THEAKSTON ENVIRONMENTAL

Consulting Engineers • Environmental Control Specialists

REPORT

PRELIMINARY PEDESTRIAN LEVEL WIND STUDY

1381 LAKESHORE ROAD EAST
MISSISSAUGA, ON

City Park Homes

REPORT NO. 19545 **August 14, 2020**

An International Reputation for Excellence

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1. EXECUTIVE SUMMARY

The mixed-use Development proposed by City Park Homes for their property municipally known as 1381 Lakeshore Road East, situated north of the intersection of Lakeshore Road East and Dixie Road in the City of Mississauga, has been assessed for environmental standards with regard to pedestrian level wind relative to comfort and safety.

The 1381 Lakeshore Road East Development involves a proposal to remove the 1 storey commercial building on site and construct a 15 storey tower with an 8 storey wing extending to the northeast. A driveway providing access to the drop-off and underground parking areas runs along the northwest boundary of the site, connecting to Dixie Road and Cherriebell Road. Main residential entrances are proposed along Lakeshore Road East and at the internal drop-off area, and retail entrances are proposed along Dixie Road. Outdoor amenity space is proposed atop the 8 storey wing at the 9th level.

The proposed Development is, for all intents and purposes, surrounded to prevailing windward directions by a suburban mix of low to mid-rise residential, commercial, and industrial buildings and open areas. 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 winds that have opportunity to accelerate over the more open lands to the east through south of the Development site. The proposed Development penetrates winds that formerly flowed over the more open existing site. These winds are redirected, tending to split with portions flowing over, around and down the proposed building's façades. At the pedestrian level, the winds redirect to travel horizontally along the building, around the corners and beyond, creating minor windswept areas at or near the building's corners, and in the gaps between buildings, and these conditions are primarily attributable to the setting. Winds emanating from remaining compass points are more effectively mitigated by the local surrounds, and as such, upon impact with the proposed, tend to split, flowing over, and to a lesser extent around and down the building's faces. At the pedestrian level, the winds redirect to travel horizontally along the ground, around corners and beyond.

With inclusion of the proposed Development, ground level winds at many locations will improve, with occasional localized areas of higher pedestrian level winds. This is primarily attributable to the exposure of the existing setting, which is well managed by the proposed design, and the resulting conditions are considered acceptable to the suburban context. Where mitigation was recommended, it was achieved through:

- steps in the façades
- podium
- canopies
- balconies
- landscaping
- plantings

and others, that were incorporated into the proposed Development's massing and landscape design. In summary, the proposed Development's design features will contribute to anticipated pedestrian comfort conditions that are suitable to the context. Application of a mitigation plan for the rooftop amenity space will result in conditions that are comfortable and seasonally suitable for the intended use. The proposed Development will realise wind conditions acceptable to a typical suburban context.

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2. INTRODUCTION

Theakston Environmental Consulting Engineers, Fergus, Ontario, were retained by City Park Homes, to study the pedestrian level wind environment for their proposed mixed-use Development at 1381 Lakeshore Road East in the City of Mississauga. The site is depicted on the Aerial Photo in Figure 2a. The Development involves a proposal to build a 15 storey tower with an 8 storey wing, in the configuration shown in Figure 2b.

Bruce McCall-Richmond of Glen Schnarr & Associates initiated the request, and Graziani + Corazza Architects 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 building and surroundings. The wind velocities are rated in accordance with the safety and comfort of pedestrians, notably at entrances to the building, 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 removed the existing 1 storey building on site and retested with the Development's proposed building. 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.
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 thirty-six (36) 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 Billy Bishop Airport for the period between 1989 and 2017. The meteorological data includes hourly wind records and annual extremes. The analysis of the hourly wind records from said stations provides information to develop the statistical climate models of wind speed and direction. From these models, 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 at 10m, 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 Billy Bishop Airport in Figure 5. Both annual and seasonal distributions are shown understanding Billy Bishop airport realises a more significant wind climate, in comparison to Pearson. From the Billy Bishop Wind Roses it is apparent that winds can occur from any direction, however, historical data indicates the directional characteristics of strong winds are from the east as well as west through southwest and said winds are most likely to occur during the winter and fall seasons. In comparison, the Pearson wind climate is dominated by north through west to southwest winds with a far less significant easterly component.

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. Graziani + Corazza Architects 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 Gust Equivalent Mean (GEM) 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

Proposed Development

The proposed Development will be constructed on a parcel of land situated to the north of the intersection of Lakeshore Road East and Dixie Road, in the City of Mississauga. The site is currently occupied by a 1 storey commercial building that will be removed, and 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 45 degrees north.

The Development involves a proposal to construct a 15 storey tower with an 8 storey wing extending to the northeast. A driveway providing access to the drop-off and underground parking areas runs along the northwest boundary of the site, connecting to Dixie Road and Cherriebell Road. Main residential entrances are proposed along Lakeshore Road East and at the internal drop-off area, and retail entrances are proposed along Dixie Road. Outdoor amenity space is proposed atop the 8 storey wing on the 9th level. The Development is proposed in the configuration shown in Figure 2b.

Proposed 1381 Lakeshore Road East Development Site Looking North.

<u>Surrounding Area</u>

The proposed Development site, for all intents and purposes, is surrounded to prevailing windward directions by suburban development and open areas, as indicated in Figure 2a.

To the northwest through north of the site are low-rise residential neighbourhoods with the open lands of the Lakeview Golf Course and Toronto Golf Club Course beyond. To the immediate northeast of the site is a vacant lot with the low-rise Ivy Motel and townhouse blocks beyond.

To the east through south of the site are the open lands of Lakeshore Park and Marie Curtis Park. Lake Ontario is approximately 700m from the site to the southeast beyond. Immediately south of the intersection of Lakeshore Road East and Dixie Road is a 2 storey warehouse building.

To the southwest of the site is a future development at 1345 Lakeshore Road East consisting of 8 and 12 storey buildings with multi-level wings extending to the north and south. The proposed 1345 Lakeshore Road East Development was included in the massing model at the request of the City. Mid to low-rise residential buildings lay to the west through southwest of the site beyond.

In summary, suburban development mainly comprised of low to mid-rise residential buildings and open lands occupy lands to all compass points relative to the subject site. The suburban landscape has mitigative effects upon the wind climate to varying degrees, providing surface roughness that reduces the wind's energy at the pedestrian level. Conversely, the relatively open areas present a relatively smooth surface to approaching winds, affording wind opportunity to accelerate. Figures 2a and 2b depict the site and its immediate context. The site model, shown in Figure 3, is built to a scale of 1:500.

Macroclimate

For the proposed Development, the upstream wind flow during testing was conditioned to simulate an atmospheric boundary layer passing over suburban terrain. The terrain within the site's immediate vicinity was incorporated into the proximity model. Historical meteorological data recorded from Billy Bishop Airport was used in this analysis and consideration was applied to Pearson International Airport data. For studies on the waterfront in the City of Mississauga, weather data from Billy Bishop Airport is deemed representative. The data is split up into four seasons, spring, summer, fall and winter, and the resulting wind roses are presented as mean velocity and percent frequency in Figures 5b-e. The mean velocities presented in the wind roses are measured at an elevation of 10m. Thus, representative ground level velocities at a height of 2m, 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 open and suburban.

Winter (November 16 to March 31) has the highest mean velocities of the seasons with prevailing winds from the west through southwest, with significant components also from the northwest and east through northeast as indicated in Figure 5b. Spring (April 1 to June 15) has the second highest mean wind velocities with the significant prevailing winds emanating from east through northeast (Figure 5c). Summer (June 16 to September 15) has the lowest mean wind velocities of the seasons with prevailing winds from the east through northeast as well, as indicated in Figure 5d. During the Fall, (September 16 to November 15) the possible directions for prevailing winds include the east through northeast as well as the northwest through southwest sector (Figure 5e). The magnitudes of the mean wind velocities are between spring and summer winds. Reported pedestrian comfort conditions generally pertain to annual conditions unless stated otherwise.

5.2 Pedestrian Level Wind Velocity Study

On the site model, thirty-six (36) wind velocity measurement probes were located around the proposed Development and other buildings and activity areas 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 building was removed, and the "existing" site model retested with the current site.

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 in the Appendix, 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 are applied.

The design probability distribution gradient wind speed and direction, taken from historical meteorological data for the area (see Figures 5a – 5e) 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 a seasonal basis in Figures 6a – 6e. Note: For assessment purposes, the proposed Development was assessed with Billy Bishop Airport.

The ratings for a given location are conservative by design; when the existing surroundings and proposed building's 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 a predominantly suburban setting to prevailing and remaining compass points with winds flowing over and between mature vegetation, low to mid-rise buildings and open spaces. As such, the surroundings can be expected to influence wind at the site to varying degrees.

High-rise buildings may exacerbate wind conditions within their immediate vicinity, to varying degrees, by redirecting wind currents to the ground level and along streets and open areas. In general, wind will split upon impact with a high-rise building, with portions flowing down the face of the building to the pedestrian level as downwash, where it is deflected, or otherwise redirected to flow along the building and around its corners, creating localized zones of increased pedestrian level wind (Figure A). Conversely, points situated to the leeside, or in the wake of buildings will often enjoy an improvement in pedestrian comfort. As such, it is reasonable to expect inclusion of the proposed development will alter wind conditions under specific wind directions and velocities from those of the existing site condition, resulting in an improvement over the existing conditions at some points, with more windy conditions at others.

Figure A

It should be noted that probes are positioned at points typically subject to windy conditions in a suburban/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, Neighbouring Site Conditions, Pedestrian Entrance Conditions, and Outdoor Amenity Space Conditions. The measurement locations are depicted in Figure 4 and the resulting pedestrian comfort conditions are listed in Figures 6a – 6e annually and for the seasons for the existing and proposed configurations. The results are also graphically depicted annually, and for the seasons in Figures 7a – 7j. The following discusses anticipated wind conditions and suitability for the points' intended use.

Public Street Conditions

Dixie Road

Probes 1 through 7 were located along Dixie Road within the zone of influence of the proposed Development. Their locations are depicted in Figure 4, their comfort ratings are listed annually and for each of the seasons in Figures 6a – 6e and depicted in Figures 7a through 7j. 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 realises conditions suitable for walking. In the winter months, windier conditions are realised in localised areas along Dixie Road, resulting in conditions suitable for walking at probe 4 and uncomfortable conditions at probe 1. The windy conditions at probe 1 can be attributed to the proximate 12 storey building proposed at 1345 Lakeshore Road East that directs winds from the east and west to flow around the northmost corner and over the intersection of Dixie Road and St. James Avenue.

Many of these points realise an improvement over the existing setting with inclusion of the proposed Development for specific wind directions, however, there are directions from which the wind is exacerbated, as seen in the Appendix Figure B Wind Radars. Portions of the street realise improvements due to blockage from the proposed to dominant winds emanating from the east. However, winds emanating from southern directions will be redirected to flow around the proposed building and ultimately over portions of Dixie Road.

As such, most of the points retain their annual comfort rating of standing, with the exception of probe 3 that realises a sufficient increase in winds to change the annual rating from standing to walking. In the winter months, probes 3, 5, 6, and 7, located proximate to the proposed Development, realised an increase in winds that changed the winter ratings from standing to walking. Conversely, probe 1 improved from walking to standing annually, and from uncomfortable to walking in the winter months. Probe 4 improved from walking to standing in the winter.

With inclusion of the proposed Development, Dixie Road remains comfortable and suitable for the intended use and falls within the pedestrian level wind velocity safety criteria as an All-Weather Area, as described in Section 4.7 and depicted in Figure 9.

Lakeshore Road East

Probes 8 through 20 were located along Lakeshore Road East within the zone of influence of the proposed Development. In the existing setting, the probes indicate conditions annually suitable for standing, with the exception of probes 8 and 17 that were rated for walking. In the winter, windier conditions are realised with probes 15, 16, 17, and 19 suitable for walking and probe 8 rated as uncomfortable. The relatively open surrounds to the east transitioning to mid to low-rise buildings along the west side of Lakeshore Road East attribute to the localised windy areas along the street.

Inclusion of the proposed Development causes a realignment in winds along Lakeshore Road East that results in a subtle increase in winds along the street. Probes 11, 12, 13, 19, and 20, situated proximate to the intersection with Dixie Road, realised a sufficient increase in winds to change the annual ratings from standing to walking. This can be mainly attributed to winds emanating from the northwest and southwest that are redirected to flow down and around the proposed building and over portions of Lakeshore Road East. In the winter months, probe 1 improves from an uncomfortable rating to suitable for walking, and the street becomes mainly suitable for walking with only probes 9, 10, 14, and 18 remaining suitable for standing.

Lakeshore Road East will remain comfortable and suitable for the intended use and will realise more comfortable conditions with consideration of design and landscape features that were too fine to include in the massing model under test. With inclusion of the proposed Development, Lakeshore Road East falls within the pedestrian level wind velocity safety criteria as an All-Weather Area, as described in Section 4.7 and depicted in Figure 9.

St. James Avenue

Probes 21 and 22 were located along St. James Avenue to the northwest of the site, and were rated suitable for standing in the existing setting, annually. The probes realise similar conditions with inclusion of the proposed, however probe 22 realised sufficient improvements to change the annual rating from standing to sitting. St. James Avenue will be comfortable and suitable for the intended purpose and falls within the safety criteria as an All-Weather Area.

Cherriebell Road

Probes 23, 24, and 25 were located along Cherriebell Road to the north of the site, and were rated suitable for standing in the existing setting, annually. With inclusion of the proposed Development, probes 23 and 24 realise subtle improvements in wind conditions, however the changes were insufficient to alter the annual ratings. In the proposed setting, probe 25 is susceptible to winds emanating from the easterly and westerly directions that accelerate around the northmost corner of the proposed building and over the area, changing the annual rating to walking. Consideration of design and landscape elements that were too fine to include in the massing model will result in more comfortable conditions than reported. Cherriebell Road remains suitable for the intended purpose and falls within the safety criteria as an All-Weather Area.

Deta Road
Probes 26 and 27 were located along Deta Road, to the northeast of the proposed Development site. The probes were rated as suitable for sitting in the summer and standing through the remainder of the year in the existing setting, and the ratings were unchanged with inclusion of the proposed Development. Deta Road remains suitable for the intended purpose and falls within the safety criteria as an All-Weather Area.

Neighbouring Site Conditions

Probes 28 and 29 were located at the main entrances to the neighbouring 12 and 8 storey buildings at 1345 Lakeshore Road East, respectively. The entrance to the 12 storey building was rated as suitable for standing in the winter and spring and sitting through the summer and fall in the existing setting. With inclusion of the proposed Development, subtle improvements changed the spring rating to suitable for sitting, however the remainder of the seasonal ratings were unchanged. The entrance to the 8 storey building was rated as suitable for walking in the winter and standing through the remainder of the year, and the ratings were unchanged with inclusion of the proposed Development.

The entrances to the neighbouring development at 1345 Lakeshore Road East will realise conditions similar to, or better than, the existing setting. Consideration of existing and proposed fine design and landscape features will result in more comfortable conditions than those reported. With inclusion of the proposed Development, the entrances to the neighbouring site fall within the pedestrian level wind velocity safety criteria as an All-Weather Area.

Pedestrian Entrance Conditions

Probes 30 and 32 were situated adjacent to the Main Residential Entrances to the proposed Development. The south entrance, represented by probe 30, is recessed into the façade and set beneath a canopy, and as such is well protected from a large majority of the wind climate. The entrance is predicted to realise conditions suitable for standing in the winter and sitting through the remainder of the year. The south entrance will be comfortable and suitable for the intended use.

The north entrance, represented by probe 32, is similarly set beneath a canopy and is protected from large portions of the wind climate by the proposed building, however the area is susceptible to winds emanating from the west flowing around the corner of the proposed building and over the space. The entrance is predicted suitable for sitting in the spring and summer, standing in the fall, and walking through the winter months. The winter walking rating is at the transition to standing, and with consideration of fine design and landscape elements, is expected to realise conditions suitable as such. The north entrance is expected to be comfortable and suitable for the intended use.

Probe 33 was situated adjacent to a retail entrance to the proposed Development, at the corner of Lakeshore Road East and Dixie Road. The entrance is rated suitable for sitting in the summer and standing throughout the rest of the year. The retail entrance will be comfortable and suitable for the intended purpose.

Wind conditions comfortable for standing or better are preferable at building entrances, while conditions suitable for walking are appropriate for sidewalks. The entrances to the proposed Development will be comfortable and suitable to the intended use. Consideration of existing and proposed surface roughness features too fine to incorporate into the massing model will further improve the comfort ratings. The proposed entrances fall within the pedestrian level wind velocity safety criteria as All Weather Areas.

Outdoor Amenity Space Conditions

Probe 31 was situated within the proposed terrace space to the north of the building, at-grade. The area is well protected by the proposed building and surrounds from the majority of the wind climate, and as such is expected to realise relatively comfortable conditions. The area is predicted to realise conditions suitable for sitting through the summer and shoulder months, and slightly windier conditions, suitable for standing, through the winter. Consideration of the proposed landscape plan which includes a trellis/arbor structure to protect the seating area from winds downwashed from the building, will improve the conditions realised in the area. The terrace space is predicted comfortable and seasonally suitable for the intended use, and further mitigation is not required at this stage.

Probes 34, 35, and 36 were situated on the 9th level outdoor amenity space, atop the 8 storey wing. The most northeastern portion of the space, represented by probe 34, is predicted suitable for sitting in the summer and shoulder seasons, and standing through the winter months. Probes 35 and 36, located closer to the tower element, realise windier conditions, suitable for standing in the summer, walking in the shoulder months, and uncomfortable in the winter. The windier conditions proximate to the tower can be attributed to winds emanating from northerly and westerly directions being redirected to flow around and down the tower and ultimately over the area. In order to achieve comfortable conditions that are suitable for the intended use, a mitigation plan is recommended for the space. The mitigation plan may include 1.8m high perimeter wind screens, raised planters, trellises over seating areas, and/or others situated about the space as necessary. With application of an appropriate mitigation plan, the rooftop amenity space is expected to experience comfortable conditions that are suitable for the intended use, much of the time.

With inclusion of the proposed Development, the above-mentioned outdoor amenity spaces fall within the pedestrian level wind velocity safety criteria as All-Weather Areas, as described in Section 4.7 and depicted in Figure 9.

6. SUMMARY

The observed wind velocity and flow patterns at the proposed Development are largely influenced by approach wind characteristics that are dictated by the suburban mix of low to mid-rise residential development, open parking areas, and green spaces supporting mature vegetation, mitigating the wind to different degrees, on approach. Historical weather data recorded at Billy Bishop Airport indicates that strong winds of a mean wind speed greater than 30 km/h occur approximately 22 percent of the time during the winter months and 3 percent of the time during the summer. Once the subject site is developed, ground level winds at many 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.

