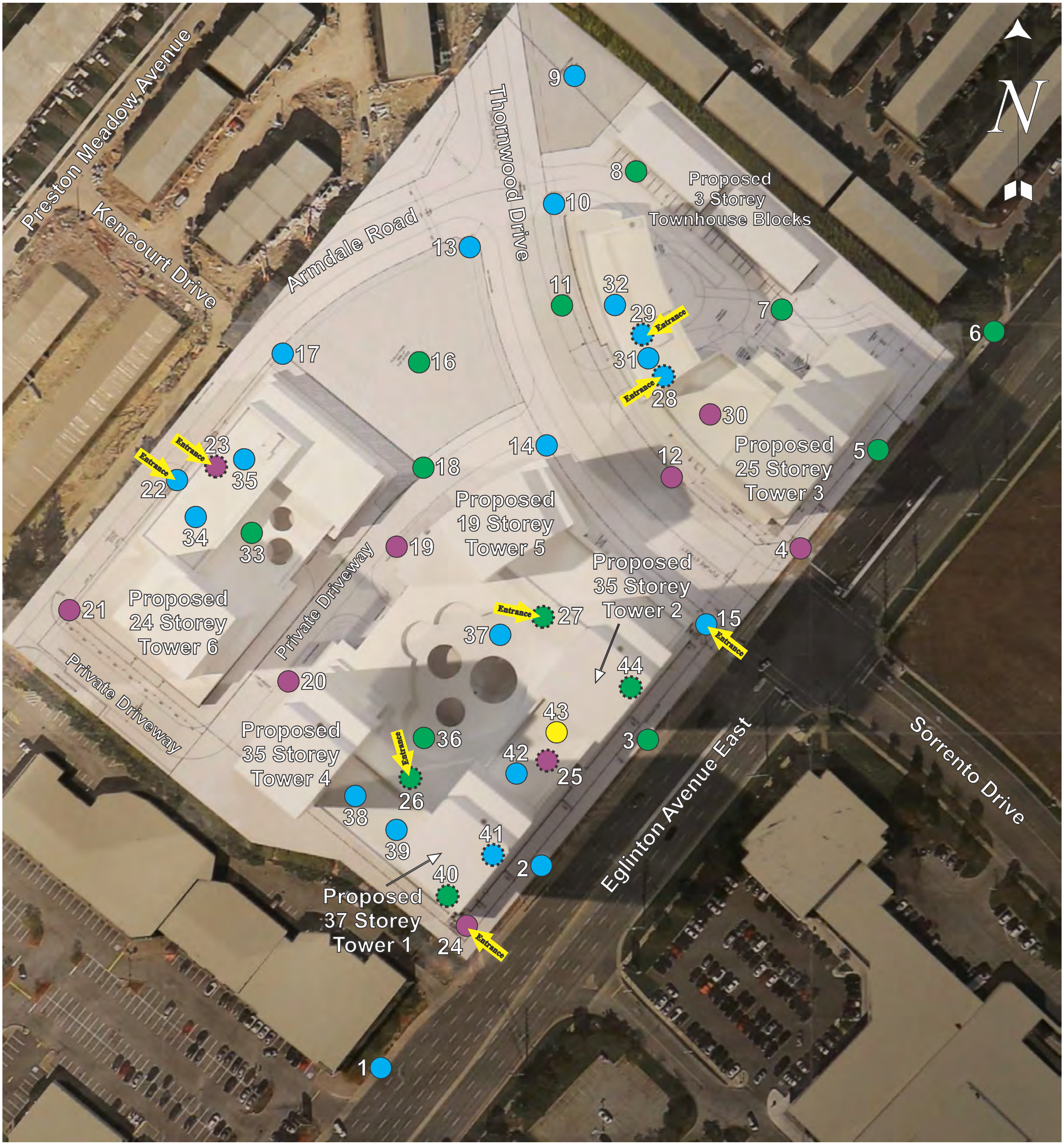
Figure 7b: Pedestrian level wind velocity comfort categories.



Comfort Categories - Annual - Proposed

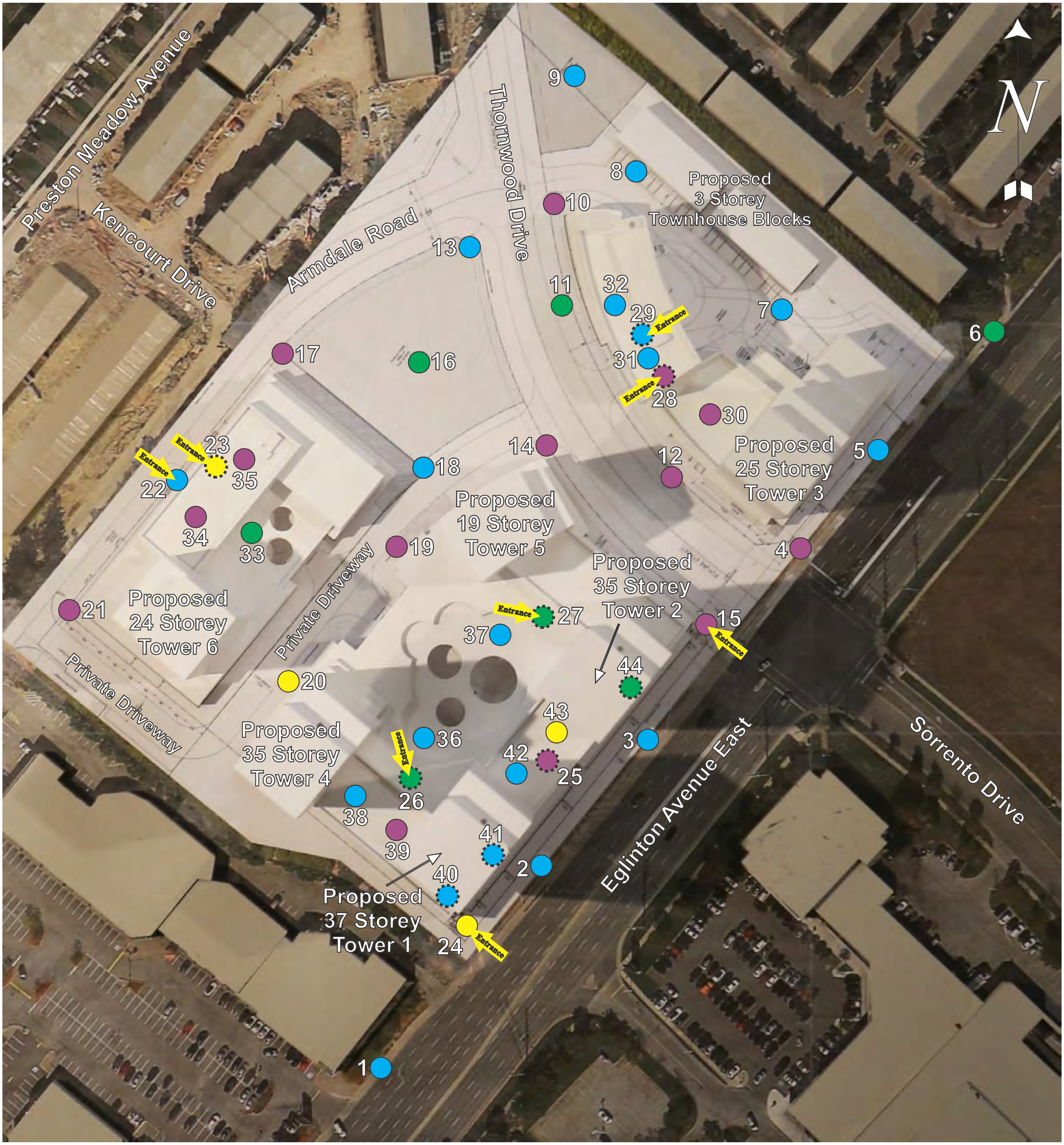
Sitting Standing Walking Uncomfortable

Figure 7c: Pedestrian level wind velocity comfort categories.

Comfort Categories - Winter - Existing

Sitting · Standing · Walking · Uncomfortable

Figure 7d: Pedestrian level wind velocity comfort categories.



Comfort Categories - Winter - Proposed

Sitting Standing Walking Uncomfortable

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Figure 7e: Pedestrian level wind velocity comfort categories.

