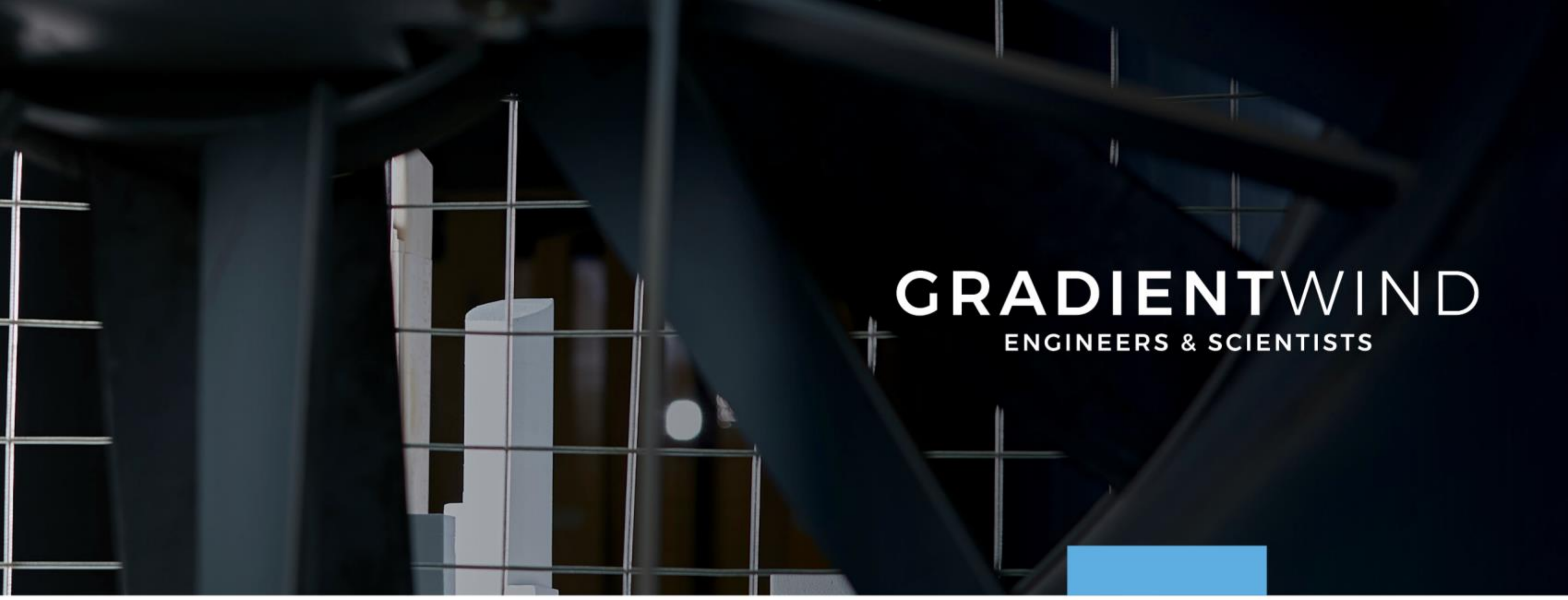
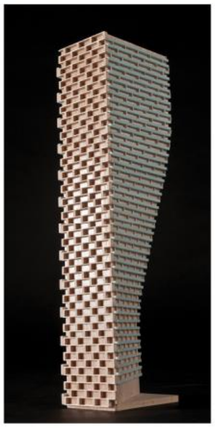
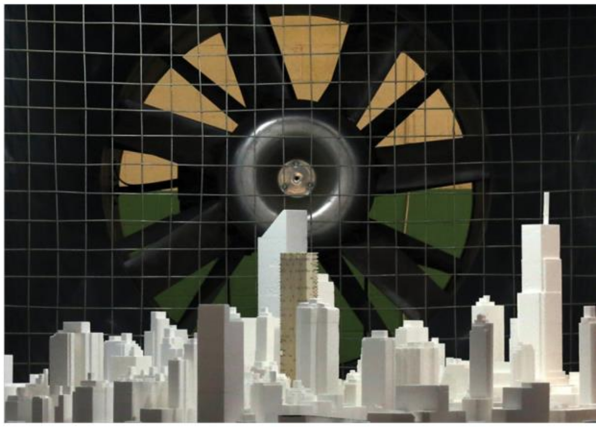


PEDESTRIAN LEVEL WIND STUDY

829 Carling Avenue
Ottawa, Ontario

Report: 21-086-PLW





April 16, 2021

PREPARED FOR
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EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study to satisfy requirements for concurrent Zoning By-law Amendment (ZBA) and Site Plan Control (SPC) application submissions for the proposed mixed-use tall building development located at 829 Carling Avenue in Ottawa, Ontario (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind comfort and safety within and surrounding the subject site, and to identify areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered.

