REPORT

PRELIMINARY PEDESTRIAN WIND STUDY

211 JOHN STREET SOUTH

HAMILTON, ONTARIO

Slate Asset Management L.P.

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1 EXECUTIVE SUMMARY

The mixed-use residential Development proposed by Slate Asset Management L.P. for 211 John Street South has been assessed for Environmental standards with regard to Pedestrian Level Wind Velocities relative to comfort and safety. The pedestrian level wind and gust velocities measured for the fifty-four (54) locations tested are within the safety criteria and most are within the comfort criteria described within the following report.

The proposed Development is located in the City of Hamilton, and occupies the block of lands bound by Young Street to the north, John Street South to the west, Forest Avenue to the south, and Catharine Street South to the east. The Development covers the block and presents street related commercial to the west portion of Young Street, and John Street South, with remaining street related façades, and above, residential.

The Development involves a proposal to build 34 and 31 storey towers with podium wings of various heights, and outdoor amenity spaces atop the podiums. The towers are square and rectangular in shape and are punctuated with balconies. As a result winds, upon contact with the towers, will display a propensity to flow around the towers with limited downwash towards the pedestrian level. Downwash that does occur will be limited to the extent of the pattern of the floor plates, understanding the stepped conditions in the massing will intercept said flows, deflecting winds from specific directions to continue around the tower.

A mix of urban/suburban lands supporting low through to high-rise residential and commercial buildings bound the Property to all compass points. Natural topographical features influencing weather conditions at the site are the Niagara Escapement, which presents a very significant grade change of approximately 90*m*, approximately 500m to the south, and lake Ontario, which is approximately 8km to the northeast. Urban intensification is progressing in Hamilton, however, no wind significant development was approved within the vicinity of the Proposed Development at the time of testing.

The subject buildings and the surrounds have a sympathetic relationship with the pending wind climate. Urban development provides turbulence inducing surface roughness that can be wind friendly, while open/suburban 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/suburban to urban settings can prove problematic, as winds exacerbated by the preceding setting are redirected to flow down, around and between buildings.

The orientation and conformation of the Proposed Development relative to the surroundings, and prevailing winds, effectively mitigates winds from significant directions which were in turn mitigated upon approach by the existing and proposed urban development of the surrounding terrain, and as such, are of reduced velocity at the site, for several dominant wind directions. Thus, for most wind conditions, pedestrian comfort conditions will be comfortable, suitable for

sitting or standing in the summer and standing or walking during the winter, suitable to the area's intended purpose throughout the year.

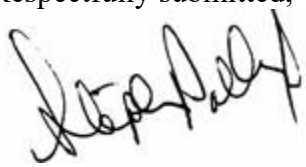
During the winter there may be occasions, however, when strong or gusty southerly winds will flow along the streets resulting in somewhat windy conditions at corners and in gaps between buildings. Entrances that are proximate to said areas and are flush with the respective building's façade might be subject to winds acting on the door leaf mechanisms. Recessing such entrances is recommended where practical to reduce this potential. Also, wind speeds over portions of the podium roof were higher than preferred for activities associated with amenity spaces. Mitigation measures were recommended to improve pedestrian comfort conditions at these locations; said mitigation will be tested and the ultimate mitigated results reported during detailed design development.

The proposed Development's massing incorporates wind friendly design elements; angular façades, overhangs, and others which, when considered in concert with the stepped podium, allow much of the impending wind climate opportunity to flow over and around, as opposed to down, the building. These elements effectively reduce the incidence of downwash, and related pedestrian level wind effects, attributable to the Development. Comfort conditions expected at the proposed Development site are considered appropriate to the urban context. Where mitigation was recommended, it was achieved through the following design features that were incorporated into the proposed Development's massing and landscape design:

- parapet walls
- stepped façade at the podium
- overhangs
- canopies
- balconies
- landscaping

In summary, the proposed Development's stepped facades, podium, and other design features will contribute to anticipated pedestrian comfort conditions that are suitable to the context. The proposed Development will realize wind conditions acceptable to a typical urban context.

Respectfully submitted,



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

2 INTRODUCTION

Theakston Environmental, Consulting Engineers, Fergus, Ontario, were retained by Slate Asset Management L.P. to study the pedestrian level wind environment for their proposed mixed-use development at 211 John Street South. The buildings will be located in the City of Hamilton, the site as depicted on the Aerial Photo in Figure 2a. The Development involves a proposal to build 34 storey and 31 storey towers with podiums and outdoor amenity space atop the podiums, in the configuration shown in Figure 2b.

Brandon G. Donnelly of Slate Asset Management L.P. Hamilton, Ontario, initiated the request; Core Architects prepared drawings for the 211 John Street South mixed-use residential Development. 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 the current study site as well as existing and proposed buildings in the surrounding area. The proposed configuration included the Development's subject buildings. The ultimate configuration assessed mitigation strategies 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. Predictions of wind speeds for various probabilities of occurrence and for various percentages of time are then 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 (Figure 1). The boundary layer wind tunnel 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.

The Boundary Layer Wind Tunnel Laboratory (BLWTL) located at The University of Western Ontario, and part of the Faculty of Engineering, in London, Ontario was used to test the physical model and provide processed data results.

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 fifty-four (54) points tested were subsequently combined with the design probability distribution of gradient wind speed and direction, (wind statistics) recorded at Hamilton international Airports, 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 5% 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 Hamilton region that was used in the analysis was based on historical records of wind speed and direction measured at Hamilton International Airport for the period between 1994 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. Based on the analysis of the hourly records, the predicted hourly-mean wind speed at 10 *m*, corrected for an urban/suburban exposure is 10.9 *km/hr*.

4.3 Statistical Wind Climate Model

For the analysis of the wind tunnel data, the wind climate model is converted to a reference height of 500 *m* using a standard urban/suburban exposure wind profile. The mean-hourly wind speed at the 500 *m* reference height used for this study is 25.8 *km/hr*.

The design probability distribution of mean-hourly wind speed and wind direction at reference height is shown for Hamilton 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 northeast and southwest and said winds are most likely to occur during the winter and fall seasons.

4.4 Wind Simulation

To simulate the correct macroclimate, the upstream flow of the wind tunnel 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 1:400. The model is based upon information gathered during a site visit to the proposed Development site, and surrounding area. Core Architects provided architectural drawings. City of Hamilton 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 1.8*m*. During testing, the model sample period is selected to represent 1*hr* of sampling time at full scale. The velocities measured in a 2.44*m* wide boundary layer wind tunnel 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 5% 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	Mean Wind Speed Exceeded 5% of the Time		Description
COMFORT	***km/hr***	***m/s*** (used in Fig. 6)	
Sitting	0-14	0-4	Tree leaves rustle, flags wave slightly. Recommended for outdoor space where people may sit for extended periods.
Standing	0-22	0-6	Small branches move, flags flap and ripple. Suitable for locations where people might sit for short periods or stand in relative comfort.
Leisurely Walk	0-29	0-8	Large branches sway, umbrellas used with difficulty, flags beat and pop. Suitable for activity areas.
Fast Walking	0-36	0-10	Whole trees sway, difficult to walk. This is considered the acceptable upper limit for comfort for the average population.
Uncomfortable	>36	>10	Winds exceed the "Fast Walking" category, can be tolerable for short duration, but will likely be an inconvenience to walking.

The activities are described as suitable for Sitting, Standing, Leisurely Walking or Fast Walking, depending on average wind speed exceeded 5% of the time. For a point to be rated as suitable for Sitting, for example, the wind conditions must not exceed 14*km/hr* (4*m/s*), more than 5% 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 and in Table 1 above. 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 22*km/hr* (6*m/s*). In this situation, the wind would rustle tree leaves and, on occasion, move smaller branches while flags flap and ripple. This category would be suitable for locations where people might sit for short periods or stand in relative comfort. The Leisurely Walking category includes wind speeds from calm up to 29*km/hr* (8*m/s*). These winds would set tree limbs in motion, lift leaves, litter and dust, and the locations are suitable for activity areas. The Fast Walking category is much more tolerant of wind, including wind speeds up to 36*km/hr* (10*m/s*). In this case, whole trees would sway and it

would be difficult to walk. This is considered as the acceptable upper limit for comfort for the average population. The Uncomfortable category covers a broad range of wind conditions, including wind speeds above 36*km/hr* (10*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 5% 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 2*m/s* (or more) interval. The location is rated as suitable for Sitting, Standing, Leisurely Walking or Fast Walking, 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 once 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. These criteria were developed for pedestrian wind studies and are used in studies around the world.

Table 2: Safety Criteria

ACTIVITY	Mean Wind Speed Exceeded once per year		Description
SAFETY	***km/hr***	***m/s*** (used in Fig. 8)	
All-Weather Areas	0-54	0-15	Areas that need to be used in all weather conditions, such as building entrances, sidewalks, etc.
Fair-Weather Areas	0-72	0-20	Areas that are not used or can be closed in severe weather, such as park benches, lookout points, etc.
Exceeding Fair Weather Areas	>72	>20	Areas that are considered to pose a serious hazard and are undesirable regardless of activity.

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. In cases where seasonal comfort is important, results have been included for four seasons; winter, spring, summer, and fall (see Figures 6b to 6e and Figures 7c to 7j).

For this site, when compared to the annual average wind speed, winter winds are about 21% higher and summer winds are about 24% lower.

5 RESULTS

5.1 Study Site and Test Conditions

The proposed Development is located in the City of Hamilton, and occupies the block of lands bound by Young Street to the north, John Street South to the west, Forest Avenue to the south, and Catharine Street South to the east. The Development covers the block with street related commercial associated with a portion of Young Street, and John Street South, and residential above, as depicted in Figure 2a. Urban intensification is taking place in Hamilton, however,

none significant to the wind climate and affecting the Proposed Development was approved in the surroundings at the time of testing.

Urban/suburban lands supporting low to high-rise commercial and residential buildings bound the Property. Two and three storey single and multifamily residential dwellings, for all intents and purposes, occupy lands to the immediate north of Young Street with a similar, though slightly coarser terrain to the east that includes Brockton Apartments, a 12 storey slab style residential building at 175 Catharine Street South. To the east are several high-rise buildings occupying lands between Young Street and Forest Avenue. The most significant to the Proposed Development is the Oakland Square II Apartments, a 21 storey slab style building at 100 Forest Avenue. To the south the surroundings are also comprised of low to mid-rise residential, and St. Joseph's Hospital precedes the Niagara Escarpment, which represents approximately a 90m grade change, with low-density residential on the bluff above. The most significant building to the southwesterly wind climate is the Villa Marie I Apartment, a 14 storey cruciform shaped building to the west at 57 Forest Ave. Figures 2a and 2b depict the site and its immediate context and the site model, shown in Figure 3, is built to a scale of 1:400.

Proposed Development

The Development, based upon project plans prepared by Core Architects, presents a proposal to construct 34 and 31 storey towers with podiums style wings of various heights, and outdoor amenity space atop the podiums. The 34 storey tower, denoted Tower A occupies the northwest corner of the site and features a 7 storey wing that extends to the east along Young Street. The ground floor beneath the tower has street related retail fronting Young Street and John Street South, and the wing has residential units along Young Street and Catharine Street South. Outdoor amenity space is proposed at the 7th level on the roof. The tower component is square in shape and is punctuated with balconies. The residential vestibule is accessed via entrances along Young Street and from a central courtyard.

The 31 storey tower, denoted Tower B occupies the southeast corner of the site and similarly features an 8 storey wing that extends to the west along Forest Avenue. The underground floor beneath the wing has retail that is accessed from John Street South, and the ground floor supports parking and commercial services. The residential entrance is along a driveway dissecting the site, between the buildings near Catharine Street South. The tower component is rectangular in shape and is punctuated with balconies. Outdoor amenity space is proposed at the 8th level on the podium roof.

Tower B has a 5 storey connective with the 7 storey wing of Tower A that fronts Catharine Street and bridges over the driveway and a landscaped Space. The Development is phased, Phase 1 comprised of Tower A and the related 7 storey wing; Phase 2 comprised of the 31 storey Tower B, 8 storey wing to the west and 5 storey connective wing to the north.

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, as well as the Niagara Escarpment, was incorporated into the proximity model. Historical meteorological data recorded from the Hamilton International Airport was used in this analysis. For studies in the City of Hamilton, the historical weather data is depicted on an annual and seasonal basis and the resulting wind roses are presented as mean velocity and percent frequency in Figures 5a-e. 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 urban and suburban.

Winter (November 16 to March 31) has the highest mean velocities of the seasons with prevailing winds from the southwesterly quadrant, with significant components from the northeast quadrant as well, as indicated in Figure 5b. Spring (April 1 to June 15) has the second highest mean wind velocities and the prevailing winds tend to be from the Northeast and westerly through southwesterly quadrants (Figure 5c). Summer (June 16 to September 15) has the lowest mean wind velocities of the seasons with prevailing winds from northeast and westerly through southwest as well, as indicated in Figure 5d. During the Fall, (September 16 to November 15) the possible directions for prevailing winds are essentially the same as spring and summer, (Figure 5e). The magnitudes of the mean wind velocities are between spring and summer winds. Reported pedestrian comfort conditions generally pertain to the Annual conditions, which are depicted in Figure 5a and tend to frequent the northeast and southwest quadrants with the greatest frequency of strong winds from more southwesterly directions.

Clearly Hamilton's wind climate is very directional and this is attributed to the City's situation between Lake Ontario, to the northeast, and Lake Erie, to the southwest. The lakes providing an energy source and the lay of the land channels winds to flow over the much lower portion of lands separating the lakes.

5.2 Pedestrian Level Wind Velocity Study

On the site model fifty-four (54) wind velocity measurement probes were located on and around the proposed Development as well as 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 proposed scenario. For the existing setting, the subject buildings were removed and the "existing" site model retested with the existing buildings. As a result, some probe locations were obstructed and could not be tested in the existing setting.

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 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.

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 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 an urban/suburban setting to prevailing and remaining compass points with winds flowing over and between tall buildings occurring from relatively limited segments of the wind climate. 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, Pedestrian Entrance Conditions, Internal Site Conditions, and Outdoor Amenity Space Conditions. The measurement locations are depicted in Figure 4 and are listed in Figures 6a – 6e annually and for the seasons for the existing and proposed configurations. The results are also graphically depicted for the existing and proposed configurations annually and the seasons in Figures 7a – 7j. The following discusses anticipated wind conditions and suitability for the points' intended use.

Public Street Conditions

Young Street

Probes 1 through 4, 23 through 29, and 47 through 50, were located along Young Street, within the zone of influence of the proposed Development, as indicated in Figure 4. Of these, most indicate comfortable conditions, suitable for sitting on an annual basis in the existing setting,

with the exception of localised slightly windier conditions to the east of the site, proximate to the Brockton Apartments. This is a 12 storey slab style building situated to the immediate east of the Proposed Development site at 175 Catharine Street. The building presents a broad façade to southwesterly winds that cause an acceleration of winds resulting in conditions suitable for standing on an annual basis at points 27 and 29. The comfortable conditions realised along the street are a reasonable expectation, given that the area is sheltered from prevailing wind directions by low to mid-rise development that tend to deflect winds to flow over their roofs, effectively sheltering leeward pedestrian areas.

Of the locations tested in the proposed setting, several points retained the relatively comfortable conditions of the existing setting, suitable for sitting, however, several became windier under specific wind conditions. Locations 2, 3, 4, 23, 26, 47, 49 and 50 realised sufficient change to go from being predicted suitable for sitting in the existing setting to being suitable for standing in the proposed, and locations 1, 24 and 29 became suitable for leisurely walking. The changes are for the most part very subtle and can be partially attributable to the proposed development deflecting prevailing winds that formerly flowed over the relatively open site area of 211 John Street South to flow around the proposed buildings.

During the winter months Young Street remains comfortable and suitable to the intended purpose with only probe location 1, which is situated at the southeast corner of the intersection of Young Street with John Street South, becoming suitable for fast walking. This is a reasonable expectation, understanding that northeasterly and southwesterly winds, which are prevailing wind directions, will be respectively deflected to flow along the Young Street and St. John Street South façades of the Proposed Development and around said corner. The street remains within the pedestrian level wind velocity safety criteria as Fair-Weather Areas, as described in Section 4.7 and depicted in Figure 9.

Catharine Street South

Probes 5, 6, 8, 9, 30, 31, 34 through 37, 53, and 54 were situated along Catharine Street South within the zone of influence of the proposed Development. These locations indicate similarly comfortable conditions to those observed along Young Street in the existing setting. This is attributed to the orientation and exposure of Catharine Street South to southwesterly winds, a dominant wind direction as indicated in Figure 5's Wind Roses. With inclusion of the proposed Development a slight realignment of winds was realised with winds from several directions improving and others exacerbated, as indicated in the ground level wind velocity plots of Appendix Figure B. Of the locations tested, points 8, 30, 31, 34, 37, and 54 realized sufficient wind to change the annual comfort rating one category from sitting to standing and from standing to leisurely walking. Conversely, probe location 35 realised a slight improvement, however, the probe was sufficiently close to the transition that it's rating improved from annually suitable for standing to sitting.

The windier conditions can be partially attributed to the proposed Development causing a realignment of winds from northeasterly and southwesterly directions that; in concert with neighbouring properties cause said windier conditions. The improvement at 35, which is to the

south of the site, can be attributed to the blocking effect of the Proposed Development to northerly winds.

During the winter months the gap between the neighbouring Brockton Apartments, a 12 storey slab style residential building to the immediate east of the Proposed Development at 175 Catharine Street South, realises a similar increase in winds resulting in pedestrian comfort conditions that are suitable for standing or leisurely walking with localised corners, locations 6 and 9, suitable for fast walking. This is a reasonable expectation for corner locations and/or gaps that are commonly exposed to winds emanating form several quadrants being deflected to flow along the buildings, around the corners and through the gaps between. The analysis indicates Catharine Street South remains comfortable and suitable to the area's intended purpose with inclusion of the Proposed Development, during the winter months and for the remaining seasons.

Reported pedestrian comfort conditions do not pose a concern to pedestrian safety as indicated in Figure 9; the points are rated as All-Weather Areas, and will improve upon consideration of massing details too fine to incorporate into the model, and urban intensification that may to occur in the immediate surroundings.

Forest Avenue

In addition to probes situated at the intersection of Catharine Street South, probes 10, 11, 12, 32, 33, 38, 39, and 42 through 45 were placed along the Avenue to the south of the Proposed Development. Conditions along Forest Avenue are also comfortable in the existing setting, suitable for sitting and standing, the latter to the east, proximate to the Oakland Square II Apartments, a 21 storey slab style building at 100 Forest Avenue, and west proximate to the Villa Marie I Apartment, a 14 storey cruciform shaped building to the west at 57 Forest Ave.

In the proposed settings similar wind conditions to those discussed above for Young Street and Catharine Street South are observed. The street remains annually suitable for sitting, for the most part along the street and removed from intersections, standing at the John Street Intersection and leisurely walking at the Catharine Street South intersection. This can be attributed to the existing buildings, presented to a significant portion of the prevailing windward climate, providing protection to the street. Conversely, probe locations 43, 44, and 45, which are to the southwest of the Proposed Development, realise an improvement to pedestrian comfort conditions, however, of these only location 43 was sufficiently close to the transition to change comfort categories from standing to sitting.

As such, comfort conditions realised along the sidewalks of Forest Avenue, with inclusion of the proposed Development, remain appropriate to the area's intended purpose. The pedestrian level wind velocity safety criteria rates Forest Avenue as All-Weather Areas, as depicted in Figure 9.

John Street South

In addition to probes situated at the intersections of Young Street and Forest Avenue, probes 13, 14, 40, 41, 46, 51 and 52 were situated along John Street South within the zone of influence of

the proposed Development. These locations indicate similarly comfortable conditions to those observed along Young Street in the existing setting, suitable for sitting on an annual basis, with the exception of the Forest Avenue intersection, which is for the most part suitable for standing, as was discussed above. This is attributed to the orientation and exposure of John Street South to southwesterly winds, a dominant wind direction as indicated in Figure 5's Wind Roses.

With inclusion of the proposed Development a realignment of winds was realised with winds from several directions improving and others exacerbated, as indicated in the ground level wind velocity plots of Appendix Figure B. Of the locations tested, points adjacent to the Proposed Development, 13, 14 and 46 realized sufficient wind to change the annual comfort rating one category, from sitting to standing. Conversely, probe locations 41 and 51 realised a slight improvement, however, they were already suitable for sitting, the most comfortable category.

The windier conditions along the street can be partially attributed to the proposed Development causing a realignment of winds from southwesterly directions that; in concert with the neighbouring Villa Marie I Apartments, a 14 storey cruciform shaped building to the west at 57 Forest Avenue, are directed to flow along the street and through the gap between. During the winter months the gap between the above-mentioned and subject buildings realises a similar increase in winds resulting in pedestrian comfort conditions that are annually suitable for standing. This is a reasonable expectation for corner locations and/or gaps that are commonly exposed to winds emanating form several quadrants being deflected to flow along the buildings, around the corners and through the gap between. The analysis indicates John Street South remains comfortable and suitable to the area's intended purpose with inclusion of the Proposed Development, during the winter months and for the remaining seasons.

Reported pedestrian comfort conditions do not pose a concern to pedestrian safety. As indicated in Figure 9, all points with the exception of Point 1, discussed above, are rated as All-Weather Areas and will improve upon consideration of massing details too fine to incorporate into the model, and urban intensification that may to occur in the immediate surroundings.

Pedestrian Entrance Conditions

Probe 2 was situated along the Young Street façade of the Proposed Development adjacent to the Main Residential Entrance to Tower A, as indicated in Figure 4. The entrance is recessed into the building such that winds deflected to flow along the street will not act upon the door leafs. In addition, the entrance has a vestibule, and as such the location will realize comfortable wind conditions, suitable for standing or better on an annual basis, as well as during the seasons, and as such is suitable for the intended purpose.

Probe 20 was situated in the Courtyard near the internal entrance to Tower A, and probe 18 adjacent to the Main Residential entrance to Tower B, which is along the driveway between the buildings near Catharine Street South. These entrances are situated adjacent to inside corners, and have vestibules, and as such are predicted to realise annual comfort conditions that are suitable for leisurely walking. During the summer they are appropriate for standing

and during the winter leisurely walking and fast walking respectively, and as such will realise comfort conditions appropriate to the intended purpose, most of the time.

Probe 13 was situated along the John Street south façade of the Proposed Development adjacent to the stairs accessing the Main Retail Entrance to Tower A and Tower B, as indicated in Figure 4. The stair is also recessed into the building such that winds deflected to flow along the street will not act upon the area. The location will realize comfortable wind conditions, suitable for standing on an annual basis, as well as during three seasons and suitable for sitting during the summer, and is appropriate to the intended purpose.

Analysis indicates generally comfortable wind conditions will be realised at all proposed entrance locations, with locations that are removed from corners slightly more so. Probe locations respectively situated along the façade of the Proposed Development adjacent to street related retail and residential entrances are suitable for their intended purpose, while locations proximate to corners will be windier. Probe location 1, situated at the southeast corner of the intersection of Young Street and John Street South will realise annual conditions as suitable for leisurely walking, fast walking during the winter, and as such would be less than ideal for an entrance.

Wind conditions comfortable for standing are preferable at building's entrances, while conditions suitable for walking are suitable for walkways. Wind conditions at the proposed entrances are considered acceptable. Consideration of existing and proposed surface roughness features too fine to incorporate into the massing model, landscaping, as well as urban intensification along Young Street and John Street South, will likely translate into comfort ratings better than those described above.

Internal Site Conditions

Probes 15 through 20 and 7 were situated about interior spaces of the Proposed Development and indicate the area is generally suitable for leisurely walking or better on an annual basis. However, probe location 7, situated in the breezeway beneath the 5 storey connective between the towers, and fronting Catharine Street South, will be windy, suitable for fast walking on an annual basis. During the winter months slightly windier conditions in the area were observed, however, only probe location 18 becomes suitable for fast walking, and the breezeway became uncomfortable.

Reported pedestrian comfort conditions within the open space do not pose a concern to pedestrian safety. As indicated in Figure 9, all were rated as All-Weather Areas and will improve upon consideration of massing details too fine to incorporate into the model, and with urban intensification that may occur in the immediate surroundings. Probe location 7, located in the breezeway is rated as a Fair-Weather Area, and as such should be avoided on the occasion of high ambient southwesterly winds. A mitigation plan is recommended for this area and this might be accomplished with landscaping. Such a plan might include coarse plantings in raised planters, recessed seating, screen walls, artistic features, and others. The wind conditions are

not excessive and to the extent the area requires mitigation will be developed through further study.

Outdoor Amenity Space

Outdoor Amenity Areas are proposed on the roof of Tower A's 7 storey wing and Tower B's 8 storey wing, respectively to the east and west of said towers. Probes 21 and 22 were respectively situated on the Outdoor Amenity Spaces and the model tested without landscaping or other fine design features in place. The modeling predicted varying results with the Tower A's amenity space realising conditions suitable for sitting, Tower B's suitable for leisurely walking. During the summer months Tower B's rating improves to Standing, however, the area remains suitable for leisurely walking during the spring and fall seasons. Comfort conditions generally suitable for sitting are preferred for amenity spaces during the summer months and it is usually preferred that this rating extend well into the shoulder seasons.

The comfortable conditions realised for Tower A's amenity space is attributed to the Proposed Development deflecting much of the "very directional", prevailing southwesterly wind climate to flow over the space. Conversely, Tower B and the neighbouring 14 storey cruciform shaped building to the west at 57 Forest Avenue deflect a portion of said climate to flow over the space resulting in windy conditions from time to time. The Tower B rooftop amenity area will require mitigation to suit the intended purpose, however, the wind conditions are not excessive and to the extent the area requires mitigation will be developed through further study.

With appropriate mitigation, the Tower B amenity space will realise comfortable conditions, suitable to the area's intended purpose, most of the time. If activities requiring long exposures are desired, the landscape plan might include trellises, recessed seating, plantings in raised planters, screen walls, and others.

Summary

The observed wind velocity and flow patterns at the Development are largely influenced by approach wind characteristics that are dictated by the surrounding areas to prevailing wind directions. Historical weather data measured at Hamilton International Airport indicates the mean winter wind speed is 17.4 km/h with wind speeds greater than 30 km/h occurring approximately 13.6 percent of the time, during the winter, and 2.2 percent of the time during the summer. Once the subject site is developed, ground level winds at several locations will improve from specific directions, 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, will improve the predicted comfort ratings beyond those reported herein, resulting in comfort conditions expected at the proposed Development site that are considered better than those required to suit the urban context.

Additional wind mitigation is not required, however, if desired, large caliper coniferous plantings positioned as near as practical to the windward corners of the buildings, near gaps between, and/or along the façades, might be employed. In addition, landscaped berms, large rocks, fences and retaining walls may be used to improve pedestrian comfort conditions. The positioning and scale of these mitigative features, if required, are best assessed in quantitative microclimatic analysis at the Site Plan Approval stage.

