THEAKSTON ENVIRONMENTAL

Consulting Engineers • Environmental Control Specialists

REPORT

CFD PEDESTRIAN LEVEL WIND ASSESSMENT

50 High Street East

Mississauga, Ontario

Mahogany Management

REPORT NO. 25211wind **June 20, 2025**

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1. EXECUTIVE SUMMARY

The Development proposed by Mahogany Management for their property municipally known as 50 High Street East, Mississauga, has been assessed for environmental standards with regard to pedestrian level wind velocities relative to comfort and safety. Based upon our analysis, wind conditions on and around the proposed Development site are considered mainly suitable for sitting or standing throughout the year, with windier conditions, rated appropriate for walking or, in some locations, uncomfortable, proximate to the corners and gaps between neighbouring mid- to high-rise buildings, in the existing setting.

The proposed Development involves construction of an 11-storey residential building, fronting High Street East. The Main Residential Entrance is located along the southeast façade fronting High Street East, proximate to the southmost corner of the building. Vehicular access to the site is provided via a private driveway connecting with High Street East along the southeast property boundary. Outdoor Amenity Space is proposed at-grade fronting High Street East, atop a step in the building at the 10th level, and atop the building at the 12th level.

The Development site is, for all intents and purposes, surrounded by a mix of open and suburban lands supporting low through high-rise residential, commercial, and institutional buildings, mature vegetation, and open spaces. Lake Ontario is approximately 350m southeast of the site. The proposed Development will have a sympathetic relationship with the pending wind climate. Urban development provides turbulence inducing surface roughness that can be wind friendly, while open, and to a lesser degree, suburban settings afford wind the opportunity to accelerate as the wind's boundary layer profile thickens at the pedestrian level, owing to lack of surface roughness. Transition zones from open and/or suburban to urban settings can prove problematic, as winds exacerbated by relatively more open settings are redirected to flow over, around, down, and between buildings.

The proposed Development redirects winds that formerly flowed over the low-rise site, the increased blockage relative to the existing setting causing wind to redirect to flow over the building without consequence, and/or, depending upon the angle of incidence, around, or down the façades towards the pedestrian level, as downwash. The Development incorporates wind mitigative design features, such as stepped conditions, overhangs, and a modest height, which, when considered in concert, reduce and deflect downwash around the building at elevations above the pedestrian level.

Based upon this analysis, wind conditions on and around the proposed Development are predicted to, in many cases, remain similar to the existing setting or improve with inclusion of the proposed Development. Localised areas proximate to the proposed Development's corners and gaps between buildings will realise slightly windier conditions, but generally remain suitable for standing, or better, year-round and remain appropriate for their intended uses. Consideration of fine design details and mitigative features will result in more comfortable conditions than reported.

A mitigation plan is recommended for the Rooftop Outdoor Amenity Space, as described within, in order to achieve conditions that are considered more appropriate for its use.

The proposed Development is predicted to realise wind conditions acceptable to a typical open / suburban context, based on this preliminary Computational Fluid Dynamics analysis.

Subsequent to testing, modifications were made to the layout of the mechanical penthouse. These changes are not anticipated to affect pedestrian level comfort categories, however, they are expected to impact conditions within the Rooftop Amenity Space. The effect of these changes will be assessed and addressed in a future submission.

Respectfully submitted,

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2. INTRODUCTION

Mahogany Management retained Theakston Environmental to assess the pedestrian level wind environment for the proposed Development at 50 High Street East, Mississauga, as shown in Figure 1. The Development involves a proposal to construct an 11-storey residential building in the configuration shown in Figure 2. Chamberlain Architect Services Limited provided architectural drawings. The co-operation and interest of the Client and their sponsors in all aspects of this assessment is gratefully acknowledged.

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

To obtain an objective analysis of the wind conditions for the property, the wind environment was tested in two configurations. The existing configuration included the current site with the existing building as well as neighbouring proposed developments in the surrounding area. The proposed configuration included the subject 50 High Street East Development.

The computational studies used in this Pedestrian Level Wind Assessment 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.

3. OBJECTIVES OF THE ASSESSMENT

1. To quantitatively assess, by computational fluid dynamic (CFD) simulation, the pedestrian level wind environment under existing and proposed conditions with the Development in accordance with the City of Mississauga's Terms of Reference.

2. To assess mitigative solutions in necessary cases.

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

4. METHOD OF ASSESSMENT

4.1 General

The Theakston Environmental wind engineering facility was developed for the assessment of, among other sciences, the pedestrian level wind environment occurring around buildings, with focus on the safety and comfort of pedestrians. Accurate digital models of the proposed Development site, and the immediate surroundings are built, and studied computationally using software by Meteodyn Inc. with resulting wind speeds stored for a surface spanning the areas likely to be frequented by pedestrians. This qualitative 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 using this method, utilise the computational fluid dynamics (CFD) program. The testing method has been developed for these kinds of environmental studies, and has been adapted with specific settings, testing procedures and protocols, accordingly.

The purpose of this Pedestrian Level Wind Assessment 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. Gust equivalent mean (GEM) values are extracted from the software for existing and proposed built scenarios, which accounts for sixteen (16) wind directions, at a surface that is uniformly at 1.5 m level above the ground in the entire field.

The wind speeds at the areas of interest were subsequently combined with the design probability distribution of gradient wind speed and direction (wind statistics) recorded at Billy Bishop Airport, to provide predictions of the full-scale pedestrian level wind environment. Predictions of the full-scale pedestrian level wind environment are presented as the GEM wind speed exceeded 20% of the time, based on two seasons, which can be found in Figures 5a – 5d.

4.2 Meteorological Data

The wind climate for the Mississauga region that was used in the analysis was based on historical records of wind speed and direction measured at Billy Bishop Airport for the period between 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.

4.3 Statistical Wind Climate Model

The design probability distribution of mean-hourly wind speed and wind direction at reference height is shown for Billy Bishop Airport in Figure 4. Seasonal distributions are shown for two seasons from the hours of 6:00 to 23:00. 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 northeast as well as the northwest through west to southwest and said winds are most likely to occur during the winter season.

4.4 Pedestrian Level Wind Velocity Assessment and Computational Setup

A digital model was created of the proposed Development and pertinent surroundings, including the existing building. The model is based upon information gathered from client drawings and Google Earth. Chamberlain Architect Services Limited provided the architectural drawings. The structures and features that would have an impact on the wind flows are included in the digital model. The existing and proposed scenarios have both been simulated in the commercially available wind simulation software by Meteodyn Inc.

A three dimensional 'mesh' is created of varying size, appropriate to the distance from the development area. In these studies, a section plane was placed at a height of 1.5m from the ground (typical level of pedestrian activity) to extract simulated GEM wind speeds. These wind speeds are an ensemble average wind speed and hence more representative of the wind microclimate in the development area. The velocities obtained from the simulation are recorded and combined with historical meteorological data via post-processing.

4.5 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 5 presents results for the GEM wind speed that is exceeded 20% of the time, based on weather data recorded between the hours of 6:00 and 23:00. The GEM is the greater of the mean wind speed or the gust wind speed divided by 1.85. The gust wind speed is obtained as the sum of the local mean speed and the product of the peak factor and rms (i.e. mean + peak factor $*$ rms). The peak factor is assumed to be 3.0 following the Gaussian distribution assumption and the rms was recalculated from the local turbulent kinetic energy obtained from the CFD simulation. These speeds are directly related to the pedestrian comfort at a particular point. Table 1, below, summarizes the comfort criteria used in the presentation of the results depicted in Figure 5.

The comfort criteria are based on those prescribed in the City of Mississauga's Terms of Reference for Wind.

Table 1: Comfort Criteria

ACTIVITY	**Gust Equivalent Mean Speed Exceeded 20% of the Time**	**Description**
COMFORT	***km/h***	
Sitting	0-10	Light breezes desired for outdoor seating areas where one can read a paper without having it blown away.
Standing	0-15	Gentle breezes suitable for passive pedestrian activities where a breeze may be tolerated.
Walking	0-20	Relatively high speeds that can be tolerated during intentional walking, running and other active movements.
Uncomfortable	>20	Strong winds, considered a nuisance for most activities.