The study involves simulation of wind speeds for selected wind directions in a three-dimensional (3D) computer model using the computational fluid dynamics (CFD) technique, combined with meteorological data integration, to assess pedestrian wind comfort and safety within and surrounding the subject site. A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-8B. Based on computer simulations using the CFD technique, meteorological data analysis of the Ottawa wind climate, City of Ottawa wind comfort and safety criteria, and experience with numerous similar developments, the study concludes that all grade-level areas within and surrounding the subject site are predicted to be acceptable for the intended pedestrian uses throughout the year.

The proposed development includes a common amenity terrace at Level 8, along the west and north sides of the podium roof. Wind mitigation measures, which are presented in Section 5.2, will be required to achieve the sitting comfort class during the typical use period within most areas. For those areas that are predicted to be moderately windy during the same period, it would be prudent to align programming of the spaces with the results in this study. Wind mitigation measures will be revisited and confirmed with the design team when the programming of the outdoor spaces is defined.

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas within or surrounding the subject site at grade level, as well as the Level 8 amenity terrace, were found to experience conditions that could be considered dangerous, as defined in Section 4.4.

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1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Claridge Homes to undertake a pedestrian level wind (PLW) study to satisfy requirements for concurrent Zoning By-law Amendment (ZBA) and Site Plan Control (SPC) application submissions for the proposed mixed-use tall building development located at 829 Carling Avenue in Ottawa, Ontario (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind comfort and safety within and surrounding the subject site, and to identify areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, where required.

Our work is based on industry standard computer simulations using the computational fluid dynamics (CFD) technique and data analysis procedures, City of Ottawa wind comfort and safety criteria, architectural drawings prepared by Hariri Pontarini Architects in March 2021, surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa, as well as recent satellite imagery.

2. TERMS OF REFERENCE

The subject site is located at 829 Carling Avenue in Ottawa, on a parcel of land situated within the northwest corner of the Carling Avenue and Preston Street intersection. The proposed development comprises a 61-storey mixed-use residential building rising 195 meters (m) from Level 1 to Level 62.

Architectural Rendering, Southeast Perspective
(Courtesy of Hariri Pontarini Architects)

At Level 1, the floorplan includes retail spaces at the northeast corner with access from Preston Street and the southwest corner from Carling Avenue. The main residential entrance is located at the southeast corner of the building fronting Preston Street. Access to six levels of below-grade parking and six levels of above-grade parking (Levels 2-7, inclusive) is provided at the northwest corner of the floorplan from Sidney Street.

At Level 8, the tall building steps back from west and north perimeters to accommodate an outdoor common amenity terrace. Indoor amenities at Level 8 include a movie theatre, party rooms, a game room, exercise areas, and a swimming pool. The swimming pool resides in a building along the west elevation of the podium that rises approximately 1.5 storeys above Level 8. The tower rises from Levels 9-21 with a common floorplate. At Level 21, the tower steps back from the west elevation and continues to Level 47 with a common floorplate. At Level 47, the tower again steps back from the west elevation and continues to the upper roof with a common floorplate.

The subject site is surrounded in the near-field (within a radius of 200 m) by low-rise buildings from the southwest clockwise to north-northeast, medium- and high-rise buildings to the east-northeast, and open land for the remaining compass azimuth. Of importance, an existing condominium building is located to the immediate northwest (7 Sidney Street), a 31-storey mixed-use residential building under construction to the immediate north (SoHo Italia at 500 Preston Street), and an existing 45-storey residential building to the immediate east-northeast (ICON I at 505 Preston Street). Additionally, Dow's Lake is situated to the east-southeast clockwise to southeast of the subject site, while the Central Experimental Farm is situated to the south clockwise to southwest. At greater distances (i.e., within a radius of 2 kilometers (km) beyond the near field), a mix of mostly low-rise buildings with some mid-rise and high-rise buildings create suburban exposures for most wind directions. From the southeast clockwise to southwest, a hybrid open-suburban exposure is created by a mix of low-rise buildings, Dow's Lake, and the Central Experimental Farm. Figures 1A illustrates the subject site and surrounding context, representing the proposed future massing scenario, while Figure 1B illustrates the site plan for the approved massing scenario (commonly referred to as 'existing'). Figures 2A-2D illustrate the computational models used to conduct the comparative study.