6 NOTES

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Appendix: Background and Theory of Wind Movement 61

Figure 1: Laboratory Testing Facility

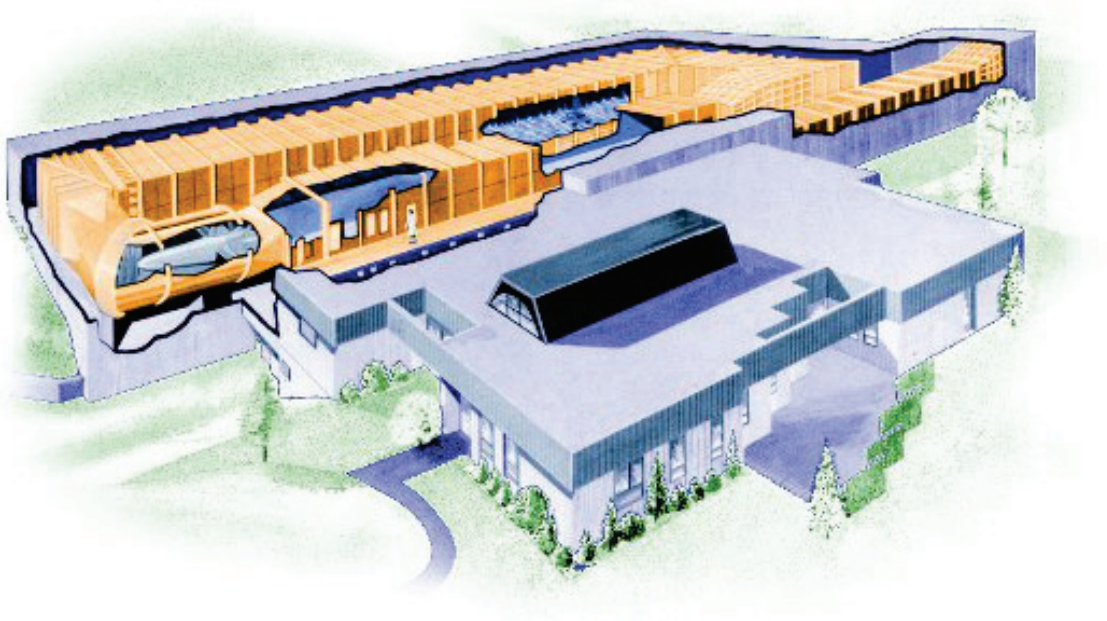


Figure 2a: Site Aerial Photo

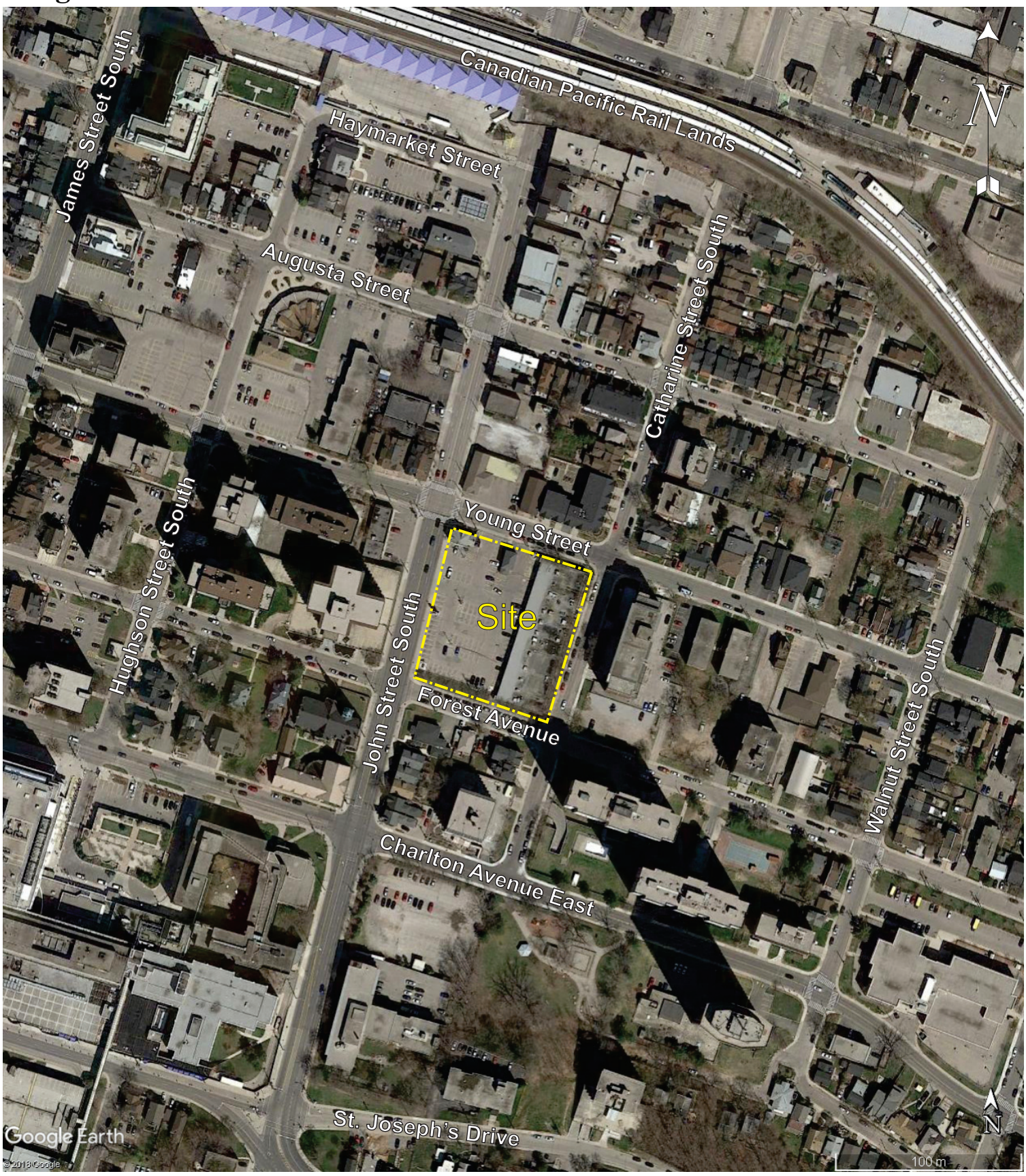


Figure 2b: Site Plan

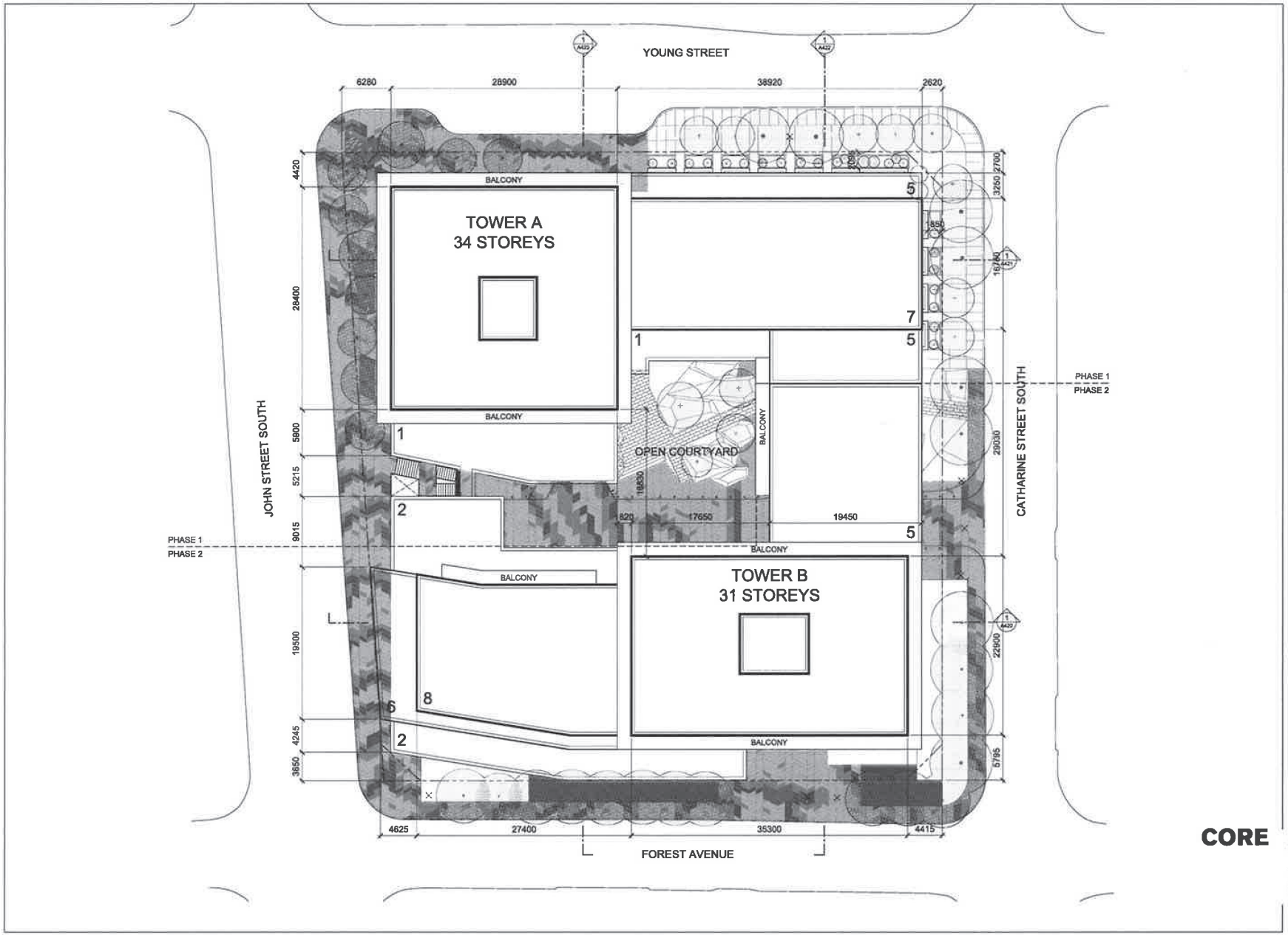
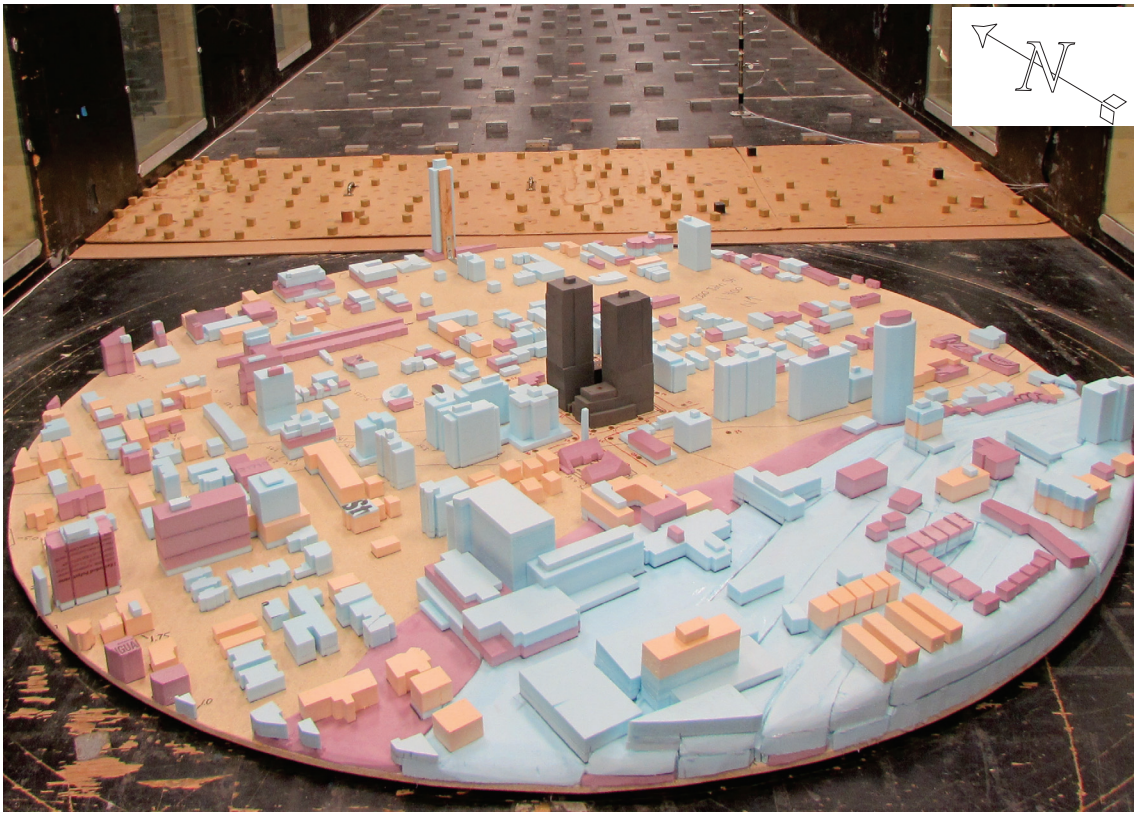
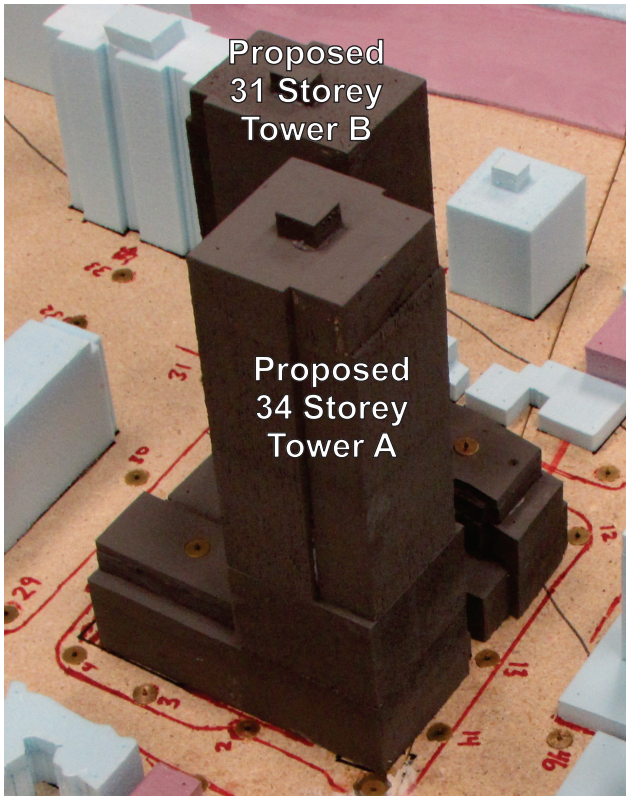


Figure 3: 1:400 Scale model of test site



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. 25

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

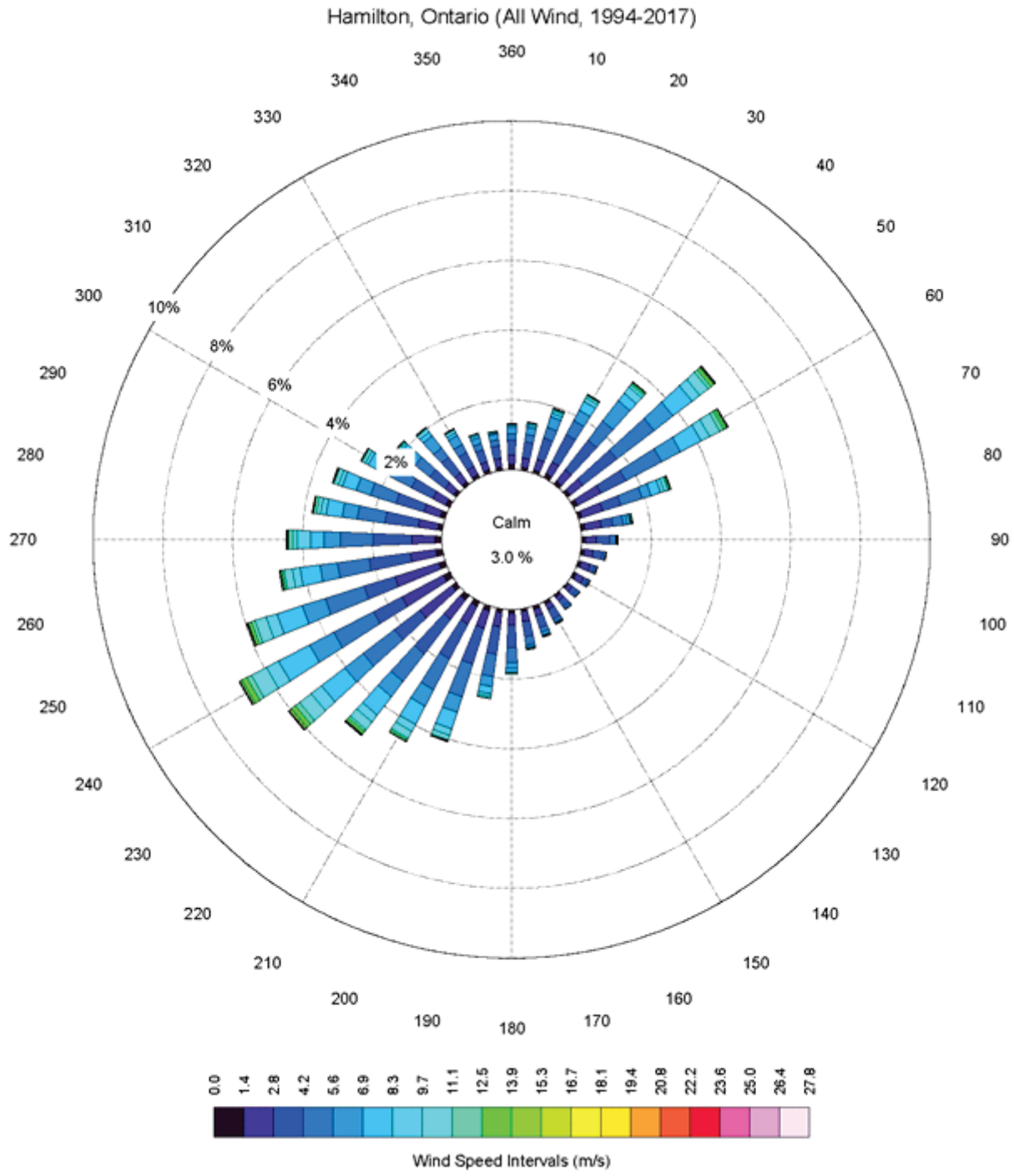


Figure 5b: Winter Wind Rose - Hamilton International Airport.

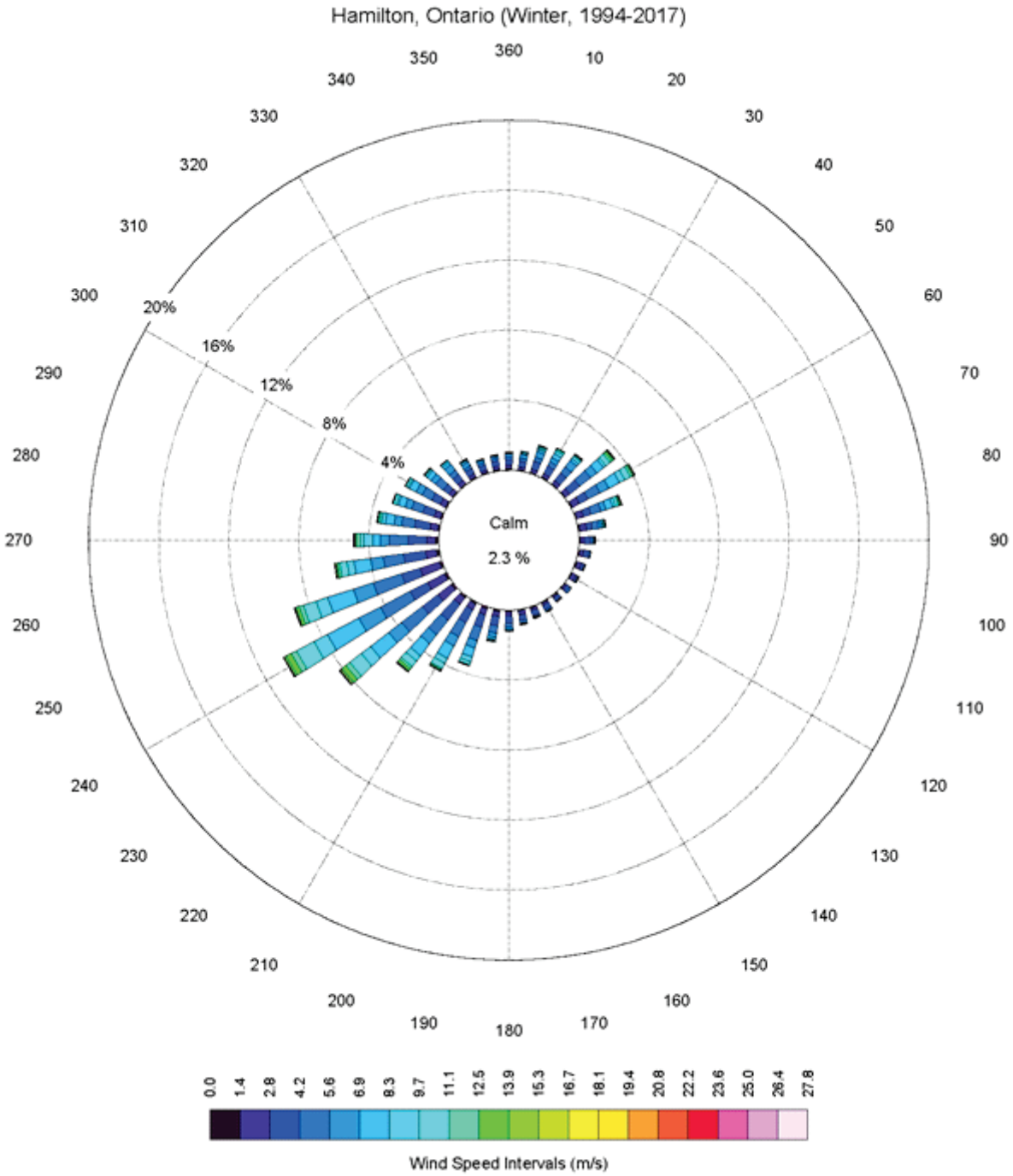


Figure 5c: Spring Wind Rose - Hamilton International Airport.

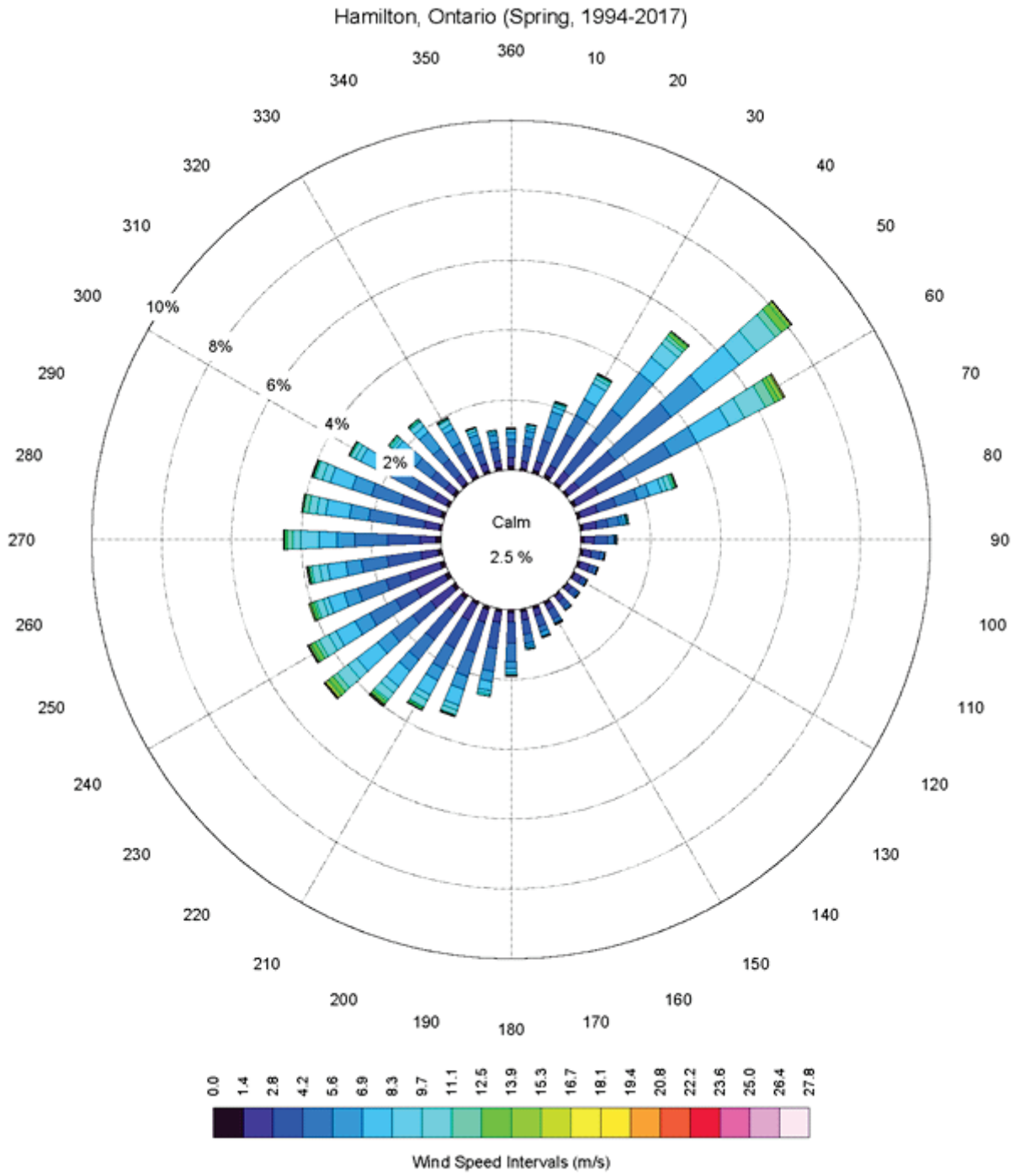


Figure 5d: Summer Wind Rose - Hamilton International Airport. 29

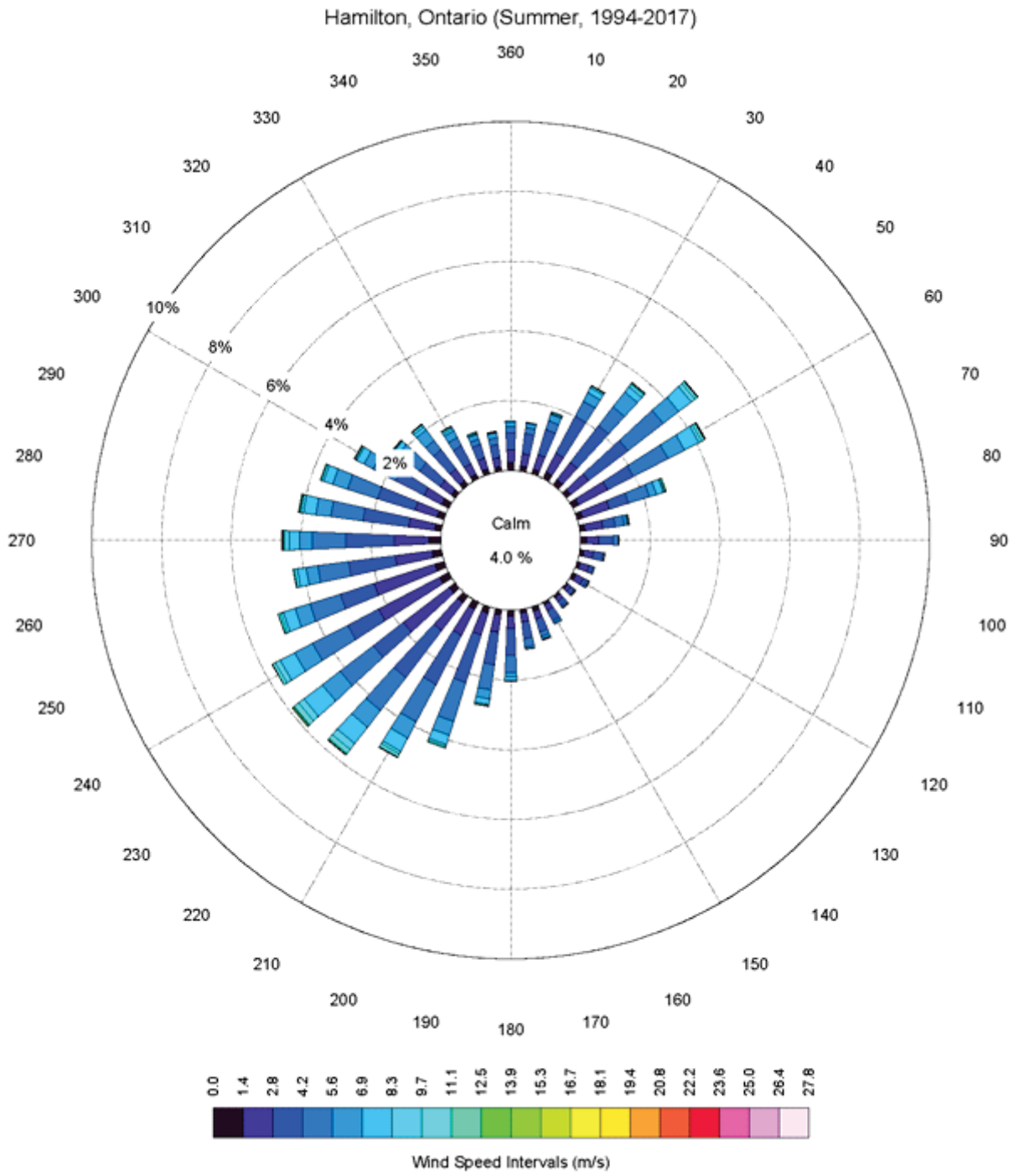


Figure 5e: Fall Wind Rose - Hamilton International Airport.