The activities are described as suitable for Sitting, Standing, Walking, or Uncomfortable, depending on the GEM wind speed exceeded 20% of the time. For a point to be rated as suitable for Sitting, for example, the wind conditions must not exceed 10km/h, more than 20% of the time. 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 Background and Theory of Wind Movement section. As the name infers, the category is recommended for outdoor space where people might sit for extended periods.

The Standing category is slightly more tolerant of wind, including wind speeds from calm up to 15km/h. 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 20km/h. 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 20km/h.

The figures represent the average person's response to wind force for two seasons. Effects such as wind chill and humidex (based on perception) are not considered.

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. People dwelling near the shore of an ocean, large lake or open field are more tolerant of wind than people residing in a sheltered wind environment.

4.6 Pedestrian Safety Criteria

An estimate of safety criteria exceedances are also included in the analysis to predict areas where strong wind gusts may occur. The estimate is based upon the gust wind speed exceeded nine times per year, or 0.1% of the time annually, based on 24 hour a day weather data. The safety criteria are shown below in Table 2. CFD modelling is limited in its ability to predict gust wind speeds and areas of concern, should they arise, may require further wind tunnel analysis.

Table 2: Safety Criteria

ACTIVITY	**Gust Wind Speed Exceeded 9 Times per year**	**Description**
SAFETY	***km/h***	
Exceeded	>90	Excessive gust speeds that can adversely affect safety and a pedestrian's balance and footing. Wind mitigation is typically required.

The estimated safety ratings for the existing and proposed settings are depicted in Figure 6.

4.7 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 clothing choices. The comfort criterion 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.

5. RESULTS

5.1 Development Site and Test Conditions

Proposed Development

The proposed Development is located at 50 High Street East and occupies a portion of the block of land bound by Park Street East to the northwest, Helene Street North to the northeast, High Street East to the southeast, and Elizabeth Street North to the southwest, as shown in Figure 1. The proposed Development site is currently occupied by a low-rise apartment building that will be removed.

The proposed Development involves construction of an 11-storey residential building, fronting High Street East. The Main Residential Entrance is located along the southeast façade fronting High Street East, proximate to the southmost corner of the building. Vehicular access to the site is provided via a private driveway connecting with High Street East along the southeast property boundary. Outdoor Amenity Space is proposed at-grade fronting High Street East, atop a step in the building at the 10^{th} level, along the southeast façade, as well as atop the building at the 12^{th} level.

The proposed Development is in a configuration as shown in Figure 2.

Surrounding Area

The proposed Development site is surrounded by a mix of low through high-rise residential, commercial, and institutional buildings, mature vegetation, and open spaces, as indicated in Figure 1. Lake Ontario is approximately 350m to the southeast of the site. A railway corridor runs in a northeast / southwest direction to the northwest of the site. The Credit River runs in a near- northwest / southeast direction to the southwest of the site.

Mid- to high-rise residential buildings surround the proposed Development to all compass points. Land to the north of the railway corridor as well as north of Rosewood Avenue & Saint Lawrence Drive, are predominantly occupied by low-rise residential neighbourhoods, interspersed with institutional buildings, low-rise retail buildings fronting Lakeshore Road East, as well as associated open spaces, and mature vegetation. Lands further to the east through south of the Development site are occupied by a mix of low- through mid-rise commercial and residential spaces, large open spaces associated with surface parking and marinas, and Lake Ontario beyond. Lands further to the south through west, are primarily occupied by low-rise buildings and open spaces associated with the Port Credit Memorial Arena and Park, and, further southwest of the Credit River, are predominantly low- and mid-rise residential buildings.

The following buildings are in various stages of approval through construction and were included in the model of the surrounds:

- 88 Park Street East
- 17, 19 Ann Street & 84, 90 High Street East & 91 Park Street East
- 128 Lakeshore Road East

Urban developments present relatively coarse terrain that moderate pedestrian level winds, whereas low-rise buildings and open spaces allow wind the opportunity to accelerate on approach. Transition zones from more open to urban settings often prove problematic, as winds exacerbated by relatively more open settings are redirected to flow over, around, down, and between buildings.

Figure 1 depicts the site and its immediate surrounds. The site plan is shown in Figure 2 and the computational geometry model is shown in Figure 3.

Macroclimate

For the proposed Development, the upstream wind flow during calculation was conditioned to simulate an atmospheric boundary layer passing over open / suburban terrain. The terrain within the site's immediate vicinity was incorporated into the proximity model. Historical meteorological data recorded at Billy Bishop Airport was used in this analysis. The data is split up into two seasons, winter and summer, and the resulting wind roses are presented as mean velocity and percent frequency in Figures 4a & 4b. 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 1.5*m*, for an urban macroclimate, are 52% of the mean values indicated on the wind rose, (for suburban and rural macroclimates the values are 63% and 78% respectively). The macroclimate for this area is predominantly open / suburban.

Winter (November through April) has the highest mean velocities of the seasons with prevailing winds from the northwest through west to southwest, with significant components also from the northeast, as indicated in Figure 4a. Summer (May through October) has lower mean wind velocities with prevailing winds from the northeast and east, as indicated in Figure 4b. Reported pedestrian comfort conditions pertain to the winter season, unless stated otherwise.

5.2 Pedestrian Level Wind Velocity Assessment

In the computational model, the full wind field measuring 480m in radius was studied to determine conditions related to comfort and safety. For the existing setting, the subject building was removed, and the "existing" site model recalculated with the current site.

The design probability distribution gradient wind speed and direction, taken from historical meteorological data for the area (see Figure 4) was combined with pedestrian level mean and gust wind speeds measured at each point to provide predictions of the percentage of time a point will be comfortable for a given activity. These predictions of mean and maximum or “gust” wind speeds are provided on a seasonal basis in Figures 5a – 5d.

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

Venturi action, scour action, downwash and other factors, as discussed in the Background and Theory of Wind Movement section, 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 exposed to a mix of open / suburban settings to prevailing and remaining compass points with winds flowing over and between low through high-rise buildings, mature vegetation, Lake Ontario, and open spaces. As such, the surroundings can be expected to influence wind at the site to varying degrees.

5.3 Review of CFD Results

The areas of interest are areas surrounding the proposed Development, mainly public streets conditions, internal site conditions, pedestrian entrance conditions, and outdoor amenity space conditions. The pedestrian level comfort results are graphically depicted for the two seasons in Figures 5a – 5d and estimated safety results are graphically depicted in Figures 6a and 6b. The following discusses anticipated wind conditions and suitability for the areas’ intended uses.

Please note: the proposed results display a section plane 1.5m above the ground and, as such, the building footprint at this height is shown as the area beneath the second level overhang of the building.

Public Street Conditions

High Street East

In the existing setting, the contour results along High Street East, within the zone of influence of the proposed Development, indicate wind conditions that are suitable for sitting or standing in the winter to the north of Elizabeth Street North, and walking conditions were noted between the high-rise buildings flanking High Street East between Stavebank Road and Elizabeth Street North. A localised uncomfortable rating was noted proximate to the intersection of High Street East with Stavebank Road. In the summer, High Street East was rated predominantly suitable for sitting, with walking conditions noted between Elizabeth Street North and Stavebank Road.

With inclusion of the proposed Development, a subtle realignment of winds was noted along High Street East, insufficient to change the comfort rating in most cases. The increase in winds can be attributed to the proposed Development redirecting winds through downwash and other phenomena to flow down the face of the building and around the corners at the pedestrian level, whereas improvements can be attributed to increased blockage to specific wind directions relative to the existing setting. In the winter, High Street East to the immediate south through southeast of the proposed Development realised an increase in winds sufficient to change the existing sitting rating to standing. An existing walking condition at the southmost corner of the neighbouring 15 Elizabeth Street North building increased in area slightly in the proposed setting. Conversely, improvements in wind conditions were noted proximate to the eastmost corner of the proposed Development, sufficient to change the existing standing rating to sitting.

In the summer, there was a very subtle change in pedestrian comfort conditions with inclusion of the proposed Development. A localised area proximate to the Development's southmost corner realised a slight increase in winds that was sufficient to change the rating from sitting to standing. Similarly, the existing standing condition proximate to the neighbouring 15 Elizabeth Street North building increased in size slightly from sitting conditions, in the proposed setting. Conversely, improvements were noted proximate to the neighbouring 12 Helene Street North and 7 Elizabeth Street North buildings, sufficient to change the standing conditions to sitting. Overall, High Street East remains comfortable and appropriate for its intended use with inclusion of the proposed Development.

