THEAKSTON ENVIRONMENTAL

Consulting Engineers • Environmental Control Specialists

REPORT

PEDESTRIAN LEVEL WIND STUDY

69 & 117 John Street

Mississauga, Ontario

13545130 Canada Inc.

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1. EXECUTIVE SUMMARY

The 69 & 117 John Street Development proposed by 13545130 Canada Inc. for the property located to the north of the intersection of Hurontario Street and John Street, in the City of Mississauga, has been assessed for environmental standards with regard to pedestrian level wind relative to comfort and safety. The pedestrian level wind and gust velocities predicted for the seventy (70) locations tested are within the safety criteria and most are within the comfort criteria described within the following report.

The 69 & 117 John Street Development involves a proposal to construct three residential towers that are 32, 31, and 24 storeys in height and are connected by 8 storey podiums. The Development is, for all intents and purposes, surrounded to prevailing windward directions by a suburban mix of residential, commercial, and institutional buildings, as well as related 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 existing site with prevailing winds that have opportunity to accelerate over the predominately low-rise lands associated with the site and adjacent streets. This setting accounts for the moderately windy conditions observed in the existing setting, on and about the Development site. With inclusion of the proposed Development, winds that formerly flowed over the existing lands are redirected, tending to split with portions flowing over, around and down the proposed buildings' façades. At the pedestrian level, the winds redirect to travel horizontally along the buildings, around the corners and beyond, creating minor windswept areas at or near the buildings' corners and in the gaps between buildings.

The site and surrounds are predicted as suitable for walking, or better, under normal wind conditions throughout the year. Consideration of existing and proposed fine design and landscape elements, as well as future urban intensification of the surrounds, will result in more comfortable conditions that are appropriate for the intended uses throughout much of the year.

The following features that contribute to an overall wind mitigative design were incorporated into the proposed Development's massing design:

- stepped façades
- textured façades
- podiums
- building overhangs

Based upon this analysis, the comfort conditions at the site and in the surrounds are generally considered appropriate for their intended uses, with exceptions. Mitigation plans are recommended for the at-grade Outdoor Amenity Spaces, Park Land, Parking Rooftop Outdoor Amenity Space, and 9th level Outdoor Amenity Spaces in order to improve conditions such that they are rated seasonally appropriate for their intended uses.

The proposed Development is predicted to realise wind conditions that are suitable to the context.

Respectfully submitted,

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2. INTRODUCTION

13545130 Canada Inc. retained Theakston Environmental Consulting Engineers to study the pedestrian level wind environment for their proposed Development municipally known as 69 & 117 John Street, in the City of Mississauga, and depicted on the Aerial Photo in Figure 2a. The Development involves a proposal to construct three residential towers, 32, 31, and 24 storeys in height, with 8 storey connective podiums, in the configuration shown in Figure 2b. Architectural drawings were provided by Tregebov Cogan Architecture. The co-operation and interest of the Client and their sponsors in all aspects of this study is gratefully acknowledged.

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

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

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

3. OBJECTIVES OF THE STUDY

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

2. To assess mitigative solutions.

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

4. METHOD OF STUDY

4.1 General

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

The techniques applied to wind and other studies carried out at the facility, utilise a boundary layer wind tunnel and/or water flume (Figure 1). The testing facility has been developed for these kinds of environmental studies, and has been adapted with equipment, testing procedures and protocols, in order to provide results comparable to full scale. Theakston's Boundary Layer Wind Tunnel, which lends itself well to the simultaneous acquisition of large data streams, was used to measure the wind environment at the site while the water flume is excellent for flow visualization and can be used to help understand problematic wind flow conditions.

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 1.5m and correlated to mean and gust wind speeds, expressed as ratios of the gradient wind speed.

The mean and gust wind speeds at the seventy (70) 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 Gust Equivalent Mean (GEM) wind speed exceeded 20% of the time, based on winter and summer winds in Figures 6a and 6b. Criterion employed by Theakston Environmental was developed by others and us and published in the attached references. The methodology has been applied to over 800 projects on this continent and abroad.

4.2 Meteorological Data

The wind climate for the Mississauga region that was used in the analysis was based on historical records of wind speed and direction measured at Pearson International Airport for the period between 1993 and 2023. The meteorological data includes hourly wind records and annual extremes. The analysis of the hourly wind records provides information to develop the statistical climate model of wind speed and direction. From this model, predicted wind speeds regardless of wind direction for various return periods can be derived. The record of annual extremes was also used to predict wind speeds at various return periods. Based on the analysis of the hourly records, the predicted hourly-mean wind speed measured at 10*m* above grade, corrected for a standard open exposure definition, is 25*m/s* for a return period of 50 years.

4.3 Statistical Wind Climate Model

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

The design probability distribution of mean-hourly wind speed and wind direction at reference height is shown for Pearson International Airport in Figure 5. Distributions for Winter and Summer are shown. From this it is apparent that winds can occur from any direction, however, historical data indicates the directional characteristics of strong winds during the winter months are north through west to southwest. Through the summer months, the winds are not as strong and are mainly from the same directions as winter winds, with the addition of winds from the southeast more often.

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 1:400. The model is based upon information gathered during a virtual site visit to the proposed Development site, and surrounding area. Architectural drawings were provided by Tregebov Cogan Architecture. 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

1.5m. 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 Comfort Categories, which are based upon two seasons and calculated as the Gust Equivalent Mean (GEM) wind speed exceeded 20% of the time, based on wind events occurring between 6:00 and 23:00. Gust Equivalent Mean (GEM) wind speed is the maximum of either mean wind speed or gust wind speed divided by 1.85. 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. A comparison of pedestrian level comfort conditions for each probe is shown in a table in Figure 10. 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 Wind Speed Exceeded 20% of the Time	Description
COMFORT	***km/h***	
Sitting	0-10	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	Gentle breezes suitable for main building entrances and bus stops.
Walking	0-20	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering.
Uncomfortable	>20	Strong winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended.

The effects of mean and gust wind conditions are described as suitable for Sitting, Standing, or Walking when said categories are realised 80% of the time, or greater. The Uncomfortable category encompasses wind conditions that exceed Walking criteria. For a point to be rated as suitable for Sitting, for example, the GEM wind conditions must not exceed 10*km/h*, 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 GEM wind speeds from calm up to 15*km/h,* occurring at least 80% of the time. 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,* occurring more than 80% of the time. 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* occurring more than 20% of the time.

In Figure 6, the probe locations are listed along the bottom of the chart; beneath the graphical representation of the GEM 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. 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 upon gust wind speeds exceeded nine times per year, using annual wind data recorded 24 hours daily, as shown in Table 2.

Both the Comfort and Safety Criteria are based on those described in the City's Terms of Reference for Wind.

Table 2: Safety Criteria

ACTIVITY	Gust Wind Speed Exceeded 9 Times per year	Description
SAFETY	***km/h***	
Pass	0 - 90	Acceptable gust speeds that will not adversely affect a pedestrian's balance and footing.
Exceeding	>90	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 "winter" or "summer" results of the study, Figures 6a and 6b and 7a through 7d. When compared to the annual average wind speed, winter winds are about 9% higher and summer winds are about 9% lower.

4.9 Wind Mitigation Strategies

Wind mitigative features such as podiums, setbacks, stepped façades, balconies, notches, overhangs, canopies, and others, assist in discouraging downwash associated with prevailing winds. These features deflect portions of said winds around buildings at elevations well above the pedestrian level, and moderate upsets to wind conditions with inclusion of new developments. Additional mitigative features may also be applied for localised areas that experience conditions that are inappropriate for the intended use. These features, discussed below, add roughness into wind streamlines and protect exposed areas from high pedestrian level winds.

Entrances to buildings may be mitigated by locating them away from building corners and through recessing the entrances into the façades of the building. Additional mitigative features such as railings, canopies, coarse plantings, porous wind screens, and others, would further assist in mitigating said areas. Examples of these wind mitigation measures are shown below.

Examples of Wind Mitigative Measures at Entrances (recessed entrances, railings, canopies, raised planters, coniferous trees).

Activity areas such as Outdoor Amenity Spaces may similarly be mitigated through implementation of 1.8m – 2.4m or higher perimeter wind screens, trellises, raised planters, coarse plantings, and others, situated about the spaces as practical. Examples of these wind mitigative measures are shown below.

Examples of Wind Mitigative Measures at Activity Spaces (wind screens, raised planters, trellises)

The model was assessed with selected mitigation strategies during these tests to determine their impact on the various wind conditions. Further testing may be required in order to determine the effectiveness of any additionally proposed wind mitigative features, if desired.

5. RESULTS

5.1 Study Site and Test Conditions

<u>Proposed Development</u>

The 69 & 117 John Street Development occupies a portion of the block of lands north of the intersection of John Street and Hurontario Street, within the City of Mississauga. The site is currently unoccupied. The Development involves a proposal to build 32, 31, and 24 storey residential towers, denoted Buildings A, B & C respectively, connected by an 8 storey podium with a step at the 5th level along the northwest and southeast façades. A 1 storey parking garage extends along the northwest façade of the combined massing. Vehicular access to the site is provided via a private driveway encircling the site interior beneath Building B and connecting with John Street. The site is in the configuration as shown in Figure 2b.

Building A is located in the southmost portion of the site, is 32 storeys in height with a stepped 3- and 6 storey podium. The Main Residential Entrance to Building A is located along the northeast façade of the building, accessed via the private driveway. Building B is located centrally on the site, is 31 storeys in height with a 3- and 6 storey stepped podium fronting John Street. The Main Residential Entrance to Building B is located beneath the building along the northeast façade, accessed via the private driveway. Building C is located within the northmost portion of the site, is 24 storeys in height with a 3 storey step along the southeast and southwest façades and a 6 storey podium extending to the northeast of the building. The Main Residential Entrance to Building C is located along the southeast façade, fronting John Street.

Outdoor Amenity Spaces are proposed at-grade to the west of Building A, at-grade to the north of Building C, atop the parking garage at the 2nd level, at the 4th level atop Building B's podium fronting John Street, and atop the podium at the 9th level between Buildings A and B and between Buildings B and C. Park Land is proposed at-grade in the northeast-most extents of the space.

View of the 69 & 117 John Street Development site looking west from John Street (Google).

<u>Surrounding Area</u>

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

The Canadian Pacific Railway runs along the northwest property boundary with low-rise residential neighbourhoods beyond. Lands to the north through east are similarly occupied by low-rise residential neighbourhoods, Thornwood Public School, and dense mature vegetation associated with Richard Jones Park. Lands to the south of John Street are mainly occupied by low and mid-rise residential buildings and surface parking. Lands to the southwest of the site are occupied by low-rise commercial buildings and surface parking.

Figures 2a and 2b depict the site and its immediate context. The site model, shown in Figure 3, is built to a scale of 1:400. For all intents and purposes, suburban development comprised of low through mid-rise buildings and related open lands surround the site. The surrounding lands present a relatively coarse terrain that will moderate pedestrian level winds approaching the site, whereas more open lands allow winds the opportunity to accelerate as they approach.

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 Pearson International Airport was used in this analysis. For studies in the City of Mississauga, the data is presented for two seasons and the resulting wind roses are presented as mean velocity and percent frequency in Figure 5. The mean velocities presented in the wind roses are measured at an elevation of 10*m*. Thus, representative ground level velocities at a height of 2*m*, for an urban macroclimate, are 52% of the mean values indicated on the wind rose, (for suburban and rural macroclimates the values are 63% and 78% respectively).

Winter (November through April) has the highest mean velocities of the seasons with prevailing winds from the north through west to southwest, with additional significant components from the east as indicated in Figure 5a. Summer (May through October) has lower mean wind velocities with prevailing winds from the north through west to southwest and additional significant components from the southeast as indicated in Figure 5b.

5.2 Pedestrian Level Wind Velocity Study

On the site model, seventy (70) 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 buildings were removed, and the "existing" site model retested with the current site.

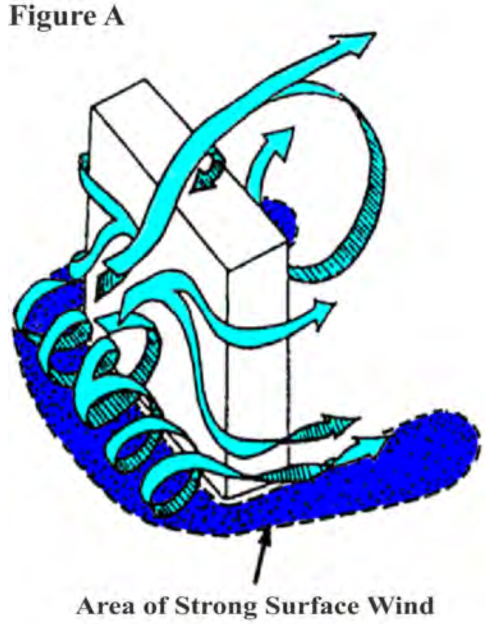
Measurements of pedestrian level mean and gust wind speeds at the various locations shown were taken over a period equivalent to one hour of measurements at full-scale. The mean ground level wind velocity measured is presented as a ratio of gradient wind speed, in the plots of Figure B in the Appendix, 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 Figure 5) was combined with pedestrian level mean and gust wind speeds measured at each point to provide predictions of the percentage of time a point will be comfortable for a given activity. These predictions of mean and maximum or "gust" wind speeds are provided for winter and summer in Figures 6a and 6b, respectively. A table comparing comfort and safety ratings for each probe is provided in Figure 10.

The ratings for a given location are conservative by design; when the existing surroundings and proposed buildings' fine massing details and actual landscaping are taken into consideration, the results tend toward a more comfortable site than quantitative testing alone would indicate.

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

Figure A



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.

5.3 Review of Probe Results

The probe results, as follows, were clustered into groups comprised of Public Street Conditions, Neighbouring Site Conditions, Interior Site Conditions, Pedestrian Entrance Conditions, and Outdoor Amenity Area Conditions. The measurement locations are depicted in Figure 4 and are listed in Figures 6a and 6b, for winter and summer and for the existing and proposed configurations. The results are also graphically depicted in Figures 7a – 7d, and compared in a table in Figure 10. The following discusses anticipated wind conditions and suitability for the points' intended use.

5.3.1 Public Street Conditions

John Street
Probes 1 through 26 were located along John Street within the zone of influence of the proposed Development site. In the existing setting, the probes indicate wind conditions that are suitable for standing throughout the year, with the exception of probes 11, 22, and 23 in the summer, which were rated appropriate for sitting. The conditions can be attributed to the relatively open surrounds to prevailing wind directions, as wind flows over the Canadian Pacific Railway and unoccupied site, affording wind the opportunity to accelerate upon approach.

With inclusion of the proposed Development, a realignment of winds was noted along John Street that caused a reduction in apparent wind effects at the pedestrian level for several wind directions, but an increase to winds for others, as indicated in the Appendices Figure B, Ground Level Wind Velocity Plots presented as a ratio of gradient wind velocity. Increased winds from specific directions are attributed to the proposed Development redirecting winds through downwash and other phenomena, to flow down and around the proposed buildings and along portions of John Street. Conversely, improvements in wind conditions can be attributed to the proposed Development effectively reducing the propensity for specific winds being deflected to flow along the street and over the areas, resulting in the observed leeward effect.

Introduction of the proposed buildings redirected winds that formerly flowed over the open site to flow down and around the buildings and along portions of John Street, resulting in localised windier conditions. The increases in winds were sufficient to change the winter standing ratings to walking at probes 2, 5, 7 – 11, 13, 14, 16, 18, 21 and 23. In the summer months, an increase in winds was sufficient to change the sitting rating to standing at probes 11 and 23 and from standing to walking at probes 5 and 14. Conversely, an improvement was noted at probe 26 that was sufficient to change the existing standing rating to sitting.

With inclusion of the proposed Development, John Street remains suitable for its intended use throughout the year. Consideration of fine design and landscape elements that were too fine to include in the massing model will result in more comfortable conditions than those reported.

John Street passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Voltarie Crescent
Probes 27 through 33 were located along Voltarie Crescent within the zone of influence of the proposed Development site. The probes situated along Voltarie Crescent indicate wind conditions in the existing setting that are suitable for sitting or standing in the winter. In the summer, Voltarie Crescent was rated appropriate for sitting. The fairly comfortable conditions can be attributed to the low-rise surroundings deflecting dominant winds to flow up and over the pedestrian level.

With inclusion of the proposed Development, very subtle changes in wind conditions were noted along Voltarie Crescent, which were insufficient to change the comfort categories in most cases. Probes 27 and 28 realised slight improvements which were sufficient to change the category from standing to sitting in the winter.

Voltarie Crescent remains comfortable and appropriate for its intended use throughout the year with inclusion of the proposed Development and passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Little John Lane
In addition to the probes situated at the intersection of John Street with Little John Lane and discussed above, probes 34 through 38 were located along Little John Lane. In the existing setting, Little John Lane was rated suitable for standing throughout the year, with the exception of probes 36 and 37 in the winter, which were rated appropriate for walking. With inclusion of the proposed Development, Little John Lane realised an improvement in pedestrian level wind conditions that was sufficient to change the winter walking ratings to standing and the standing ratings at probes 35 and 36 to sitting in the summer. The improvement can be attributed the proposed Development providing increased blockage relative to the existing setting to a significant percentage of the prevailing wind climate.

As a result, Little John Lane remains appropriate for its intended use with inclusion of the proposed Development and passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

5.3.2 Neighbouring Site Conditions

Probe 39 was located within the neighbouring 3180 Kirwin Avenue property to the south of John Street, as shown in Figure 4. In the existing setting, the area was rated appropriate for walking in the winter and standing in the summer. In the proposed setting, the area realised an improvement sufficient to change the winter walking rating to standing. The area passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

5.3.3 Interior Site Conditions

In addition to the probes located proximate to the Main Residential Entrances to the proposed Development and within Outdoor Amenity Spaces, which are discussed in the following sections, probes 42 – 45, 48 and 49 were situated throughout the site interior. Probes 42 – 44 were located along the southwest façade of Building A. The area is programmed for private patios. The area was rated suitable for walking throughout the year, with the exception of probe 43 in the summer, which was rated appropriate for standing. The area was tested with 1.5m high privacy screens around the perimeter of the patios, however the probes were positioned outside of the patios. Conditions within the patios will be more comfortable and are predicted appropriate for their intended use.

Probe 45 was located along the northeast façade of Building A, proximate to a building exit near the vehicle lay-by area. The area was rated suitable for standing throughout the year and is considered appropriate for its intended use. Probe 48 was located along a walkway accessing the Main Residential Entrance to Building B. The area is well protected from much of the prevailing wind climate by the surrounding buildings and was, as a result, rated suitable for sitting throughout the year. The walkway is therefore considered appropriate for its intended use. Probe 49 was located along the southwest façade of Building C. The area is programmed for private patios and was rated suitable for sitting in the summer and standing in the winter and is considered appropriate for its intended use.