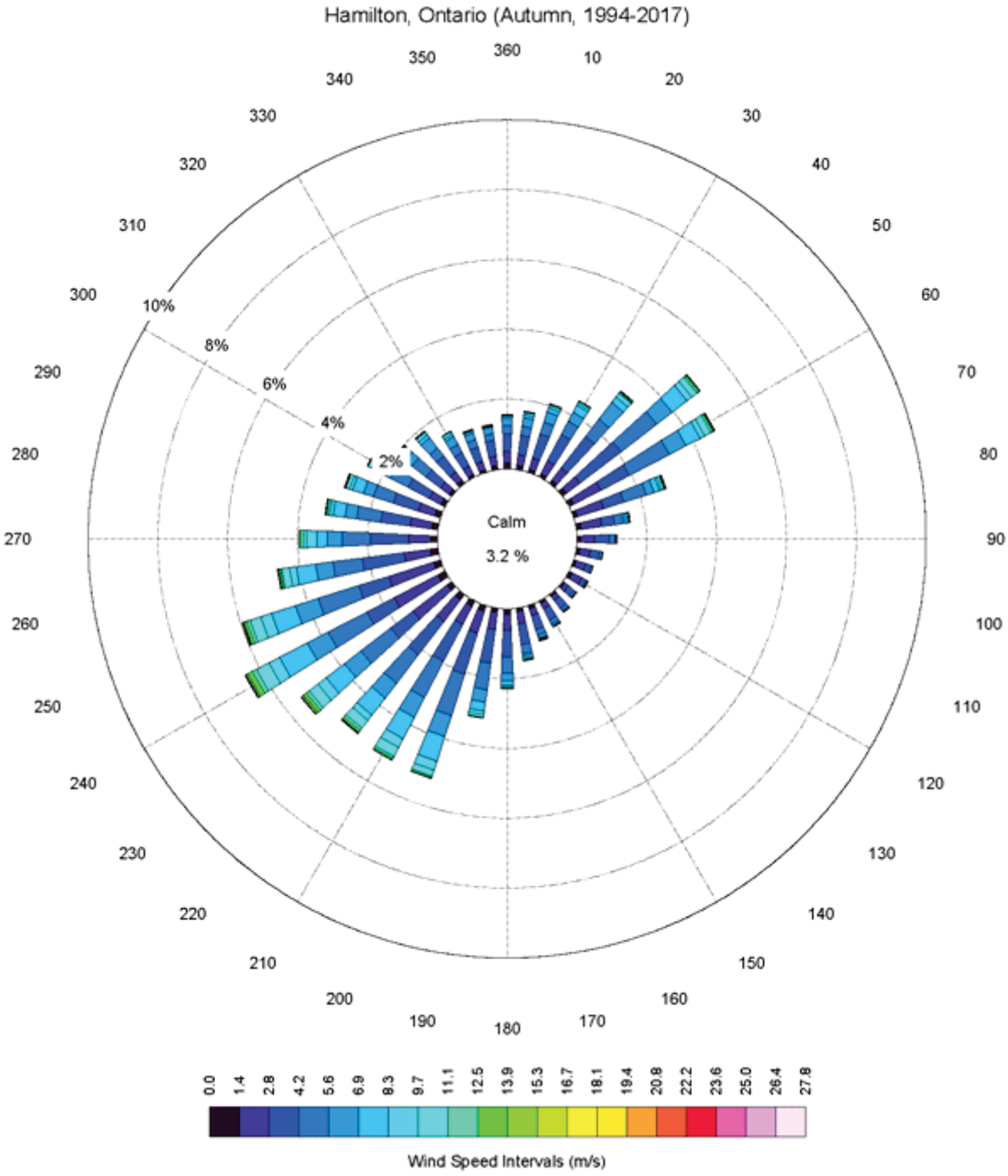


Figure 6a: ANNUAL - Wind Speed Exceeded 5% of the Time (Locations 1 to 20).

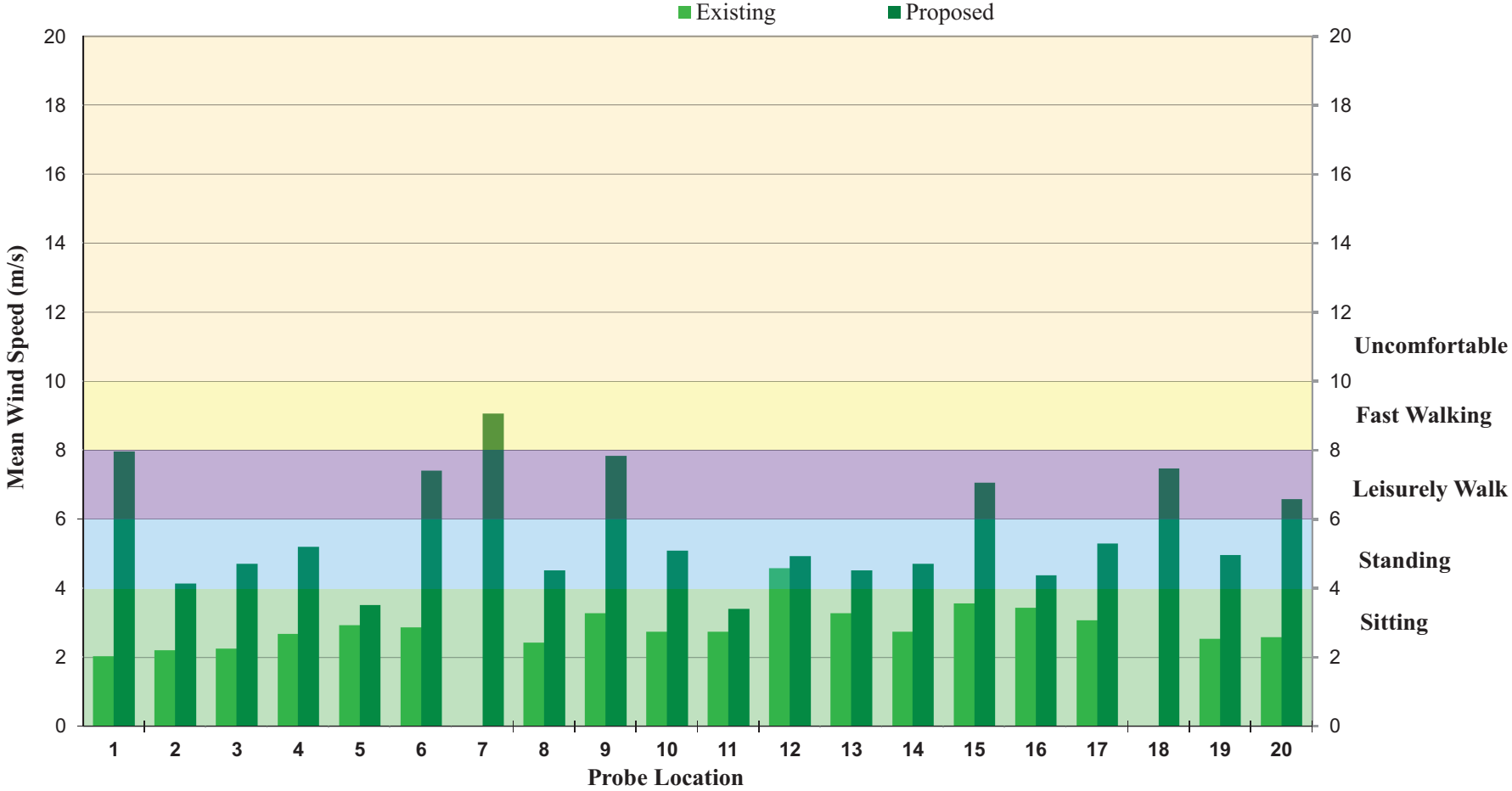


Figure 6a: ANNUAL - Wind Speed Exceeded 5% of the Time (Locations 21 to 40).

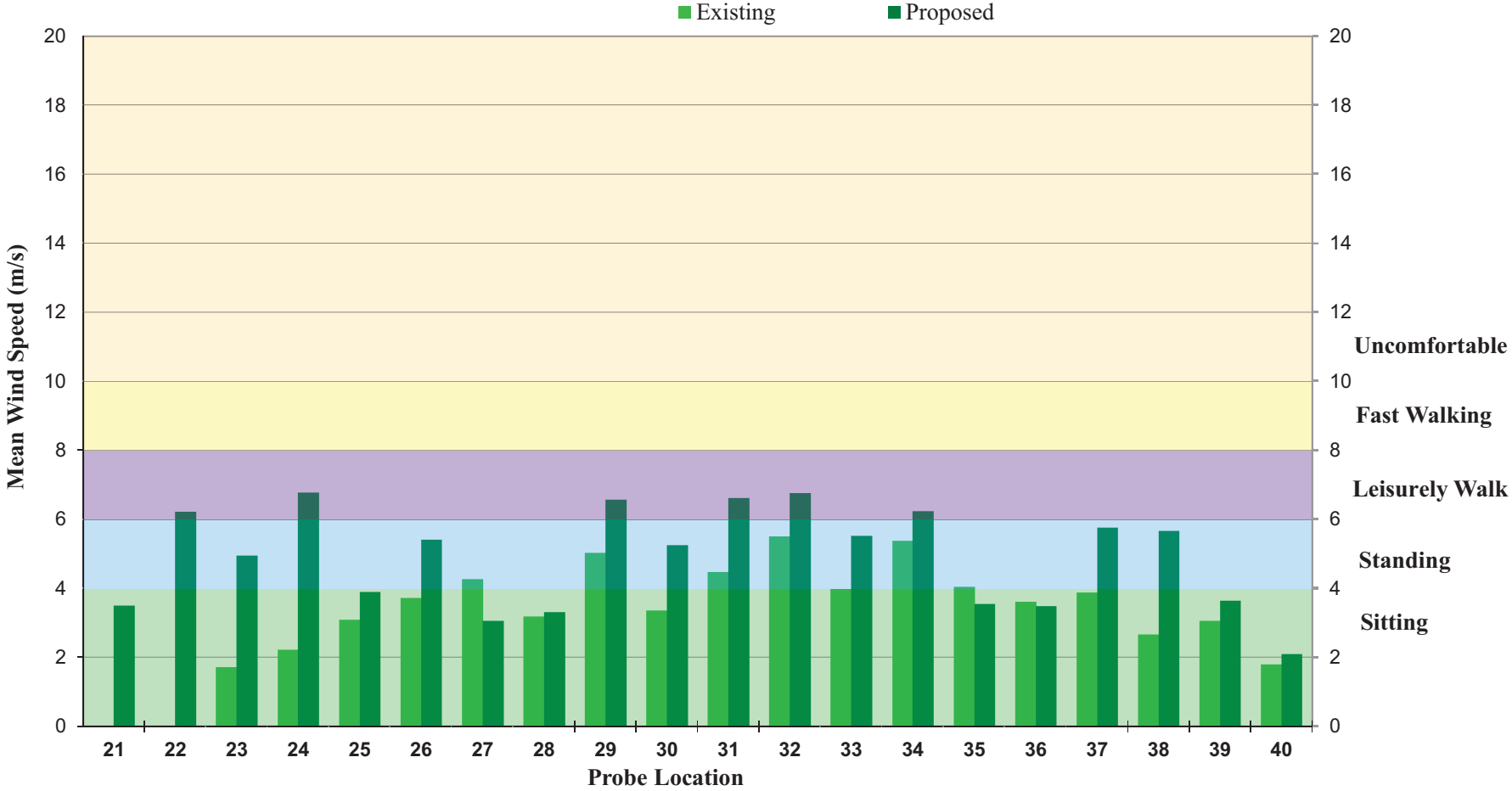


Figure 6a: ANNUAL - Wind Speed Exceeded 5% of the Time (Locations 41 to 54).

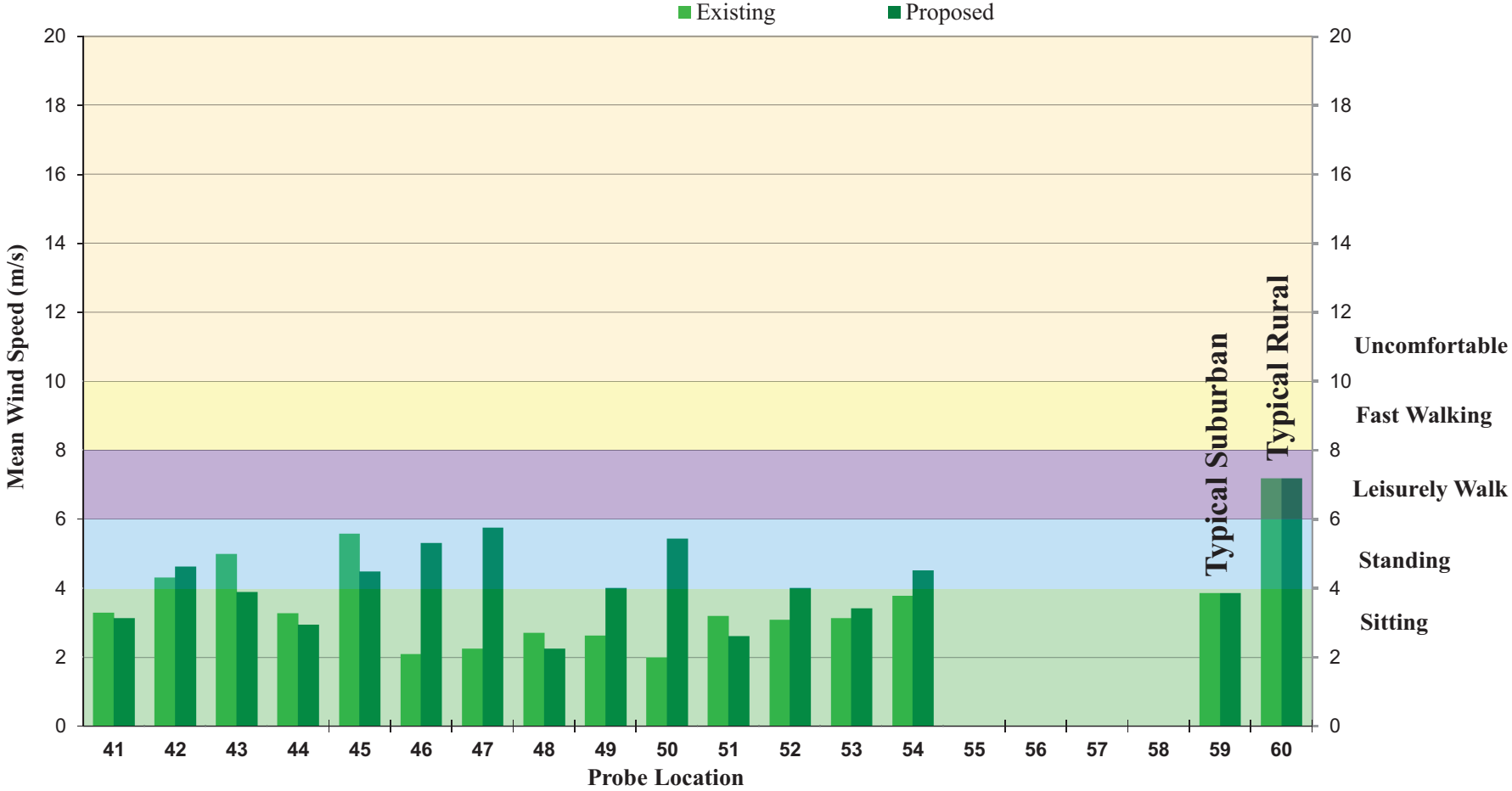


Figure 6b: WINTER - Wind Speed Exceeded 5% of the Time (Locations 1 to 20).

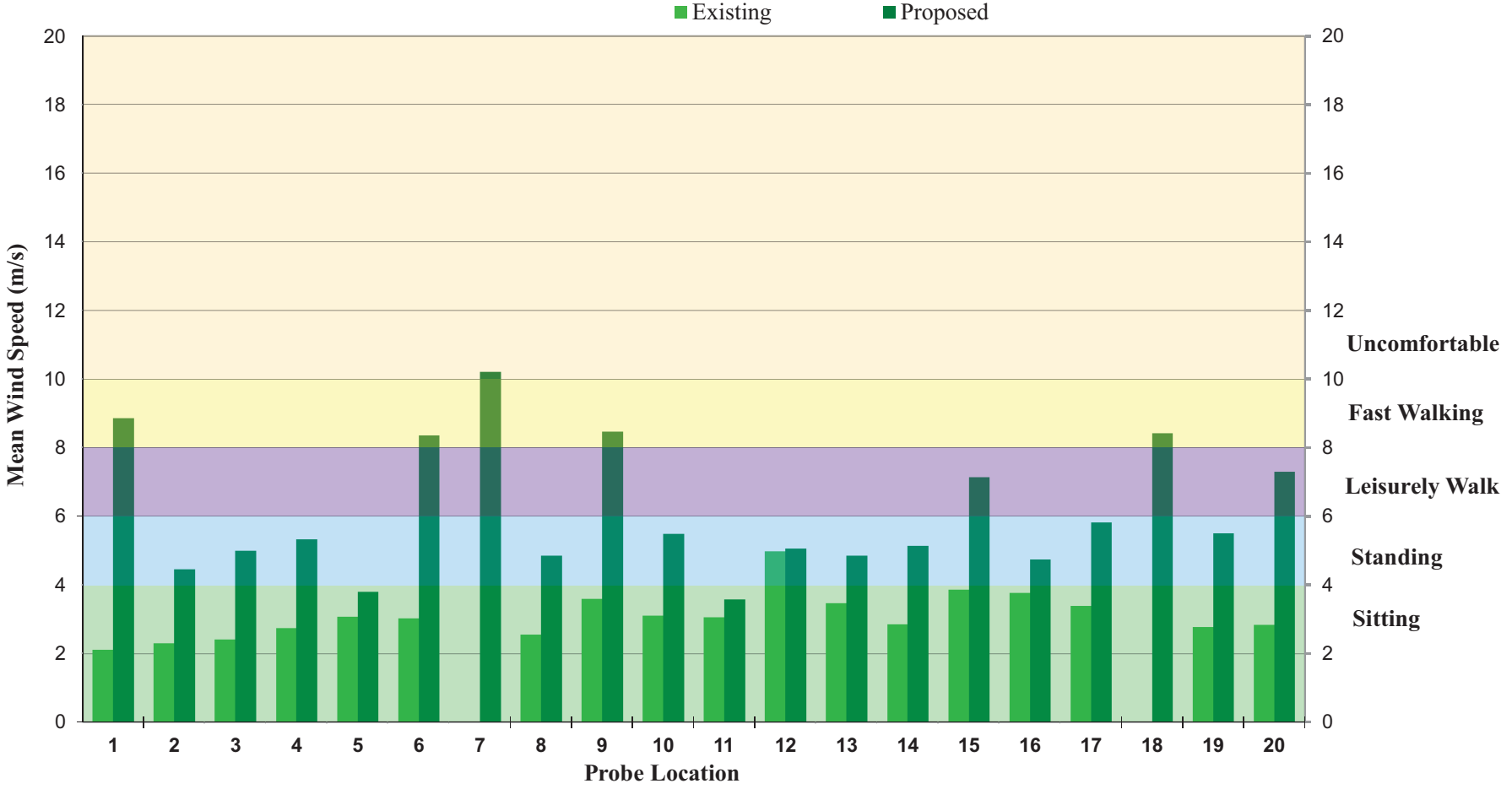


Figure 6b: WINTER - Wind Speed Exceeded 5% of the Time (Locations 21 to 40).

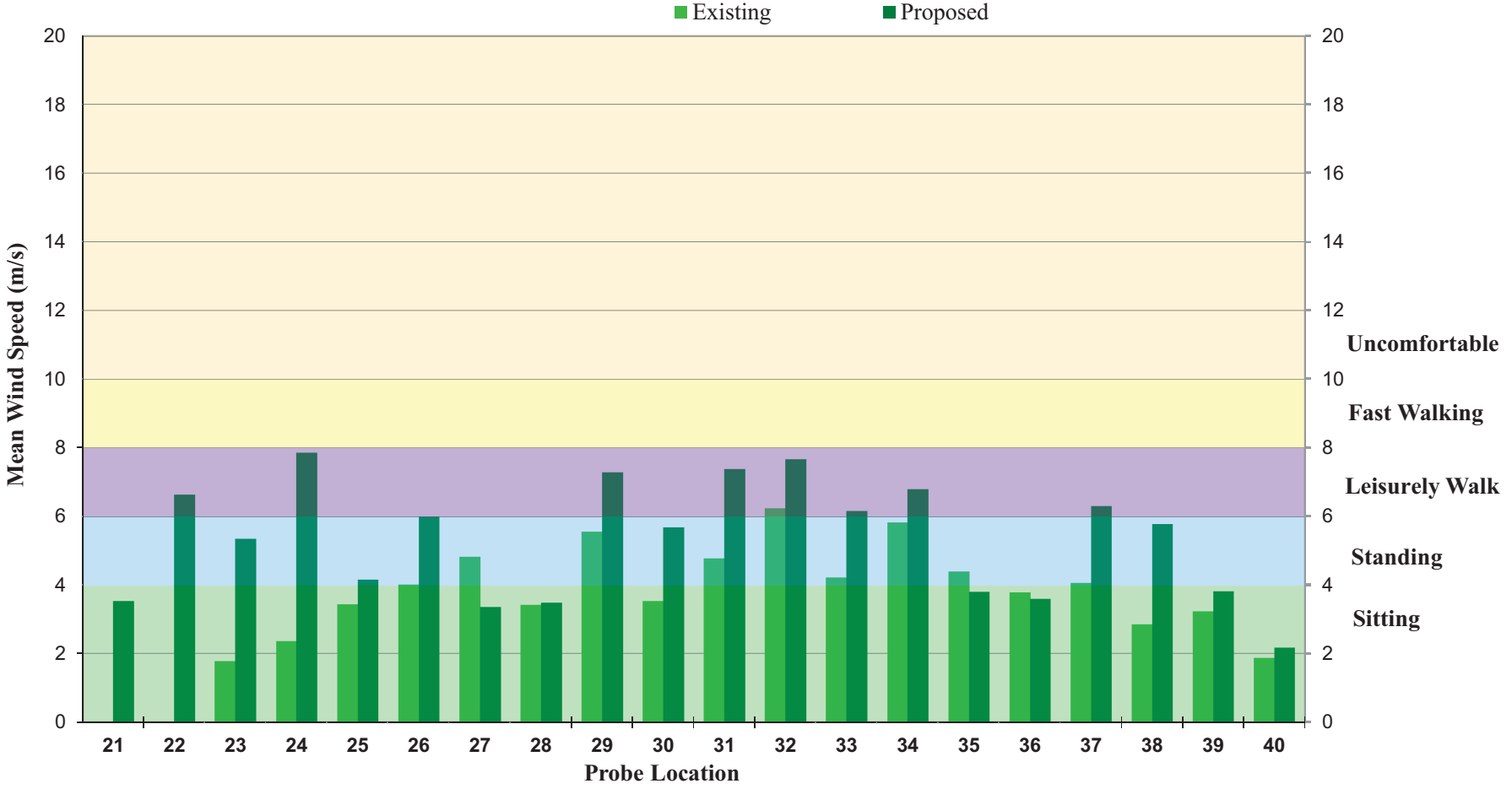


Figure 6b: WINTER - Wind Speed Exceeded 5% of the Time (Locations 41 to 54).

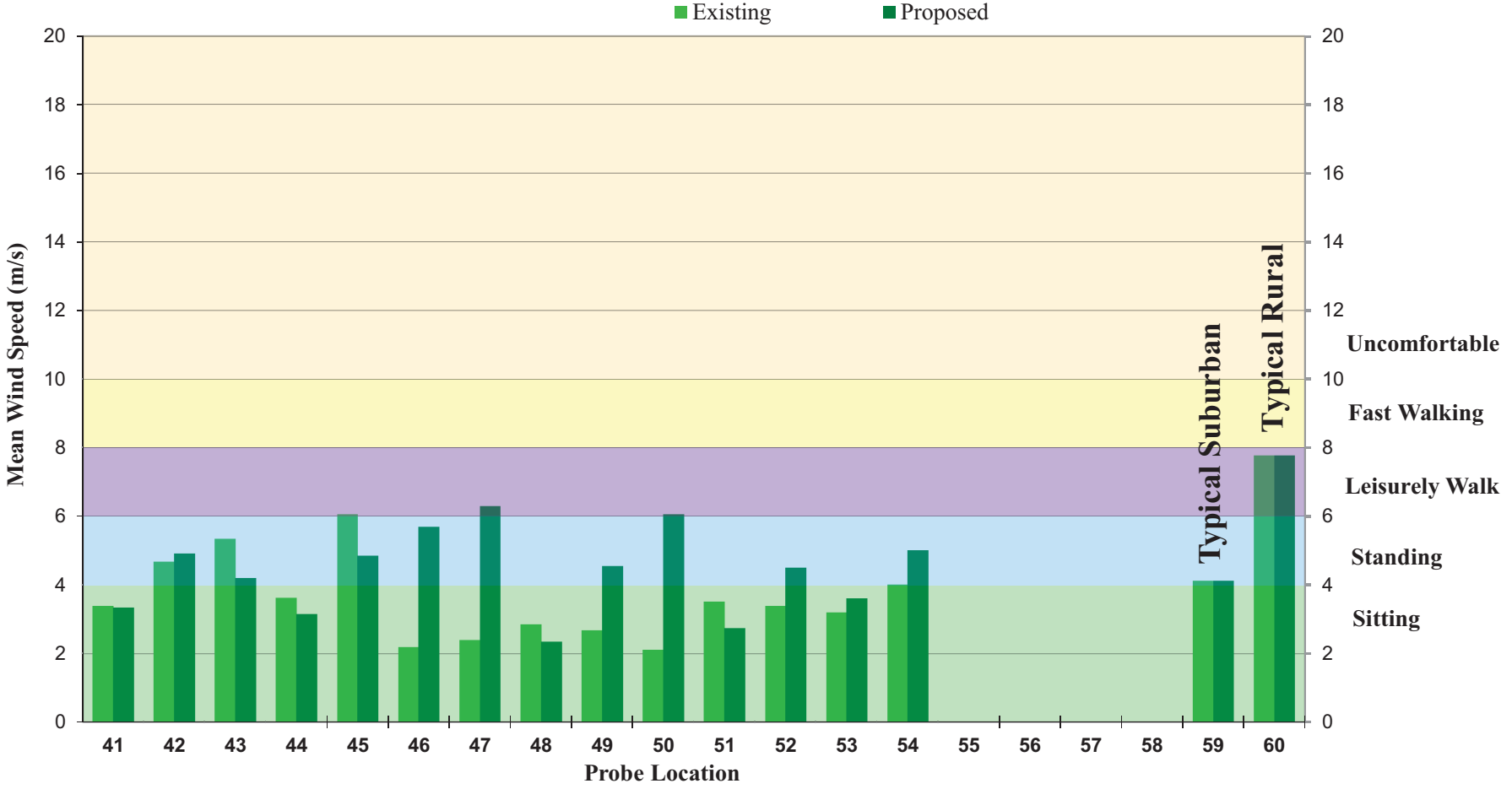


Figure 6c: SPRING - Wind Speed Exceeded 5% of the Time (Locations 1 to 20).

