THEAKSTON ENVIRONMENTAL

Consulting Engineers • Environmental Control Specialists

REPORT

PEDESTRIAN LEVEL WIND STUDY

Erin Mills Town Centre – Phase 1

5100 Erin Mills Parkway
Mississauga, Ontario

EMTC Holdings Inc.

REPORT NO. 24159 (23064)wind **October 23, 2024**

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1. EXECUTIVE SUMMARY

The residential Development proposed by EMTC Holdings Inc. for Phase 1 of the Erin Mills Town Centre redevelopment located at 5100 Erin Mills Parkway, in the City of Mississauga, 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 one hundred and twenty-six (126) locations tested are, for the most part, within the safety and comfort criteria described within. Exceedances and mitigation recommendations are described within.

The Development involves a proposal to remove the existing low-rise commercial buildings on site, and construct 8 buildings, denoted Buildings A through H, to the west of the existing Erin Mills Town Centre Shopping Centre. The proposed Development is, for all intents and purposes, surrounded to prevailing windward directions by a suburban mix of mainly low-rise residential, commercial, and institutional buildings, with surrounding related open areas.

Urban developments provide surface roughness, which induces turbulence that can be wind friendly, while suburban settings similarly, though to a lesser extent, prevent wind from accelerating as the wind's boundary layer profile thins at the pedestrian level. Conversely, open settings afford wind the opportunity to accelerate. 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, and/or suburban, to urban settings often prove problematic, as winds exacerbated by relatively more open settings are redirected to flow over, around, down, and between buildings.

The proposed Development penetrates winds that formerly flowed over the low-rise and open site, the increased blockage relative to the existing setting causing wind to redirect to flow over the buildings, without consequence, and/or, depending upon the angle of incidence, around, or down the buildings towards the pedestrian level, as downwash. The Development features wind friendly design elements such as podiums, overhangs, landscaping, and others, which, when considered in concert, moderate wind at the pedestrian level.

Based upon this analysis ground level winds at some locations will improve, relative to the existing setting, with localized areas of higher pedestrian level winds. The site and surrounds are predicted to be generally suitable for walking, standing, or sitting throughout the year, with uncomfortable conditions predicted in the winter within the gaps between buildings and proximate to Building F2's northmost corner and Buildings A and D's southmost corners. The gaps between Buildings A and B and Buildings E and F1 exceed the pedestrian level wind velocity safety criteria and mitigation is required in order to improve the safety conditions.

The site was originally tested without wind mitigation in place and the resulting wind conditions used to inform development of a wind mitigation plan. Said plan was applied to the model and the site retested with wind mitigation in place, and the results reported herein. An appreciable improvement to predicted pedestrian comfort conditions was noted at many locations: however, additional wind mitigation is required and recommended to further improve the above-mentioned uncomfortable conditions as well as those realised at the Main Residential Entrance to Building H along the north façade. Additional mitigation is also recommended for the Outdoor Amenity Spaces, including the Urban Plaza, Parkland, Open Public Spaces 1, 2, & 3, and the above-grade Outdoor Amenity Spaces in order to achieve conditions that are considered seasonally appropriate for the Spaces.

Consideration of proposed surface roughness, such as fine design and landscape features that were too fine to include in the massing model, will result in more comfortable conditions than those reported.

The proposed Development will realize wind conditions acceptable to a typical suburban context with development of appropriate mitigation plans.

Respectfully submitted,

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2. INTRODUCTION

Theakston Environmental Consulting Engineers, Fergus, Ontario, were retained by EMTC Holdings Inc. to study the pedestrian level wind environment for Phase 1 of the Erin Mills Town Centre redevelopment located at 5100 Erin Mills Parkway, in the City of Mississauga, as shown on the Aerial Photo in Figure 2a. The Development involves a proposal to remove the existing low-rise commercial buildings on site, and construct 8 buildings, denoted Buildings A through H, to the west of the existing Erin Mills Mall, in the configuration shown in Figure 2b. BDP Quadrangle provided architectural drawings for the proposed 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 buildings currently on site as well as existing and approved buildings in the surrounding area. The proposed configuration replaced the existing buildings with the proposed Development. Mitigation procedures were assessed during these tests to determine their impact on the various wind conditions.

The laboratory techniques used in this Pedestrian Level Wind 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, which is excellent for flow visualisation, 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, 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 one hundred twenty-six (126) 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 the seasons 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 1980 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 at 10m, corrected for a standard open exposure definition, is 25 m/s for a return period of 50 years.

4.3 Statistical Wind Climate Model

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

The design probability distribution of mean-hourly wind speed and wind direction at reference height is shown for Pearson International Airport in Figure 5. 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 from the north through west to southwest as well as the east, and said winds are most likely to occur during the winter months.

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. BDP Quadrangle provided architectural drawings. City of Mississauga aerial photographs were also used in development of the model to ensure the model reasonably represents conditions at the proposed Development. The model is constructed on a circular base so that, by rotation, any range of wind directions can be assessed. Structures and features that are deemed to have an impact on the wind flows are included upwind of the scale model.

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

4.6 Pedestrian Comfort Criteria

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

Figure 6 presents results for the Comfort Categories, which are based upon the 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

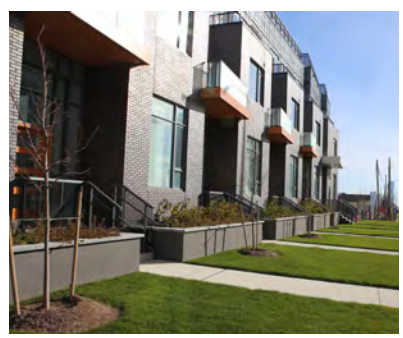
The level of comfort perceived by an individual is highly dependent on seasonal variations of climate. Perceived comfort is also specific to each individual and depends on the clothing choices. The comfort criterion that is being used averages the results across the general population to remove effects 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.

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 – 3.2m high 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

Proposed Development

The proposed Development occupies the western portion of the block of lands bound by Erin Centre Boulevard to the northwest, Glen Erin Drive to the southwest, Eglinton Avenue West to the southeast, and Erin Mills Parkway to the northeast, in the City of Mississauga. The development site is currently occupied by low-rise commercial buildings that will be removed. The site and its immediate surrounds are shown in Figure 2a.

The proposed Development involves construction of 8 buildings, denoted Buildings A through H, situated to the west of the existing Erin Mills Mall.

Buildings A through C are located along the southwest boundary of the site, fronting Glen Erin Drive. They are 30, 25, and 20 storeys in height, with 6, 5, and 4 storey podiums, respectively. The area atop the podiums provides Outdoor Amenity Spaces. The Main Residential Entrances to Buildings A through C are located along the southwest and northeast façades of the buildings.

Buildings D through F are located along the northwest boundary of the site, fronting Erin Centre Boulevard. Buildings D and E are respectively 20 and 25 storeys in height with 4 and 5 storey podiums. The area atop the podiums provides Outdoor Amenity Spaces. The Main Residential Entrances to Buildings D and E are located along the northwest and southeast façades of the buildings. Building F is comprised of two towers, denoted F1 and F2, which are 27 and 30 storeys in height, respectively. The towers are connected by a 6 storey podium and the area atop the podium, between the towers, is assigned to Outdoor Amenity Space. The Main Residential Entrances to Building F are located along the northwest and southeast facades of the podium.

Buildings G and H are located central to the site, flanking the proposed Parkland, and are respectively 44 and 39 storeys in height. The buildings each have 6 storey podiums accommodating Outdoor Amenity Spaces to the west of the towers. The Main Residential Entrances to Buildings G and H are accessed along the north and south façades of the buildings.

An Urban Plaza is proposed at the west corner of the site, fronting the intersection of Glen Erin Drive and Erin Centre Boulevard. A Parkland is proposed central to the site, between Buildings G and H. Open Public Spaces are located throughout the site, to the northeast of Buildings A and B, as well as to the southeast of Building E. Terraces are proposed at the mechanical penthouse level of the Buildings. The analysis is based upon project plans prepared by BDP Quadrangle and the site plan is presented in Figure 2b.

View of the existing conditions at the proposed Development site looking north from Glen Erin Drive (Google).

The model was tested with wind mitigation in place, as depicted on STUDIOtla's landscape plans dated October 2, 2024. This included 3.0m high wind screens, trellises, coniferous vegetation, and raised planter beds, as shown below.

View of the wind mitigation tested at the proposed Development site looking east from the intersection of Glen Erin Drive and Erin Centre Boulevard.

Surrounding Area

The proposed Development site, for all intents and purposes, is surrounded to prevailing windward directions by a suburban mix of low-rise residential, commercial, and institutional buildings, as indicated in Figure 2a. High-rise residential buildings are located further beyond, to the south of Eglinton Avenue West and north of Erin Centre Boulevard.

Lands to the north of the site are occupied by the low-rise John Fraser Secondary School, with related open sportsfields and parkland to the north through northwest beyond. Lands to the west of the site are mainly occupied by low-rise residential neighbourhoods, with the low-rise Merciful Redeemer Parish located to the west of the intersection of Glen Erin Drive and Erin Centre Boulevard. To the southwest of the site are the Erin Mills Library and Saint Aloysius Gonzaga Secondary School, with surrounding open lands and sportsfields. Low-rise commercial buildings are located to the south through southeast of the site fronting Glen Erin Drive and Eglinton Avenue West with a number of high-rise buildings along the southeast side of Eglinton Avenue West. Lands to the east of the site are occupied by the existing Erin Mills Mall and surrounding open parking areas.

In summary, suburban development mainly comprised of low-rise residential, commercial, and institutional buildings, and related open parks and parking spaces, occupy lands to all compass points relative to the subject site. 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.

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 Toronto Pearson International Airport was used in this analysis. For studies in the City of Mississauga, the data is presented for two seasons, winter and summer; the resulting wind roses are presented as mean velocity and percent frequency in Figures 5a & 5b. The mean velocities presented in the wind roses are measured at an elevation of 10m. Thus, representative ground level velocities at a height of 2m, for an urban macroclimate, are 52% of the mean values indicated on the wind rose (for suburban and rural macroclimates the values are 63% and 78% respectively). The macroclimate for the area varies, with the terrain types associated with wind direction, resulting in what is generally considered suburban terrain.

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

5.2 Pedestrian Level Wind Velocity Study

On the site model, one hundred twenty-six (126) wind velocity measurement probes were located around the proposed 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 Figures 5a & 5b) 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 the seasons in Figures 6a & 6b. 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, 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 buildings 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, Internal Site Conditions, Pedestrian Entrance Conditions, and Outdoor Amenity Space Conditions. The measurement locations are depicted in Figure 4 and the resulting pedestrian comfort conditions are listed in Figures 6a & 6b for the two seasons for the existing and proposed configurations. The results are also graphically depicted in Figures 7a – 7d. The following discusses anticipated wind conditions and suitability for the points' intended use.

Public Street Conditions

Erin Centre Boulevard

Probes 1 through 15 were located along Erin Centre Boulevard to the northwest of the site, within the zone of influence of the proposed Development. Their locations are depicted in Figure 4, the comfort ratings are listed for the seasons in Figures 6a & 6b and depicted in Figures 7a - 7d. The wind environment along Erin Centre Boulevard is preconditioned upon approach by the predominantly low-rise buildings and large open spaces, resulting in conditions in the existing setting that are rated appropriate for walking in the winter, with the exception of probes 2 and 3, which were rated suitable for standing, and appropriate for standing in the summer.

With inclusion of the proposed Development, a realignment of winds was noted along Erin Centre Boulevard that reduces apparent wind effects at the pedestrian level for several wind directions, but causes an increase to winds for others, as indicated in the Appendixes Figure B, Ground Level Wind Velocity Plots presented as a ratio of gradient wind velocity. Increased winds can be attributed to the proposed buildings redirecting winds through downwash and other phenomena to flow along Erin Centre Boulevard. Conversely, improvements in wind conditions can be attributed to the buildings effectively reducing the propensity for specific winds being deflected to flow along the street.

Winds that formerly flowed over the low-rise and open site will be redirected by the proposed Development to flow down the buildings' façades towards the pedestrian level, along the façades at the pedestrian level, through the gaps between buildings and around the buildings' corners. This results in a more directional flow of winds along Erin Centre Boulevard relative to the existing setting, with winds flowing mainly from the southwest and north to northeast, as shown in the Appendices Figure B: Ground Level Wind Velocity Plots. Erin Centre Boulevard remains, for the most part, appropriate for walking in the winter, with the exception of probe 5, located at the northmost corner of Building F2, which was rated uncomfortable. Mitigation is recommended in order to achieve more appropriate conditions and can include wind screens, raised planter beds populated with coarse plantings, trellises, coniferous vegetation, and others. In the summer, Erin Centre Boulevard remains, for the most part, appropriate for standing, with exception of probes 2, 5, 9, 12, and 14, which were rated appropriate for walking. These windier conditions were generally realised proximate to the buildings' corners and gaps between buildings.

Conversely, sections of Erin Centre Boulevard located centrally along the proposed buildings' northwest façades, away from the corners, will realise an improvement to wind conditions relative to the existing setting, as a result of increased blockage to winds emanating from the northeast through east to south through southwest directions, however, the improvements were insufficient to change the comfort ratings.

Consideration of fine design and landscape elements too fine to incorporate into the massing model will result in more comfortable conditions than those reported.

With inclusion of the proposed Development, Erin Centre Boulevard remains comfortable and appropriate for its intended use throughout the year, with the above-noted uncomfortable rating in the winter, and passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Glen Erin Drive

In addition to the probes located at the intersection with Erin Centre Boulevard and discussed above, probes 16 through 26 and 44 were located along Glen Erin Drive within the zone of influence of the proposed Development. In the existing setting, the probes indicate conditions suitable for walking in the winter and standing in the summer. These conditions can be attributed to the largely open surrounds, affording wind the opportunity to accelerate upon approach.

Winds approaching Glen Erin Drive that formerly flowed over the low-rise buildings and open surface parking areas, upon contact with Buildings A, B, and C, are redirected to flow down and around the buildings, along the façades, through the gaps between buildings, around the corners, and beyond. This results in a realignment of winds that reduces apparent wind effects at the pedestrian level for several wind directions, but causes an increase to winds for others, as indicated in the Appendixes Figure B, Ground Level Wind Velocity Plots presented as a ratio of gradient wind velocity.

An improvement to wind conditions was observed along the southwest façades of the buildings, removed from the corners, however the changes were insufficient to improve the comfort ratings among the areas tested. In the proposed setting, probes 19 and 20 were rated suitable for standing in the winter. Conversely, localised areas of Glen Erin Drive are exposed to winds that are redirected to flow down and around the proposed Development and through the gaps between buildings. The increase in winds was sufficient to change the rating at probe 23, located at the southmost corner of Building A, from walking to uncomfortable in the winter and from standing to walking in the summer. The remainder of the probes tested retained their original comfort ratings throughout the year. Mitigation will therefore be required in order to achieve more appropriate conditions and can include wind screens, raised planter beds populated with coarse plantings, trellises, coniferous vegetation, and others. Consideration of fine design and landscape elements too fine to incorporate into the massing model will result in more comfortable conditions than those reported.

Glen Erin Drive remains comfortable and appropriate for its intended use throughout the year with inclusion of the proposed Development, with the above-noted uncomfortable exception, and passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Ring Road

Probes 27 through 40 were located along Ring Road within the zone of influence of the proposed Development. In the existing setting, the street realises conditions mainly suitable for walking in the winter and standing in the summer, with the exception of probes 33 and 34 in the winter, which were rated suitable for standing. The conditions can similarly be attributed to the largely open surrounds, affording wind the opportunity to accelerate. The more comfortable conditions were noted in close proximity to the existing building.

With inclusion of the proposed Development, areas of Ring Road benefit from increased blockage to prevailing winds relative to the existing setting. The increased blockage was sufficient to improve the winter comfort rating at probes 28, 29, 31, 39 and 40 from walking to standing and from walking to sitting at probe 32. Conversely, probes 33 and 34 realised an increase in winds sufficient to change the winter rating from standing to walking. In the summer, improvements to wind conditions sufficient to change the rating from standing to sitting were noted at probes 31 and 32. Conversely, probes 30 and 34 realised increases in winds sufficient to change the rating from standing to walking.

Overall, Ring Road remains suitable 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.

Probes 41 and 42 were located along the connecting road between Glen Erin Drive and Ring Road to the southeast of the Development and probe 50 was located along the connecting road between Erin Centre Boulevard and Ring Road to the northeast of the Development. In the existing setting, the areas were rated suitable for walking in the winter and standing in the summer. With inclusion of the proposed Development, these areas benefit from increased blockage to prevailing winds sufficient to improve the category at probe 42 from walking to standing in the winter. The areas remain comfortable and appropriate for their intended use throughout the year in the proposed setting and pass the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Neighbouring Site Conditions

Probes 45 – 47 were located along sidewalks throughout the surface parking lots to the east of the Development, providing pedestrian access to the Erin Mills Town Centre Shopping Centre. The areas were rated suitable for standing throughout the year, with the exception of probe 47 in the winter, which was rated appropriate for walking. Wind conditions improved with inclusion of the proposed Development, sufficient to improve the comfort category at probe 47 from walking to standing in the winter and probe 46 changed from standing to sitting in the summer. The remainder of the probes retained their original comfort ratings throughout the year.

Probes 48 and 49 were located on neighbouring sidewalks to the north and south of the intersection of Erin Centre Boulevard with Glen Erin Drive, respectively. They were rated appropriate for walking in the winter and standing in the summer in the existing setting. With inclusion of the proposed Development, a decrease in westerly and easterly winds, as shown in the Appendices Figure B, resulted in an improvement to wind conditions sufficient to change the winter rating to standing at both locations and they retained their original comfort ratings in the summer.

The above-mentioned neighbouring sidewalks are therefore considered comfortable and appropriate for their intended use throughout the year and pass the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Internal Site Conditions

In addition to the probes situated along Erin Centre Boulevard and discussed above, probes 51 through 62 were located around the perimeters of Buildings D, E, and F. Probes positioned within the gaps between the buildings, as well as the southmost corner of Building D, as represented by probes 54, 55, 57, 58, and 60, indicate conditions that are uncomfortable in the winter and suitable for walking in the summer, with the exception of probe 55, which remains uncomfortable. Further, the gaps between Buildings E and F1, as represented by probes 54 and 55, exceed the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9 and wind mitigation will be required. Probe 53 was rated suitable for walking in the winter, probe 62 was rated suitable for walking throughout the year, and the remainder of the probes situated around the perimeters of Buildings D, E, and F were rated suitable for standing or sitting throughout the year. These areas are considered appropriate for their intended uses and pass the pedestrian level wind velocity safety criteria.

Probes 63 through 72 were located around the perimeters of Buildings H and G. Probe 65 was positioned proximate to the northeast corner of Building H and uncomfortable conditions were predicted in the winter and walking conditions in the summer. Mitigation will therefore be required. The remainder of the locations tested were rated suitable for walking in the winter and standing in the summer, with exception of probes 63 and 72 in the summer, which were rated appropriate for walking. With the above-noted exception, the area surrounding Buildings H and G are predicted comfortable and appropriate for their intended use throughout the year and pass the pedestrian level wind velocity safety criteria.

Probes 73 through 78 and 80 through 85 were situated around the perimeters of Buildings A, B, and C. Similar to above, the gaps between buildings and the buildings' corners tend to experience windier conditions, whereas areas located more centrally along the façades tend to experience more calm conditions. Probes 74, 77, and 83, were rated uncomfortable in the winter and suitable for walking in the summer. Probe 83 also exceeded the pedestrian level wind velocity safety criteria. As a result, mitigation is recommended in order to improve comfort and safety conditions in these areas. Probes 73, 75, 76, and 80 – 82 were rated suitable for walking in the winter and the remainder of the locations tested in this area were rated suitable standing, or better throughout the year.

With exception of the above-noted uncomfortable ratings and safety exceedance, the areas surrounding Buildings A, B, and C are predicted comfortable and appropriate for their intended use and pass the pedestrian level wind velocity safety criteria.

Pedestrian Entrance Conditions

Probes 84 and 85 were located proximate to the Main Residential Entrances to Building A, located along the northeast and southwest façades proximate to the northmost and westmost corners, respectively. They were predicted suitable for standing in the winter and the northeast entrance was rated suitable for sitting and the southwest was rated suitable for standing in the summer. Conditions appropriate for standing, or better, are preferrable for Entrances, whereas walking conditions are acceptable for the sidewalks beyond. As a result, the Main Residential Entrances to Building A are predicted comfortable and appropriate for their use.

Probes 78 and 21 were situated proximate to the Main Residential Entrances to Building B, located along to the northeast and southwest façades proximate to the eastmost and southmost corners, respectively. The Entrance along the northeast façade was rated suitable for standing in the winter and sitting in the summer and is therefore considered comfortable and appropriate for its intended use. The Entrance along the southwest façade was rated suitable for walking in the winter and standing in the summer. The Entrance is recessed into the façade such that wind flowing along the southwest façade cannot act upon the door leaves and will experience conditions more comfortable than the probe indicated beyond, such that it is considered appropriate for its intended use.

Probes 75 and 18 were located proximate to the Main Residential Entrances to Building C, located along the northeast and southwest façades proximate to the northmost and westmost corners, respectively. The Entrances were rated suitable for walking in the winter and standing in the summer. The Entrances are recessed into their façades such that wind flowing along the façades cannot act upon the door leaves and the Entrance will experience more comfortable conditions than the probe beyond indicated.

Probes 53 and 79 were located proximate to the Main Residential Entrances to Building D, located along the northwest and southeast façades proximate to the westmost and southmost corners of the building, respectively. The northwest Entrance was rated suitable for walking in the winter and standing in the summer. The southeast Entrance was rated suitable for standing throughout the year. Similar to above, the Entrances are recessed into the façade and are predicted to realise more comfortable conditions than indicated by the probe beyond.

Probes 10 and 52 were located proximate to the Main Residential Entrances to Building E, located along the northwest and southeast façades proximate to the northmost and eastmost corners, respectively. The northwest Entrance was rated suitable for walking in the winter and standing in the summer. The southeast Entrance was rated suitable for standing in the winter and sitting in the summer. Similar to above, the Entrances are recessed into the façade and are predicted to realise more comfortable conditions than indicated by the probe beyond.

Probes 7 and 32 were located proximate to the Main Residential Entrances to Buildings F1 and F2, located within the podium connecting the towers along the northwest and southeast façade, respectively. The northwest Entrance was predicted appropriate for walking in the winter and standing in the summer. The southeast Entrance was rated appropriate for sitting throughout the year. The Entrances were similarly recessed into the façade and are predicted to realise more comfortable conditions than indicated by the probe beyond.

Probes 65 and 66 were located proximate to the Main Residential Entrances to Building H, located along the north and south façades proximate to the east corners, respectively. The north Entrance was predicted uncomfortable in the winter and suitable for walking in the summer. The south Entrance was rated appropriate for walking in the winter and standing in the summer. Both Entrances have been recessed into their façades, however additional mitigation is recommended for the north Entrance and can include relocating the Entrance away from the corner.

Probes 69 and 70 were located proximate to the Main Residential Entrances to Building G, located along the north and south façades proximate to the east corners, respectively. The Entrances were predicted suitable for walking in the winter and standing in the summer. The Entrances have been recessed into their façades such that wind flowing along the façades cannot act upon the door leaves.

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

Outdoor Amenity Space Conditions

Probes 86 – 89, 117 and 118 were located at-grade within the Urban Plaza, located east of the intersection of Erin Centre Boulevard and Glen Erin Drive. The area was tested with wind mitigation in place, including porous wind screens, trellises, and coniferous vegetation. It is predominantly exposed to prevailing winds flowing in a west/east direction through the gap between buildings. As a result, the Urban Plaza was rated suitable for walking in the winter, with the exception of probe 117, which was rated suitable for standing. In the summer, the area was rated suitable for standing. Generally sitting conditions are desired within Outdoor Amenity Spaces in the summer and, as a result, additional mitigation will be required in order to achieve conditions that are seasonally appropriate for the area's intended use.

Probes 90 through 98 were located at-grade within the Parkland between Buildings G and H. The Parkland was similarly tested with wind mitigation in place, including coniferous trees, wind screens, and trellises. The resulting wind conditions were rated suitable for sitting at probes 91 and 97 in the winter and summer. In the winter, probes 92 and 93 were rated suitable for standing and the remainder of the Space was rated suitable for walking. In the summer, the remainder of the Space was rated suitable for standing. Portions of the Amenity Space in close proximity to the wind screens and trellises are therefore considered seasonally appropriate for their intended use. Additional mitigation will be required if sitting conditions are desired throughout the Parkland in the summer.

Probe 99 was positioned at-grade within the Open Public Space 3, located between Buildings E and H, as well as probes 33 and 43. The area was tested with mitigation in place, including the proposed coniferous trees. In the winter, probe 43, located closer to the gap between Buildings

E, D, and H, was rated uncomfortable and probes 33 and 99 were rated suitable for walking. In the summer, probe 43 was rated appropriate for walking and probes 99 and 33 were rated appropriate for standing. Additional mitigation will therefore be required in order to improve the uncomfortable rating in the winter and achieve sitting conditions in the summer.

Probes 100 through 103 and 107 were located at-grade within the Open Public Space 2, located to the south of Building G. The area was tested with wind mitigation in place including coniferous trees. Probe 107, located within the gap between Buildings G and B, is exposed to winds flowing through said gap, and, as a result, were rated uncomfortable in the winter and appropriate for walking in the summer. The uncomfortable rating was very near the transition to walking conditions and will likely be suitable for such with consideration of fine design and landscape detail. The remainder of the probes indicated conditions suitable for walking in the winter and standing in the summer, with the exception of probe 100 in the summer, which was rated suitable for walking. Mitigation will therefore be required in order to achieve conditions seasonally appropriate for the area's intended use.

Probes 104 - 106 were located at-grade within the Open Public Space 1, located to the northeast of Building A. The area was tested with wind mitigation in place including coniferous trees. The area was rated suitable for walking in the winter and standing in the summer and mitigation will be required in order to achieve conditions seasonally appropriate for its intended use.

Outdoor Amenity Spaces are proposed atop the podiums. Probes were positioned along the northwest and southeast façades of Building A, the northwest façade of Building B, the southwest façade of Building E, between towers F1 and F2, and along the west façades of Buildings G and H, as shown in Figure 2b: Site Plan. The Amenity Spaces were tested with 2.6m high screen walls around the perimeters of the Spaces and were represented by probes 108 – 116 and 119 - 126.

In the summer, sitting conditions were predicted at probe 119 on the southeast façade of Building A and at probe 110 on the northwest façade of Building B. The remainder of the probe locations tested within the above-grade Outdoor Amenity Spaces were rated suitable for standing in the summer, with exception of probes 114 and 115, located between Buildings F1 and F2, which were rated appropriate for walking. In the winter, probe 115 was rated uncomfortable and the remainder of the above-grade Outdoor Amenity Spaces were rated suitable for walking or standing. Additional mitigation will be required in order to achieve sitting conditions throughout the Spaces in the summer and can include raising the perimeter screens, incorporating trellises, canopies, raised planter beds populated with coarse plantings, and/or others.

Terraces are proposed at the mechanical penthouse level of the Buildings. The areas were too narrow to instrument with probes and a qualitative analysis of wind conditions is provided. The Terraces are exposed to the prevailing wind climate unmitigated upon approach by the low-rise and open surrounds. Mitigation will be required in order to achieve sitting conditions in the summer and should include perimeter screens.

The above-mentioned Outdoor Amenity Spaces pass the pedestrian level wind velocity safety criteria, as described in Section 4.6 and depicted in Figure 9.

5.4 Summary

The observed wind velocity and flow patterns at the proposed Development are largely influenced by approach wind characteristics that are dictated by the surrounding areas to prevailing and less dominant wind directions. The low-rise buildings and open surroundings afford wind the opportunity to accelerate upon approach, resulting in generally windy conditions in the existing setting. Historical weather data recorded at Toronto Pearson International Airport indicates that strong winds of a mean wind speed greater than 30 km/h occur approximately 15 percent of the time during the winter months and 7 percent of the time during the summer.

Once the subject site is developed, the site and surrounds are predicted to be generally suitable for walking, standing, or sitting throughout the year, with localised areas within the gaps between buildings and proximate to Building F2's northmost corner and Building A & D's southmost corners that were predicted as uncomfortable during the winter months. The pedestrian level wind velocity safety criteria were exceeded within the gap between Buildings A and B and between Buildings E and F1.

The site was tested with mitigation in place, however additional mitigation is recommended for the above-mentioned corners and gaps between buildings and the Main Residential Entrance to Building H along the north façade. Additional mitigation is also recommended for the Outdoor Amenity Spaces, including the Urban Plaza, Parkland, Open Public Spaces 1, 2, & 3, and the above-grade Outdoor Amenity Spaces in order to achieve conditions that are considered seasonally appropriate for the spaces.

Consideration of proposed surface roughness, such as fine design and landscape features that were too fine to include in the massing model will result in more comfortable conditions than those reported. The relationship between surface roughness and wind is discussed in the Appendix and shown graphically in Figure A of the same section.

The proposed Development will realize wind conditions acceptable to a typical suburban context with inclusion of appropriate mitigation plans.