The above-mentioned Interior Site Conditions pass the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

5.3.4 Pedestrian Entrance Conditions

Residential Entrances

Probe 46 was situated proximate to the Main Residential Entrance to Building A, along the northeast façade of the building and accessed via the private driveway connecting with John Street. The entrance is well protected by the surrounding buildings for much of the prevailing wind climate and was, as a result, rated suitable for sitting throughout the year. Wind conditions suitable for standing, or better, are preferred at entrances, while conditions appropriate for walking are suitable for their adjacent sidewalks. As a result, the Main Residential Entrance to Building A is considered comfortable and appropriate for its intended use throughout the year.

Probe 47 was located proximate to the Main Residential Entrance to Building B, located beneath the building and accessed via the private driveway. The Entrance is well protected by the building from much of the prevailing wind climate and was, as a result, rated suitable for sitting throughout the year and considered appropriate for its intended use.

Probe 17 was located proximate to the Main Residential Entrance to Building C, fronting John Street. The entrance is predominantly exposed to winds from the north through northeast and south through southwest flowing down and around the proposed Development along John

Street. The Entrance was rated suitable for standing throughout the year and is therefore considered comfortable and appropriate for its intended use.

The above-mentioned Residential Entrances to the proposed Development pass the pedestrian level wind velocity safety criteria, as described above in Section 4.7 and depicted in Figure 9.

5.3.5 Outdoor Amenity Area Conditions

Probes 40 and 41 were situated within the Outdoor Amenity Space at-grade to the west of Building A. Probe 40 was rated suitable for walking throughout the year and probe 41 was rated suitable for standing throughout the year. The area is exposed to prevailing winds, which are unmitigated upon approach from over the low-rise surrounds, being redirected by the proposed buildings to flow down and around the development and over the space. Generally, sitting conditions are required within Outdoor Amenity Spaces in the summer. As such, mitigation will be required in order to achieve more appropriate conditions for the areas' intended use. This can include porous fencing, dense coniferous vegetation, raised planter beds populated with coarse plantings, wind screens, trellises, and / or others.

Probes 50 – 53 were located within the Park Land proposed at-grade within the northmost extents of the site. Probe 50 was rated suitable for walking throughout the year, probe 51 was rated as suitable for walking in the winter and standing in the summer, probe 52 was rated suitable for sitting throughout the year, and probe 53 was rated as appropriate for standing throughout the year. The Park Land is primarily exposed to winds from the north through west being redirected by the towers and podium to flow down and around the buildings and over the area. Mitigation, as described above, will be required in order to achieve sitting conditions in the summer.

Probes 54 – 57 were situated within the Outdoor Amenity Space located at-grade to the north of Building C. Probe 56 was located in the southmost portion of the space, is fairly well protected by the building and was, as a result, rated as suitable for sitting throughout the year. The remainder of the space is slightly more exposed to winds flowing down and around the building and was rated appropriate for standing throughout the year. Mitigation, as described above, will be required in order to achieve sitting conditions in the summer.

Probes 58 – 62 were located within the 2nd level Outdoor Amenity Space on the Parking Rooftop. The area was tested with 2.4 m high wind screens around the perimeter of the space and 1.5m high wind screens around the private patios along the podium. The area is predominantly exposed to northeasterly and southwesterly winds flowing along the podium, resulting in wind conditions rated as appropriate for standing in the summer and walking in the winter. As such, mitigation will be required in order to achieve sitting conditions in the summer.

Probes 63 and 64 were located within the Outdoor Amenity Space at the 4th level of Building B, fronting John Street. The Amenity Space was tested with 1.8m high wind screens around the perimeter of the space. The resulting wind conditions were rated as suitable for sitting throughout the year and the Space is therefore considered comfortable and appropriate for its intended use.

Probes 65 – 67 were located within the Outdoor Amenity Space atop the podium at the 9th level, between Buildings A and B. The area will benefit from wind protection from the adjacent towers for certain wind directions, however, it remains exposed to winds that are redirected by the towers to flow down the façades and through the gap between. The area was tested with 1.8m high wind screens around the perimeter of the space. The area was rated appropriate for standing in the summer. In the winter, probes 65 and 66 were rated appropriate for walking and probe 67 was rated appropriate for standing. The Amenity Space will therefore require mitigation in order to achieve more appropriate conditions for its intended use, which can include raising the perimeter screen walls, coniferous plantings, raised planter beds populated with coarse plantings, wind screens, trellises, and/or others.

Probes 68 – 70 were located within the Outdoor Amenity Space atop the podium at the 9th level, between Buildings B and C. The area was tested with 1.8m high wind screens around the perimeter of the space. The area was rated appropriate for standing in the summer. In the winter, probes 68 and 69 were rated appropriate for walking and probe 70 was rated appropriate for standing. The conditions can similarly be attributed to the proposed towers redirecting winds to flow down and around the façades and through the gap between. Mitigation, as described above, will be required in order to achieve sitting conditions in the summer.

Consideration of fine design and landscape features will result in more comfortable conditions than those reported within. The above-mentioned Outdoor Amenity Spaces pass the pedestrian level wind velocity safety criteria.

6. FIGURES:

Figure 1: Laboratory Testing Facility

Figure 2a: Site Aerial Photo

Figure 2b: Site Plan

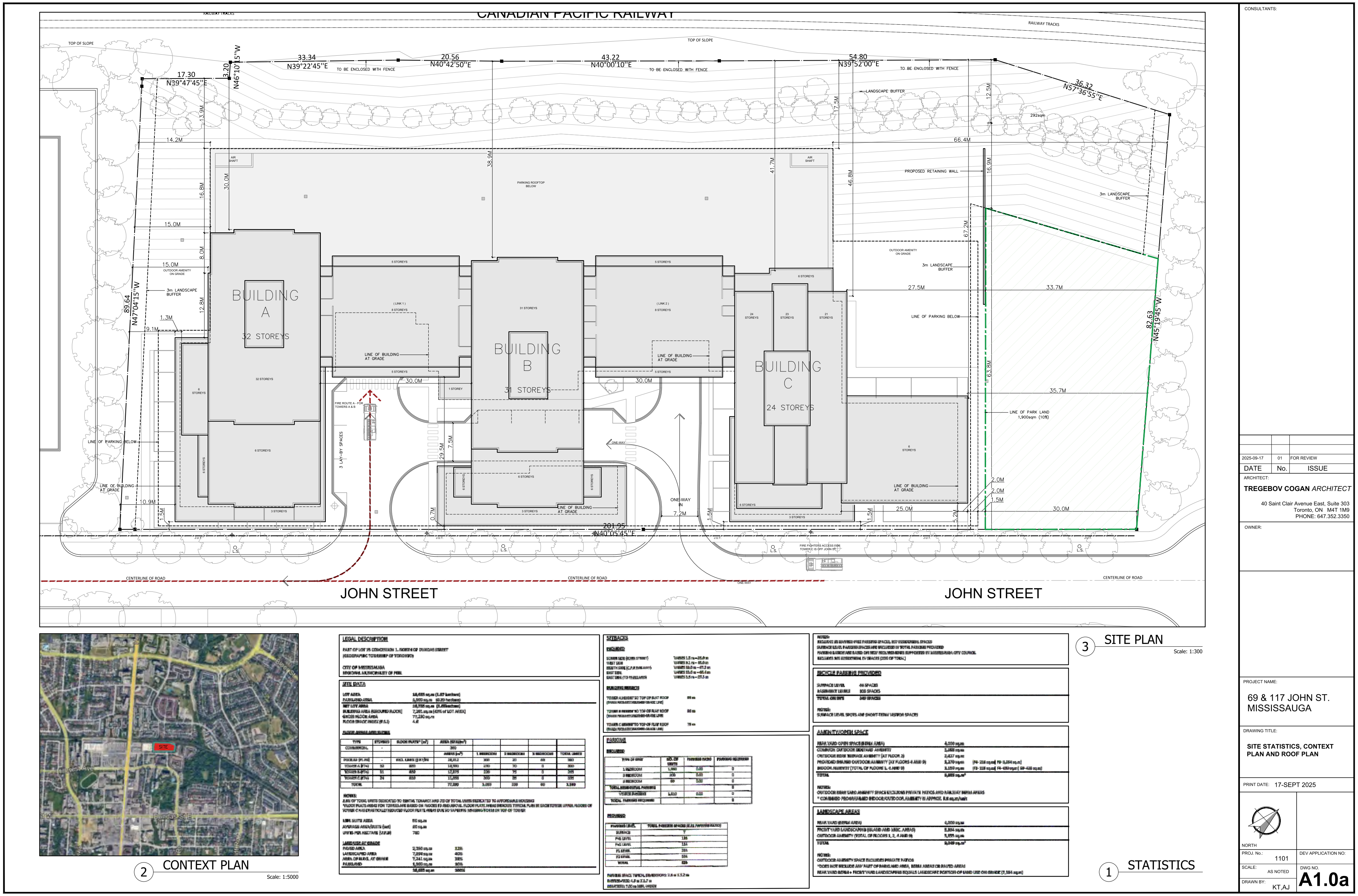
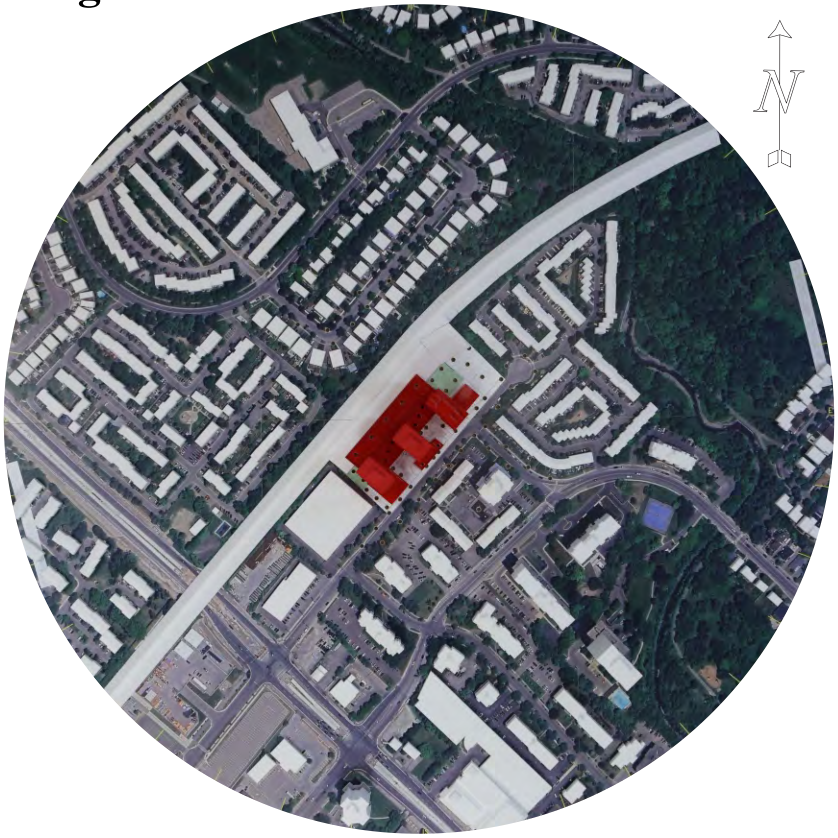
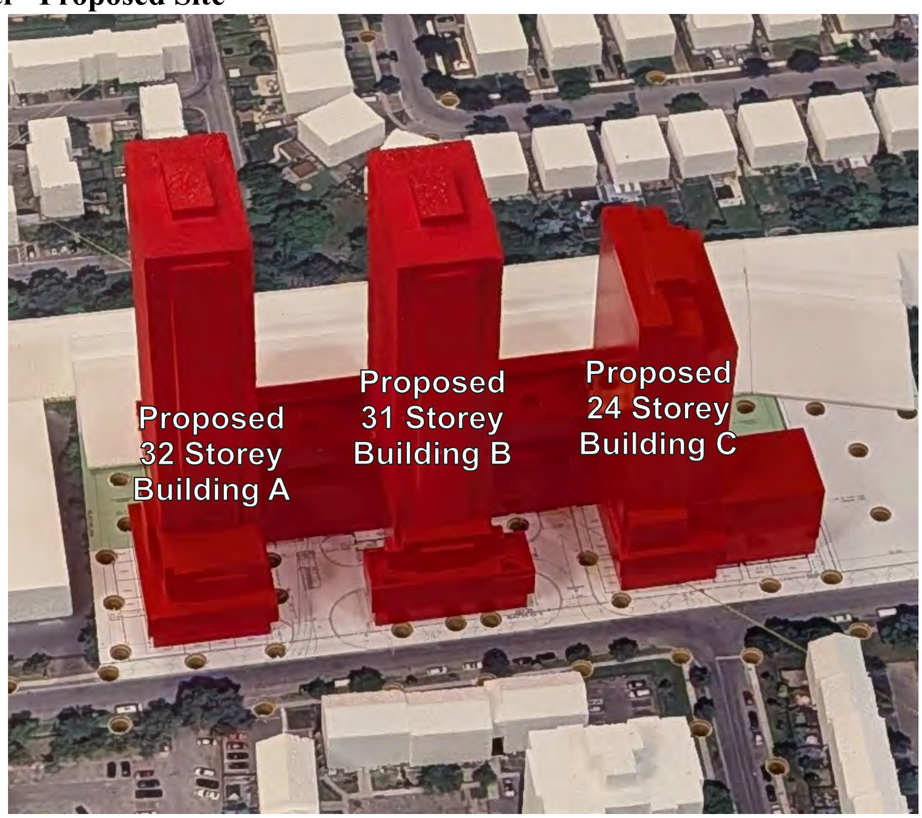


Figure 3: 1:400 Scale Model of Test Site



a) Overall View of Model - Proposed Site

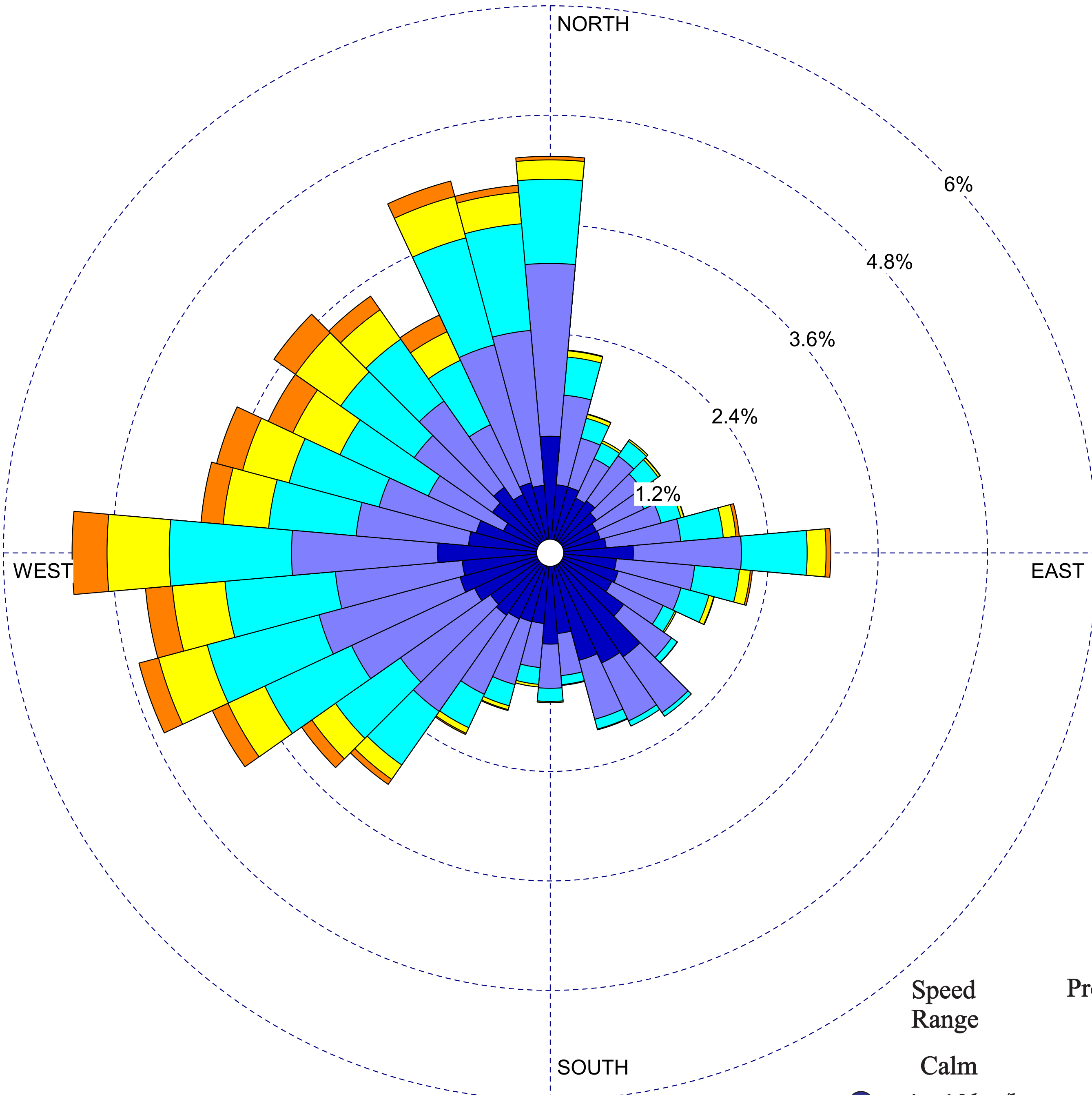


b) Close-Up View of Model - Proposed Site

Figure 4: Location Plan for Pedestrian Level Wind Velocity Measurements

Figure 5a: Winter Wind Rose - Pearson International Airport

Historical Directional Distribution of Winds (@ 10*m* height)
November through April (1993 - 2023)