As such, inclusion of the proposed Development will result in a subtle realignment of winds along High Street East and the overall comfort conditions remain suitable for the intended purpose throughout the year with inclusion of the proposed Development. Consideration of fine design and landscape elements that were too fine to include in the computational model will result in more comfortable conditions than those reported.

The estimated safety conditions along High Street East pass pedestrian level wind velocity safety criteria, as described in Section 4.6 and depicted in Figures 6a and 6b.

Helene Street North

In the existing setting, the contour results along Helene Street North, within the zone of influence of the proposed Development, indicate wind conditions that are generally suitable for sitting or standing in the winter, and walking conditions were noted proximate to the mid- to high-rise buildings located near the intersection of Helene Street North with Park Street East. The walking conditions transition further to an uncomfortable rating proximate to the 70 Park Street East building. In the summer, Helene Street North is predominantly rated suitable for sitting, with the exception of standing conditions proximate to the 70 Park Street East building, with a localised walking rating proximate to the southmost corner of the building. With inclusion of the proposed Development, Helene Street North realises subtle improvements. The above-mentioned walking and uncomfortable ratings decreased in area and the remainder of the Street retained its original comfort ratings.

Helene Street North remains comfortable and appropriate for its intended use throughout the year with inclusion of the proposed Development, with the exception of the above-noted uncomfortable rating, which was an existing condition that improved in the proposed setting.

The estimated safety conditions along Helene Street North pass the pedestrian level wind velocity safety criteria, as described in Section 4.6 and depicted in Figure 6.

Elizabeth Street North

In the existing setting, Elizabeth Street North was rated predominantly suitable for standing in the winter, with the exception of localised walking conditions noted proximate to the intersections with Park Street East and High Street East. In the summer, Elizabeth Street North was rated suitable for sitting or standing. With inclusion of the proposed Development, Elizabeth Street North largely retained its original comfort ratings throughout the year. In the winter, the walking conditions increased in area slightly from standing and in the summer, the standing category increased in area slightly from sitting conditions between Park Street East and High Street East. Overall, the area remains comfortable and appropriate for its intended use throughout the year with inclusion of the proposed Development and the estimated safety conditions pass the pedestrian level wind velocity safety criteria.

Park Street East

In the existing setting, Park Street East was rated predominantly suitable for sitting or standing in the winter between Elizabeth Street North and Helene Street North, with walking conditions noted more removed, and the aforementioned uncomfortable condition, which was noted proximate to the 70 Park Street East building. In the summer, Park Street East was rated suitable for sitting or standing, with a localised walking rating proximate to the 70 Park Street East building. With inclusion of the proposed

Development, very subtle improvements in wind conditions were noted along Park Street East, sufficient to decrease the area rated suitable for walking. Overall, Park Street East remains comfortable and appropriate for its intended use throughout the year and the estimated safety conditions pass the pedestrian level wind velocity safety criteria.

Internal Site Conditions

Internal site conditions are generally predicted to be suitable for sitting or standing in the winter. In the summer, the area is suitable for sitting, with the exception of localised standing conditions proximate to the southmost corner of the building. As such, internal site conditions are predicted comfortable and suitable for their intended uses, and the estimated safety conditions pass the pedestrian level wind velocity safety criteria.

Pedestrian Entrance Conditions

The Main Residential Entrance to the building is located along the southeast façade, fronting High Street East, proximate to the southmost corner of the building. Wind conditions comfortable for standing, or better, are preferable at building entrances, while conditions suitable for walking are appropriate for their adjacent sidewalks.

The Main Residential Entrance was predicted suitable for sitting or standing throughout the year and is therefore considered comfortable and appropriate for its intended use. This can partly be attributed to the proposed Development's wind friendly design features, including stepped conditions, overhangs, and modest height, which, when considered in concert, intercept winds approaching the proposed Development in upper streamlines that are redirected by the proposed building to flow down the façade of the building towards the pedestrian level. The building is also located in the aerodynamic shade region of the neighbouring 10-storey apartment buildings for winds emanating from the near northeast and southwest directions, which together make up a significant portion of the prevailing wind climate.

The wind conditions proximate to the Main Residential Entrance are therefore considered suitable for its intended use throughout the year and the estimated safety conditions pass the pedestrian level wind velocity safety criteria, as described in Section 4.6 and depicted in Figure 6.

Outdoor Amenity Space Conditions

Outdoor Amenity Spaces are proposed at-grade, fronting High Street East, atop a step in the building at the 10th level, along the southeast façade, as well as atop the building at the 12th level.

The Outdoor Amenity Space proposed at-grade, fronting High Street East, was predicted predominantly suitable for sitting in the summer, as shown in Figure 5d. In the winter, the Amenity Space was rated suitable for sitting and transitioned to standing conditions towards the south extents of the Space, as shown in Figure 5b. Overall, the Amenity Space is considered seasonally appropriate for its intended use.

The Outdoor Amenity Space located atop the step in the building at the 10th level, along the southeast façade, was too narrow to perform point analysis within the CFD software and, as such, a qualitative assessment of anticipated with conditions is provided. Portions of the Amenity Space are well protected by the proposed and neighbouring buildings for much of the prevailing wind climate, however the area remains exposed to winds emanating from the south through southeast, which occur with moderate frequency in the summer but are typically of lower velocity. With consideration of the 1.5m high screen walls around the perimeter of the space, and its narrow design, the Amenity Space is predicted seasonally appropriate for its intended use.

Point analysis was performed within the CFD model to determine the conditions realised above the pedestrian level for the rooftop Amenity Space. Portions of the Amenity Space will be within the aerodynamic shade region of the mechanical penthouse for wind emanating from specific directions, however the rooftop is higher than the neighbouring surroundings and is therefore exposed to winds that are unmitigated upon approach. The Amenity Space was tested with 1.5m high screen walls around the perimeter of the space and the resulting wind conditions are shown in Figure 5. In the winter, points 5, 14, and 15 were rated suitable for sitting, points 1 – 4, 6, 7, 12, & 13 were rated appropriate for standing, and points 8 – 11 were rated appropriate for walking. In the summer, points 4 – 6, 12, 14 & 15 were rated appropriate for sitting and the remainder of the points were rated suitable for standing. Portions of the Amenity Space are therefore considered seasonally appropriate for their intended use. A mitigation plan is recommended in order to achieve more appropriate conditions throughout the Space, which could include higher perimeter screens, trellis/shade structures, privacy / wind screens, raised planter beds populated with coarse plantings, coniferous vegetation, and / or others.

The estimated safety conditions within the at-grade, 10th and 12th level Outdoor Amenity Spaces pass or are predicted to pass the pedestrian safety criteria.

5.4 Summary

The observed wind velocity and flow patterns at the proposed Development site are largely influenced by approach wind characteristics that are dictated by the surrounding areas to prevailing and less dominant wind directions. These surroundings present a mix of open and suburban terrain to prevailing winds, generally affording wind the opportunity to accelerate. This results in some windy conditions in the existing setting, notably in the winter, proximate to the corners of neighbouring mid- and high-rise buildings, as well as in the gaps between buildings, and more comfortable conditions were predicted in the summer.

Once the subject site is developed, ground level wind conditions remain similar to or better than the existing setting for the most part, with localized areas of increased pedestrian level winds noted proximate to the proposed Development's corners and gaps between buildings, which remain comfortable and appropriate to the areas' intended purposes throughout the year. Consideration of fine design details and landscape features will result in more comfortable conditions than reported. The relationship between surface roughness and wind is discussed in the Background and Theory of Wind Movement section and shown graphically in Figure A of the same section.

A mitigation plan is recommended in order to achieve more comfortable conditions throughout the rooftop Outdoor Amenity Space.

The proposed Development is predicted to realise wind conditions acceptable to a typical open / suburban context, based on this preliminary Computational Fluid Dynamics analysis.