Comfort Categories - Spring - Existing

Sitting Standing Walking Uncomfortable

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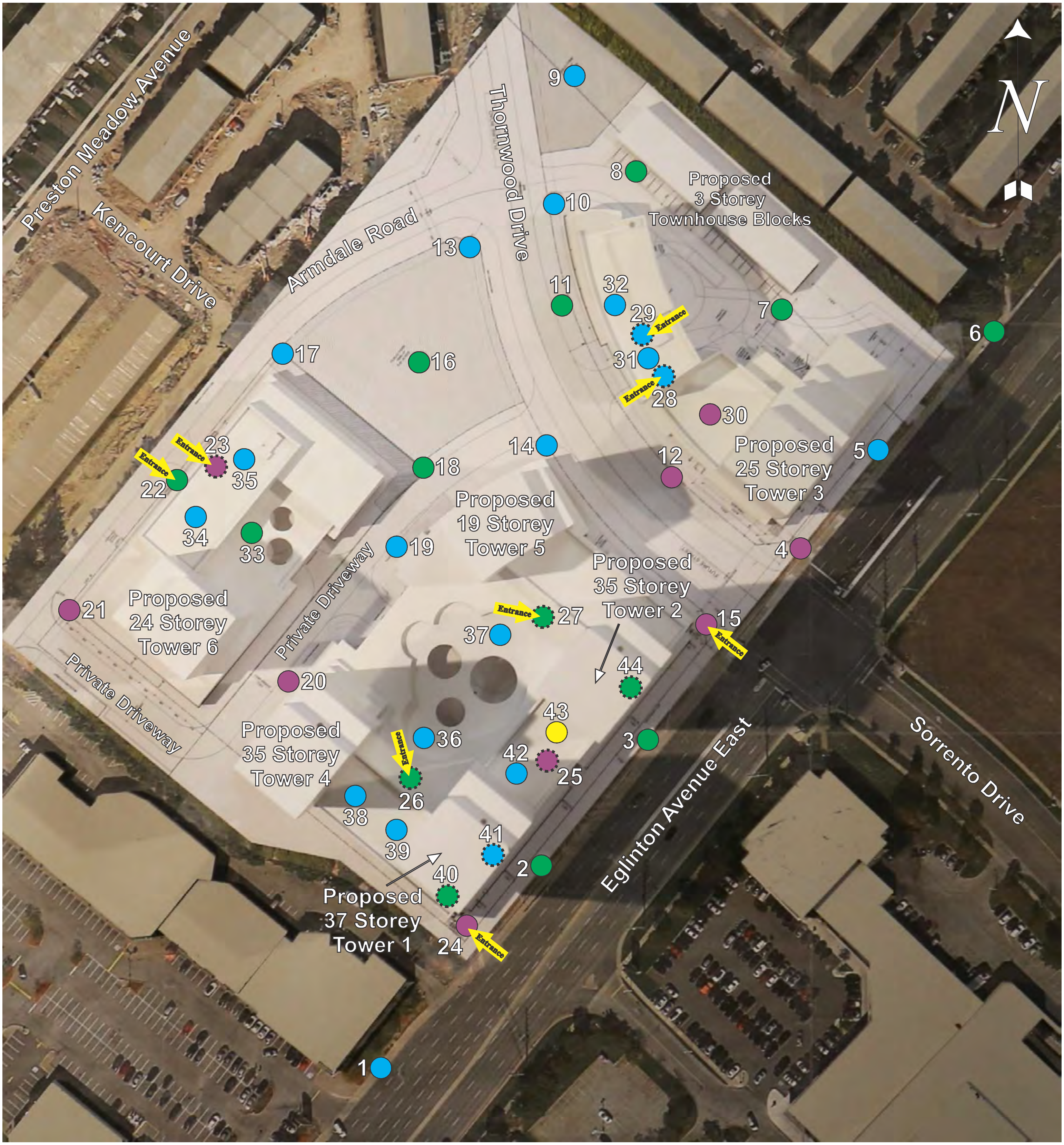
Figure 7f: Pedestrian level wind velocity comfort categories.



Comfort Categories - Spring - Proposed

Sitting Standing Walking Uncomfortable

Theakston Environmental

Figure 7g: Pedestrian level wind velocity comfort categories.

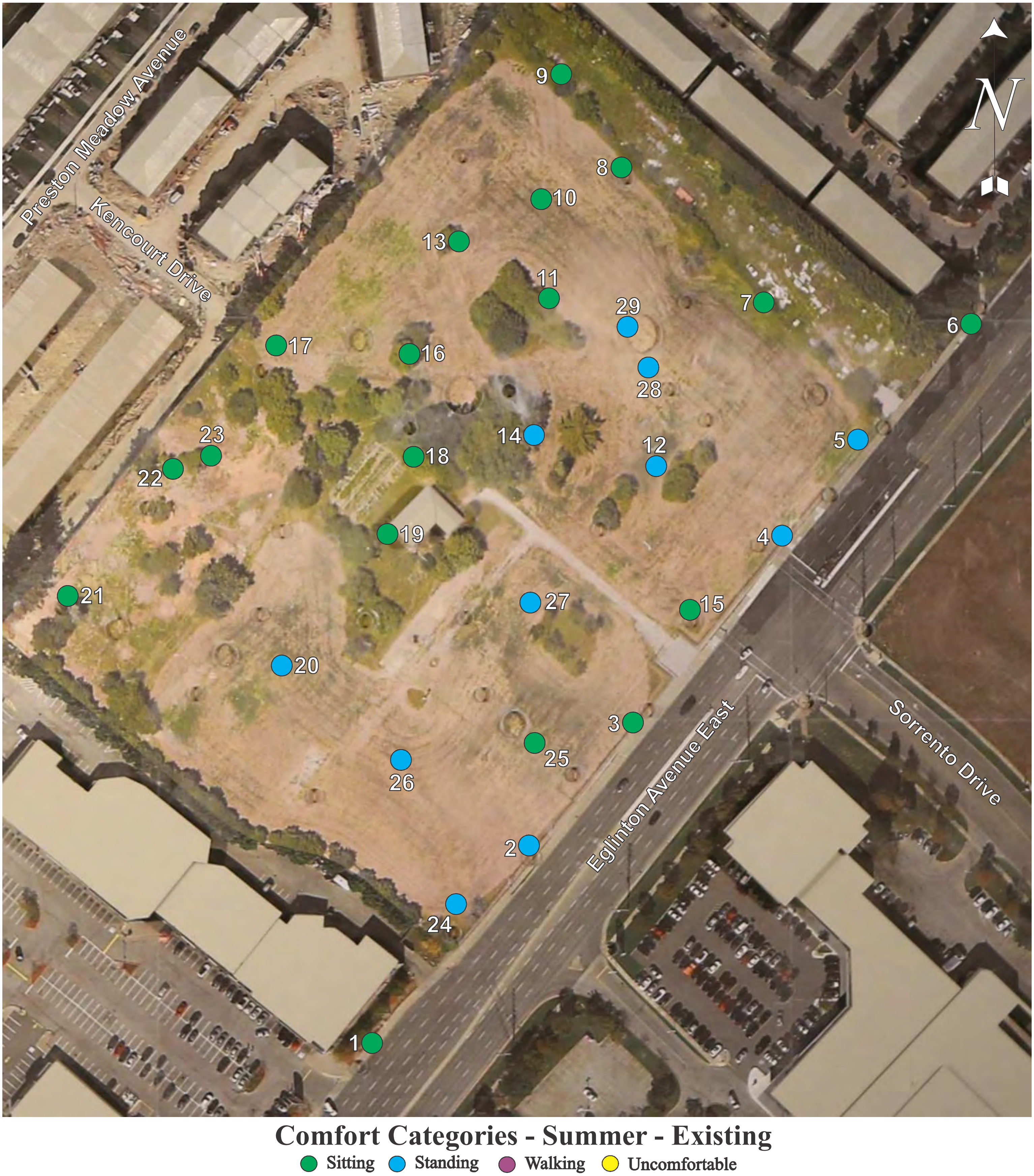
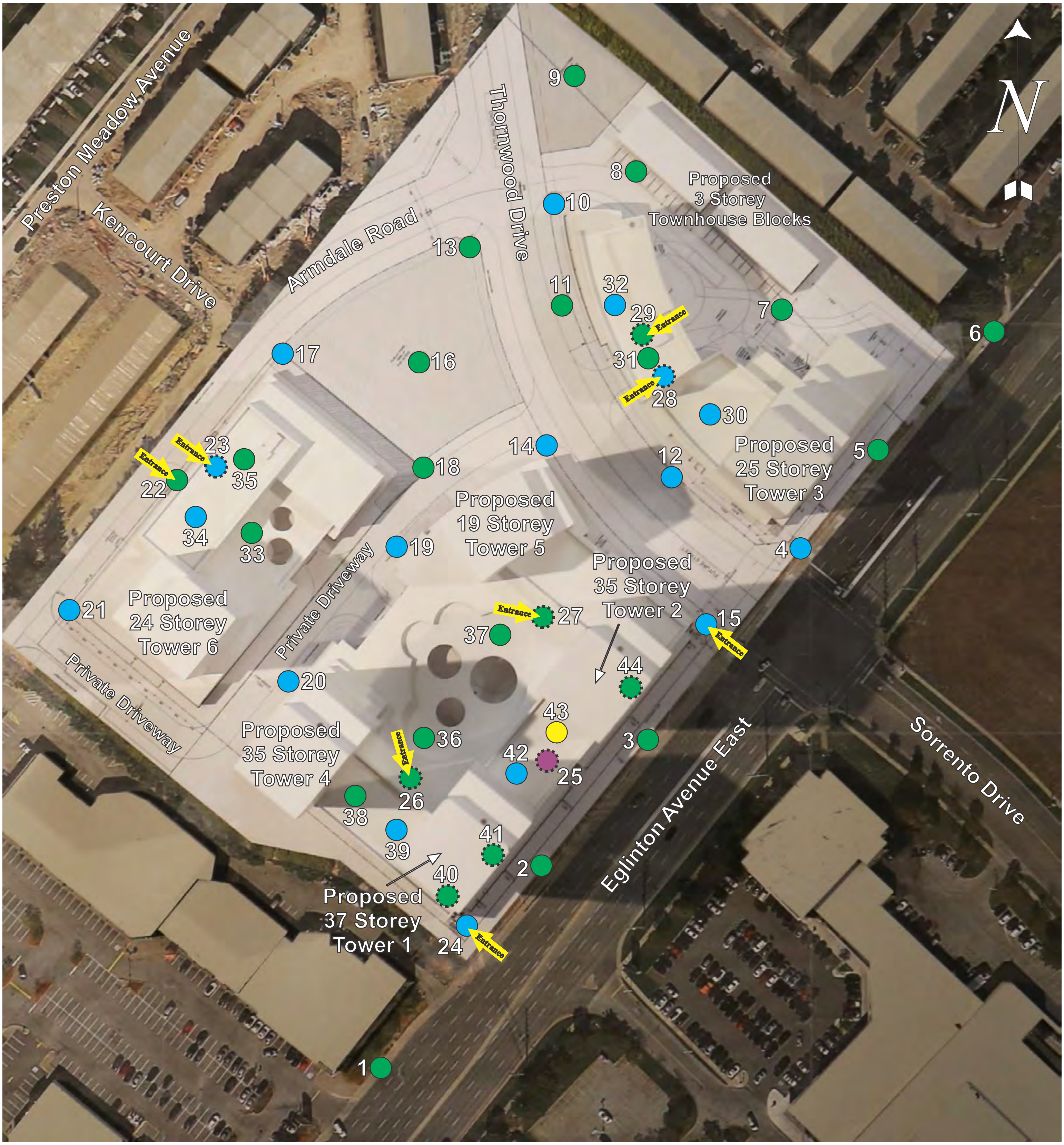


Figure 7h: Pedestrian level wind velocity comfort categories.