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

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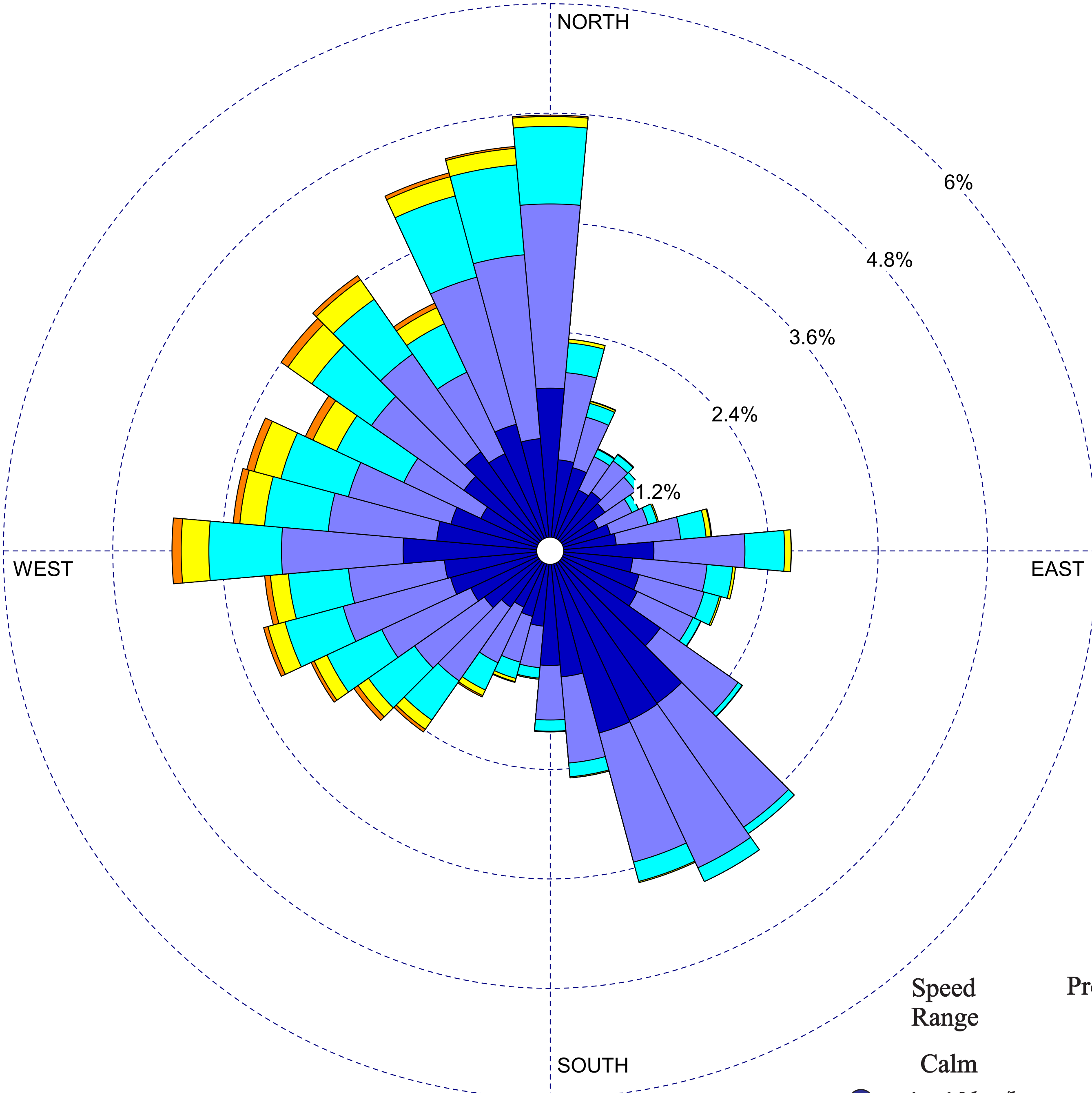
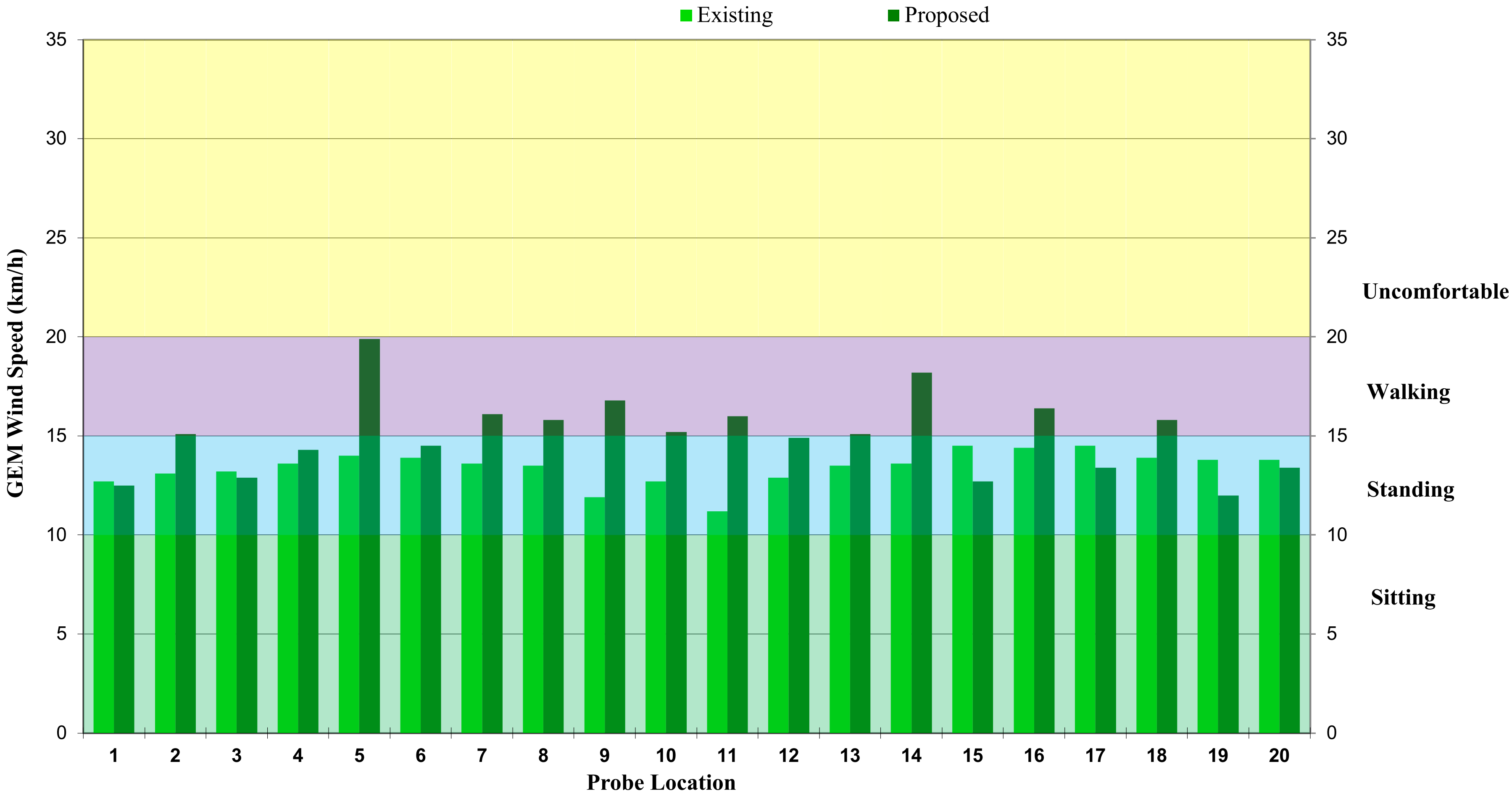
Figure 5b: Summer Wind Rose - Pearson International Airport

Historical Directional Distribution of Winds (@ 10*m* height)
May through October (1993 - 2023)



Speed Range	Probability (%)
Calm	4 %
1 - 10*km/h*	41 %
11 - 20*km/h*	36 %
21 - 30*km/h*	15 %
31 - 40*km/h*	4 %
> 40*km/h*	<1 %

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



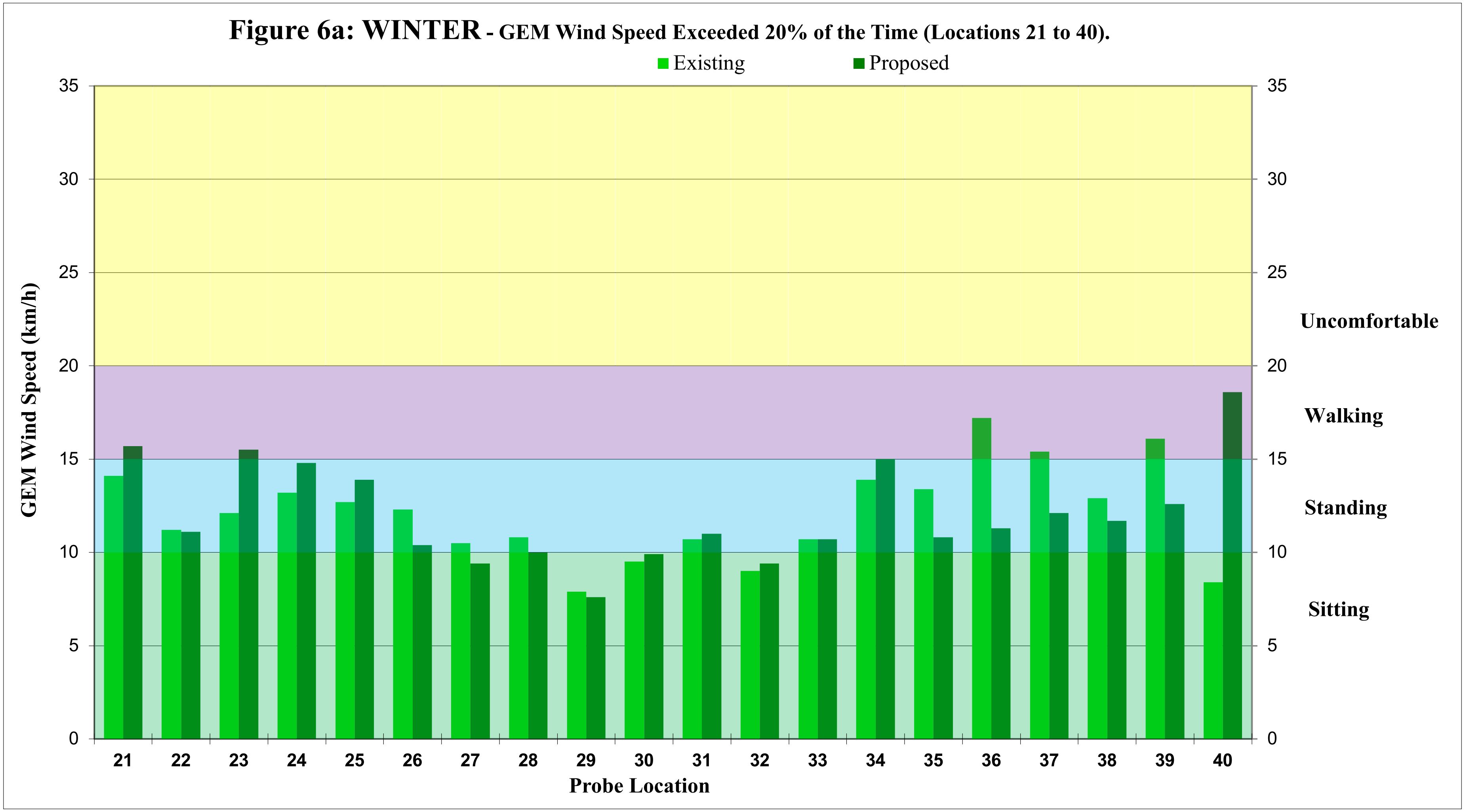


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
GEM Wind Speed (km/h)
0
5
10
15
20
25
30
35
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location
Uncomfortable
Walking
Standing
Sitting

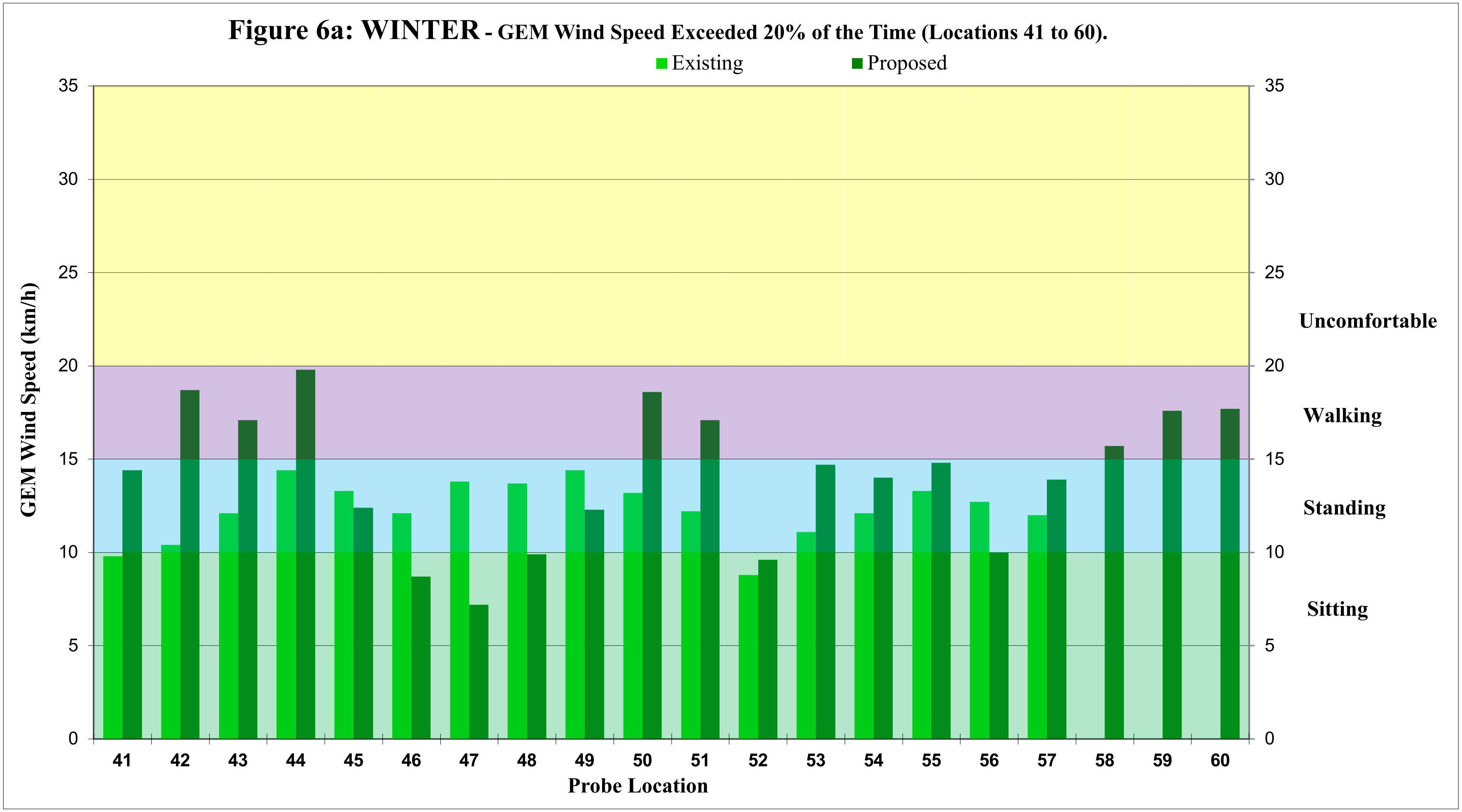


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 41 to 60).
Existing
Proposed
GEM Wind Speed (km/h)
0
5
10
15
20
25
30
35
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Probe Location
Uncomfortable
Walking
Standing
Sitting

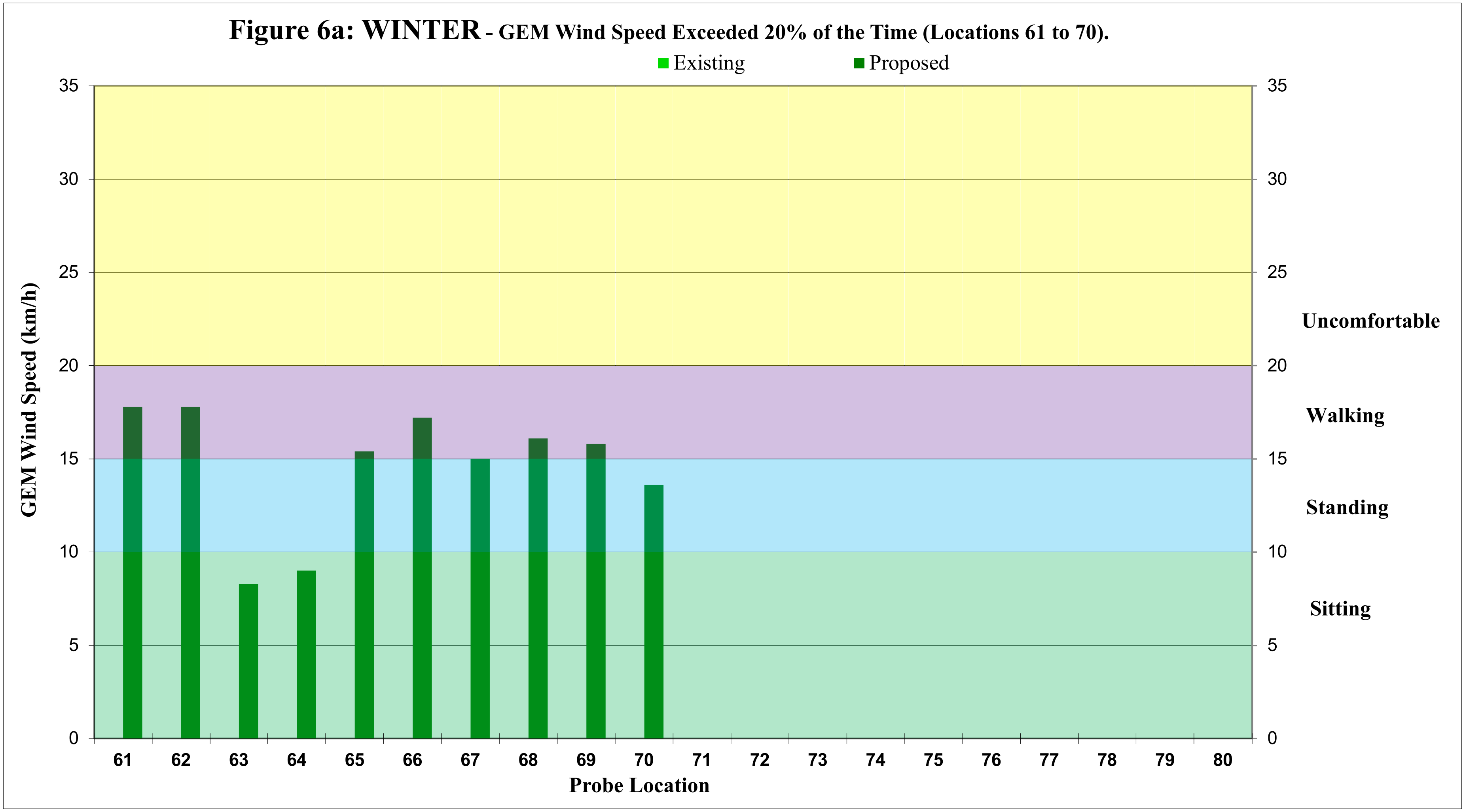


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 61 to 70).
Existing
Proposed
GEM Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80