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, a few localized areas may be windy from time to time, but the areas remain appropriate to the intended purpose. The rooftop amenity space will require application of a mitigation plan in order to achieve seasonally comfortable conditions that are appropriate for the intended use. The consideration of proposed surface roughness will result in conditions more comfortable than those reported herein.

The site is predicted to realise conditions suitable to a typical suburban context.

Note: The proposed Development was assessed with historical weather data from Billy Bishop Airport.

7. FIGURES

Figure 1: Laboratory Testing Facility

Figure 2a: Site Aerial Photo

Figure 2b: Site Plan

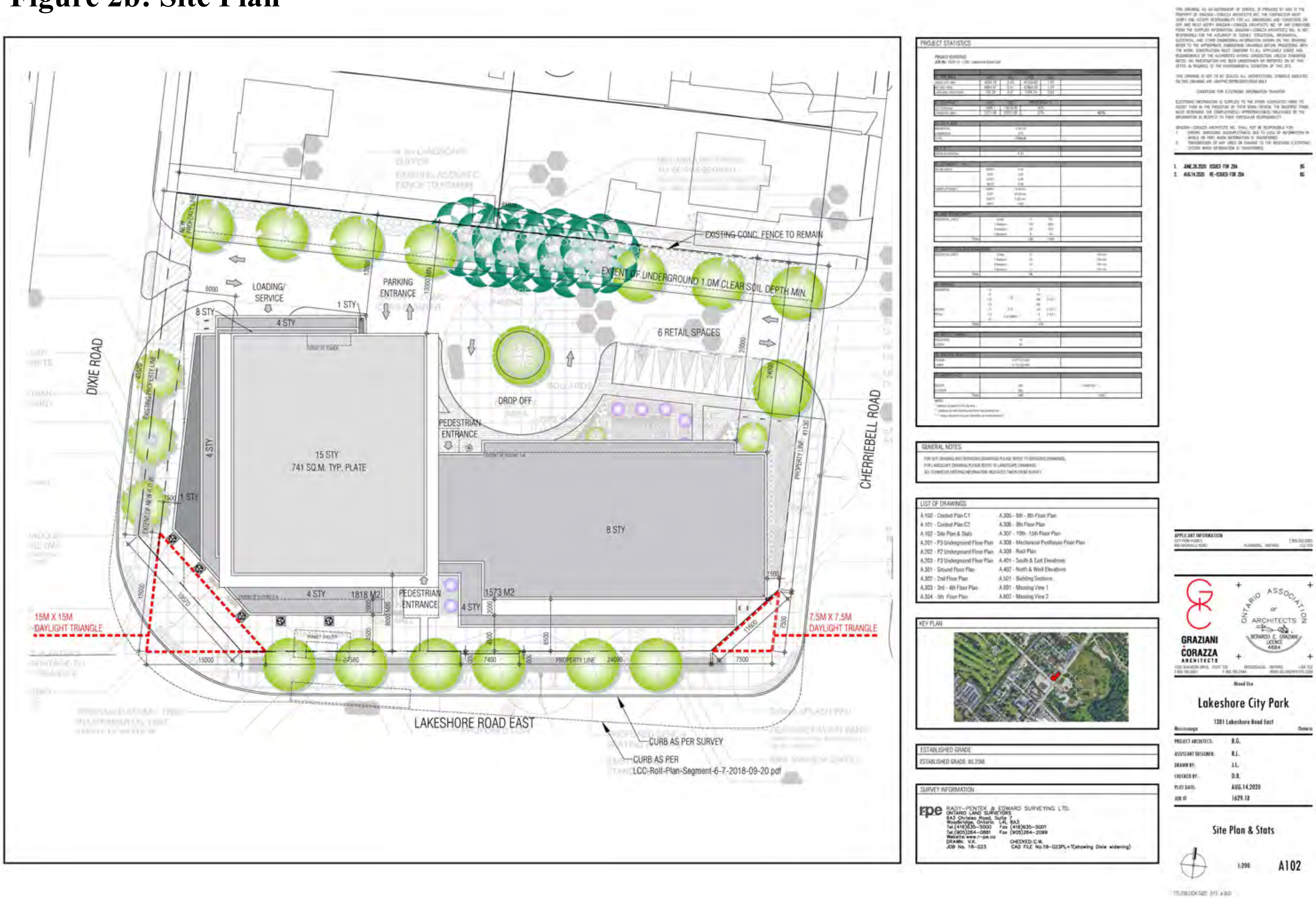
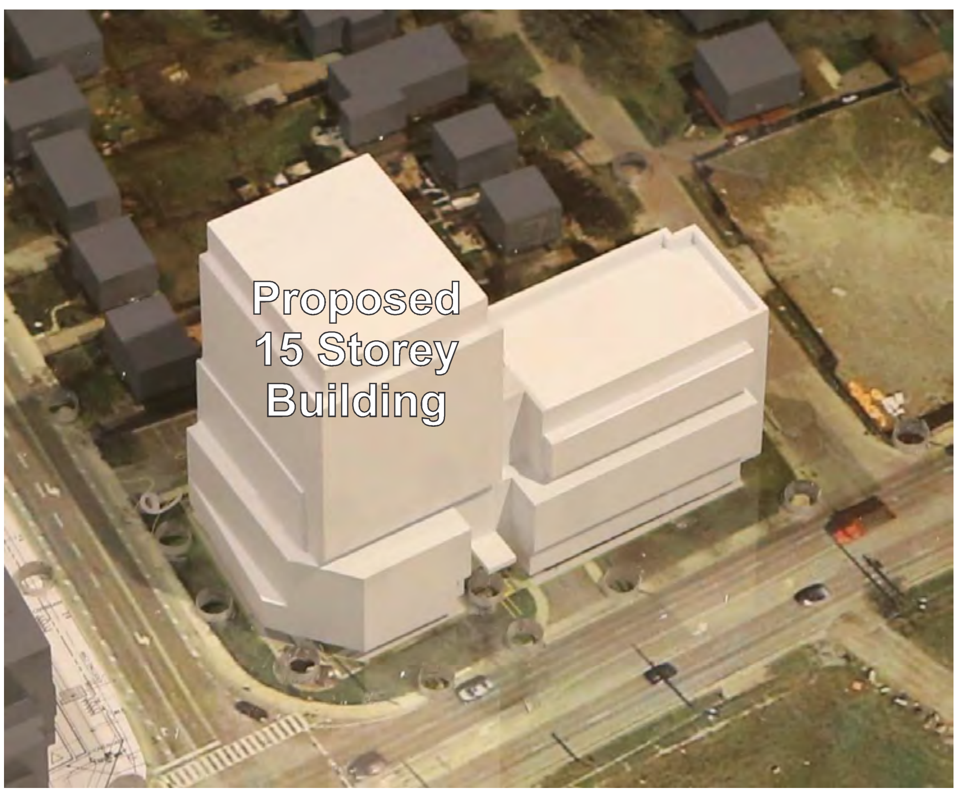


Figure 3: 1:500 Scale model of test site

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.

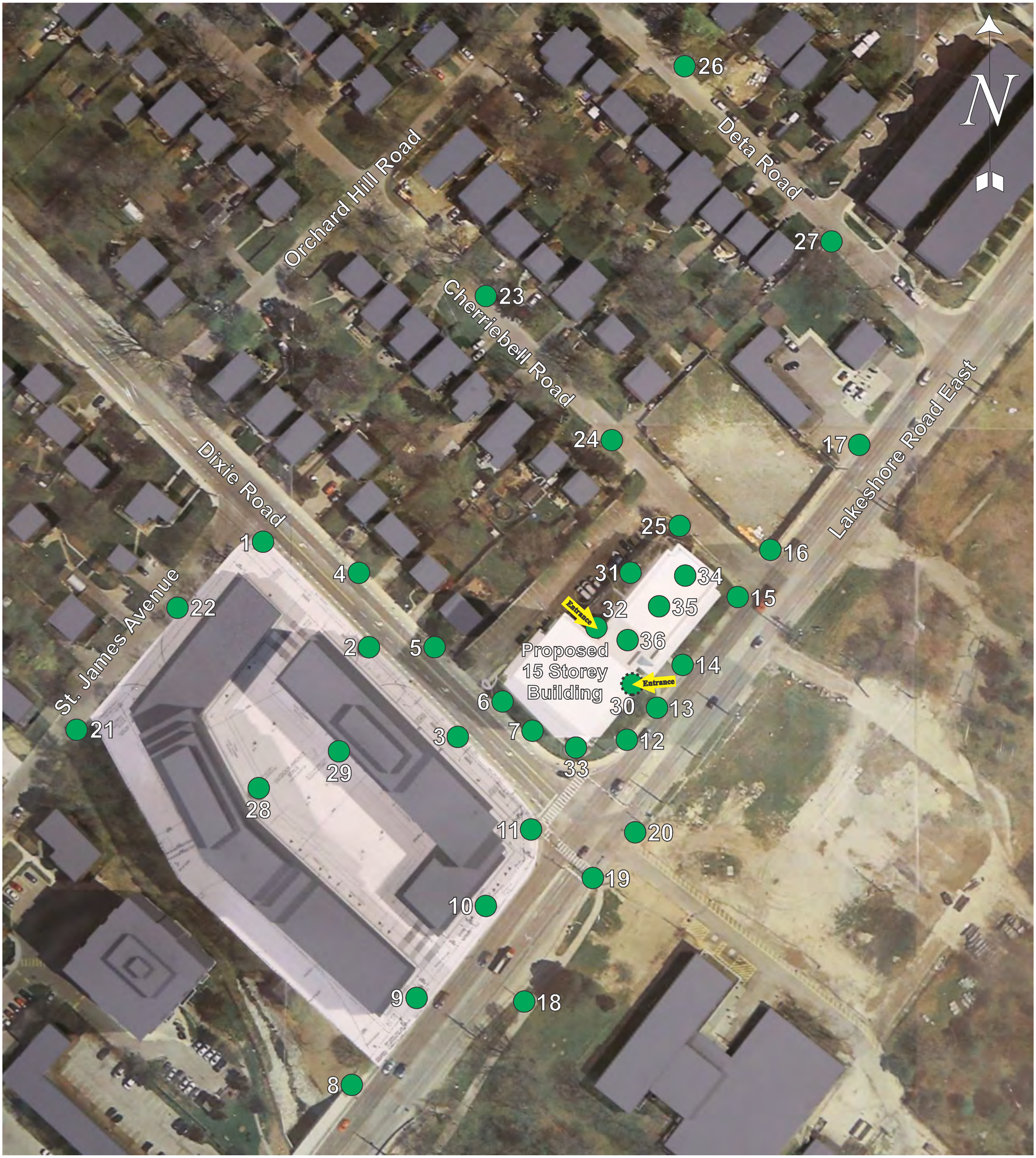
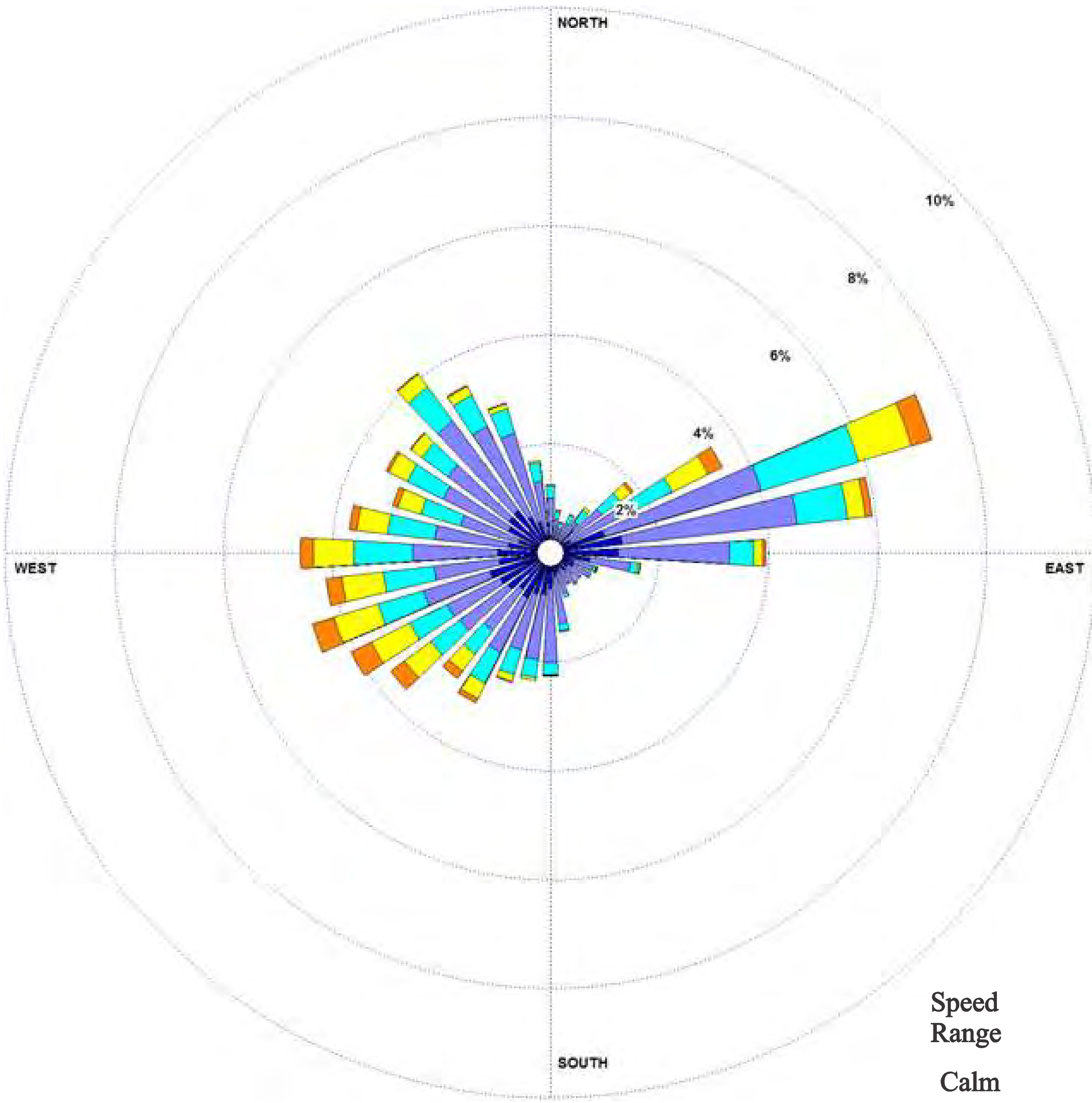


Figure 5a: Annual Wind Rose - Billy Bishop Airport.

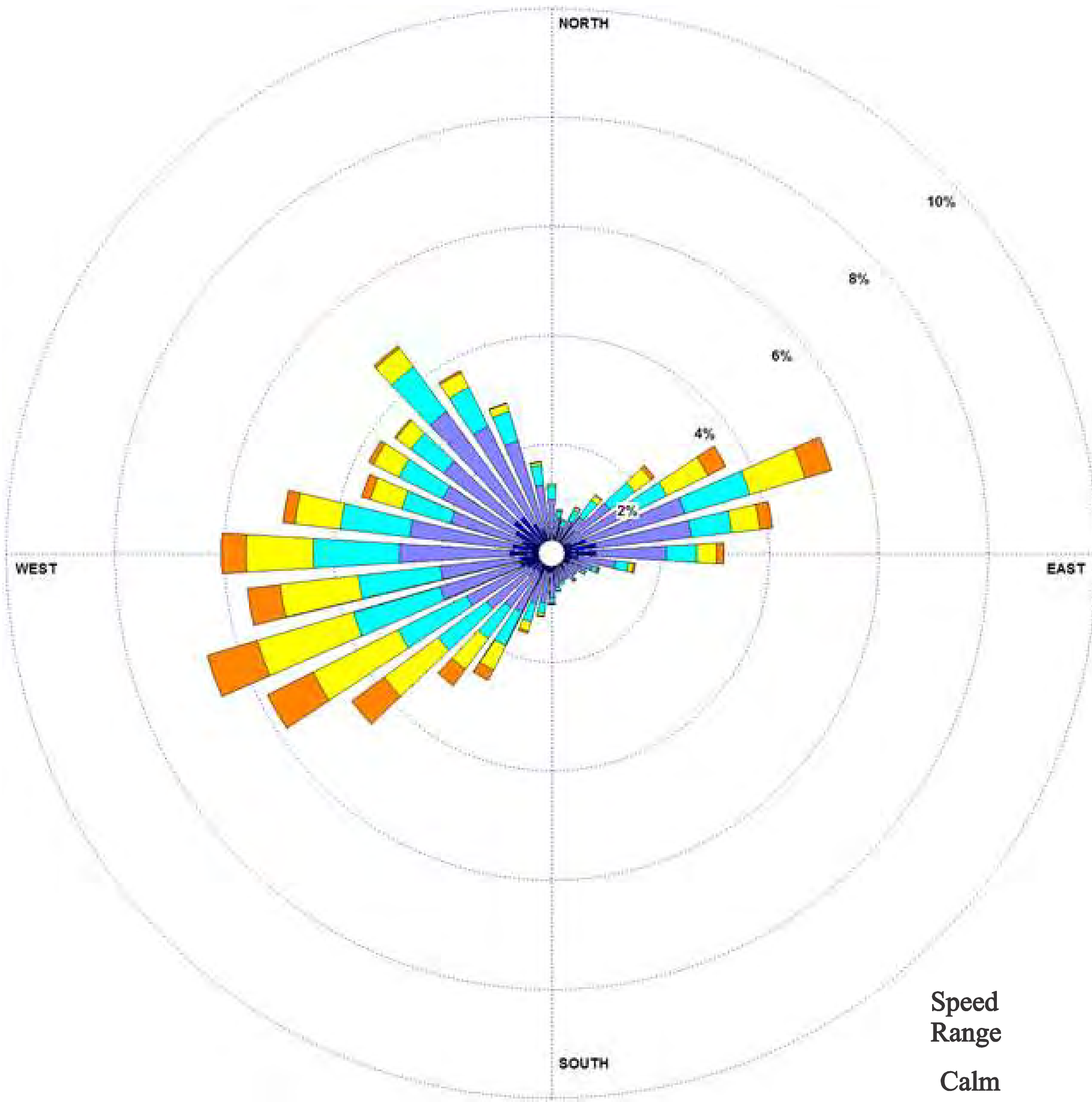
Historical Directional Distribution of Winds (@ 10*m* height)
(1989 - 2017)



Speed Range	Probability (%)
Calm	6%
1 - 10*km/h*	24%
11 - 20*km/h*	40%
21 - 30*km/h*	17%
31 - 40*km/h*	10%
> 40*km/h*	3%

Figure 5b: Winter Wind Rose - Billy Bishop Airport.