Comfort Categories - Summer - Proposed

Sitting Standing Walking Uncomfortable

Theakston
Environmental

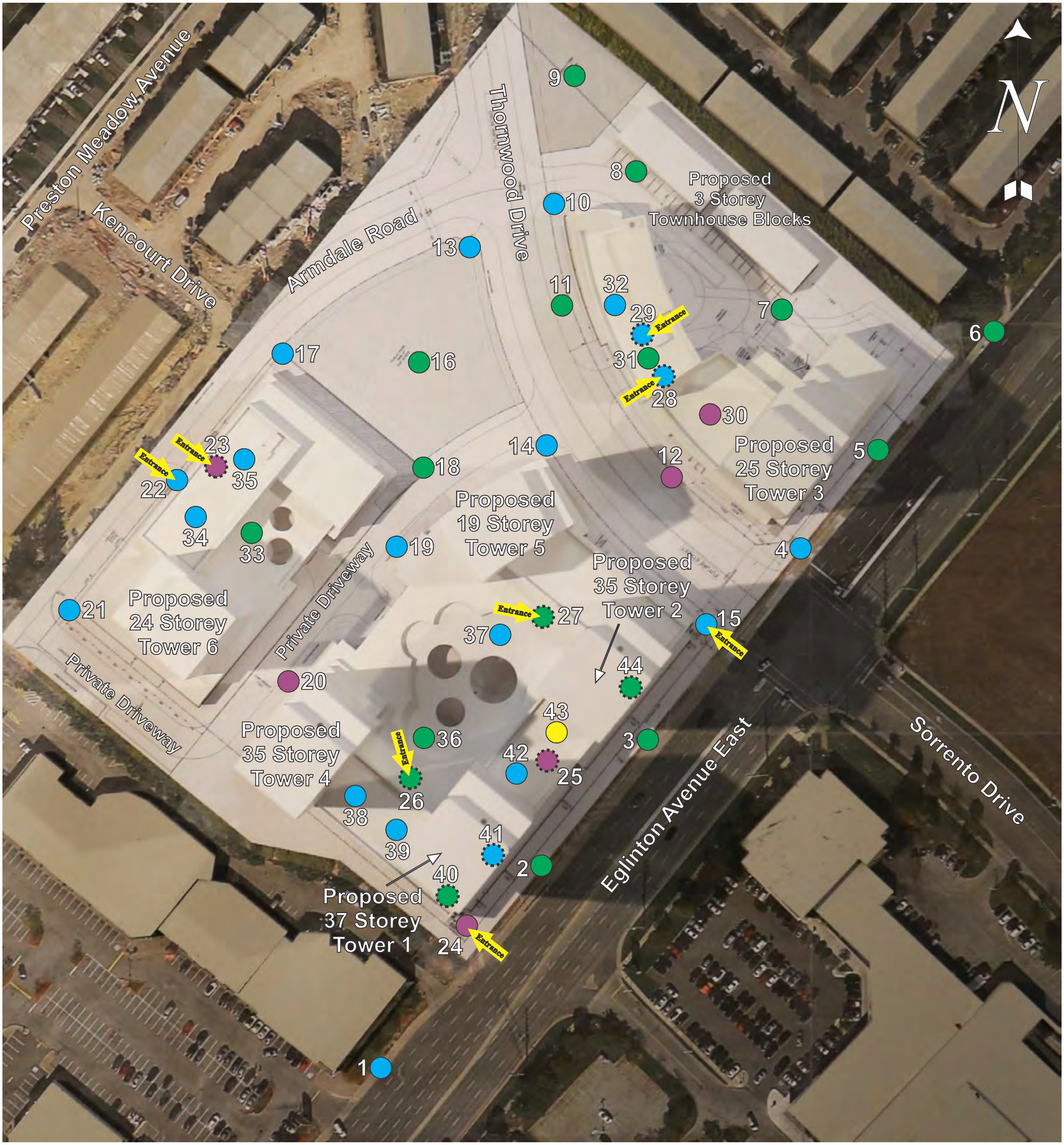
Figure 7i: Pedestrian level wind velocity comfort categories.

Comfort Categories - Fall - Existing

Sitting Standing Walking Uncomfortable

Theakston Environmental

Figure 7j: Pedestrian level wind velocity comfort categories.



Comfort Categories - Fall - Proposed

Sitting Standing Walking Uncomfortable

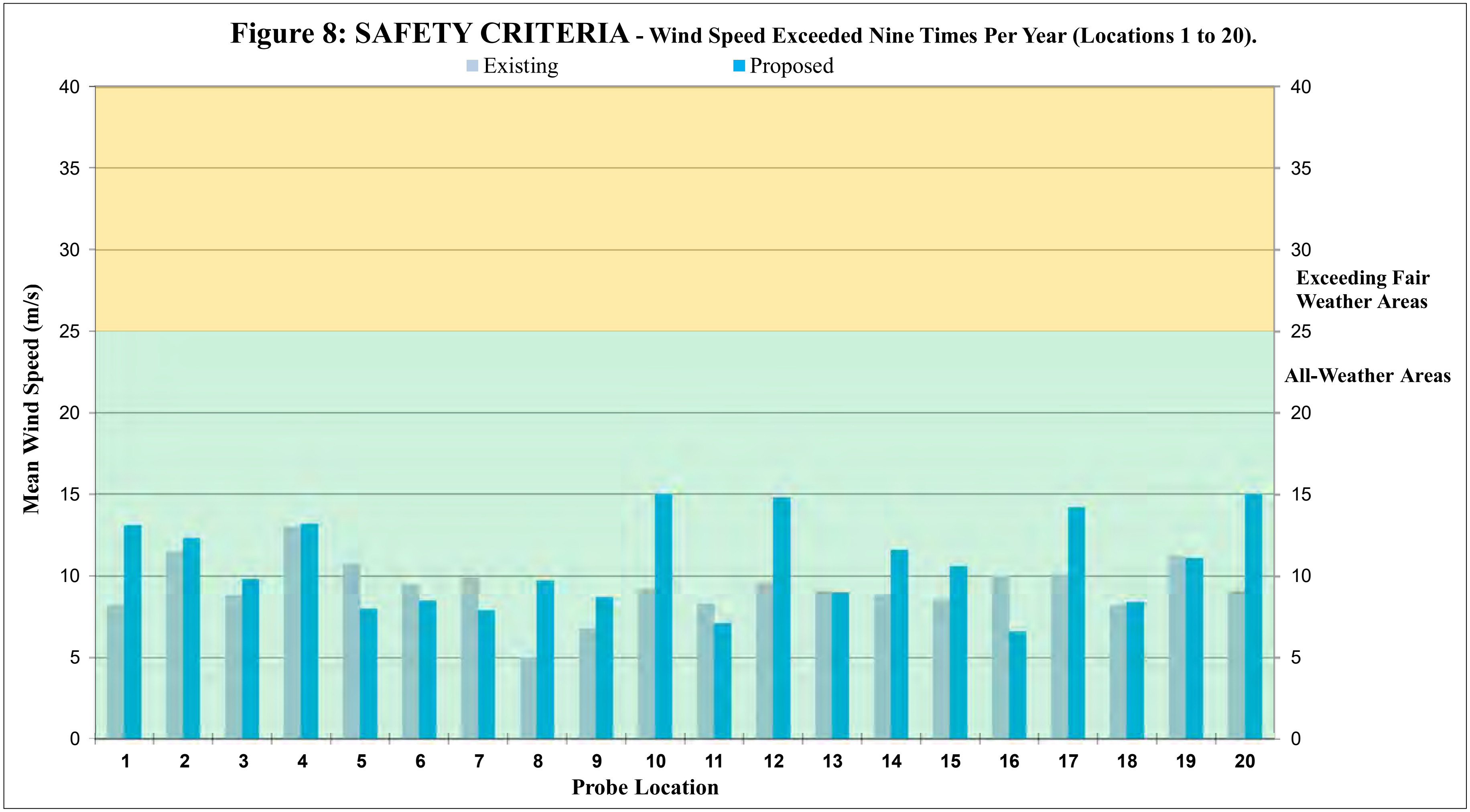


Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Nine Times Per Year (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Exceeding Fair Weather Areas
All-Weather Areas
0
5
10
15
20
25
30
35
40
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