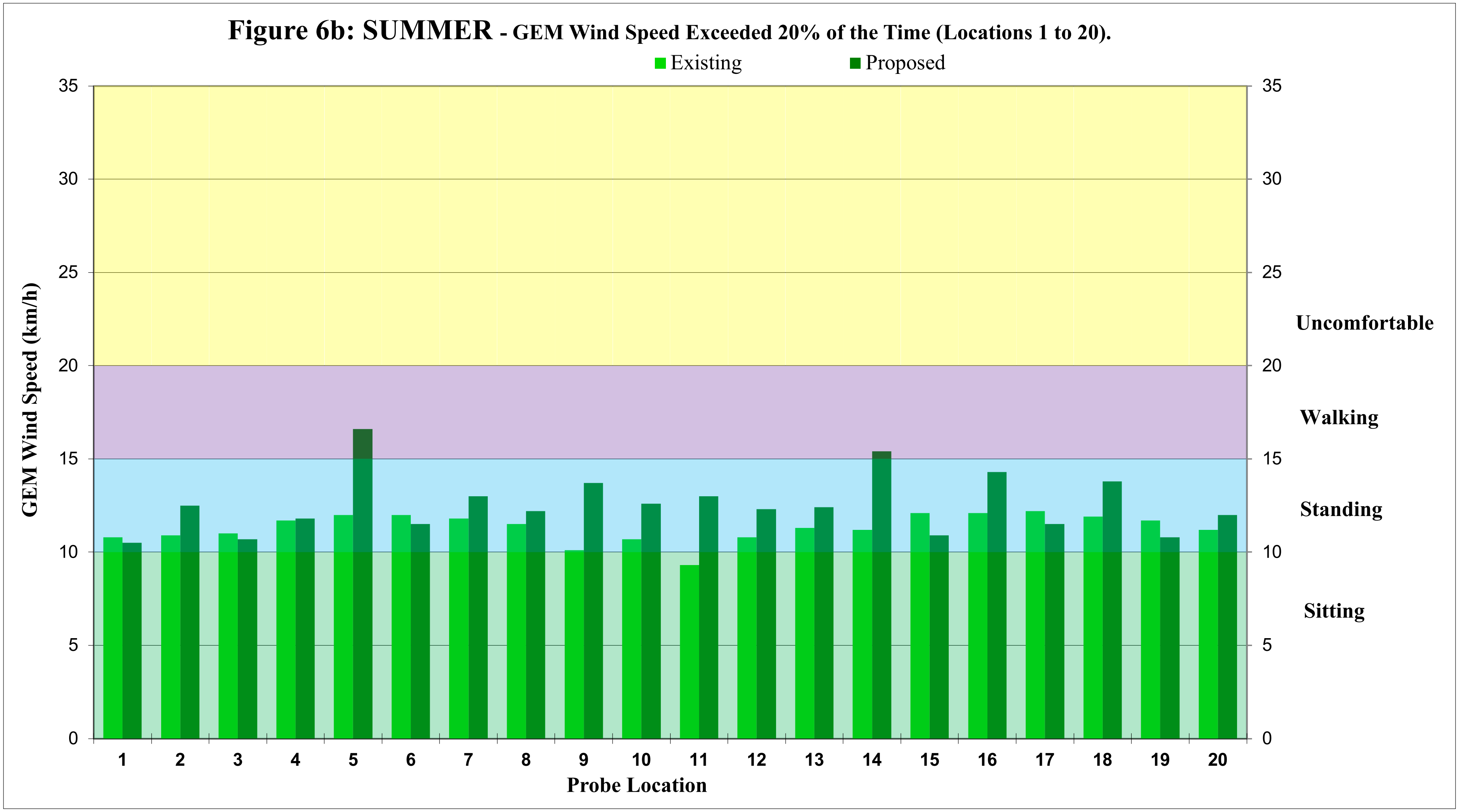
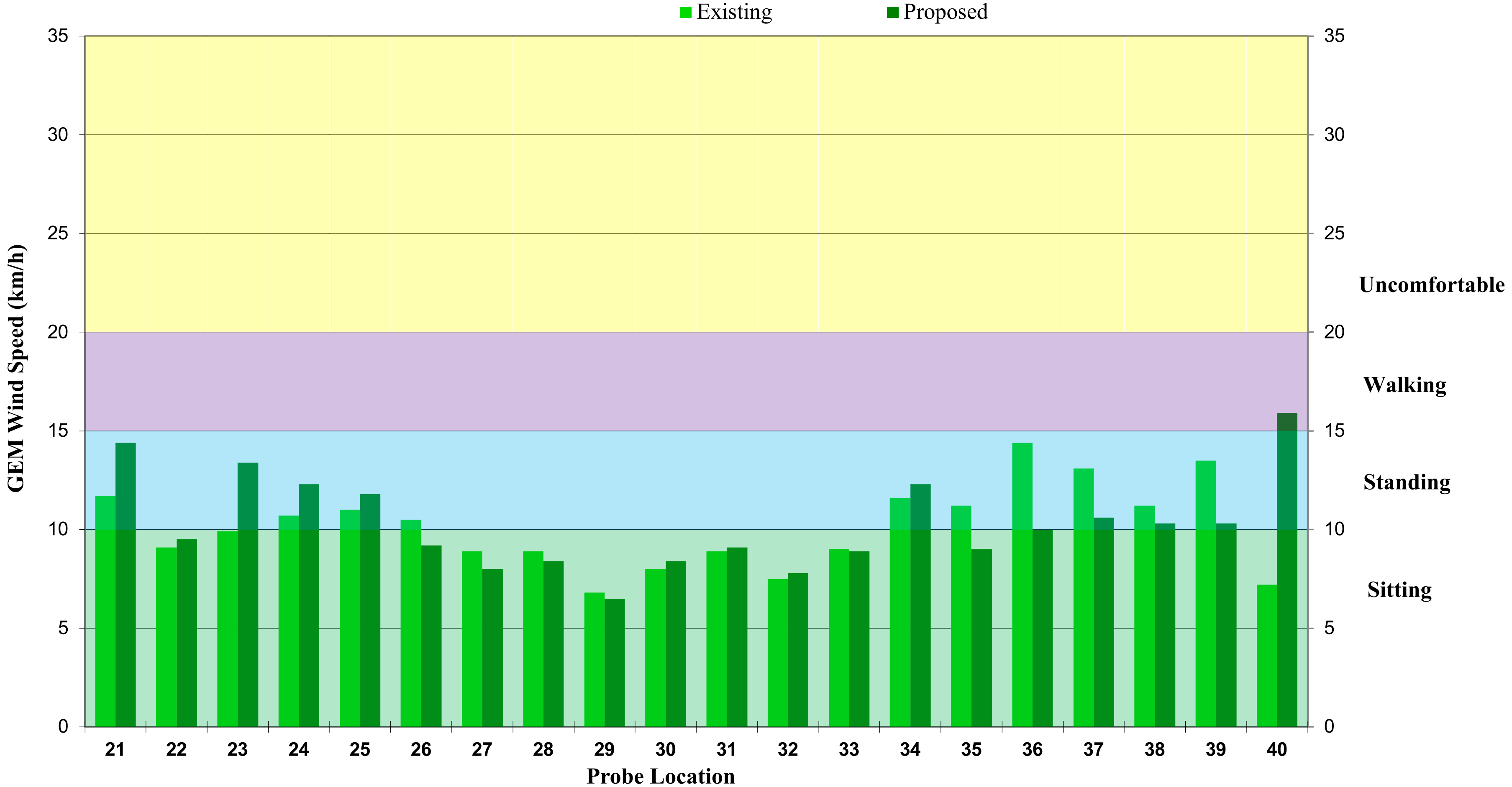


Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
GEM Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 21 to 40).



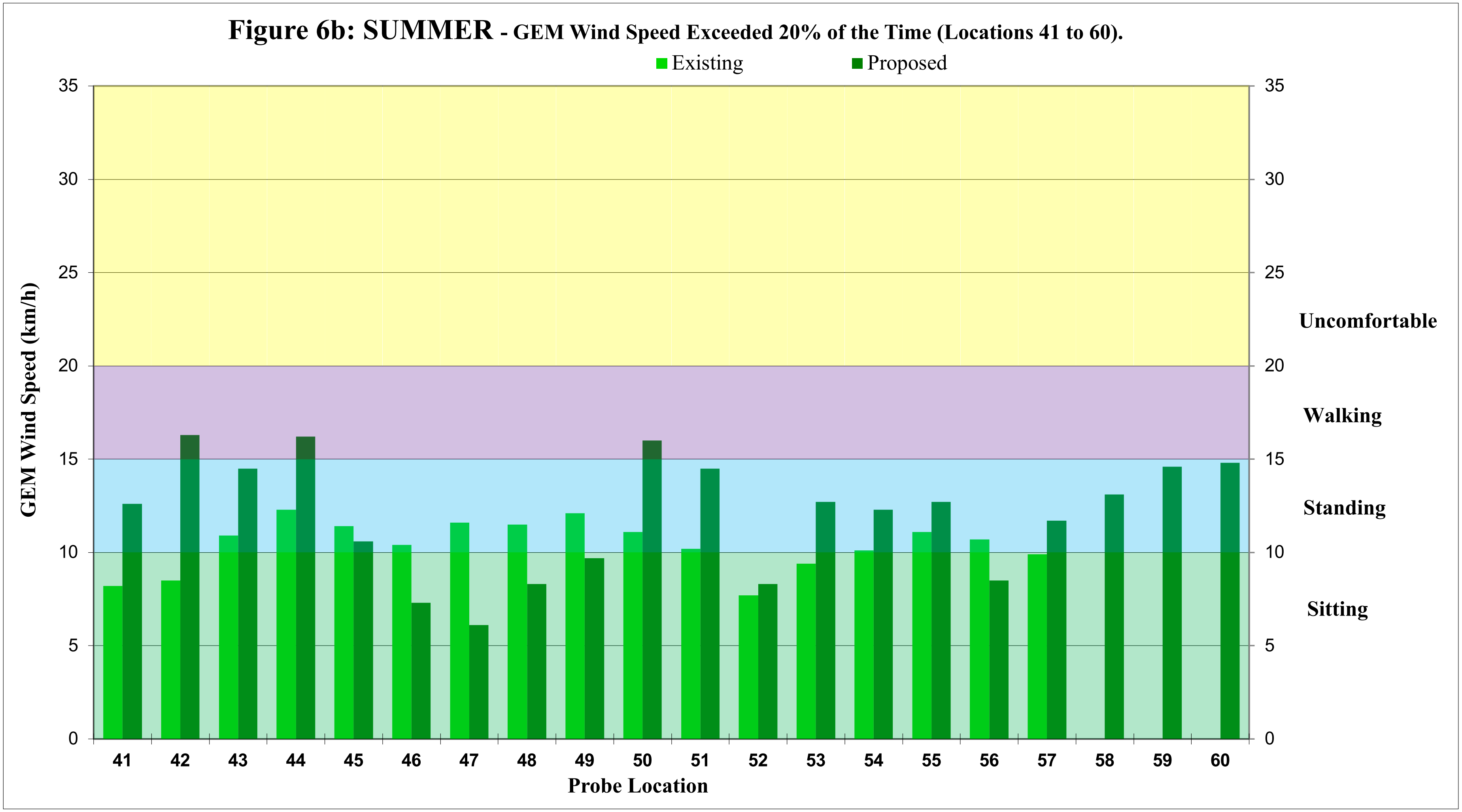


Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 41 to 60).
Existing
Proposed
GEM Wind Speed (km/h)
35
30
25
20
15
10
5
0
Uncomfortable
Walking
Standing
Sitting
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Probe Location

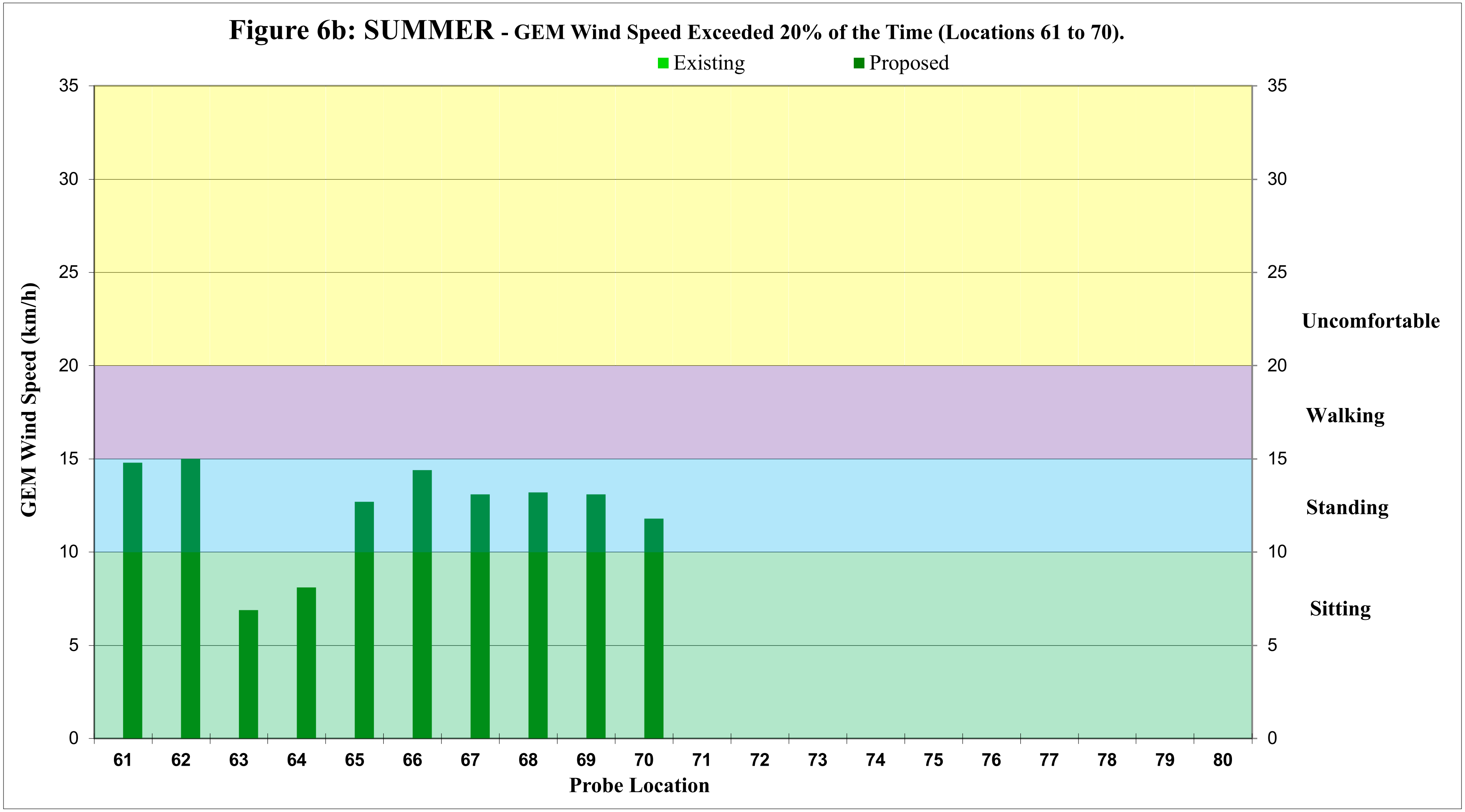
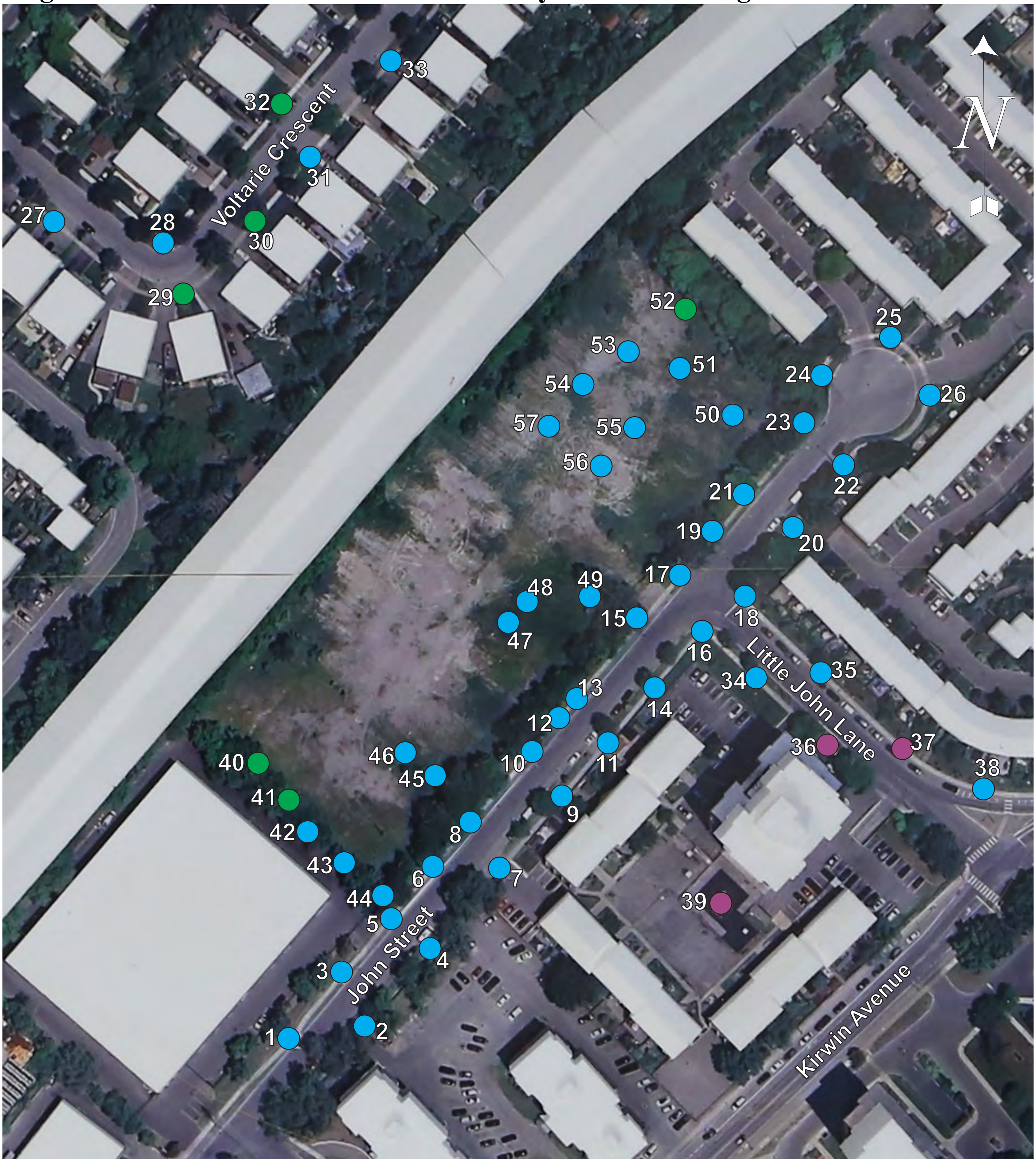


Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 61 to 70).
Existing
Proposed
GEM Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80