Historical Directional Distribution of Winds (@ 10*m* height)
November 16 through March 31 (1989 - 2017)



Speed Range	Probability (%)
Calm	3%
1 - 10*km/h*	16%
11 - 20*km/h*	37%
21 - 30*km/h*	22%
31 - 40*km/h*	16%
> 40*km/h*	6%

Figure 5c: Spring Wind Rose - Billy Bishop Airport.

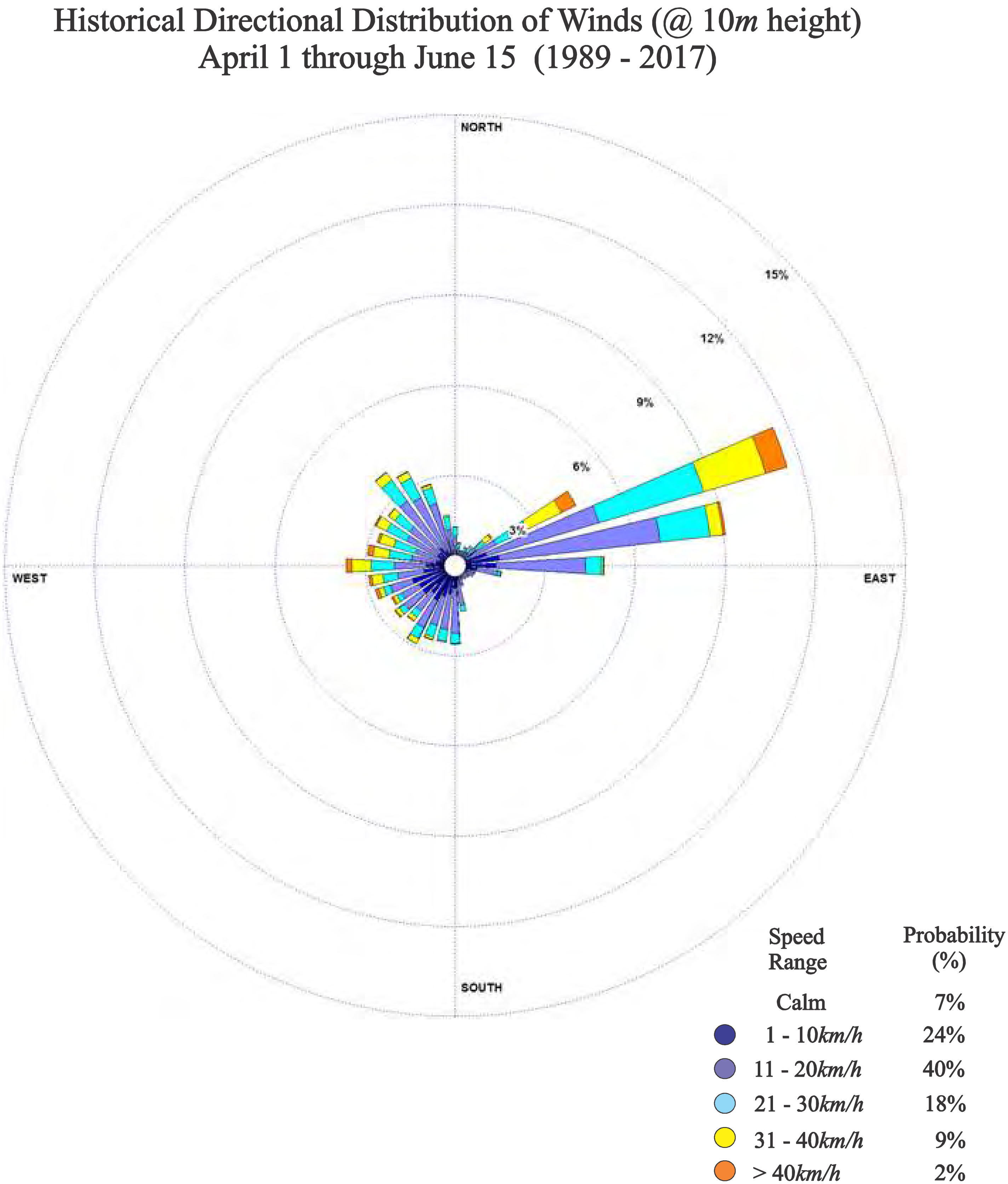
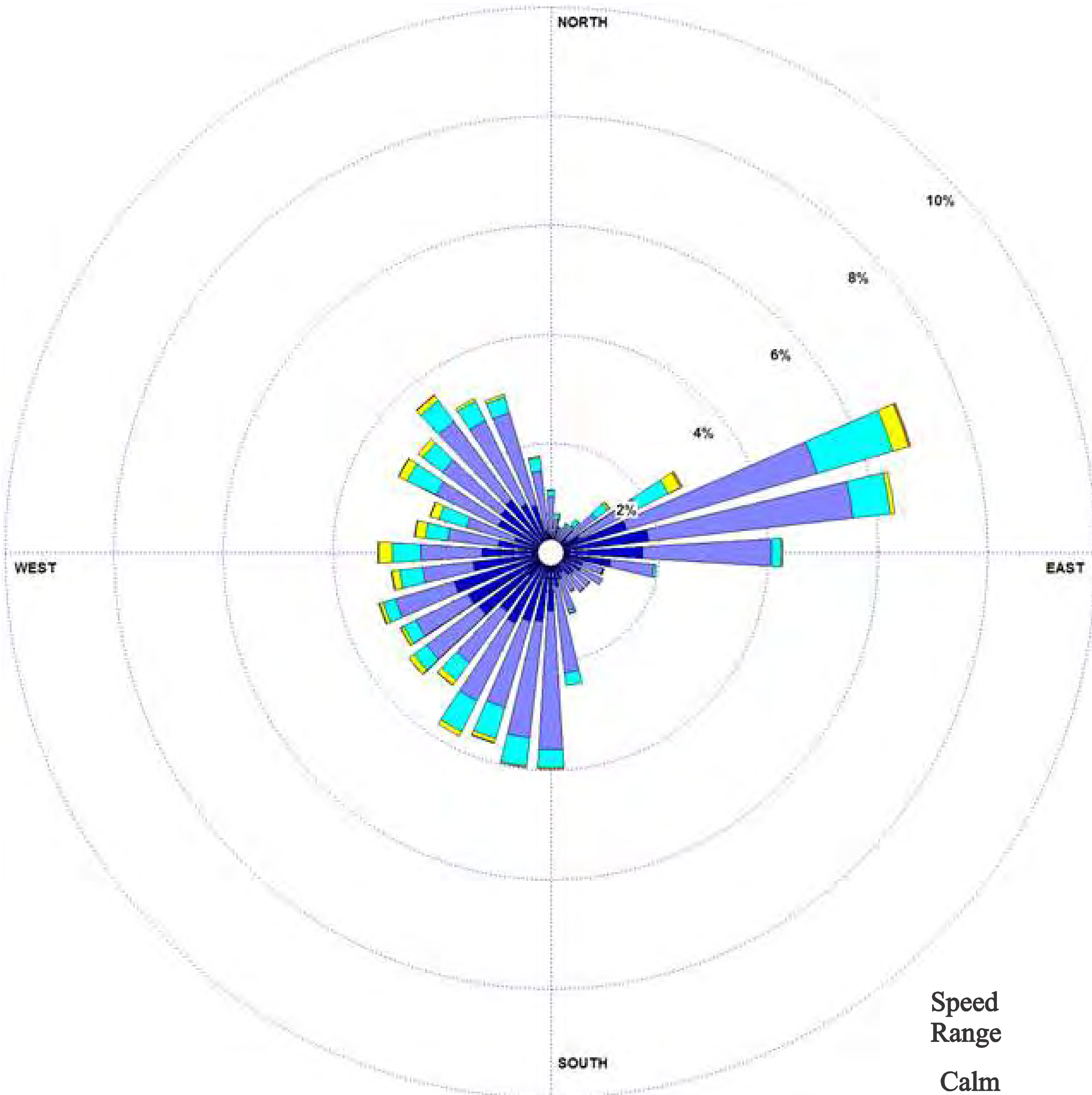


Figure 5d: Summer Wind Rose - Billy Bishop Airport.

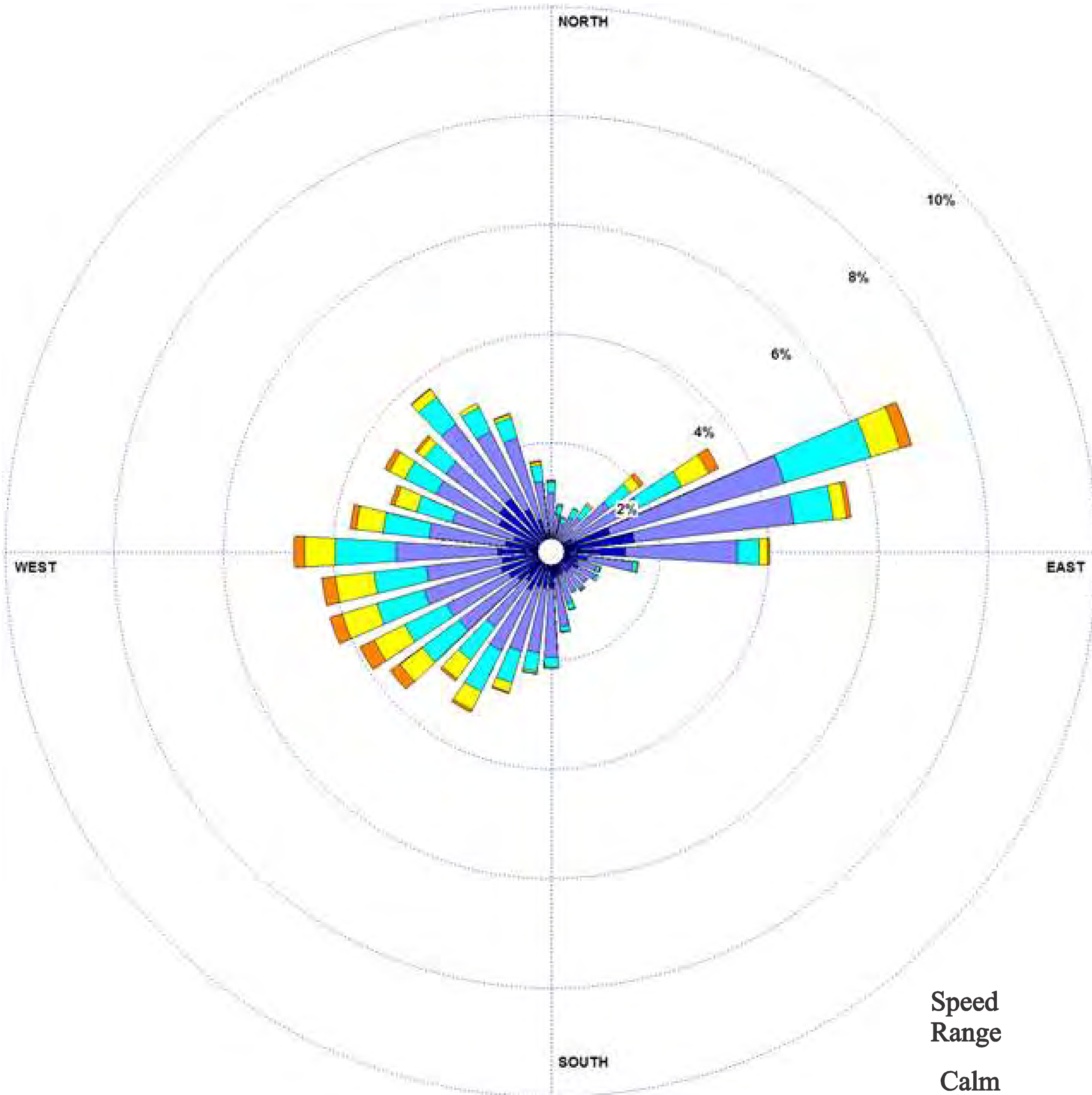
Historical Directional Distribution of Winds (@ 10*m* height)
June 16 through September 15 (1989 - 2017)



Speed Range	Probability (%)
Calm	8%
1 - 10*km/h*	34%
11 - 20*km/h*	44%
21 - 30*km/h*	11%
31 - 40*km/h*	3%
> 40*km/h*	<1%

Figure 5e: Fall Wind Rose - Billy Bishop Airport.

Historical Directional Distribution of Winds (@ 10*m* height)
September 16 through November 15 (1989 - 2017)



Speed Range	Probability (%)
Calm	6%
1 - 10*km/h*	25%
11 - 20*km/h*	43%
21 - 30*km/h*	17%
31 - 40*km/h*	7%
> 40*km/h*	2%

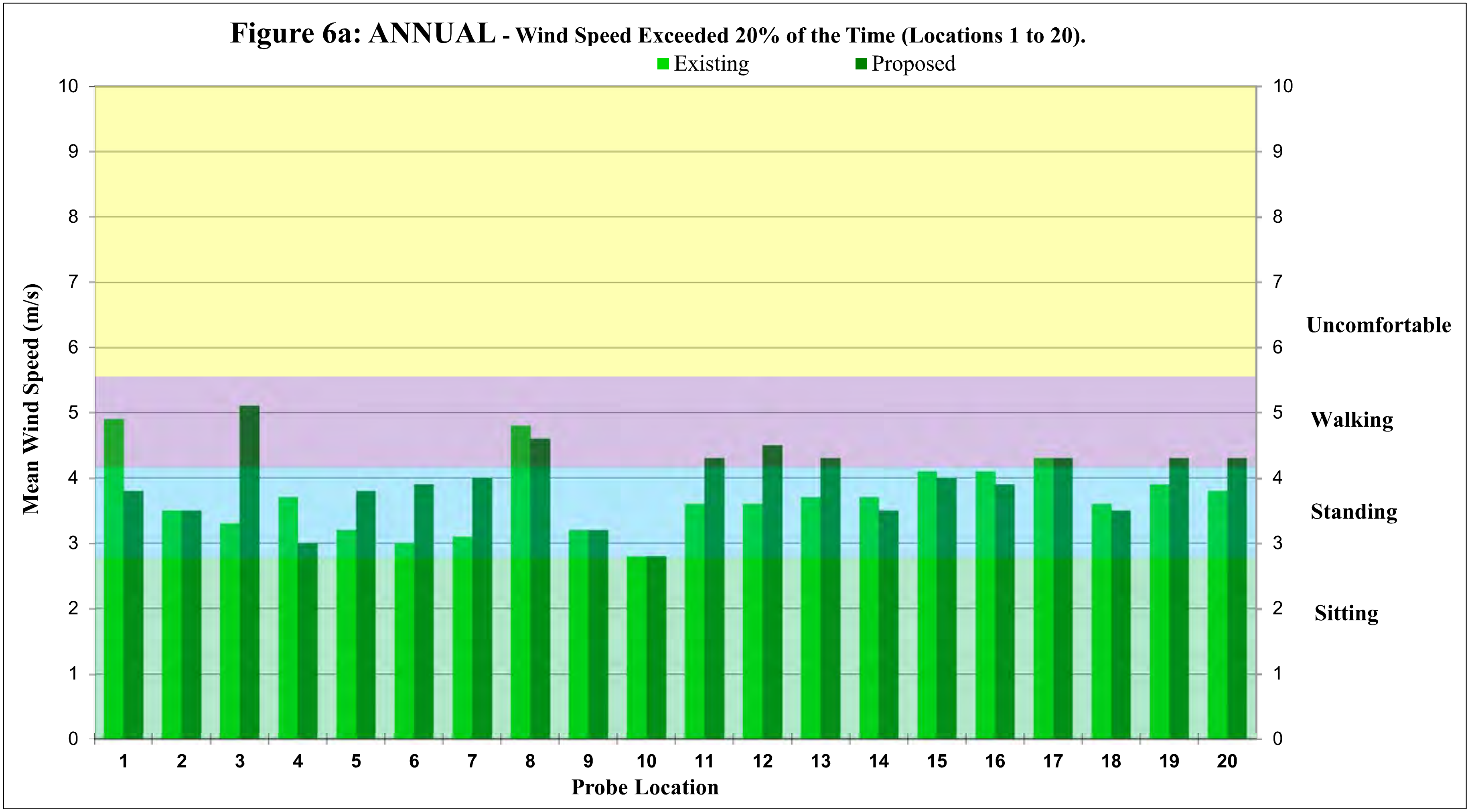
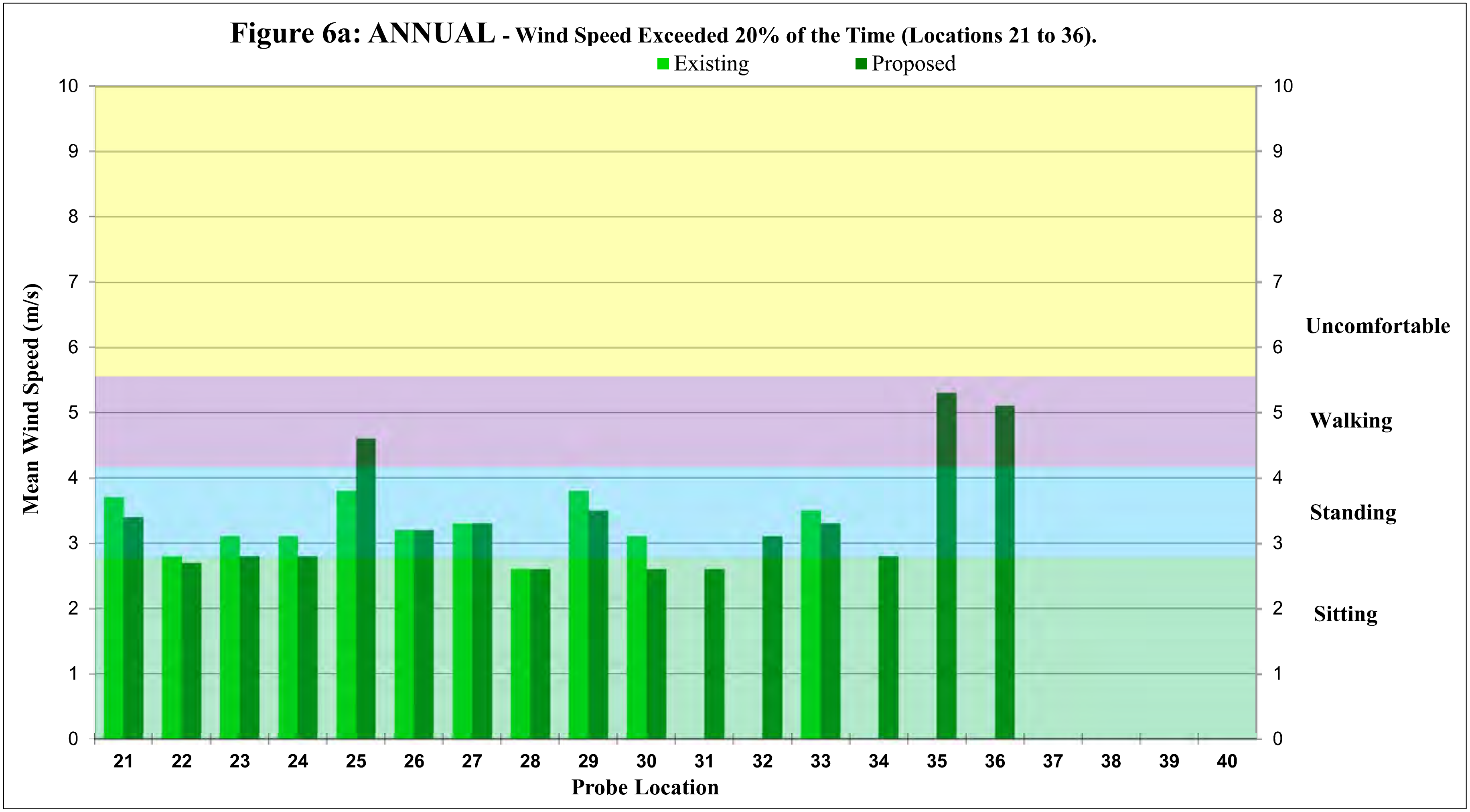