6. FIGURES

Figure 1: Site Aerial Photo

Figure 2: Site Plan

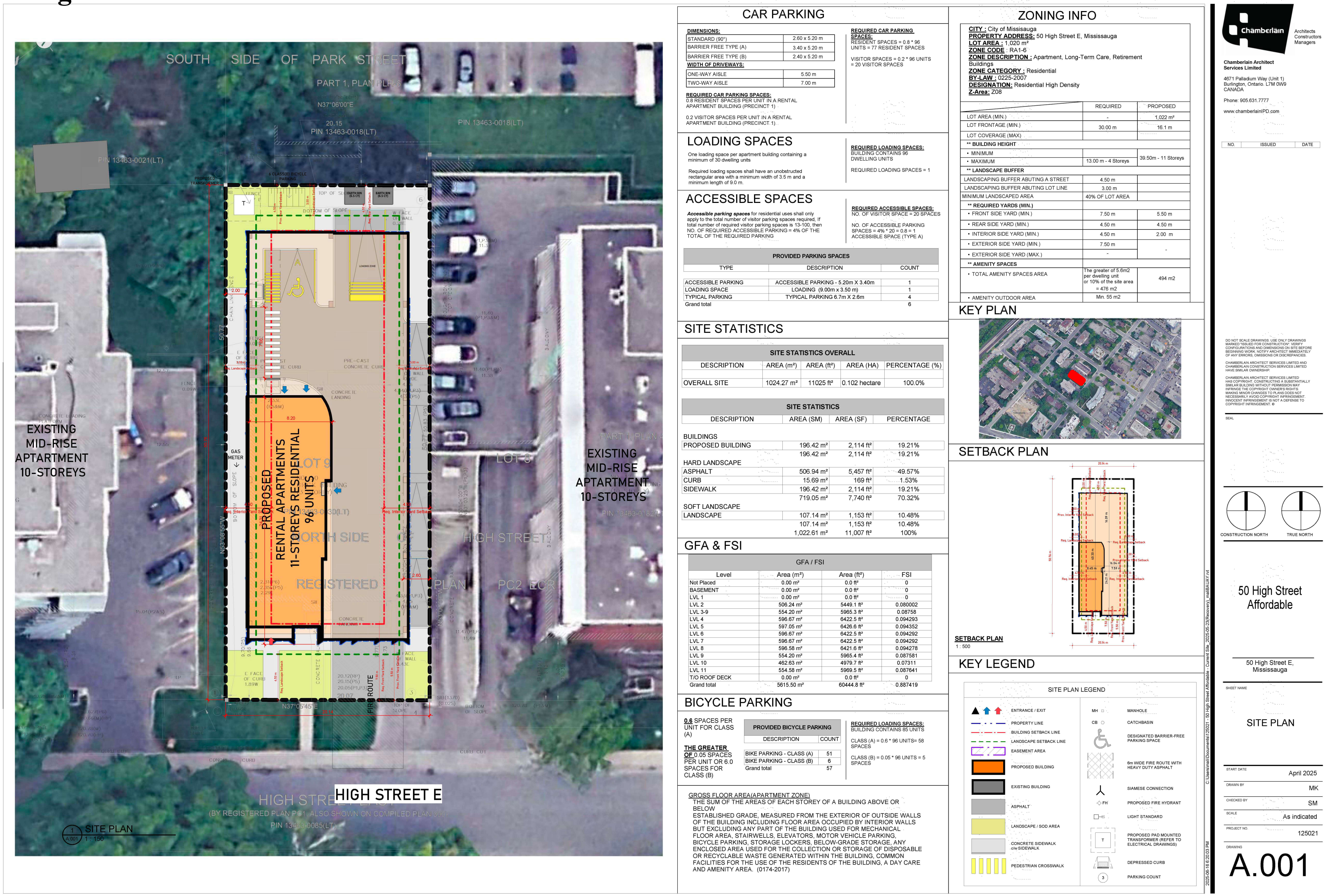

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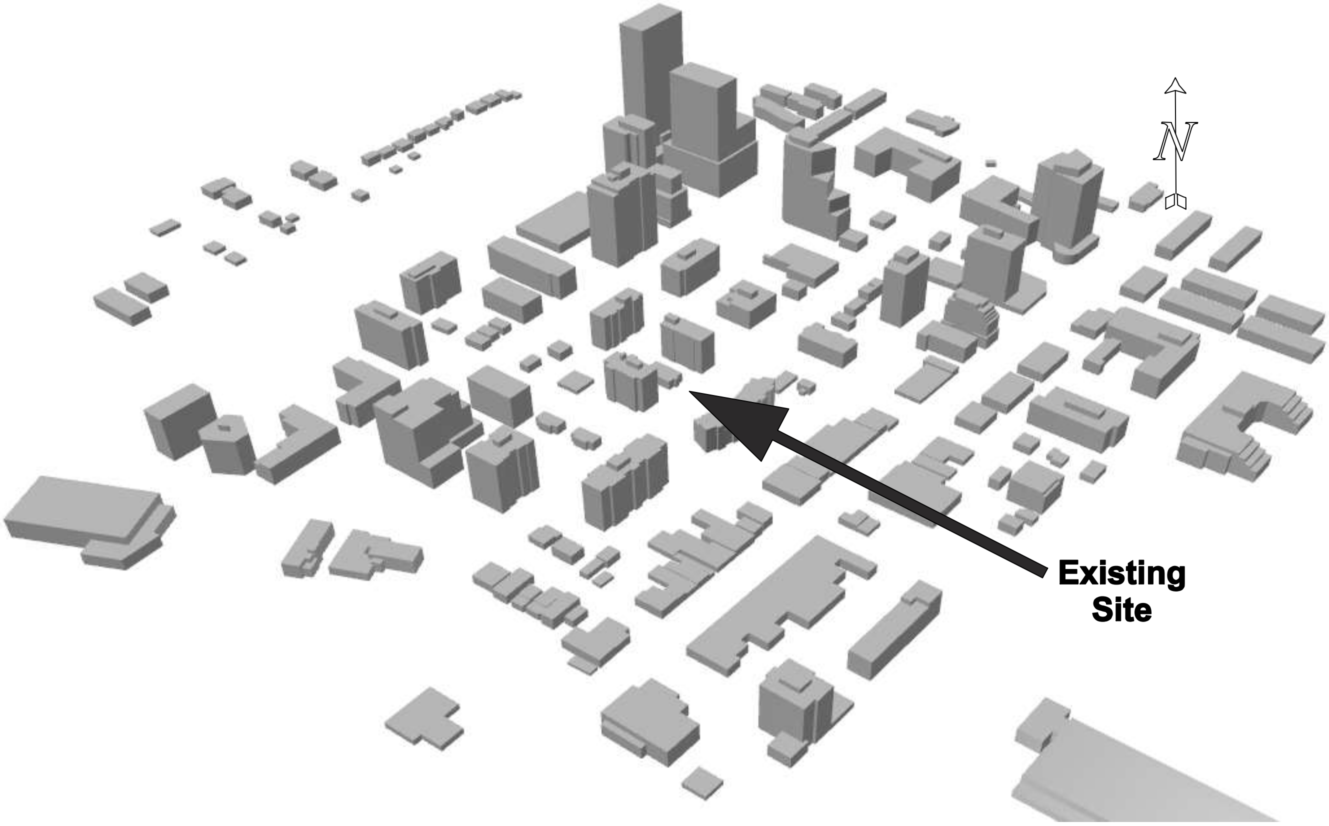
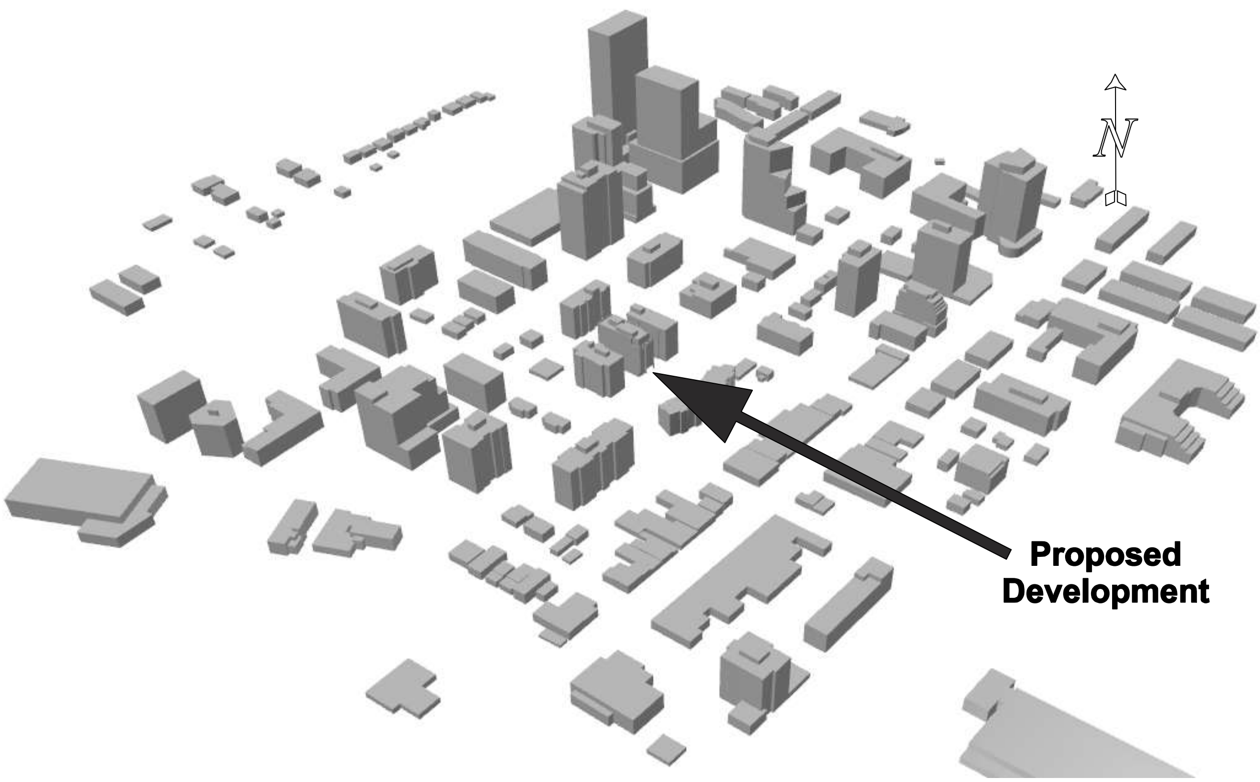
Figure 3: Computational Geometry