Figure 7a: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Winter - Existing

Sitting · Standing · Walking · Uncomfortable

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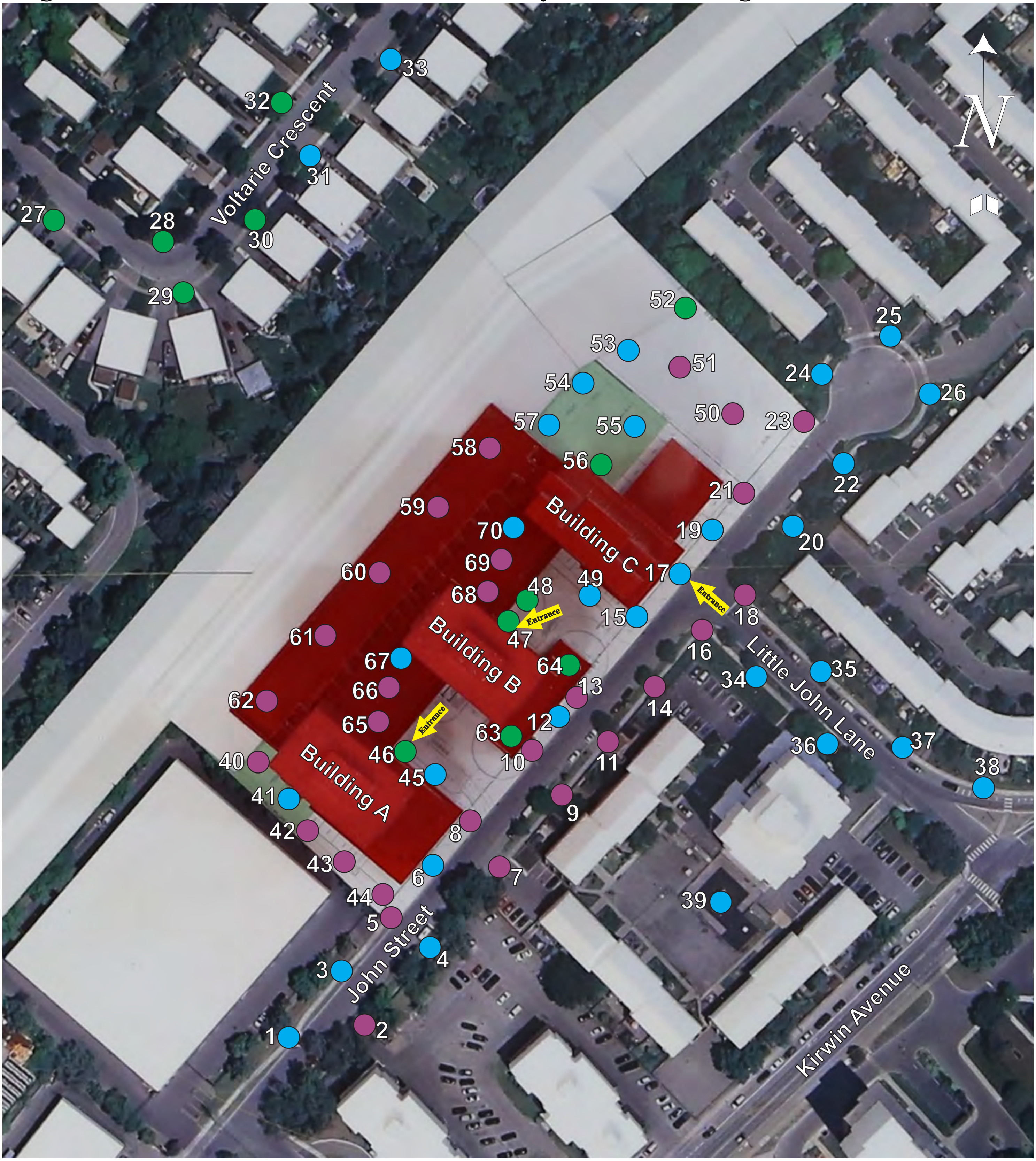
Figure 7b: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Winter - Proposed

Sitting Standing Walking Uncomfortable

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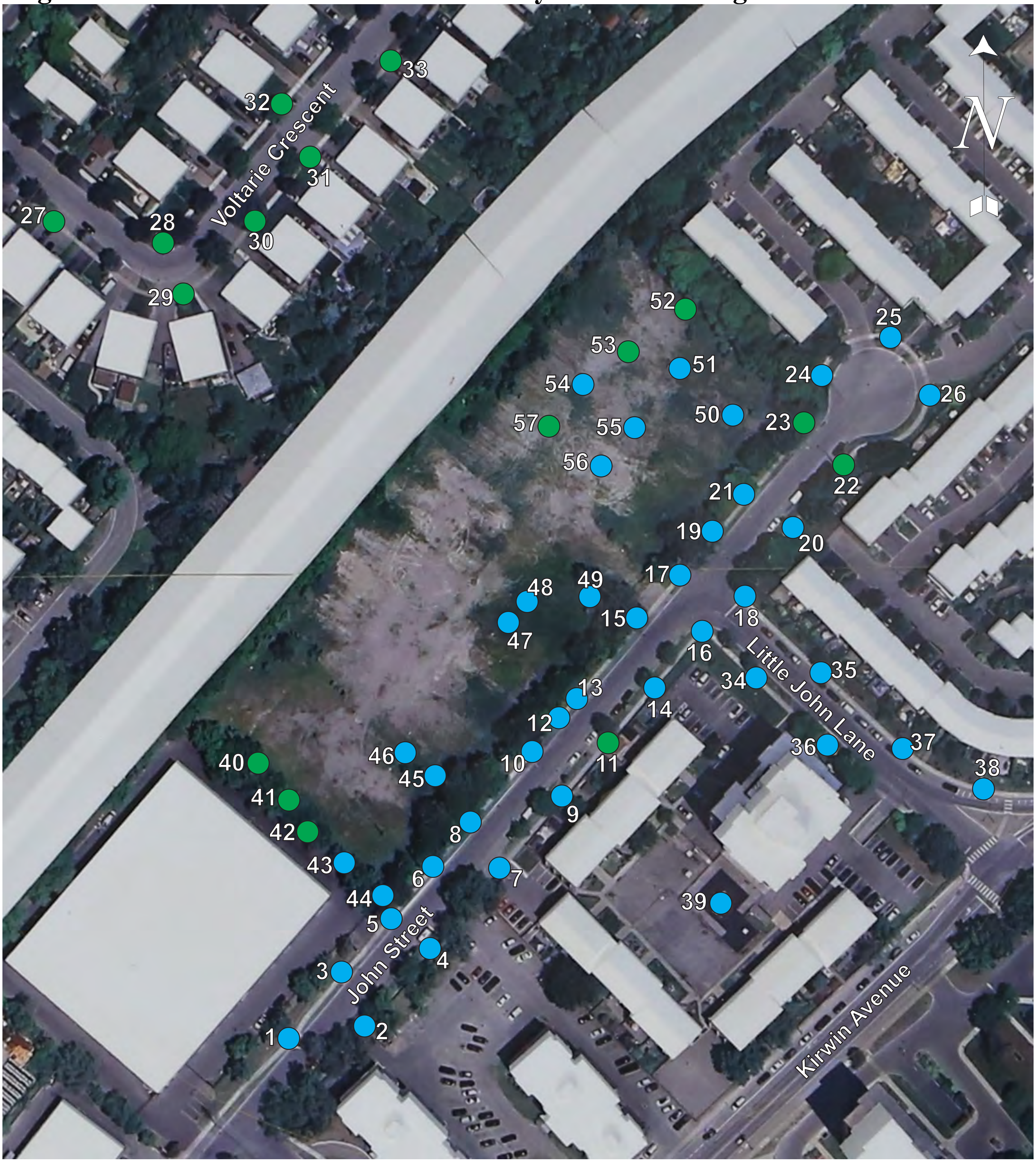
Figure 7c: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Summer - Existing

Sitting Standing Walking Uncomfortable

Figure 7d: Pedestrian Level Wind Velocity Comfort Categories

Comfort Categories - Summer - Proposed

Sitting · Standing · Walking · Uncomfortable

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

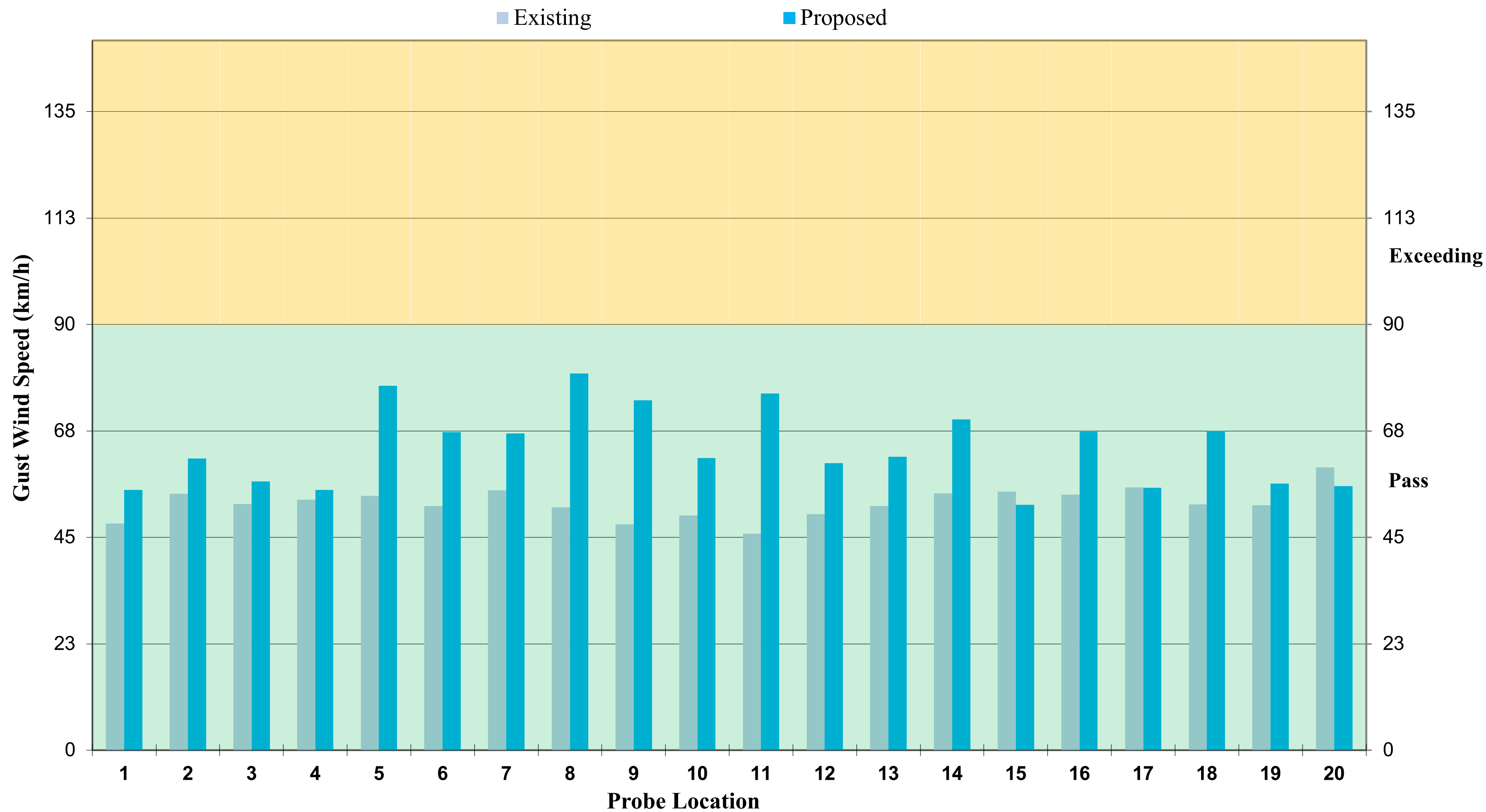


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 21 to 40).

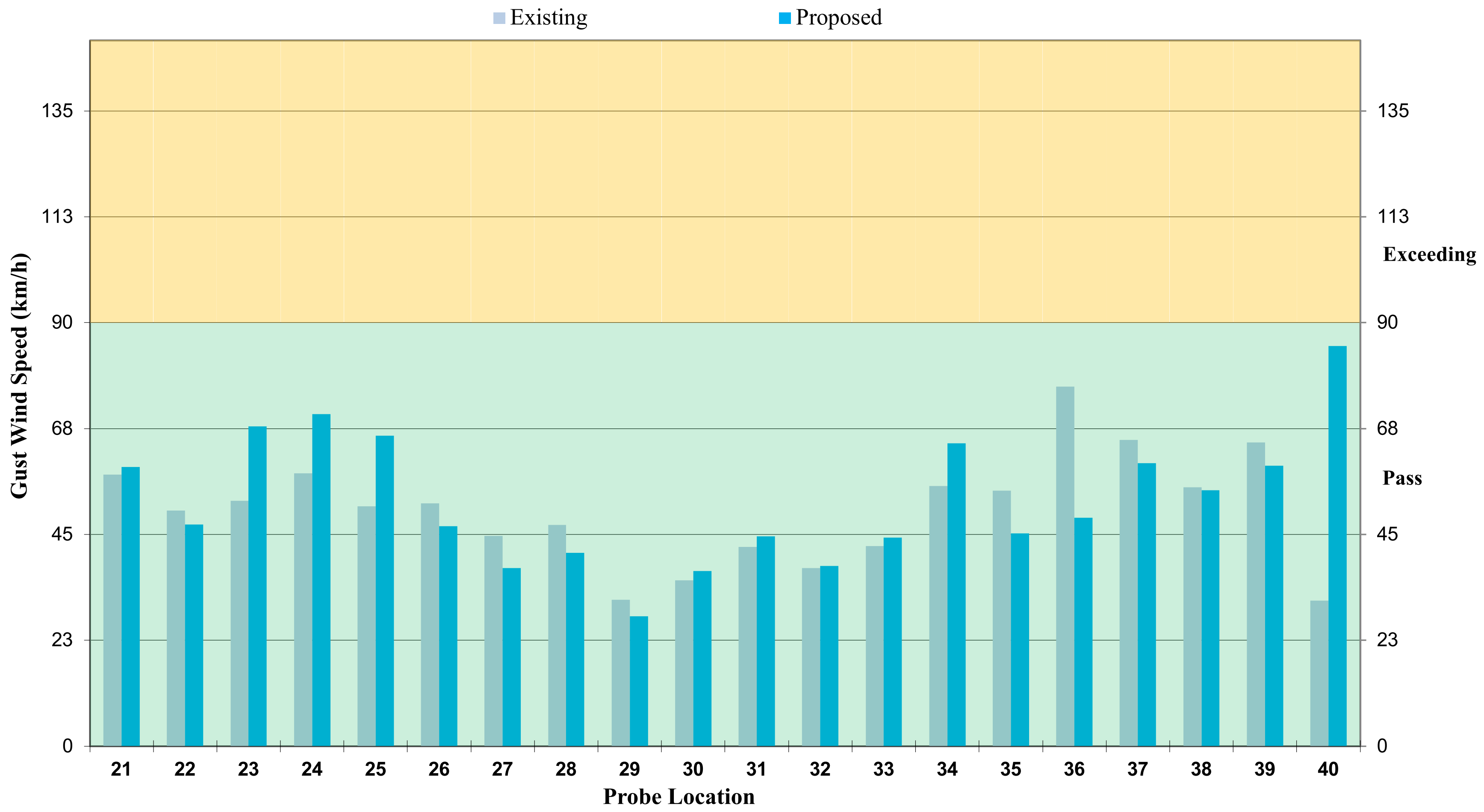


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 41 to 60).

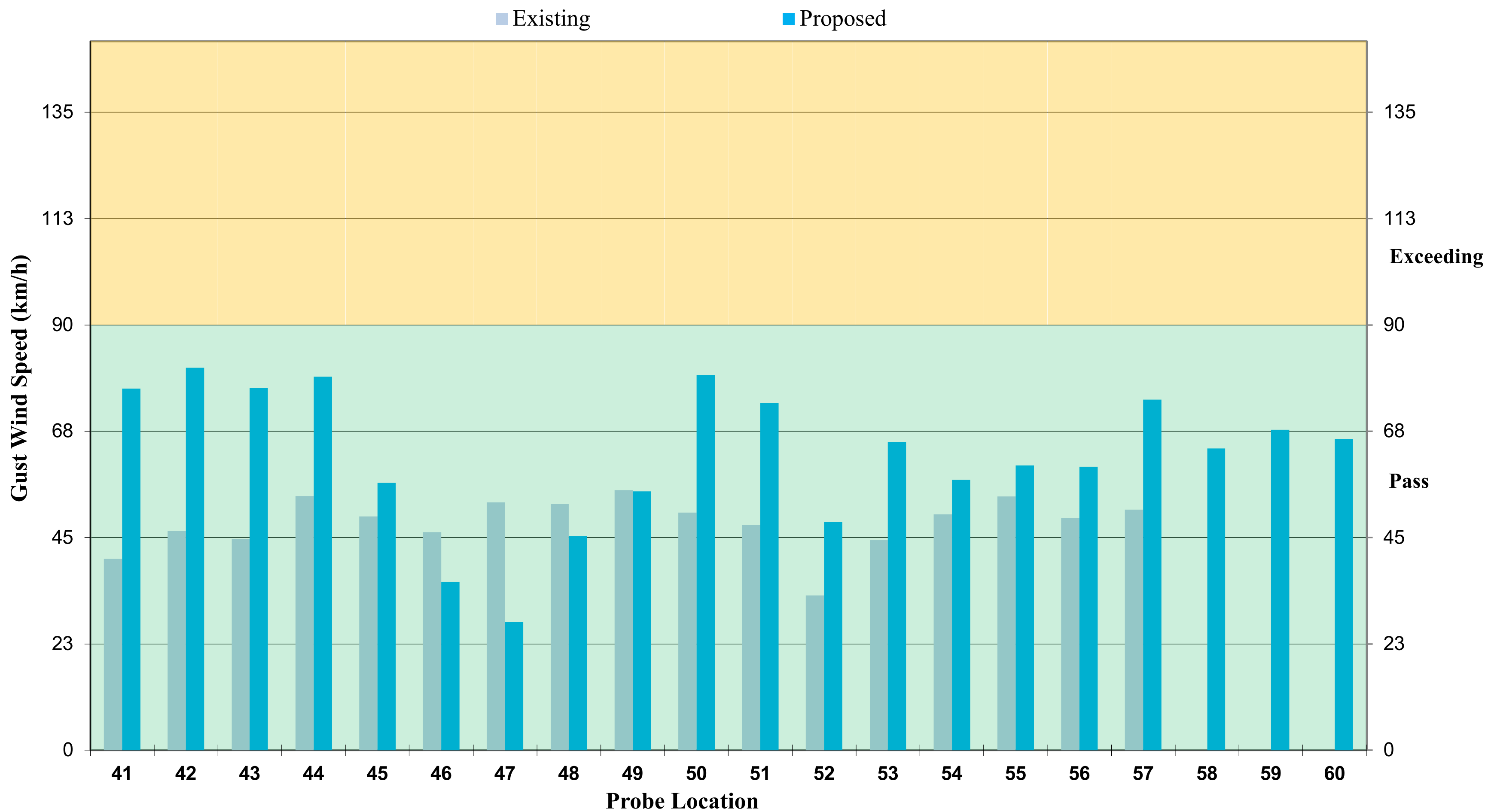


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 61 to 70).