Figure 6a: ANNUAL - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
0
1
2
3
4
5
6
7
8
9
10
Uncomfortable
Walking
Standing
Sitting
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Probe Location



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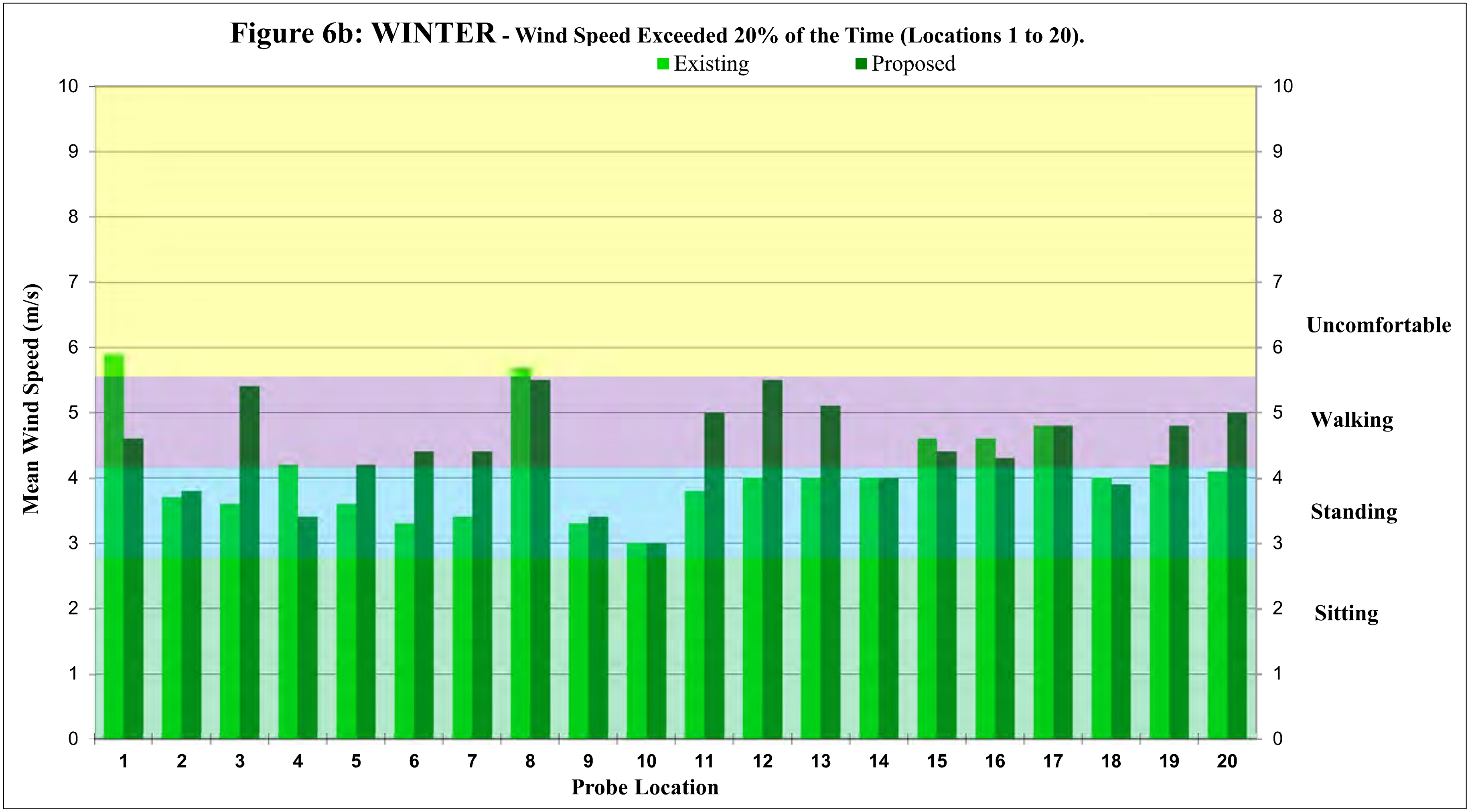


Figure 6b: WINTER - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
1
2
3
4
5
6
7
8
9
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

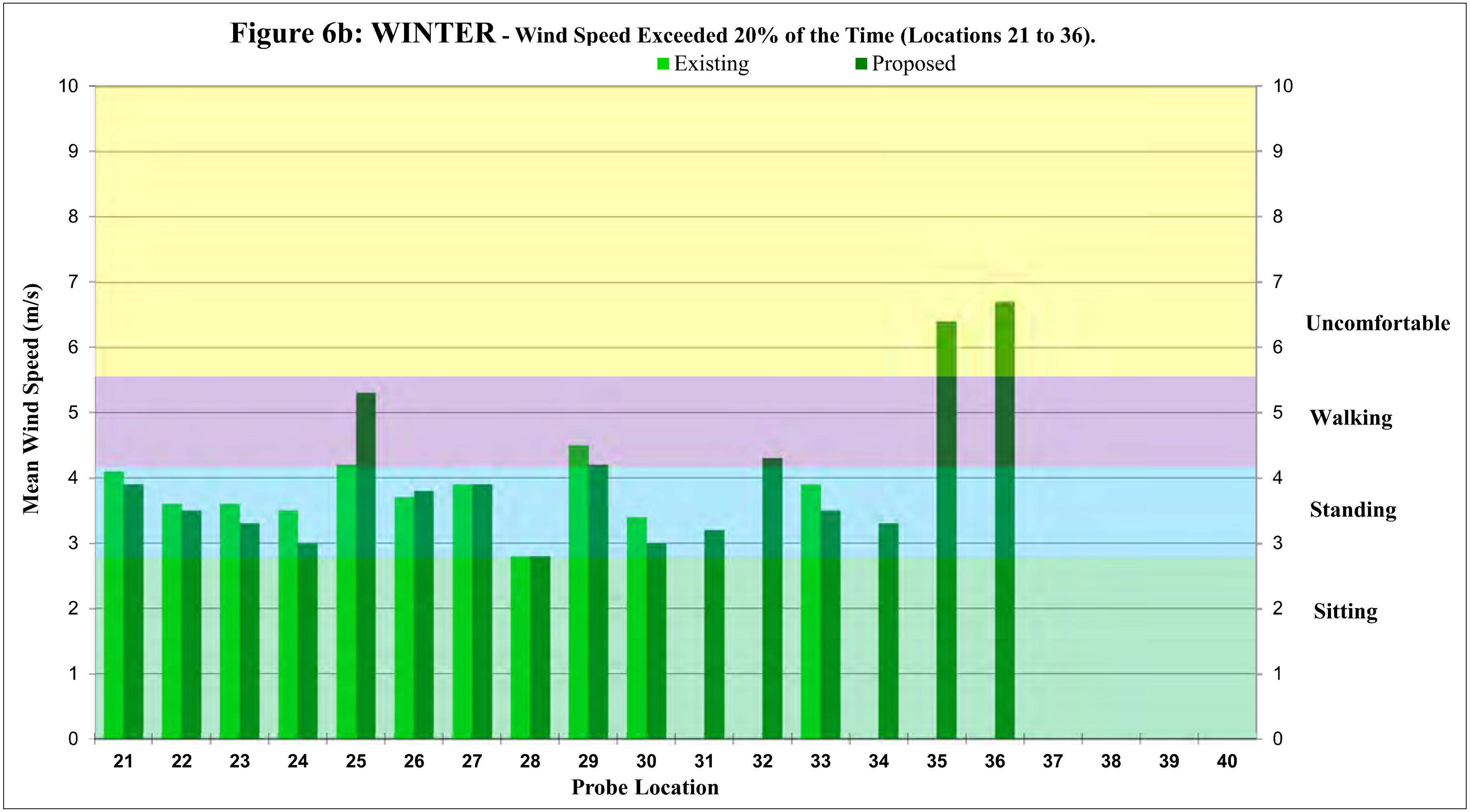


Figure 6b: WINTER - Wind Speed Exceeded 20% of the Time (Locations 21 to 36).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
0
1
2
3
4
5
6
7
8
9
10
Uncomfortable
Walking
Standing
Sitting

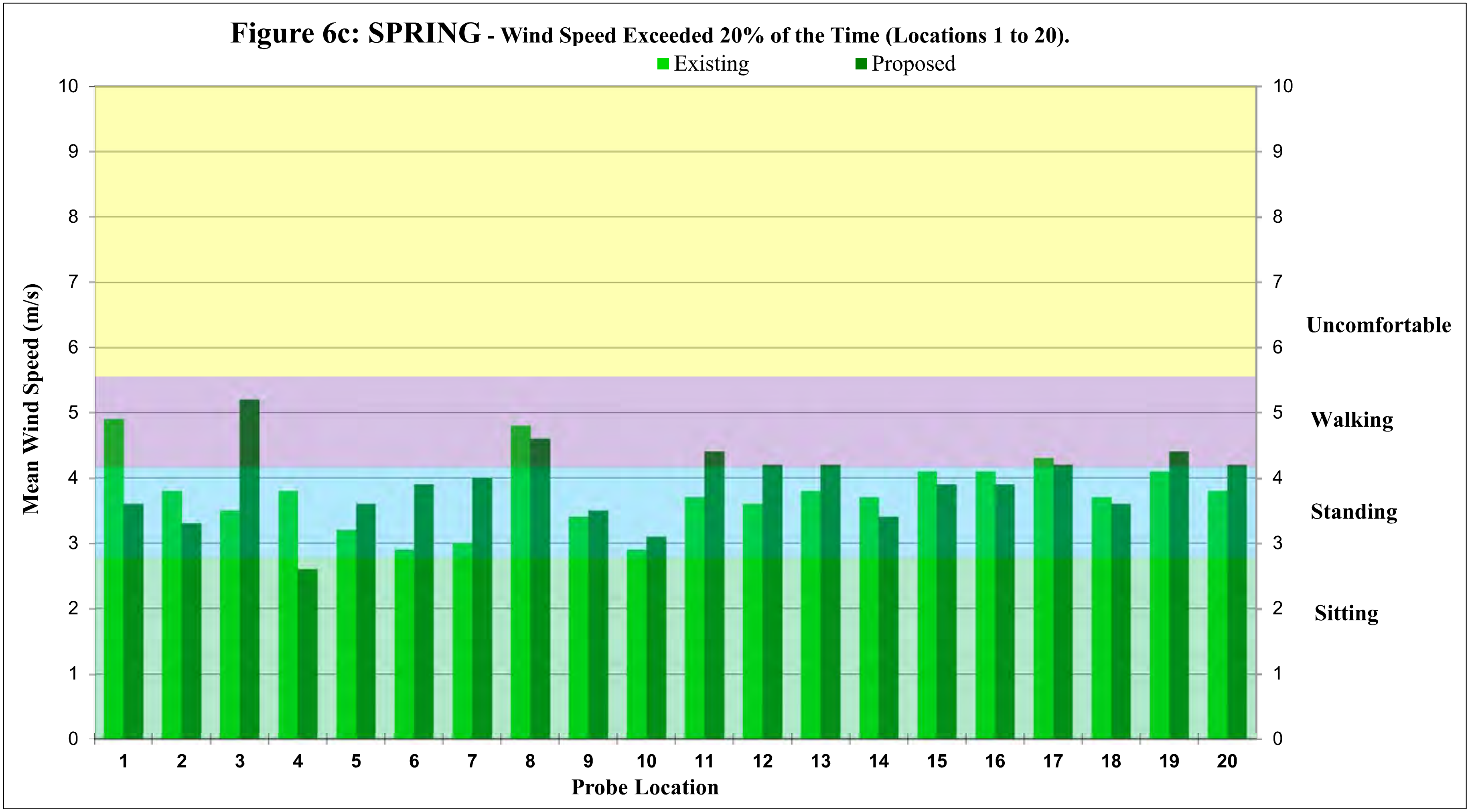


Figure 6c: SPRING - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting

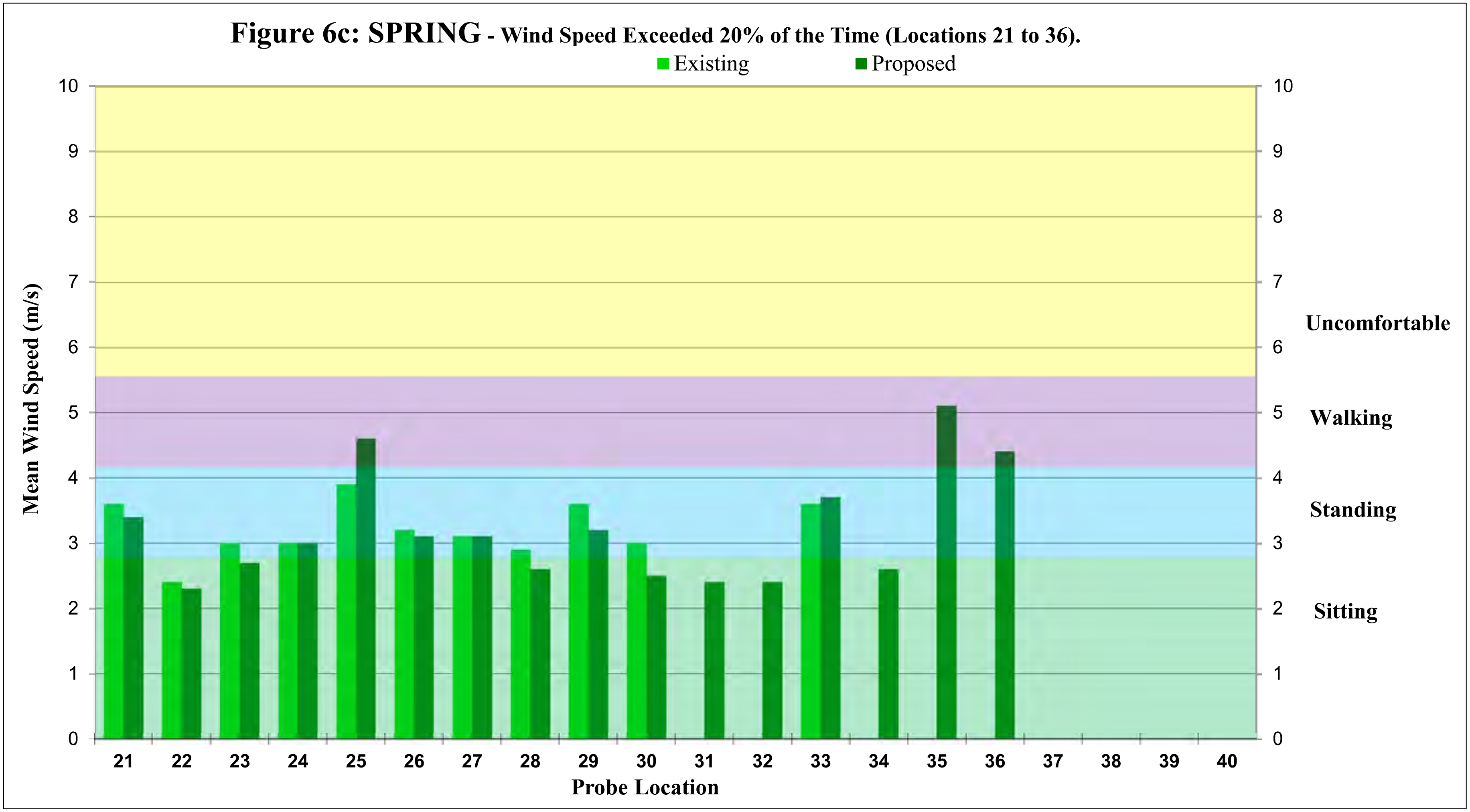


Figure 6c: SPRING - Wind Speed Exceeded 20% of the Time (Locations 21 to 36).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
0
1
2
3
4
5
6
7
8
9
10
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Uncomfortable
Walking
Standing
Sitting