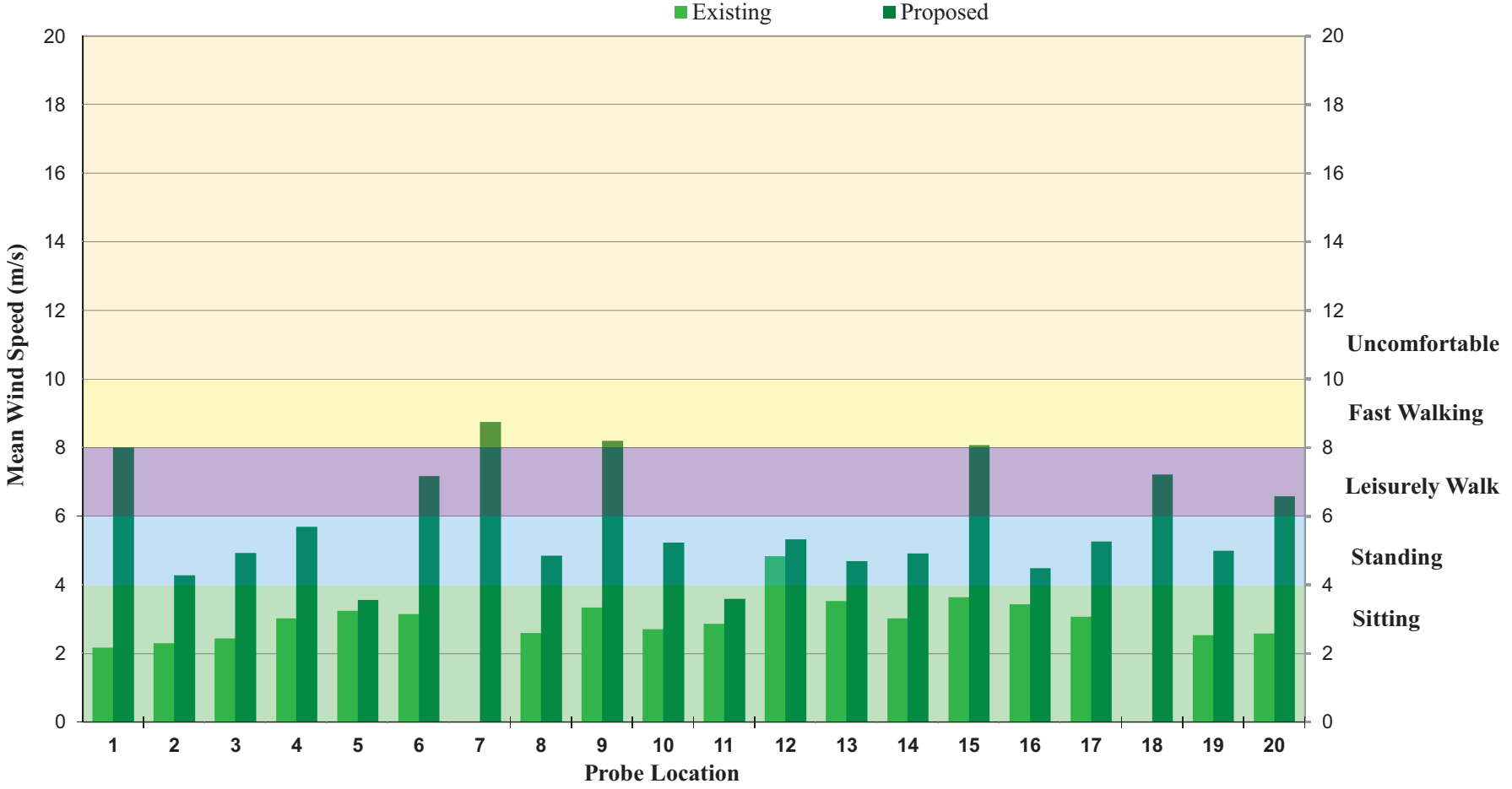


Figure 6c: SPRING - Wind Speed Exceeded 5% of the Time (Locations 21 to 40).

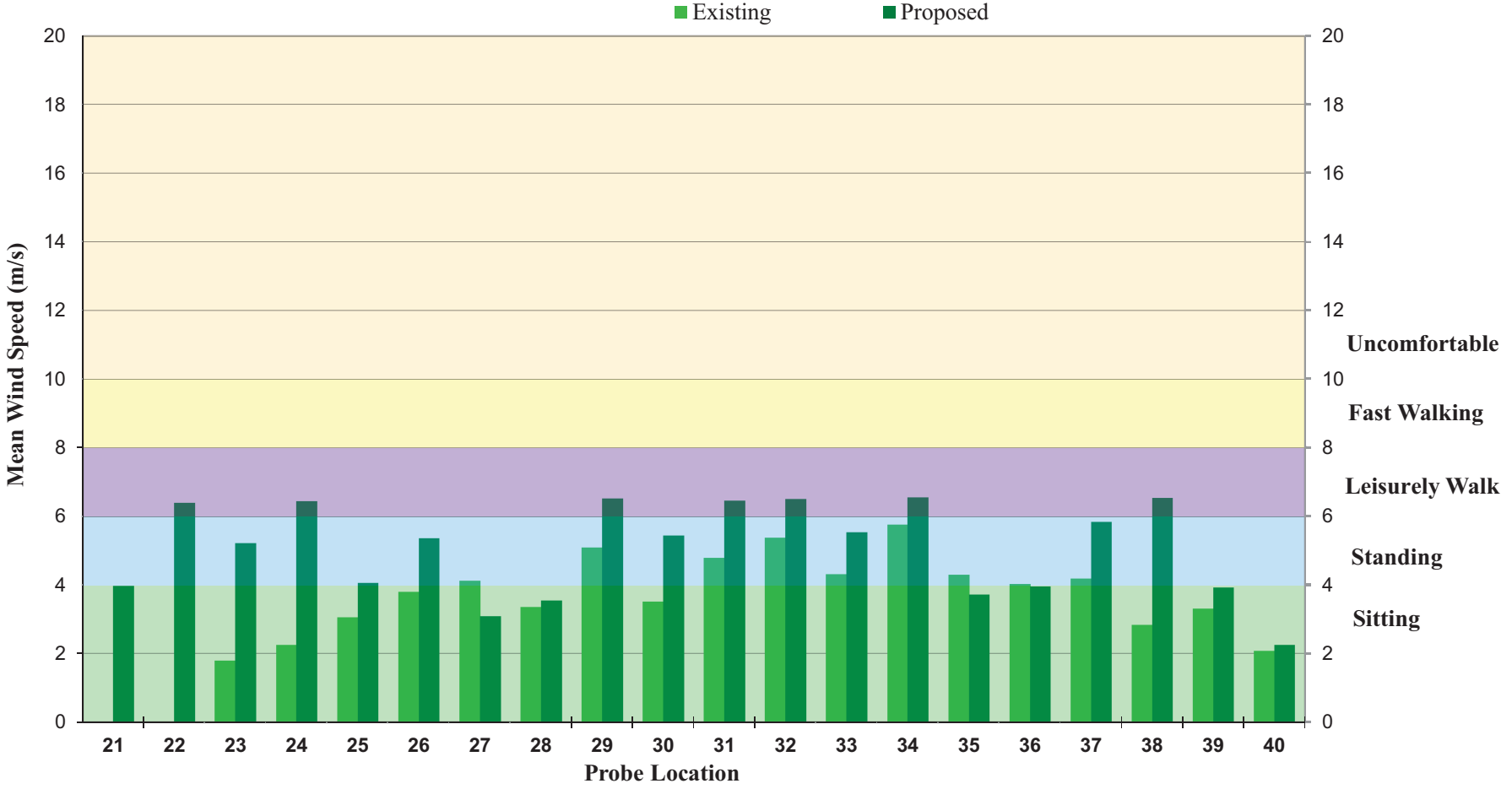


Figure 6c: SPRING - Wind Speed Exceeded 5% of the Time (Locations 41 to 54).

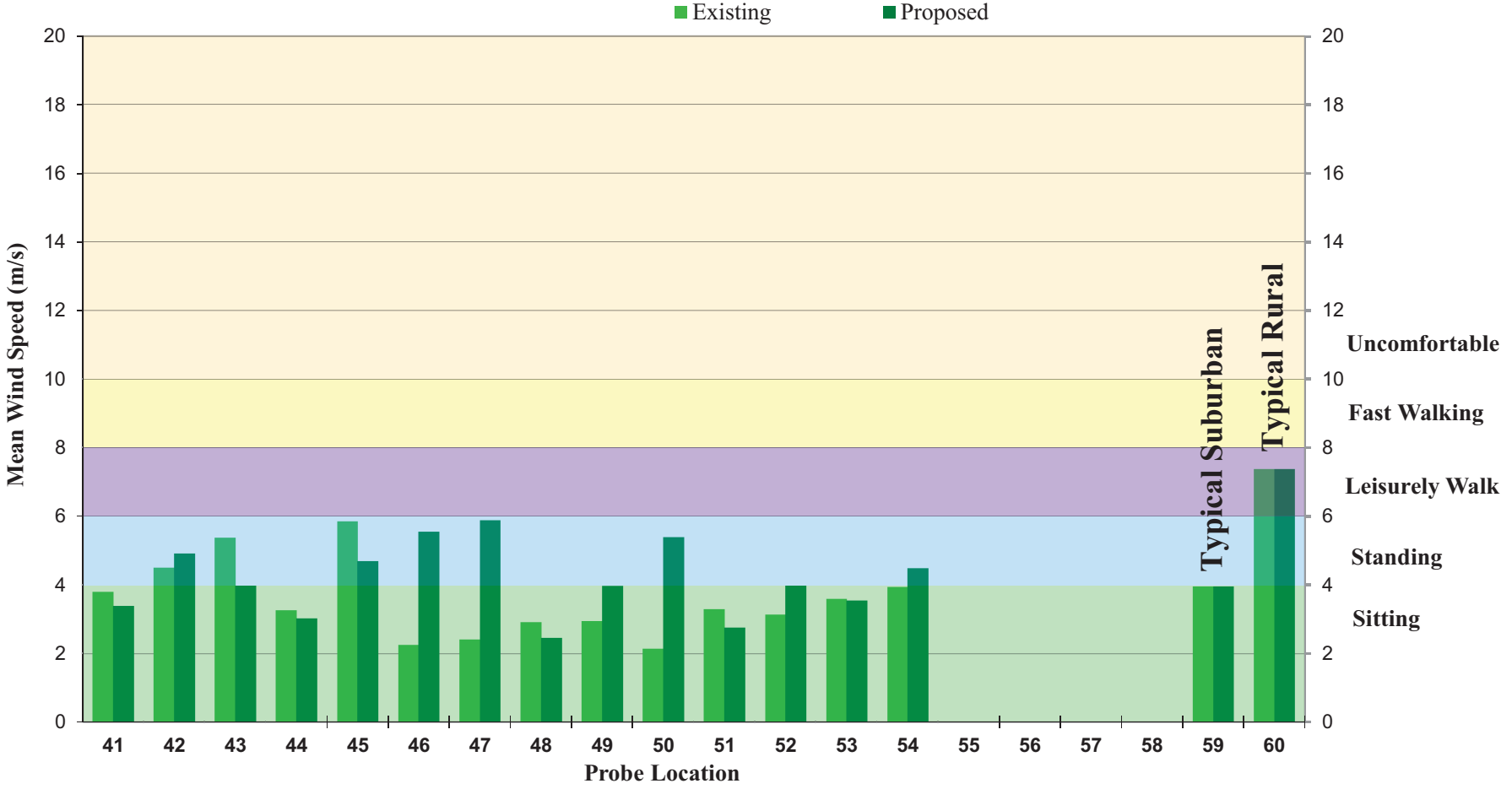


Figure 6d: SUMMER - Wind Speed Exceeded 5% of the Time (Locations 1 to 20).

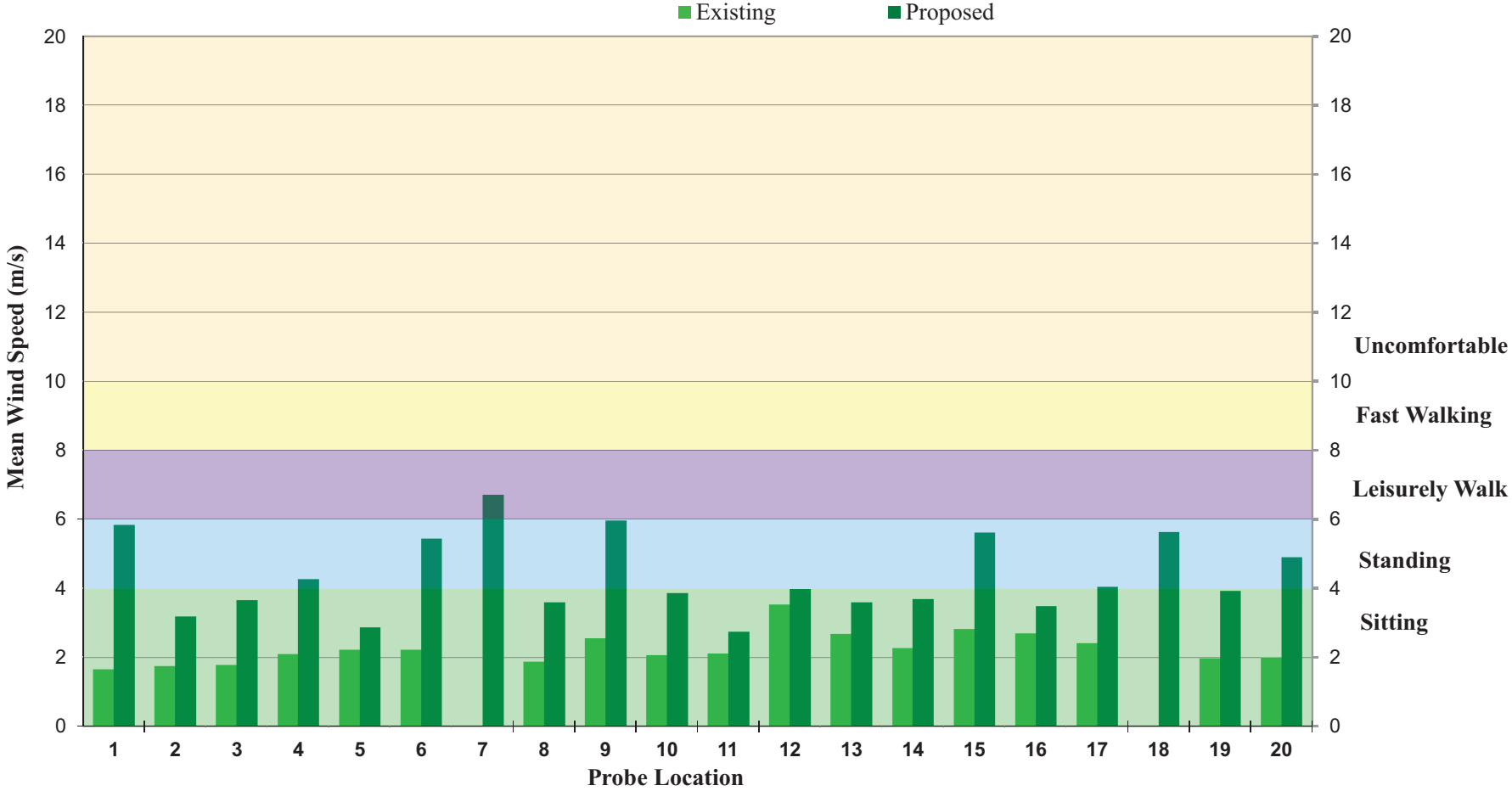


Figure 6d: SUMMER - Wind Speed Exceeded 5% of the Time (Locations 21 to 40).

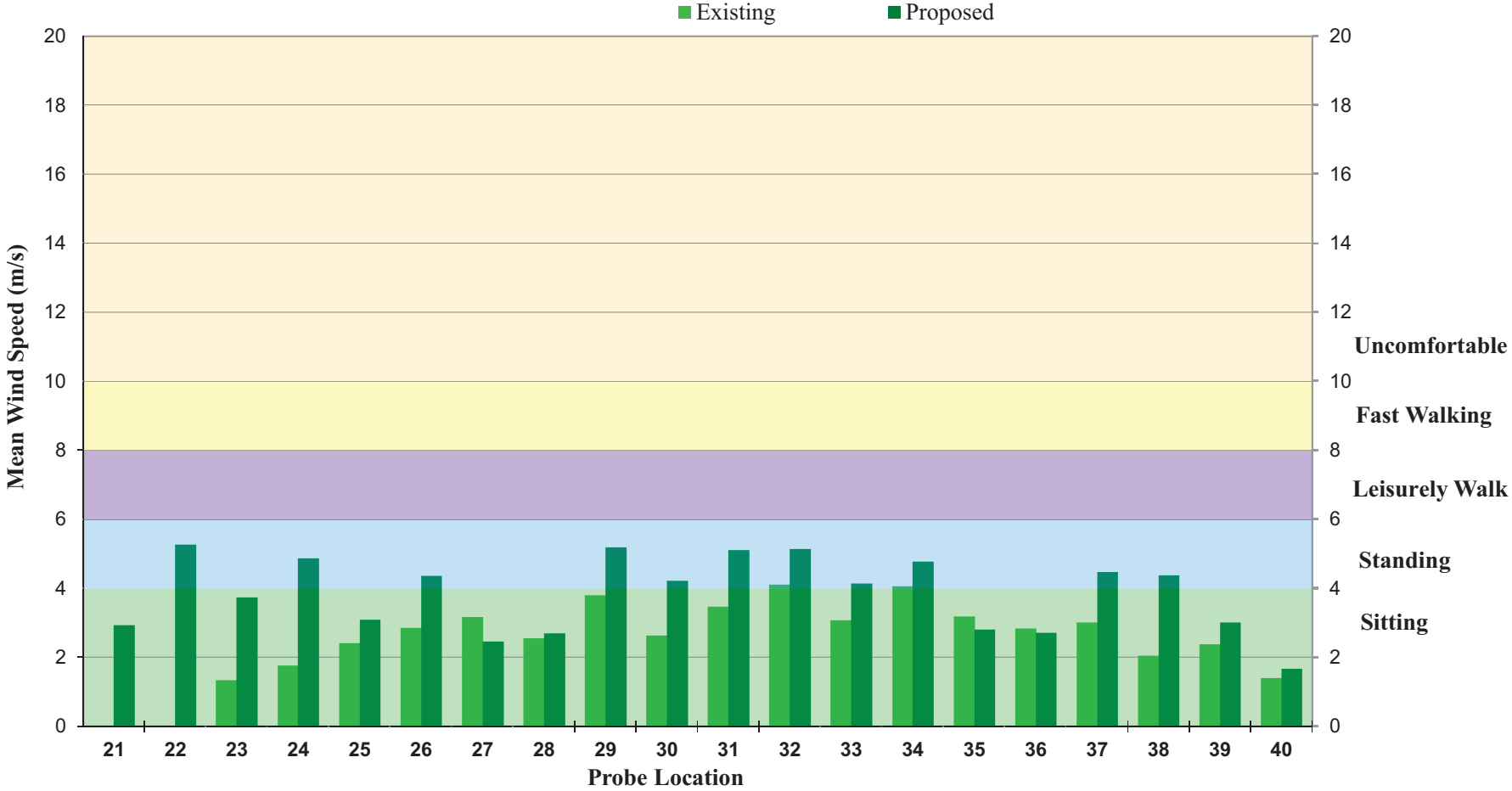


Figure 6d: SUMMER - Wind Speed Exceeded 5% of the Time (Locations 41 to 54).

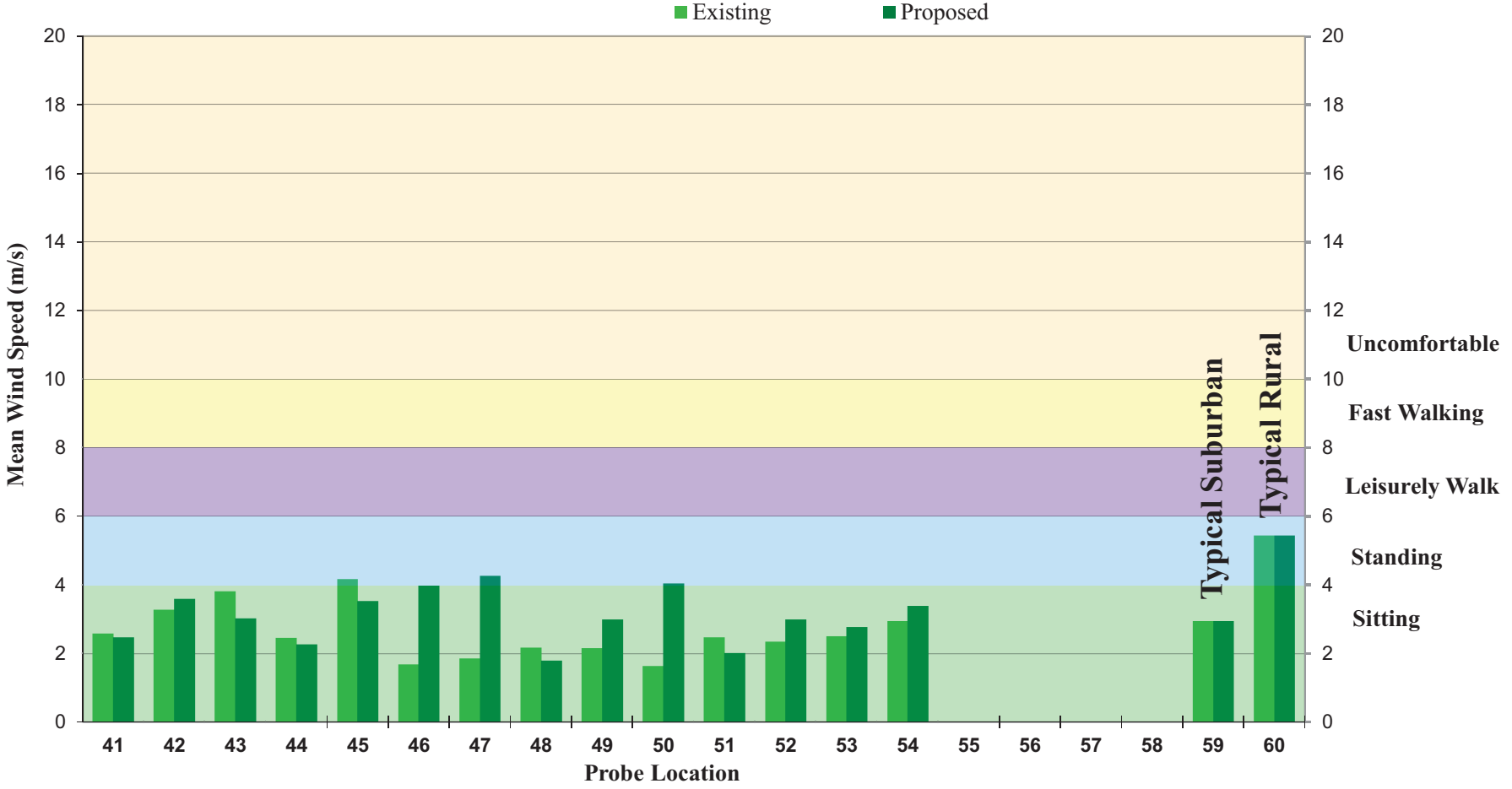


Figure 6e: FALL - Wind Speed Exceeded 5% of the Time (Locations 1 to 20).

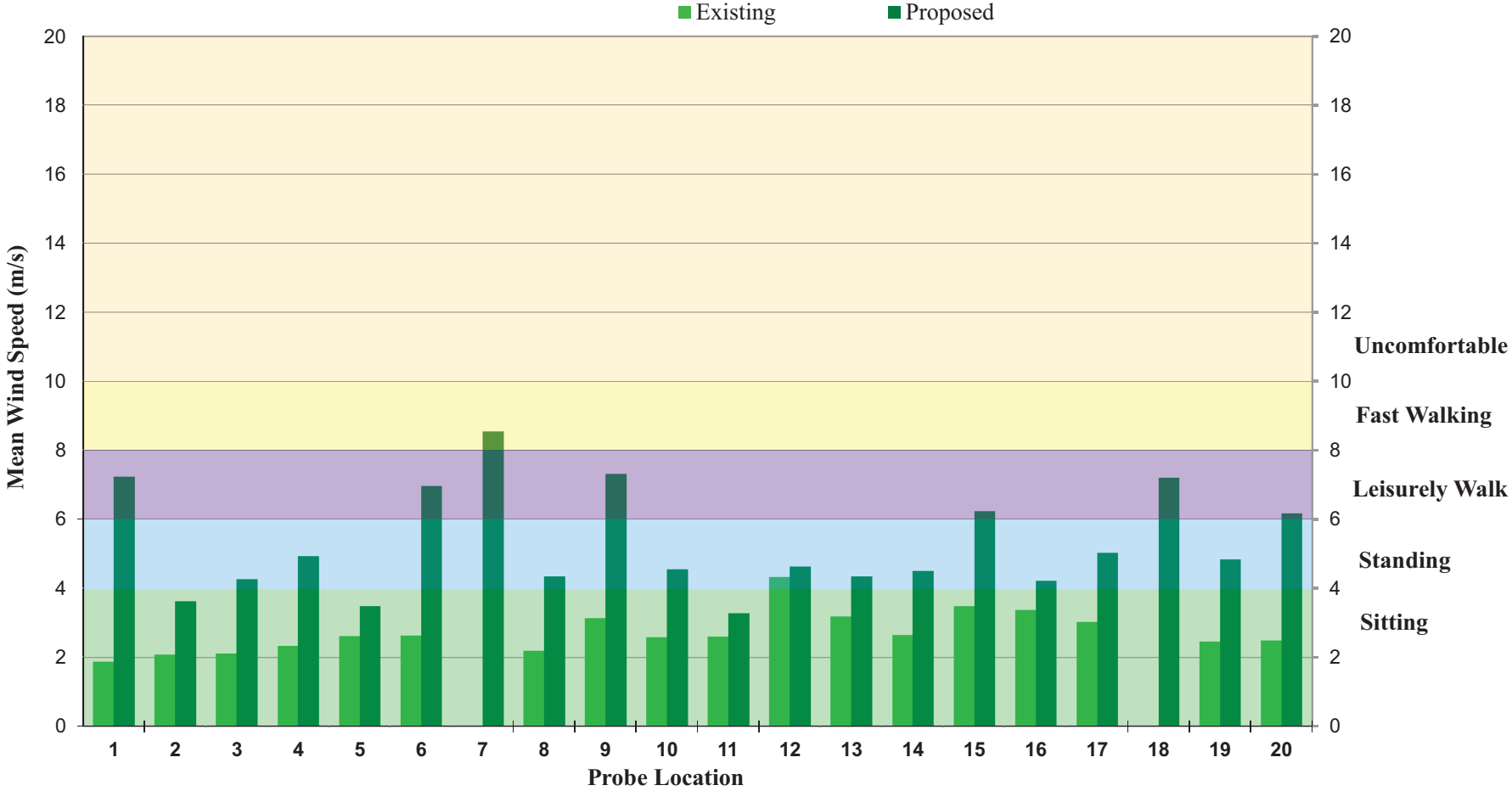


Figure 6e: FALL - Wind Speed Exceeded 5% of the Time (Locations 21 to 40).