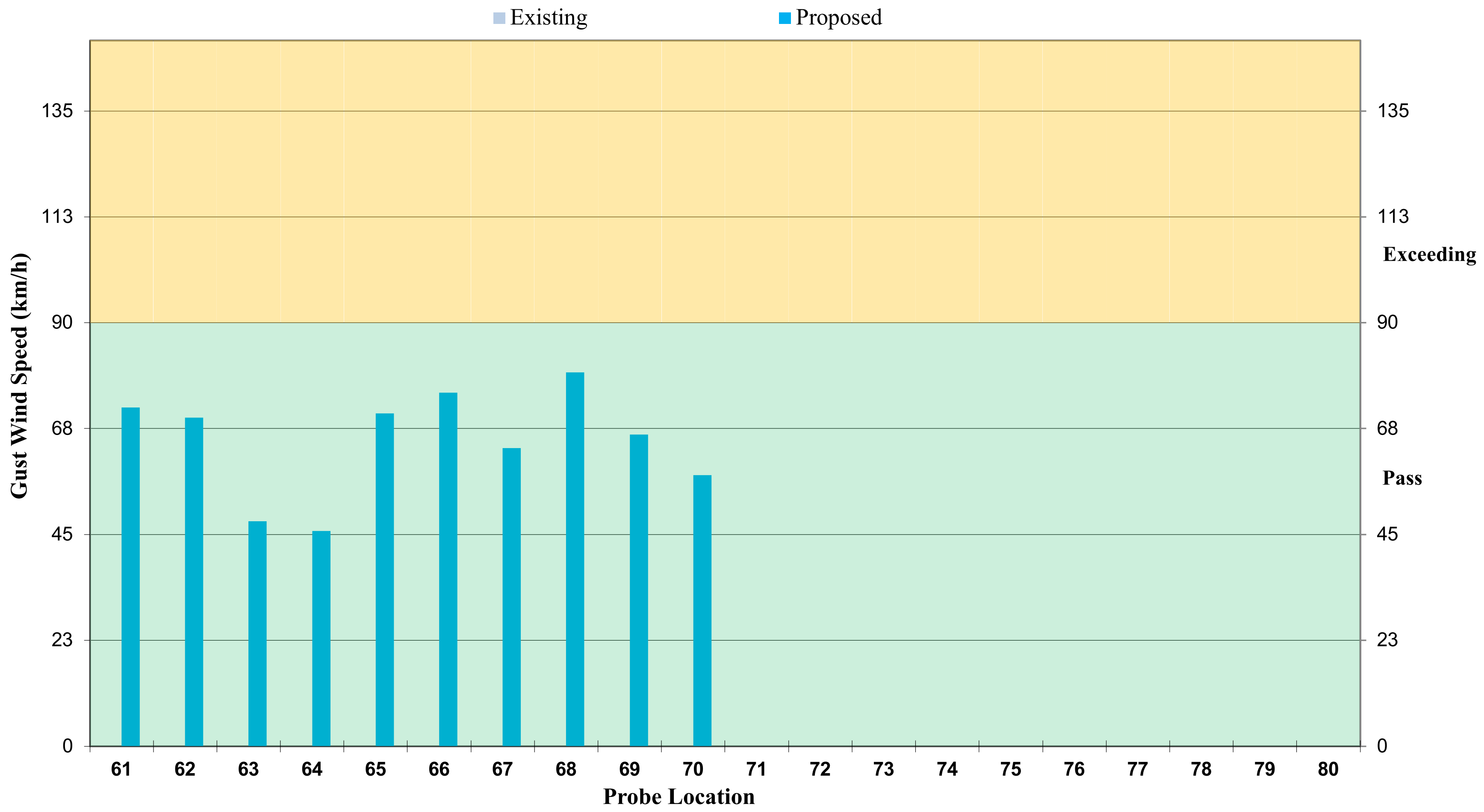


Figure 9a: Pedestrian Level Wind Velocity Safety Criteria

Safety Criteria - Existing

Pass Exceeding

Figure 9b: Pedestrian Level Wind Velocity Safety Criteria

Safety Criteria - Proposed

Pass Exceeding

Figure 10: Pedestrian Level Wind Comfort and Safety Comparison Table

	GEM Speed (km/h)				Gust Speed (km/h)	
	Winter		Summer		Safety	
Probe	Existing	Proposed	Existing	Proposed	Existing	Proposed
1	12.7	12.5	10.8	10.5	48.0	55.0
2	13.1	15.1	10.9	12.5	54.3	61.7
3	13.2	12.9	11.0	10.7	52.1	56.8
4	13.6	14.3	11.7	11.8	53.0	55.0
5	14.0	19.9	12.0	16.6	53.8	77.0
6	13.9	14.5	12.0	11.5	51.6	67.2
7	13.6	16.1	11.8	13.0	54.9	67.0
8	13.5	15.8	11.5	12.2	51.4	79.6
9	11.9	16.8	10.1	13.7	47.8	74.0
10	12.7	15.2	10.7	12.6	49.7	61.8
11	11.2	16.0	9.3	13.0	45.8	75.5
12	12.9	14.9	10.8	12.3	49.9	60.7
13	13.5	15.1	11.3	12.4	51.6	62.1
14	13.6	18.2	11.2	15.4	54.3	69.9
15	14.5	12.7	12.1	10.9	54.7	51.9
16	14.4	16.4	12.1	14.3	54.1	67.3
17	14.5	13.4	12.2	11.5	55.6	55.4
18	13.9	15.8	11.9	13.8	51.9	67.5
19	13.8	12.0	11.7	10.8	51.8	56.3
20	13.8	13.4	11.2	12.0	59.8	55.9
21	14.1	15.7	11.7	14.4	57.7	59.4
22	11.2	11.1	9.1	9.5	50.1	47.1
23	12.1	15.5	9.9	13.4	52.2	67.9
24	13.2	14.8	10.7	12.3	58.0	70.6
25	12.7	13.9	11.0	11.8	51.0	66.0
26	12.3	10.4	10.5	9.2	51.6	46.8
27	10.5	9.4	8.9	8.0	44.7	37.9
28	10.8	10.0	8.9	8.4	47.0	41.1
29	7.9	7.6	6.8	6.5	31.1	27.6
30	9.5	9.9	8.0	8.4	35.2	37.2
31	10.7	11.0	8.9	9.1	42.3	44.6
32	9.0	9.4	7.5	7.8	37.8	38.3
33	10.7	10.7	9.0	8.9	42.5	44.3
34	13.9	15.0	11.6	12.3	55.3	64.4
35	13.4	10.8	11.2	9.0	54.3	45.2
36	17.2	11.3	14.4	10.0	76.4	48.5
37	15.4	12.1	13.1	10.6	65.1	60.1
38	12.9	11.7	11.2	10.3	55.0	54.4
39	16.1	12.6	13.5	10.3	64.6	59.7
40	8.4	18.6	7.2	15.9	30.9	85.0
41	9.8	14.4	8.2	12.6	40.5	76.6
42	10.4	18.7	8.5	16.3	46.4	81.0
43	12.1	17.1	10.9	14.5	44.7	76.6
44	14.4	19.8	12.3	16.2	53.8	79.1
45	13.3	12.4	11.4	10.6	49.5	56.6
46	12.1	8.7	10.4	7.3	46.2	35.6
47	13.8	7.2	11.6	6.1	52.4	27.1
48	13.7	9.9	11.5	8.3	52.1	45.3
49	14.4	12.3	12.1	9.7	55.0	54.8
50	13.2	18.6	11.1	16.0	50.3	79.5
51	12.2	17.1	10.2	14.5	47.7	73.5
52	8.8	9.6	7.7	8.3	32.8	48.3
53	11.1	14.7	9.4	12.7	44.5	65.2
54	12.1	14.0	10.1	12.3	49.9	57.2
55	13.3	14.8	11.1	12.7	53.7	60.3
56	12.7	10.0	10.7	8.5	49.1	60.0
57	12.0	13.9	9.9	11.7	50.9	74.2
58	0.0	15.7	0.0	13.1	0.0	63.9
59	0.0	17.6	0.0	14.6	0.0	67.8
60	0.0	17.7	0.0	14.8	0.0	65.8
61	0.0	17.8	0.0	14.8	0.0	72.0
62	0.0	17.8	0.0	15.0	0.0	69.8
63	0.0	8.3	0.0	6.9	0.0	47.8
64	0.0	9.0	0.0	8.1	0.0	45.8
65	0.0	15.4	0.0	12.7	0.0	70.8
66	0.0	17.2	0.0	14.4	0.0	75.1
67	0.0	15.0	0.0	13.1	0.0	63.4
68	0.0	16.1	0.0	13.2	0.0	79.5
69	0.0	15.8	0.0	13.1	0.0	66.2
70	0.0	13.6	0.0	11.8	0.0	57.6
71	0.0	0.0	0.0	0.0	0.0	0.0
72	0.0	0.0	0.0	0.0	0.0	0.0
73	0.0	0.0	0.0	0.0	0.0	0.0
74	0.0	0.0	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0	0.0	0.0
76	0.0	0.0	0.0	0.0	0.0	0.0
77	0.0	0.0	0.0	0.0	0.0	0.0
78	0.0	0.0	0.0	0.0	0.0	0.0
79	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0

Comfort (km/h)				Safety (km/h)	
0 - 10	Sitting	15 - 20	Walking	0 - 90	Pass
10 - 15	Standing	20 +	Uncomf	90 +	Exceed

7. APPENDIX

BACKGROUND AND THEORY OF WIND MOVEMENT

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

Macroclimate

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

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

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

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

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

Typical values for a and z_F are summarized below:

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

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

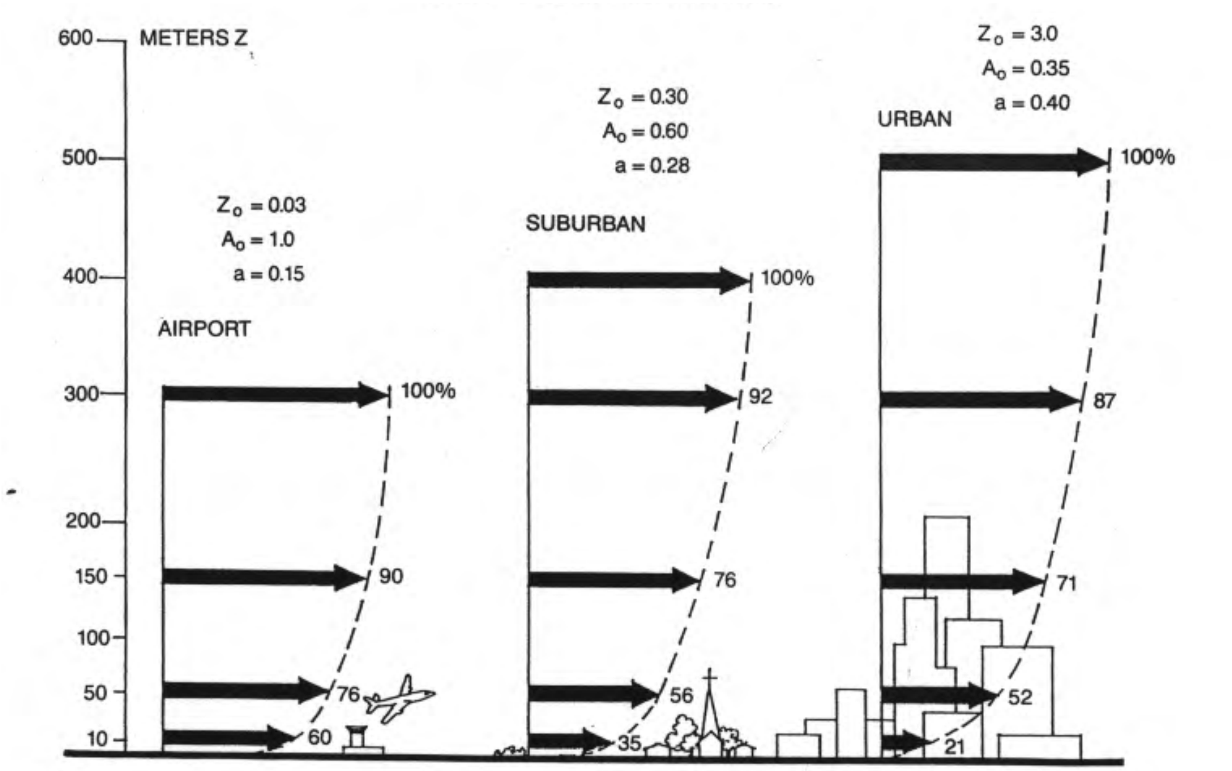


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

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

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

Microclimate

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

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

The microclimate establishes the effect that surrounding buildings or landscape features have on the subject building and the effect the subject building has on the surrounds. For the majority of urban test sites the proper microclimate can be established by modelling an area of 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.