a) Existing Setting



b) Proposed Setting

Figure 4a: Winter Wind Rose - Billy Bishop Airport

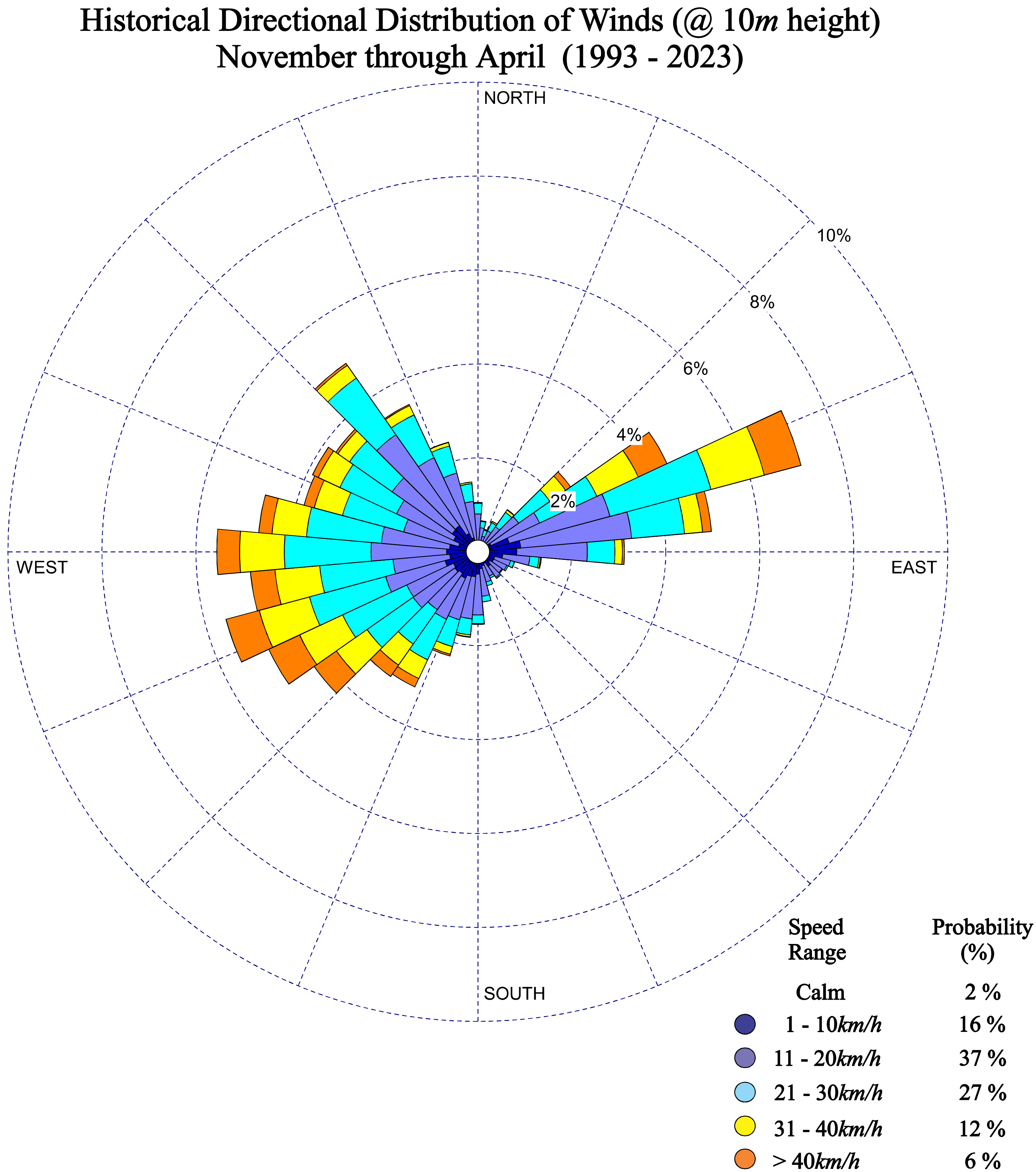


Figure 4b: Summer Wind Rose - Billy Bishop Airport