6. FIGURES

Figure 1: Laboratory Testing Facility

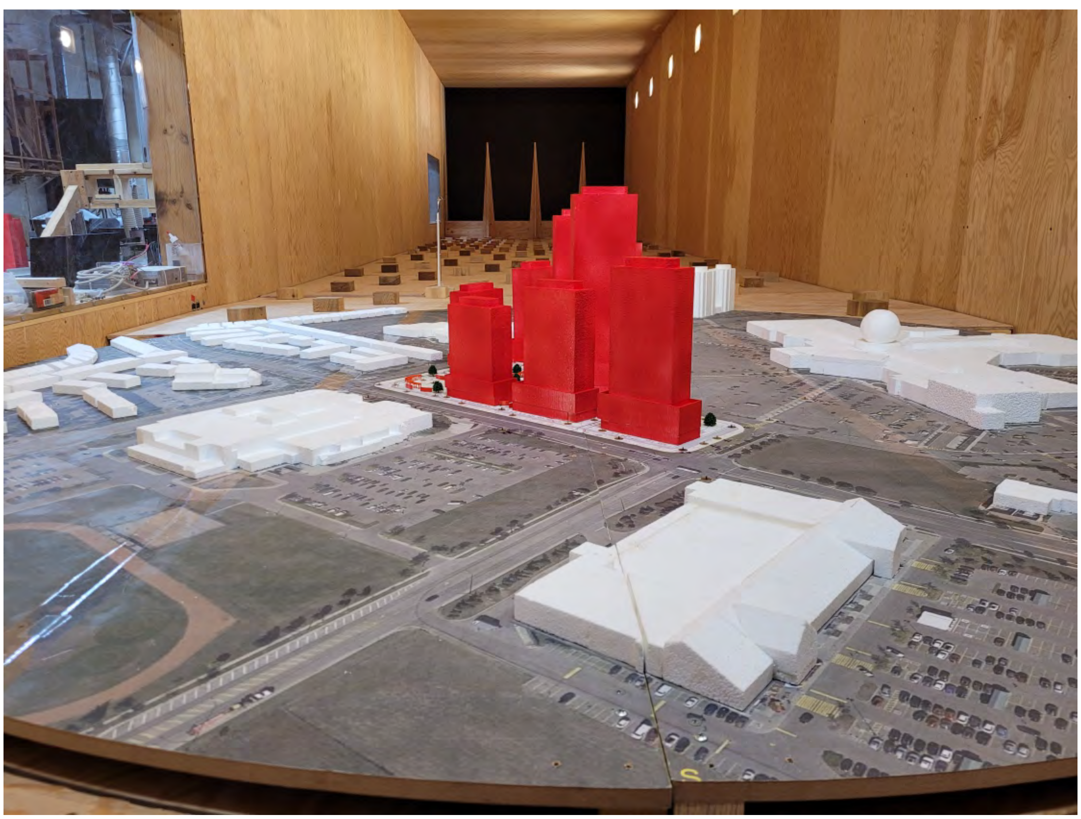


Figure 2a: Site Aerial Photo

Figure 2b: Site Plan

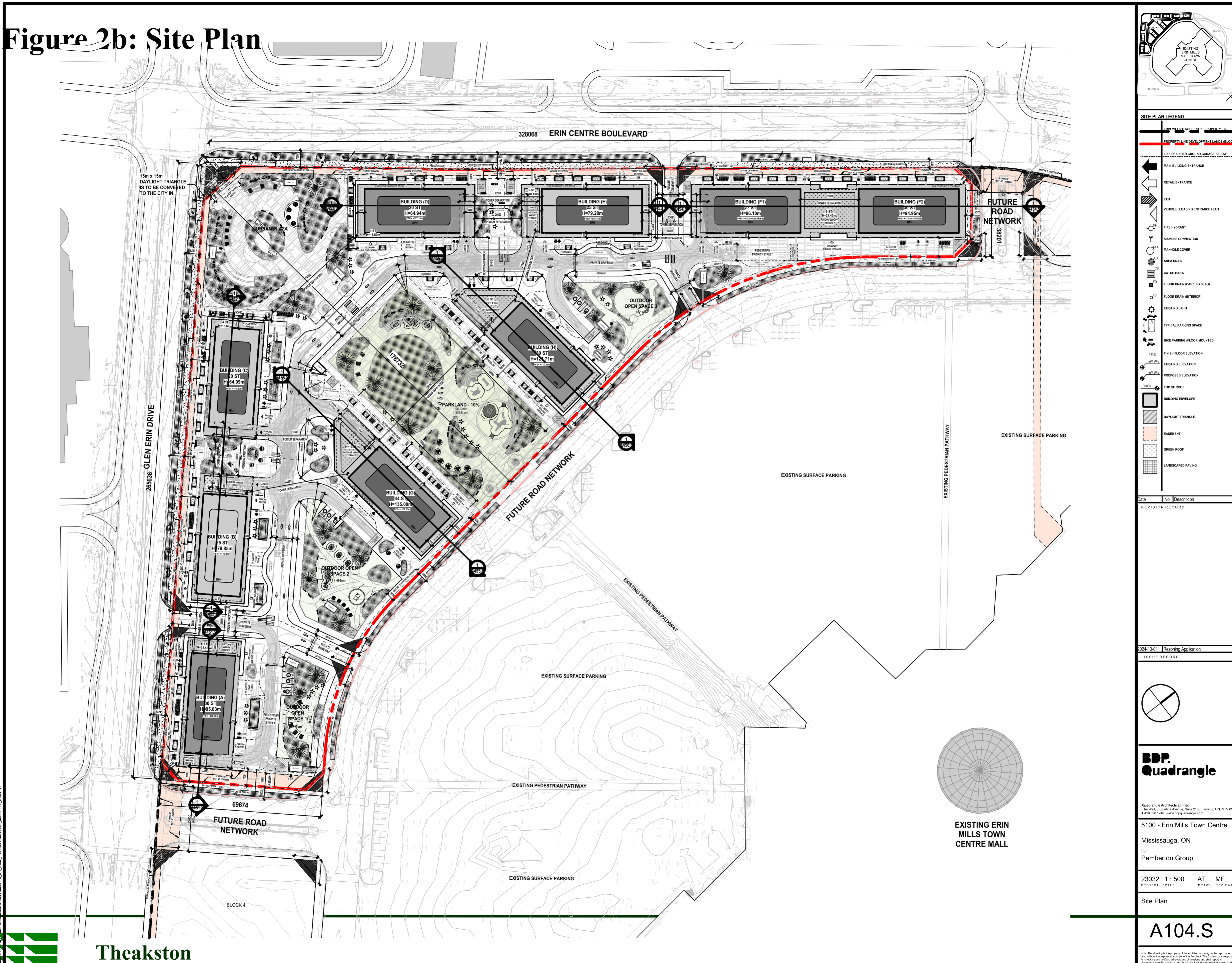
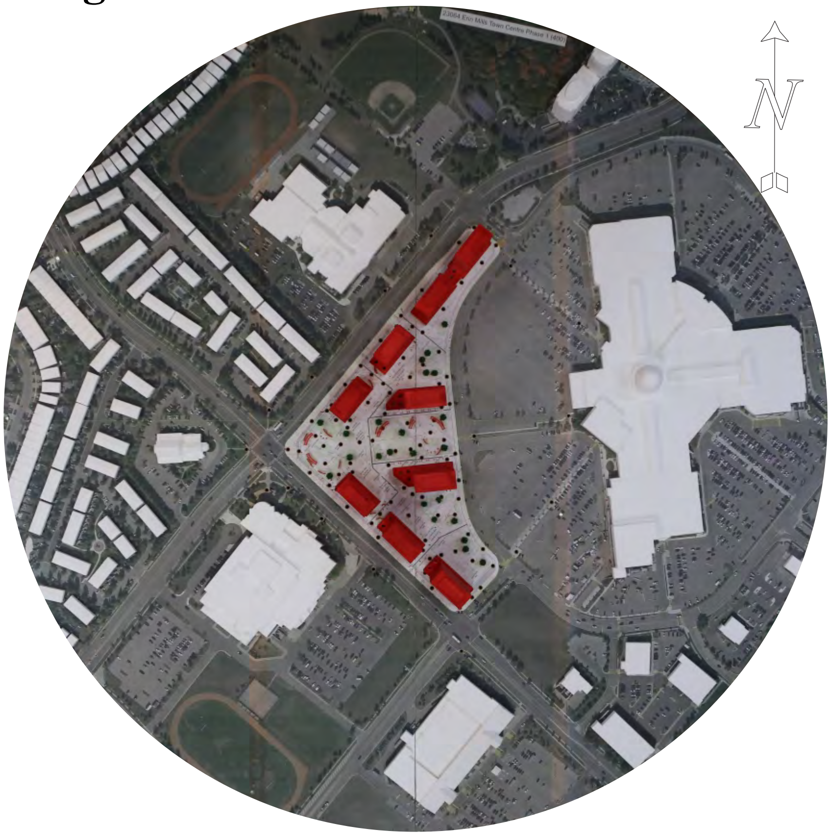
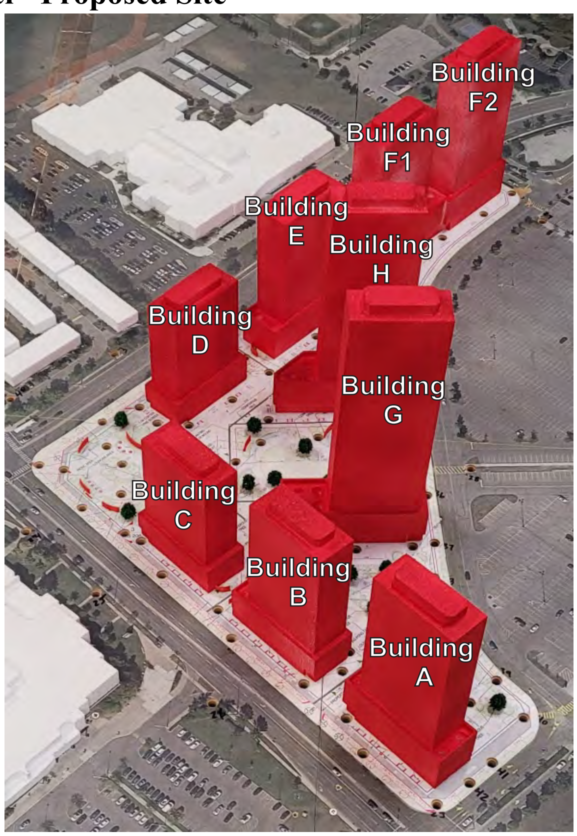


Figure 3: 1:400 Scale Model of Test Site



a) Overall View of Model - Proposed Site

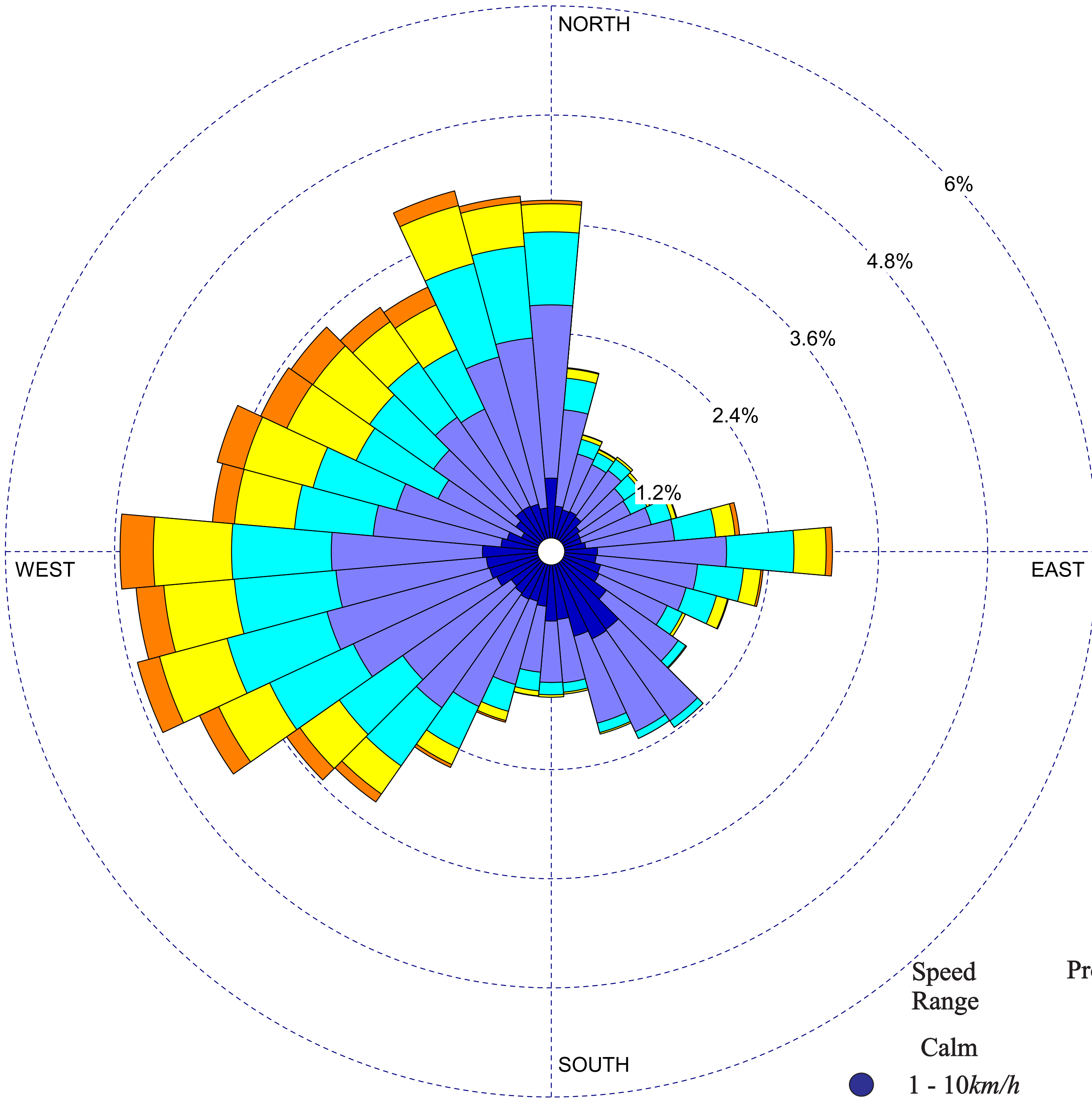


b) Close-Up View of Model - Proposed Site

Figure 4: Location Plan for Pedestrian Level Wind Velocity Measurements

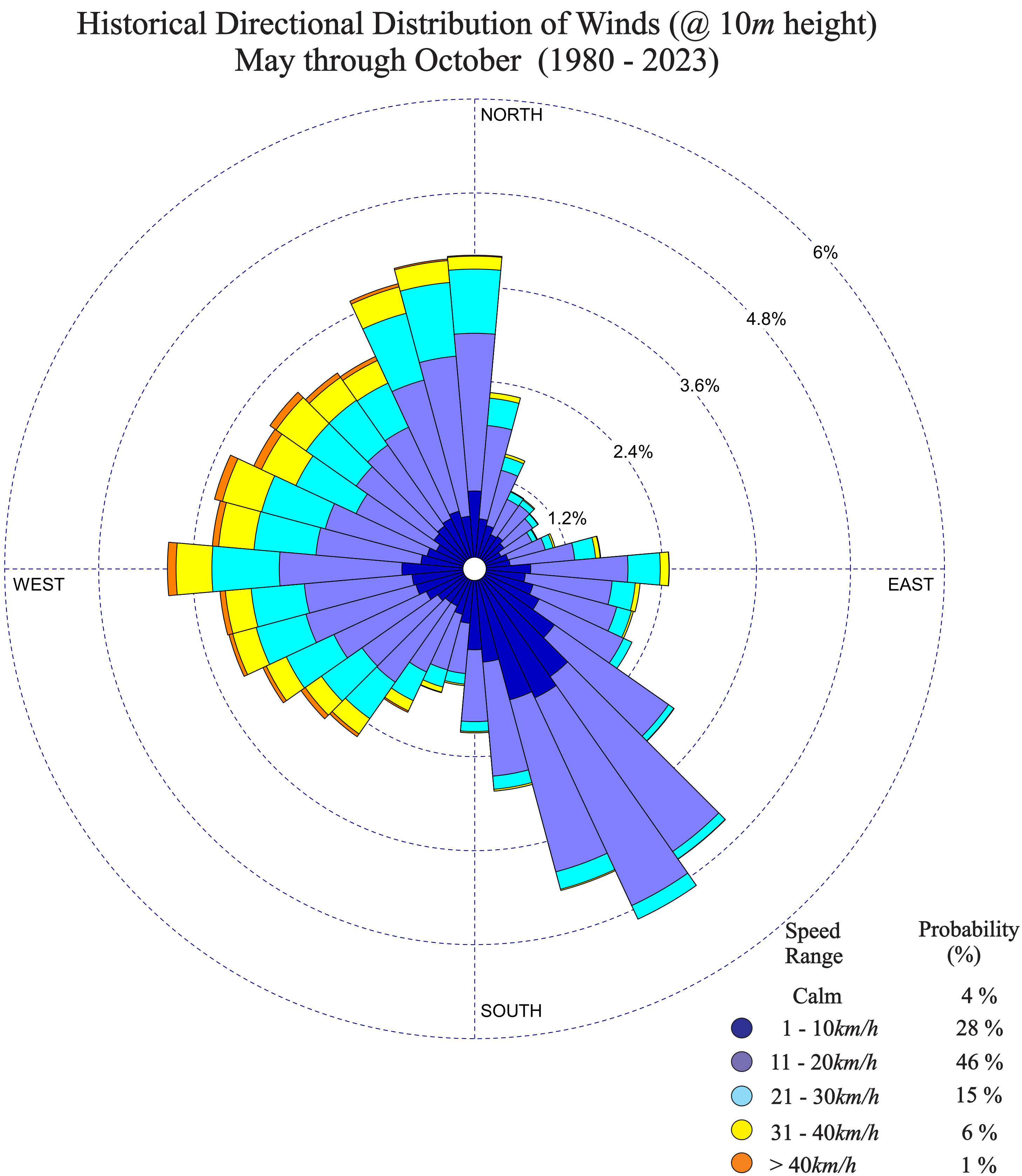
Figure 5a: Winter Wind Rose - Pearson International Airport

Historical Directional Distribution of Winds (@ 10*m* height)
November through April (1980 - 2023)



Speed Range	Probability (%)
Calm	3 %
1 - 10*km/h*	21 %
11 - 20*km/h*	42 %
21 - 30*km/h*	19 %
31 - 40*km/h*	11 %
> 40*km/h*	4 %

Figure 5b: Summer Wind Rose - Pearson International Airport



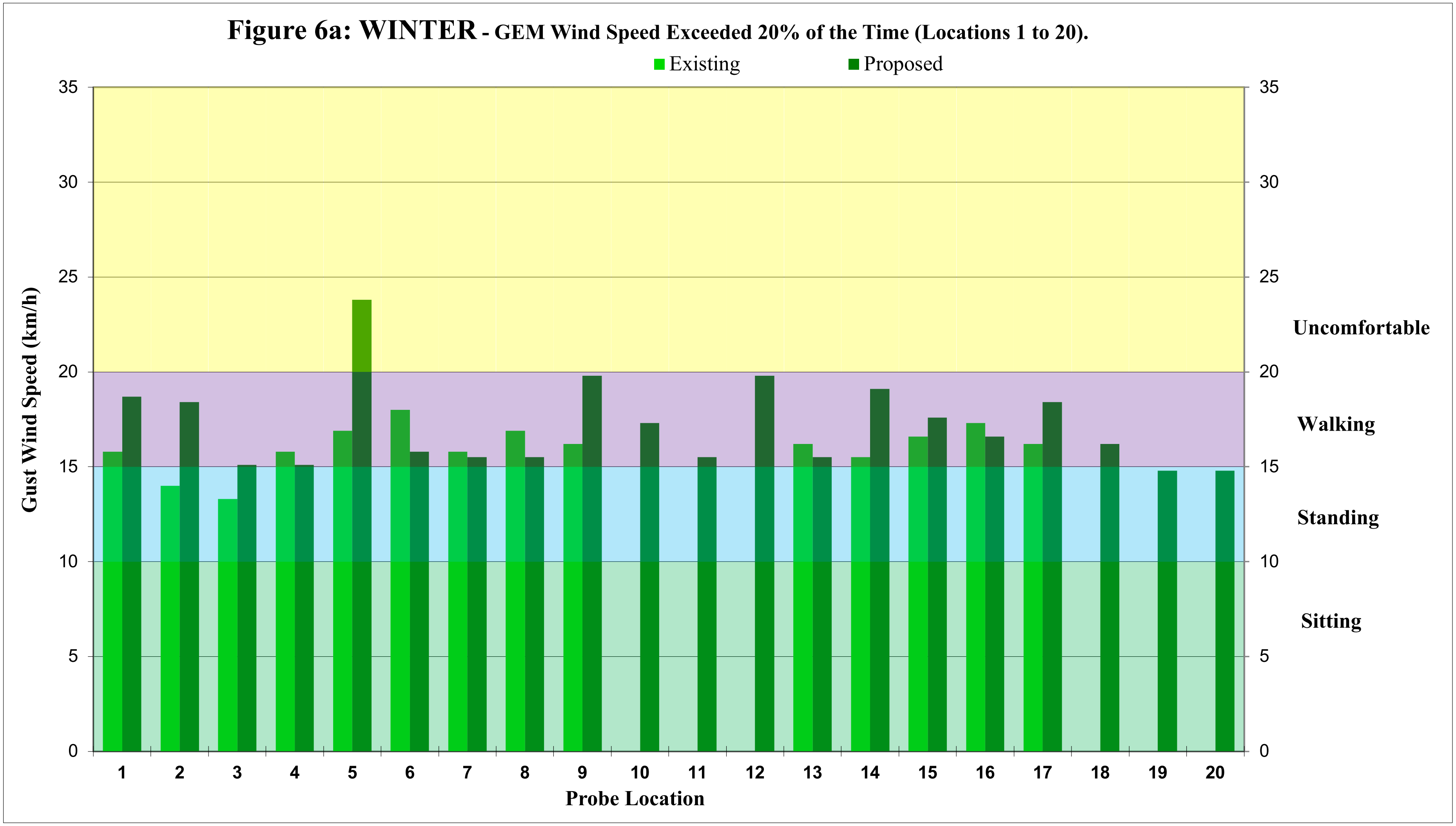


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Gust Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting

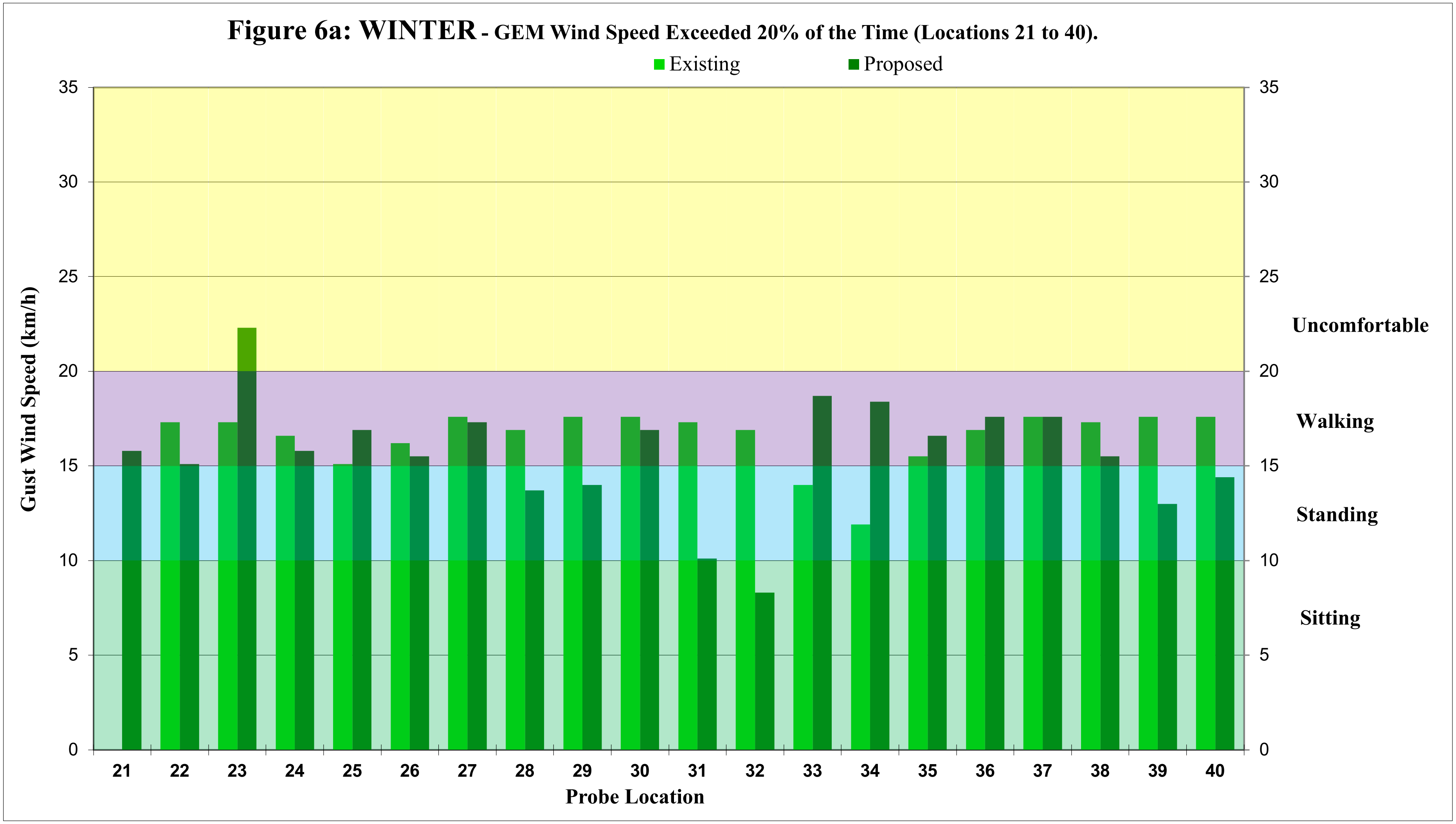


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
Gust Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting

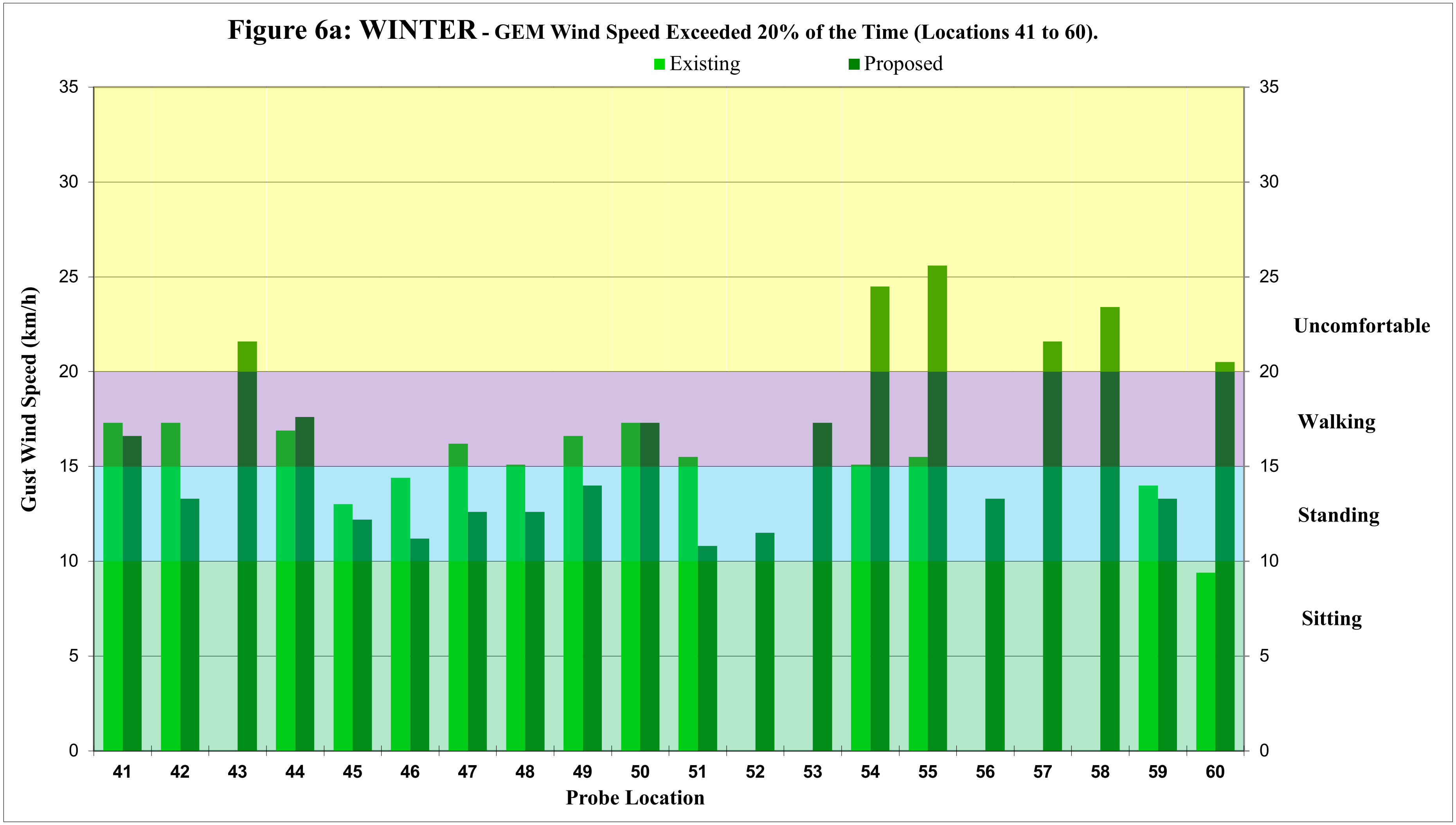


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 41 to 60).
Existing
Proposed
Gust Wind Speed (km/h)
0
5
10
15
20
25
30
35
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Probe Location
Uncomfortable
Walking
Standing
Sitting