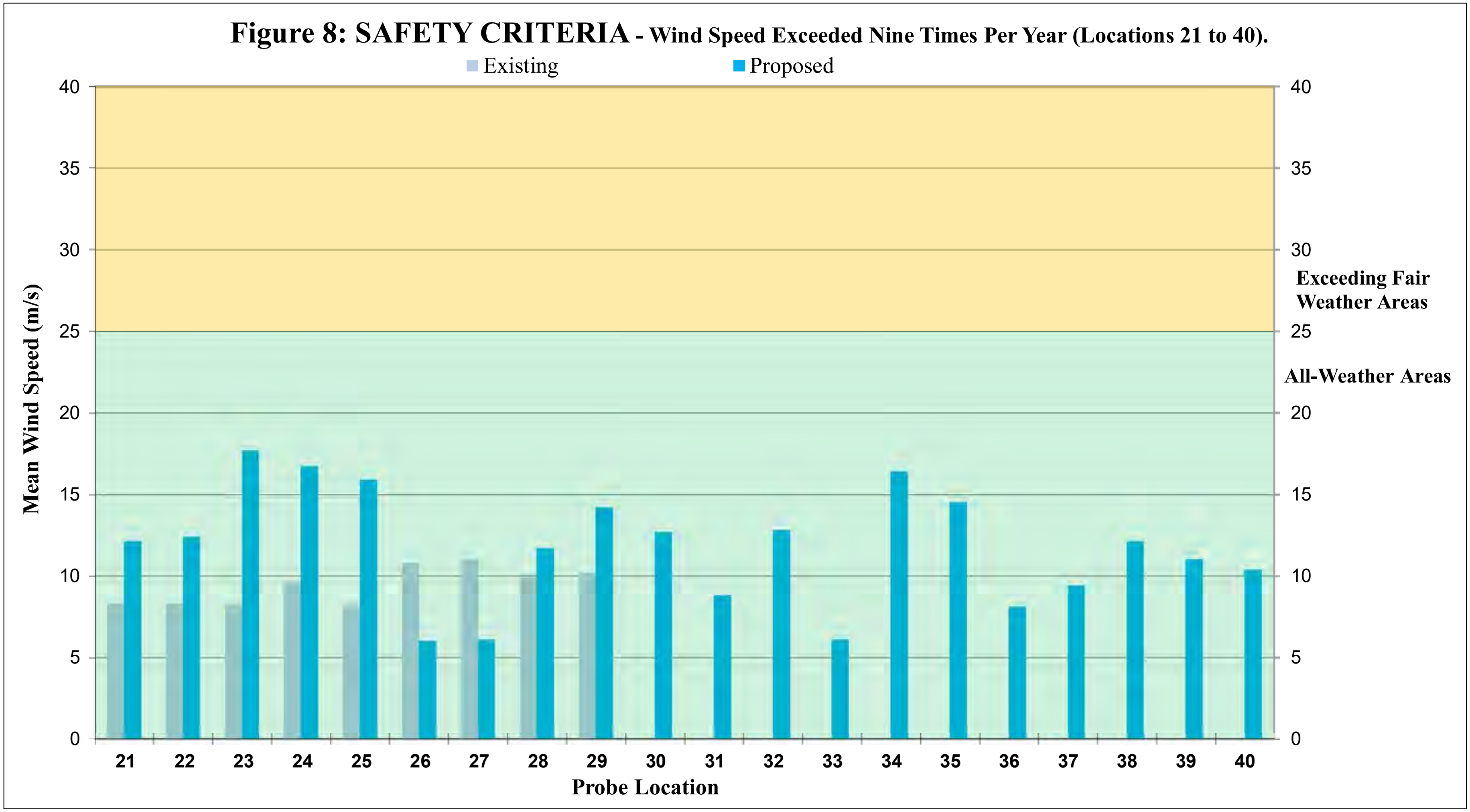


Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Nine Times Per Year (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (m/s)
0
5
10
15
20
25
30
35
40
Exceeding Fair Weather Areas
All-Weather Areas
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location

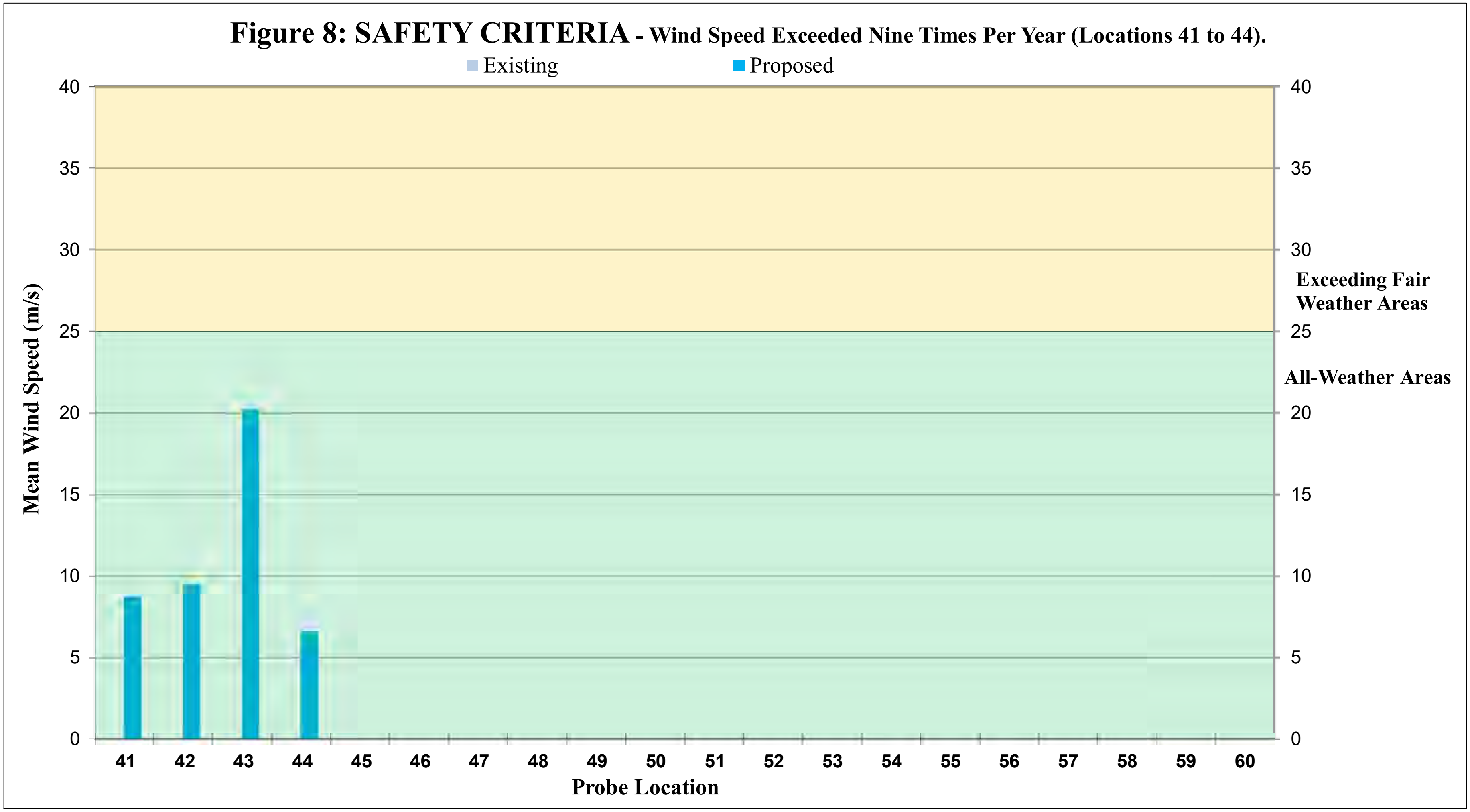


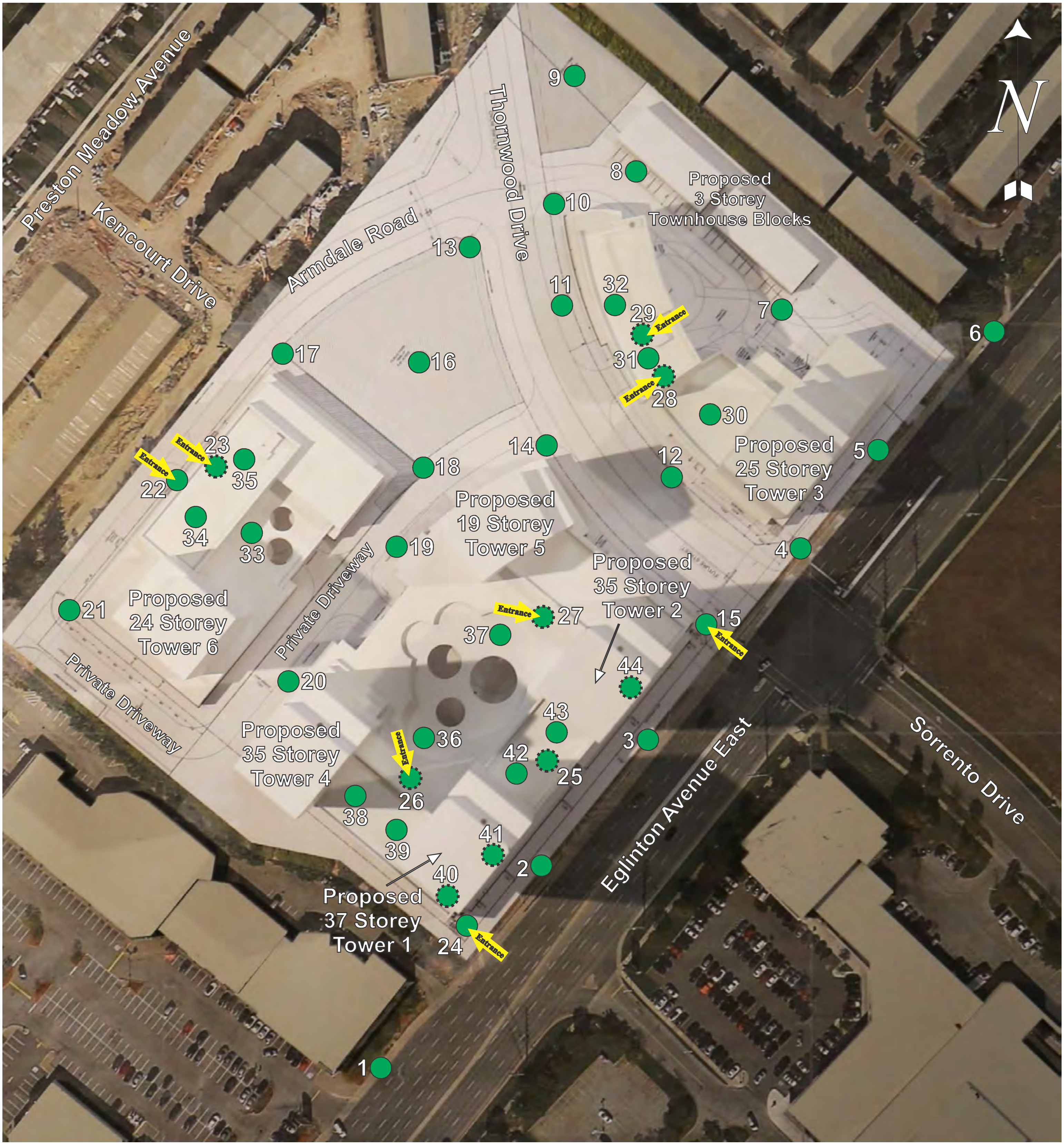
Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Nine Times Per Year (Locations 41 to 44).
Existing
Proposed
Mean Wind Speed (m/s)
Exceeding Fair Weather Areas
All-Weather Areas
Probe Location
0
5
10
15
20
25
30
35
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Figure 9a: Pedestrian level wind velocity safety criteria.

Safety Criteria - Existing

All-Weather Areas   Exceeding Fair-Weather Areas

Figure 9b: Pedestrian level wind velocity safety criteria.



Safety Criteria - Proposed

All-Weather Areas
Exceeding Fair-Weather Areas

7. APPENDIX

BACKGROUND AND THEORY OF WIND MOVEMENT

During the course of a modular analysis of an existing or proposed site, pertinent wind directions must be analysed with regard to the macroclimate and microclimate. In order for the results of the study to be valid, the effects of both climates must be modelled in test procedures.

Macroclimate

Wind velocity, frequency and directions are used in tests with models to establish part of the macroclimate. These variables are determined from meteorological data collected at the closest weather monitoring station. This information is used in the analysis of the site to establish upstream (approach) wind and weather conditions.