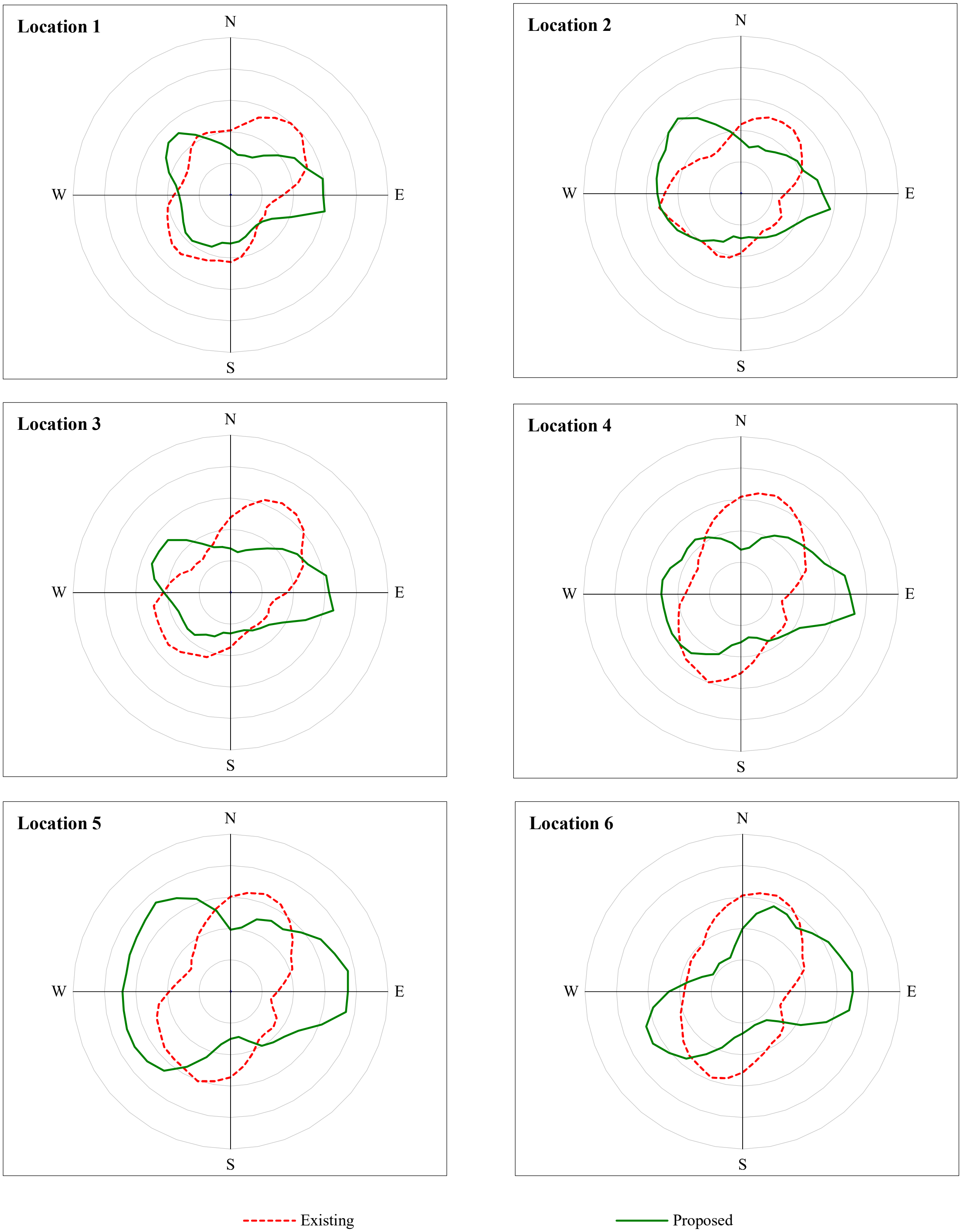


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

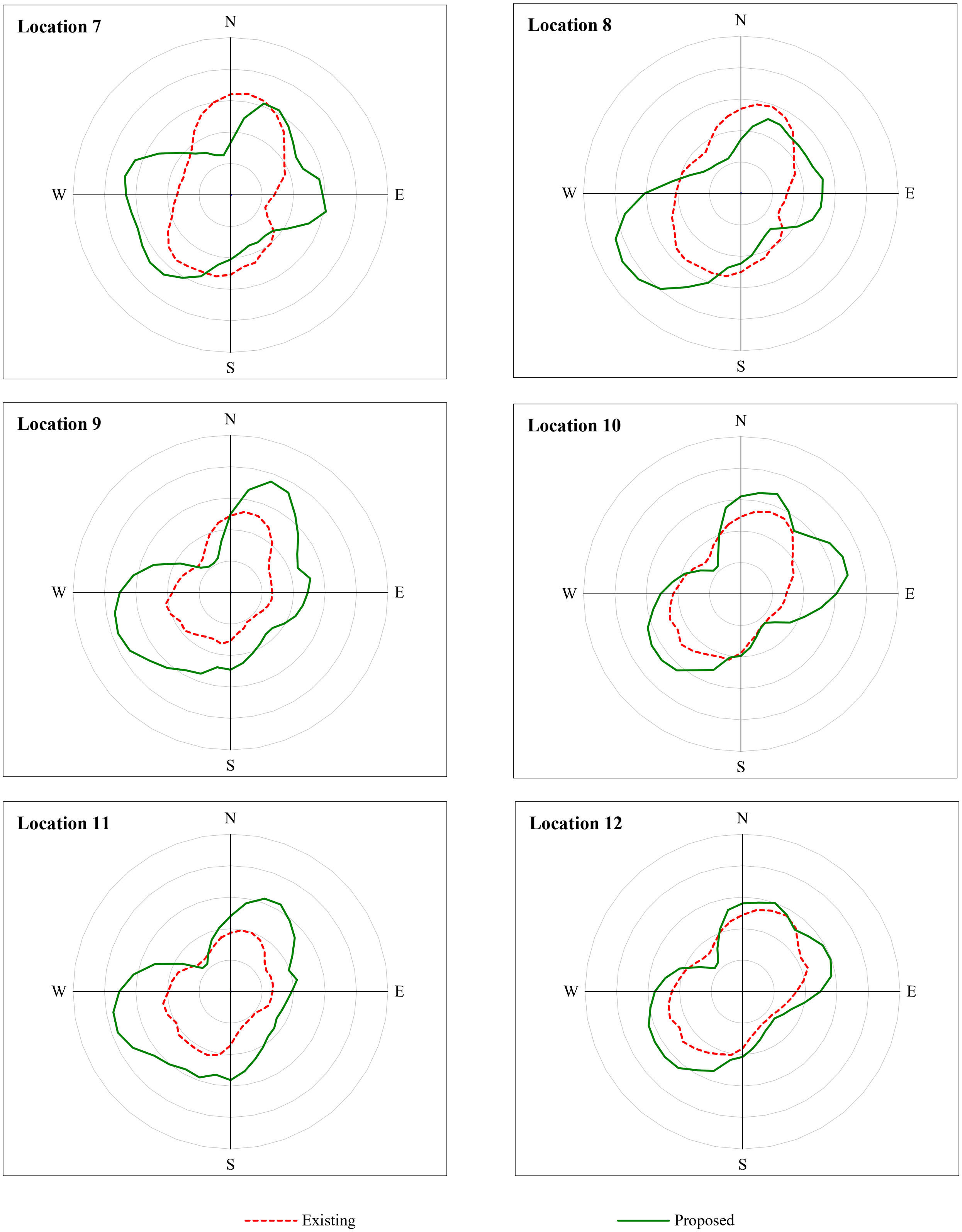
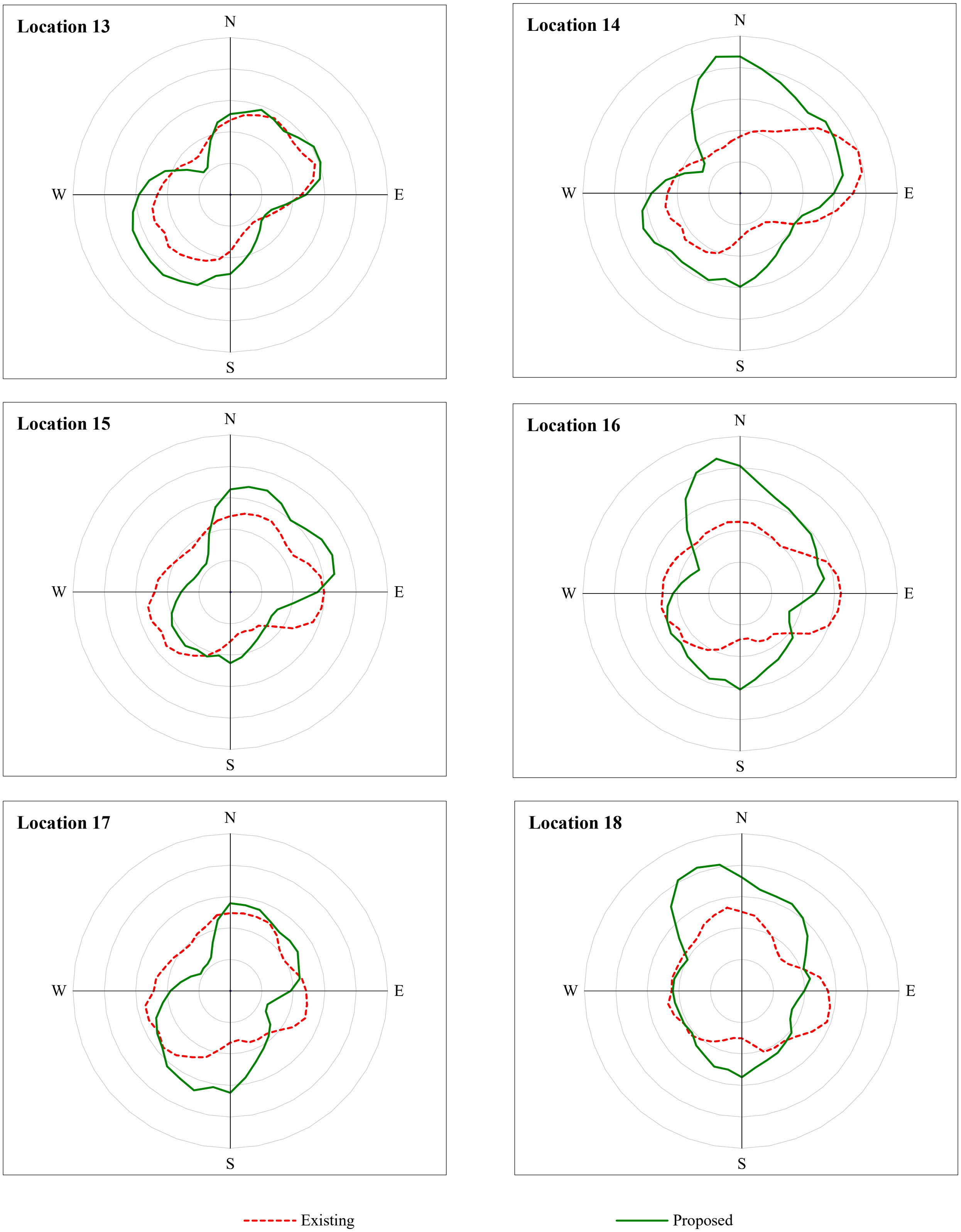


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.



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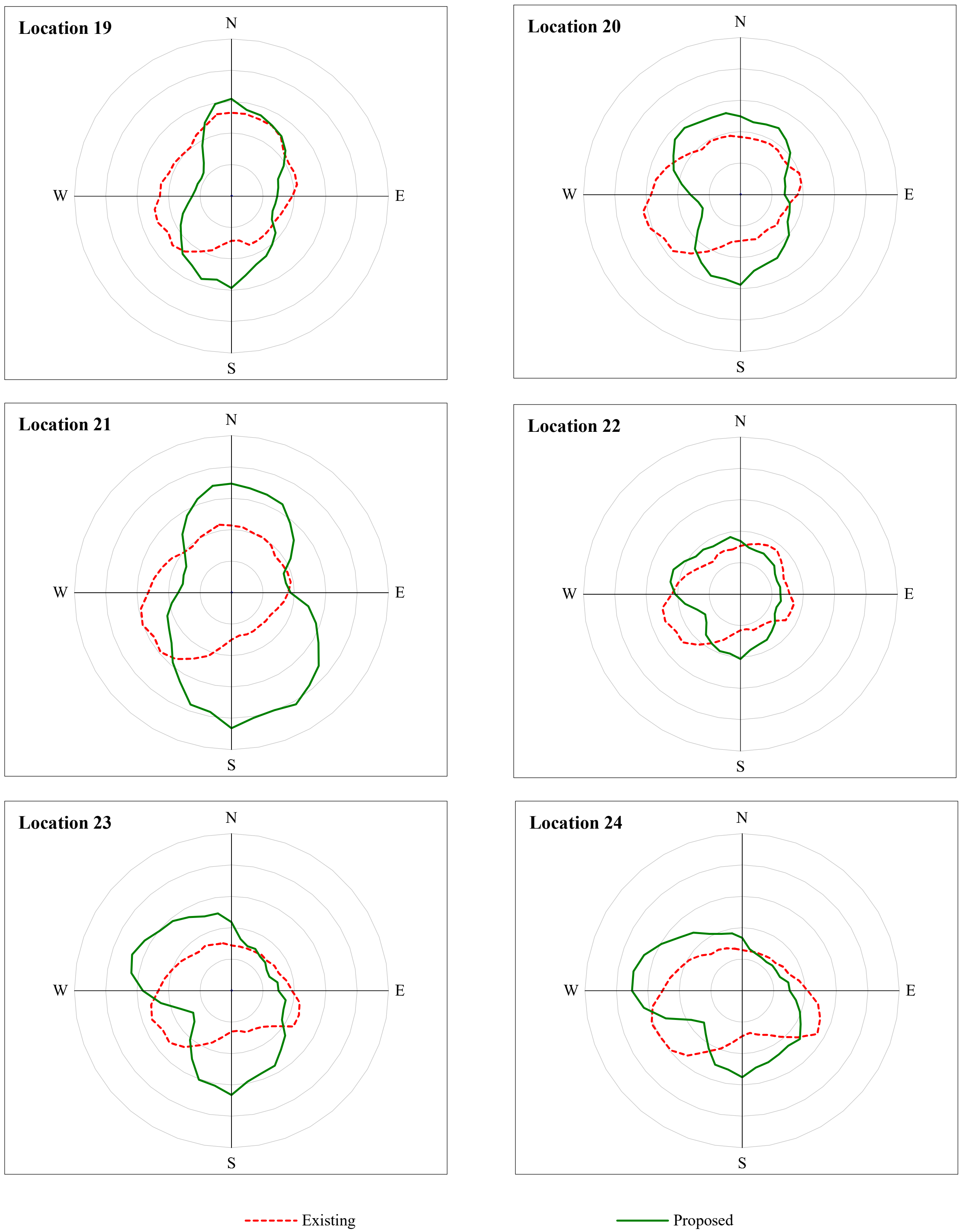

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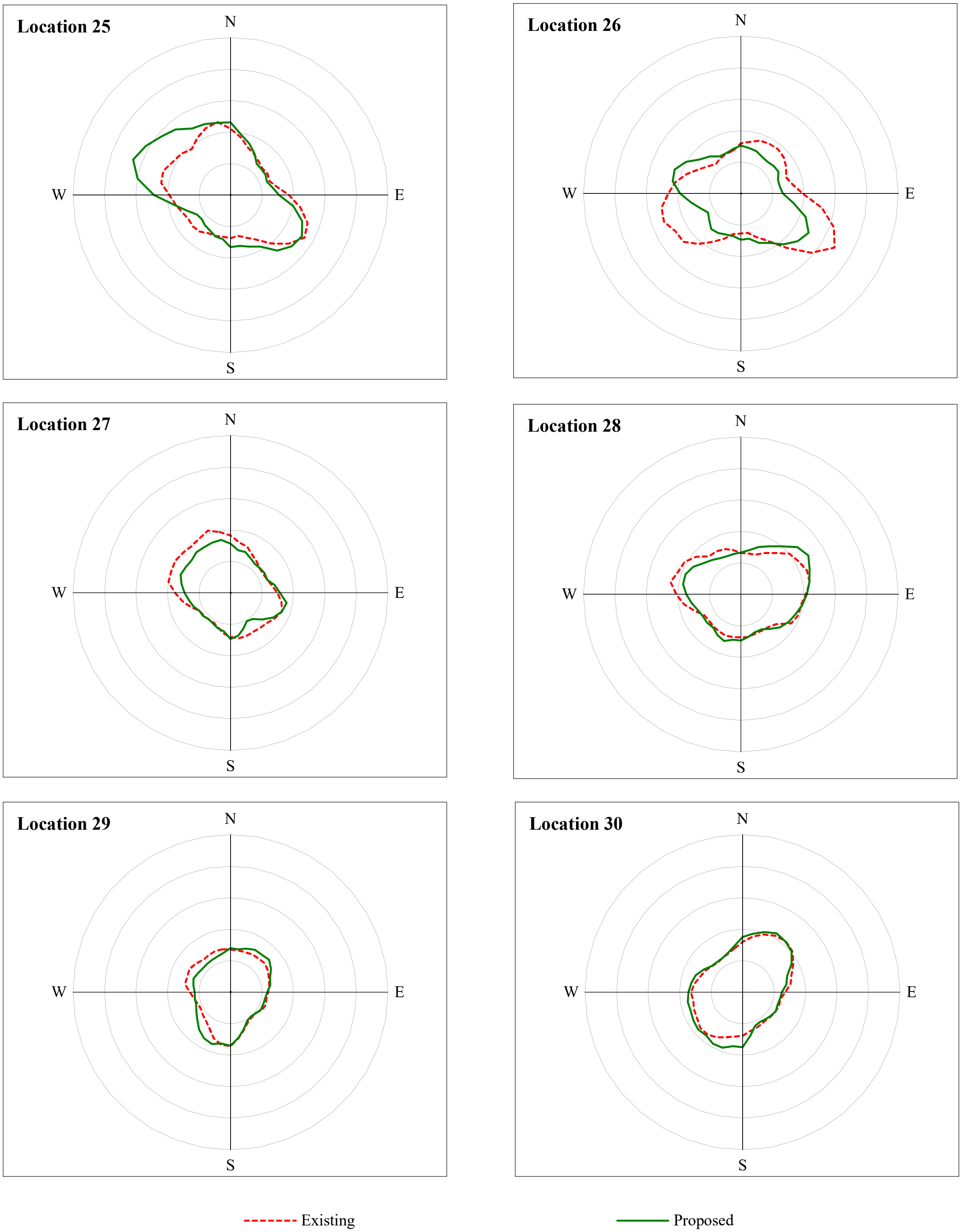

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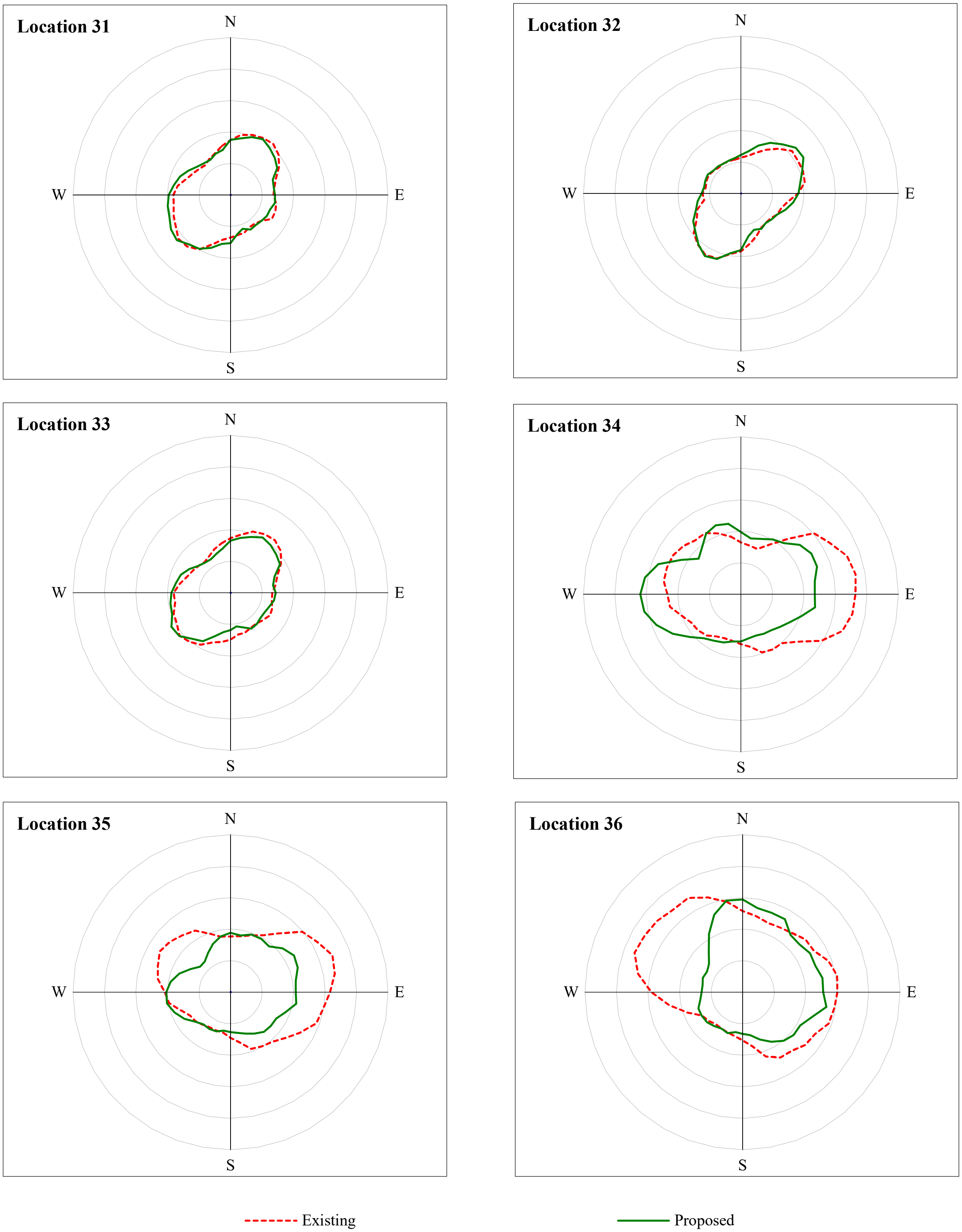

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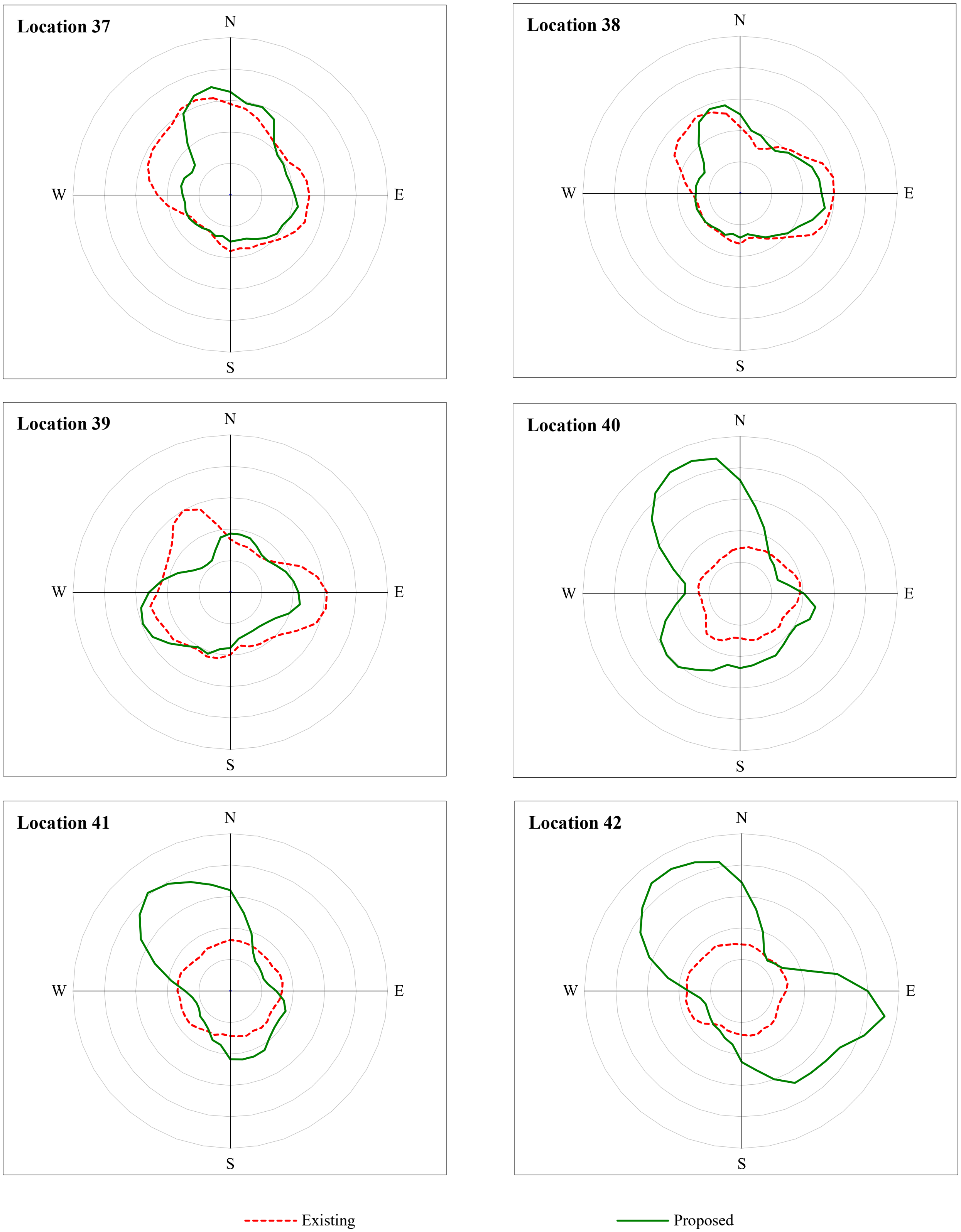