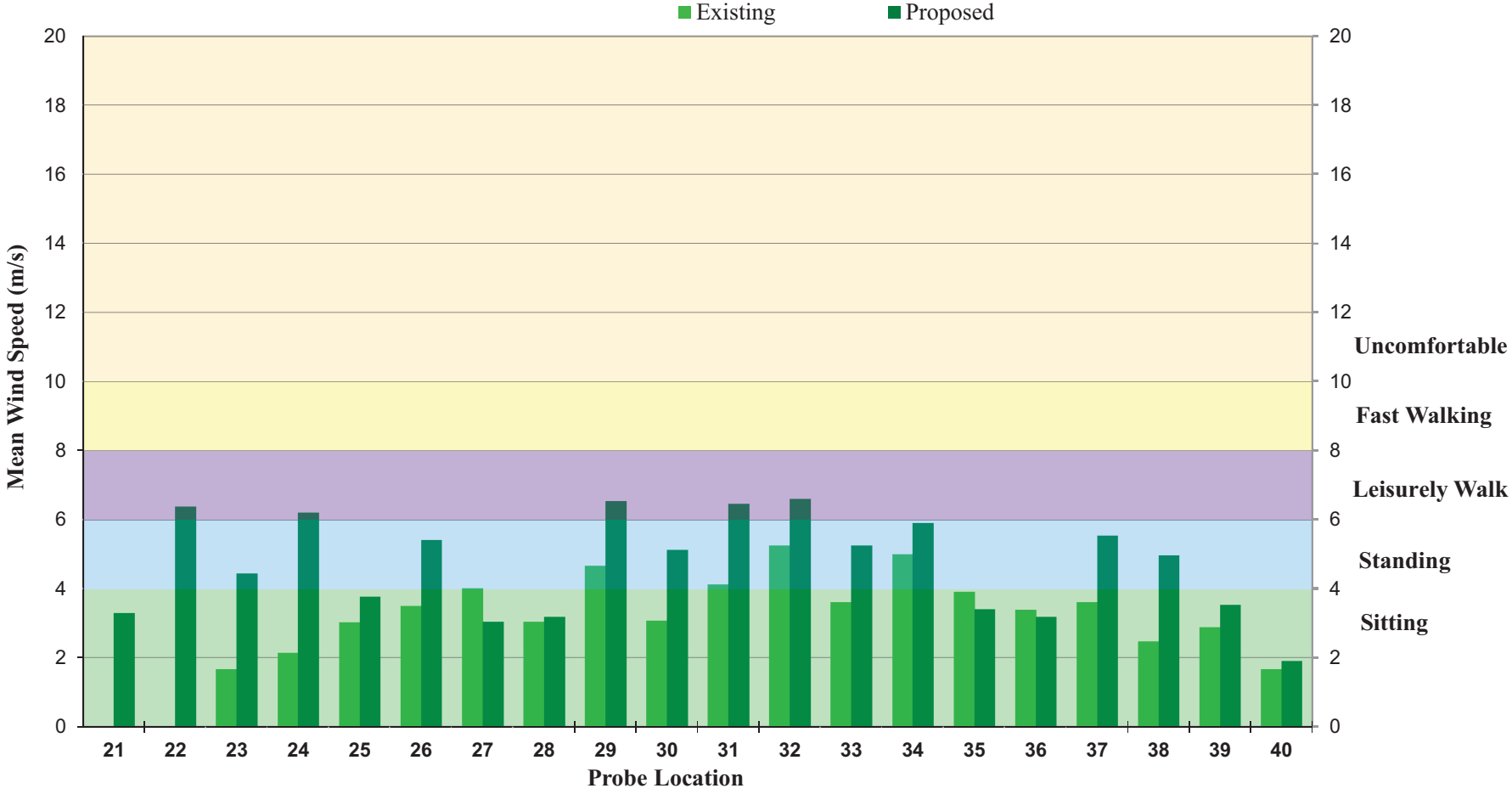


Figure 6e: FALL - Wind Speed Exceeded 5% of the Time (Locations 41 to 54).

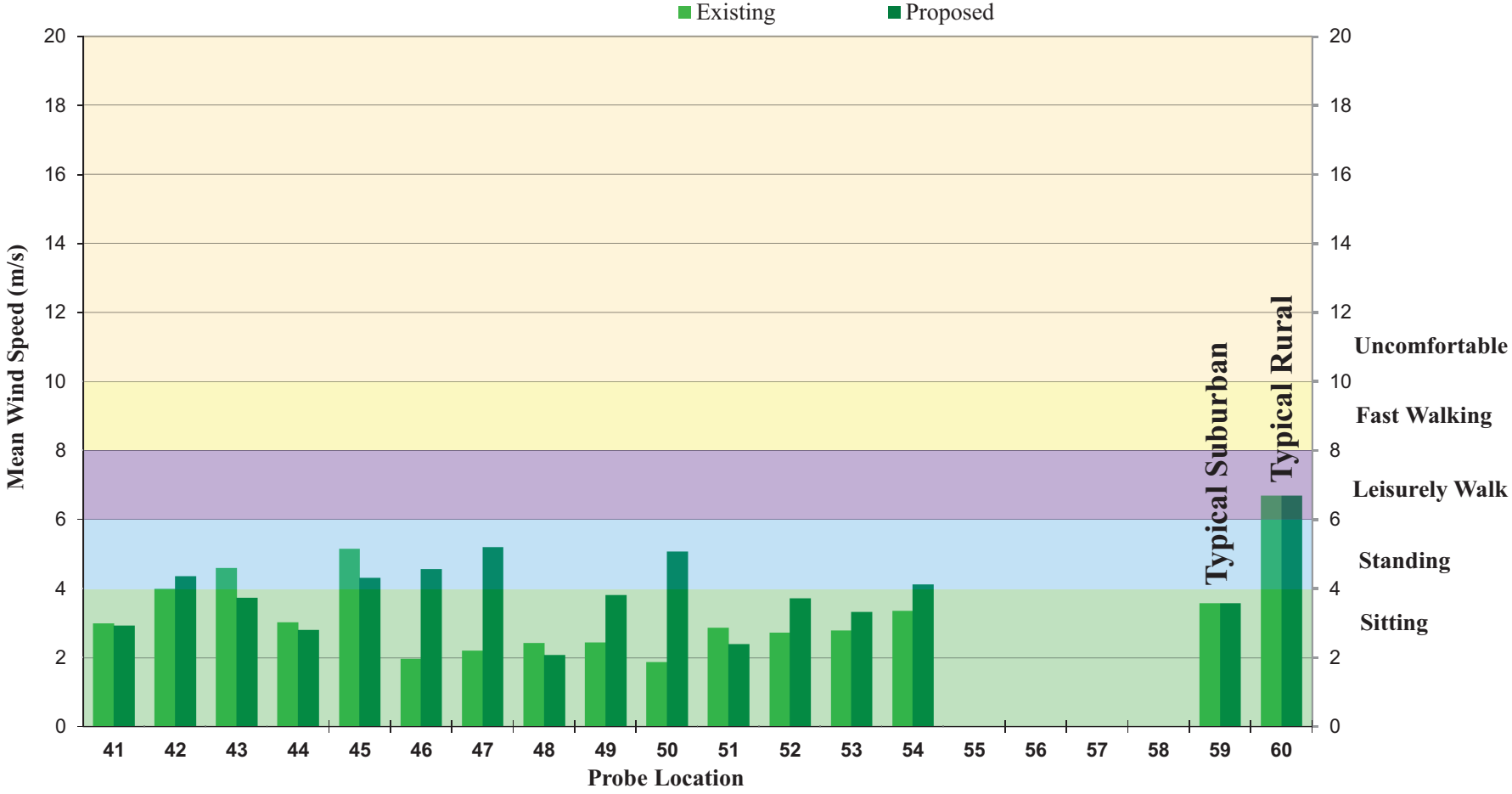
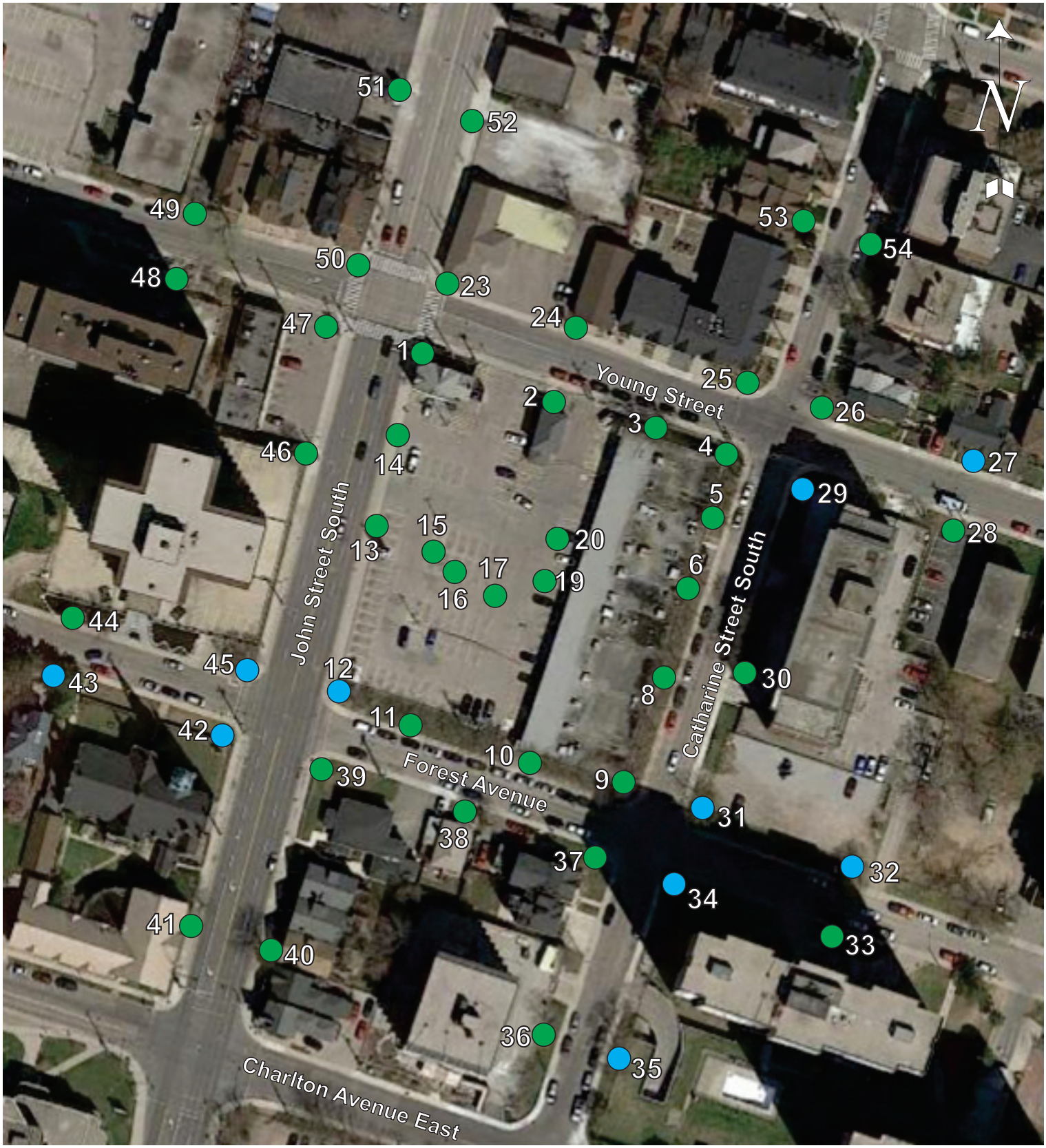


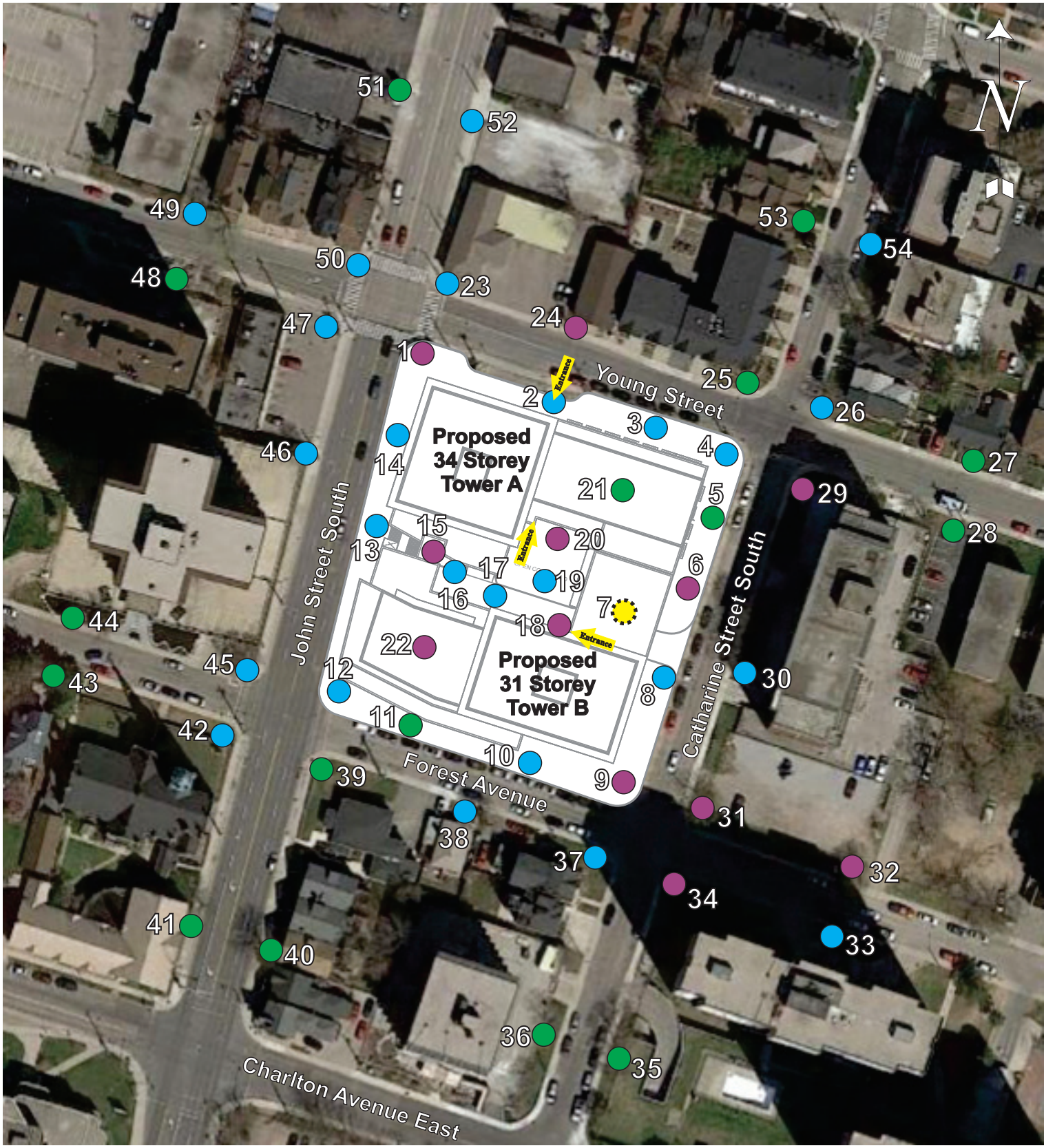
Figure 7a: Pedestrian level wind velocity comfort categories.



Comfort Categories - Annual - Existing

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

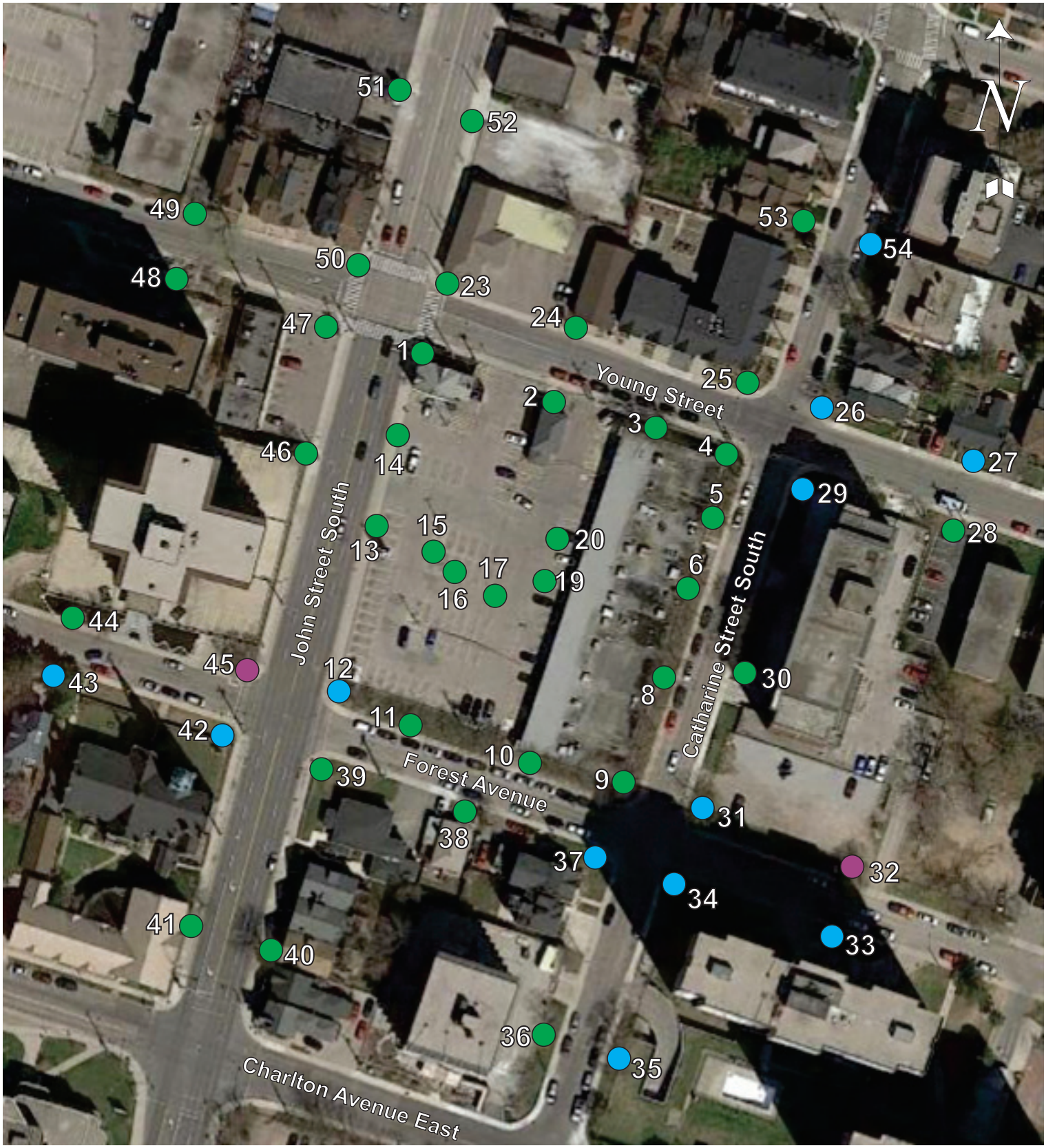
Figure 7b: Pedestrian level wind velocity comfort categories.



Comfort Categories - Annual - Proposed

Sitting · Standing · Leisurely Walking · Fast Walking · Uncomfortable

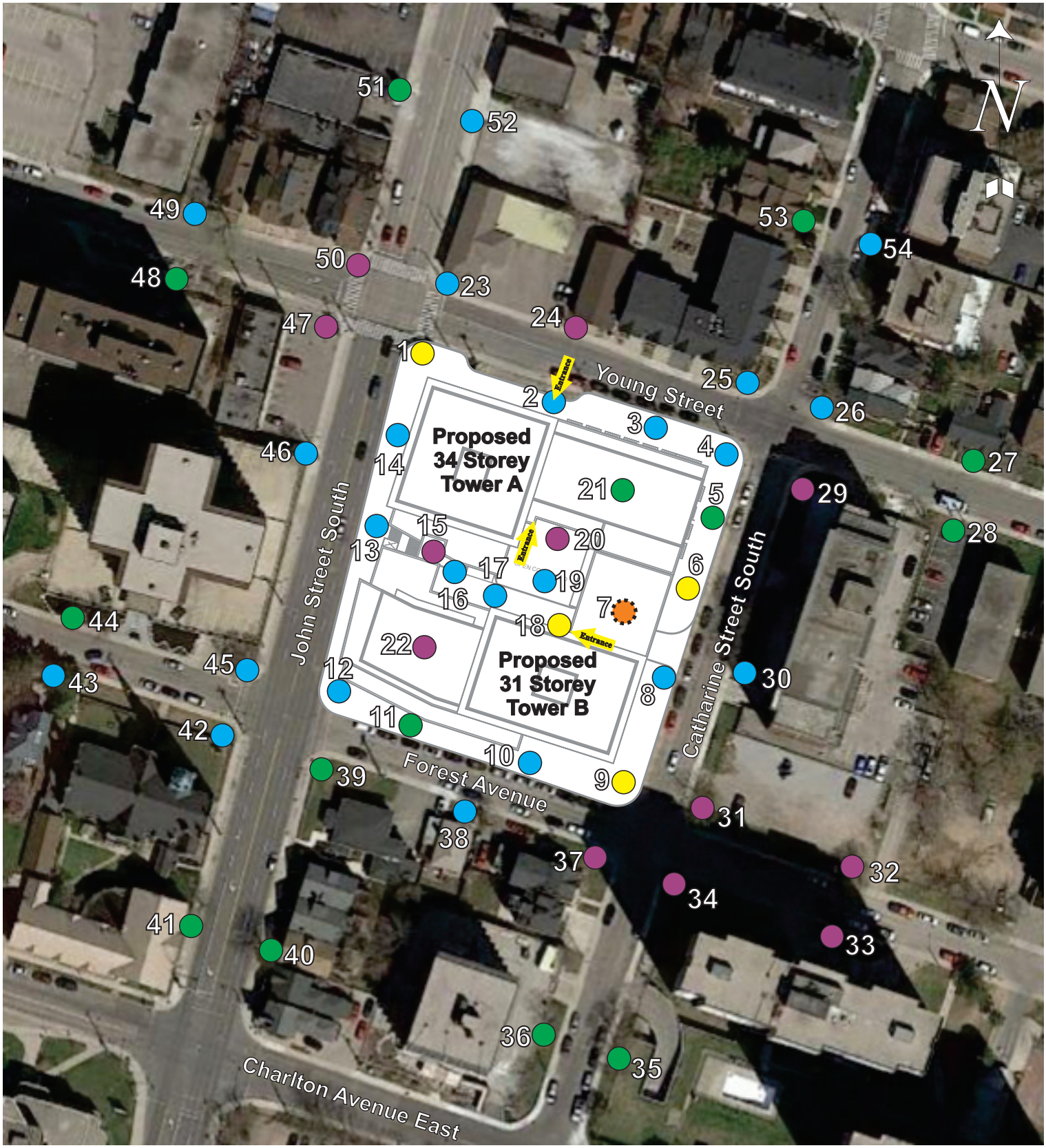
Figure 7c: Pedestrian level wind velocity comfort categories.



Comfort Categories - Winter - Existing

Sitting | Standing | Leisurely Walking | Fast Walking | Uncomfortable

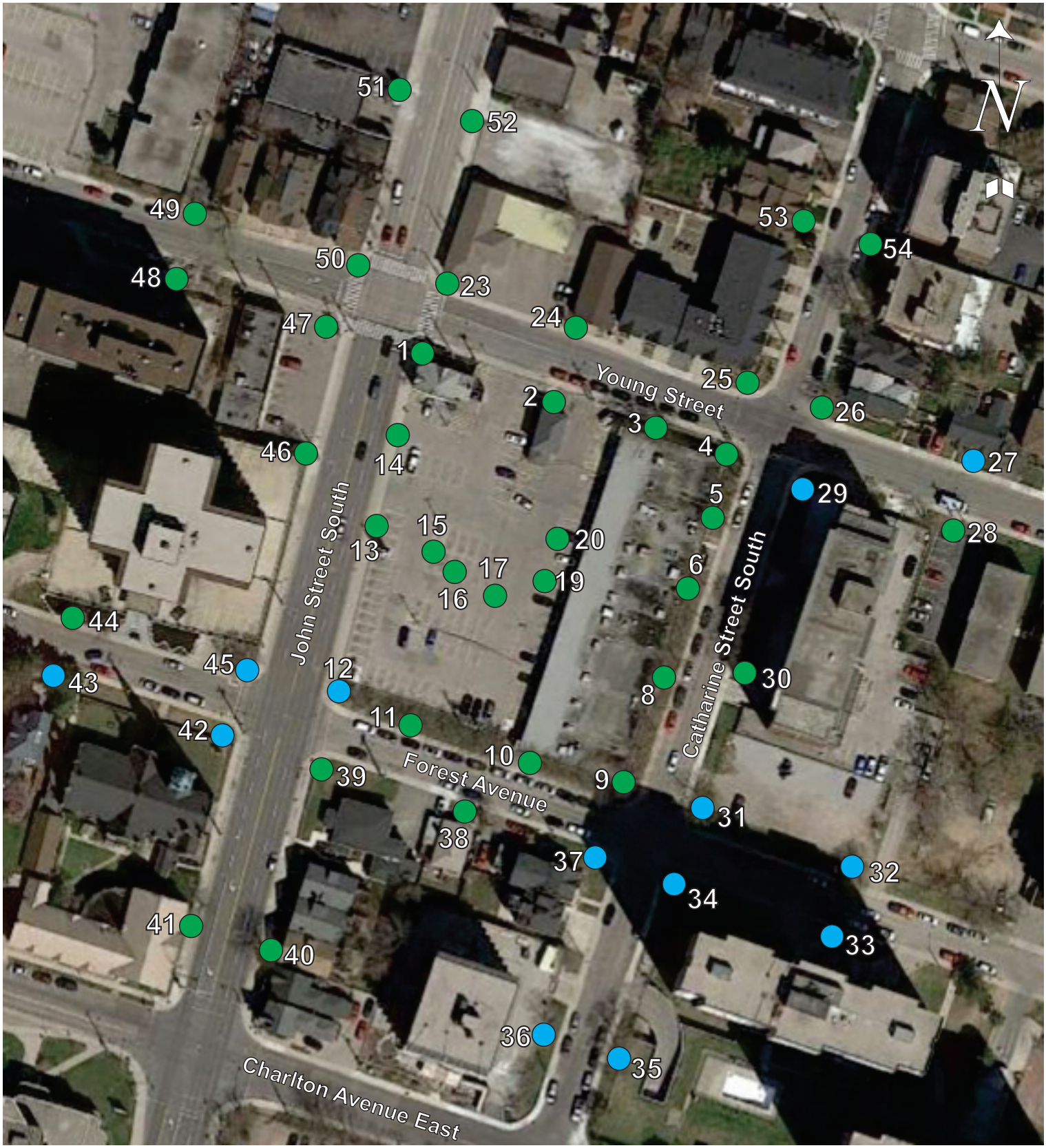
Figure 7d: Pedestrian level wind velocity comfort categories.