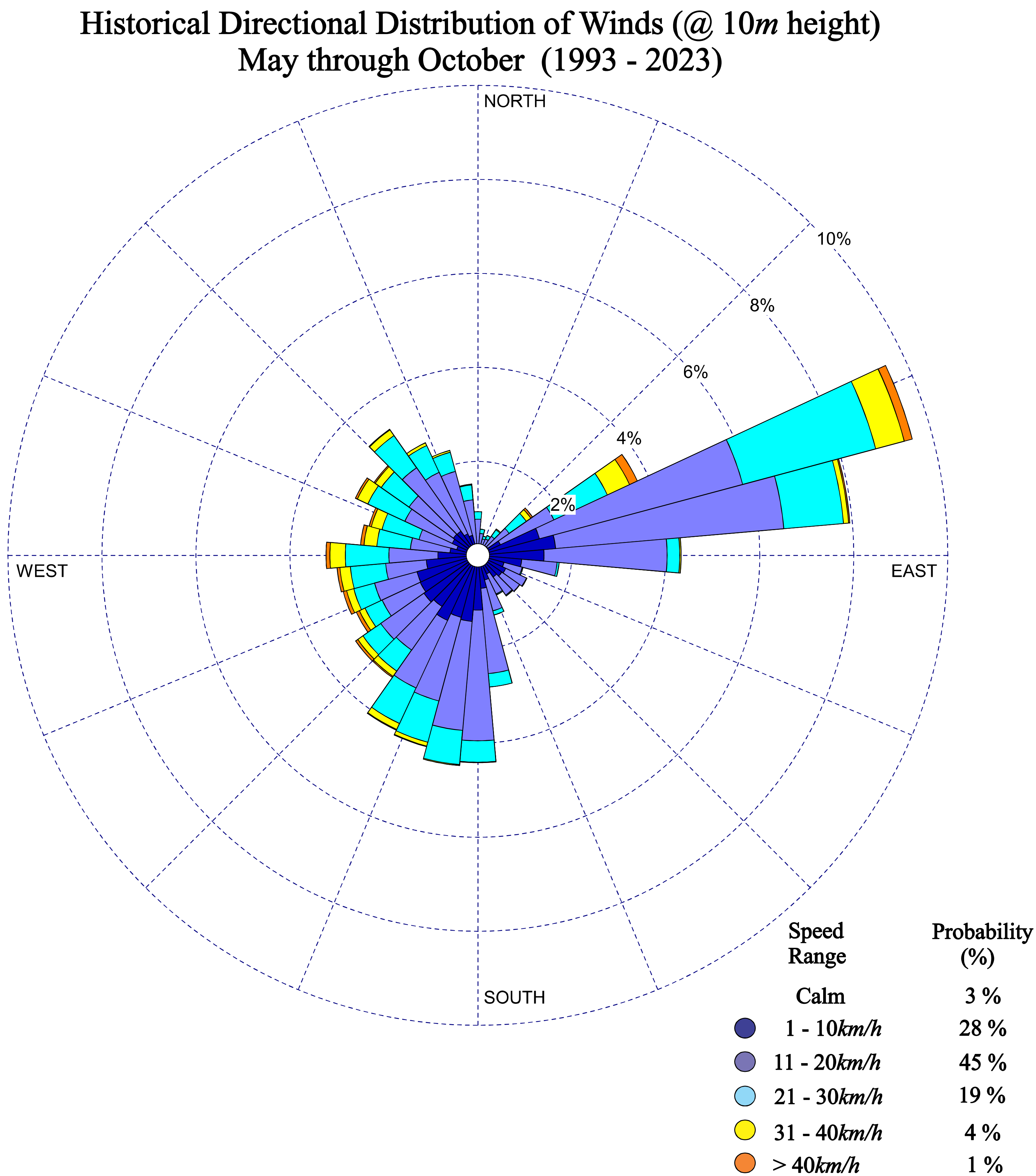


Figure 5a: Pedestrian Level Wind Velocity Comfort Categories

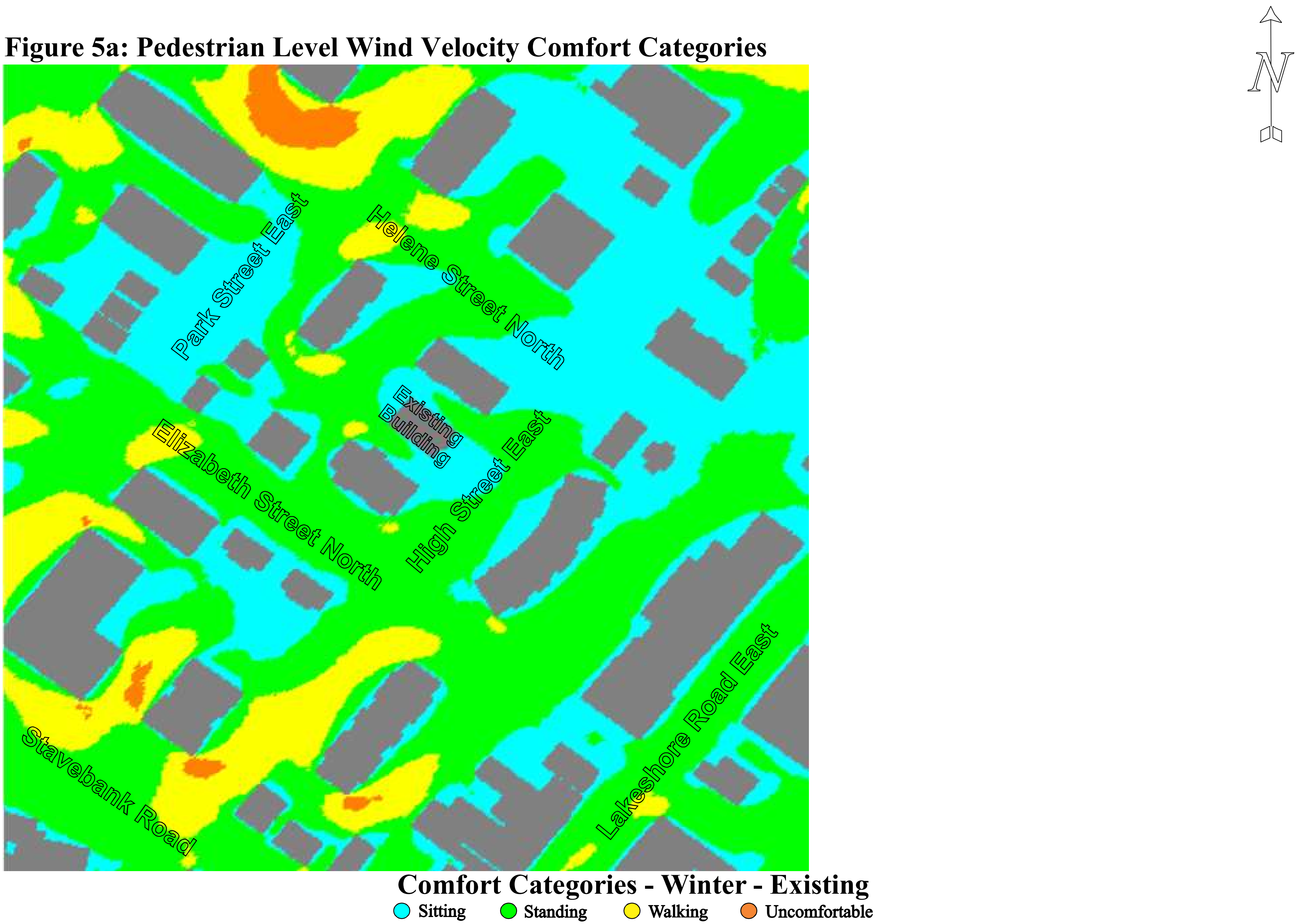
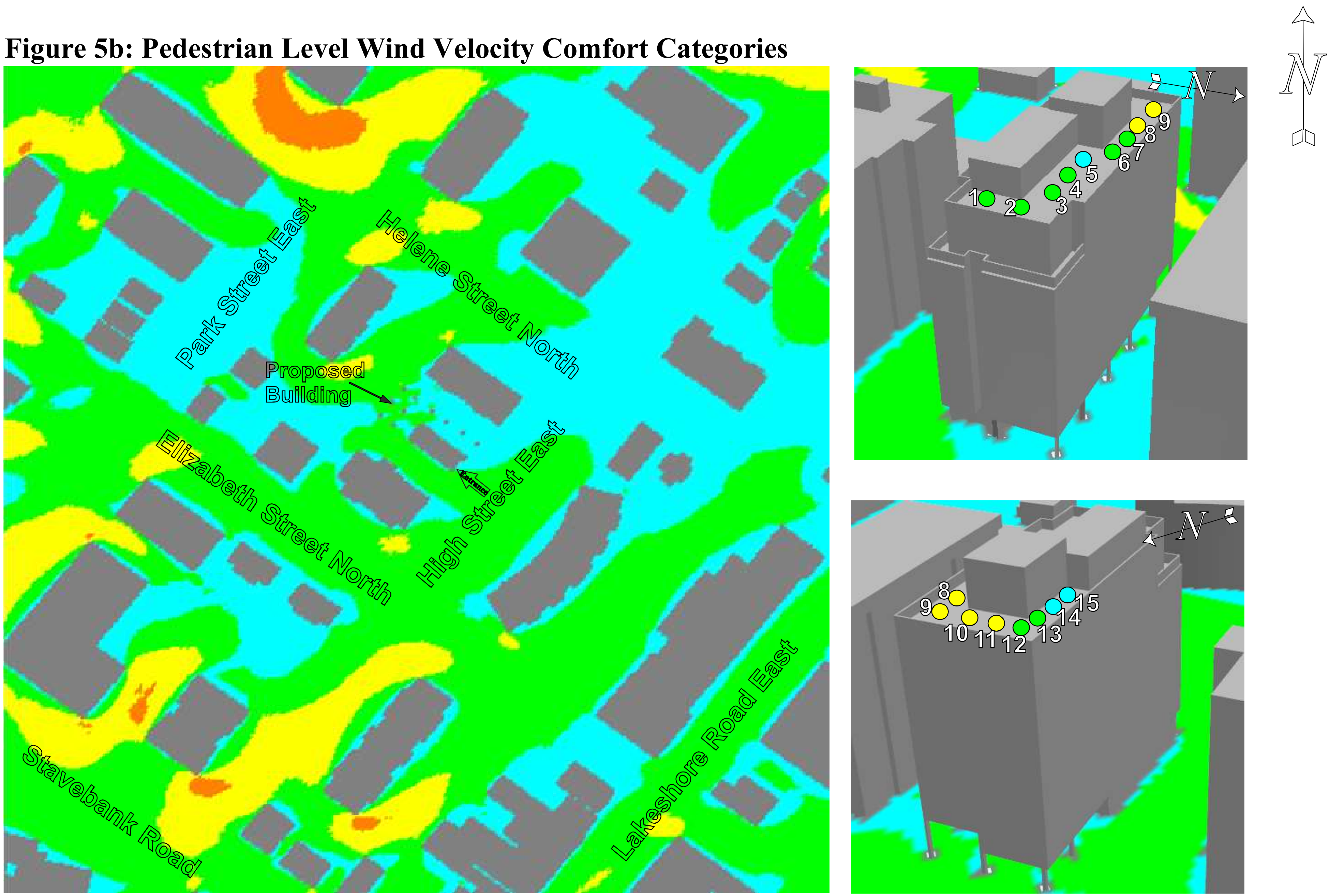