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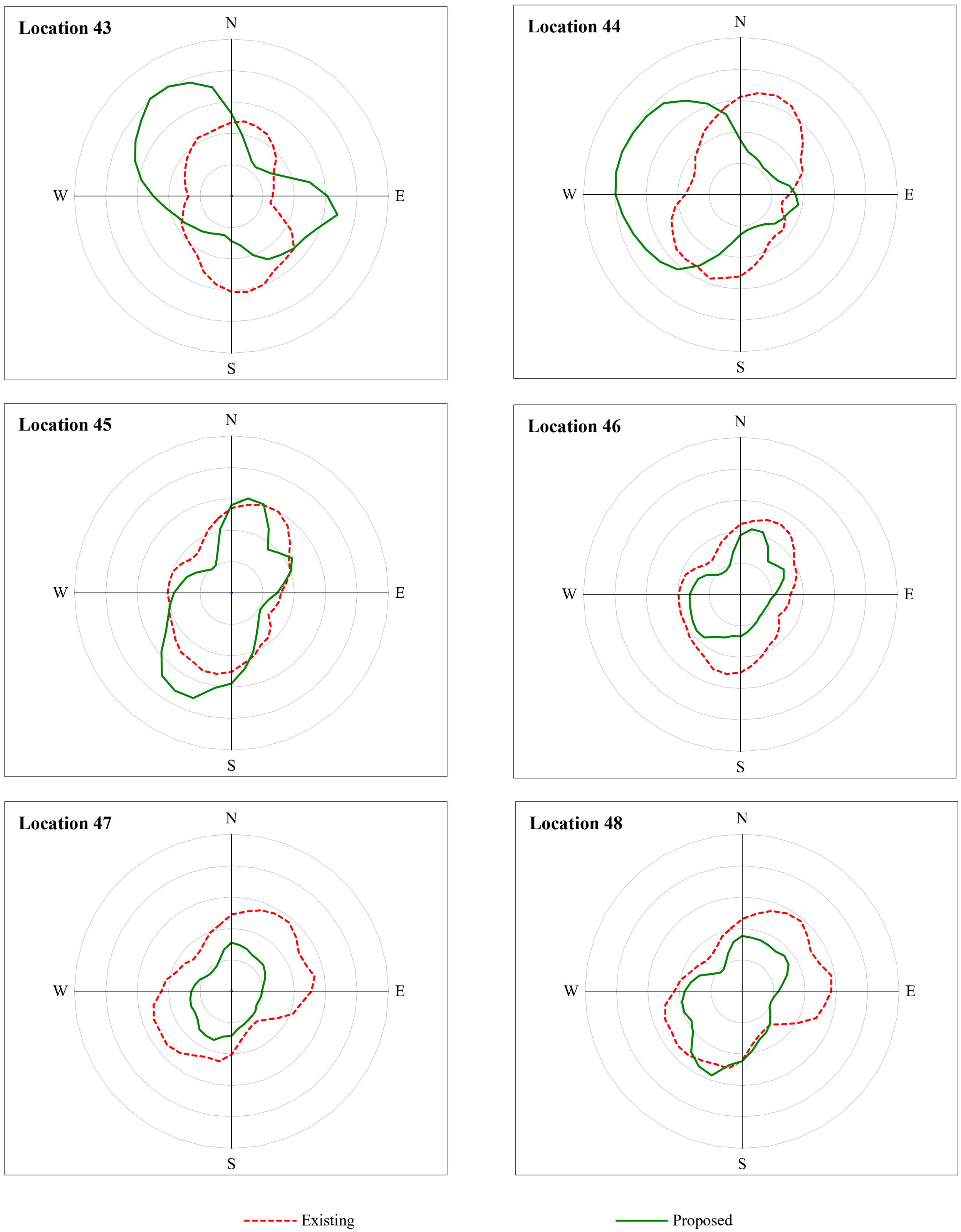

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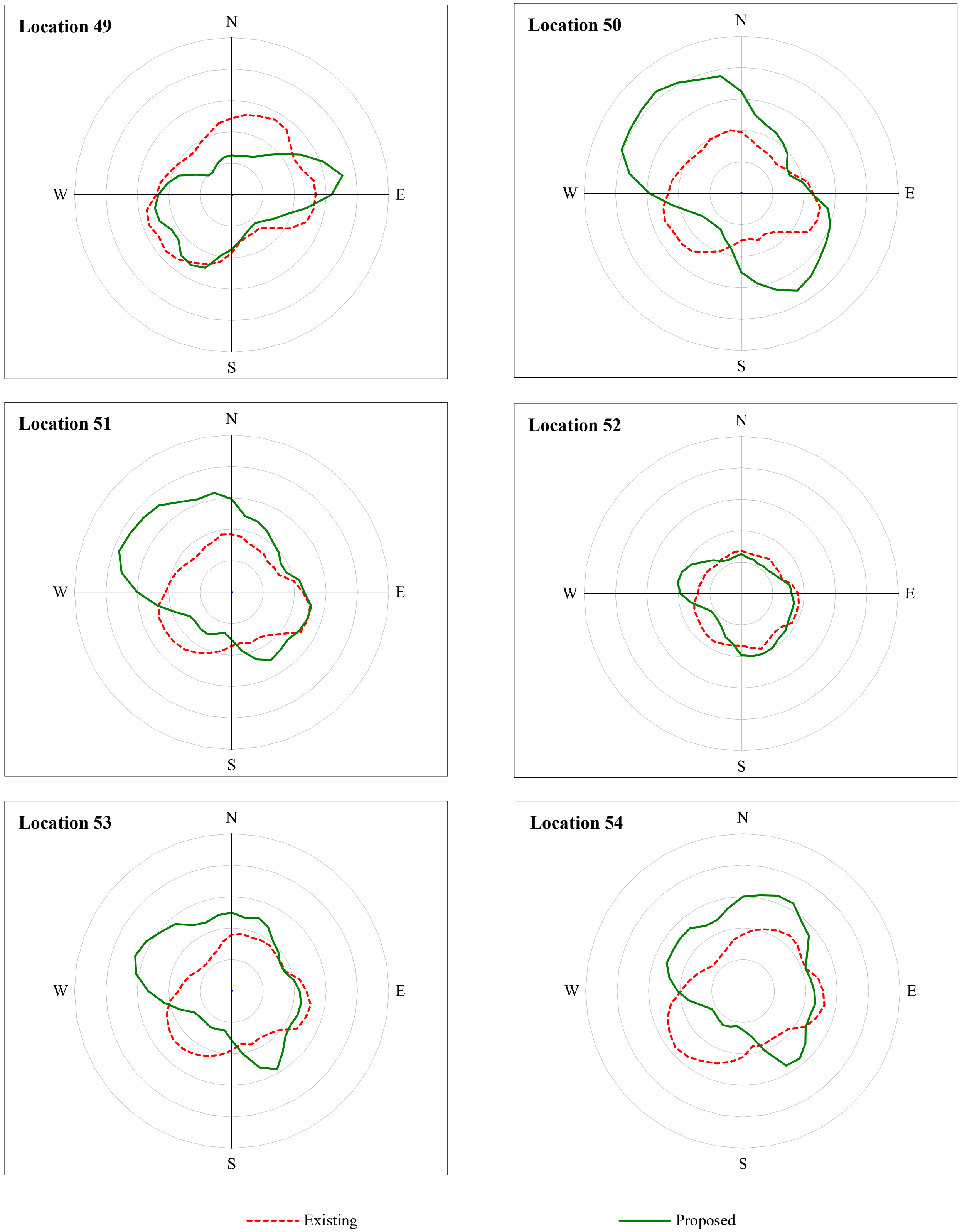

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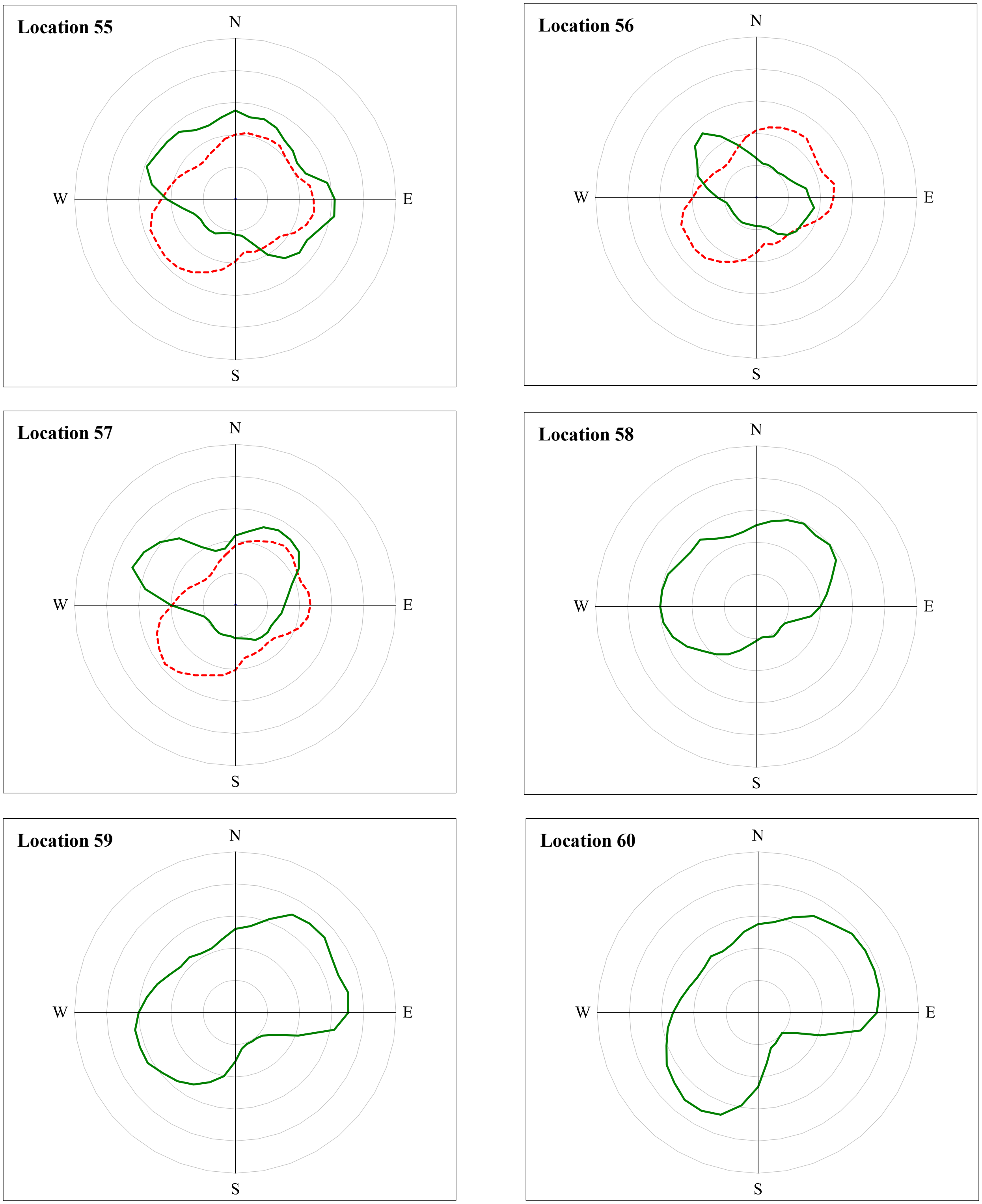
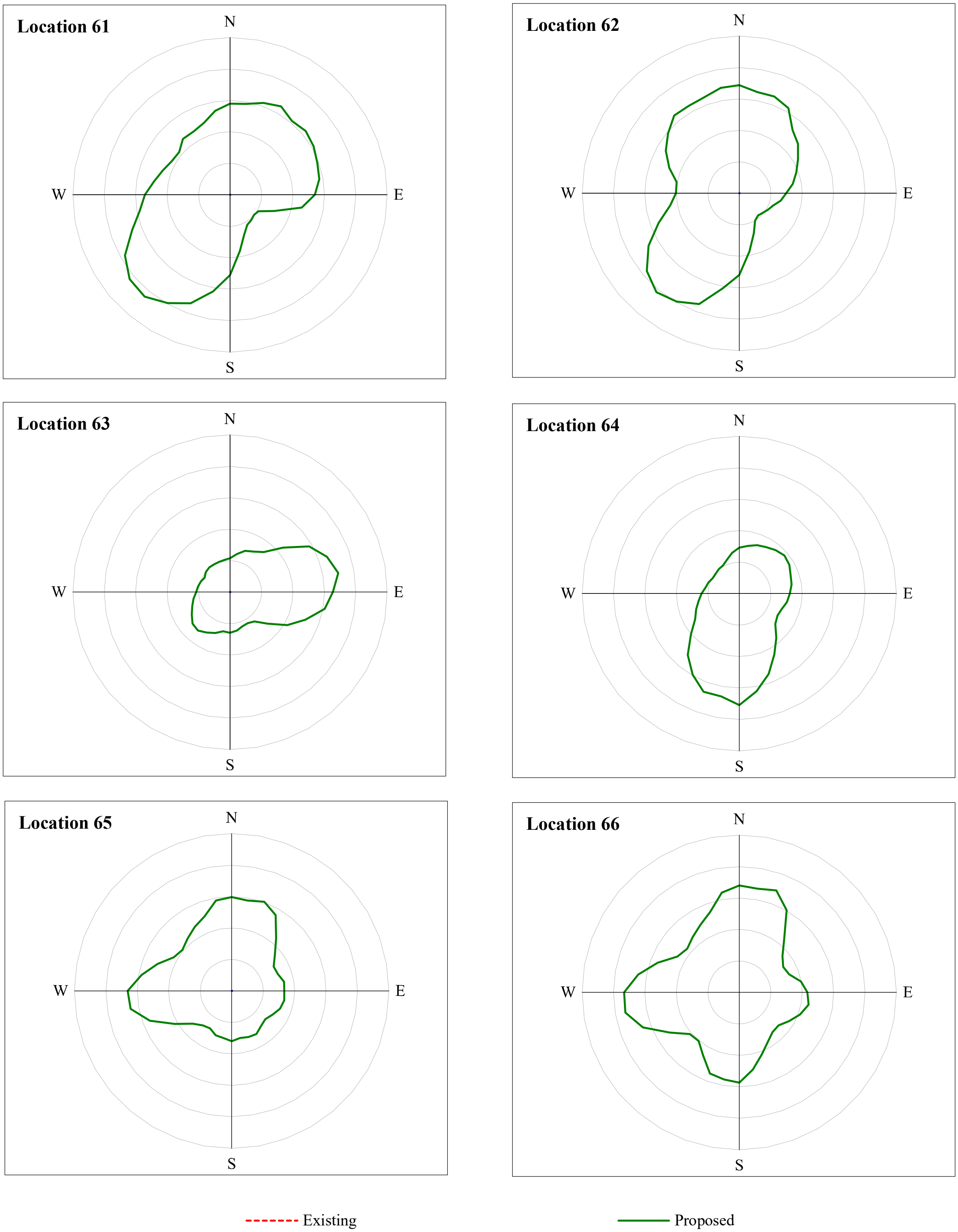


Existing   Proposed

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



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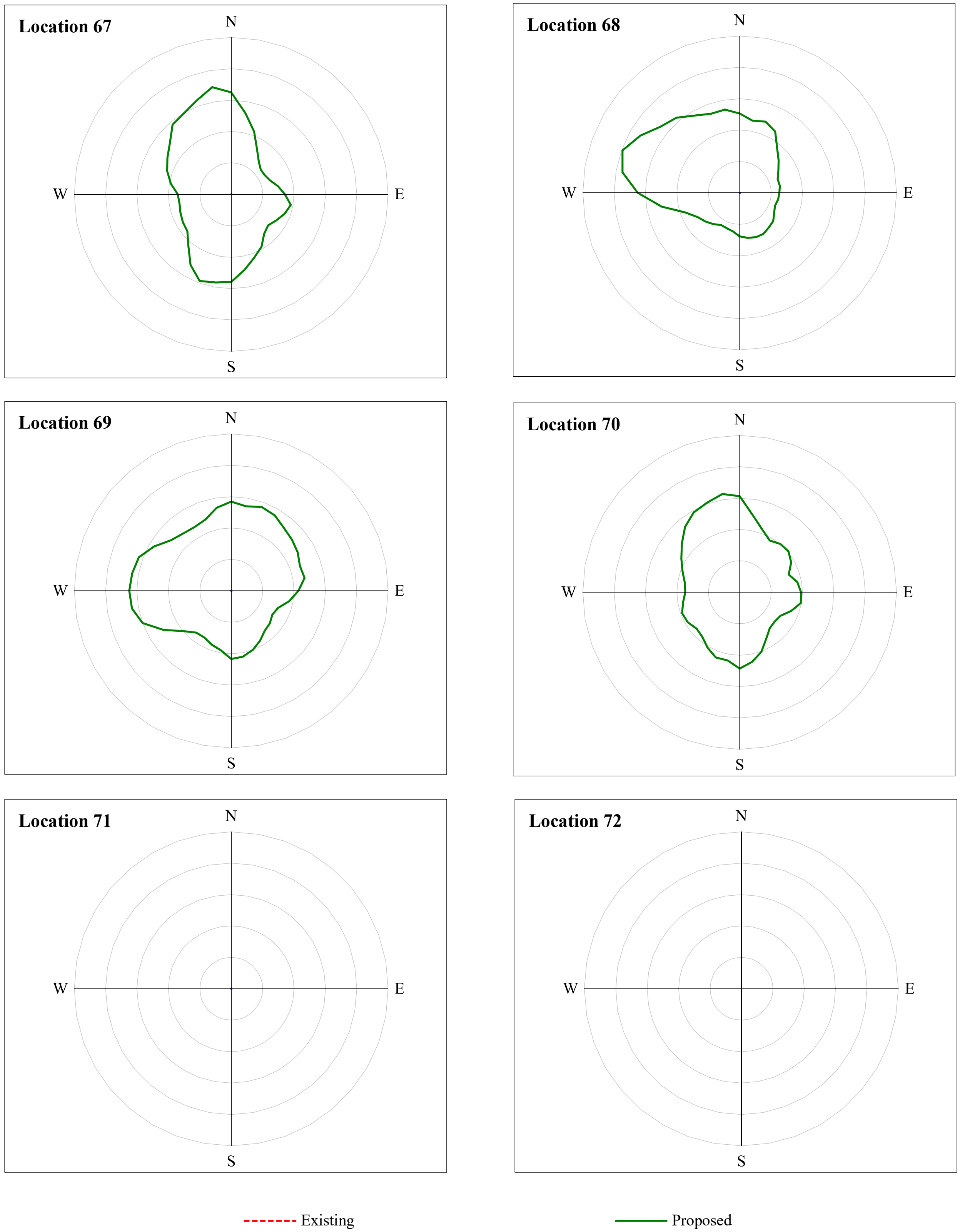

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