Comfort Categories - Winter - Proposed

Sitting · Standing · Leisurely Walking · Fast Walking · Uncomfortable

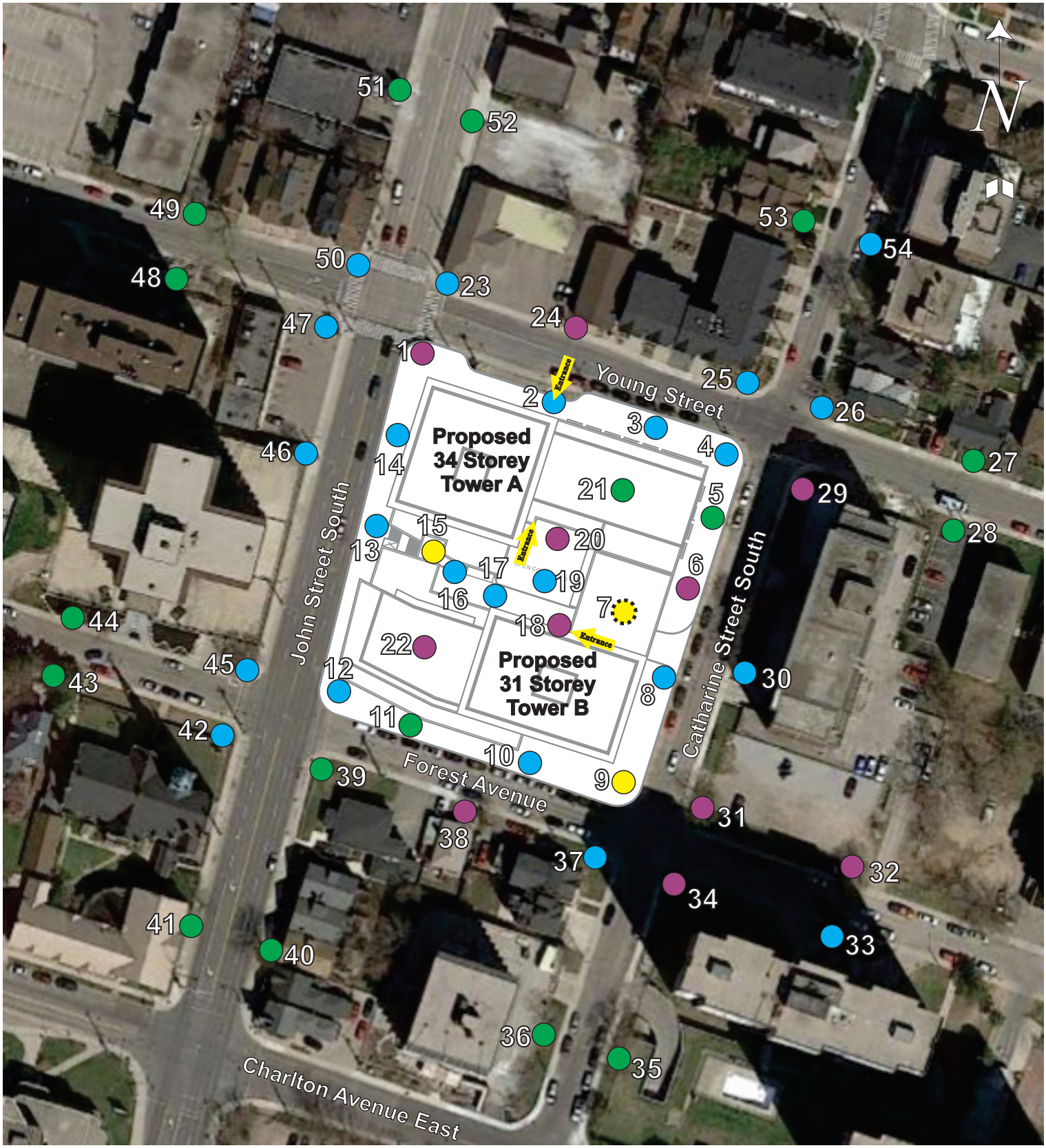
Figure 7e: Pedestrian level wind velocity comfort categories.



Comfort Categories - Spring - Existing

Sitting | Standing | Leisurely Walking | Fast Walking | Uncomfortable

Figure 7f: Pedestrian level wind velocity comfort categories.



Comfort Categories - Spring - Proposed

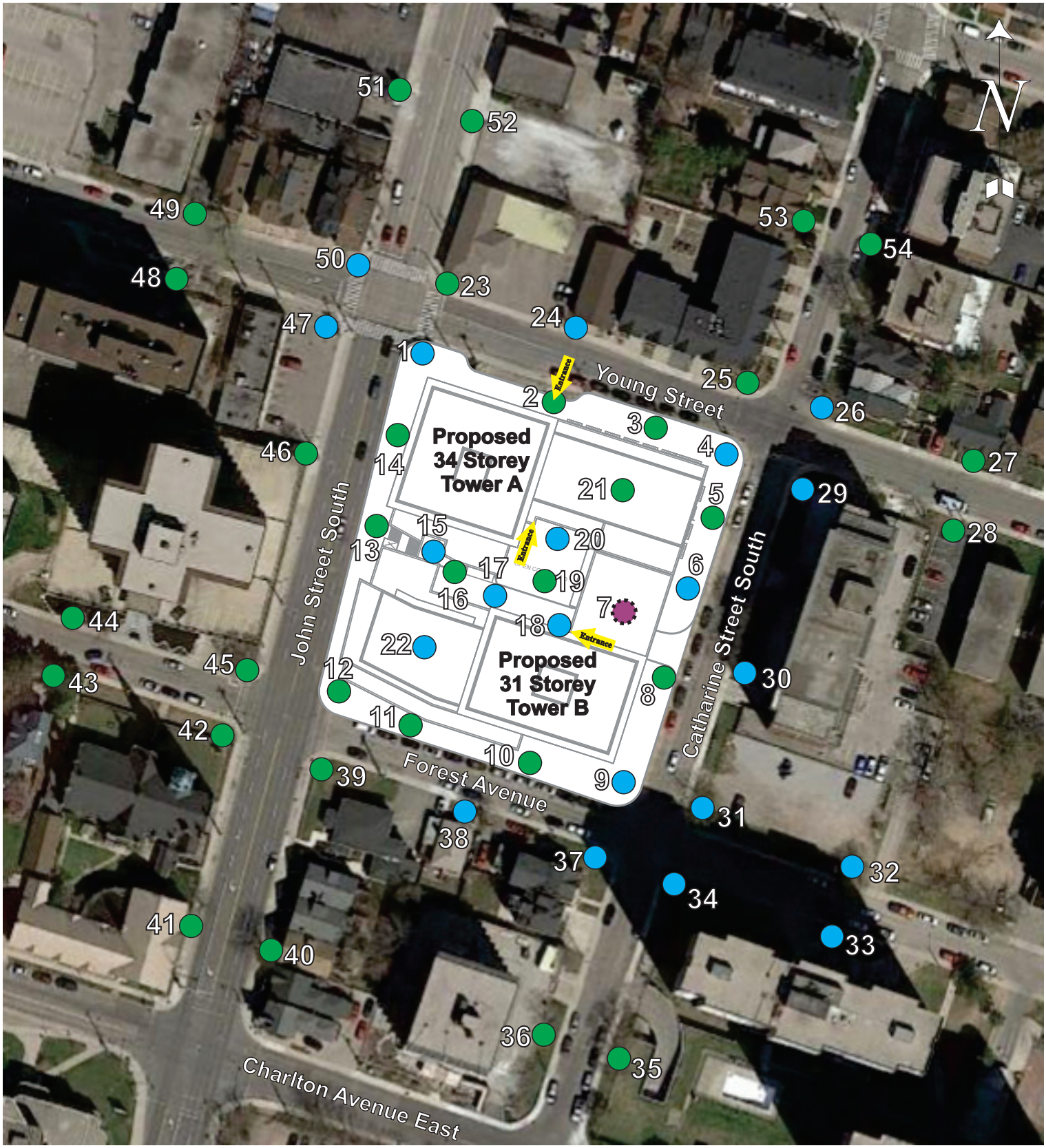
Sitting Standing Leisurely Walking Fast Walking Uncomfortable

Figure 7g: Pedestrian level wind velocity comfort categories.

Comfort Categories - Summer - Existing

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

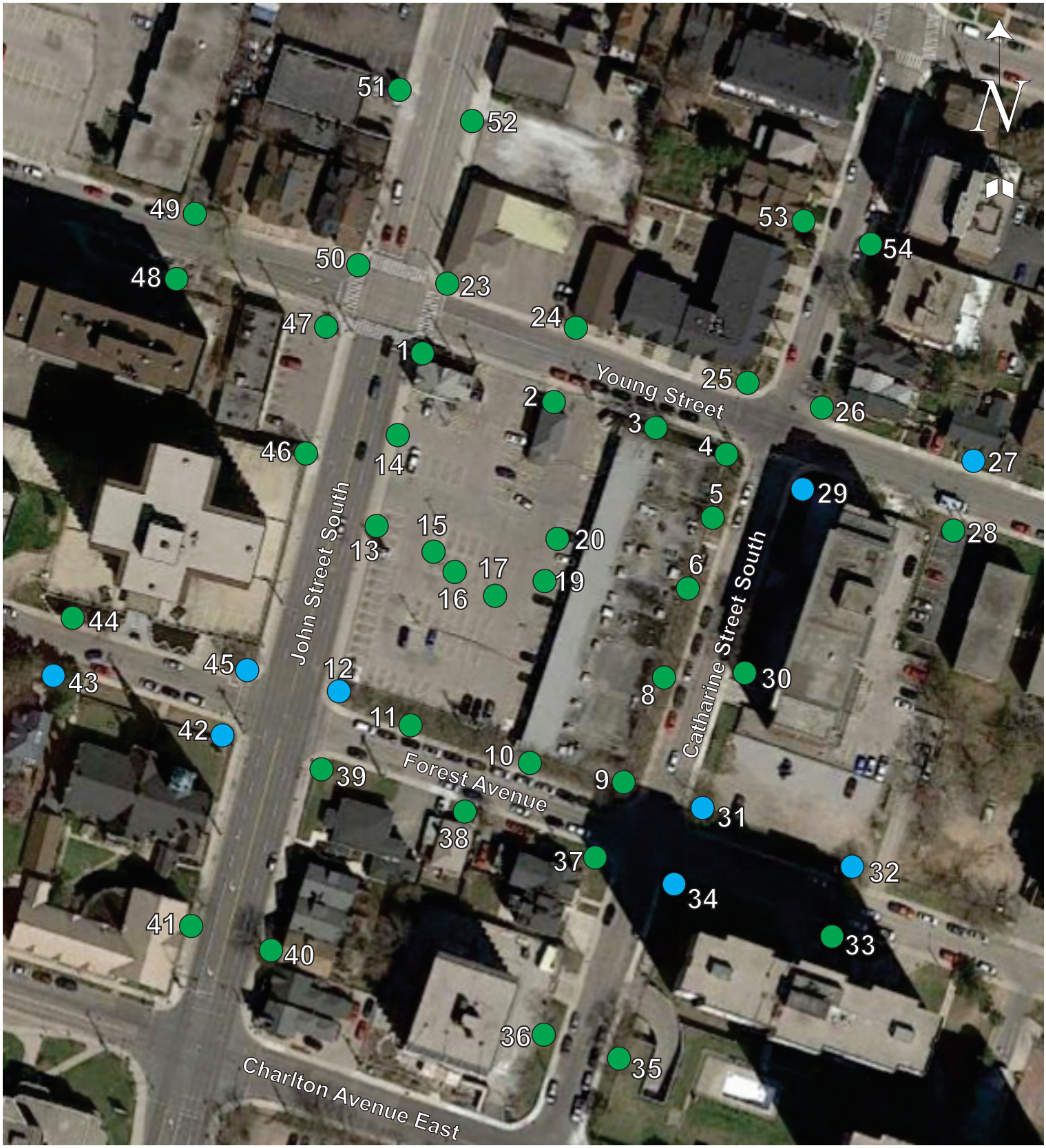
Figure 7h: Pedestrian level wind velocity comfort categories.



Comfort Categories - Summer - Proposed

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

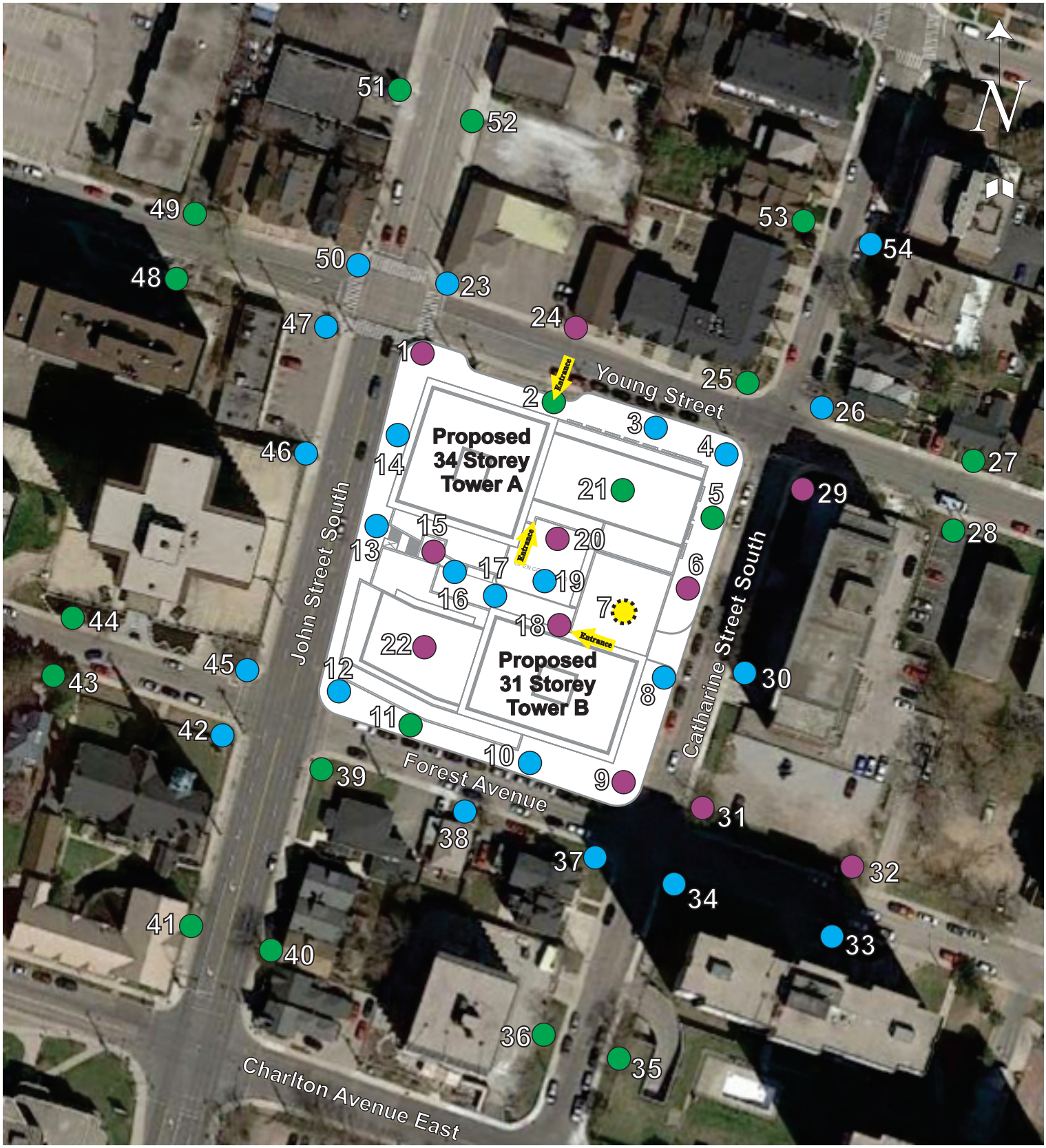
Figure 7i: Pedestrian level wind velocity comfort categories.



Comfort Categories - Fall - Existing

Sitting | Standing | Leisurely Walking | Fast Walking | Uncomfortable

Figure 7j: Pedestrian level wind velocity comfort categories.



Comfort Categories - Fall - Proposed

Sitting | Standing | Leisurely Walking | Fast Walking | Uncomfortable

Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Once Per Year (Locations 1 to 20).

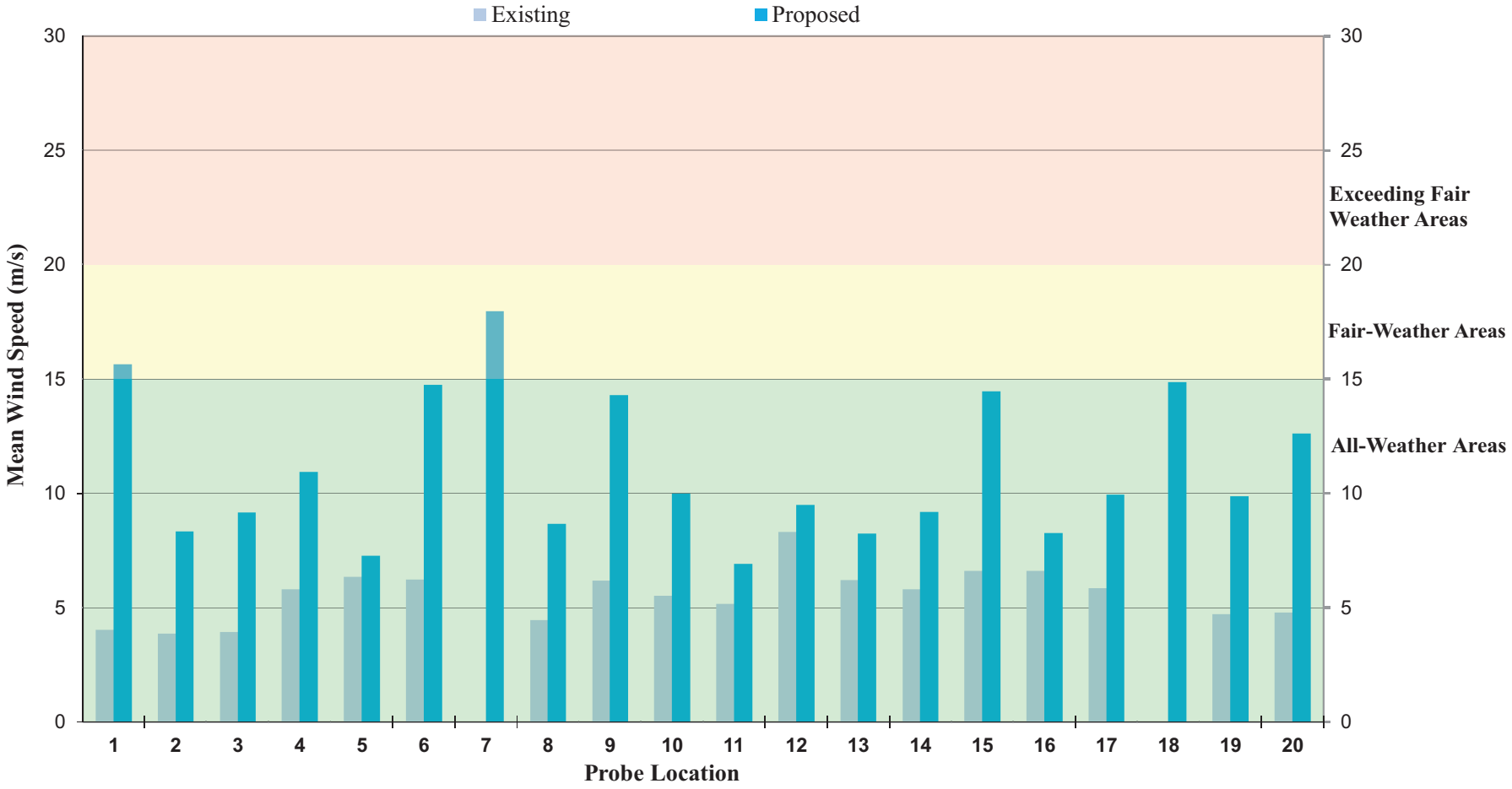


Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Once Per Year (Locations 21 to 40).

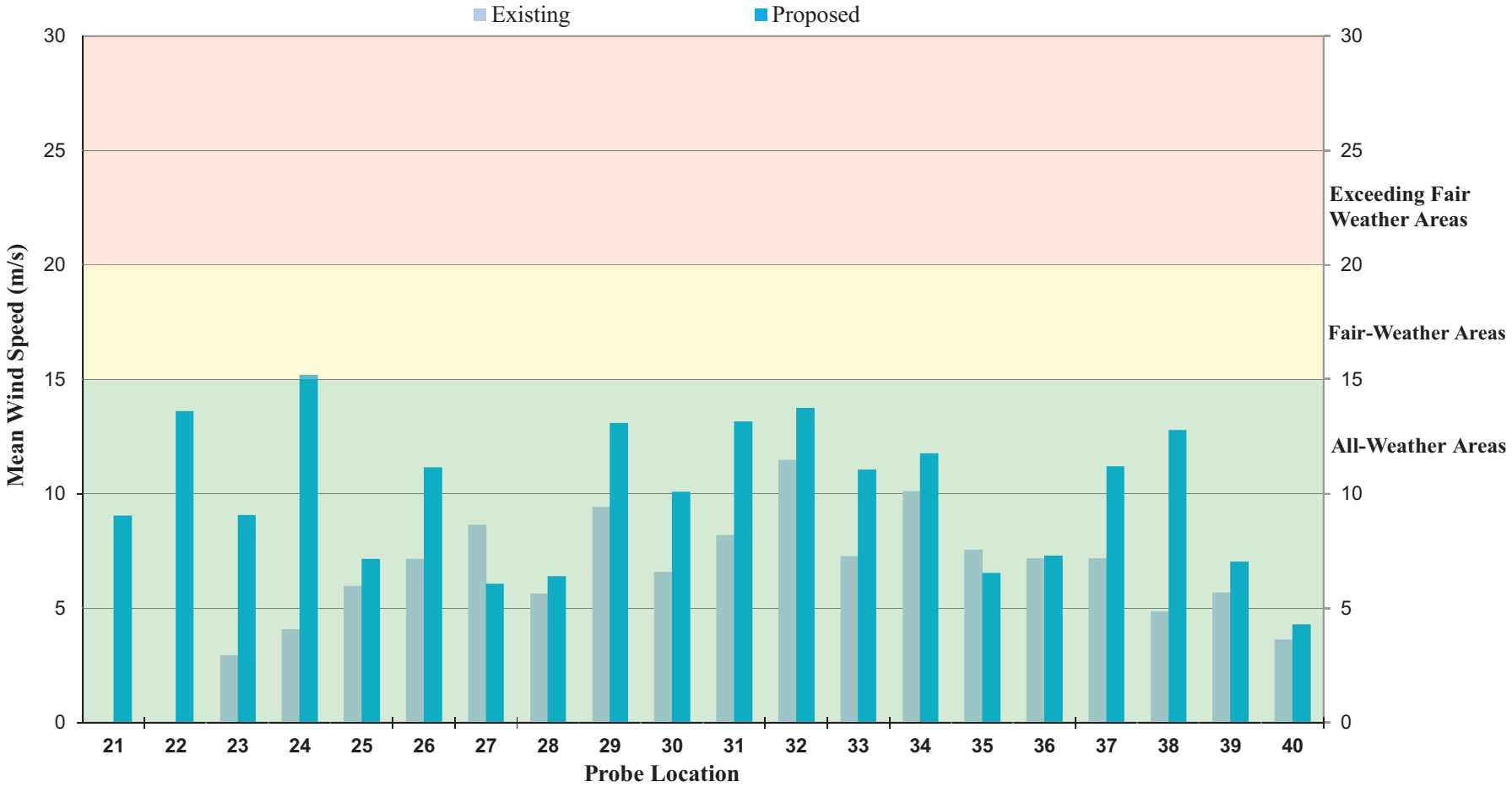


Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Once Per Year (Locations 41 to 54).

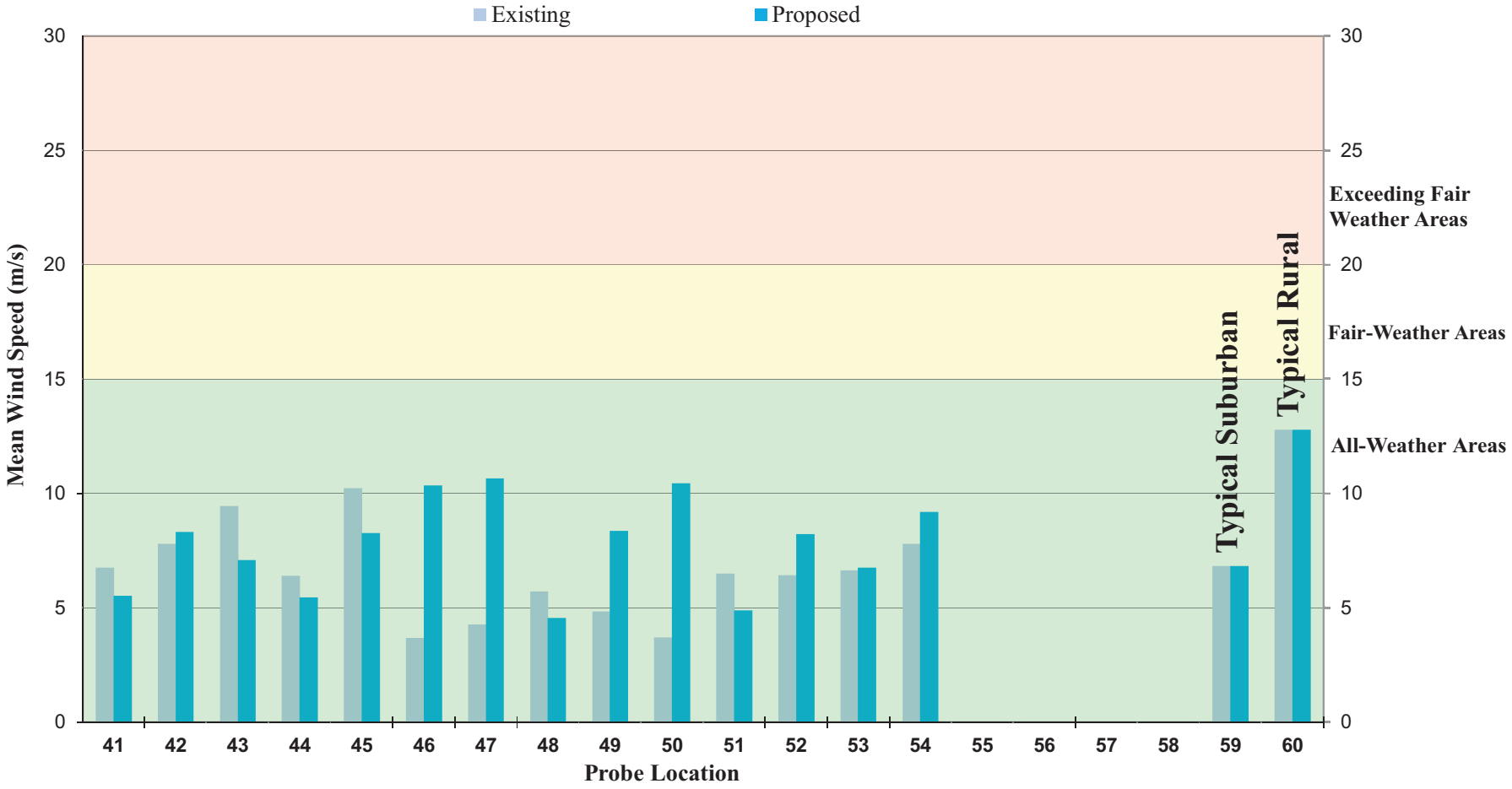


Figure 9a: Pedestrian level wind velocity safety criteria.