3. OBJECTIVES

The principal objectives of this study are to (i) determine comparative pedestrian level wind comfort and safety conditions at key areas within and surrounding the subject site; (ii) identify areas where wind conditions may interfere with the intended uses of outdoor spaces; and (iii) recommend suitable mitigation measures, where required.

4. METHODOLOGY

The approach followed to quantify pedestrian wind conditions over the site is based on CFD simulations of wind speeds across the subject site within a virtual environment, meteorological analysis of the Ottawa area wind climate, and synthesis of computational data with City of Ottawa wind comfort and safety criteria[1]. The following sections describe the analysis procedures, including a discussion of the noted pedestrian wind criteria.

4.1 Computer-Based Context Modelling

A computer based PLW study was performed to determine the influence of the wind environment on pedestrian comfort over the proposed development site. Pedestrian comfort predictions, based on the mechanical effects of wind, were determined by combining measured wind speed data from CFD simulations with statistical weather data obtained from Ottawa Macdonald-Cartier International Airport. The general concept and approach to CFD modelling is to represent building and topographic details in the immediate vicinity of the study site on the surrounding model, and to create suitable atmospheric wind profiles at the model boundary. The wind profiles are designed to have similar mean and turbulent wind properties consistent with actual site exposures.

An industry standard practice is to omit trees, vegetation, and other existing and proposed landscape elements from the model due to the difficulty of providing accurate seasonal representation of vegetation. The omission of trees and other landscaping elements produces slightly more conservative (i.e., windier) wind speed values.

[1] City of Ottawa Terms of References: Wind Analysis
https://documents.ottawa.ca/sites/default/files/torwindanalysis_en.pdf

4.2 Wind Speed Measurements

The PLW analysis was performed by simulating wind flows and gathering velocity data over a CFD model of the site for 12 wind directions. The CFD simulation model was centered on the study building, complete with surrounding massing within a diameter of approximately 820 m.