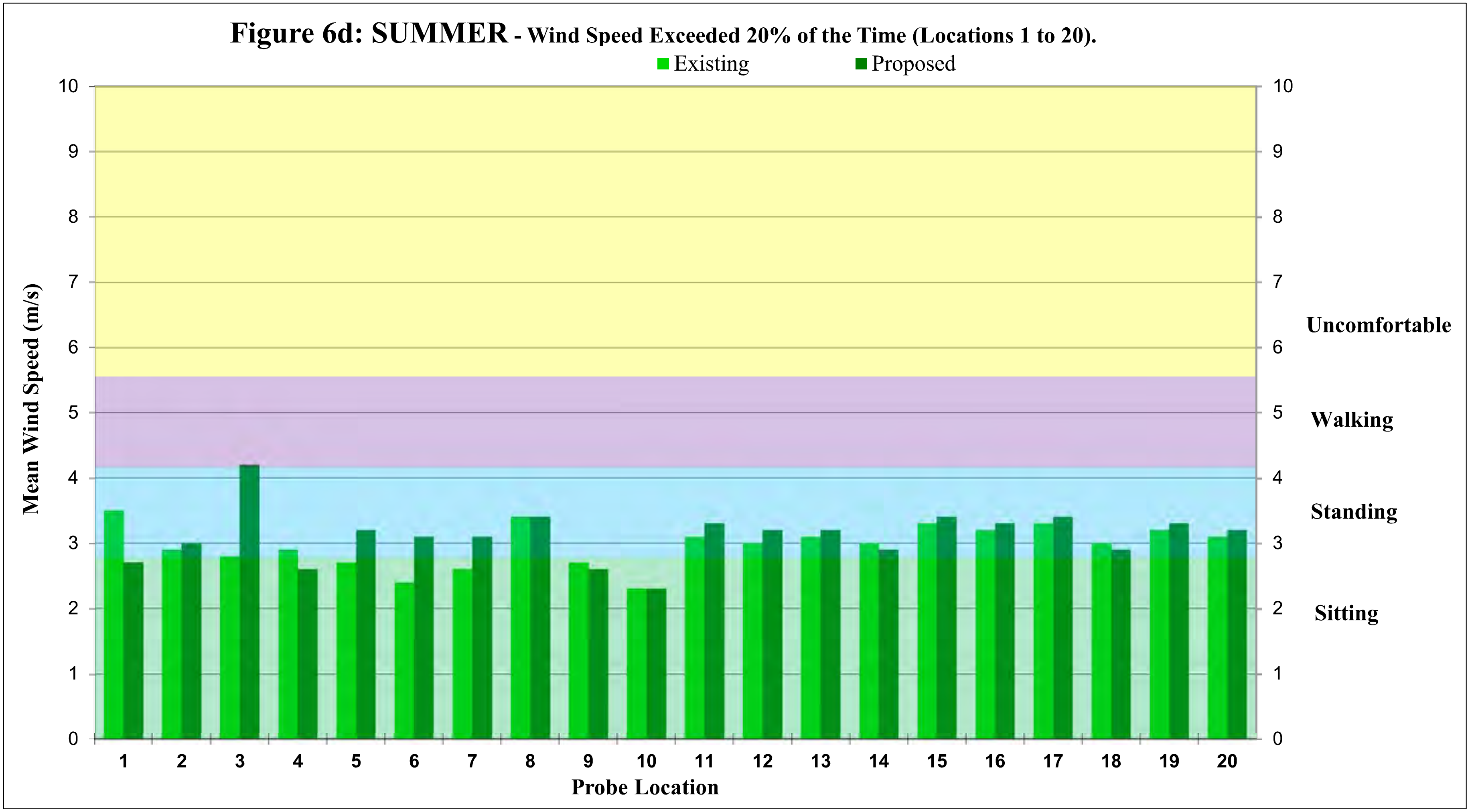


Figure 6d: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
1
2
3
4
5
6
7
8
9
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

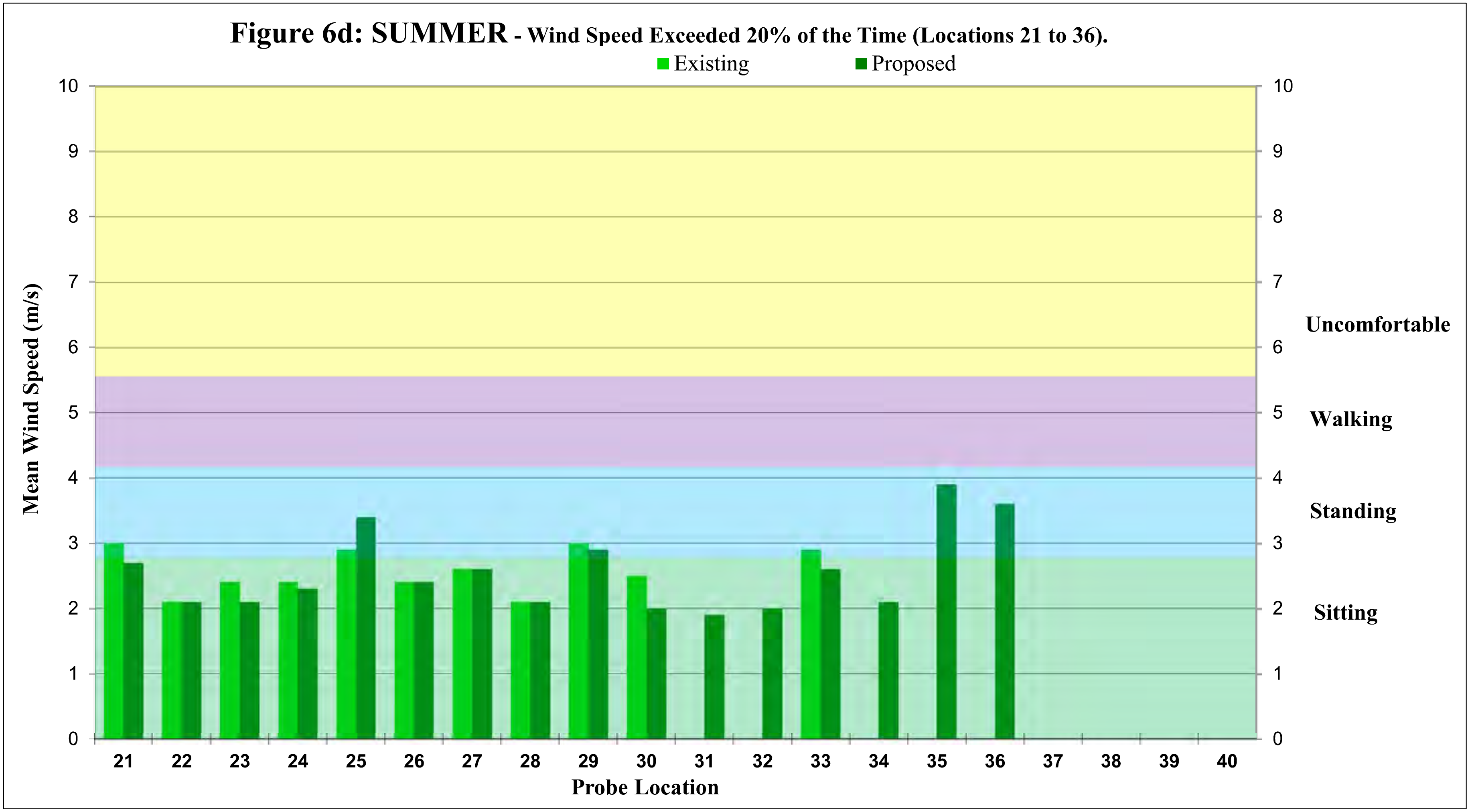
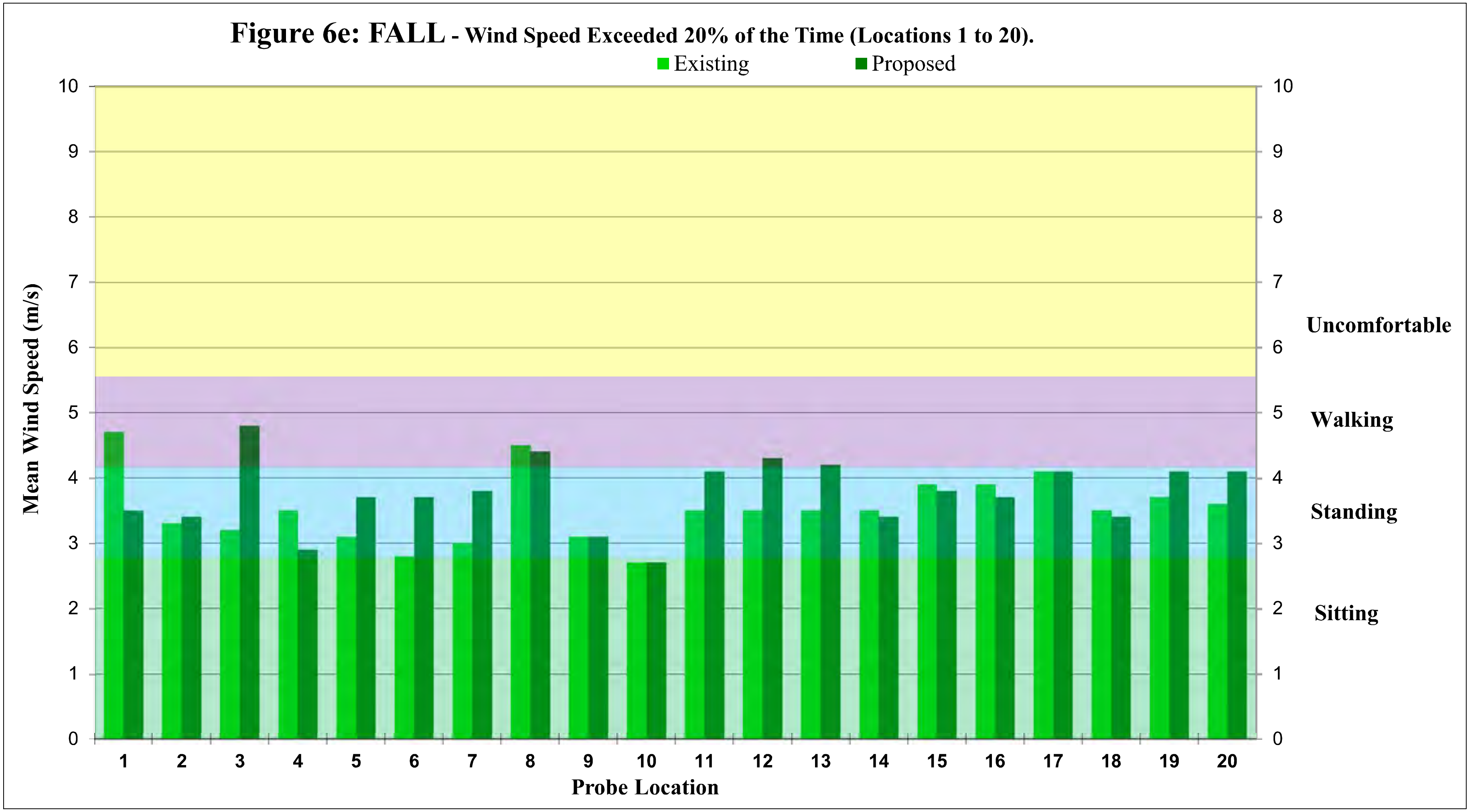


Figure 6d: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 21 to 36).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
1
2
3
4
5
6
7
8
9
10
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40



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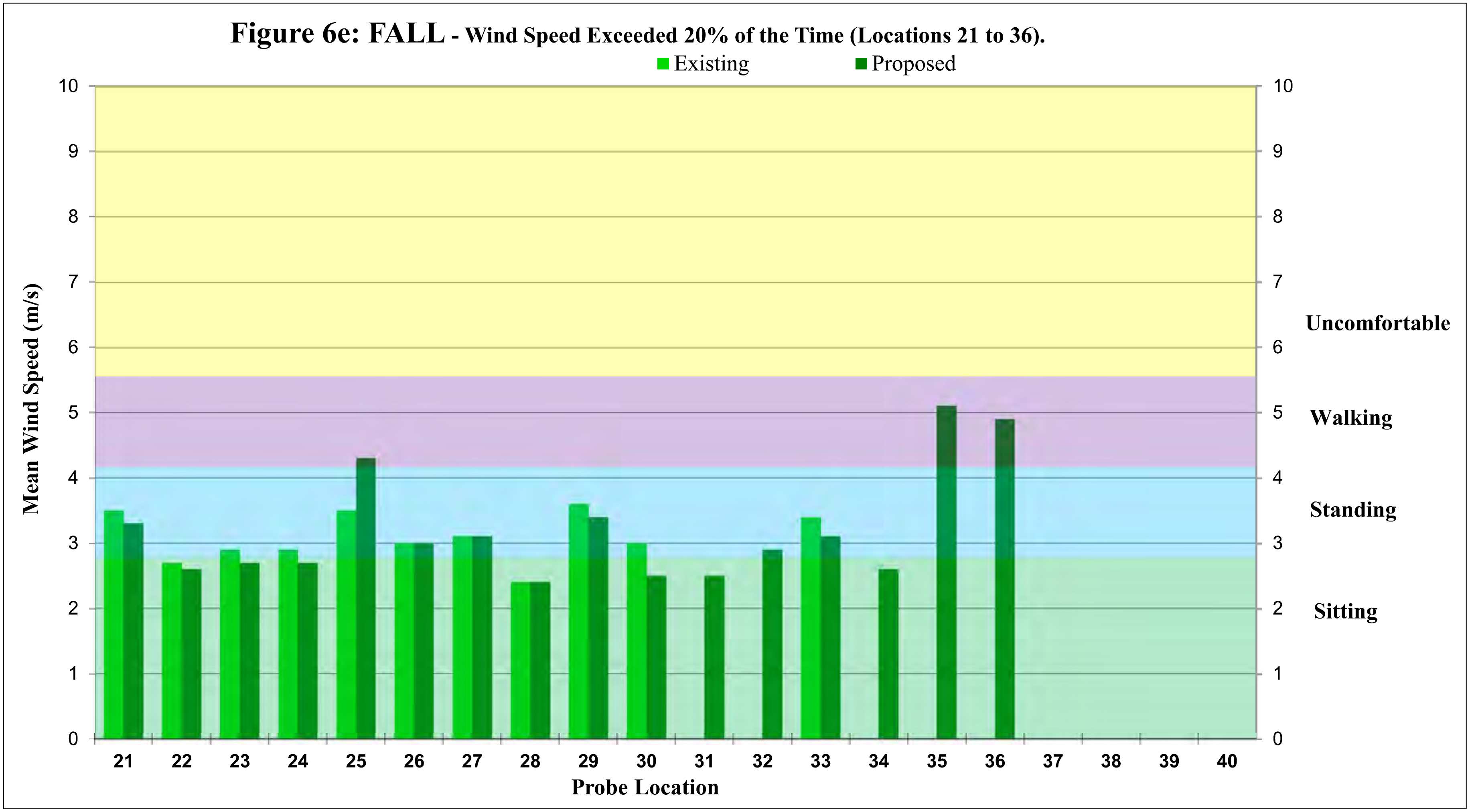

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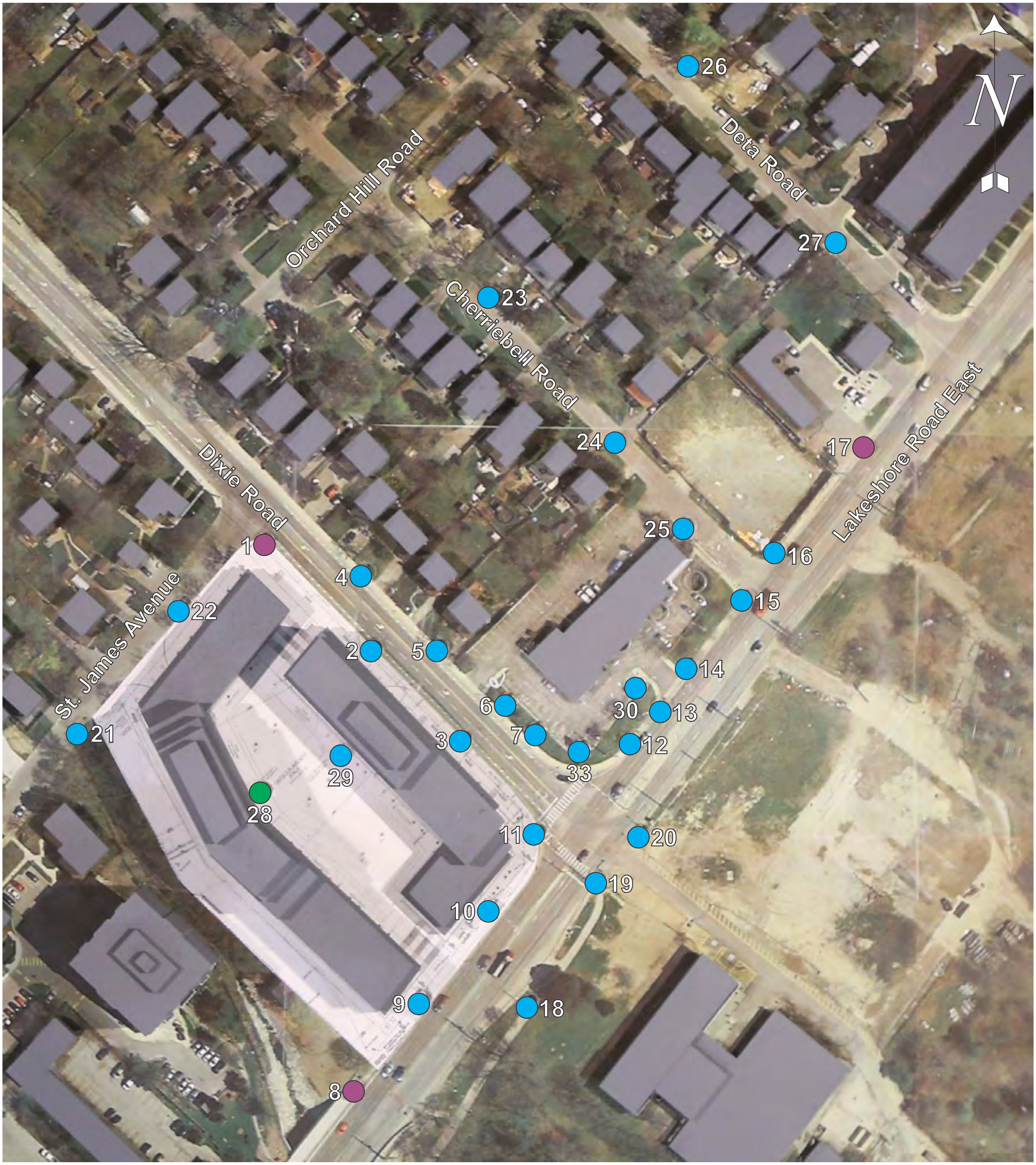
Figure 7a: Pedestrian level wind velocity comfort categories.