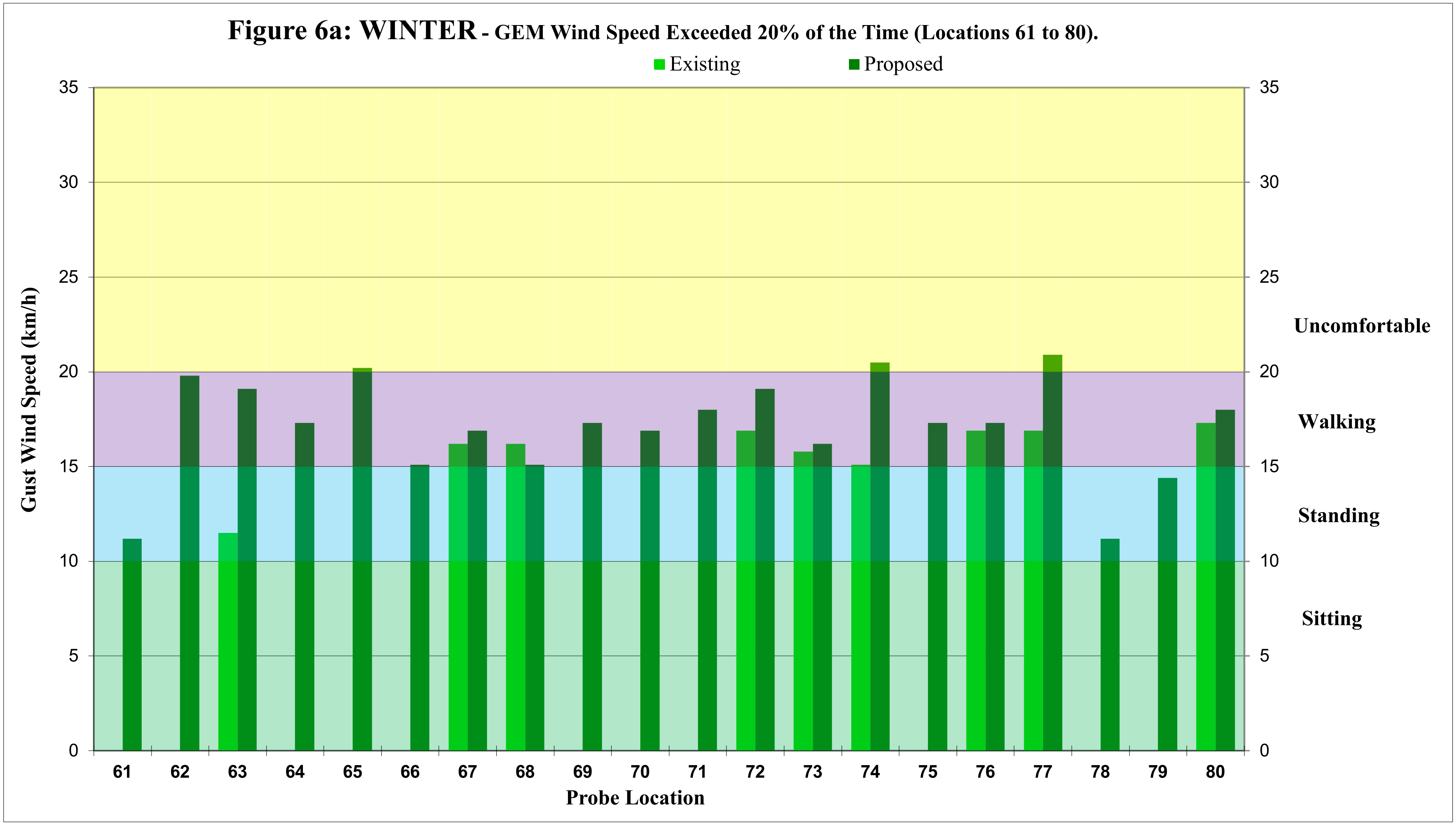


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 61 to 80).
Existing
Proposed
Gust Wind Speed (km/h)
Probe Location
0
5
10
15
20
25
30
35
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
Uncomfortable
Walking
Standing
Sitting

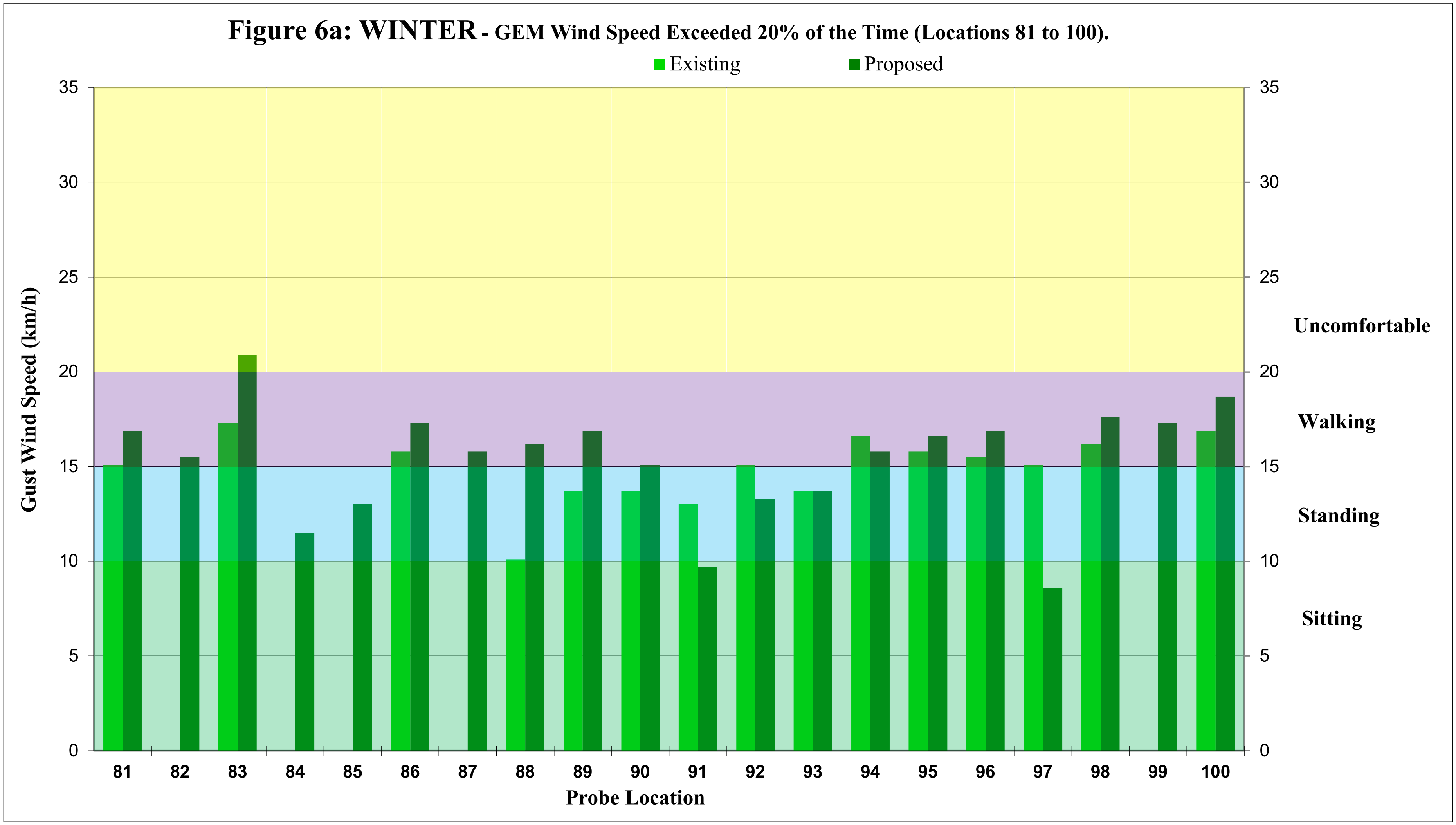
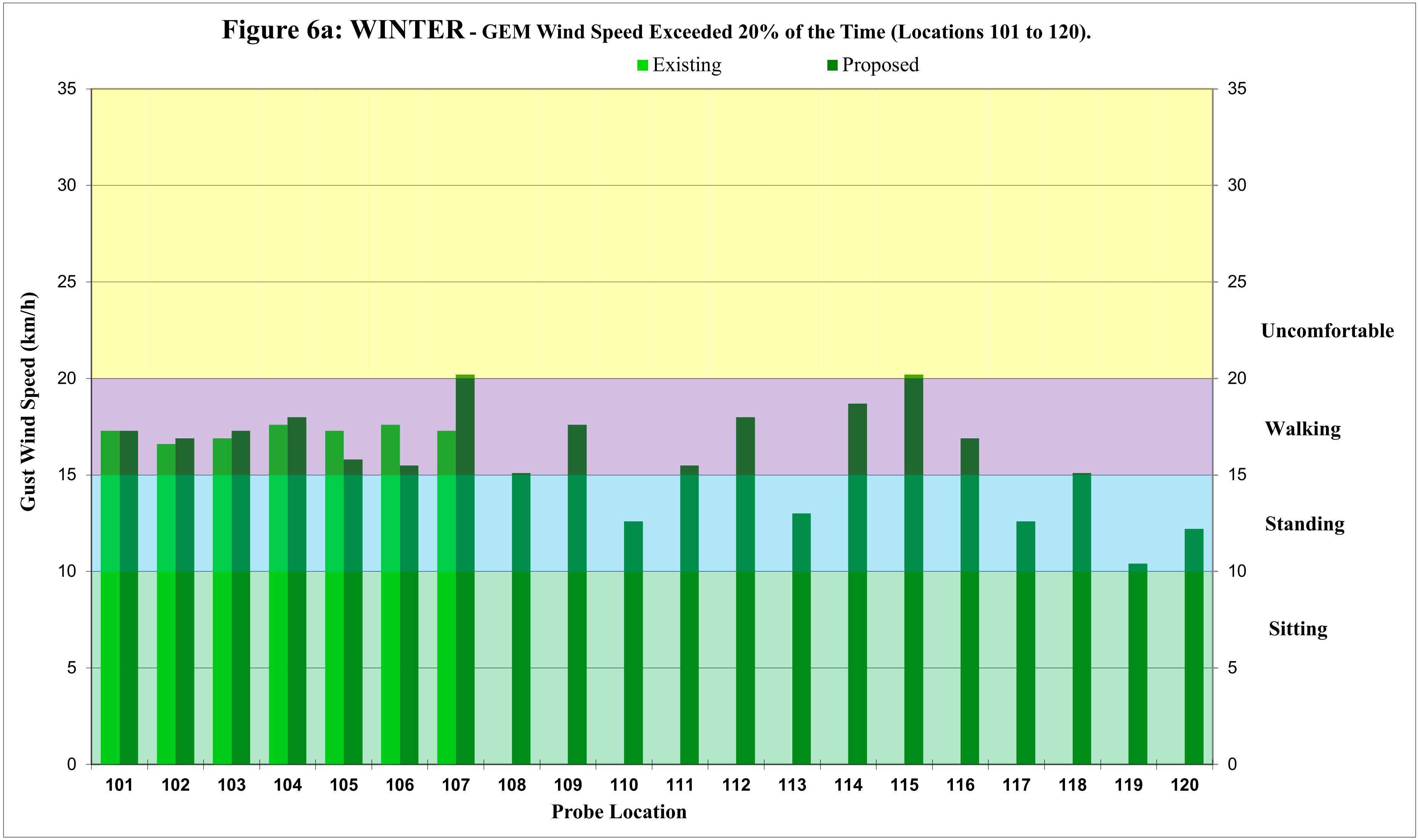
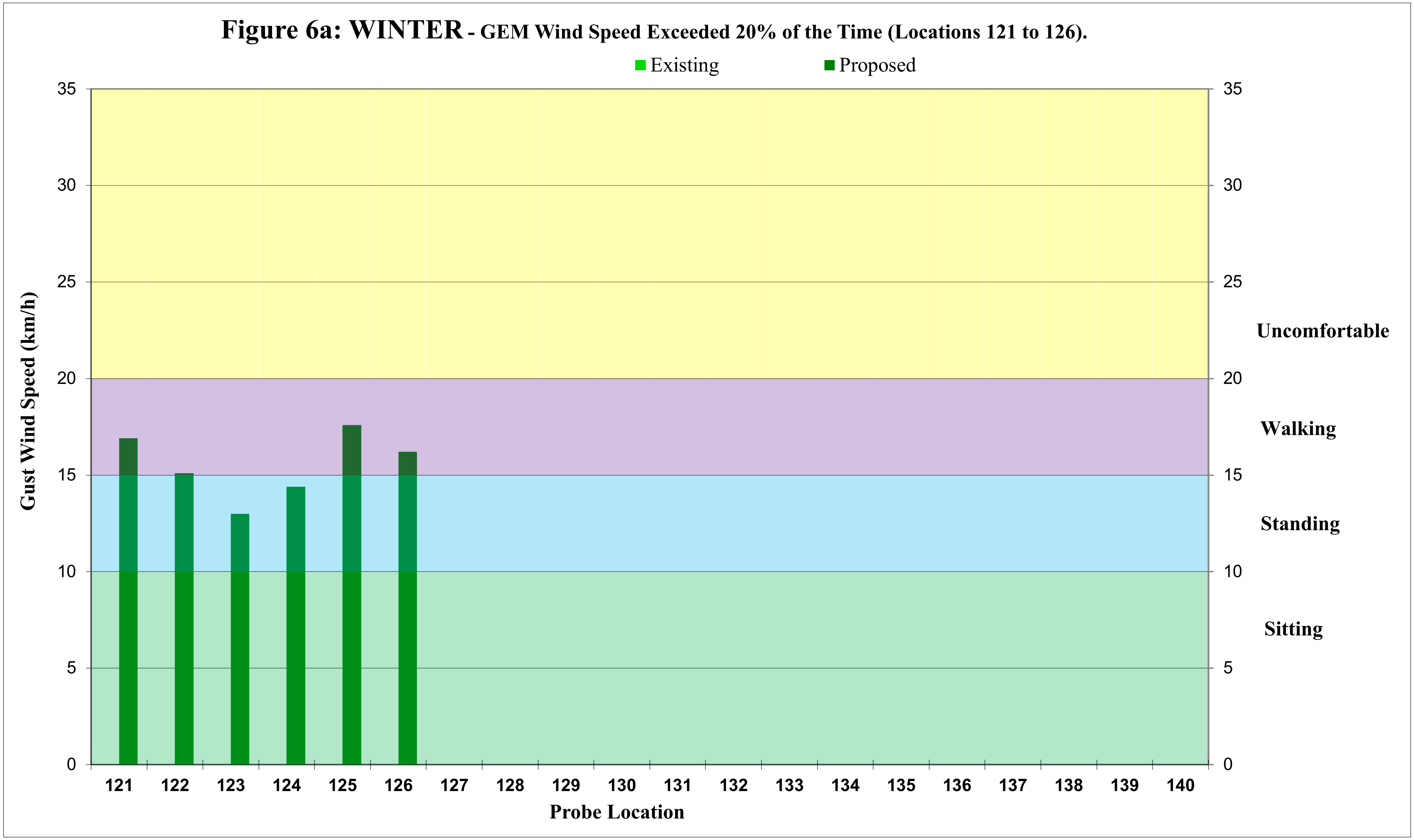


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 81 to 100).
Existing
Proposed
Gust Wind Speed (km/h)
35
30
25
20
15
10
5
0
Uncomfortable
Walking
Standing
Sitting
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
Probe Location



Theakston Environmental



Theakston Environmental

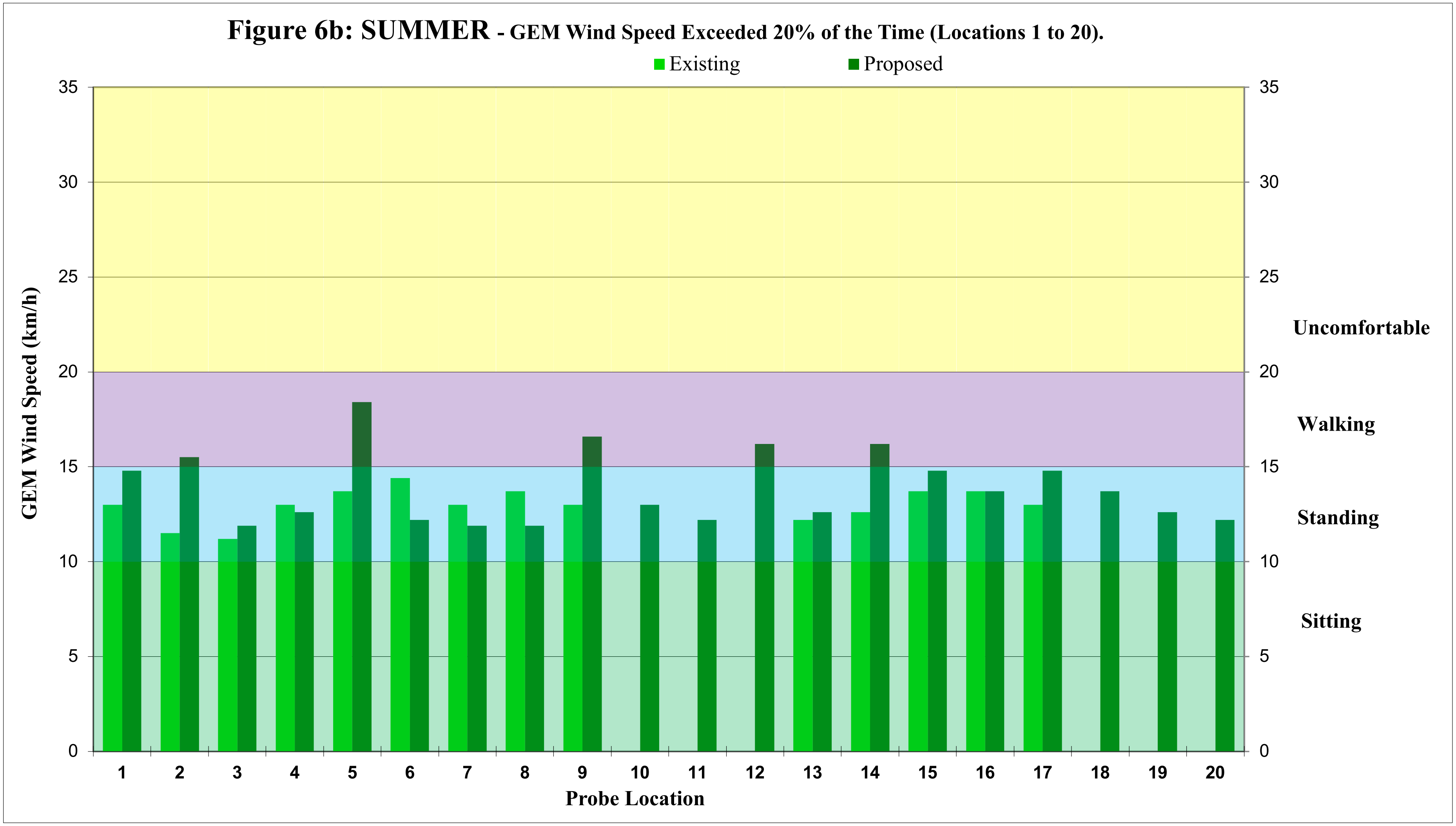


Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
GEM Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

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

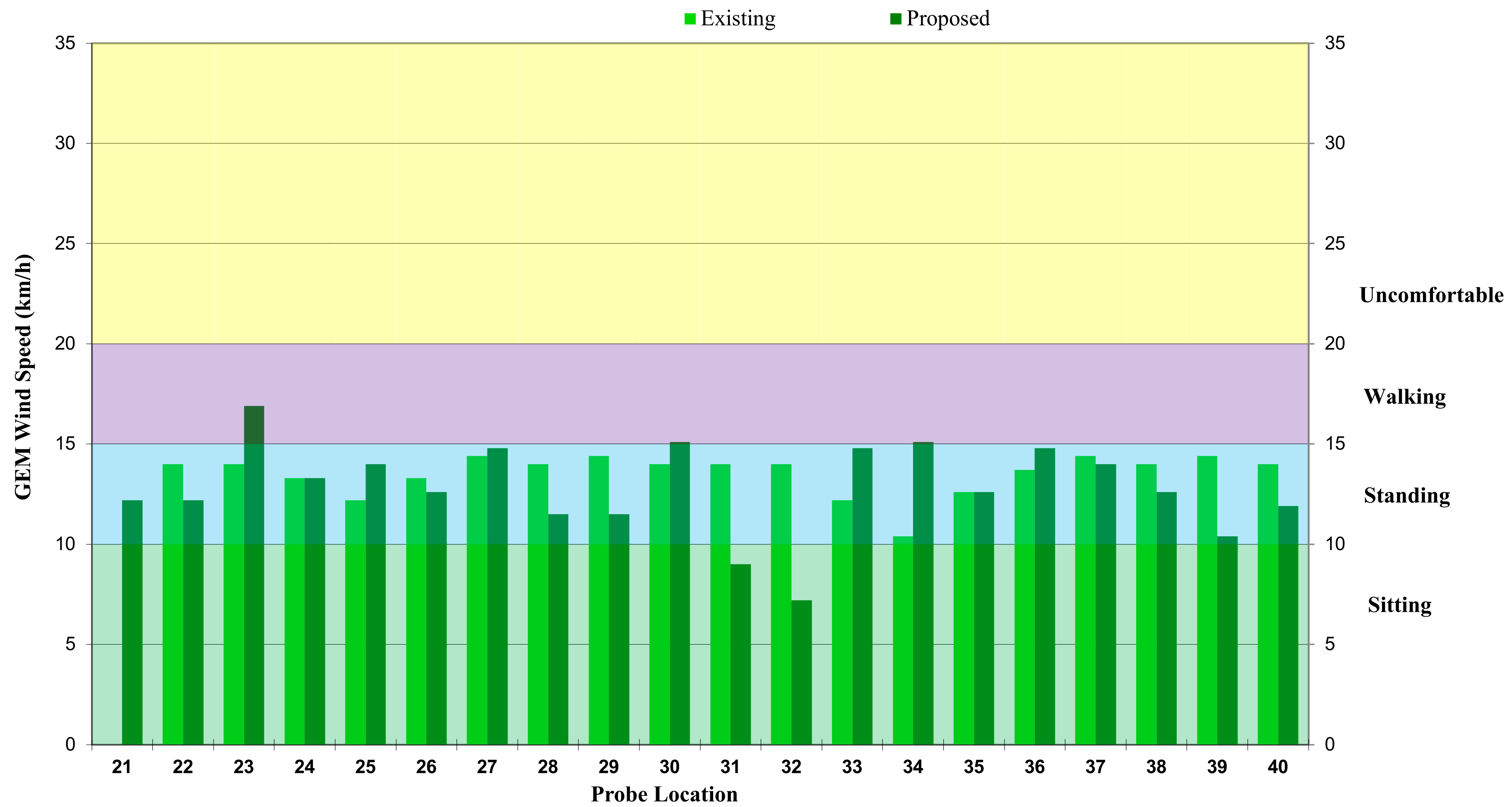
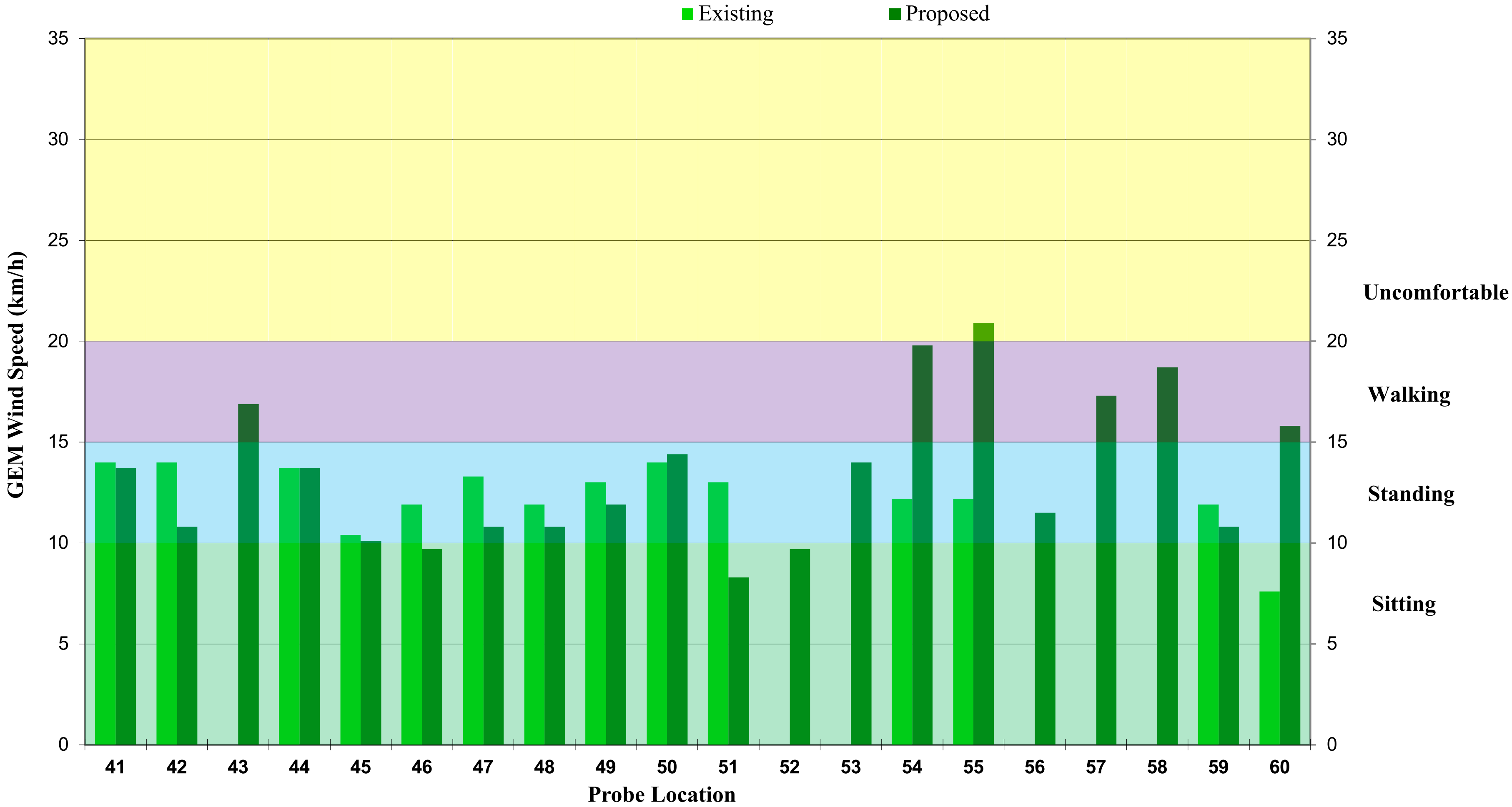


Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 41 to 60).