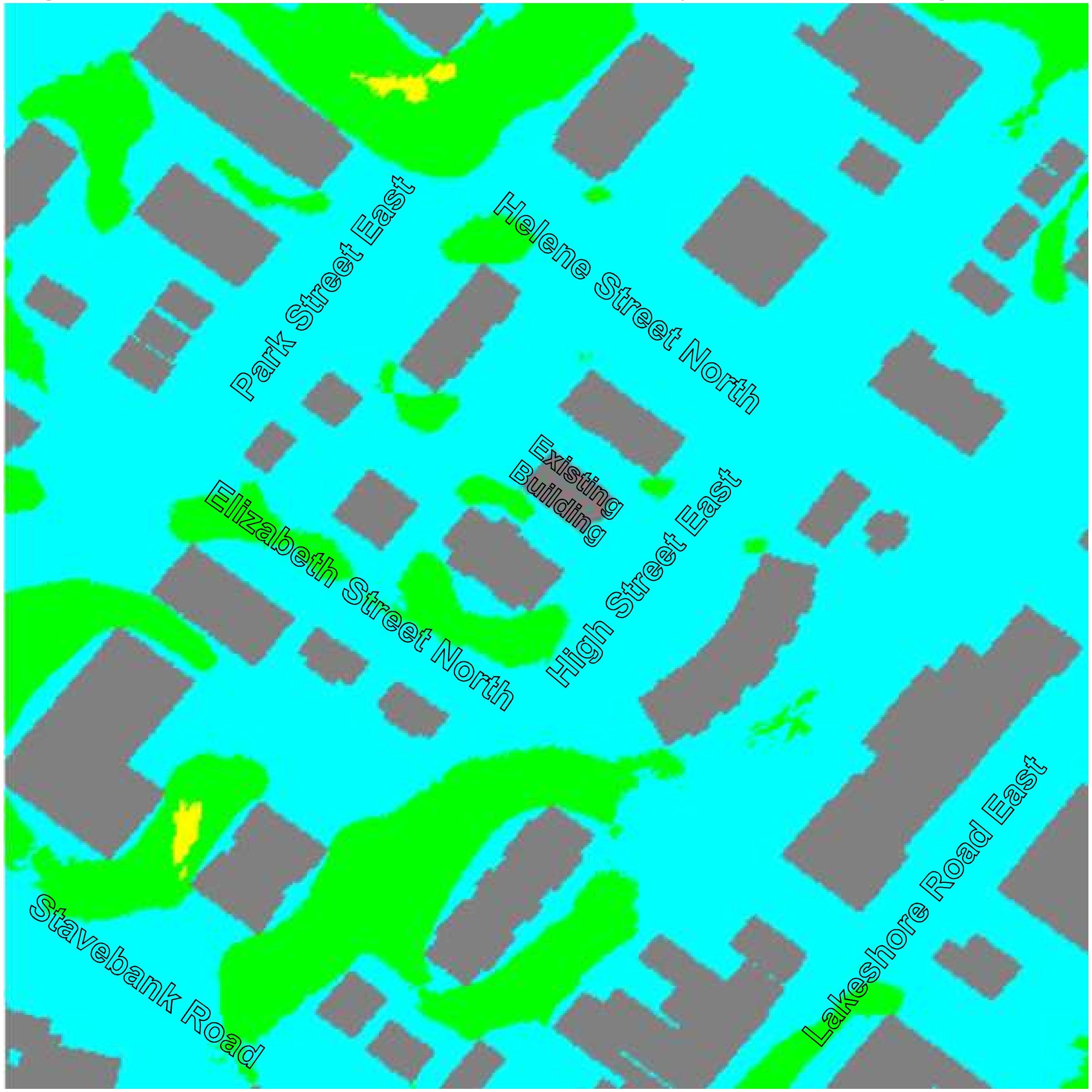
Figure 5b: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Winter - Proposed

Sitting Standing Walking Uncomfortable

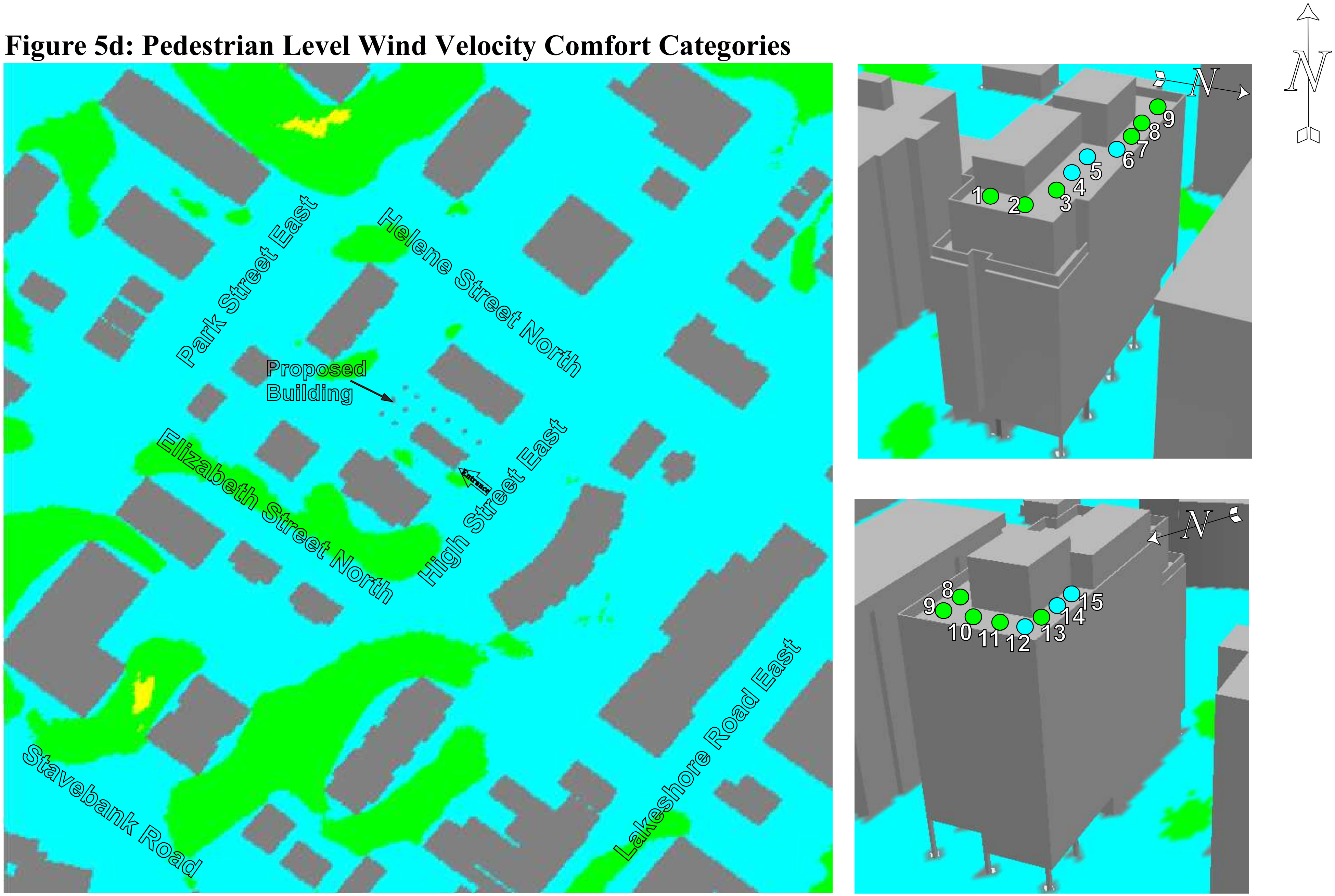
Figure 5c: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Summer - Existing