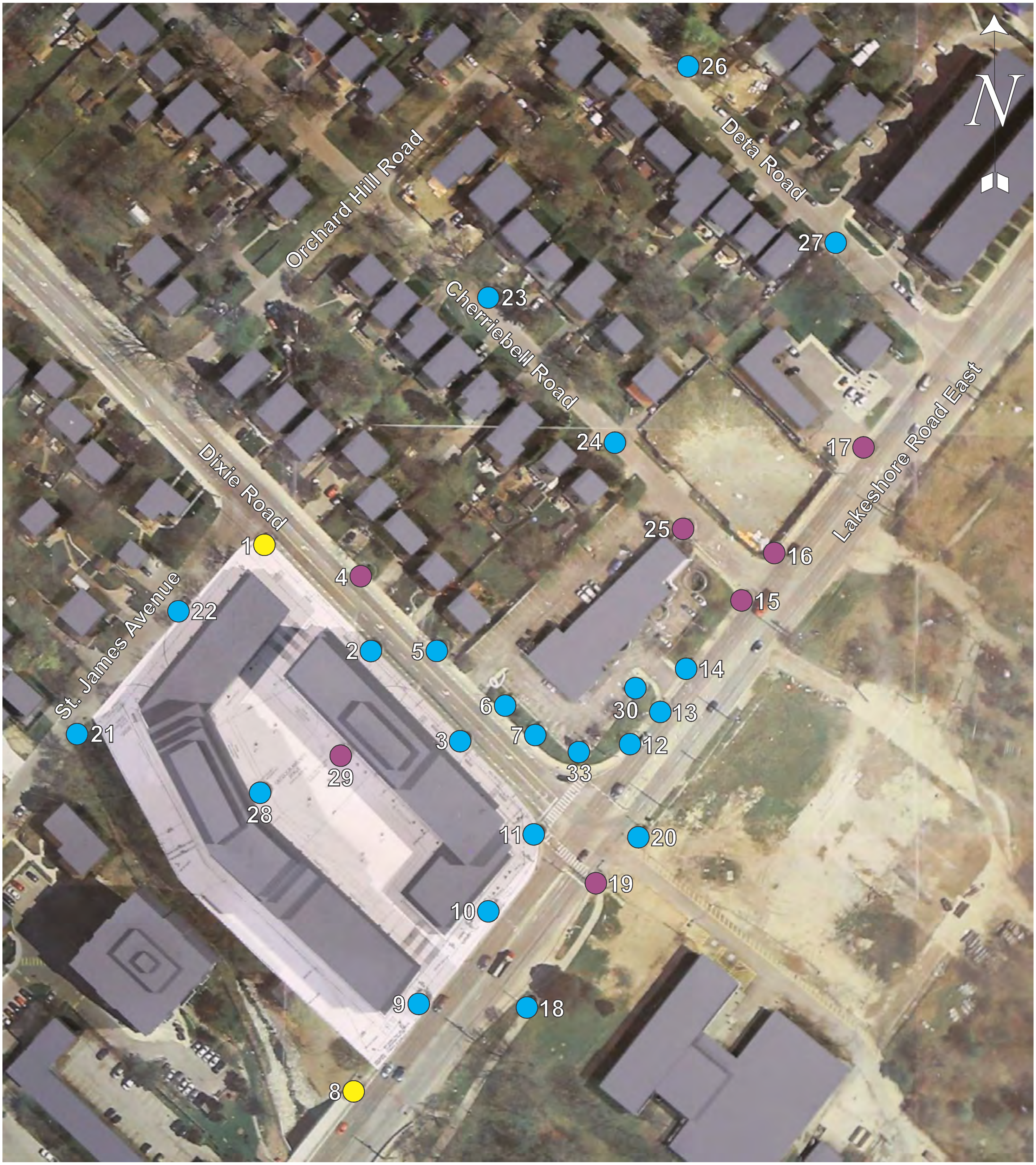


Comfort Categories - Annual - Existing

Sitting   Standing   Walking   Uncomfortable

Figure 7b: Pedestrian level wind velocity comfort categories.

Figure 7c: Pedestrian level wind velocity comfort categories.



Comfort Categories - Winter - Existing

Sitting · Standing · Walking · Uncomfortable

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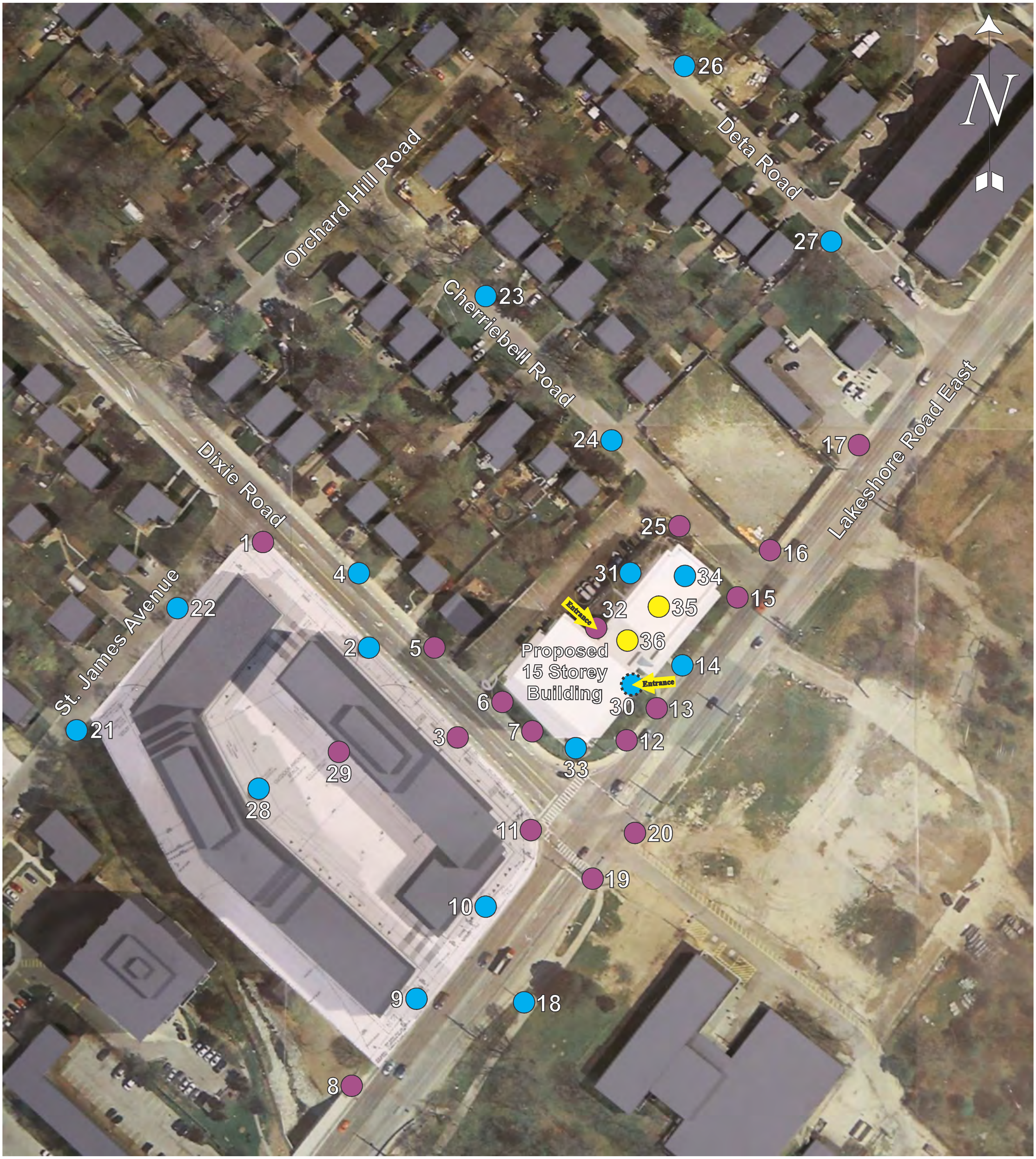
Figure 7d: Pedestrian level wind velocity comfort categories.



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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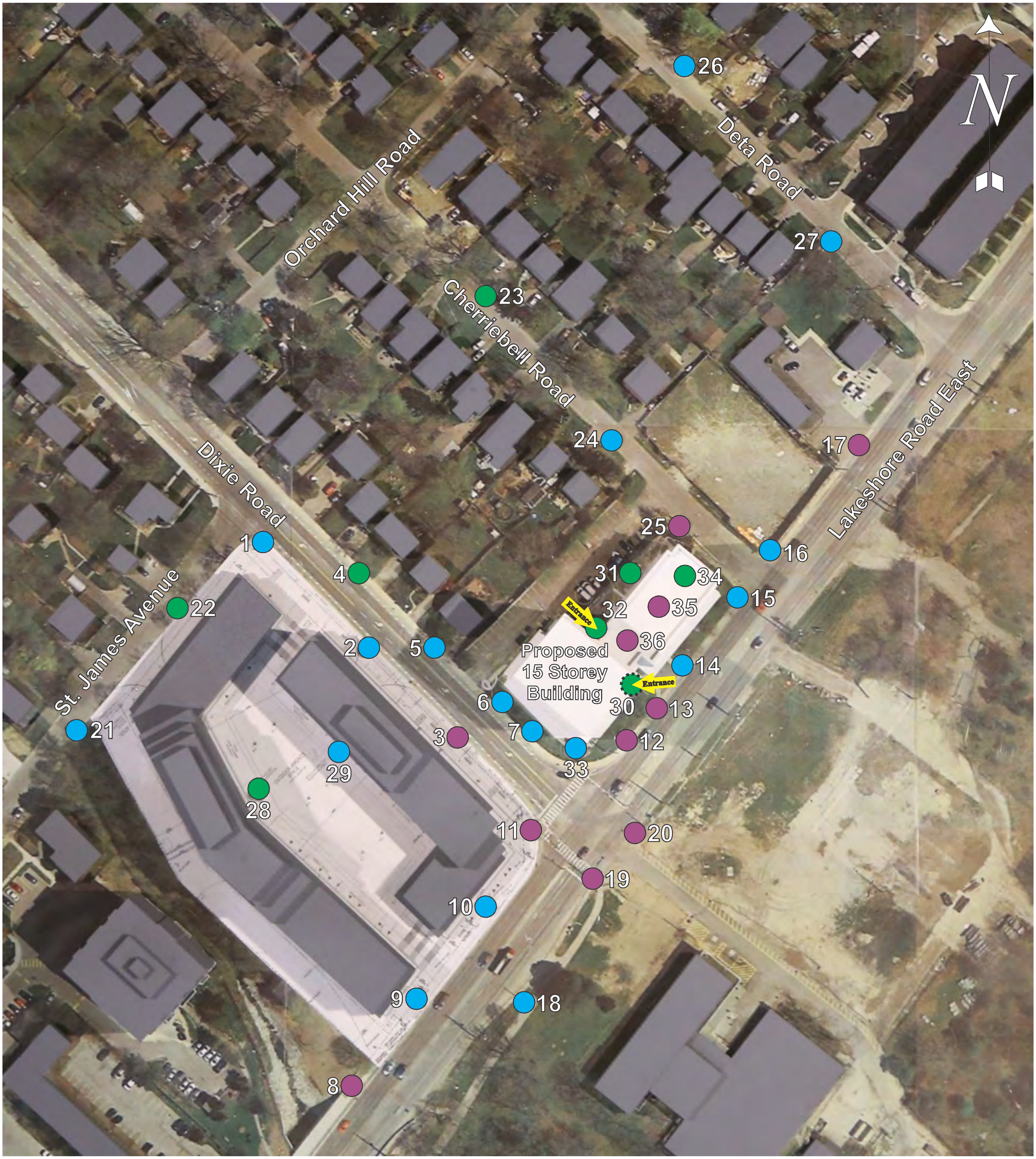
Figure 7f: Pedestrian level wind velocity comfort categories.



Comfort Categories - Spring - Proposed

Sitting Standing Walking Uncomfortable

Figure 7g: Pedestrian level wind velocity comfort categories.

Comfort Categories - Summer - Existing

Sitting Standing Walking Uncomfortable

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Figure 7h: Pedestrian level wind velocity comfort categories.

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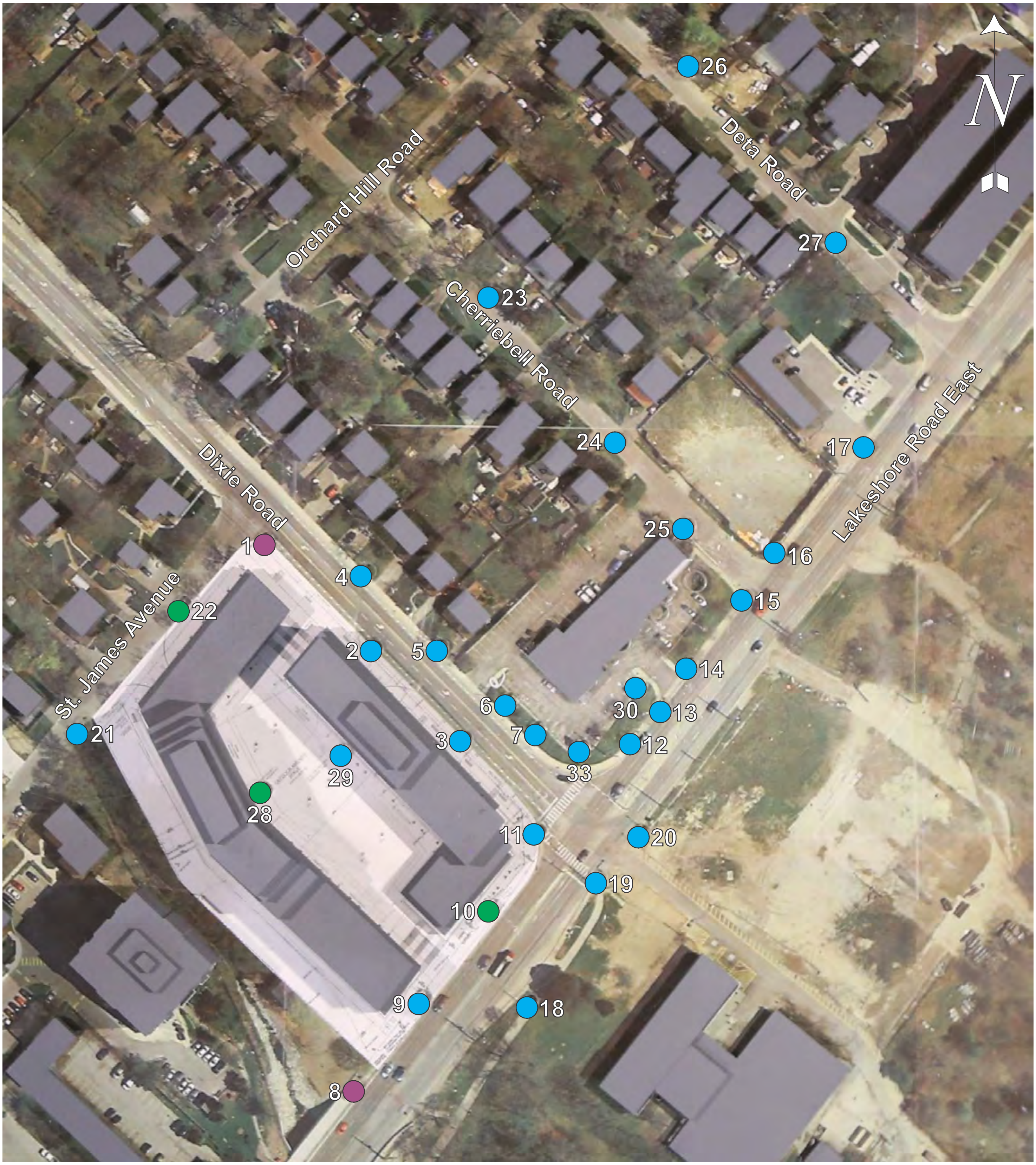
Figure 7i: Pedestrian level wind velocity comfort categories.



Comfort Categories - Fall - Existing

Sitting Standing Walking Uncomfortable

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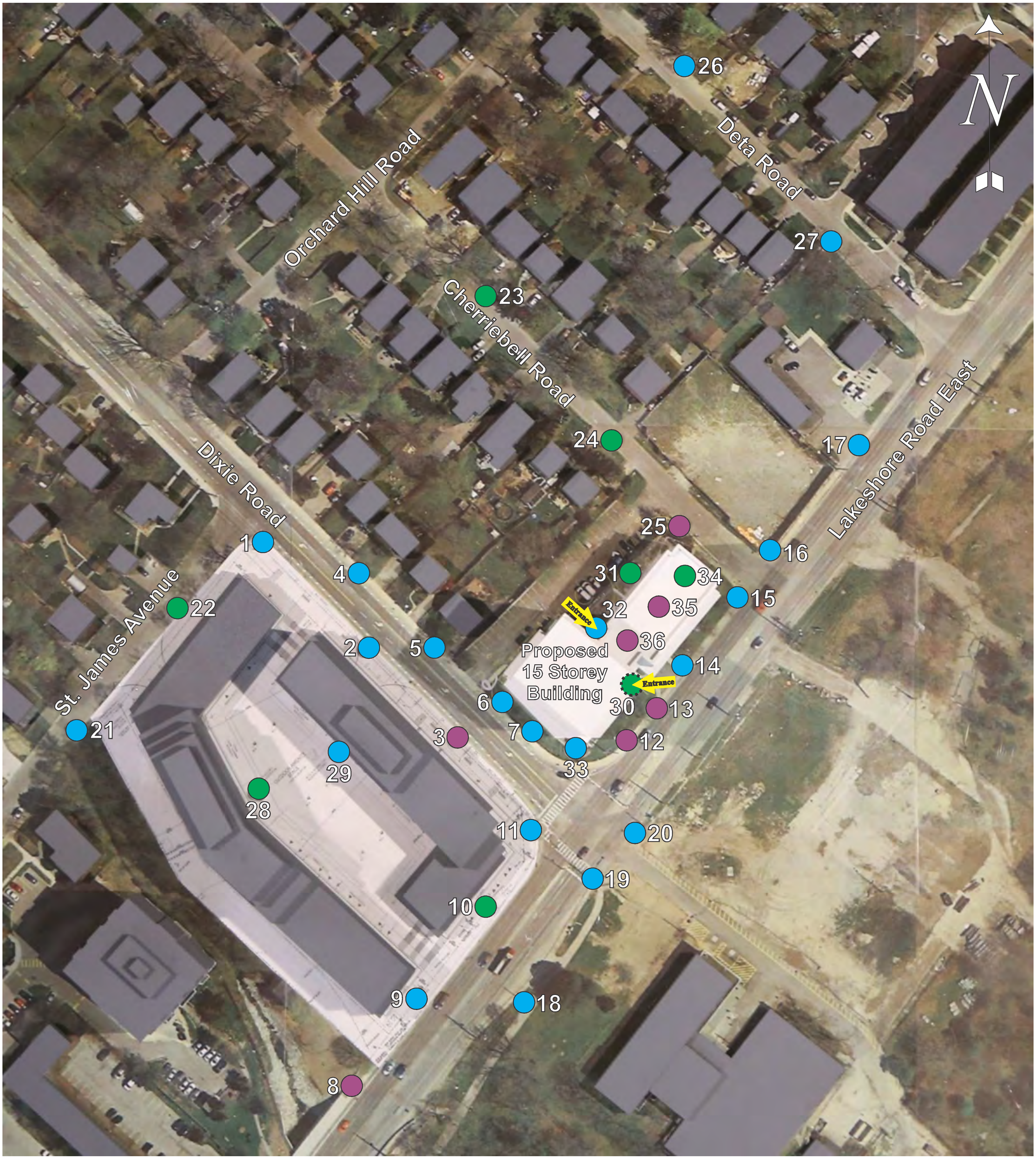
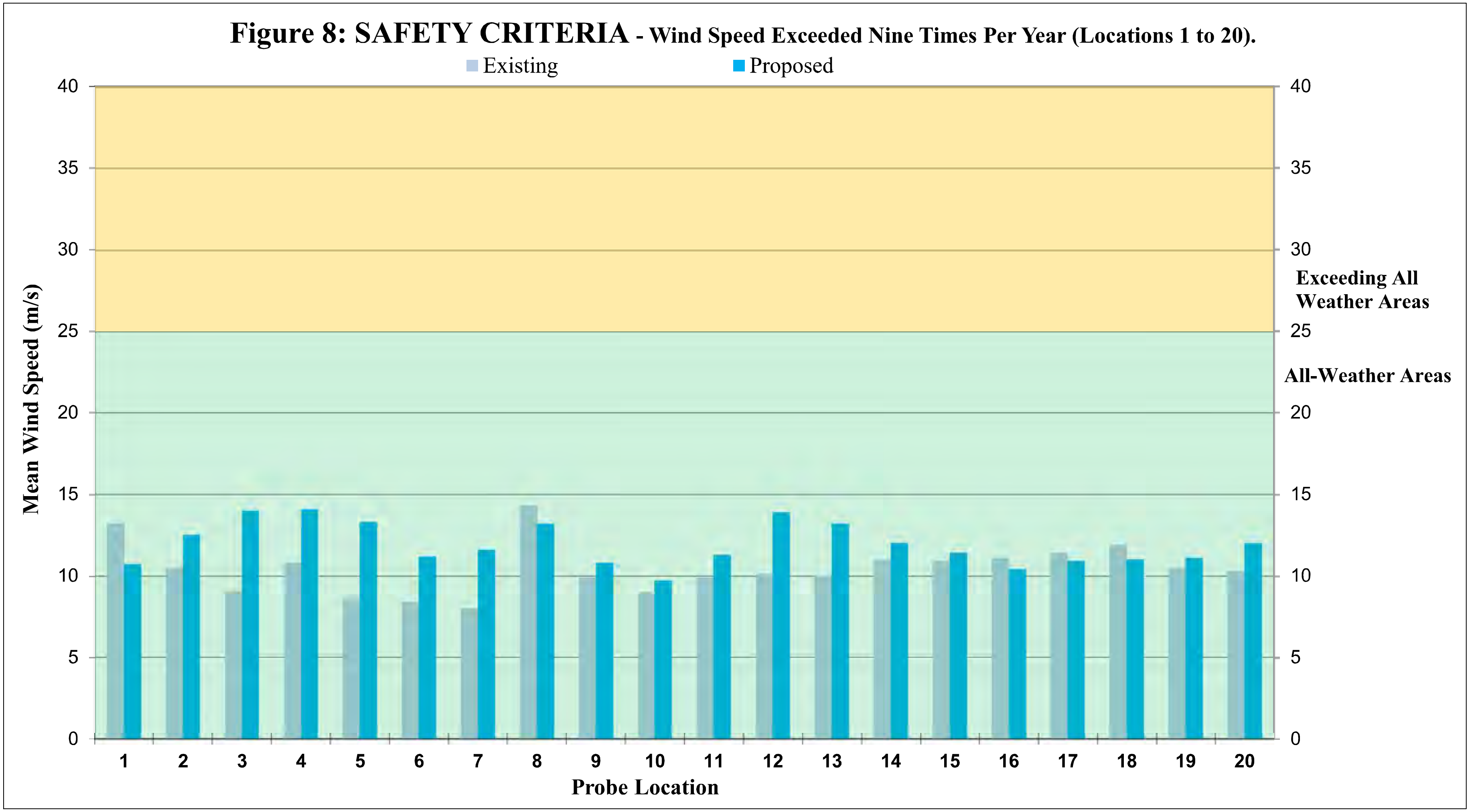
Figure 7j: Pedestrian level wind velocity comfort categories.