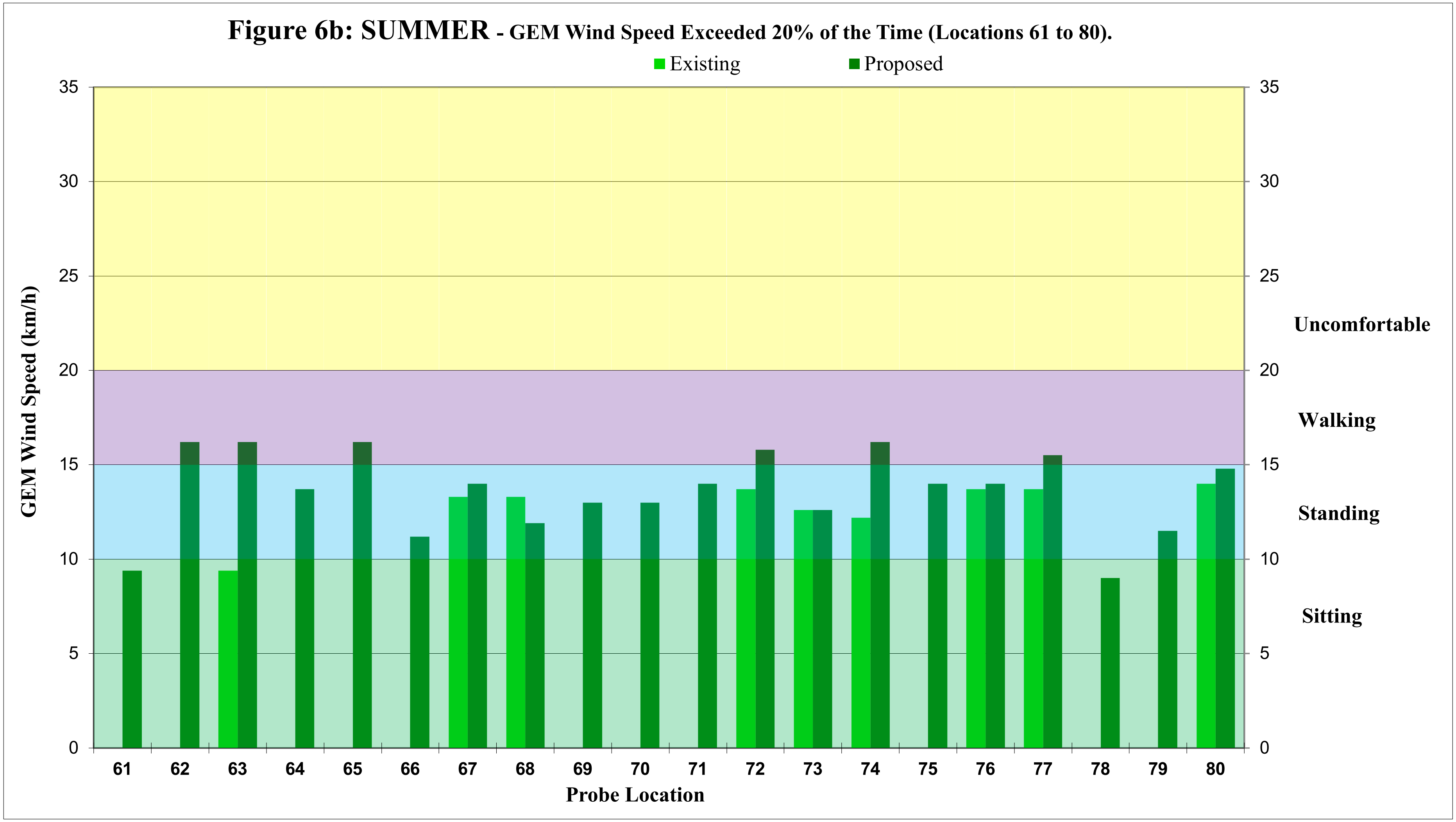


Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 61 to 80).
Existing
Proposed
GEM Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting

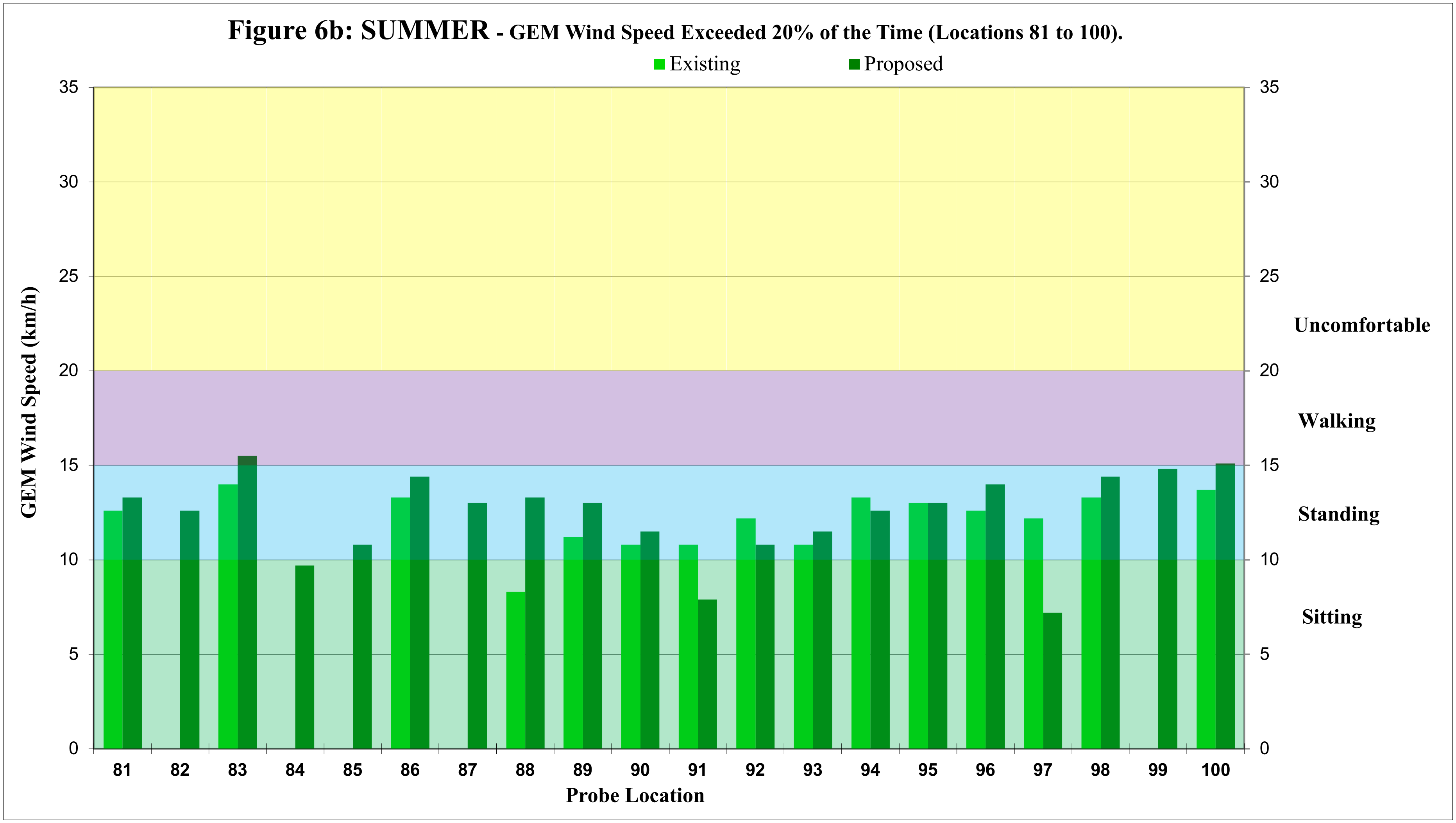
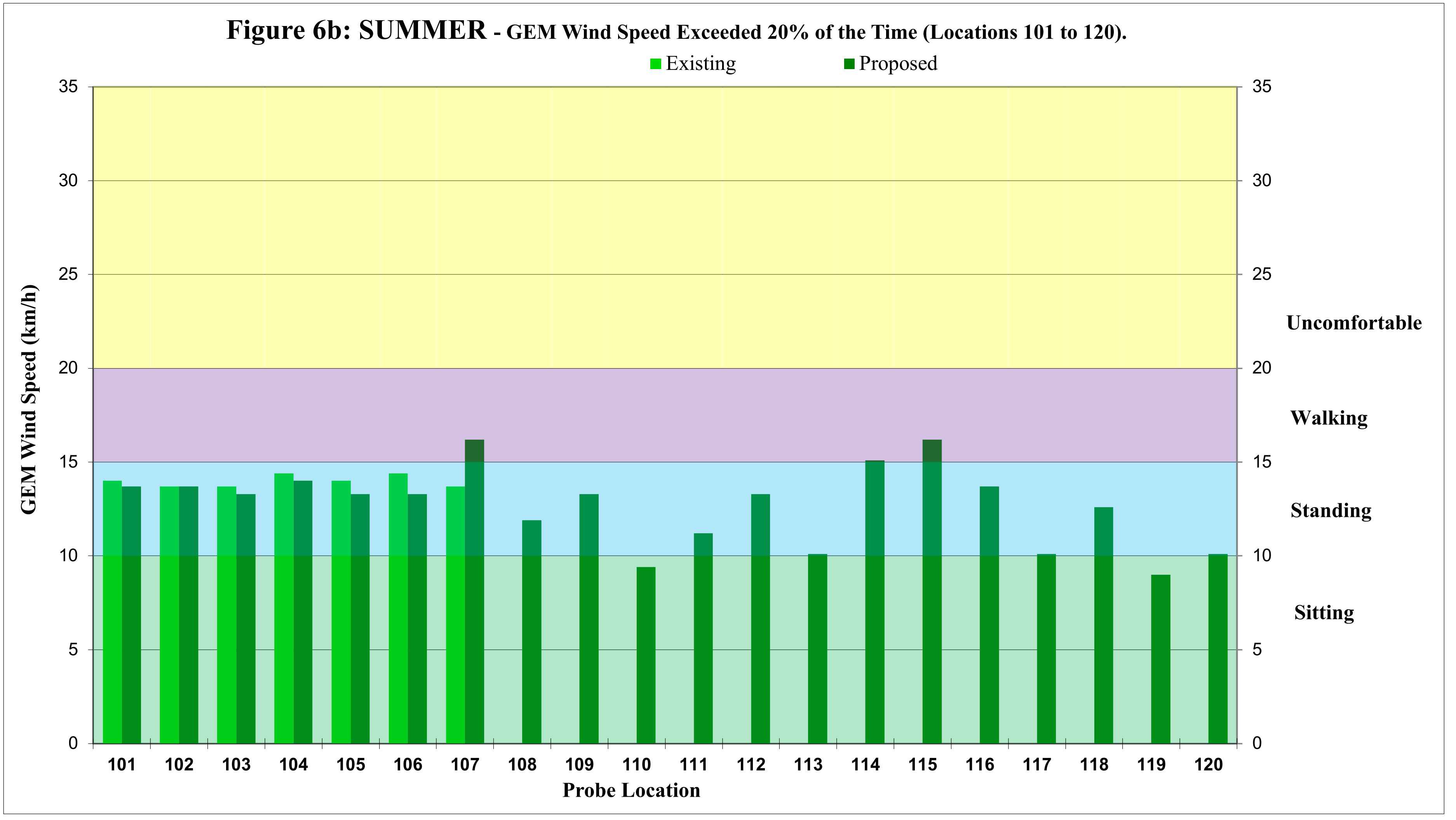


Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 81 to 100).
Existing
Proposed
GEM Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100



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Environmental

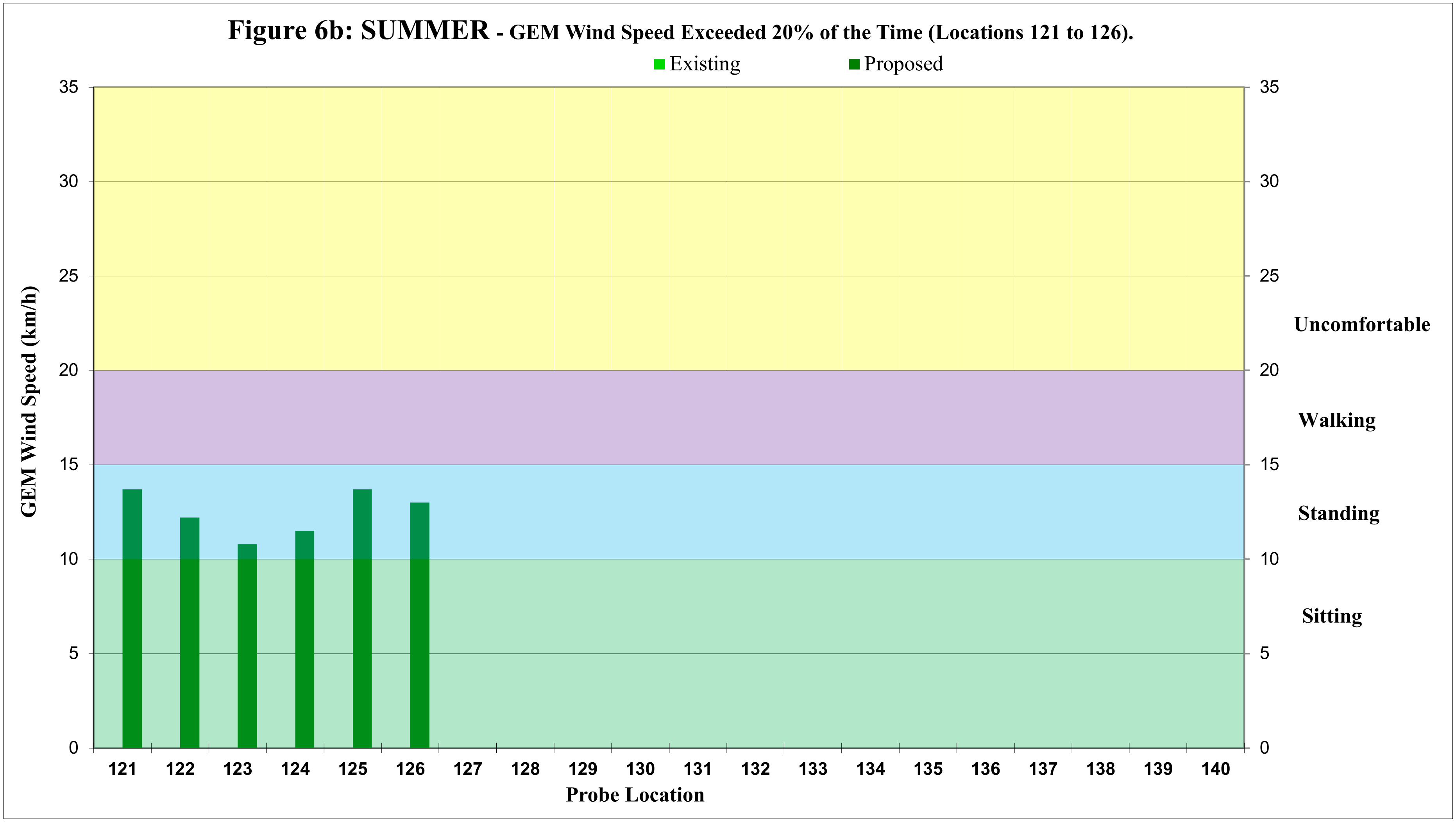
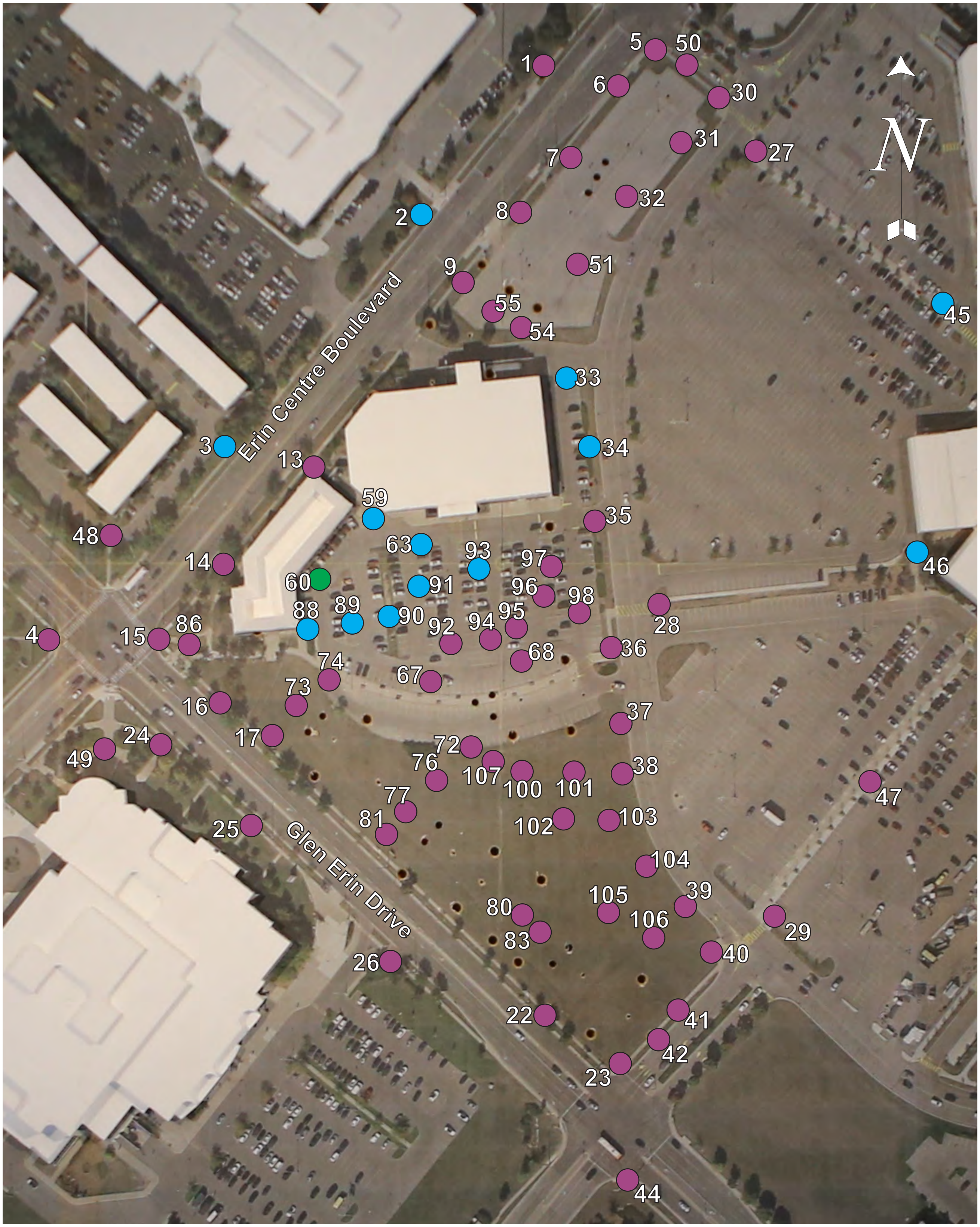


Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 121 to 126).
Existing
Proposed
GEM Wind Speed (km/h)
35
30
25
20
15
10
5
0
Uncomfortable
Walking
Standing
Sitting
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
Probe Location

Figure 7a: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Winter - Existing

Sitting Standing Walking Uncomfortable

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

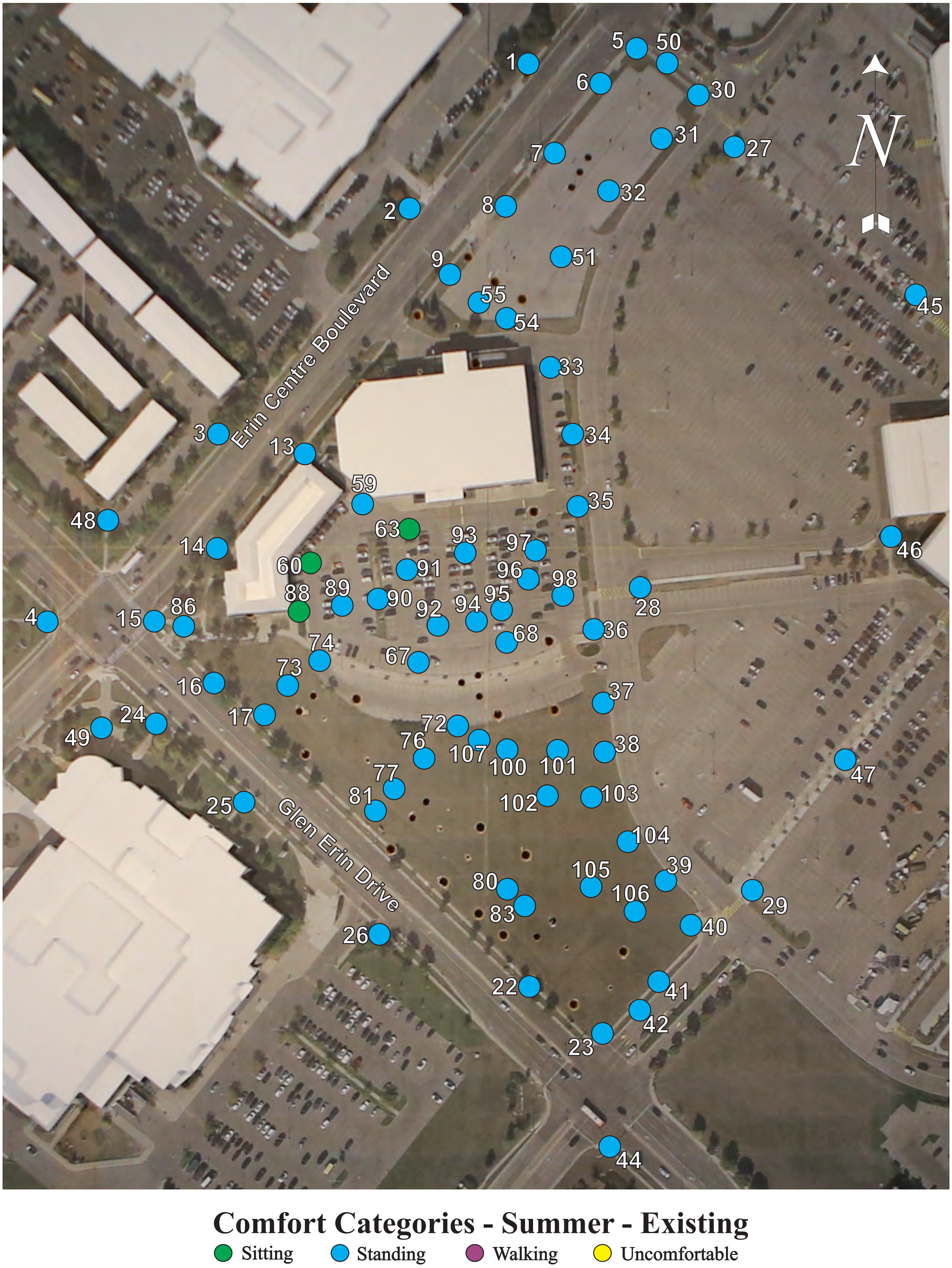

Figure 7d: Pedestrian Level Wind Velocity Comfort Categories

Comfort Categories - Summer - Proposed

Sitting Standing Walking Uncomfortable

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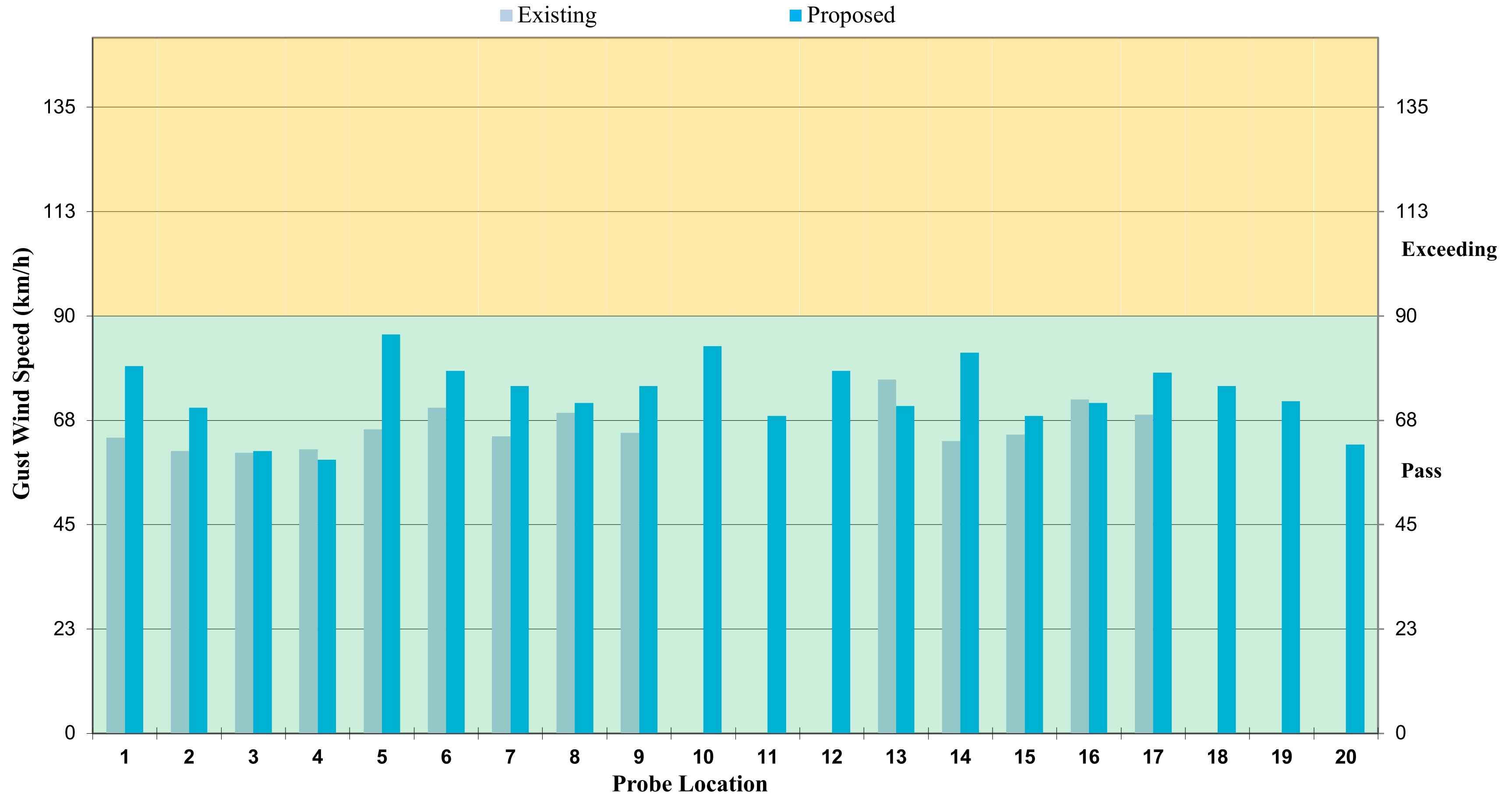
Environmental

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



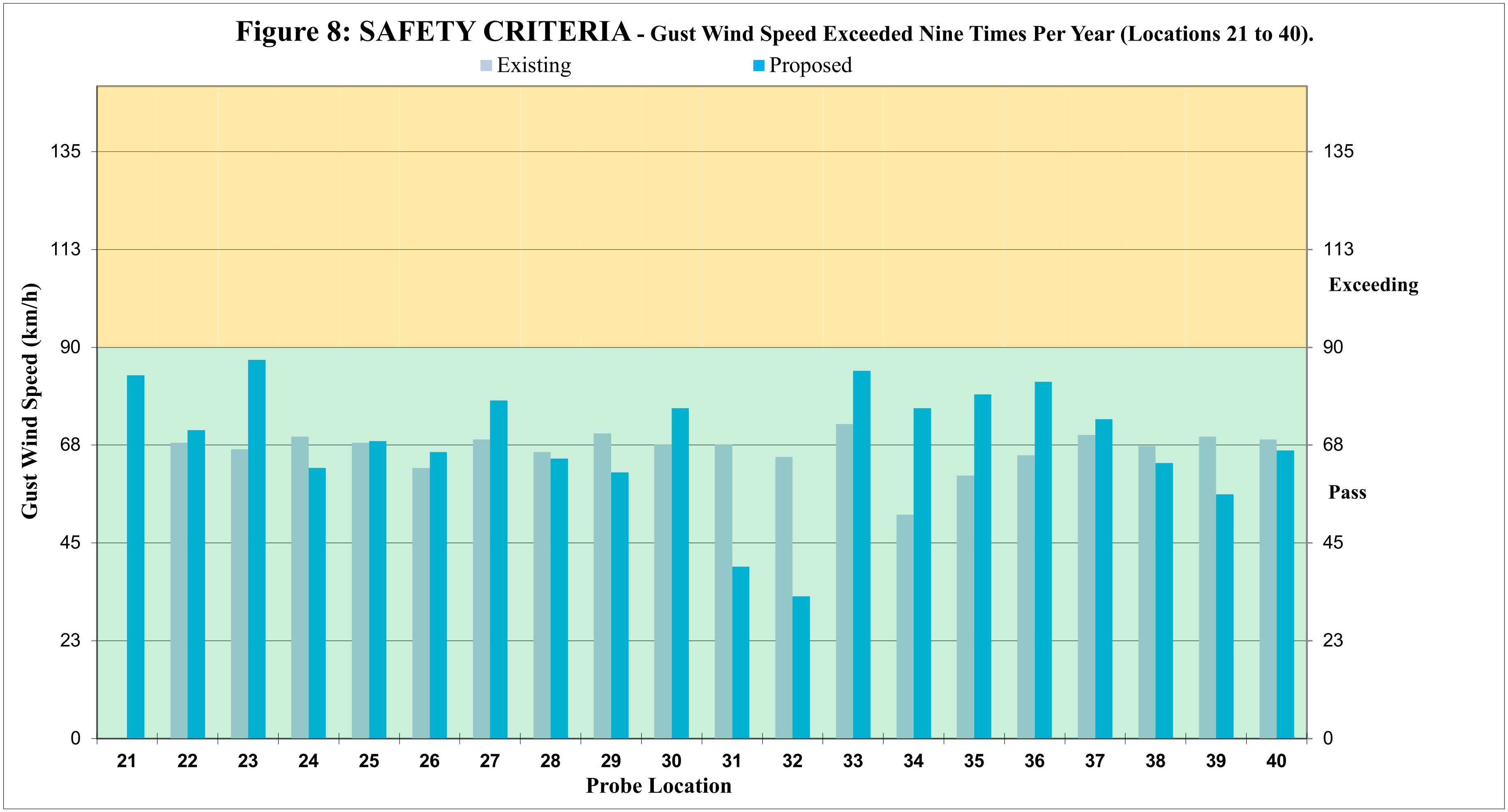
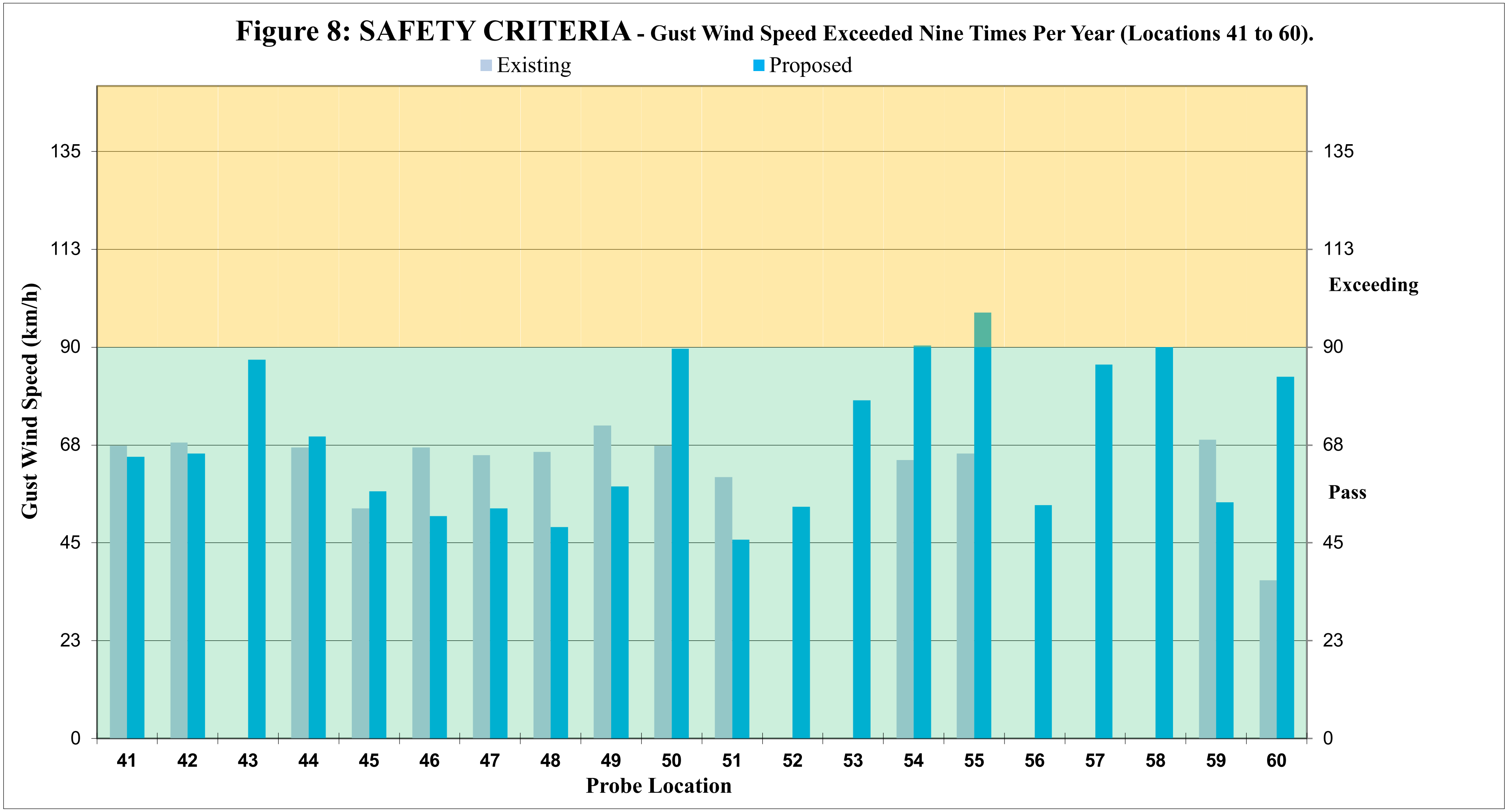