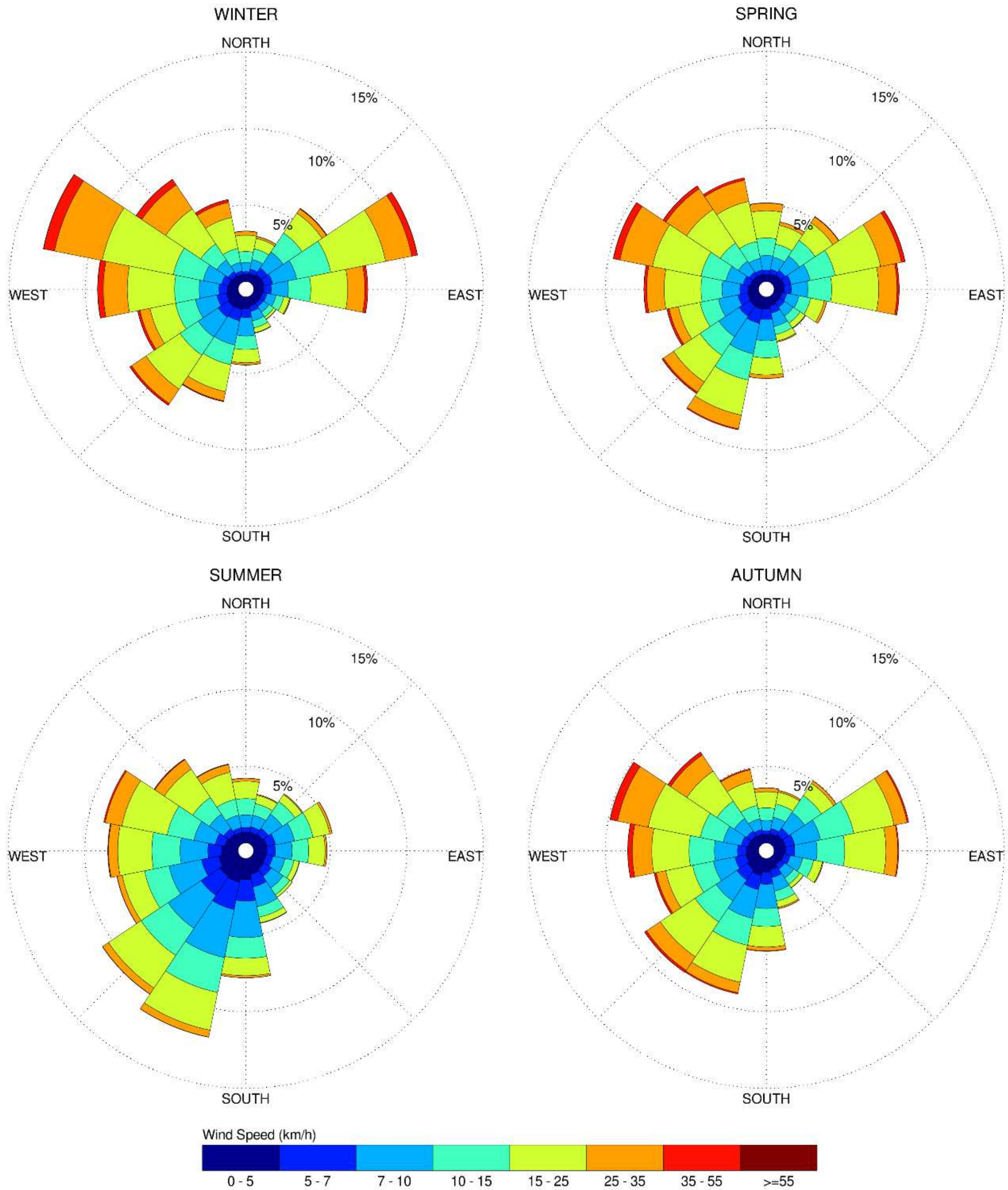
Mean and peak wind speed data obtained over the study site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade were referenced to the wind speed at gradient height to generate mean and peak velocity ratios, which were used to calculate full-scale values. Gradient height represents the theoretical depth of the boundary layer of the earth's atmosphere, above which the mean wind speed remains constant. Further details of the wind flow simulation technique are presented in Appendix A.

4.3 Meteorological Data Analysis

A statistical model for winds in Ottawa was developed from approximately 40 years of hourly meteorological wind data recorded at Ottawa Macdonald-Cartier International Airport and obtained from Environment and Climate Change Canada. Wind speed and direction data were analyzed for each month of the year to determine the statistically prominent wind directions and corresponding speeds, and to characterize similarities between monthly weather patterns.

The statistical model of the Ottawa area wind climate, which indicates the directional character of local winds on a seasonal basis, is illustrated on the following page. The plots illustrate seasonal distribution of measured wind speeds and directions in kilometers per hour (km/h). Probabilities of occurrence of different wind speeds are represented as stacked polar bars in sixteen azimuth divisions. The radial direction represents the percentage of time for various wind speed ranges per wind direction during the measurement period. The preferred wind speeds and directions can be identified by the longer length of the bars. For Ottawa, the most common winds occur for westerly wind directions, followed by those from the east, while the most common wind speeds are below 36 km/h. The directional preference and relative magnitude of wind speed changes somewhat from season to season.

SEASONAL DISTRIBUTION OF WIND
OTTAWA MACDONALD-CARTIER INTERNATIONAL AIRPORT



Notes:

1. Radial distances indicate percentage of time of wind events.
2. Wind speeds are mean hourly in km/h, measured at 10 m above the ground.

4.4 Pedestrian Comfort and Safety Criteria – City of Ottawa

Pedestrian comfort and safety criteria are based on the mechanical effects of wind without consideration of other meteorological conditions (i.e., temperature, relative humidity). The comfort criteria assume that pedestrians are appropriately dressed for a specified outdoor activity during any given season. Five pedestrian comfort classes are based on 20% non-exceedance mean wind speed ranges, which include (1) Sitting; (2) Standing; (3) Strolling; (4) Walking; and (5) Uncomfortable. More specifically, the comfort classes and associated mean wind speed ranges are summarized as follows:

1) **Sitting:** Mean wind speeds no greater than 10 km/h occurring at least 80% of the time. The equivalent gust wind speed is approximately 16 km/h.