Comfort Categories - Fall - Proposed

Sitting Standing Walking Uncomfortable



Theakston Environmental

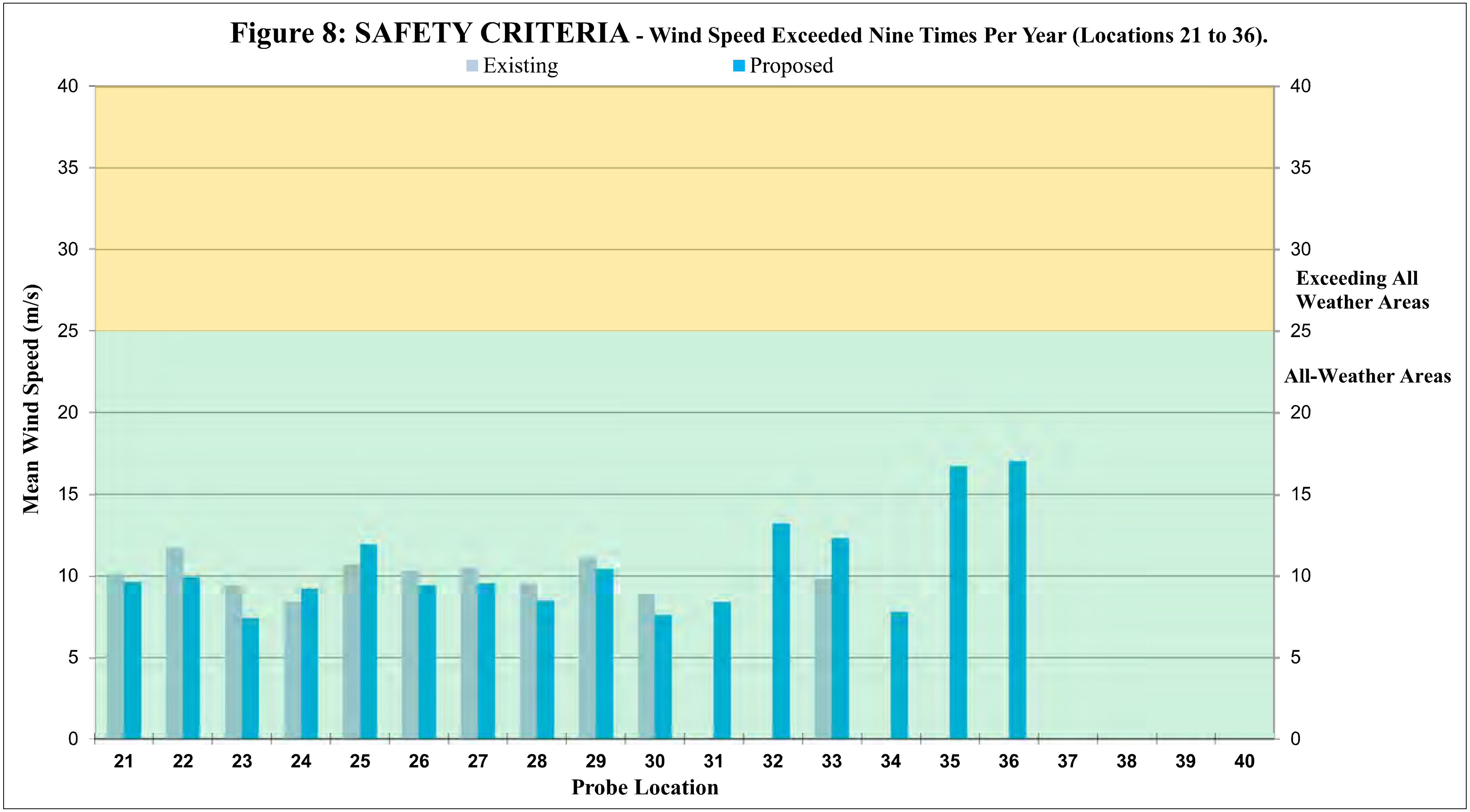


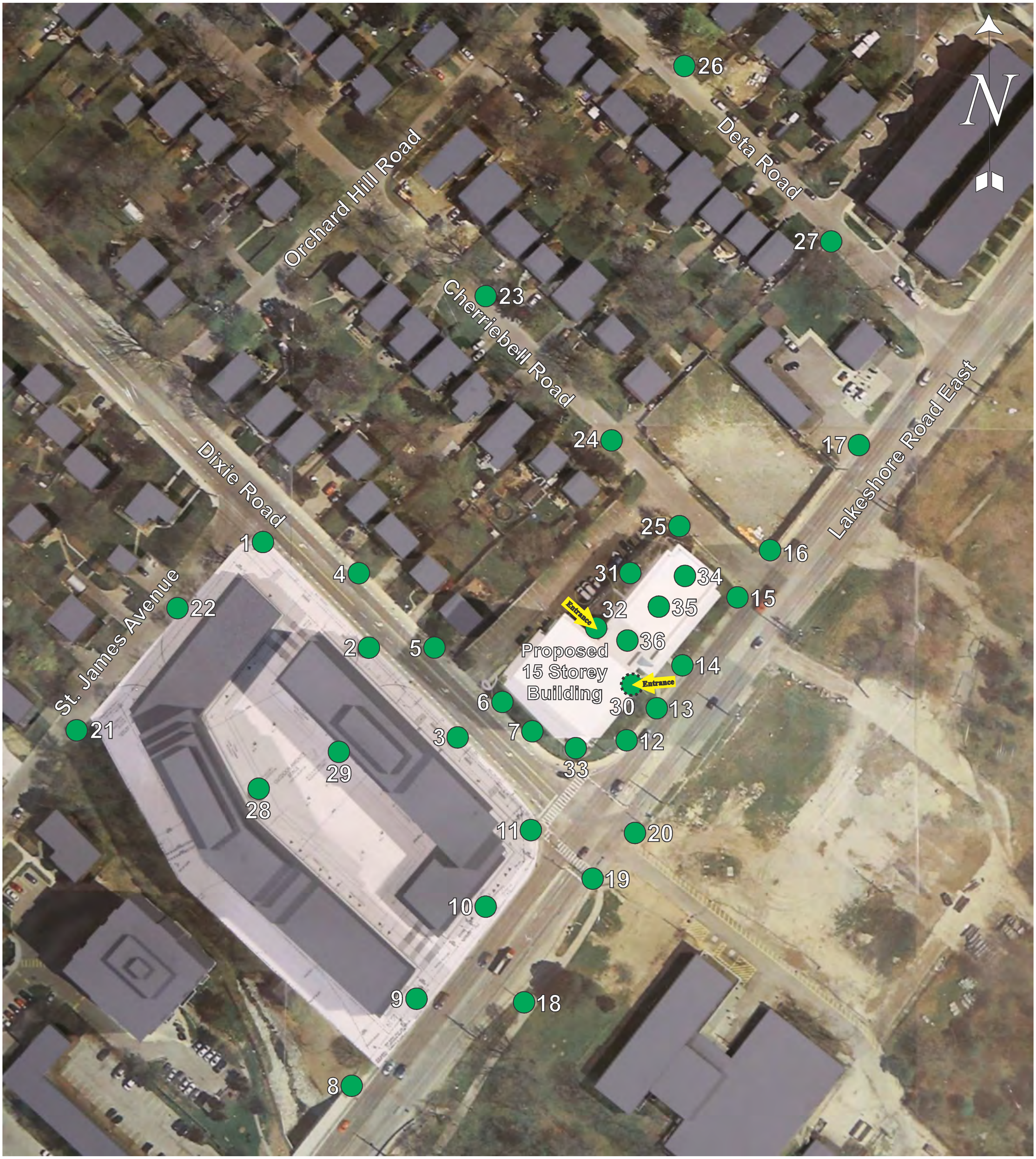
Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Nine Times Per Year (Locations 21 to 36).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Exceeding All Weather Areas
All-Weather Areas
0
5
10
15
20
25
30
35
40
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

Figure 9a: Pedestrian level wind velocity safety criteria.

Safety Criteria - Existing

All-Weather Areas Exceeding All-Weather Areas

Figure 9b: Pedestrian level wind velocity safety criteria.



Safety Criteria - Proposed

All-Weather Areas   Exceeding All-Weather Areas

8. 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:

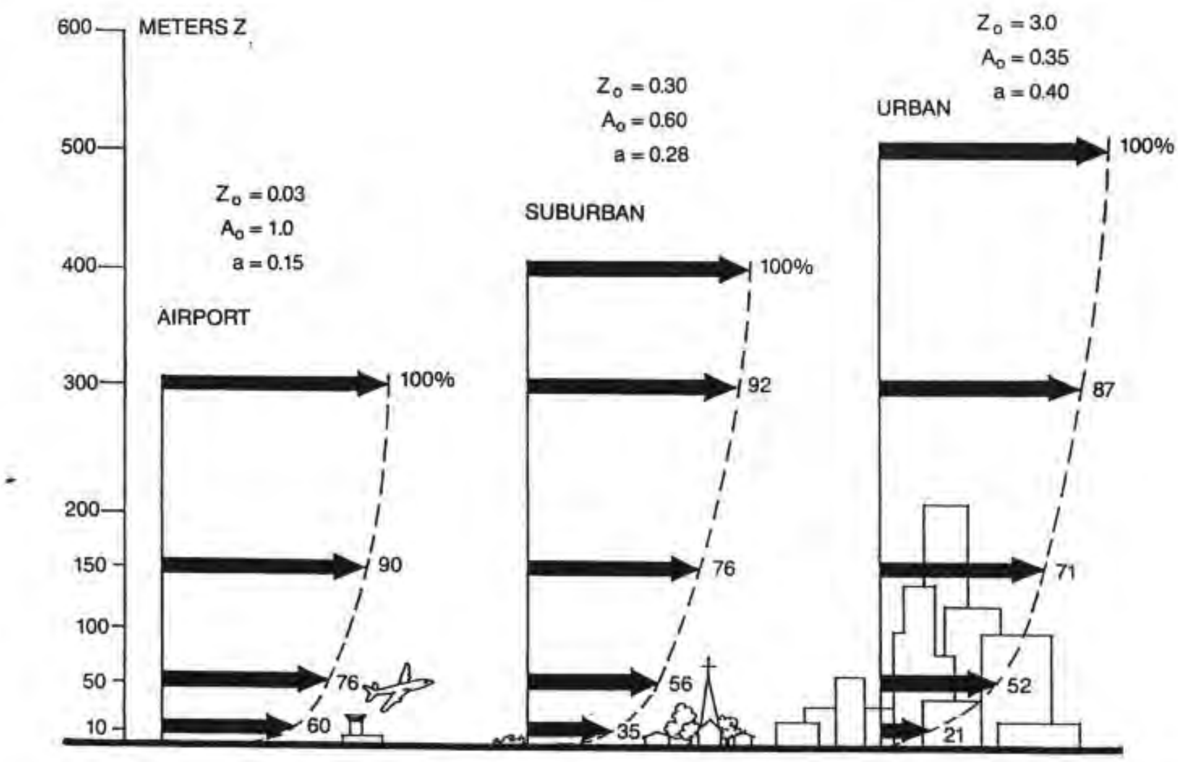


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

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 300m 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.