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 21 to 40).
Existing
Proposed
Gust Wind Speed (km/h)
0
23
45
68
90
113
135
Exceeding
Pass
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location



Theakston
Environmental

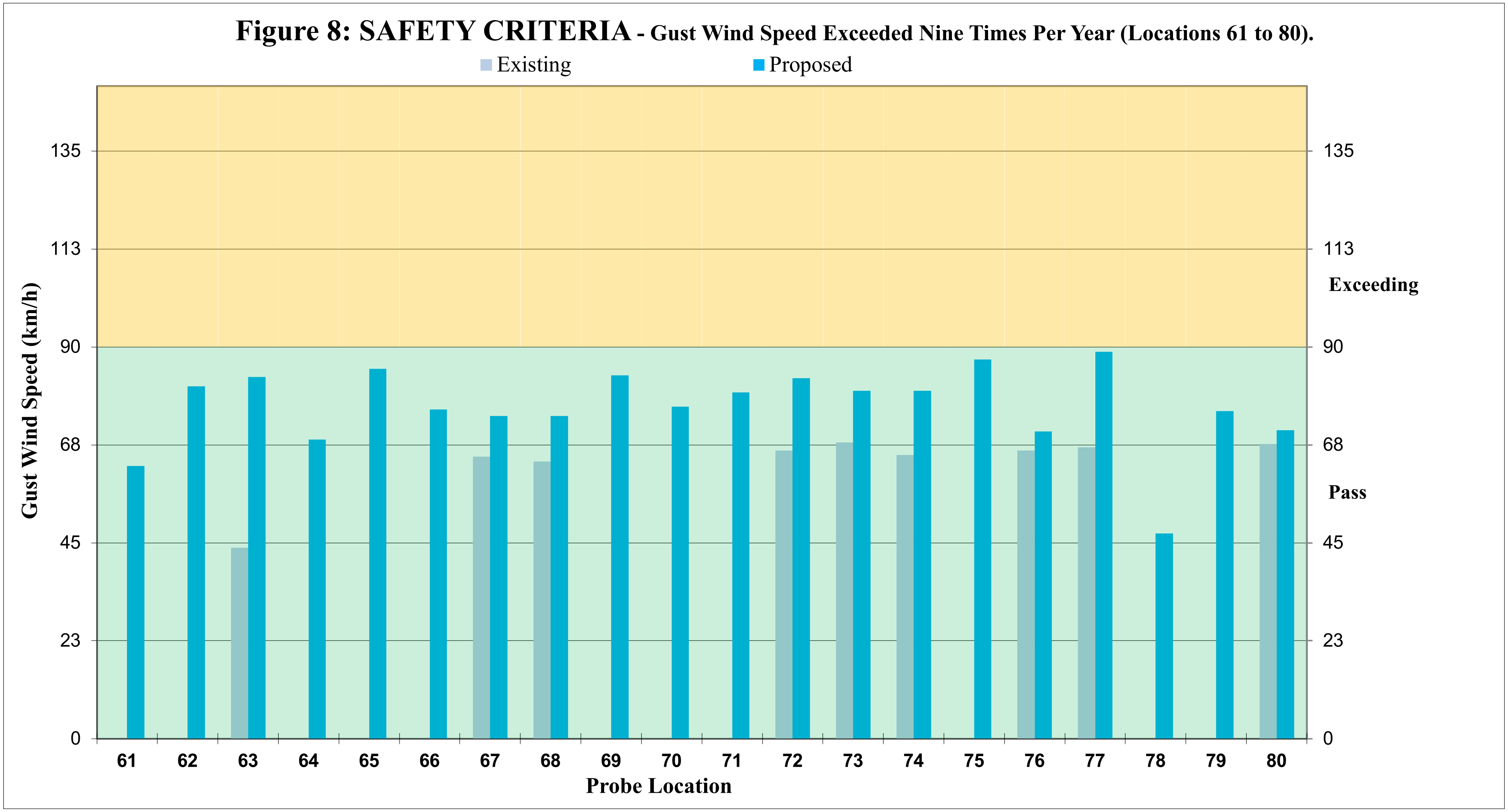
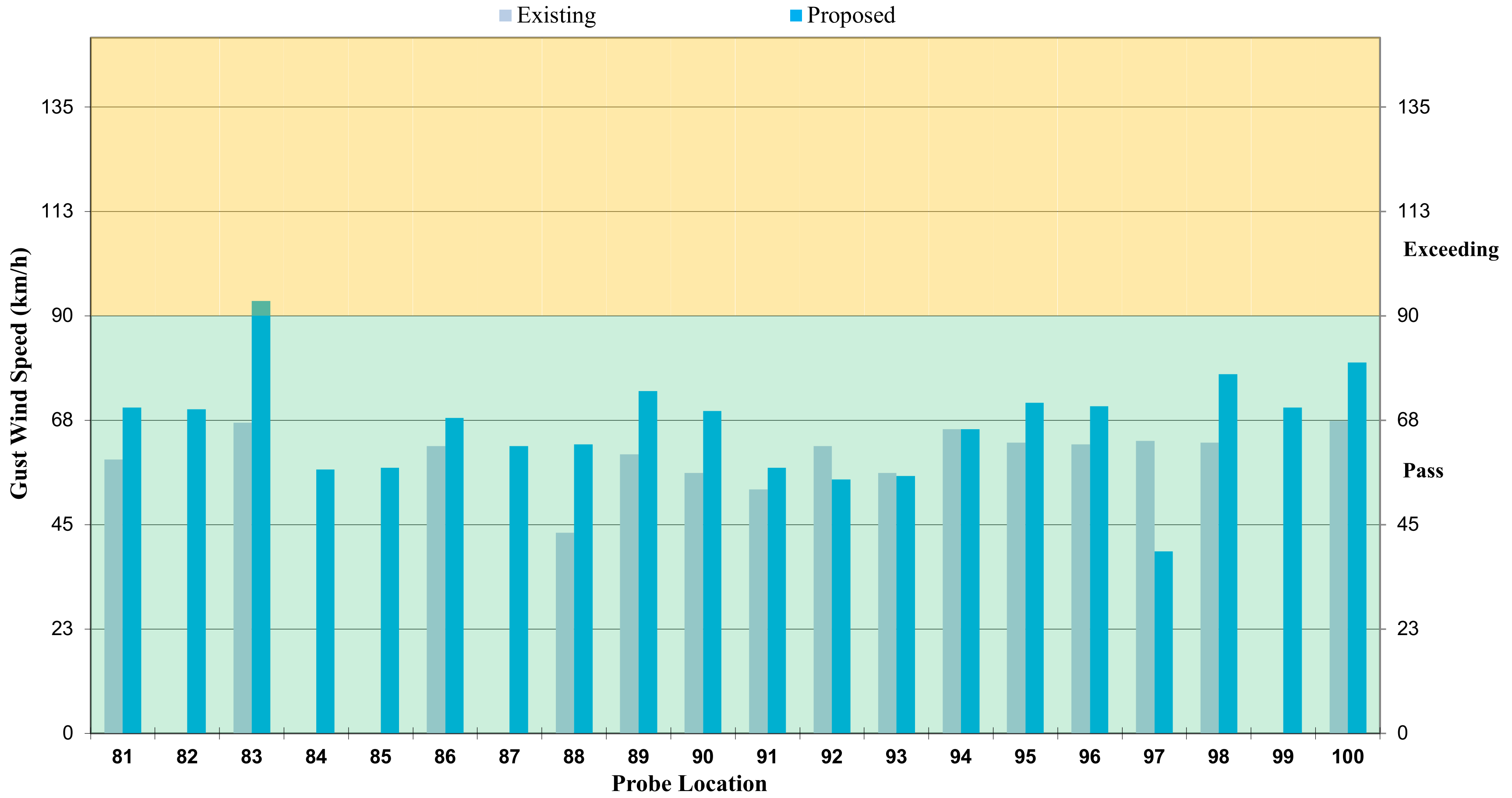


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 61 to 80).
Existing
Proposed
Gust Wind Speed (km/h)
135
113
90
68
45
23
0
Exceeding
Pass
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
Probe Location

Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 81 to 100).



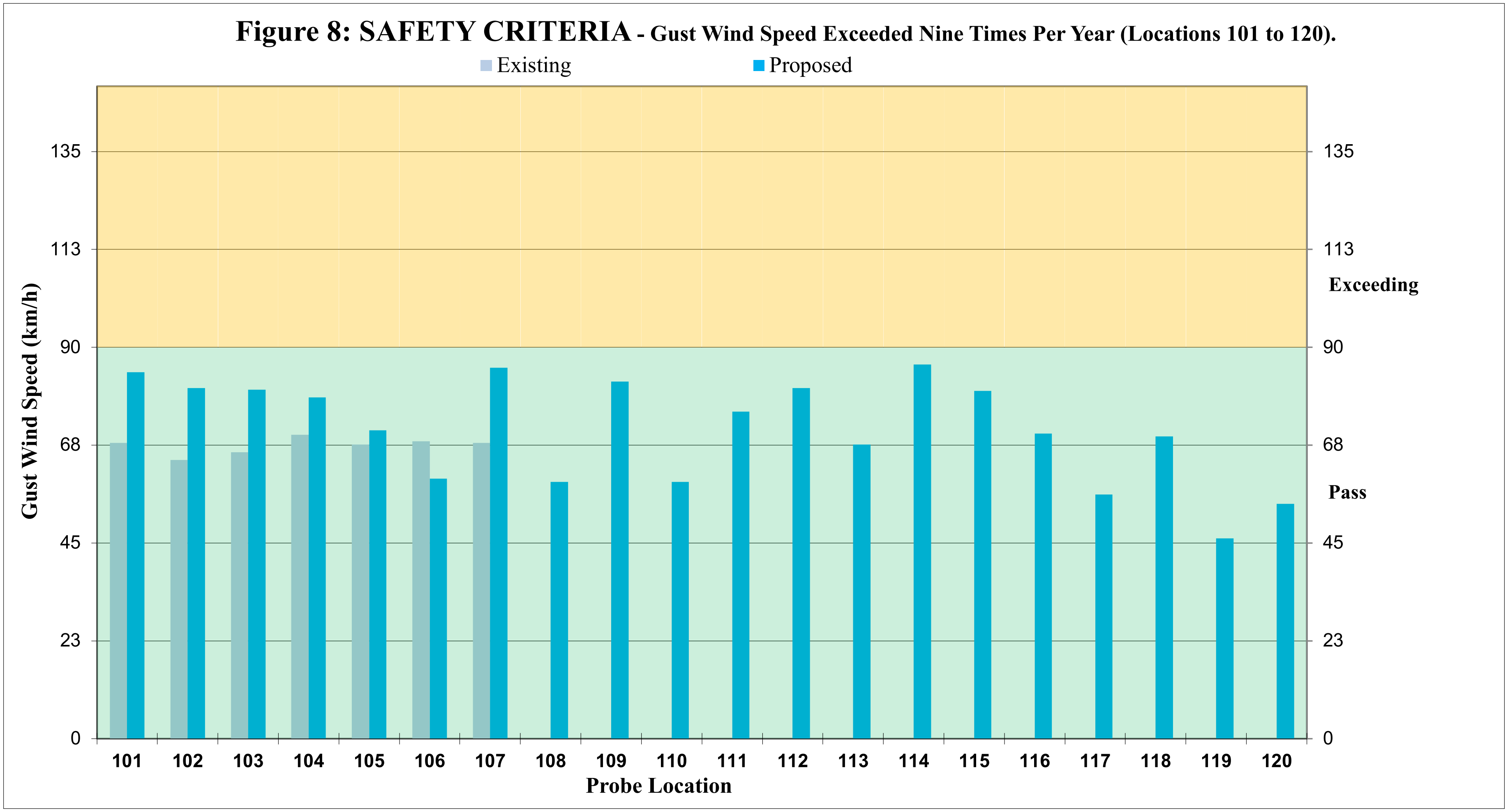


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 101 to 120).
Existing
Proposed
Gust Wind Speed (km/h)
135
113
90
68
45
23
0
Exceeding
Pass
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
Probe Location

Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 121 to 126).

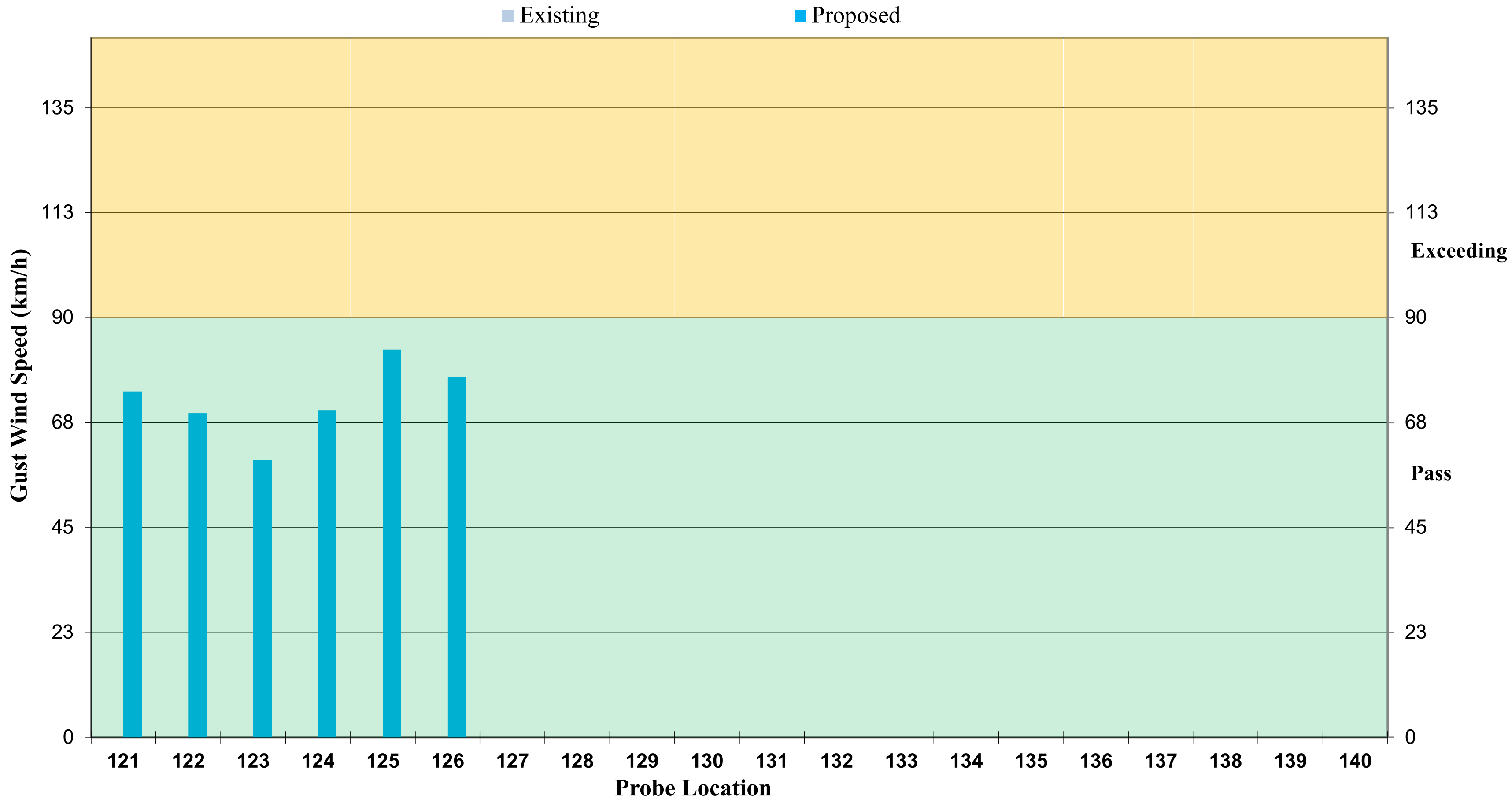
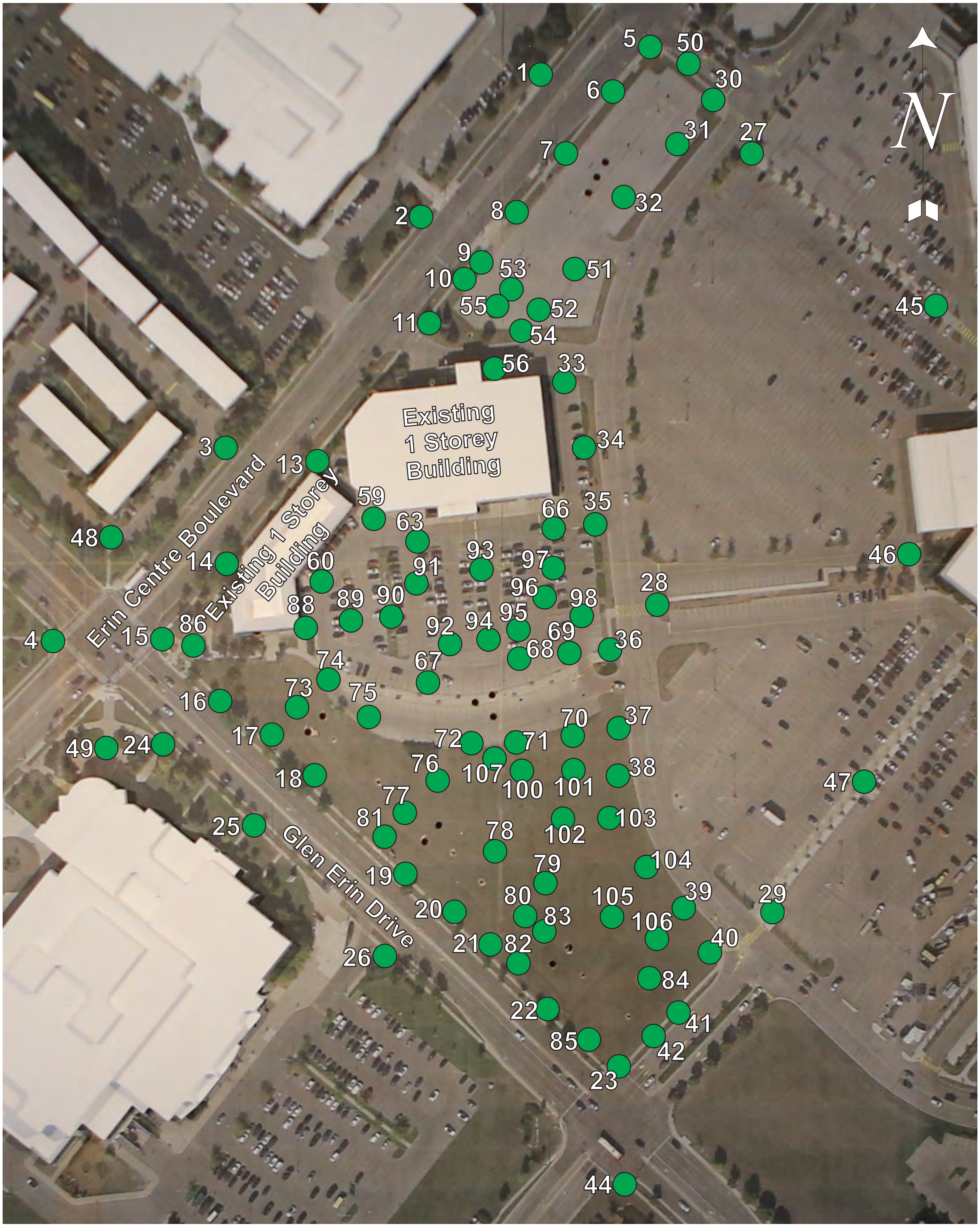


Figure 9a: Pedestrian Level Wind Velocity Safety Criteria



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	15.8	18.7	13.0	14.8	63.7	79.2
2	14.0	18.4	11.5	15.5	60.8	70.2
3	13.3	15.1	11.2	11.9	60.5	60.8
4	15.8	15.1	13.0	12.6	61.2	59.0
5	16.9	23.8	13.7	18.4	65.5	86.0
6	18.0	15.8	14.4	12.2	70.2	78.1
7	15.8	15.5	13.0	11.9	64.1	74.9
8	16.9	15.5	13.7	11.9	69.1	71.3
9	16.2	19.8	13.0	16.6	64.8	74.9
10	0.0	17.3	0.0	13.0	0.0	83.5
11	0.0	15.5	0.0	12.2	0.0	68.4
12	0.0	19.8	0.0	16.2	0.0	78.1
13	16.2	15.5	12.2	12.6	76.3	70.6
14	15.5	19.1	12.6	16.2	63.0	82.1
15	16.6	17.6	13.7	14.8	64.4	68.4
16	17.3	16.6	13.7	13.7	72.0	71.3
17	16.2	18.4	13.0	14.8	68.8	77.8
18	0.0	16.2	0.0	13.7	0.0	74.9
19	0.0	14.8	0.0	12.6	0.0	71.6
20	0.0	14.8	0.0	12.2	0.0	62.3
21	0.0	15.8	0.0	12.2	0.0	83.5
22	17.3	15.1	14.0	12.2	68.0	70.9
23	17.3	22.3	14.0	16.9	66.6	87.1
24	16.6	15.8	13.3	13.3	69.5	62.3
25	15.1	16.9	12.2	14.0	68.0	68.4
26	16.2	15.5	13.3	12.6	62.3	65.9
27	17.6	17.3	14.4	14.8	68.8	77.8
28	16.9	13.7	14.0	11.5	65.9	64.4
29	17.6	14.0	14.4	11.5	70.2	61.2
30	17.6	16.9	14.0	15.1	67.7	76.0
31	17.3	10.1	14.0	9.0	67.7	39.6
32	16.9	8.3	14.0	7.2	64.8	32.8
33	14.0	18.7	12.2	14.8	72.4	84.6
34	11.9	18.4	10.4	15.1	51.5	76.0
35	15.5	16.6	12.6	12.6	60.5	79.2
36	16.9	17.6	13.7	14.8	65.2	82.1
37	17.6	17.6	14.4	14.0	69.8	73.4
38	17.3	15.5	14.0	12.6	67.3	63.4
39	17.6	13.0	14.4	10.4	69.5	56.2
40	17.6	14.4	14.0	11.9	68.8	66.2
41	17.3	16.6	14.0	13.7	67.3	64.8
42	17.3	13.3	14.0	10.8	68.0	65.5
43	0.0	21.6	0.0	16.9	0.0	87.1
44	16.9	17.6	13.7	13.7	67.0	69.5
45	13.0	12.2	10.4	10.1	52.9	56.9
46	14.4	11.2	11.9	9.7	67.0	51.1
47	16.2	12.6	13.3	10.8	65.2	52.9
48	15.1	12.6	11.9	10.8	65.9	48.6
49	16.6	14.0	13.0	11.9	72.0	58.0
50	17.3	17.3	14.0	14.4	67.3	89.6
51	15.5	10.8	13.0	8.3	60.1	45.7
52	0.0	11.5	0.0	9.7	0.0	53.3
53	0.0	17.3	0.0	14.0	0.0	77.8
54	15.1	24.5	12.2	19.8	64.1	90.4
55	15.5	25.6	12.2	20.9	65.5	97.9
56	0.0	13.3	0.0	11.5	0.0	53.6
57	0.0	21.6	0.0	17.3	0.0	86.0
58	0.0	23.4	0.0	18.7	0.0	90.0
59	14.0	13.3	11.9	10.8	68.8	54.4
60	9.4	20.5	7.6	15.8	36.4	83.2
61	0.0	11.2	0.0	9.4	0.0	62.6
62	0.0	19.8	0.0	16.2	0.0	81.0
63	11.5	19.1	9.4	16.2	43.9	83.2
64	0.0	17.3	0.0	13.7	0.0	68.8
65	0.0	20.2	0.0	16.2	0.0	85.0
66	0.0	15.1	0.0	11.2	0.0	75.6
67	16.2	16.9	13.3	14.0	64.8	74.2
68	16.2	15.1	13.3	11.9	63.7	74.2
69	0.0	17.3	0.0	13.0	0.0	83.5
70	0.0	16.9	0.0	13.0	0.0	76.3
71	0.0	18.0	0.0	14.0	0.0	79.6
72	16.9	19.1	13.7	15.8	66.2	82.8
73	15.8	16.2	12.6	12.6	68.0	79.9
74	15.1	20.5	12.2	16.2	65.2	79.9
75	0.0	17.3	0.0	14.0	0.0	87.1
76	16.9	17.3	13.7	14.0	66.2	70.6
77	16.9	20.9	13.7	15.5	67.0	88.9
78	0.0	11.2	0.0	9.0	0.0	47.2
79	0.0	14.4	0.0	11.5	0.0	75.2
80	17.3	18.0	14.0	14.8	67.7	70.9
81	15.1	16.9	12.6	13.3	59.0	70.2
82	0.0	15.5	0.0	12.6	0.0	69.8
83	17.3	20.9	14.0	15.5	67.0	93.2
84	0.0	11.5	0.0	9.7	0.0	56.9
85	0.0	13.0	0.0	10.8	0.0	57.2
86	15.8	17.3	13.3	14.4	61.9	68.0
87	0.0	15.8	0.0	13.0	0.0	61.9
88	10.1	16.2	8.3	13.3	43.2	62.3
89	13.7	16.9	11.2	13.0	60.1	73.8
90	13.7	15.1	10.8	11.5	56.2	69.5
91	13.0	9.7	10.8	7.9	52.6	57.2
92	15.1	13.3	12.2	10.8	61.9	54.7
93	13.7	13.7	10.8	11.5	56.2	55.4
94	16.6	15.8	13.3	12.6	65.5	65.5
95	15.8	16.6	13.0	13.0	62.6	71.3
96	15.5	16.9	12.6	14.0	62.3	70.6
97	15.1	8.6	12.2	7.2	63.0	39.2
98	16.2	17.6	13.3	14.4	62.6	77.4
99	0.0	17.3	0.0	14.8	0.0	70.2
100	16.9	18.7	13.7	15.1	67.3	79.9
101	17.3	17.3	14.0	13.7	68.0	84.2
102	16.6	16.9	13.7	13.7	64.1	80.6
103	16.9	17.3	13.7	13.3	65.9	80.3
104	17.6	18.0	14.4	14.0	69.8	78.5
105	17.3	15.8	14.0	13.3	67.7	70.9
106	17.6	15.5	14.4	13.3	68.4	59.8
107	17.3	20.2	13.7	16.2	68.0	85.3
108	0.0	15.1	0.0	11.9	0.0	59.0
109	0.0	17.6	0.0	13.3	0.0	82.1
110	0.0	12.6	0.0	9.4	0.0	59.0
111	0.0	15.5	0.0	11.2	0.0	75.2
112	0.0	18.0	0.0	13.3	0.0	80.6
113	0.0	13.0	0.0	10.1	0.0	67.7
114	0.0	18.7	0.0	15.1	0.0	86.0
115	0.0	20.2	0.0	16.2	0.0	79.9
116	0.0	16.9	0.0	13.7	0.0	70.2
117	0.0	12.6	0.0	10.1	0.0	56.2
118	0.0	15.1	0.0	12.6	0.0	69.5
119	0.0	10.4	0.0	9.0	0.0	46.1
120	0.0	12.2	0.0	10.1	0.0	54.0
121	0.0	16.9	0.0	13.7	0.0	74.2
122	0.0	15.1	0.0	12.2	0.0	69.5
123	0.0	13.0	0.0	10.8	0.0	59.4
124	0.0	14.4	0.0	11.5	0.0	70.2
125	0.0	17.6	0.0	13.7	0.0	83.2
126	0.0	16.2	0.0	13.0	0.0	77.4
127	0.0	0.0	0.0	0.0	0.0	0.0
128	0.0	0.0	0.0	0.0	0.0	0.0
129	0.0	0.0	0.0	0.0	0.0	0.0
130	0.0	0.0	0.0	0.0	0.0	0.0
131	0.0	0.0	0.0	0.0	0.0	0.0
132	0.0	0.0	0.0	0.0	0.0	0.0
133	0.0	0.0	0.0	0.0	0.0	0.0
134	0.0	0.0	0.0	0.0	0.0	0.0
135	0.0	0.0	0.0	0.0	0.0	0.0
136	0.0	0.0	0.0	0.0	0.0	0.0
137	0.0	0.0	0.0	0.0	0.0	0.0
138	0.0	0.0	0.0	0.0	0.0	0.0
139	0.0	0.0	0.0	0.0	0.0	0.0
140	0.0	0.0	0.0	0.0	0.0	0.0
141	0.0	0.0	0.0	0.0	0.0	0.0
142	0.0	0.0	0.0	0.0	0.0	0.0
143	0.0	0.0	0.0	0.0	0.0	0.0
144	0.0	0.0	0.0	0.0	0.0	0.0
145	0.0	0.0	0.0	0.0	0.0	0.0
146	0.0	0.0	0.0	0.0	0.0	0.0
147	0.0	0.0	0.0	0.0	0.0	0.0
148	0.0	0.0	0.0	0.0	0.0	0.0
149	0.0	0.0	0.0	0.0	0.0	0.0
150	0.0	0.0	0.0	0.0	0.0	0.0
151	0.0	0.0	0.0	0.0	0.0	0.0
152	0.0	0.0	0.0	0.0	0.0	0.0
153	0.0	0.0	0.0	0.0	0.0	0.0
154	0.0	0.0	0.0	0.0	0.0	0.0
155	0.0	0.0	0.0	0.0	0.0	0.0
156	0.0	0.0	0.0	0.0	0.0	0.0
157	0.0	0.0	0.0	0.0	0.0	0.0
158	0.0	0.0	0.0	0.0	0.0	0.0
159	0.0	0.0	0.0	0.0	0.0	0.0
160	0.0	0.0	0.0	0.0	0.0	0.0
161	0.0	0.0	0.0	0.0	0.0	0.0
162	0.0	0.0	0.0	0.0	0.0	0.0
163	0.0	0.0	0.0	0.0	0.0	0.0
164	0.0	0.0	0.0	0.0	0.0	0.0
165	0.0	0.0	0.0	0.0	0.0	0.0
166	0.0	0.0	0.0	0.0	0.0	0.0
167	0.0	0.0	0.0	0.0	0.0	0.0
168	0.0	0.0	0.0	0.0	0.0	0.0
169	0.0	0.0	0.0	0.0	0.0	0.0
170	0.0	0.0	0.0	0.0	0.0	0.0
171	0.0	0.0	0.0	0.0	0.0	0.0
172	0.0	0.0	0.0	0.0	0.0	0.0
173	0.0	0.0	0.0	0.0	0.0	0.0
174	0.0	0.0	0.0	0.0	0.0	0.0
175	0.0	0.0	0.0	0.0	0.0	0.0
176	0.0	0.0	0.0	0.0	0.0	0.0
177	0.0	0.0	0.0	0.0	0.0	0.0
178	0.0	0.0	0.0	0.0	0.0	0.0
179	0.0	0.0	0.0	0.0	0.0	0.0
180	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:

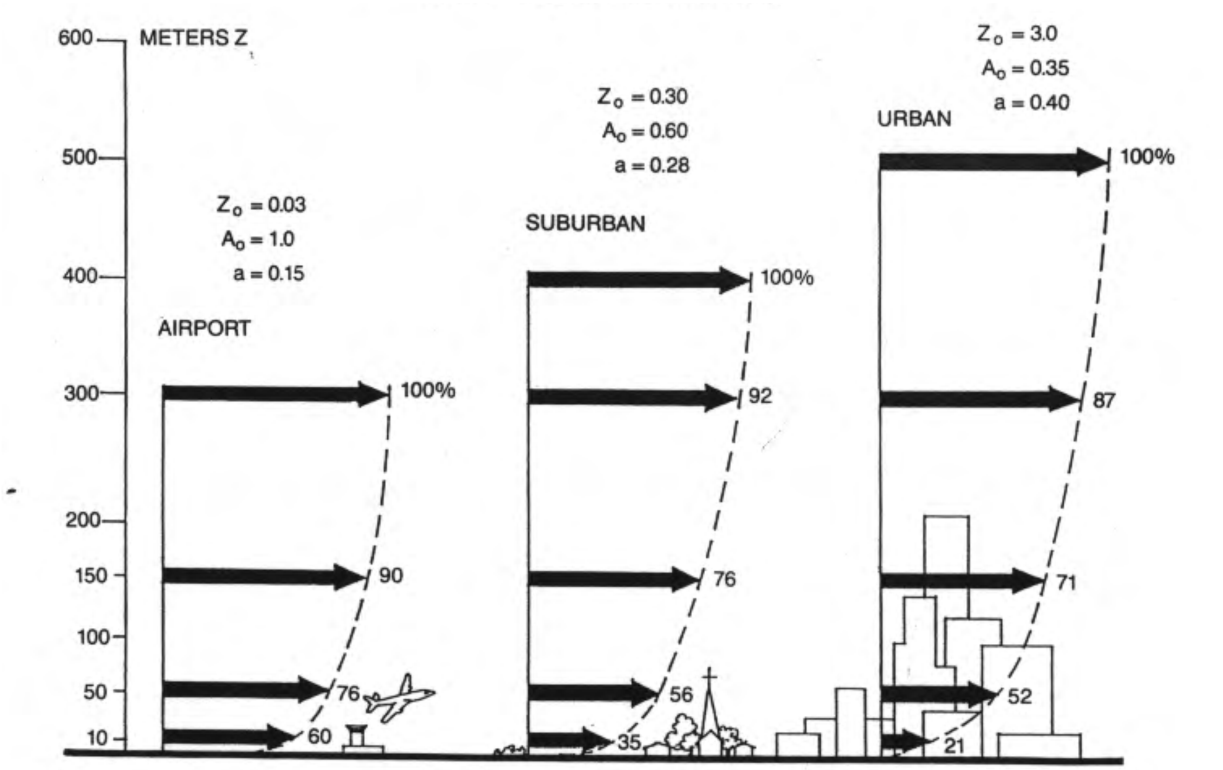


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

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 300*m* in radius around the subject building. If extremely tall buildings are present then the study area must be larger, and if the building elevations are on the order of a few floors, smaller areas will suffice to establish the required microclimate.

General Wind Flow Phenomena

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

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

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

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

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

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

Abbreviated Beaufort Scale

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

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

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

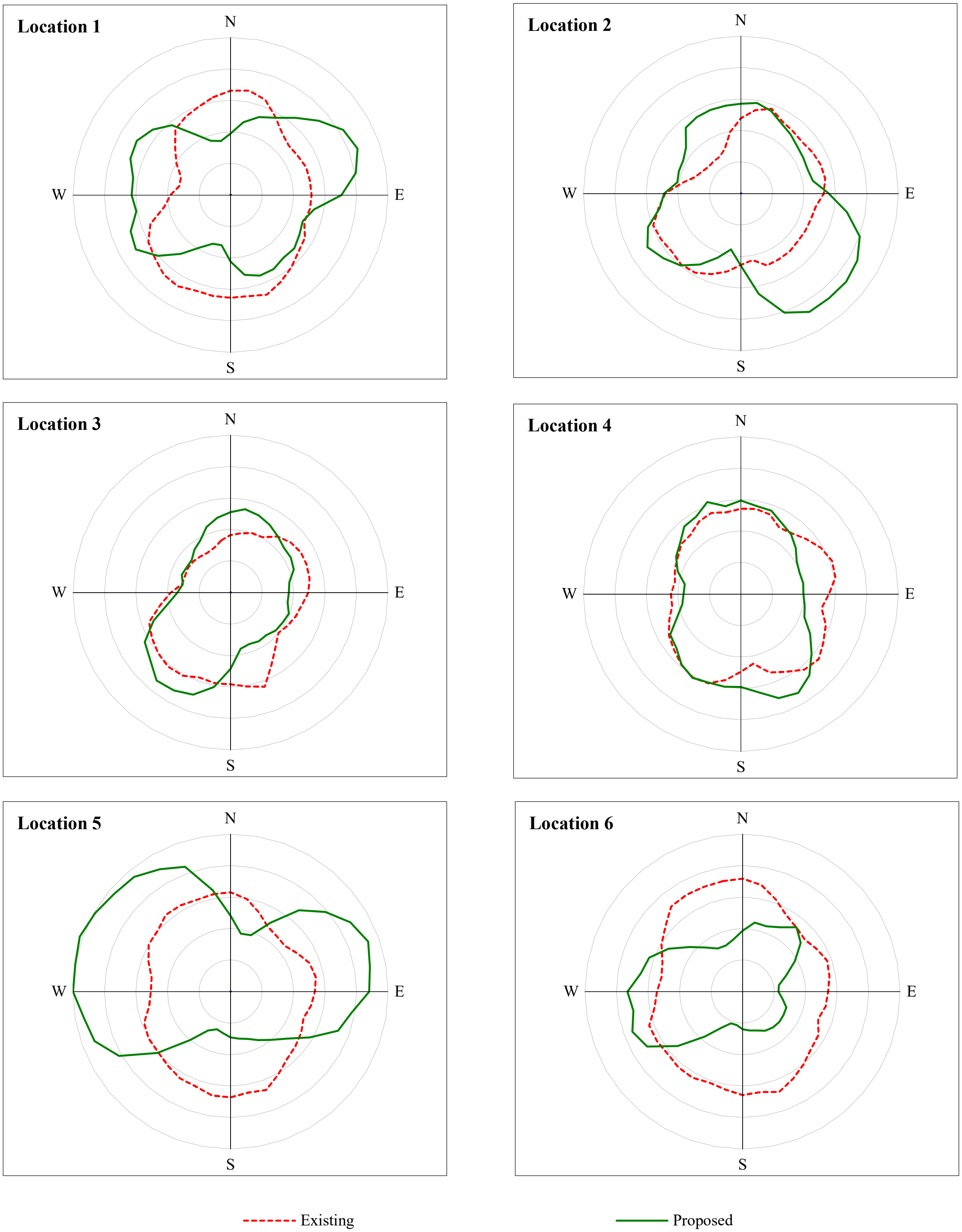


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

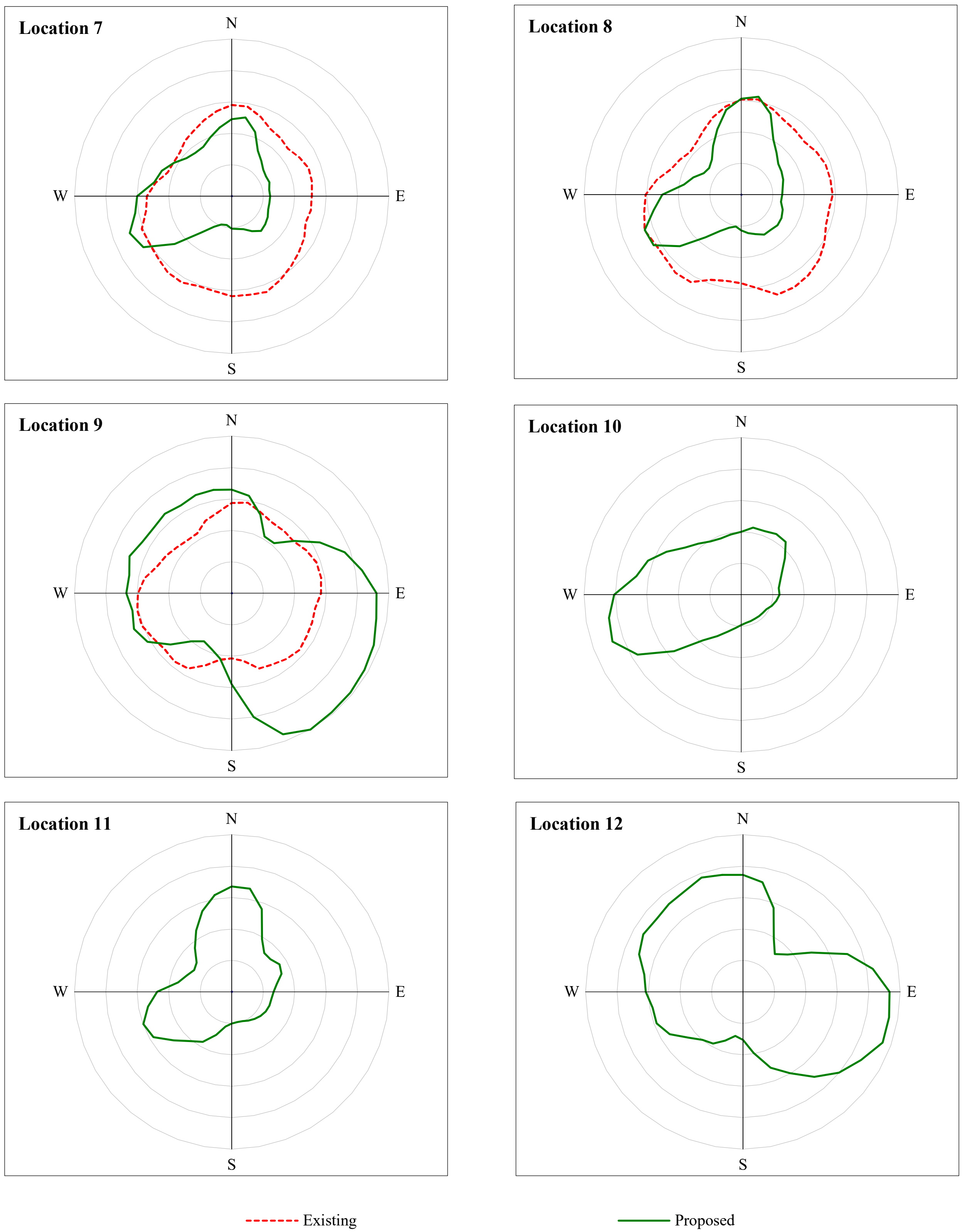


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

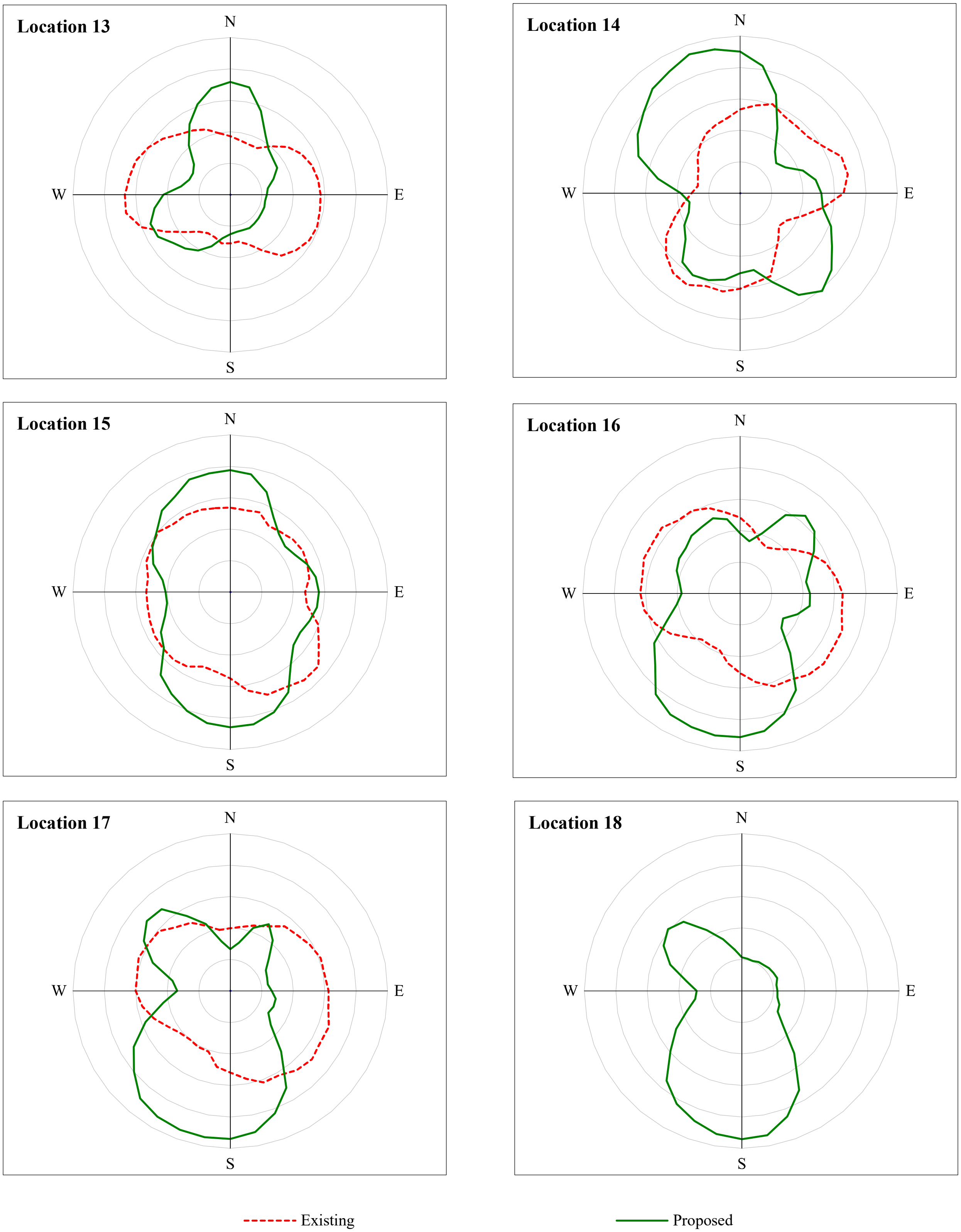


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

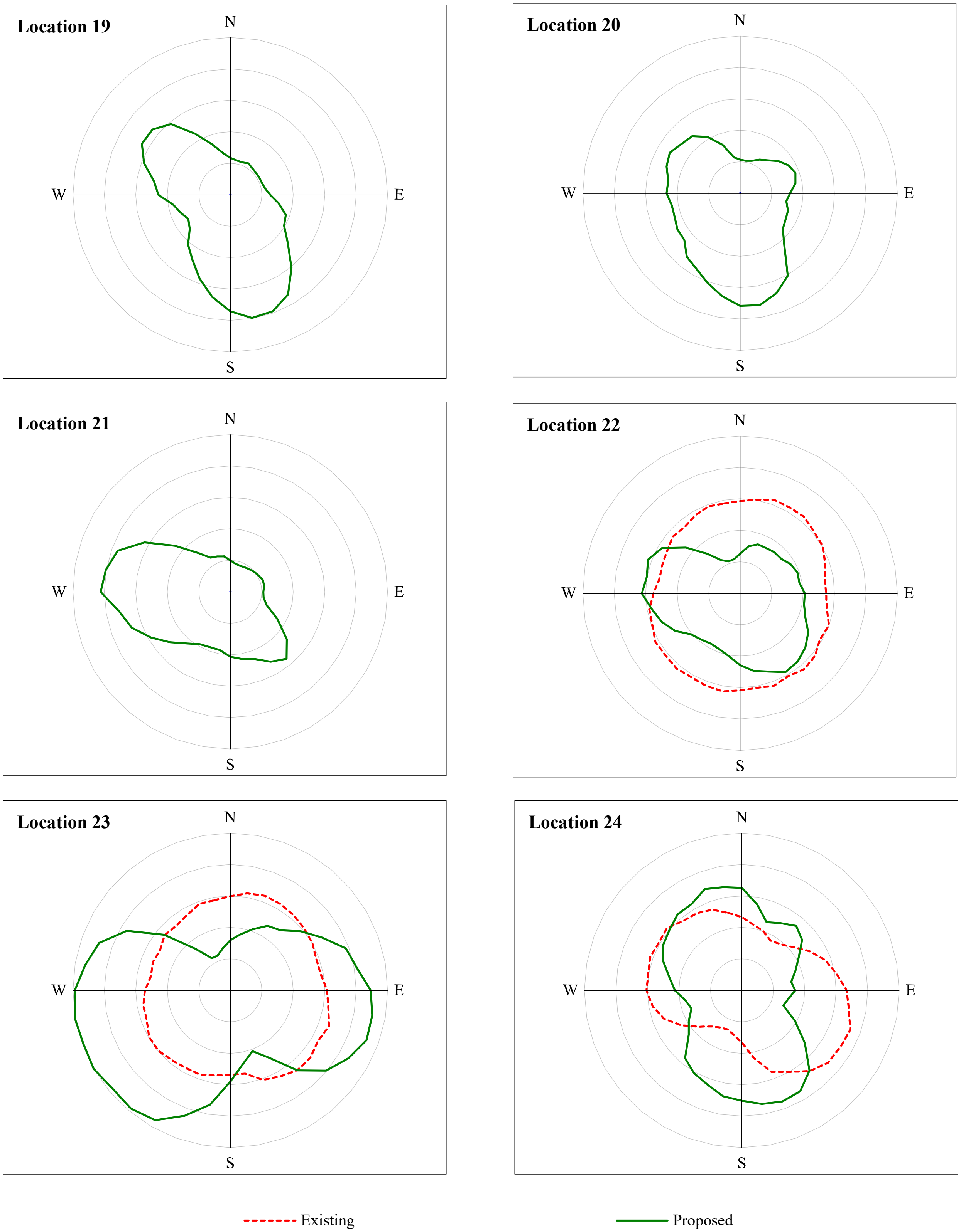
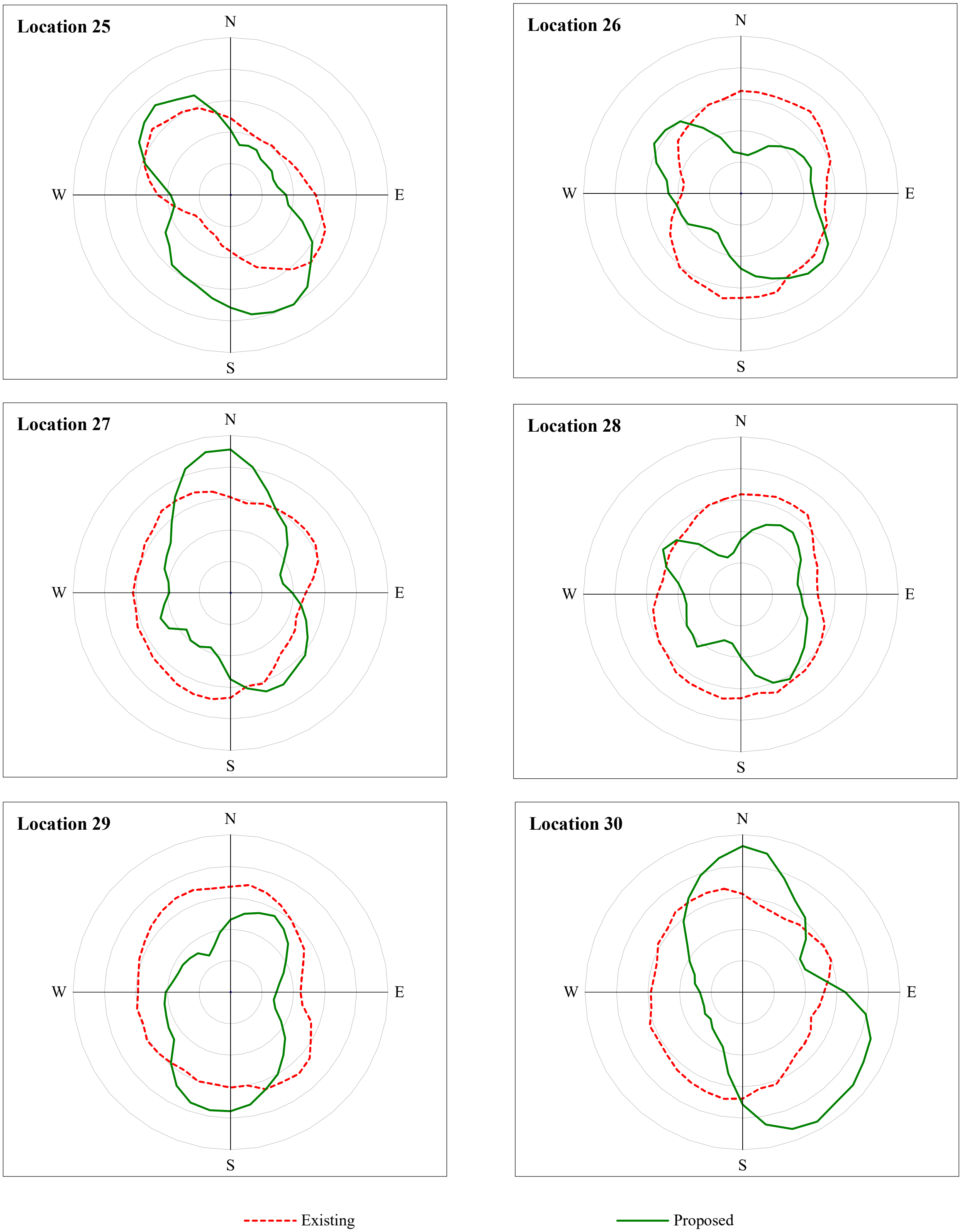


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.