Safety Criteria - Existing

All-Weather Areas Fair-Weather Areas Exceeding Fair-Weather Areas

Figure 9b: Pedestrian level wind velocity safety criteria.

Safety Criteria - Proposed

All-Weather Areas Fair-Weather Areas Exceeding Fair-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:

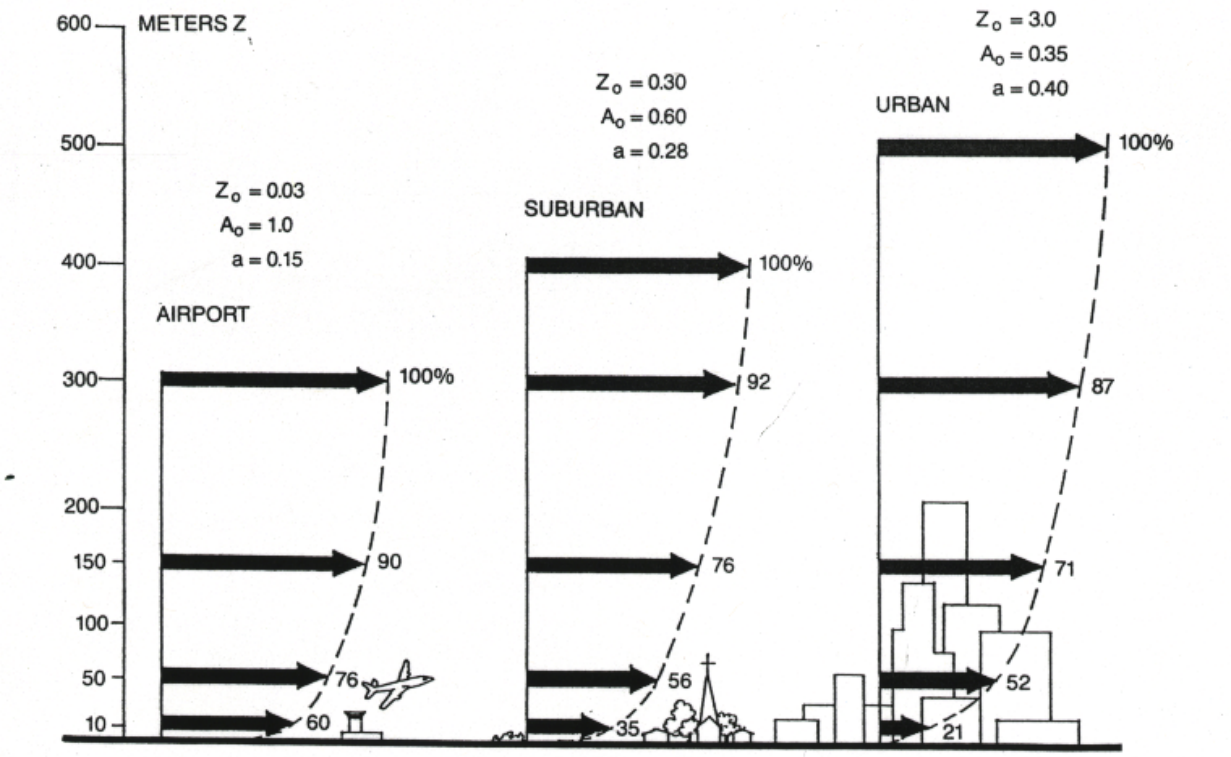


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

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 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.

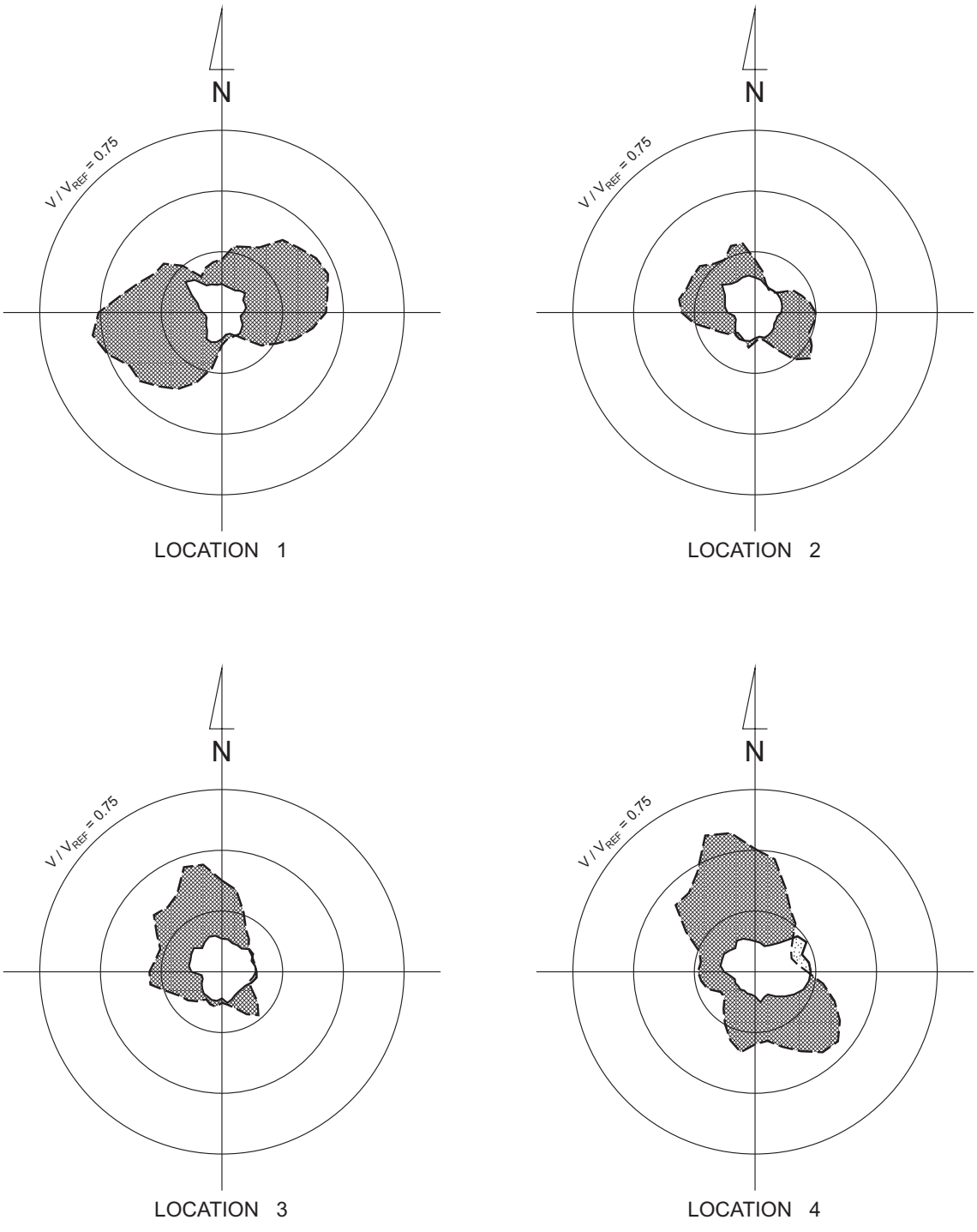
The Beaufort Scale is often used as a numerical relationship to wind speed based upon an observation of the effects of wind. Rear-Admiral Sir Francis Beaufort, commander of the Royal Navy, developed the wind force scale in 1805, and by 1838 the Beaufort wind force scale was made mandatory for log entries 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.



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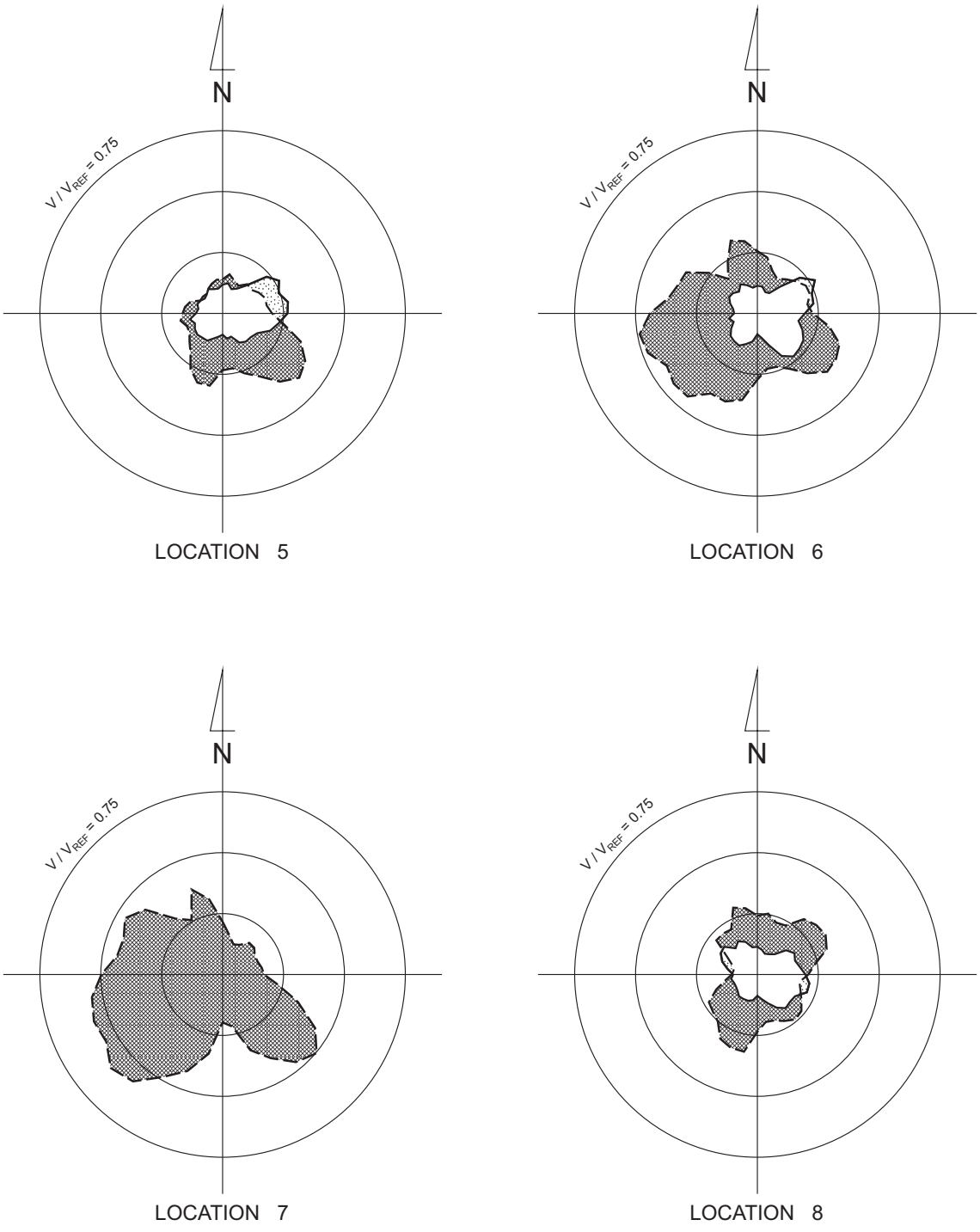

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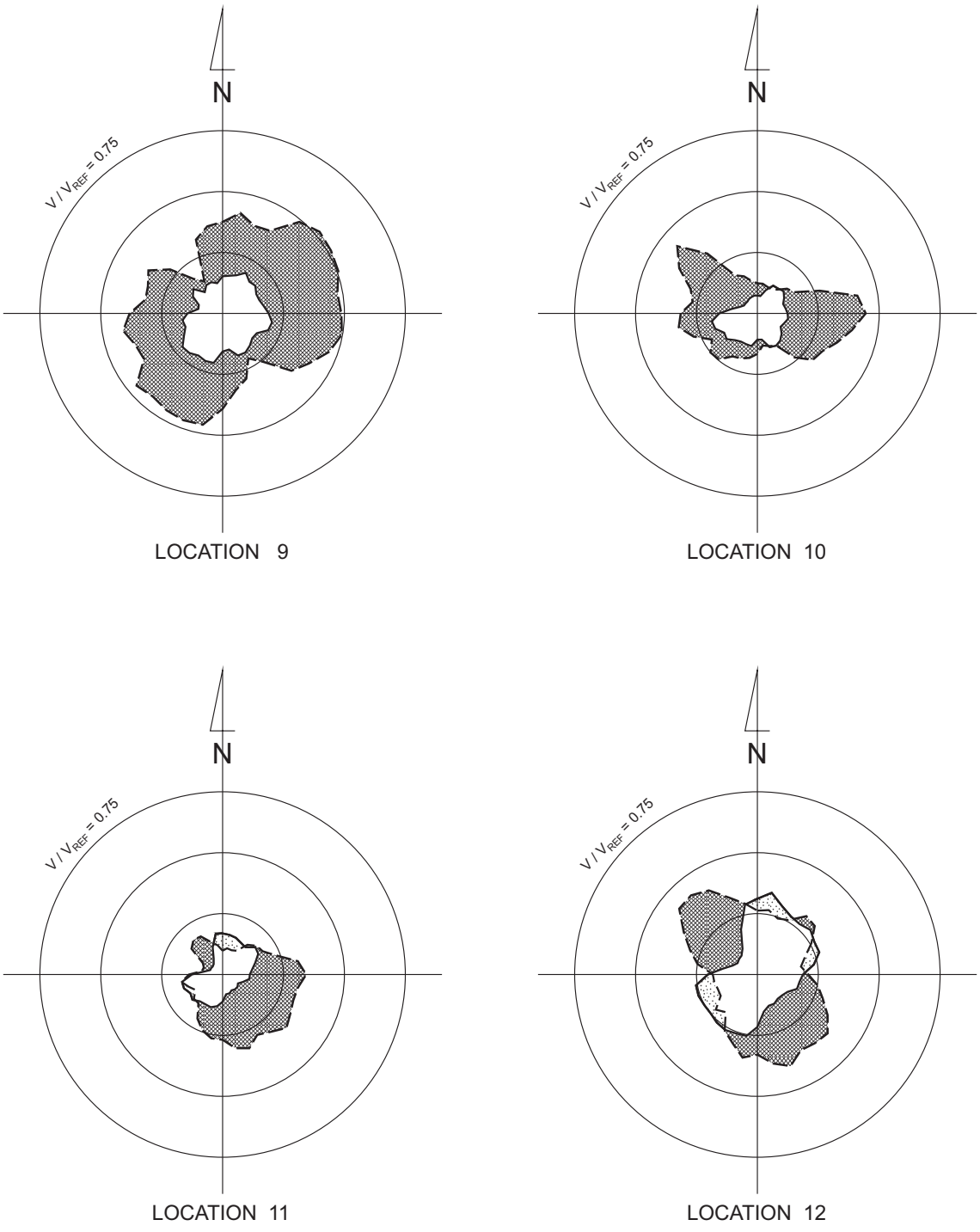

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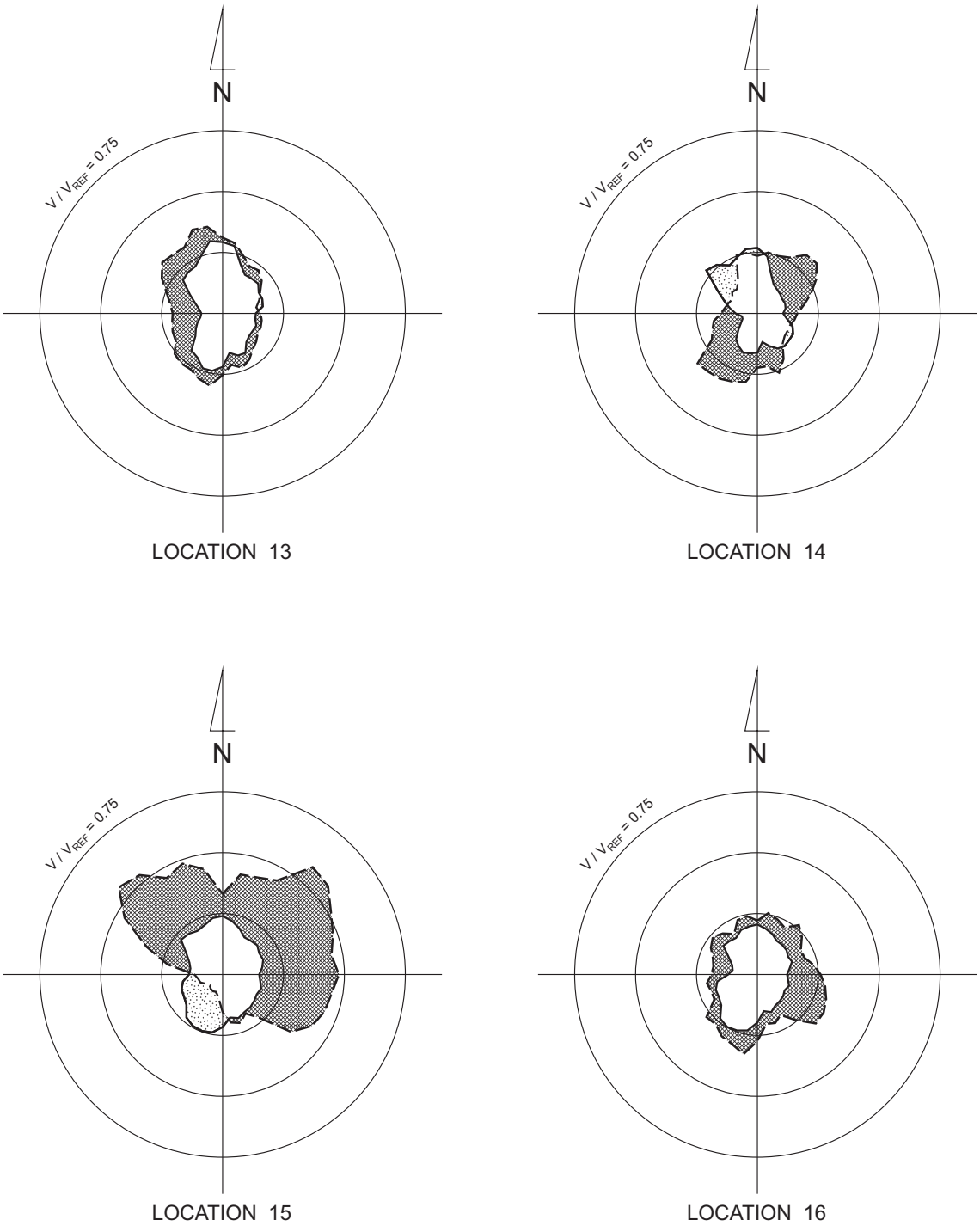

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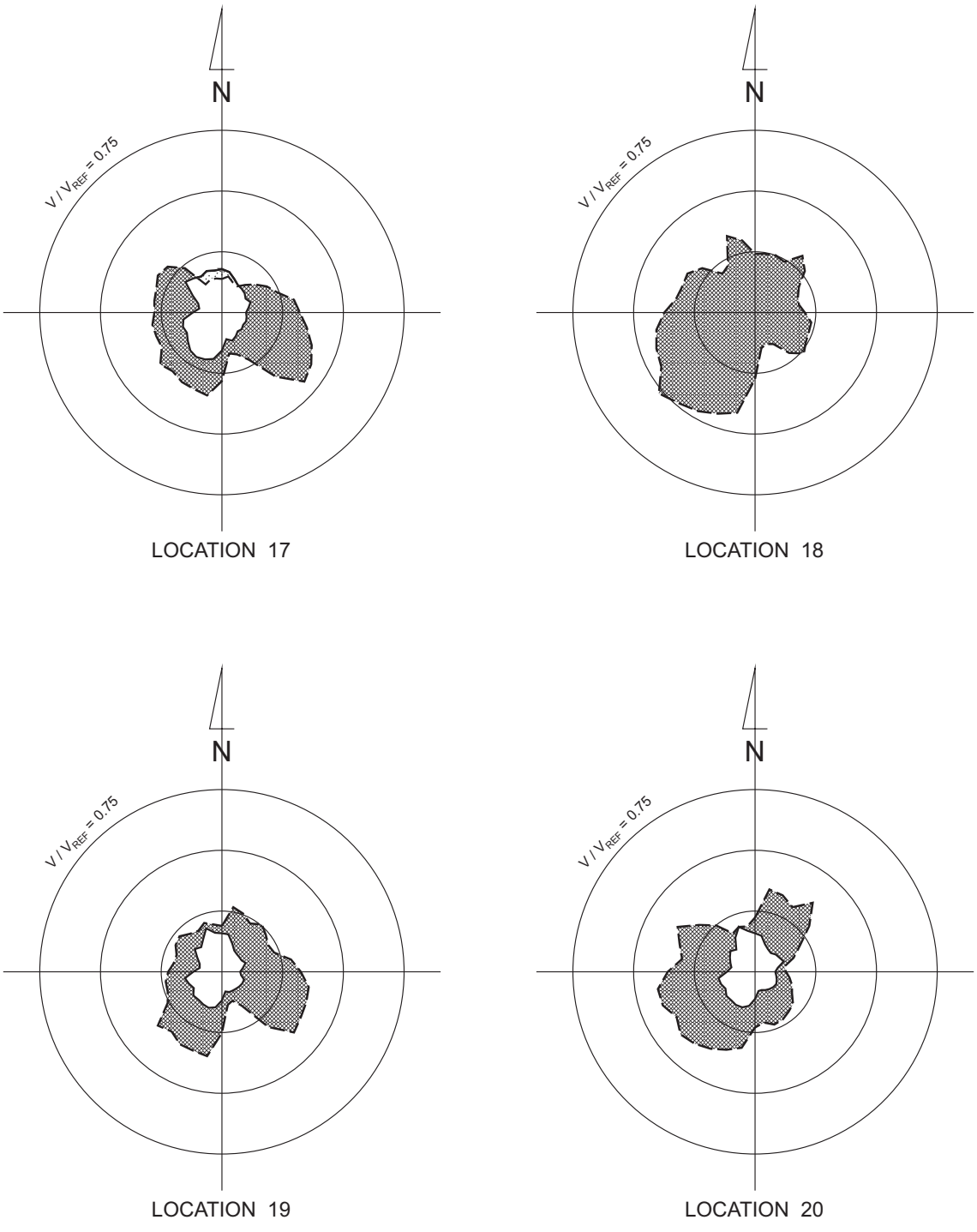

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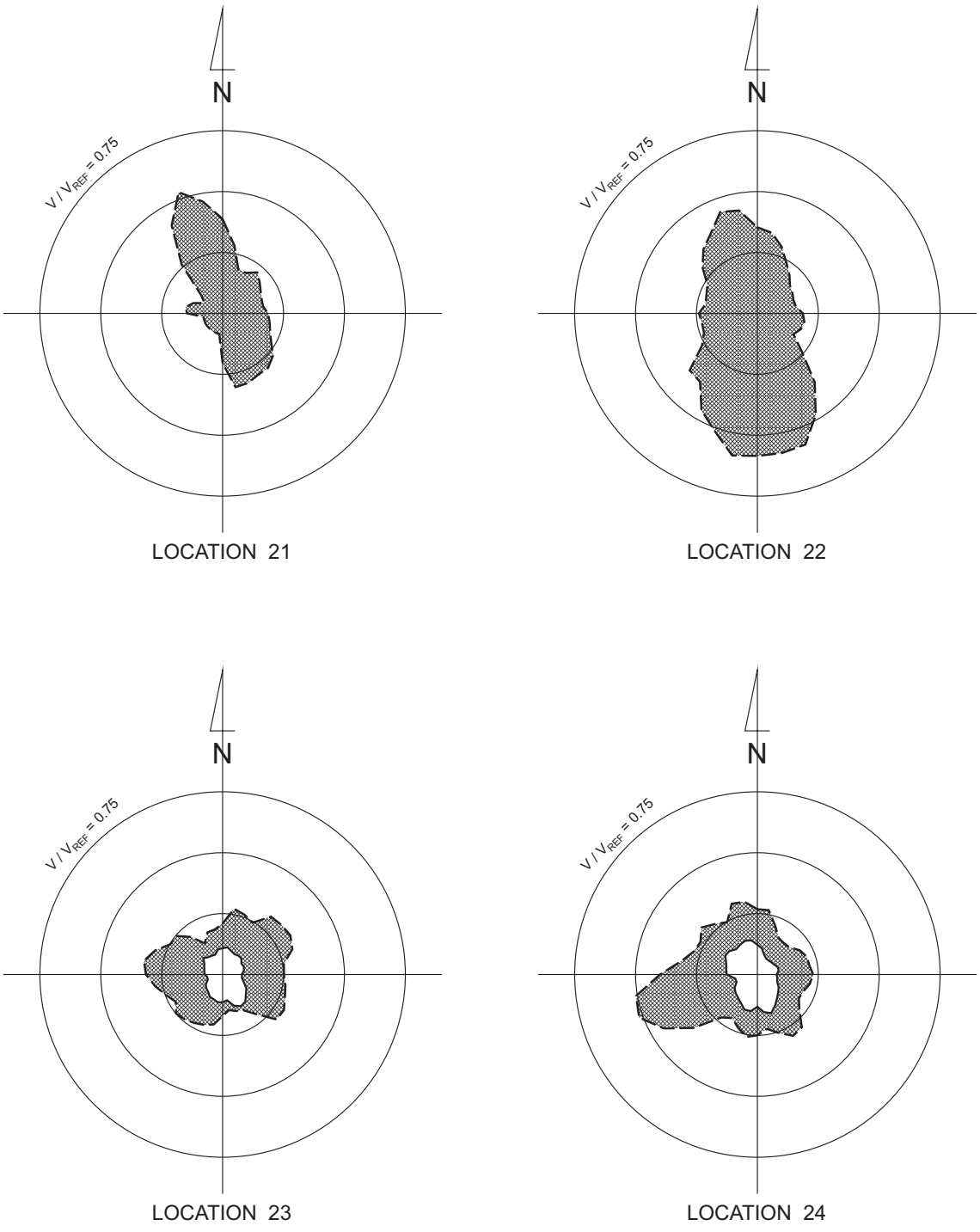