When evaluating approach wind velocities and characteristic profiles in the field it is necessary to evaluate certain boundary conditions. At the earth’s surface, "no slip" conditions require the wind speed to be zero. At an altitude of approximately one kilometre above the earth’s surface, the motion of the wind is governed by pressure distributions associated with large-scale weather systems. Consequently, these winds, known as "geostrophic" or "freestream" winds, are independent of the surface topography. In model simulation, as in the field, the area of concern is the boundary layer between the earth's surface and the geostrophic winds. The term boundary layer is used to describe the velocity profile of wind currents as they increase from zero to the geostrophic velocity.

The approach boundary layer profile is affected by specific surface topography upstream of the test site. Over relatively rough terrain (urban) the boundary layer is thicker and the wind speed increases rather slowly with height. The opposite is true over open terrain (rural). The following power law equation is used to represent the mean velocity profile for any given topographic condition:

$$\frac{U}{U_F} = \left(\frac{z}{z_F}\right)^a$$

where U = wind velocity (m/s) at height z (m)
a = power law exponent
and subscript $_F$ refers to freestream conditions

Typical values for a and z_F are summarized below:

Terrain	a	z_F (m)
Rural	0.14 - 0.17	260 - 300
Suburban	0.20 - 0.28	300 - 420
Urban	0.28 - 0.40	420 - 550

Wind data is recorded at meteorological stations at a height z_{ref} , usually equal to about 10m above grade. This historical mean wind velocity and frequency data is often presented in the form of a wind rose. The mean wind velocity at z_{ref} , along with the appropriate constants based on terrain type, are used to determine the value for U_F , completing the definition of the boundary layer profile specific to the site. The following Figure shows representations of the boundary layer profile for each of the above terrain conditions:

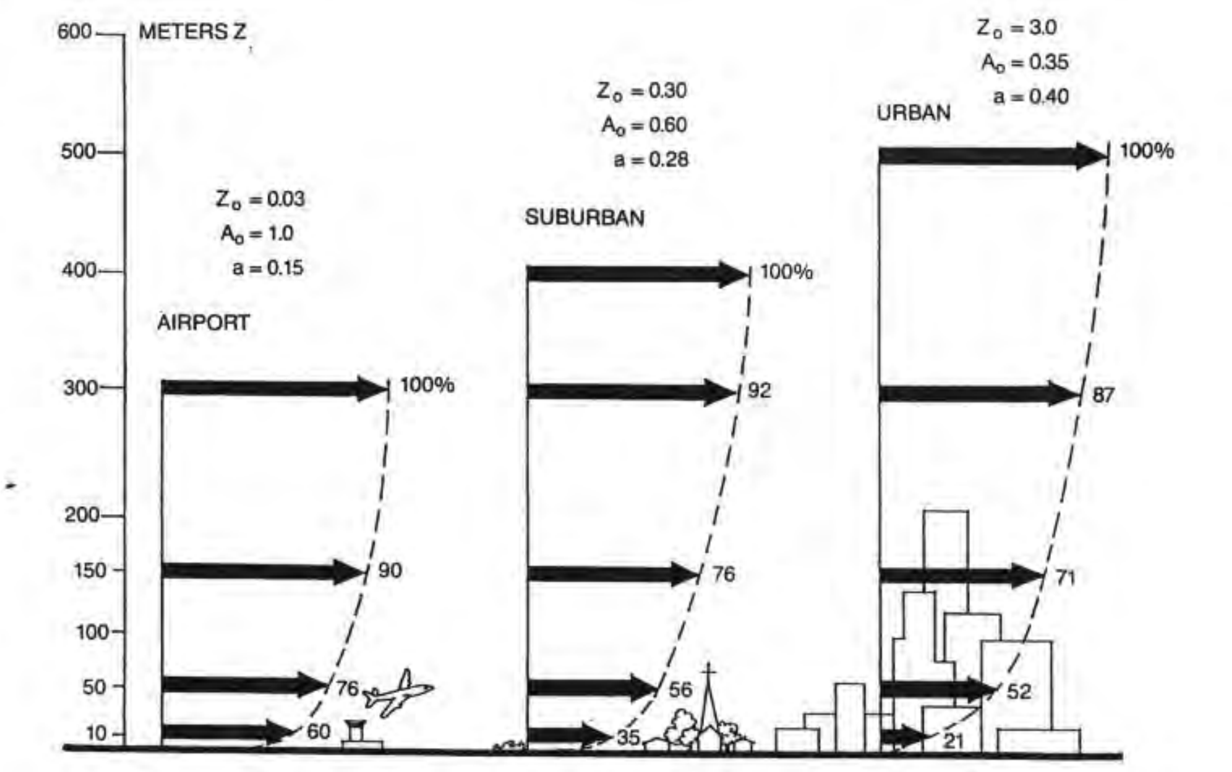


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

For the above velocity profiles, ground level velocities at a height of $z = 2m$, for an urban macroclimate are approximately 52% of the mean values recorded at the meteorological station at a height equal to $z_{ref} = 10m$. For suburban and rural conditions, the values are 63% and 78% respectively. Thus, for a given wind speed at z_{ref} open terrain or fields (rural) will experience significantly higher ground level wind velocities than suburban or urban areas.

When a boundary layer wind flows over one terrain onto another, the boundary layer profile shape rapidly changes to that dictated by the new terrain. If the preceding wind flow is over rough suburban terrain and an open area is encountered a rapid increase in ground level winds will be realized. A similar effect will occur when large low-density residential areas are demolished to accommodate high-rise developments. The transitional open area will experience significantly higher pedestrian level winds than the previous suburban setting. Once the high-rise development is established, ground level winds will moderate with localized areas of higher pedestrian level winds likely to occur. Pedestrian level wind velocities respond to orientation and shape of the development and if the site is not appropriately engineered or mitigated, pedestrian level wind may be problematic.

Microclimate

The specific wind conditions related to the study site are known as the microclimate, which are dictated mainly by the following factors:

- The orientation and conformation of buildings within the vicinity of the site.
- The surrounding contours and pertinent landscape features.

The microclimate establishes the effect that surrounding buildings or landscape features have on the subject building and the effect the subject building has on the surrounds. For the majority of urban test sites the proper microclimate can be established by modelling an area of 300*m* in radius around the subject building. If extremely tall buildings are present then the study area must be larger, and if the building elevations are on the order of a few floors, smaller areas will suffice to establish the required microclimate.

General Wind Flow Phenomena

Wind flow across undulating terrain contains parallel streamlines with the lowest streamline adjacent to the surface. These conditions continue until the streamlines approach vertical objects. When this occurs there is a general movement of the streamlines upward ("Wind Velocity Gradient") and as they reach the top of the objects turbulence is generated on the lee side. This is one of the reasons for unexpected high wind velocities as this turbulent action moves to the base of the objects on the lee side.

Other fluid action occurs through narrow gaps between buildings (Venturi Action) and at sharp edges of a building or other vertical objects (Scour Action). These conditions are predictable at selected locations but do not conform to a set direction of wind as described by a macroclimate condition. In fact, the orientation and conformation of buildings, streets and landscaping establish a microclimate.

Because of the "Wind Velocity Gradient" phenomena, there is a "downwash" of wind at the face of buildings and this effect is felt at the pedestrian level. It may be experienced as high gusty winds or drifting snow. These effects can be obviated by windbreak devices on the windward side or by canopies over windows and doors on the lee side of the building.

The intersection of two streets or pedestrian walkways have funnelling effects of wind currents from any one of the four directions and is particularly severe at corners if the buildings project to the street line or are close to walkways.

Some high-rise buildings have gust effects as the wind velocities are generated suddenly due to the orientation and conformation of the site. Since wind velocities are the result of energy induced wind currents the solution to most problems is to reduce the wind energy at selected locations by carefully designed windbreak devices, often landscaping, to blend with the surrounds.

The Beaufort Scale is often used as a numerical relationship to wind speed based upon an observation of the effects of wind. Rear-Admiral Sir Francis Beaufort, commander of the Royal Navy, developed the wind force scale in 1805, and by 1838 the Beaufort wind force scale was made mandatory for log entries in ships of the Royal Navy. The original scale was an association of integers from 0 to 12, with a description of the effect of wind on the behaviour of a full-rigged man-of-war. The lower Beaufort numbers described wind in terms of ship speed, mid-range numbers were related to her sail carrying ability and upper numbers were in terms of survival. The Beaufort Scale was adopted in 1874 by the International Meteorological Committee for international use in weather telegraphy and, with the advent of anemometers, the scale was eventually adopted for meteorological purposes. Eventually, a uniform set of equivalents that non-mariners could relate to was developed, and by 1955, wind velocities in knots had replaced Beaufort numbers on weather maps. While the Beaufort Scale lost ground to technology, there remains the need to relate wind speed to observable wind effects and the Beaufort Scale remains a useful tool.

Abbreviated Beaufort Scale

Beaufort Number	Description	Wind Speed			Observations
		km/h	*m/s*	h=2*m* for Urban *m/s*	
2	Slight Breeze	6-11	1.6-3.3	< ~2	Tree leaves rustle; flags wave slightly; vanes show wind direction; small wavelets or scale waves.
3	Gentle Breeze	12-19	3.4-5.4	< ~3	Leaves and twigs in constant motion; small flags extended; long unbreaking waves.
4	Moderate Breeze	20-28	5.5-7.9	< ~4	Small branches move; flags flap; waves with whitecaps.
5	Fresh Breeze	29-38	8.0-10.7	< ~6	Small trees sway; flags flap and ripple; moderate waves with many whitecaps.
6	Strong Breeze	39-49	10.8-13.8	< ~8	Large branches sway; umbrellas used with difficulty; flags beat and pop; larger waves with regular whitecaps.
7	Moderate Gale	50-61	13.9-17.1	< ~10	Sea heaps up, white foam streaks; whole trees sway; difficult to walk; large waves.
8	Fresh Gale	62-74	17.2-20.7	> ~10	Twigs break off trees; moderately high sea with blowing foam.
9	Strong Gale	75-88	20.8-24.4		Branches break off trees; tiles blown from roofs; high crested waves.