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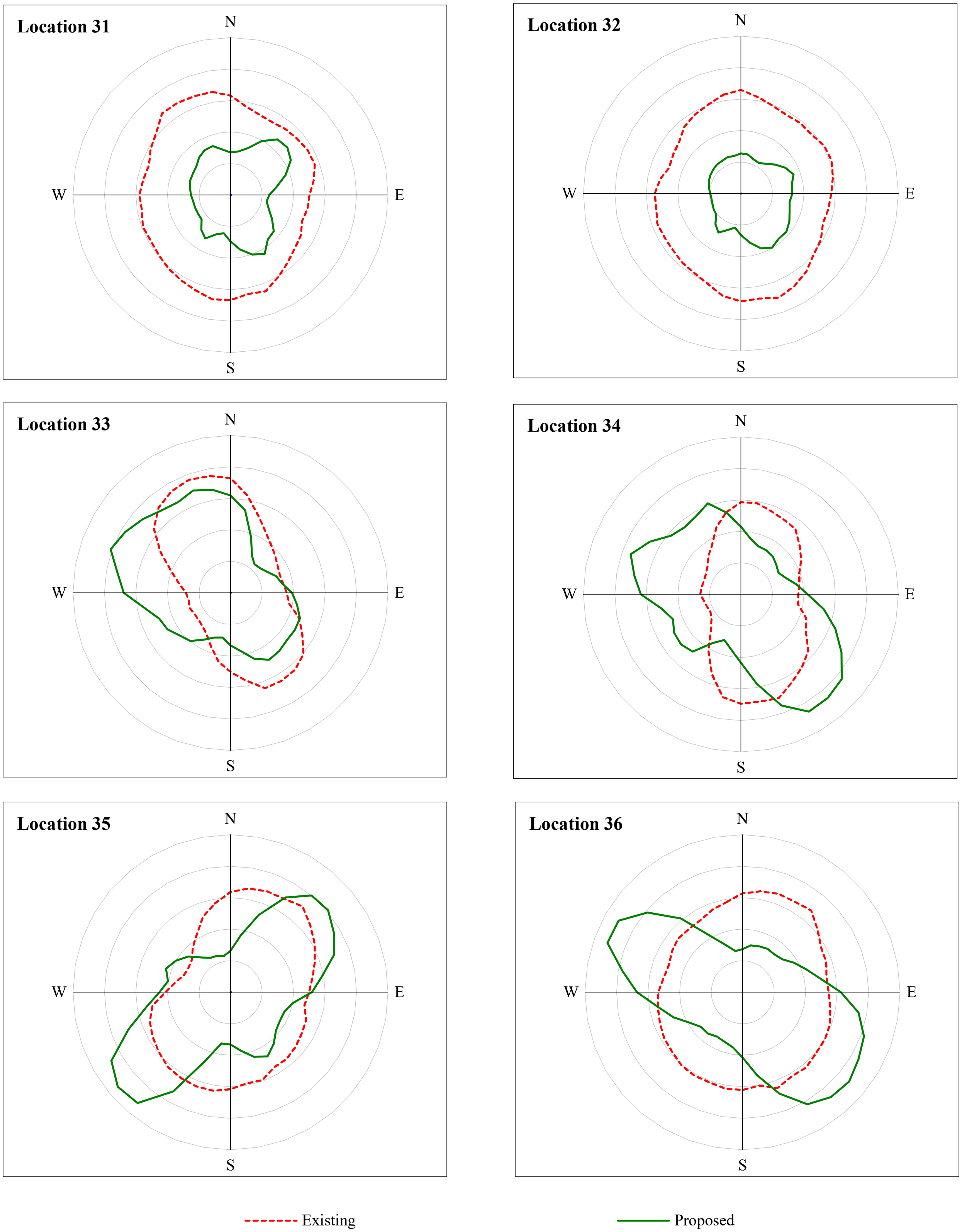

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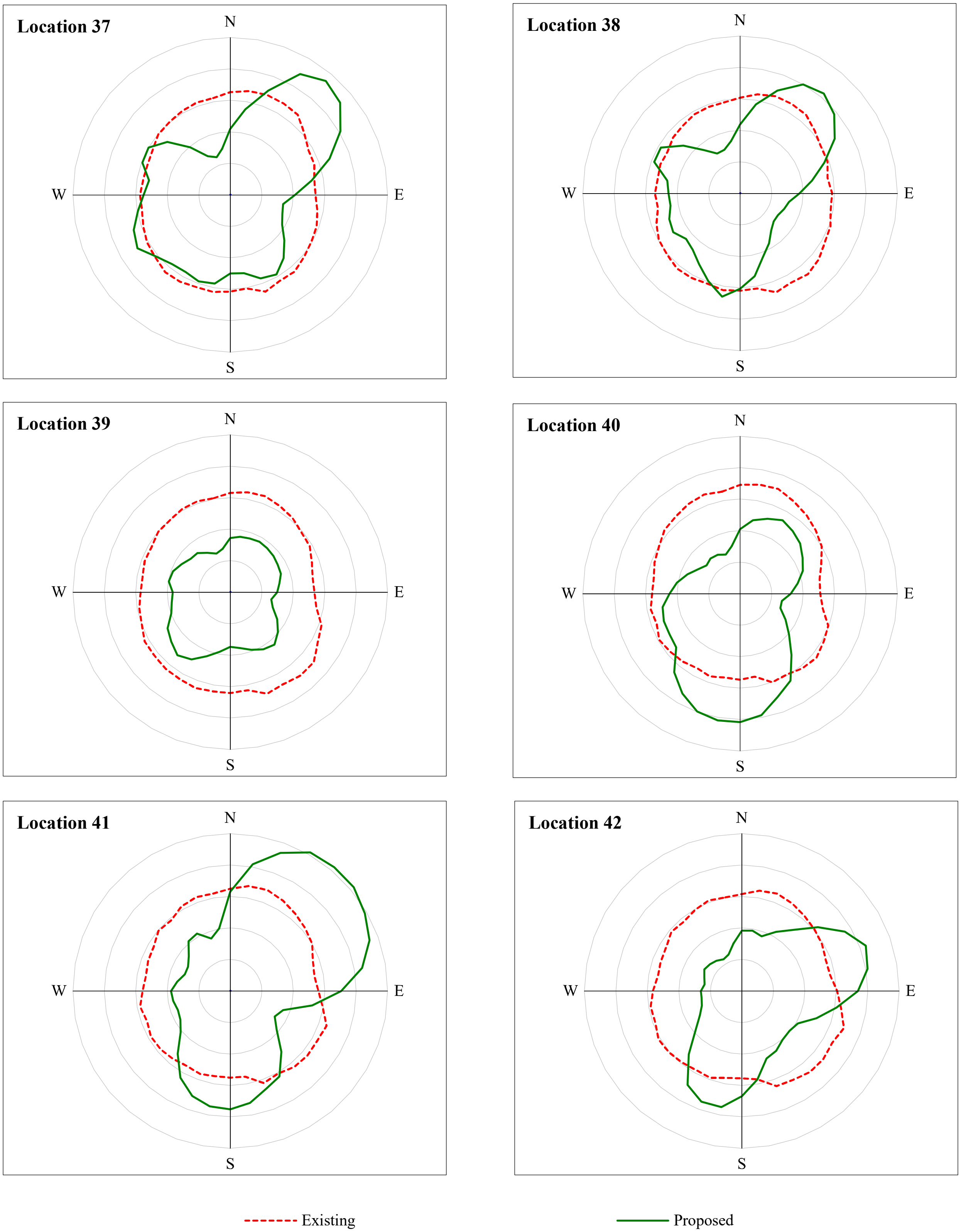

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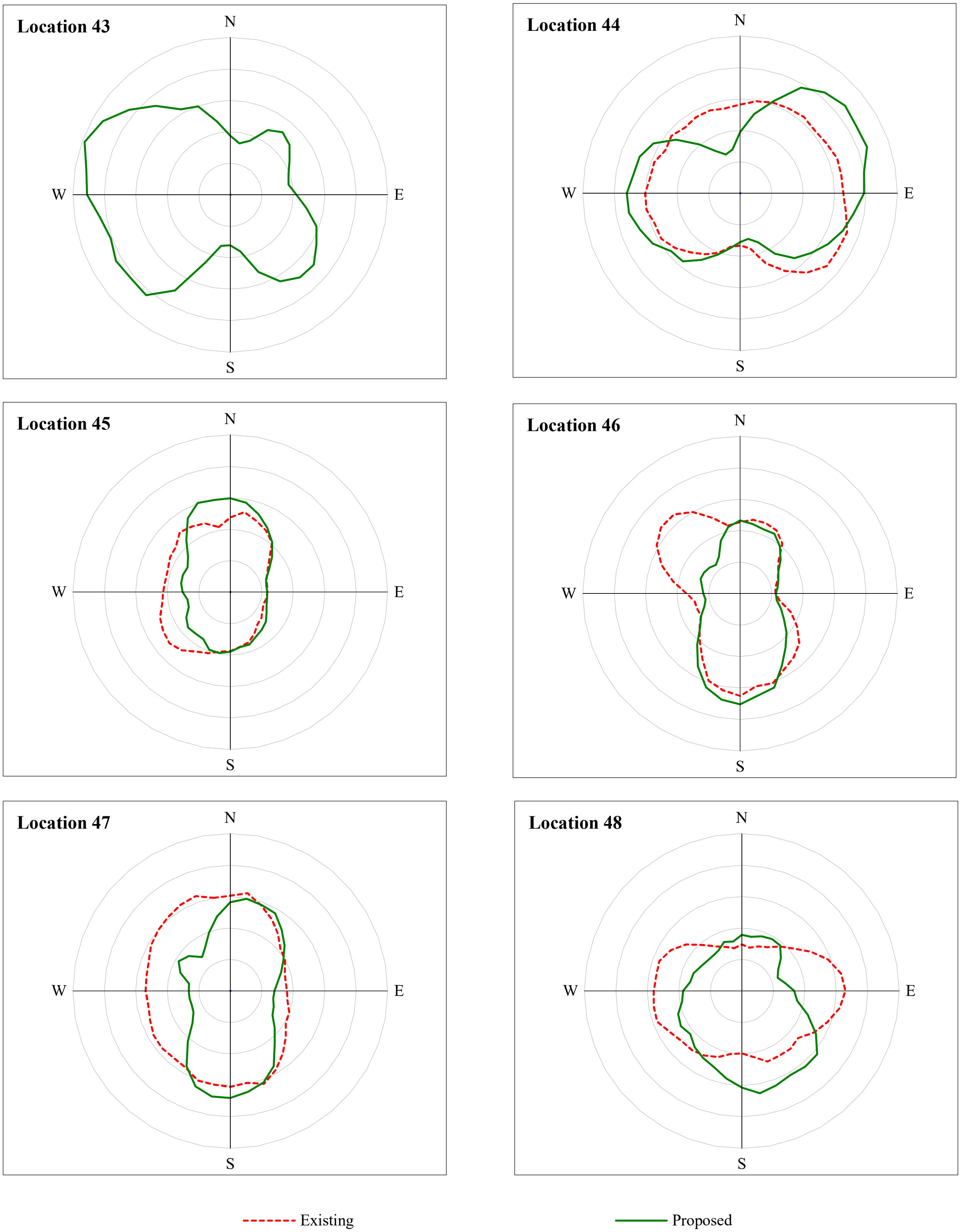

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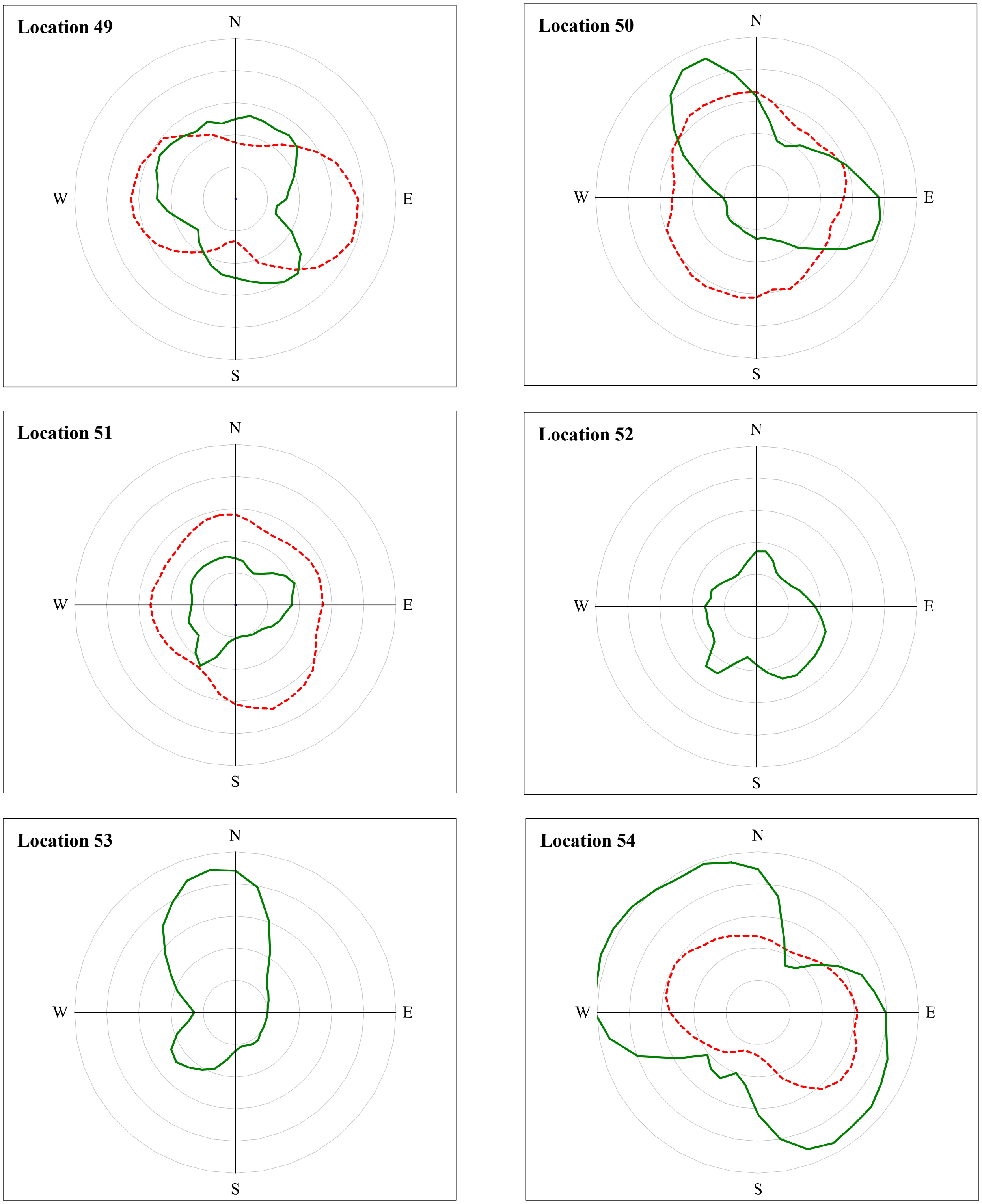

Existing   Proposed

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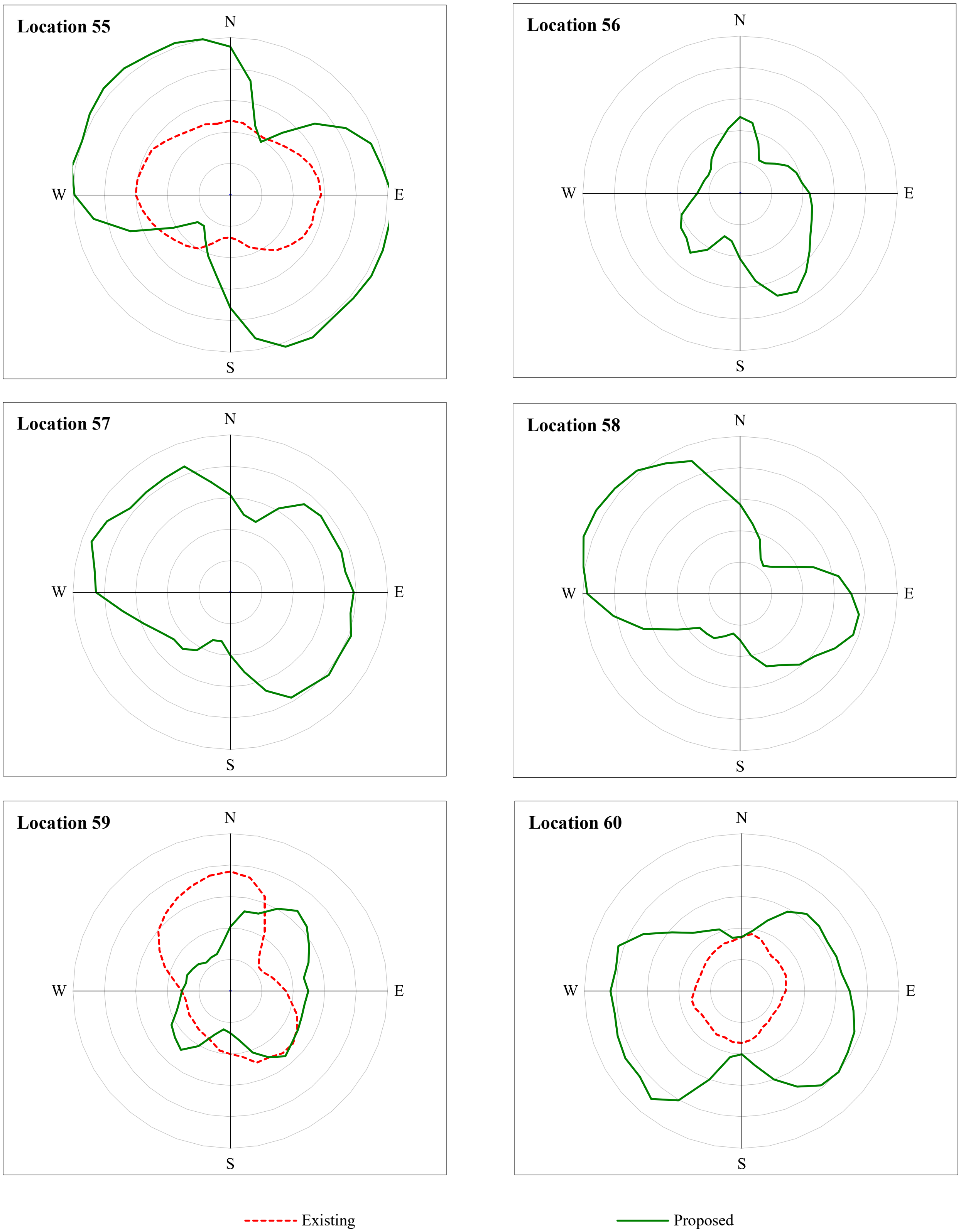

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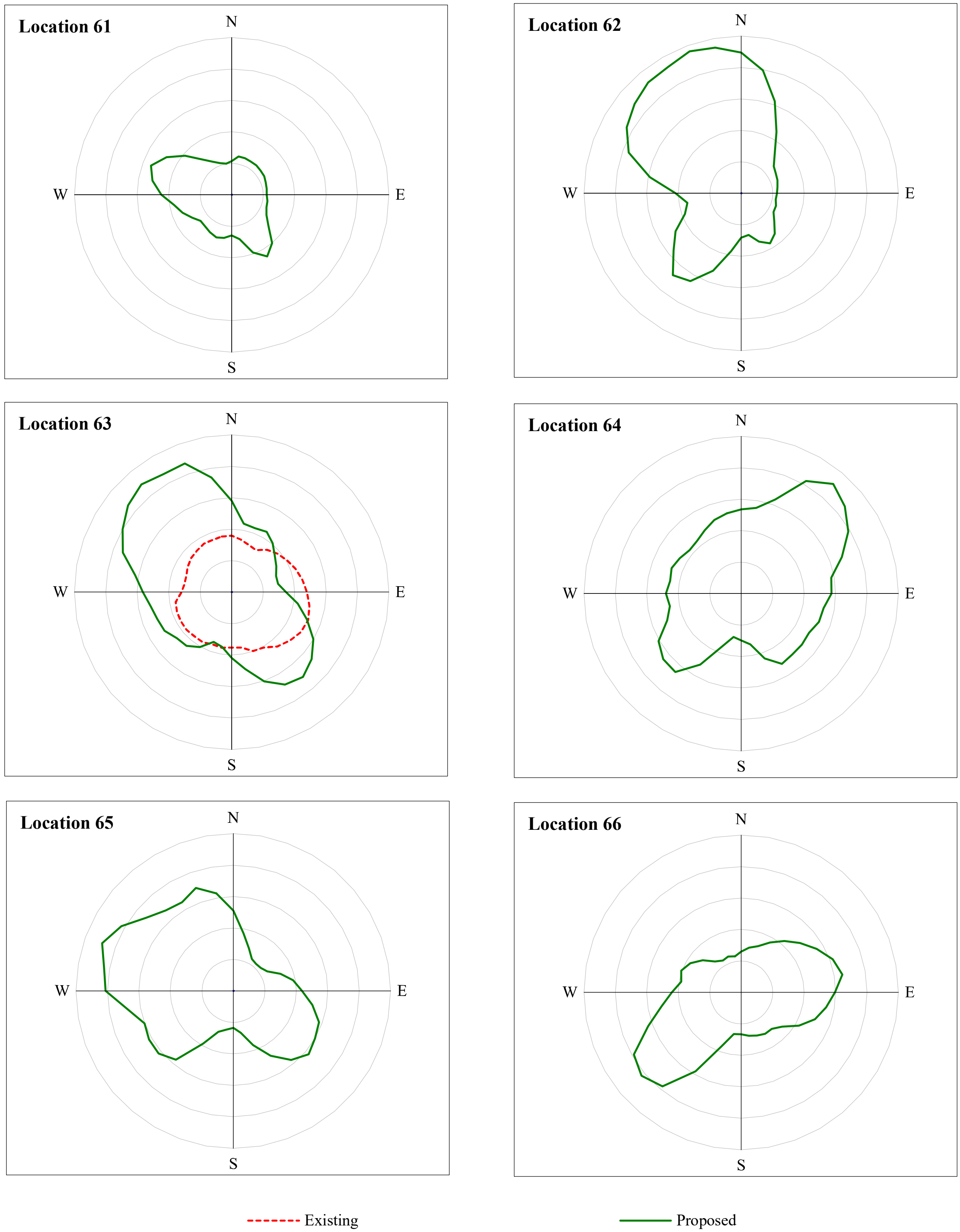

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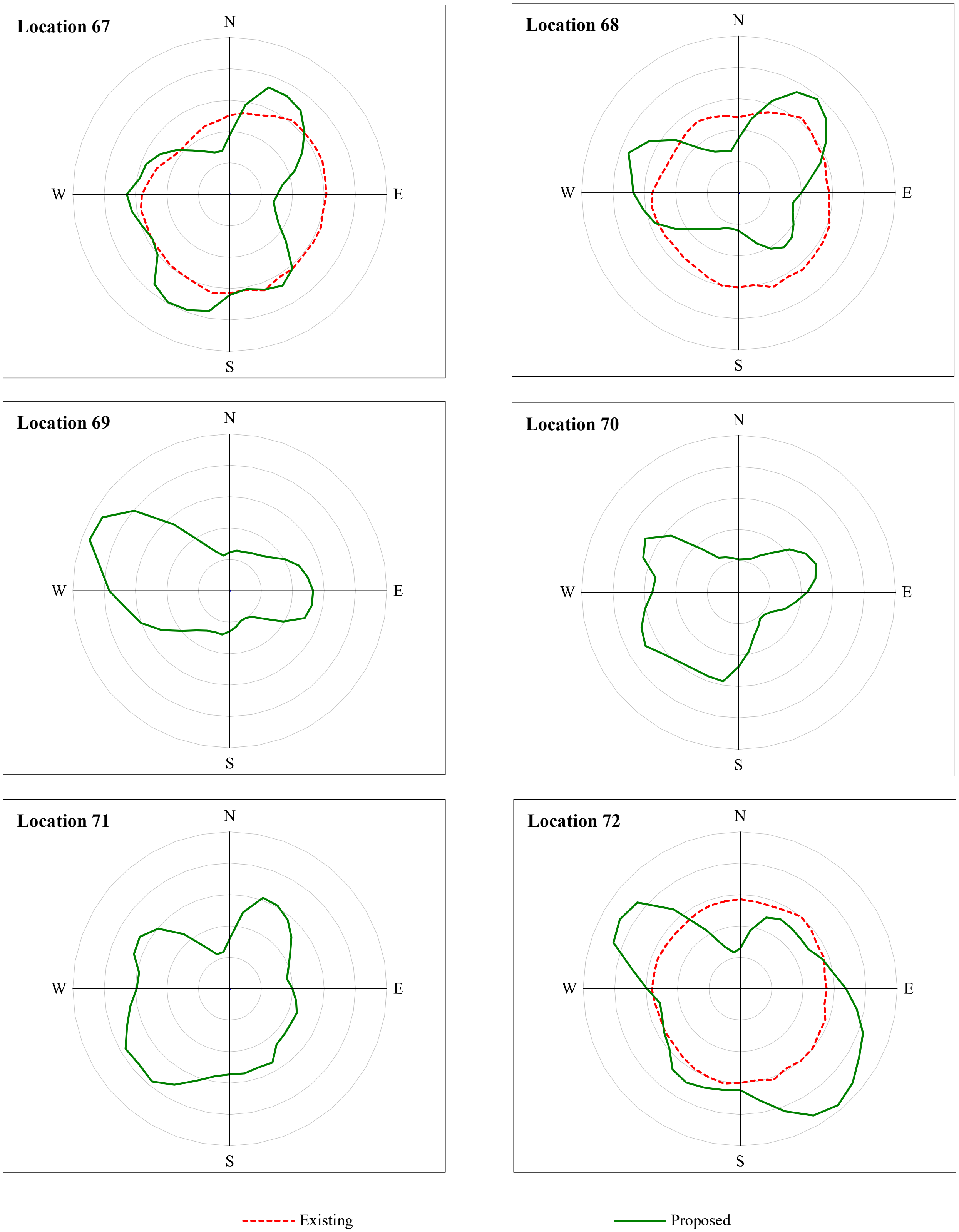

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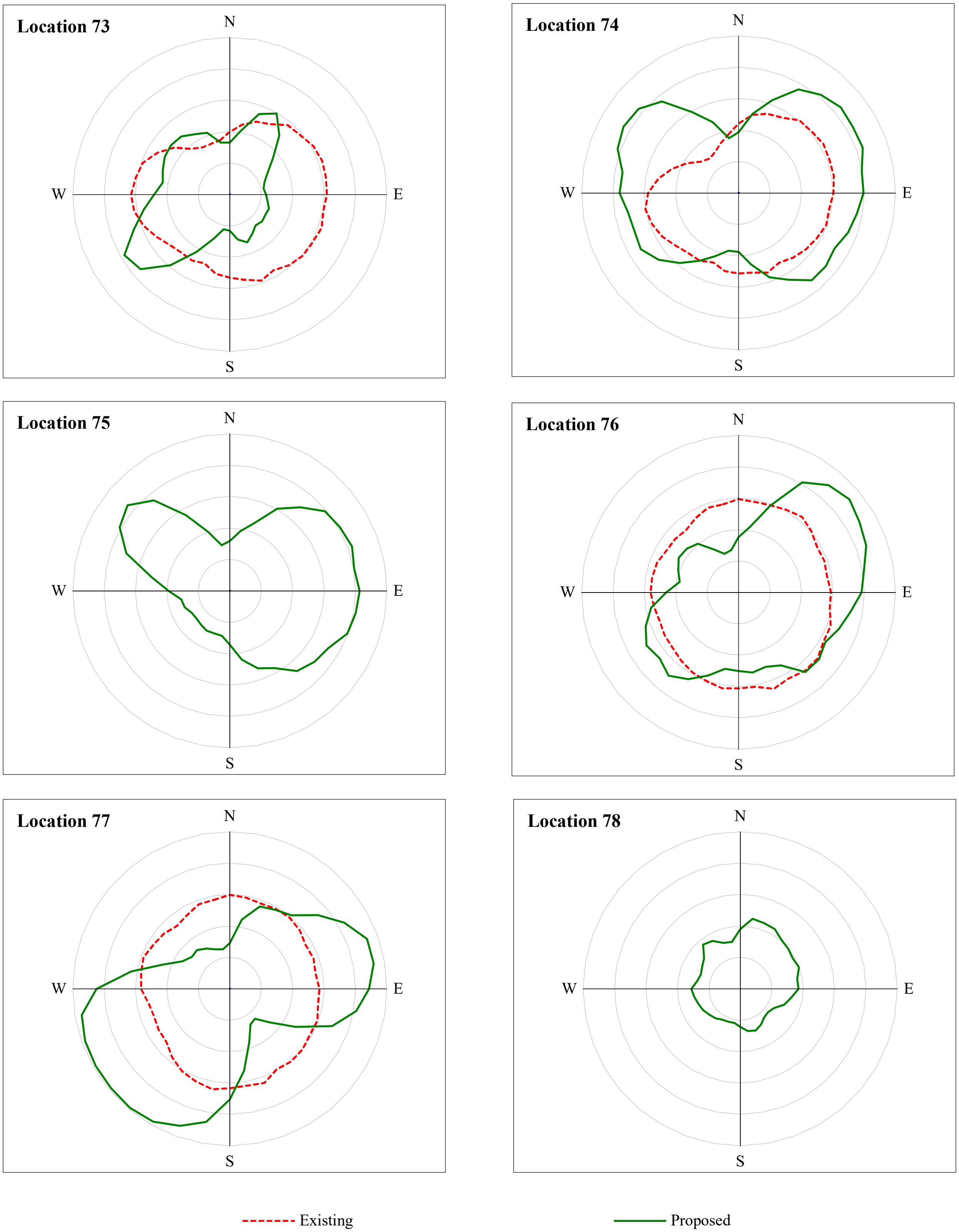

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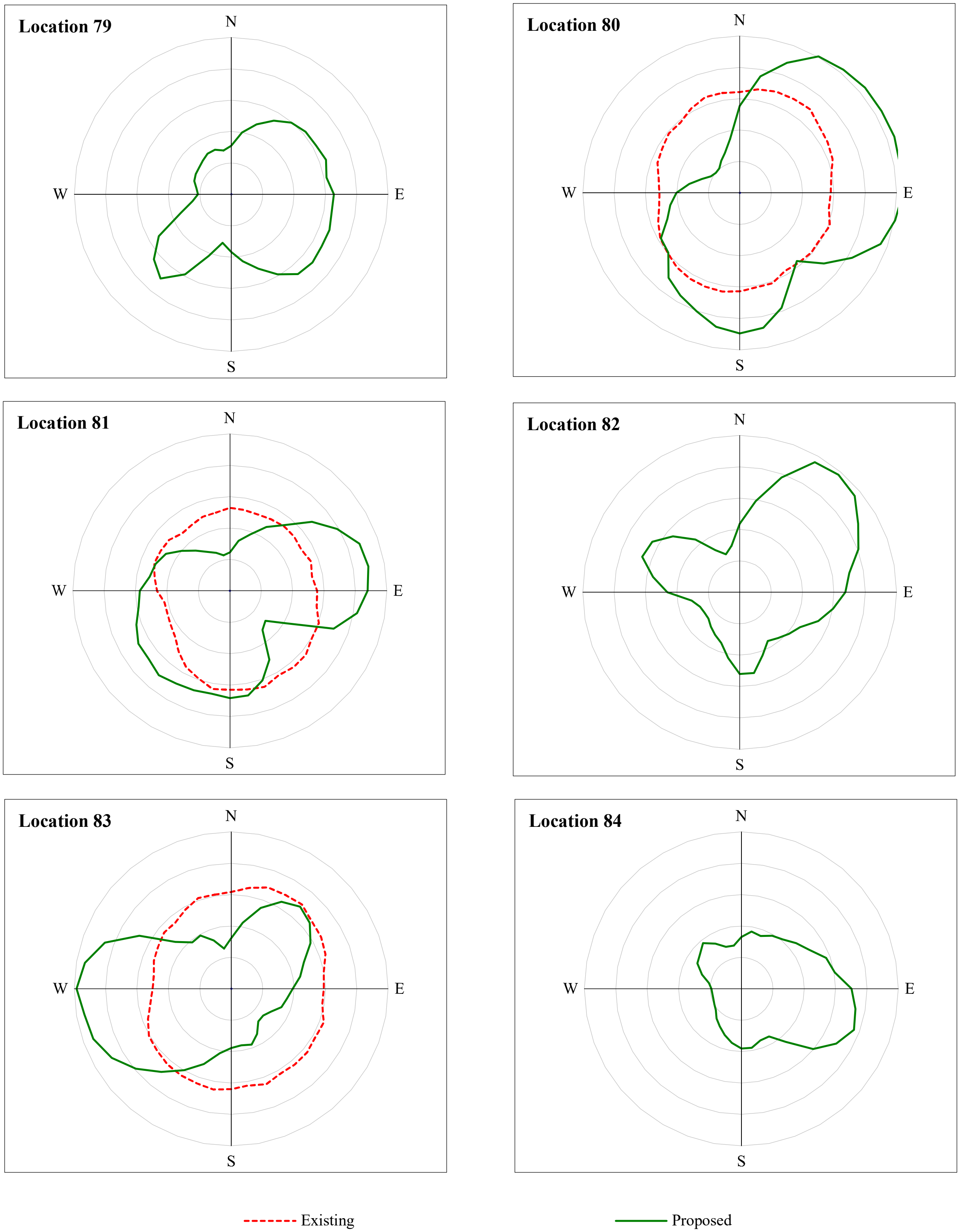