Sitting Standing Walking Uncomfortable

Figure 5d: Pedestrian Level Wind Velocity Comfort Categories

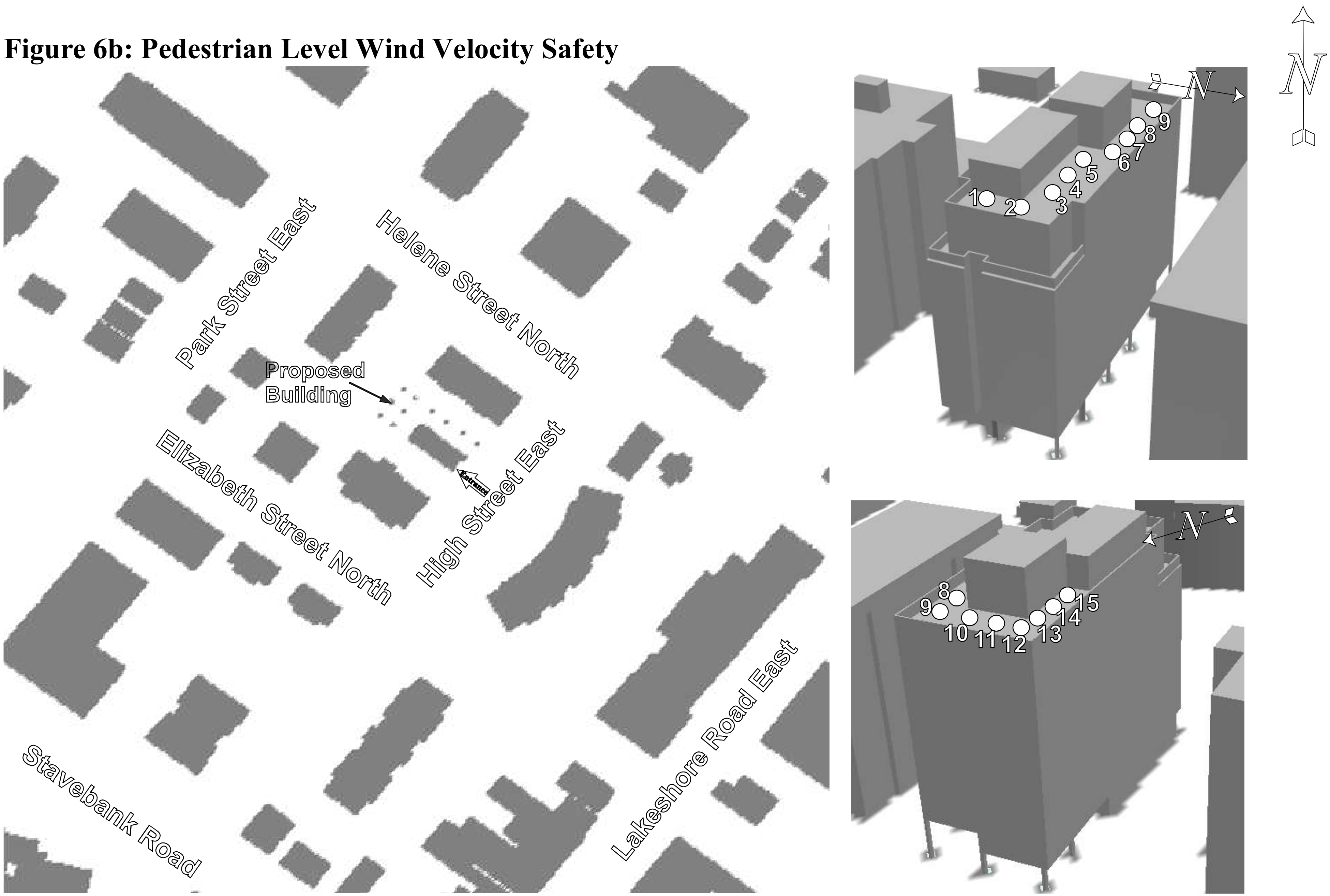


Comfort Categories - Summer - Proposed

Sitting Standing Walking Uncomfortable

Figure 6a: Pedestrian Level Wind Velocity Safety

Figure 6b: Pedestrian Level Wind Velocity Safety



Safety Criteria - Proposed

Exceeding Safety Criteria *Estimated

Theakston Environmental

7. 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 assessment 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:

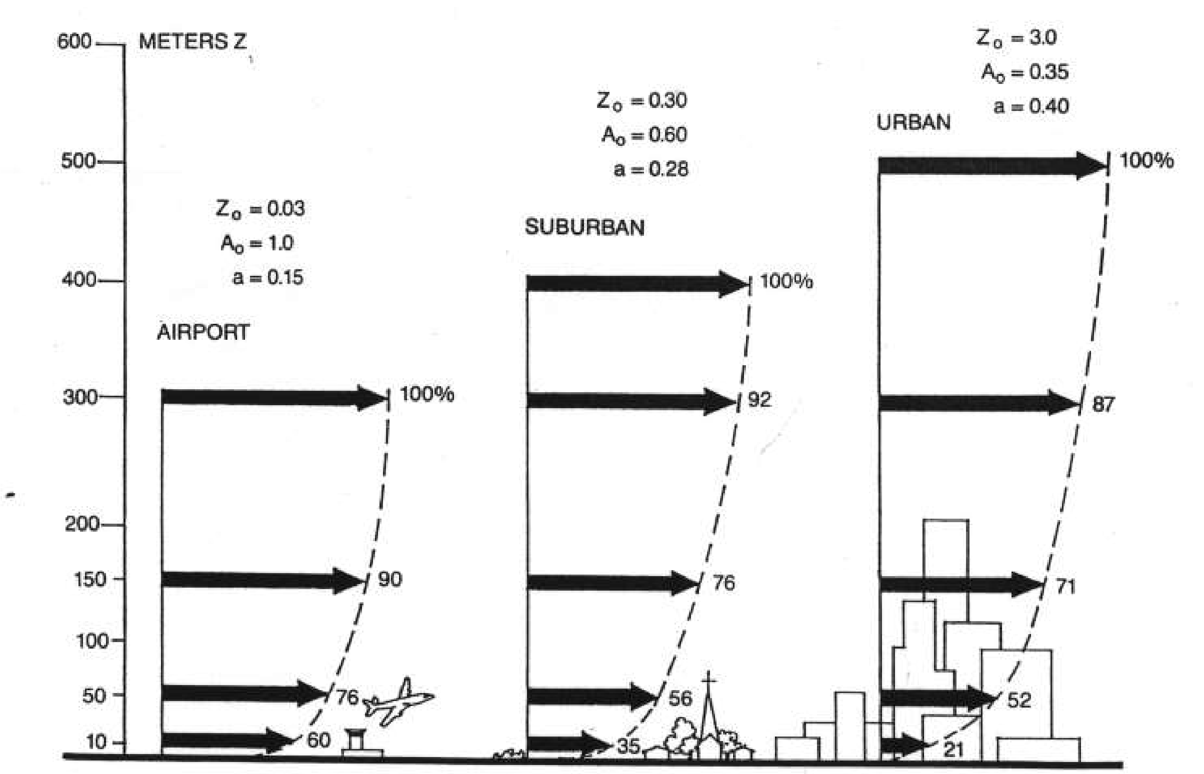


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

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 development 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 development 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 section above.

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