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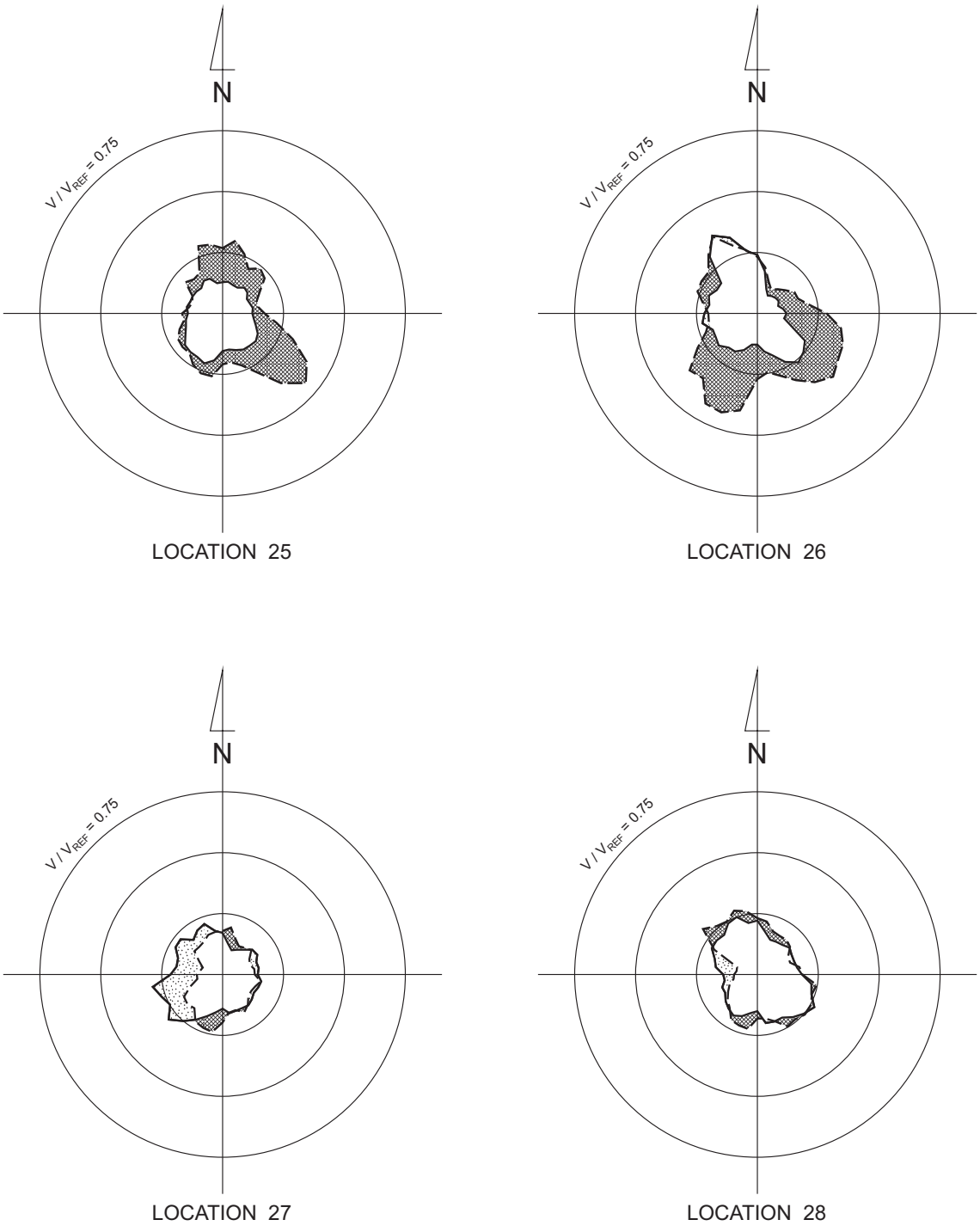

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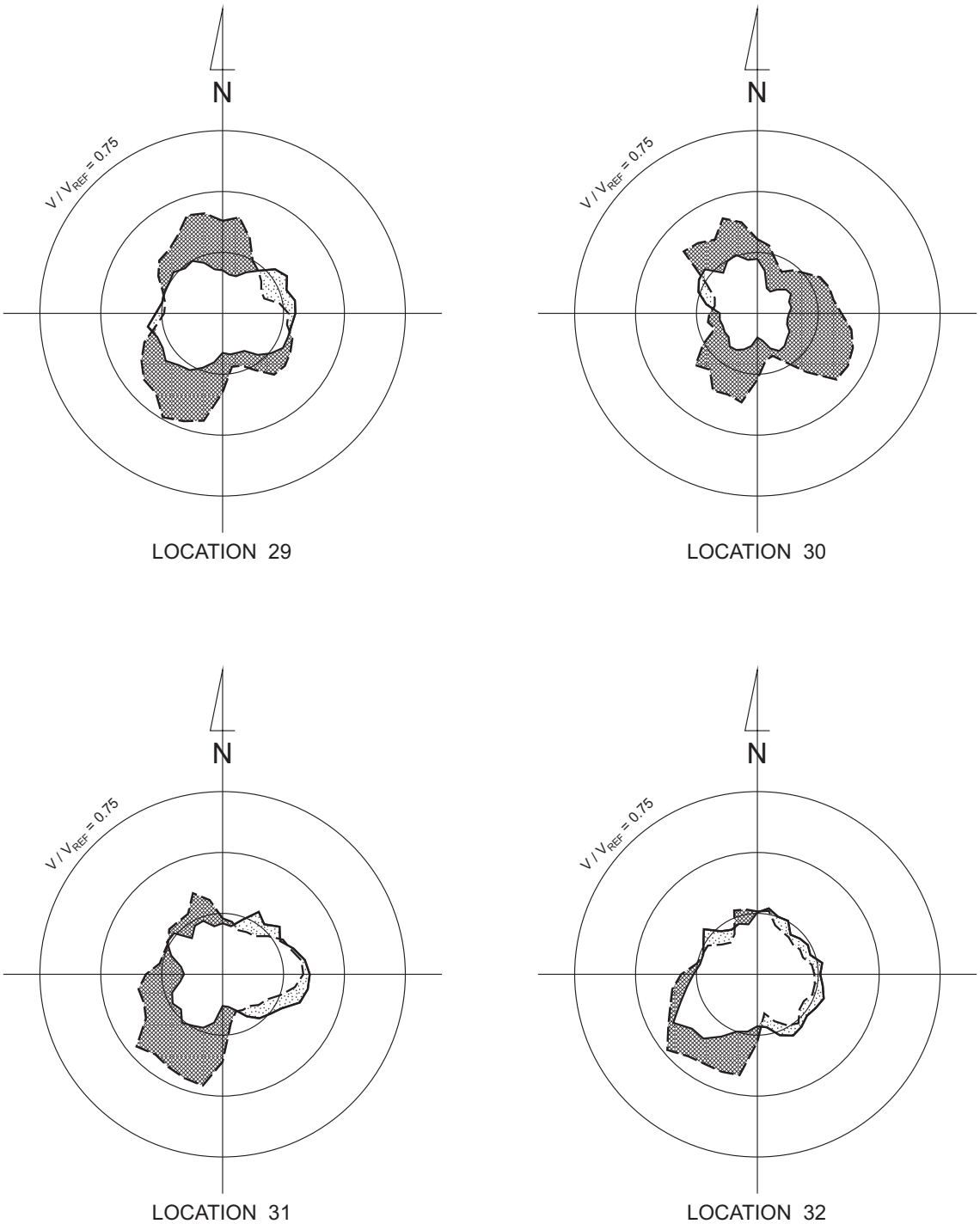

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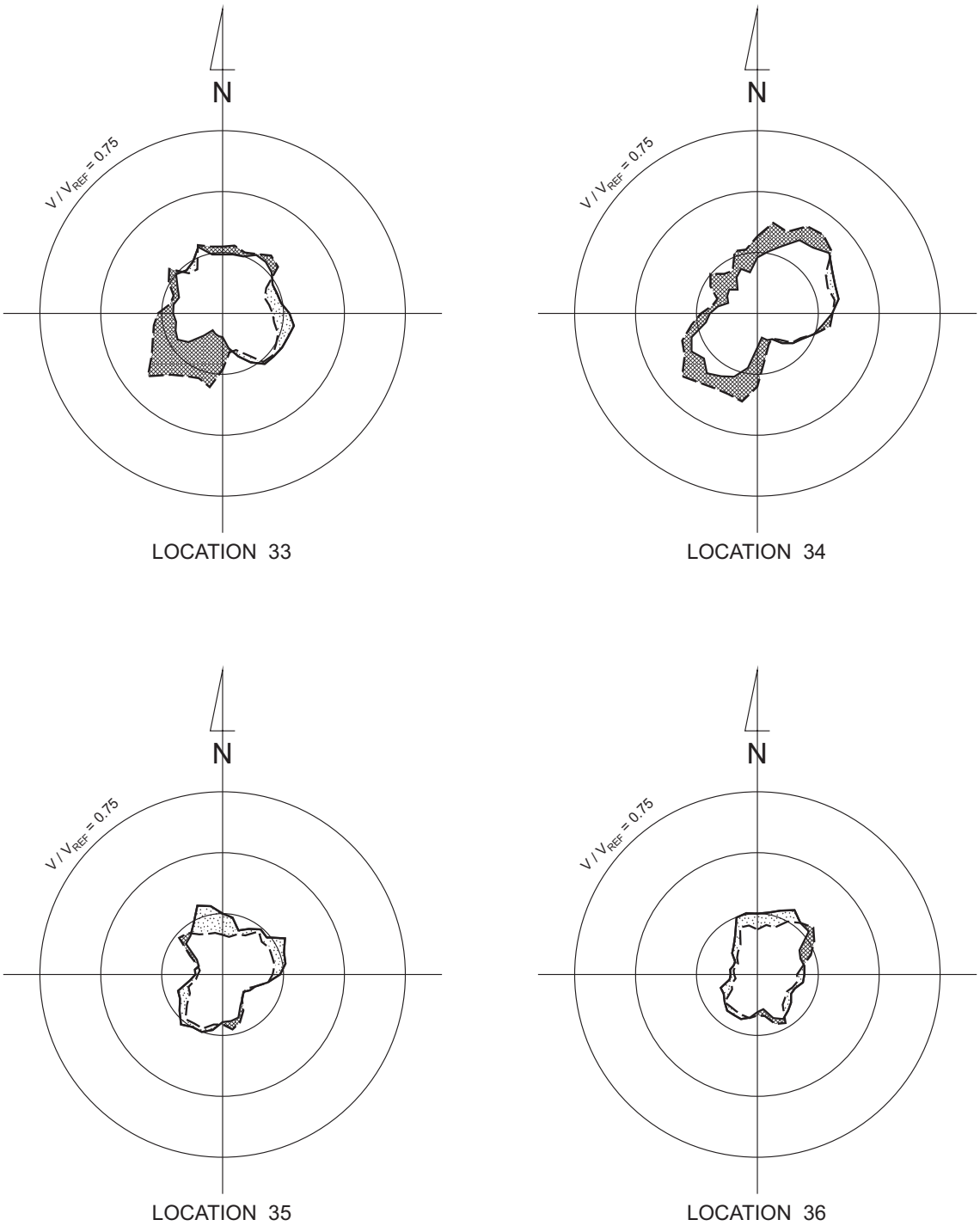

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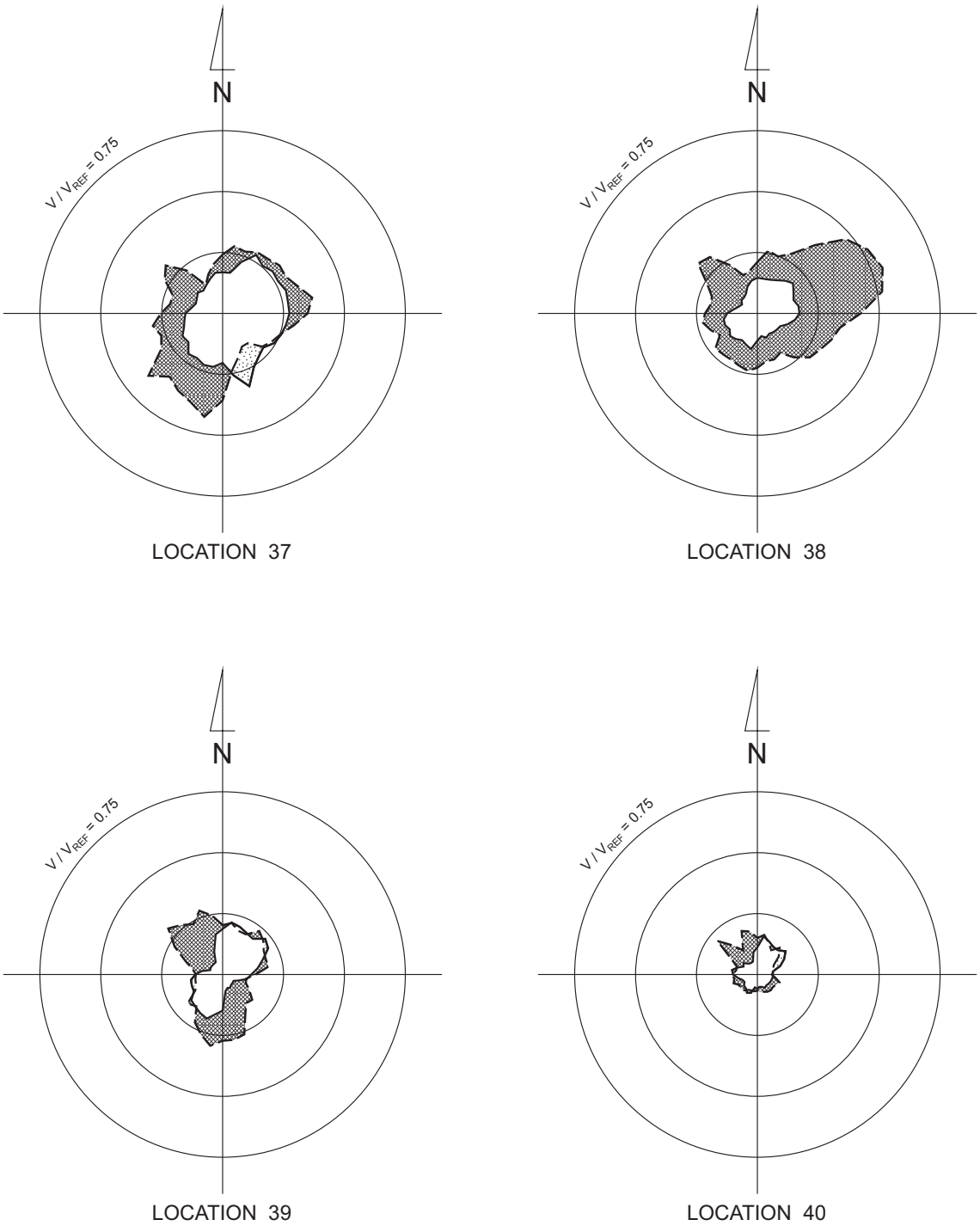

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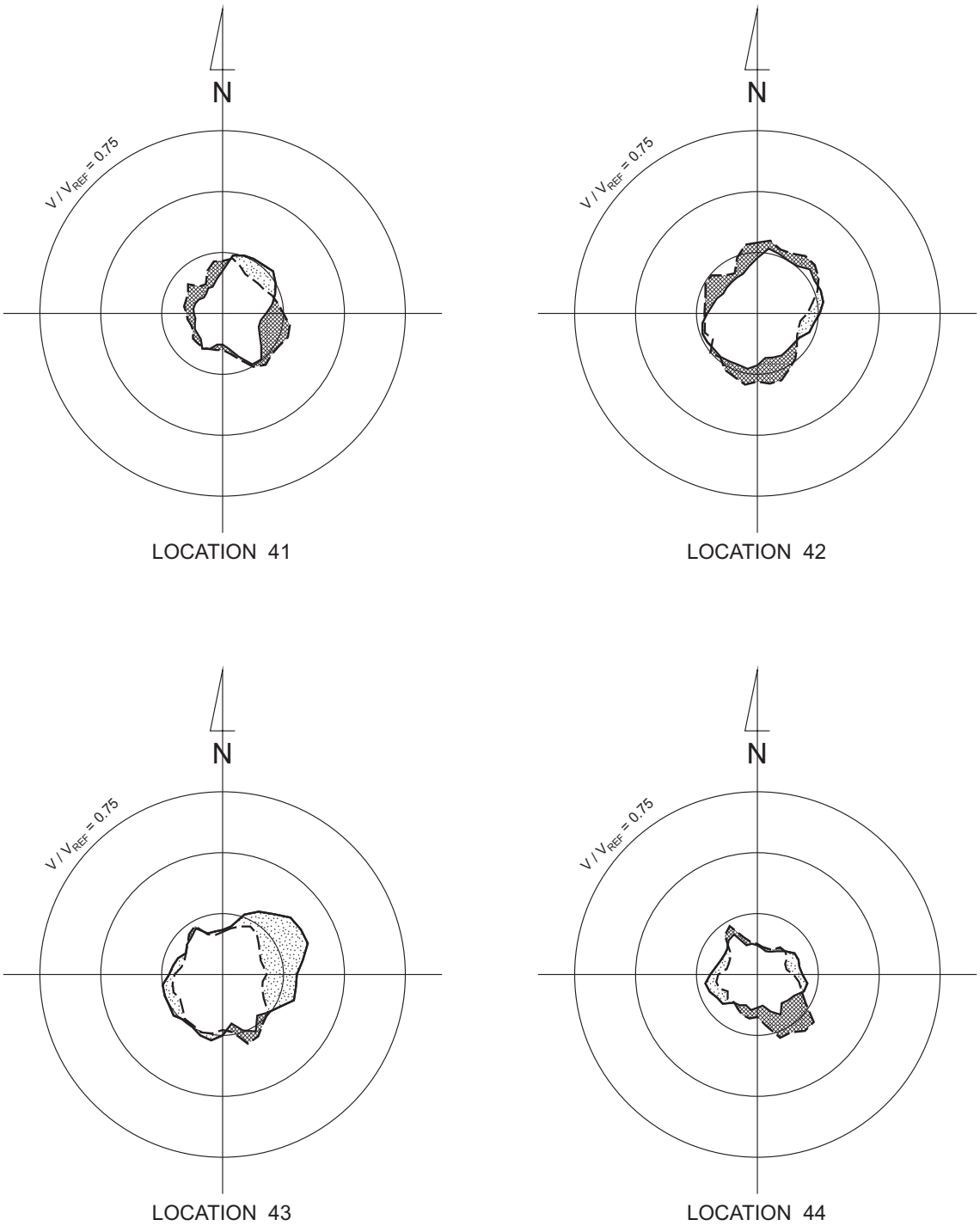

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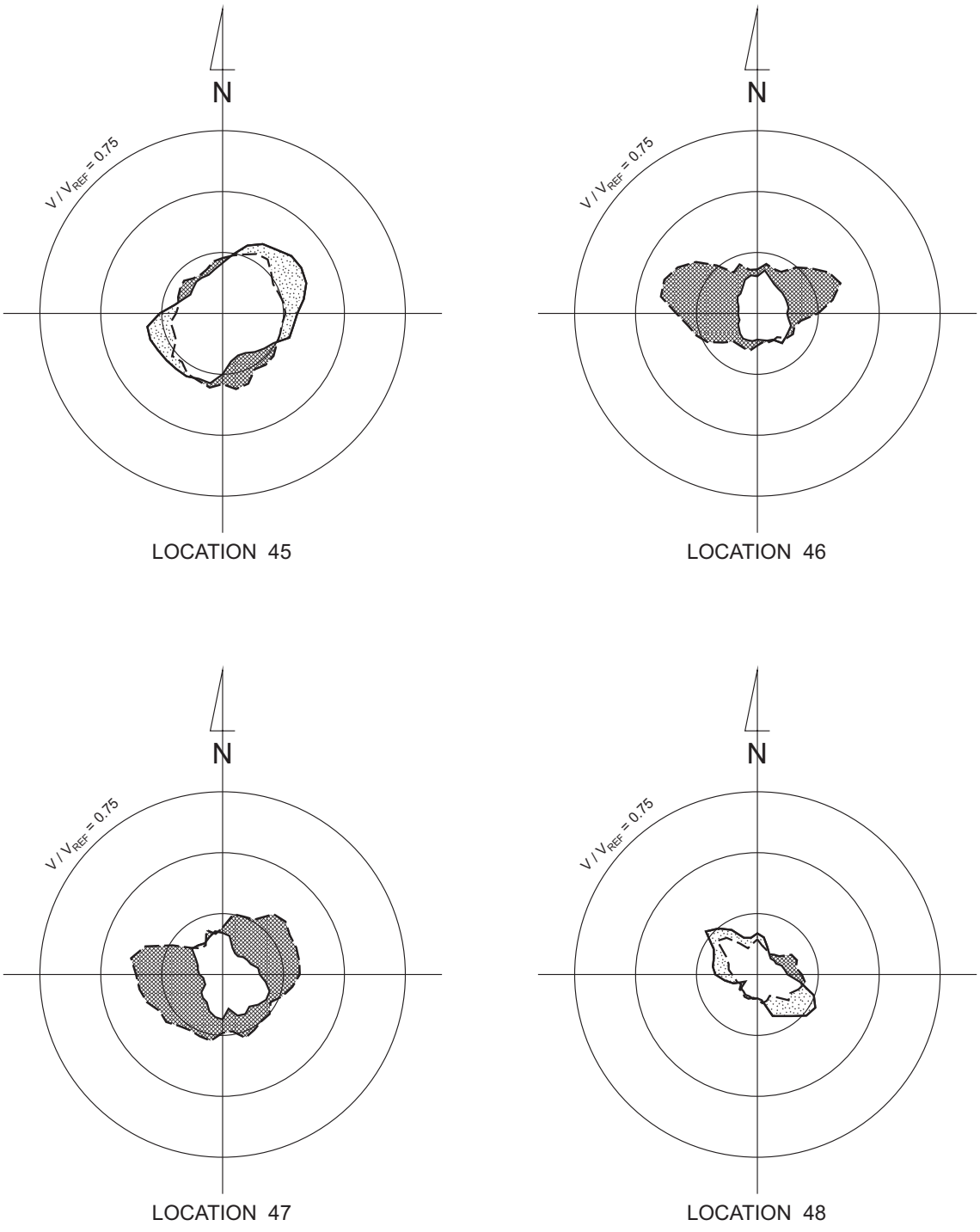

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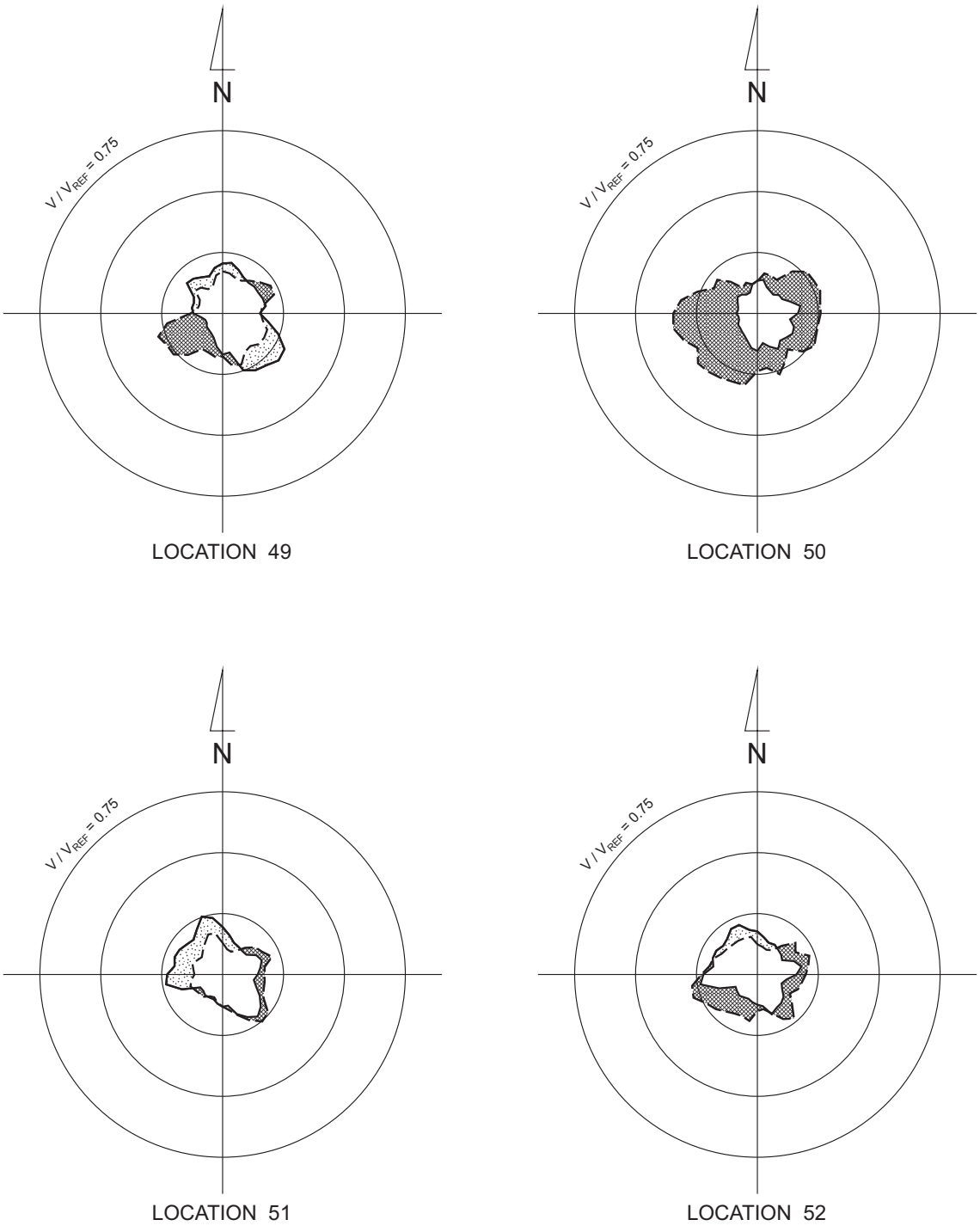

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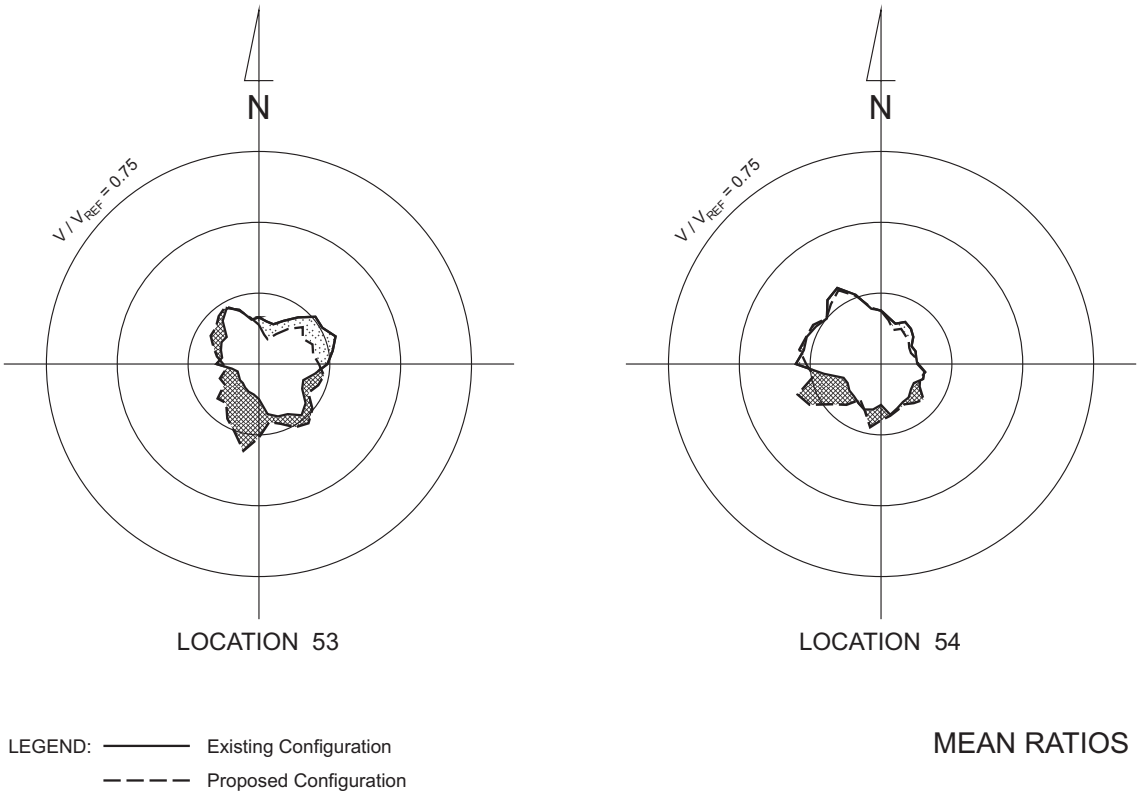

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