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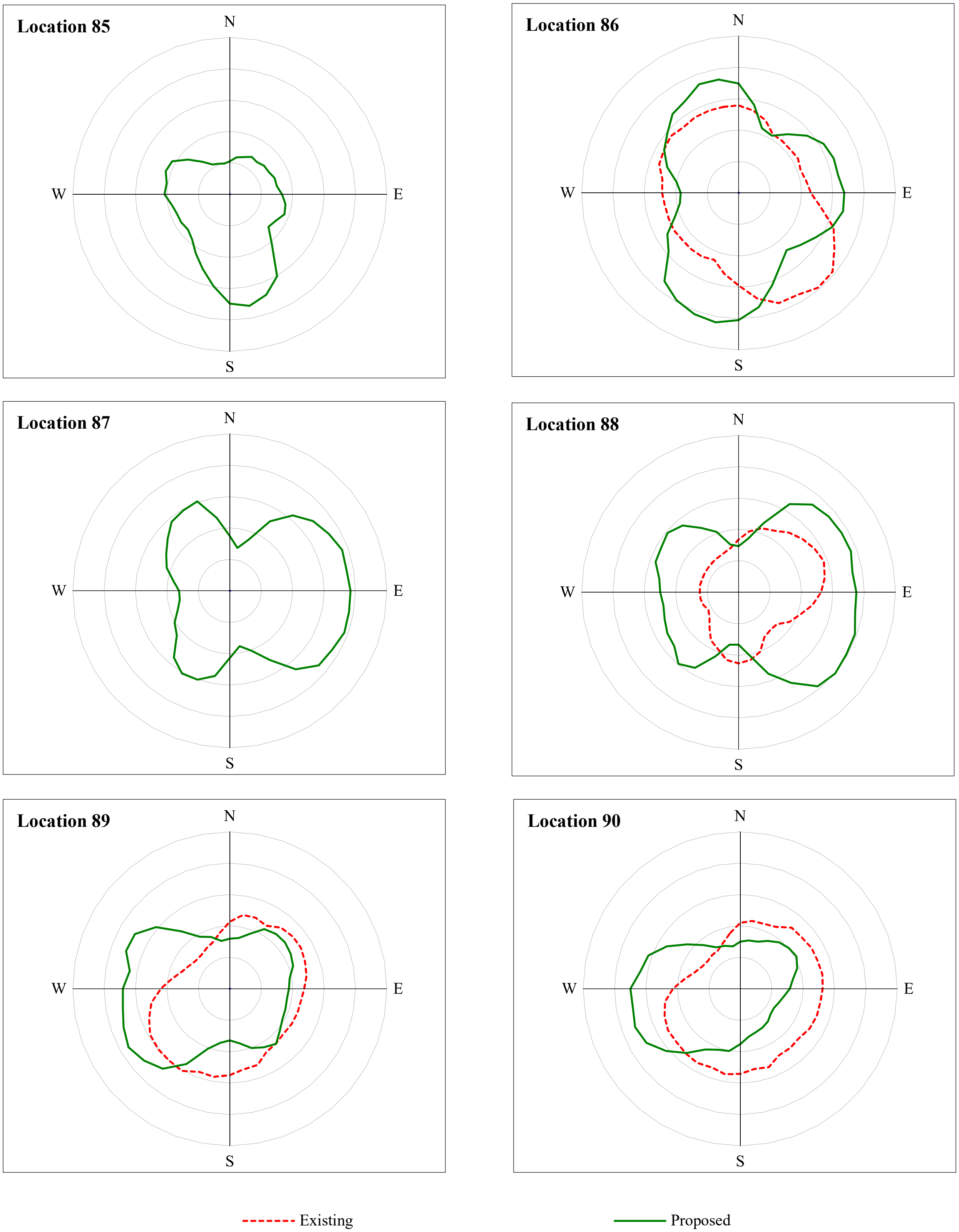

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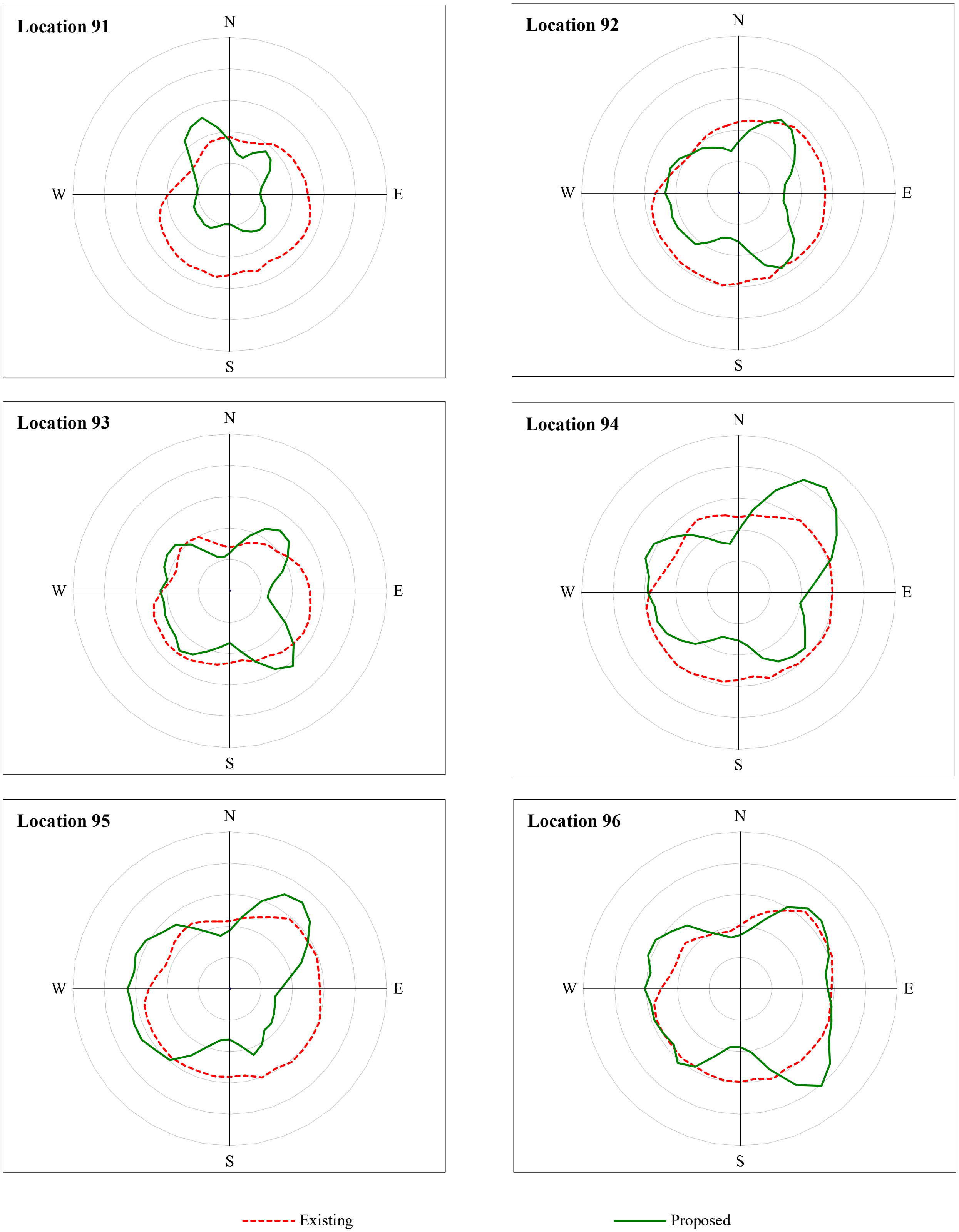

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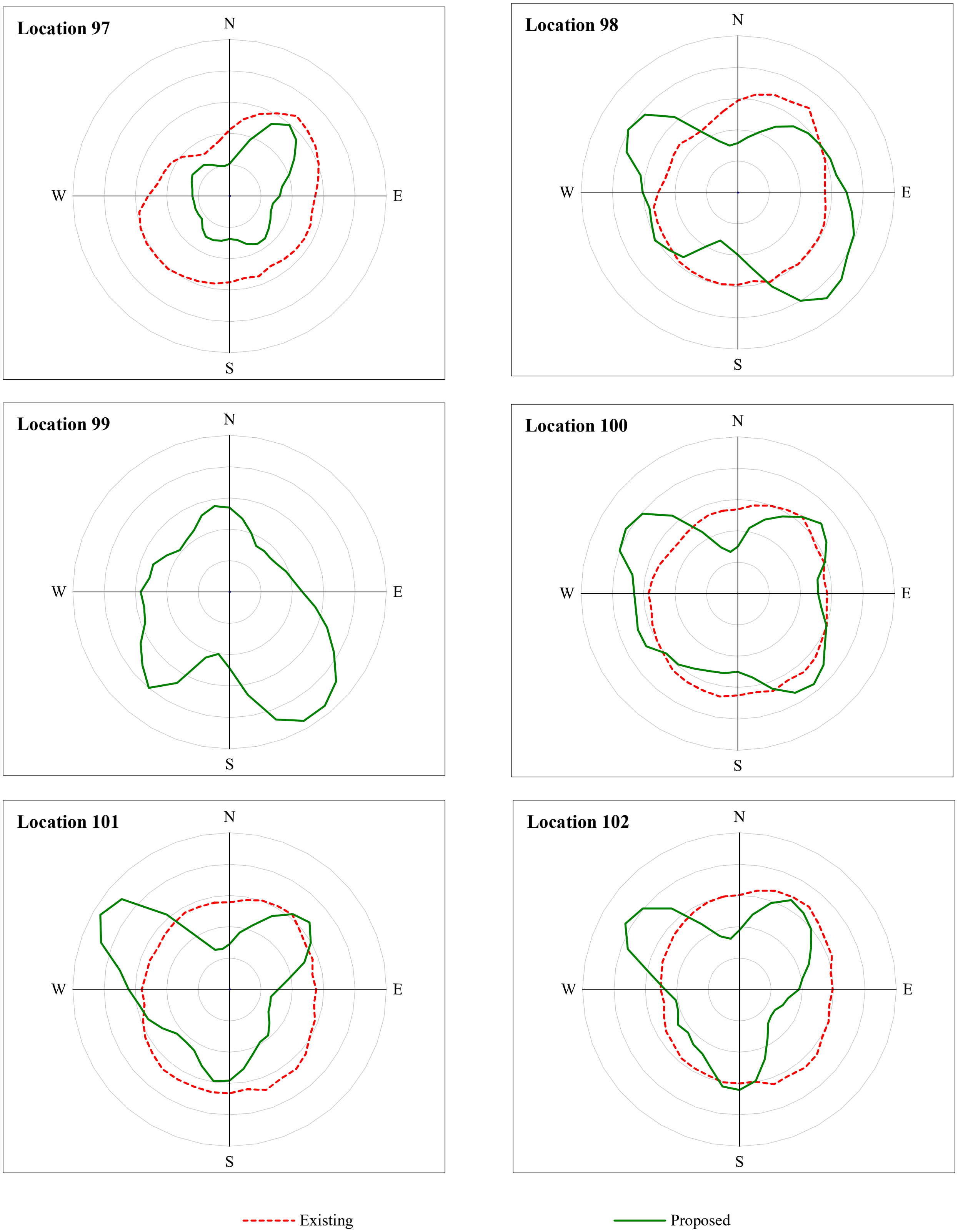

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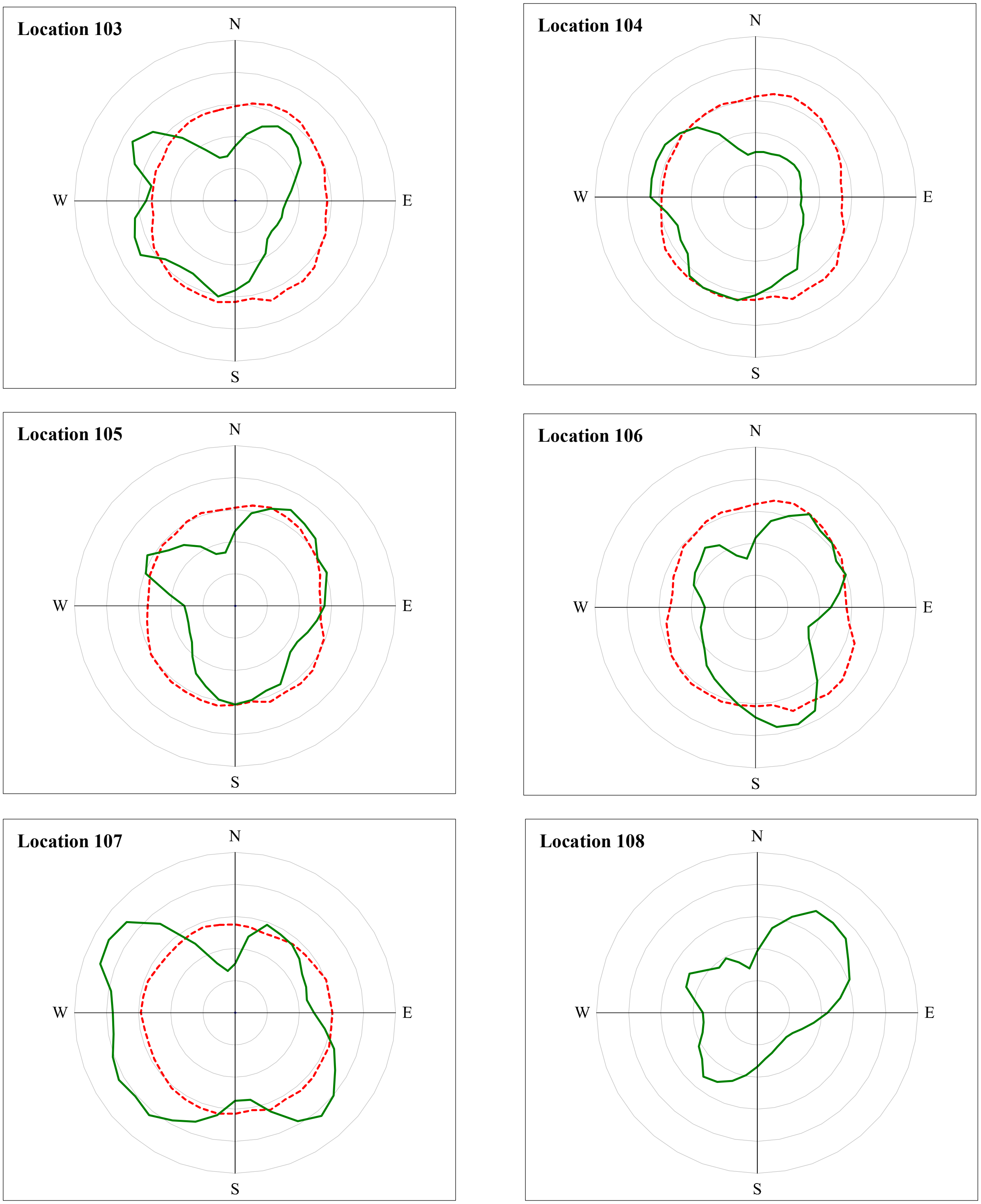

Existing   Proposed

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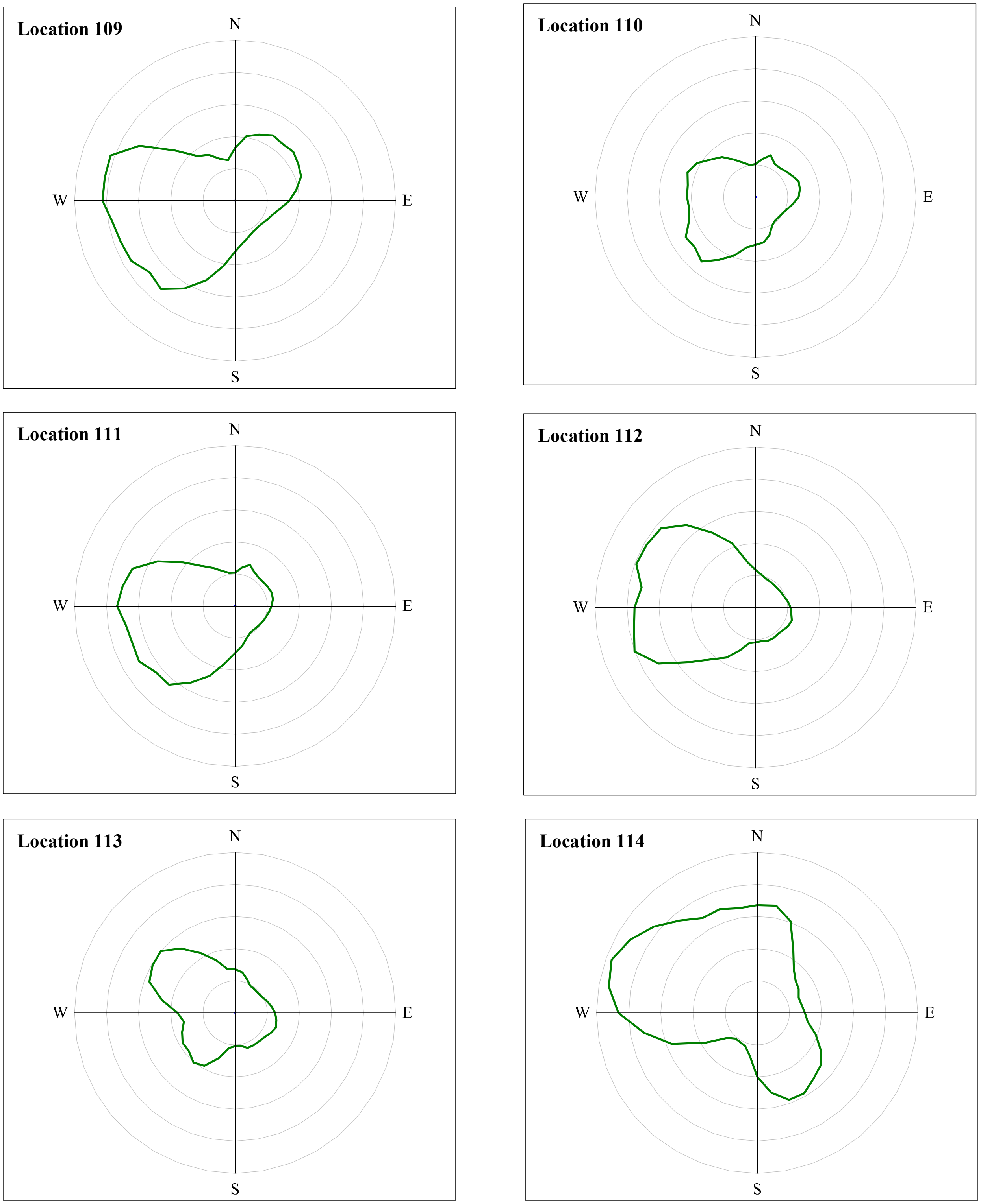

Existing   Proposed

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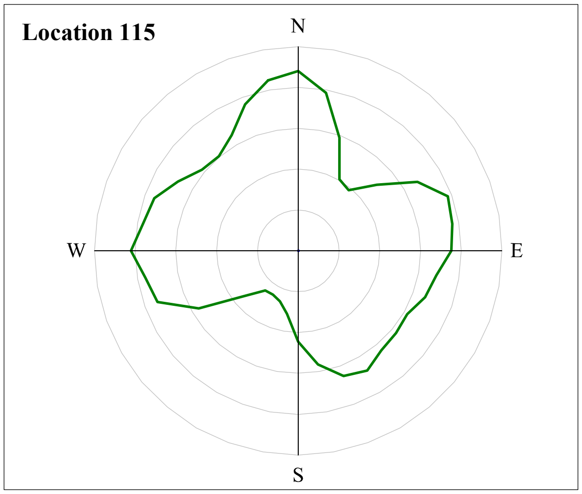

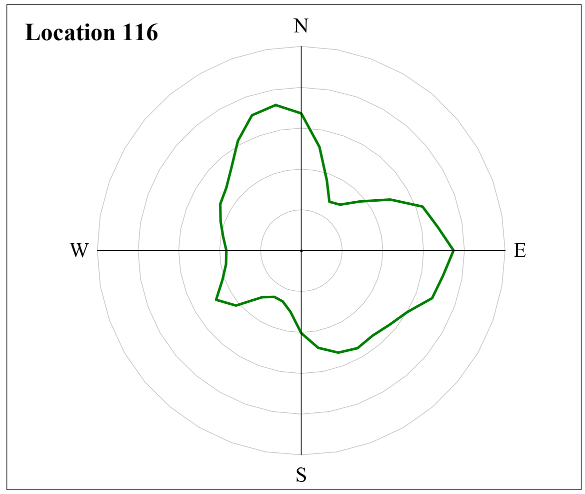

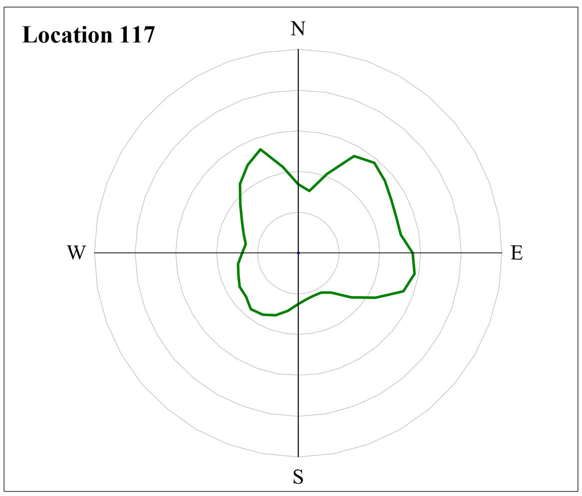

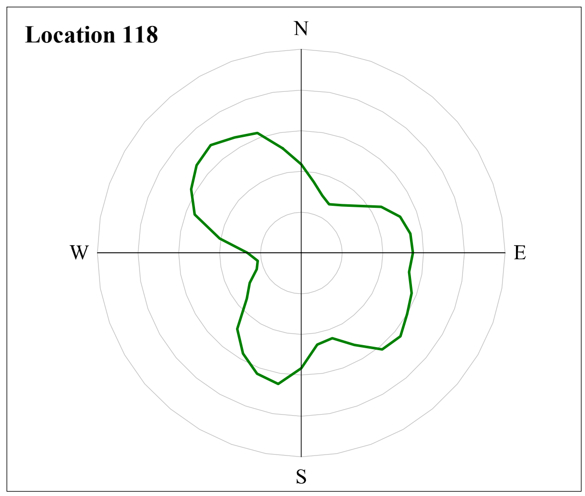

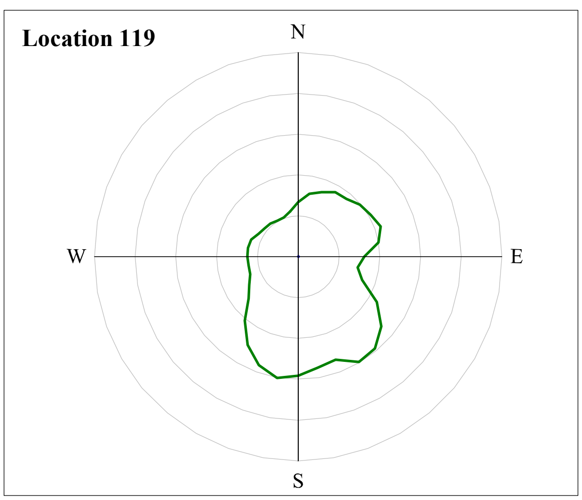

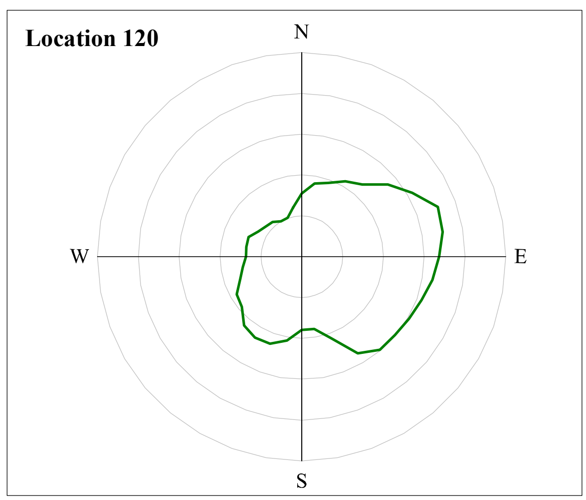

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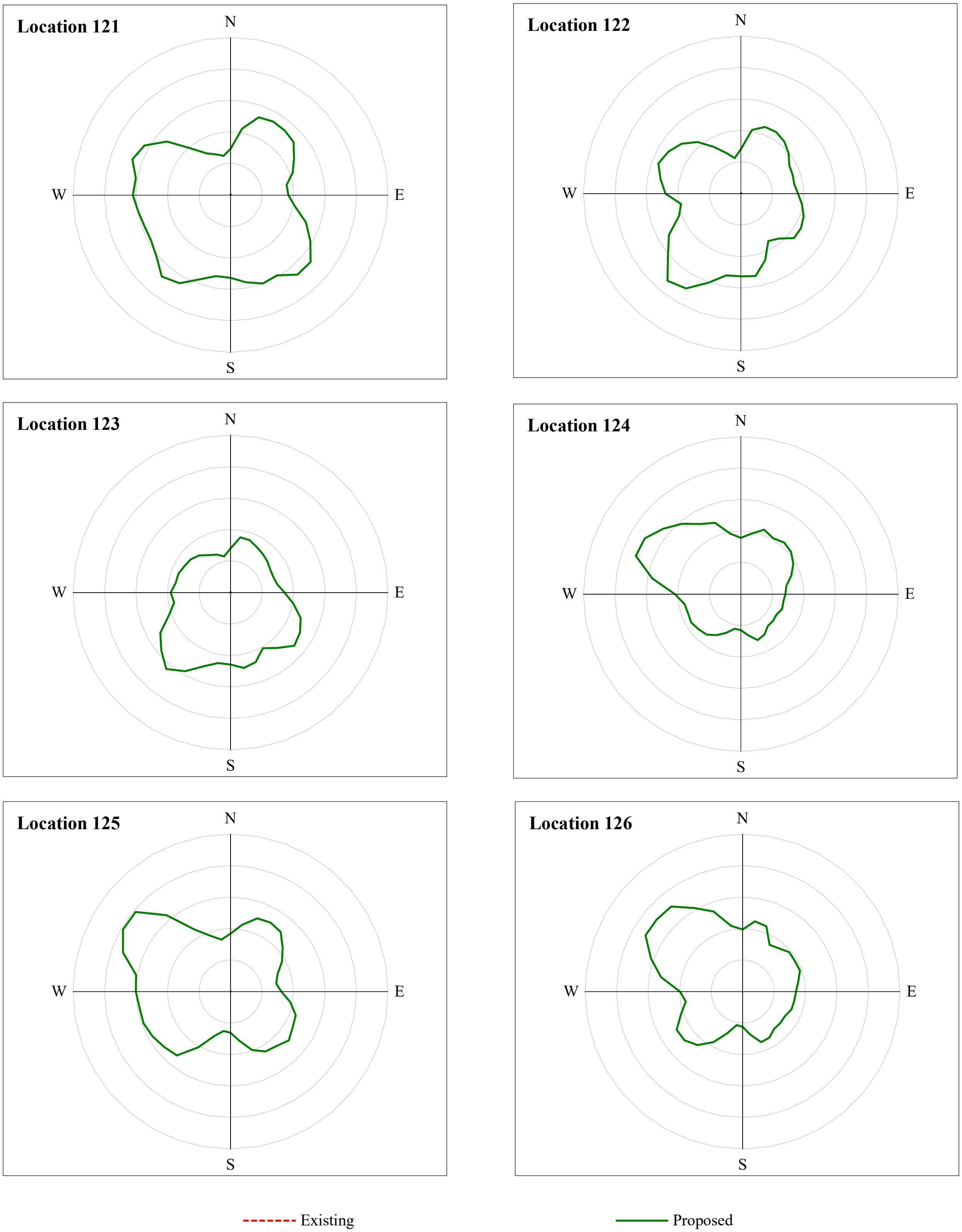

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