Wind speeds indicated above, in *km/h* and *m/s*, are at a reference height of 10 metres, as are the wind speeds indicated on the Figure 5 wind roses. The mean wind speeds at pedestrian level, for an urban climate, would be approximately 56% of these values. The 3rd column for wind speed is shown for reference, at a height of 2*m*, in an urban setting. The approximate Comfort Category Colours are shown above. The relationship between wind speed and height relative to terrain is discussed in the appendices.

Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

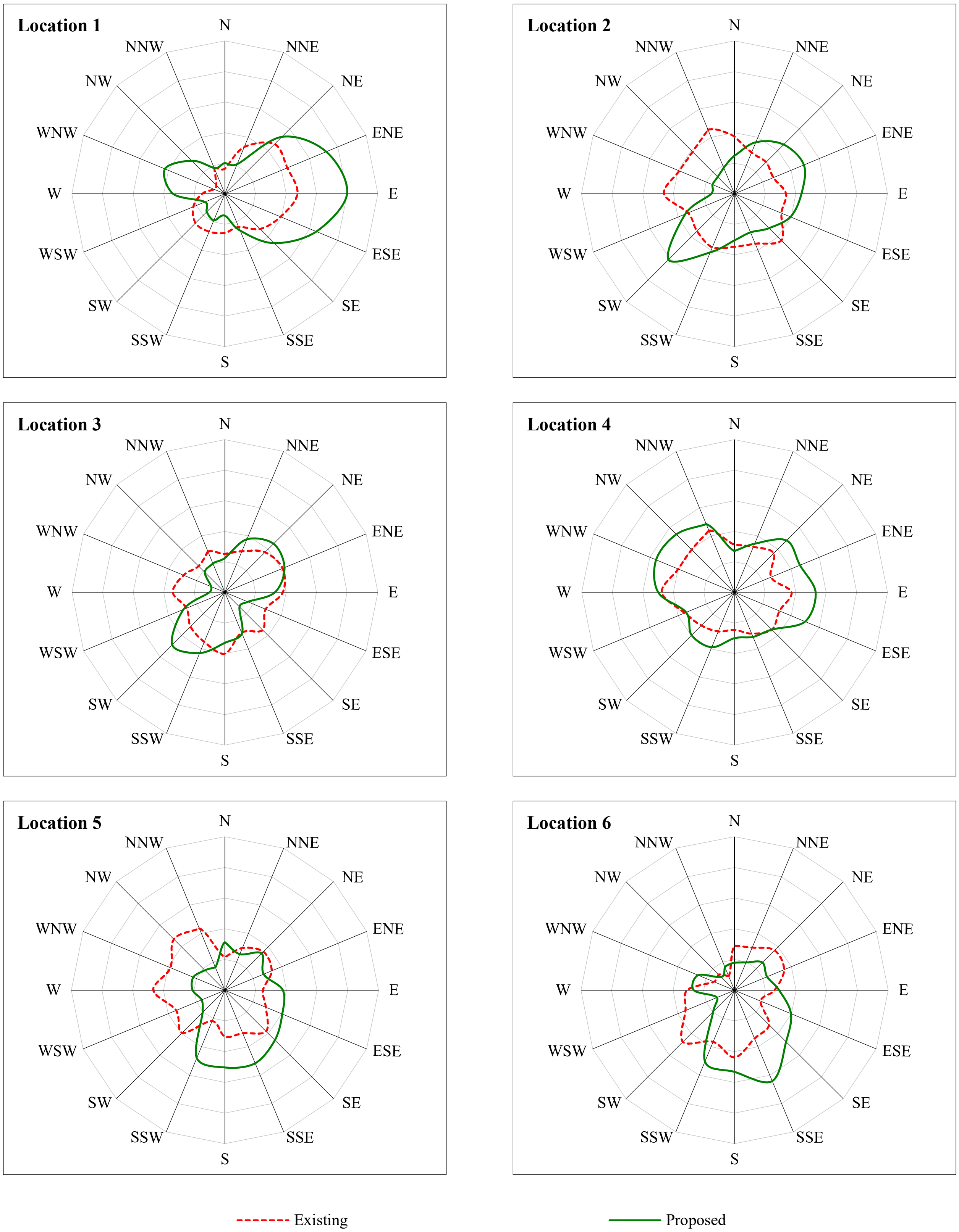
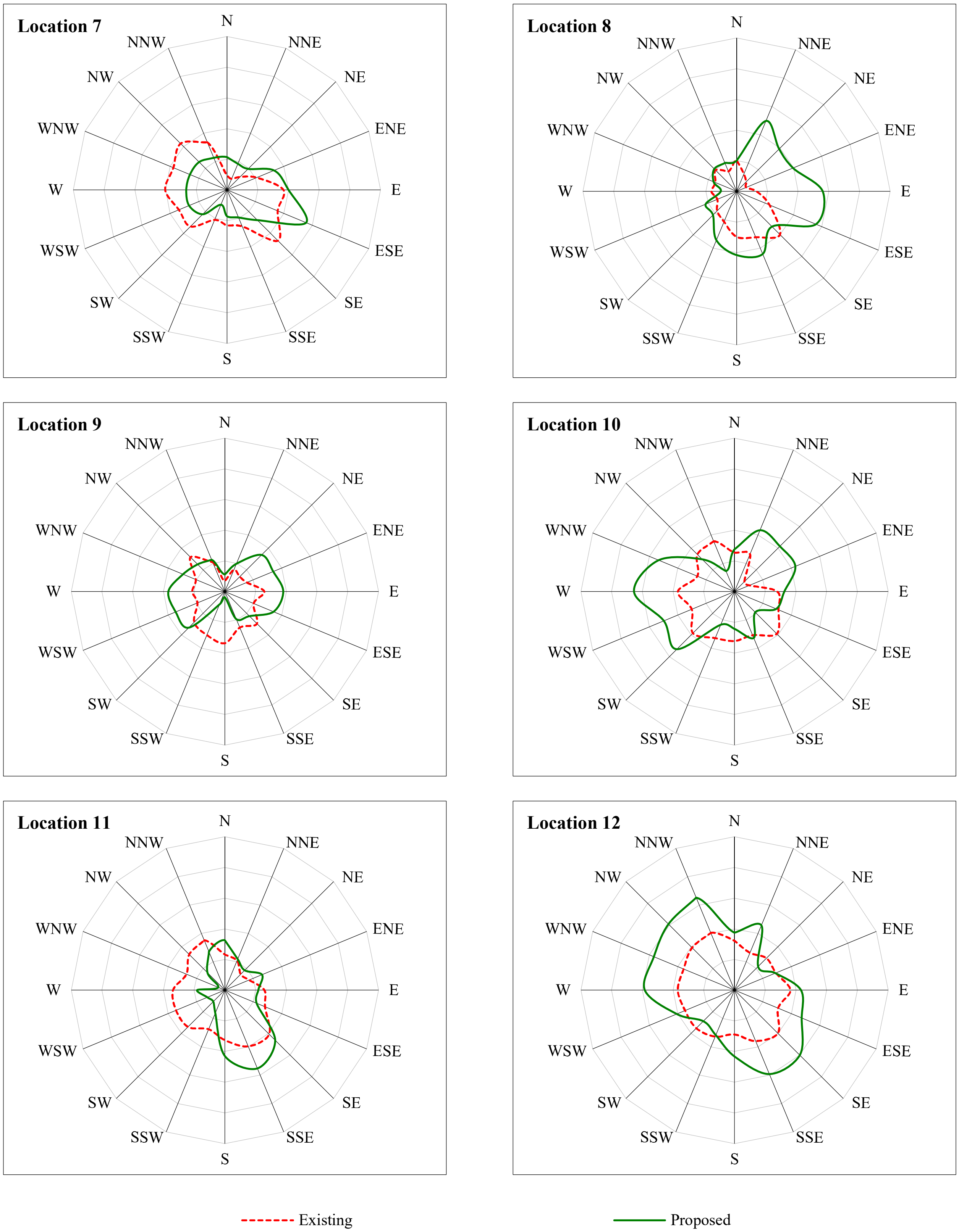


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.



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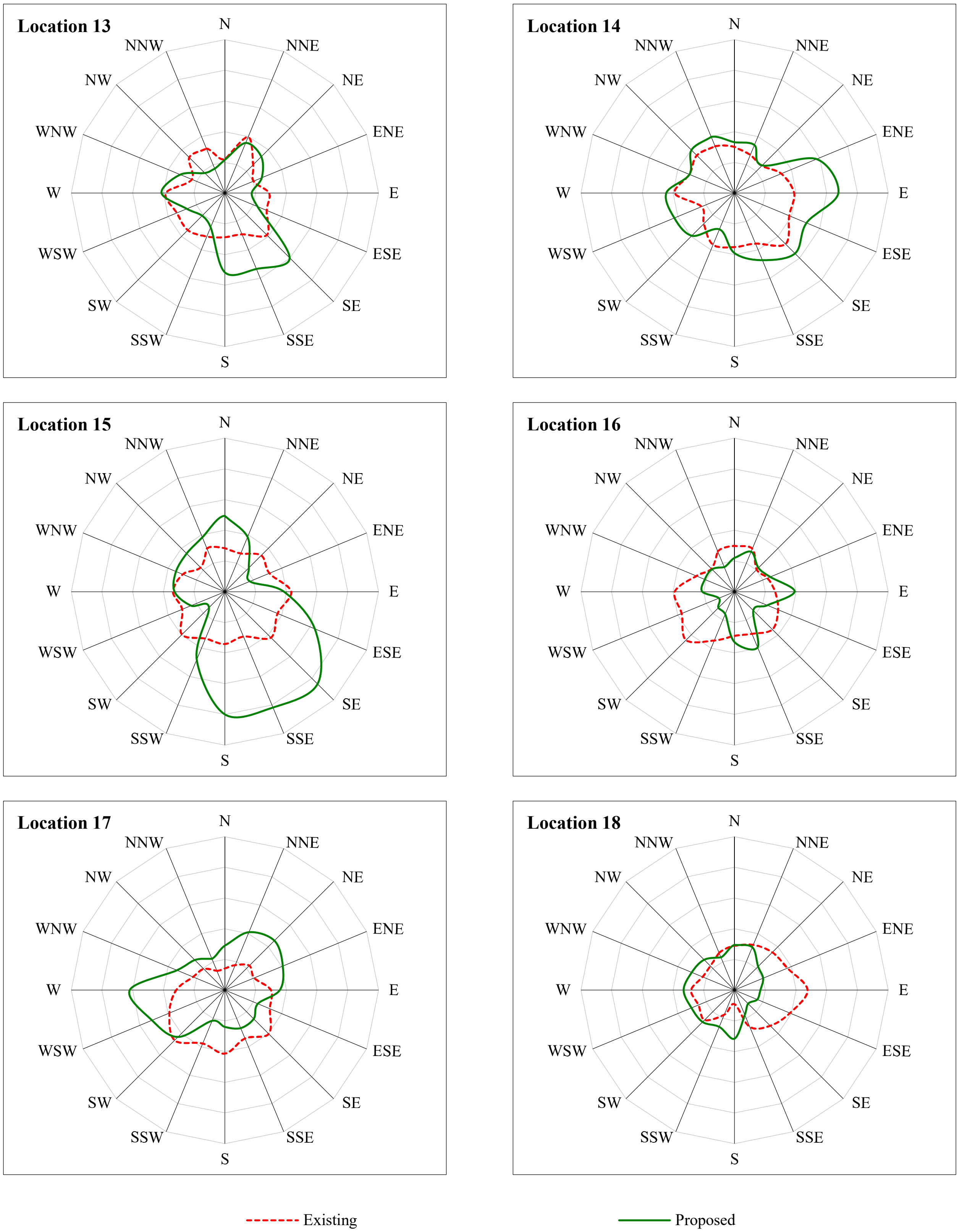