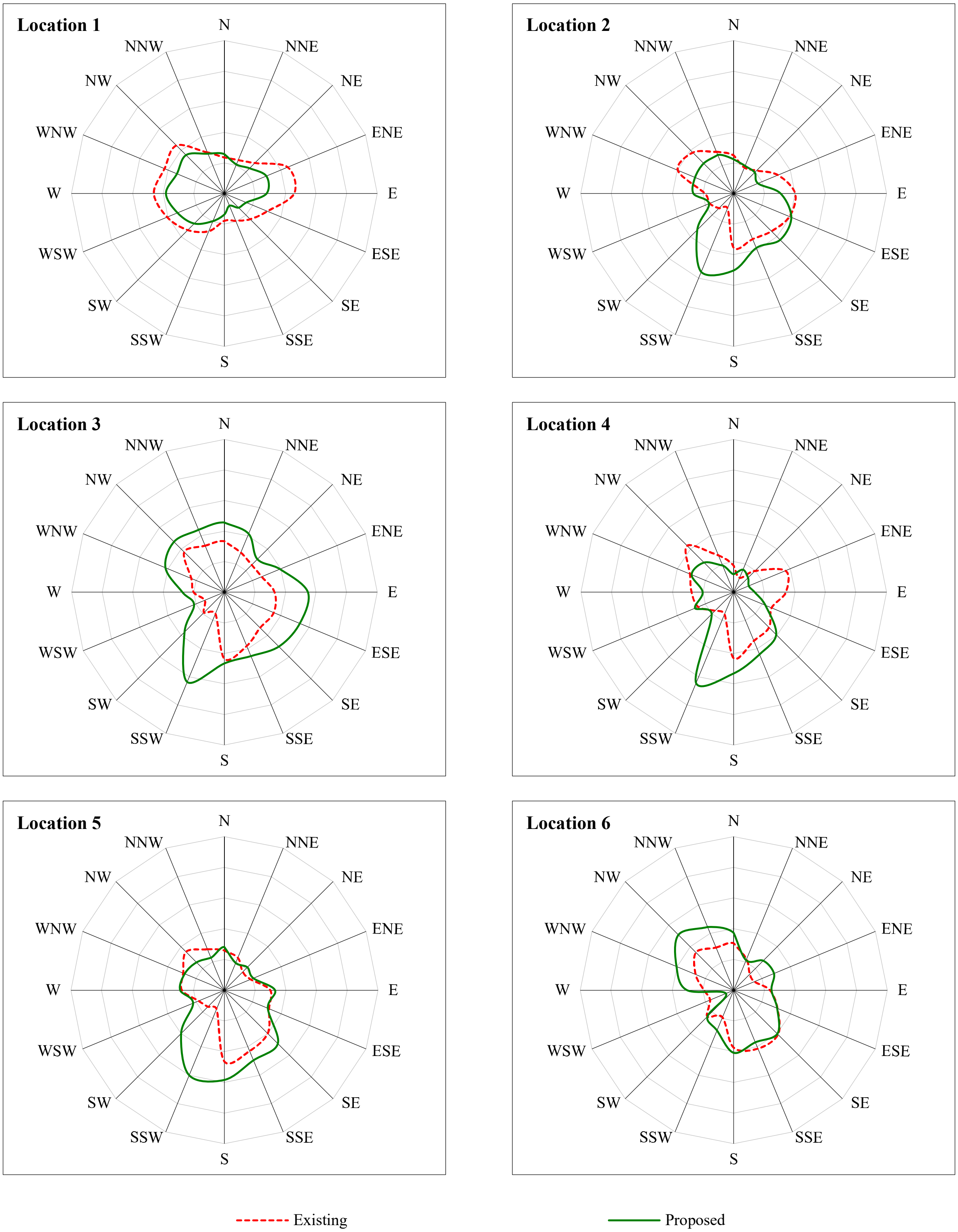


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

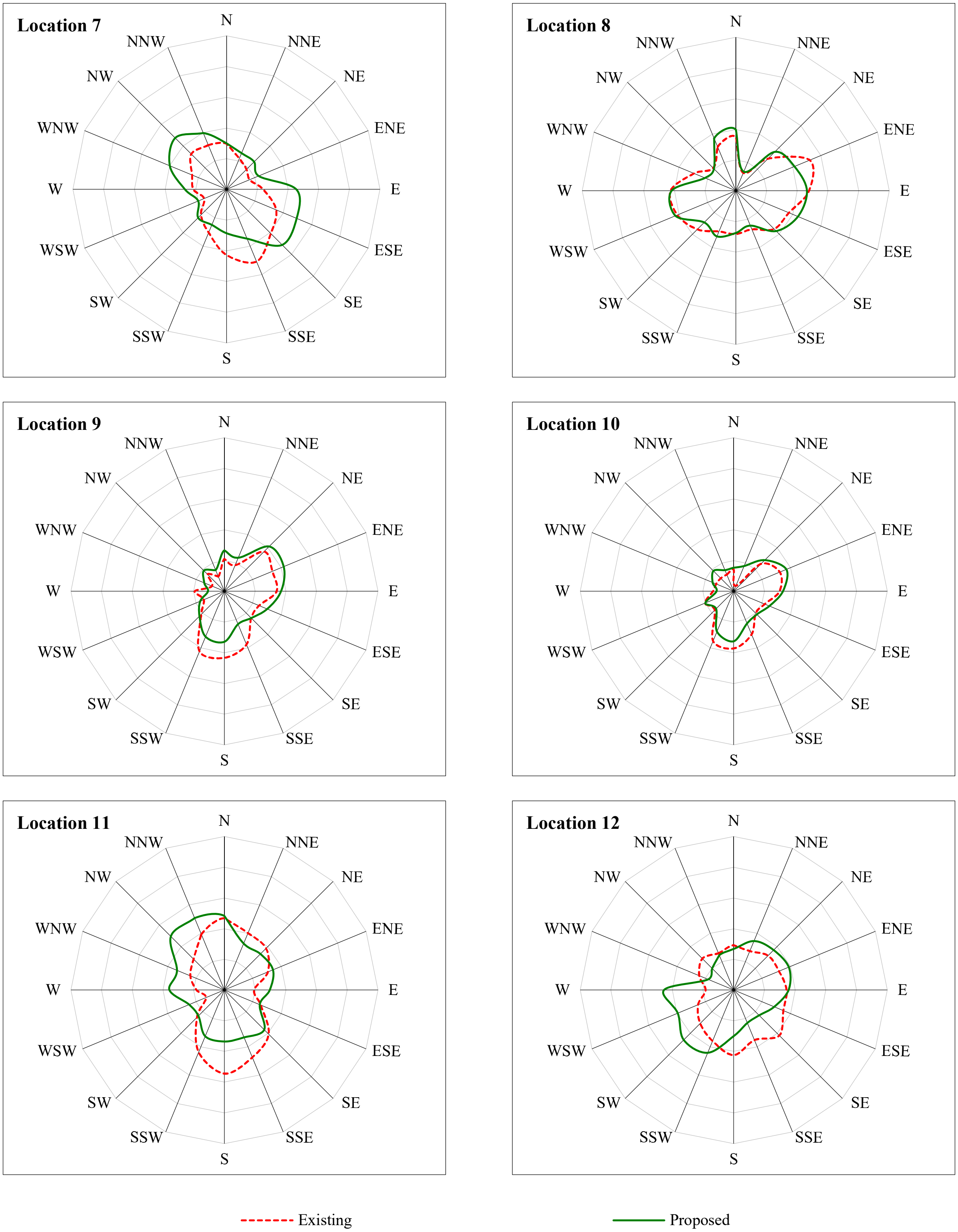


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

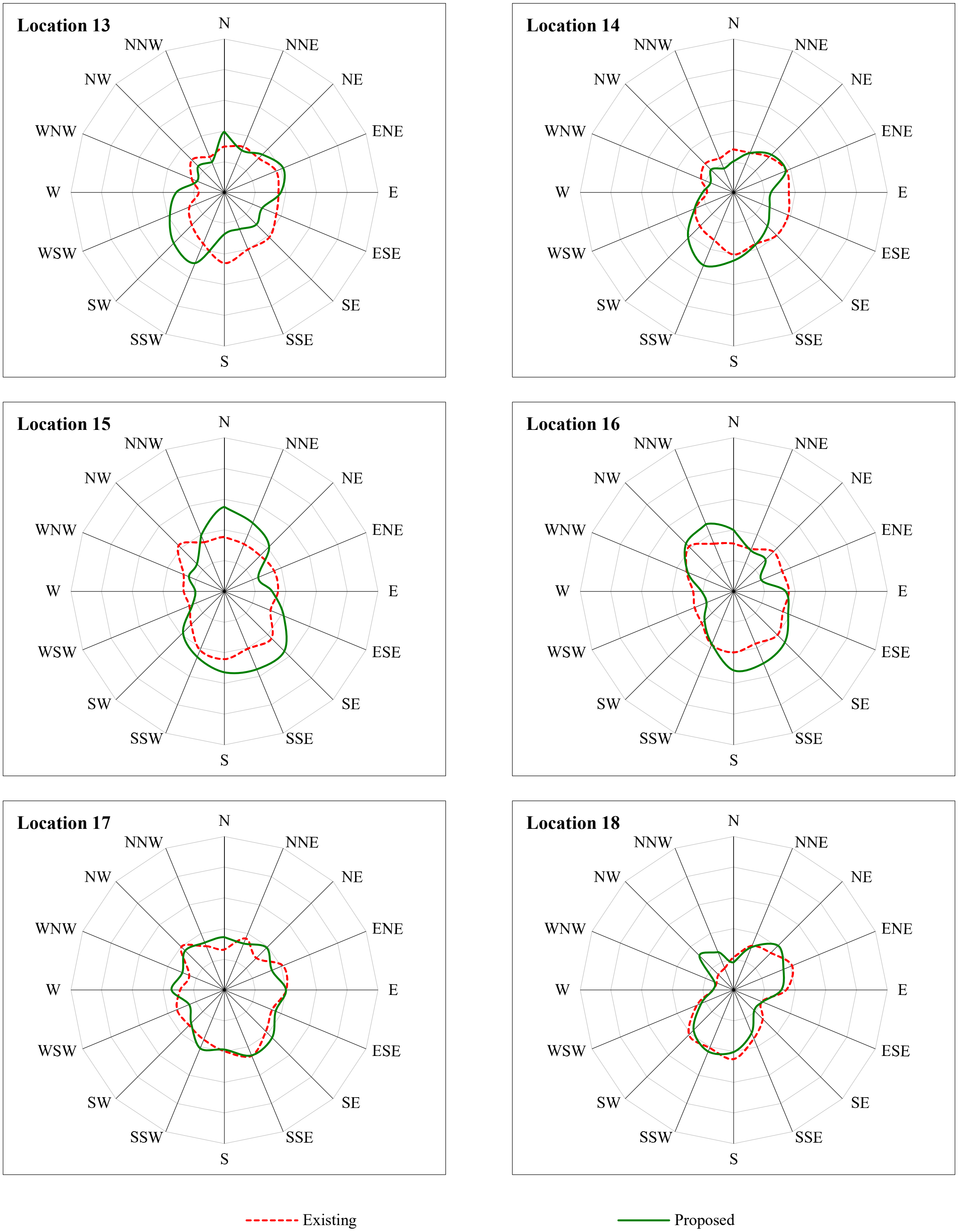


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

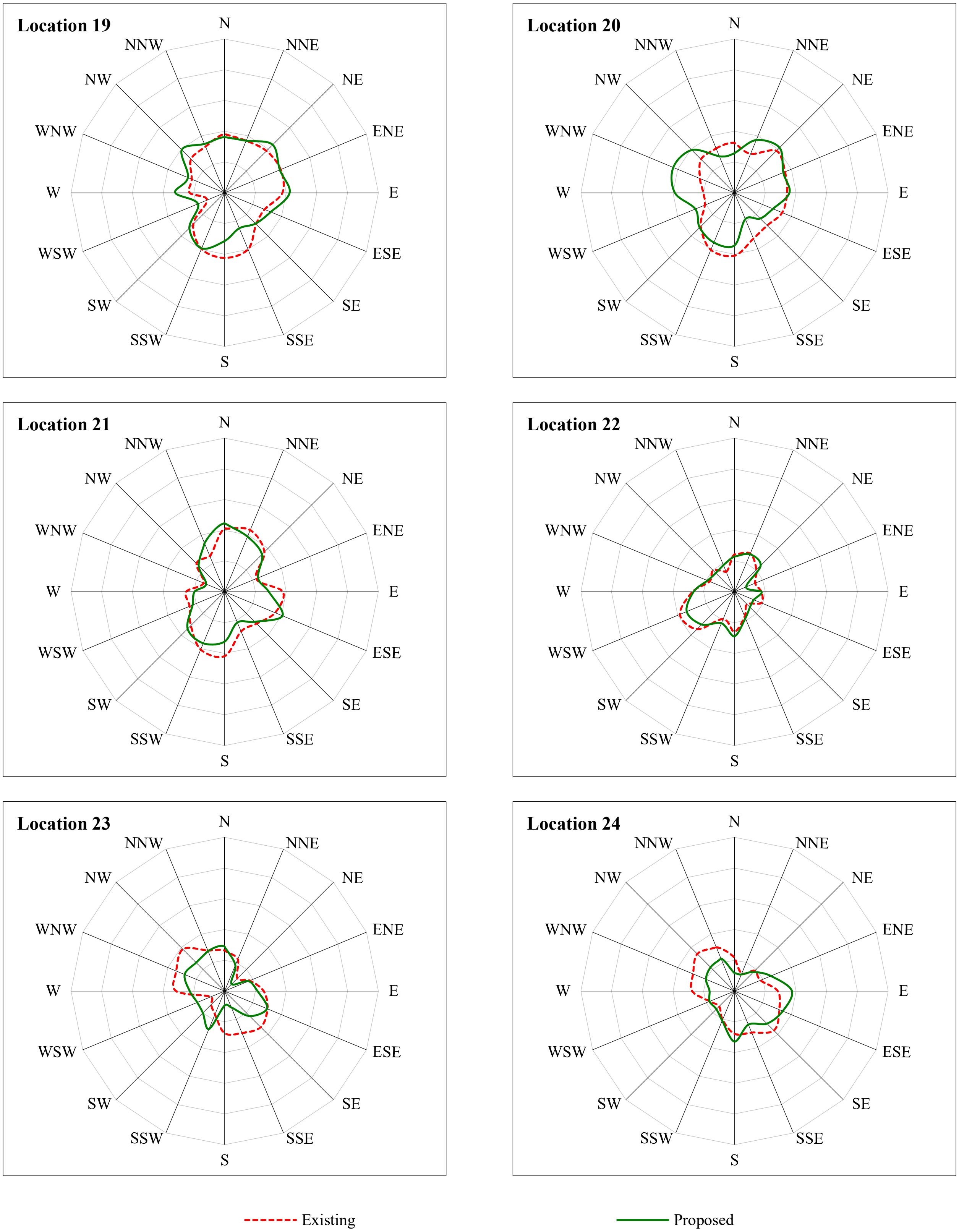


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

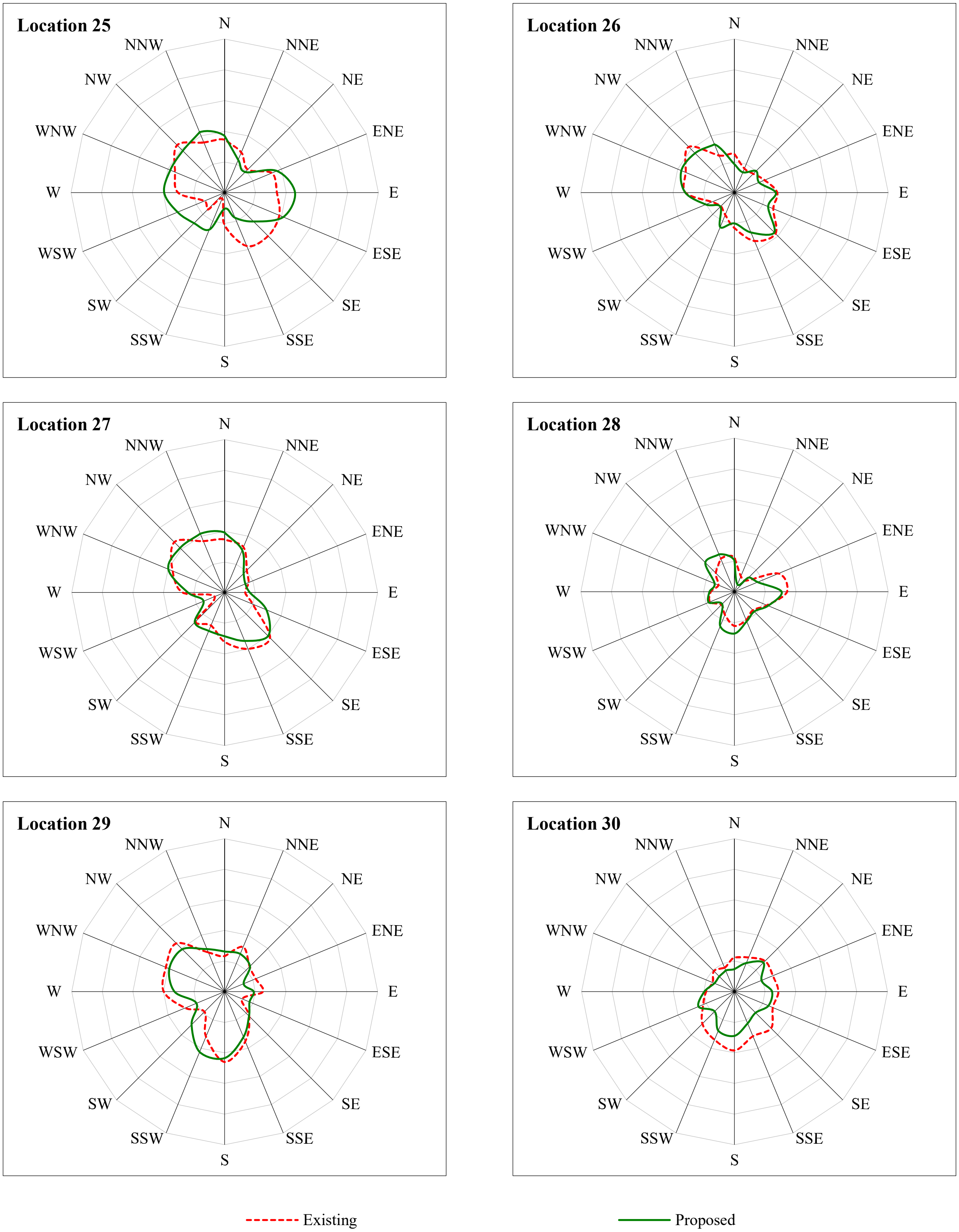
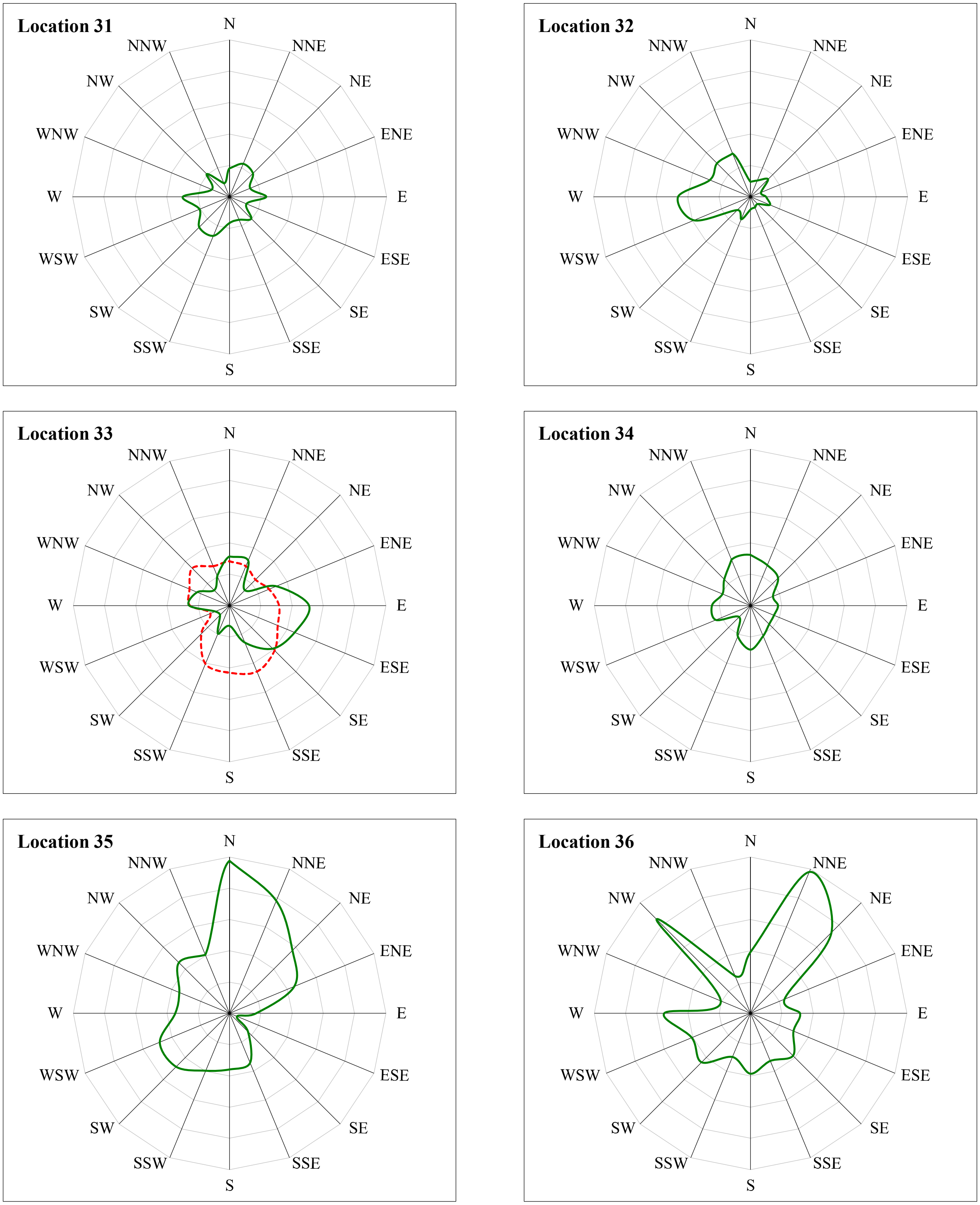


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.



------- Existing ——— Proposed

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