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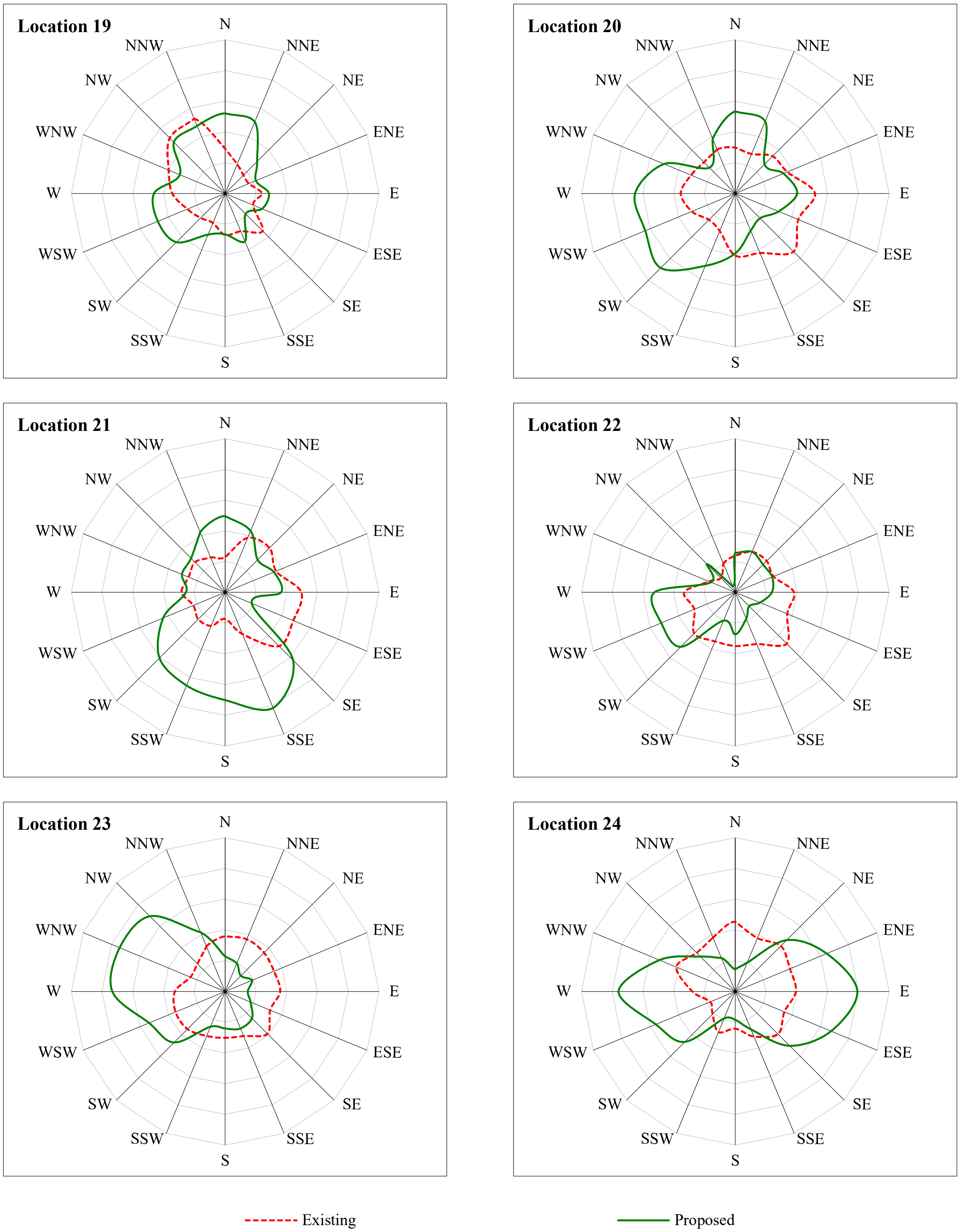

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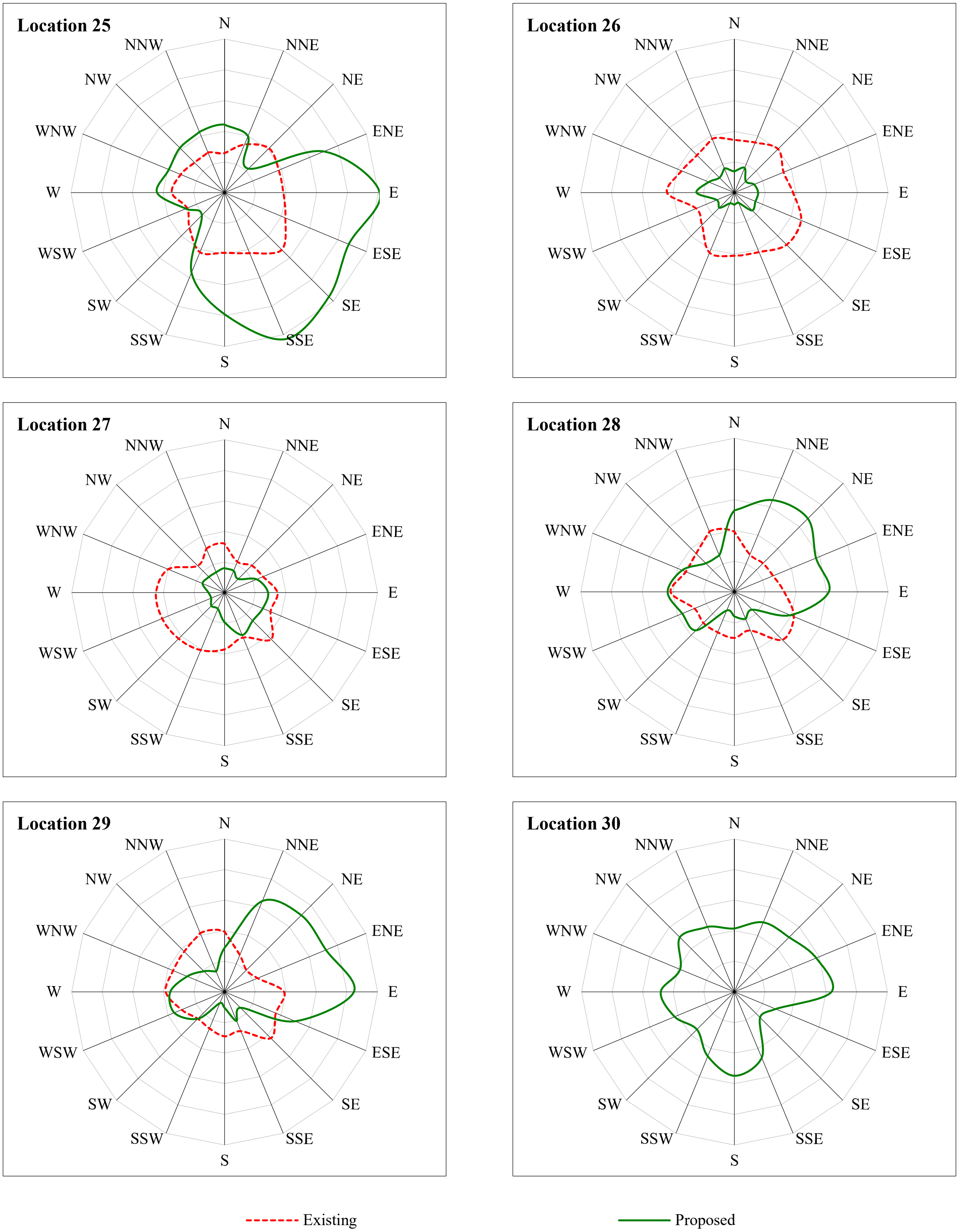

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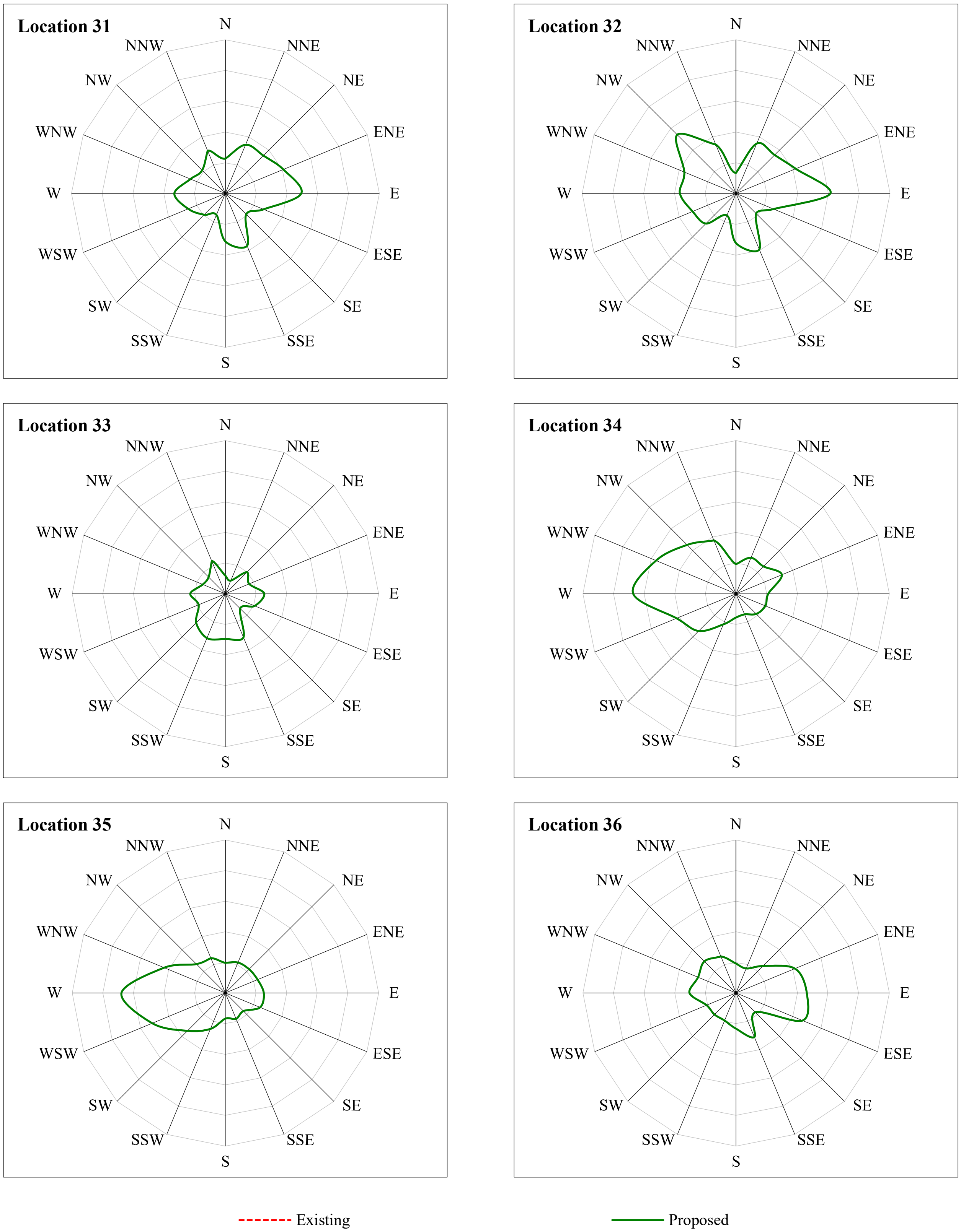

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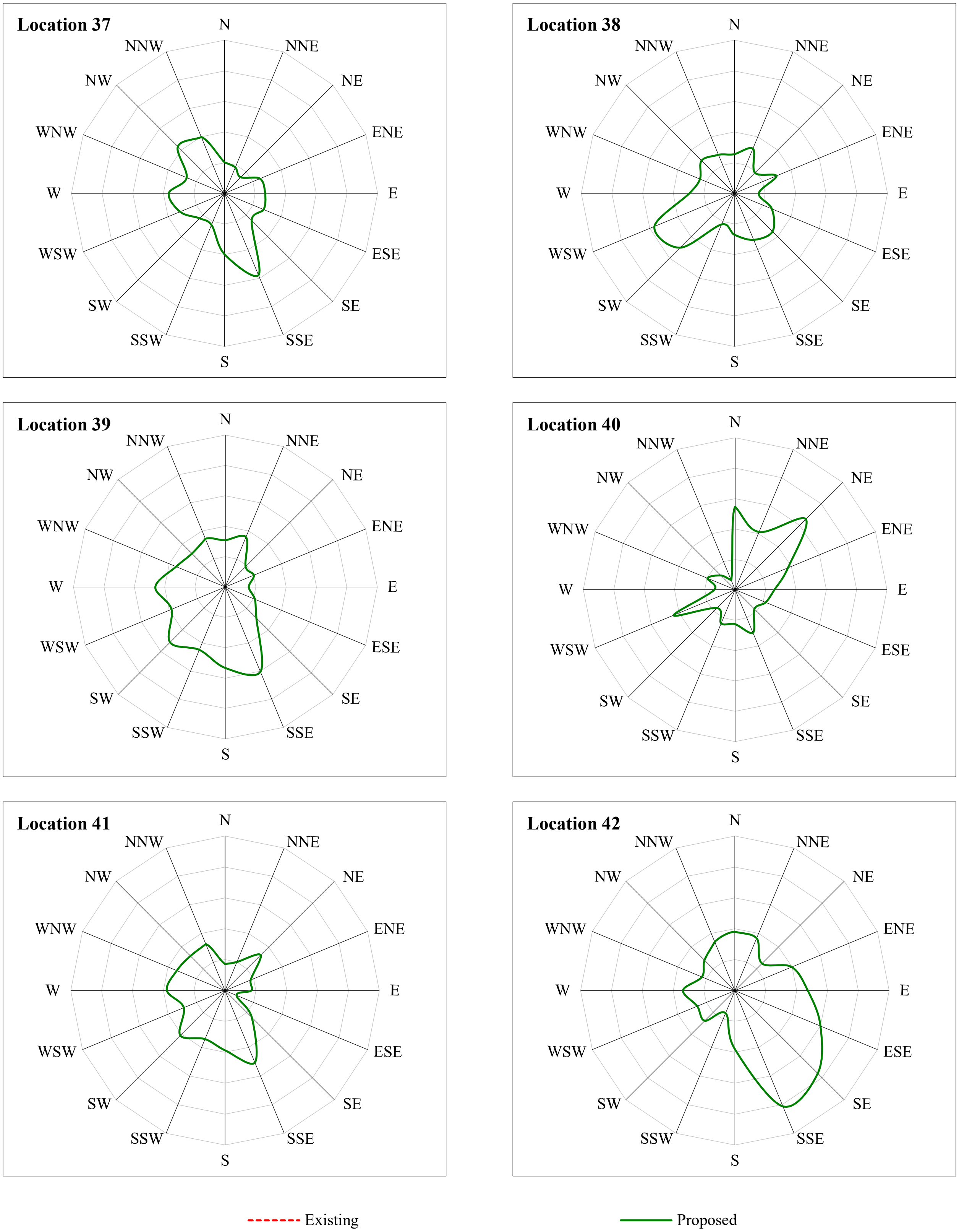

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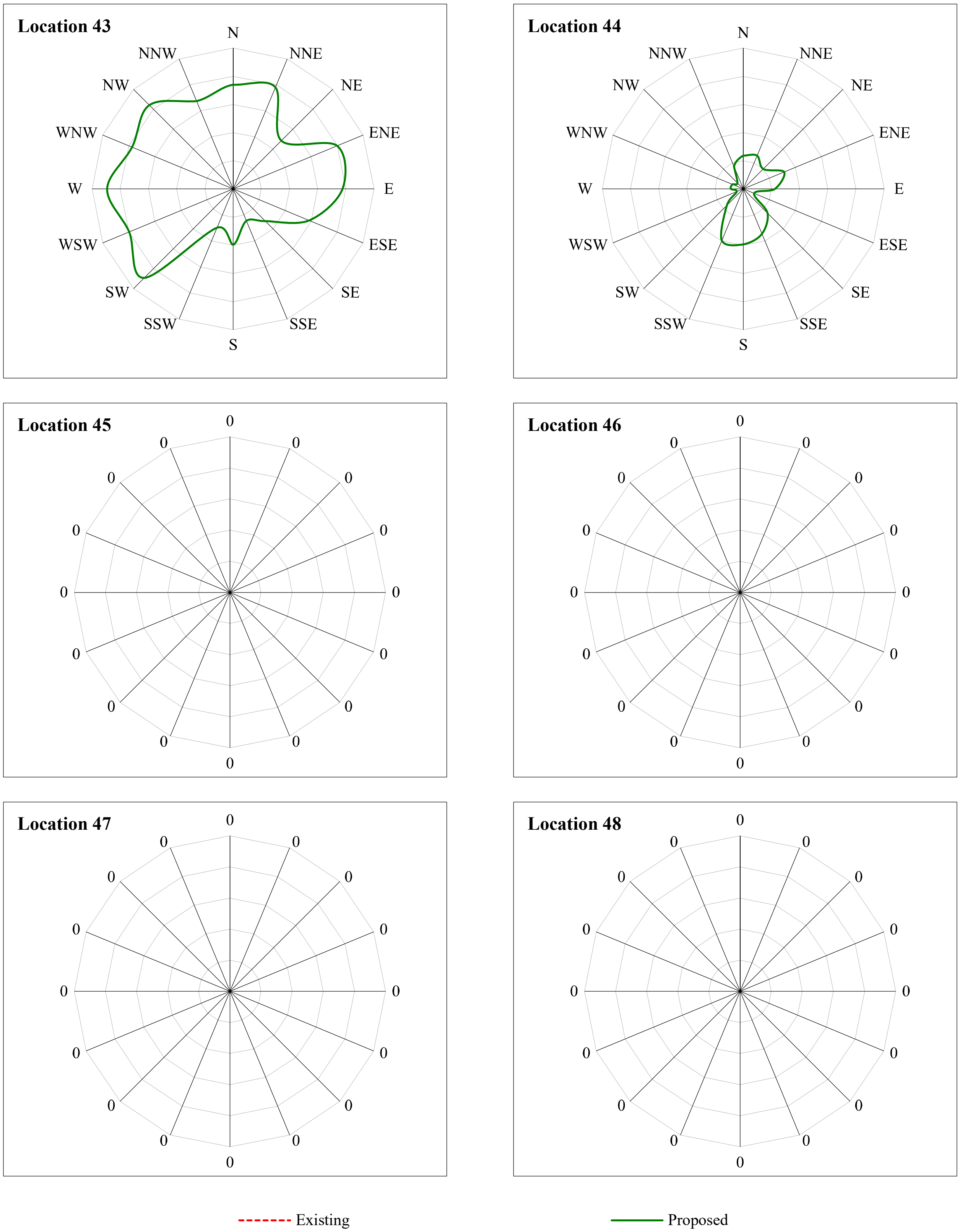

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