2) **Standing:** Mean wind speeds no greater than 14 km/h occurring at least 80% of the time. The equivalent gust wind speed is approximately 22 km/h.

3) **Strolling:** Mean wind speeds no greater than 17 km/h occurring at least 80% of the time. The equivalent gust wind speed is approximately 27 km/h.

4) **Walking:** Mean wind speeds no greater than 20 km/h occurring at least 80% of the time. The equivalent gust wind speed is approximately 32 km/h.

5) **Uncomfortable:** Uncomfortable conditions are characterized by predicted values that fall below the 80% target for walking. Brisk walking and exercise, such as jogging, would be acceptable for moderate excesses of this criterion.

The pedestrian safety wind speed criterion is based on the approximate threshold that would cause a vulnerable member of the population to fall. A 0.1% exceedance gust wind speed of 90 km/h is classified as dangerous. The gust speeds, and equivalent mean speeds, are selected based on 'The Beaufort Scale', presented on the following page, which describes the effects of forces produced by varying wind speed levels on objects. Gust speeds are included because pedestrians tend to be more sensitive to wind gusts than to steady winds for lower wind speed ranges. For strong winds approaching dangerous levels, this effect is less important because the mean wind can also create problems for pedestrians.

THE BEAUFORT SCALE

Number	Description	Wind Speed (km/h)		Description
		Mean	Gust	
2	Light Breeze	6-11	9-17	Wind felt on faces
3	Gentle Breeze	12-19	18-29	Leaves and small twigs in constant motion; wind extends light flags
4	Moderate Breeze	20-28	30-42	Wind raises dust and loose paper; small branches are moved
5	Fresh Breeze	29-38	43-57	Small trees in leaf begin to sway
6	Strong Breeze	39-49	58-74	Large branches in motion; Whistling heard in electrical wires; umbrellas used with difficulty
7	Moderate Gale	50-61	75-92	Whole trees in motion; inconvenient walking against wind
8	Gale	62-74	93-111	Breaks twigs off trees; generally impedes progress

Experience and research on people's perception of mechanical wind effects has shown that if the wind speed levels are exceeded for more than 20% of the time, the activity level would be judged to be uncomfortable by most people. For instance, if a mean wind speed of 10 km/h were exceeded for more than 20% of the time most pedestrians would judge that location to be too windy for sitting. Similarly, if mean wind speed of 20 km/h at a location were exceeded for more than 20% of the time, walking or less vigorous activities would be considered uncomfortable. As these criteria are based on subjective reactions of a population to wind forces, their application is partly based on experience and judgment.

Once the pedestrian wind speed predictions have been established throughout the site, the assessment of pedestrian comfort involves determining the suitability of the predicted wind conditions for discrete regions within and surrounding the subject site. This step involves comparing the predicted comfort classes to the desired comfort classes, which are dictated by the location type for each region (i.e., a sidewalk, building entrance, amenity space, or other). An overview of common pedestrian location types and their desired comfort classes are summarized on the following page.

DESIRED PEDESTRIAN COMFORT CLASSES FOR VARIOUS LOCATION TYPES

Location Types	Desired Comfort Classes
Primary Building Entrance	Standing
Secondary Building Access Point	Standing / Strolling / Walking
Primary Public Sidewalk	Strolling / Walking
Secondary Public Sidewalk / Bicycle Path	Walking
Outdoor Amenity Space	Sitting / Standing / Strolling
Café / Patio / Bench / Garden	Sitting
Transit Stop	Sitting / Standing
Public Park / Plaza	Standing / Strolling
Garage / Service Entrance	Walking
Parking Lot	Strolling / Walking
Vehicular Drop-Off Zone	Standing / Strolling / Walking

5. RESULTS AND DISCUSSION

The following discussion of the predicted pedestrian wind conditions for the subject site is accompanied by Figures 3A-6B, which illustrate seasonal wind conditions at grade level for the proposed and approved (existing) massing scenarios, and Figures 7A-7D, which illustrate seasonal wind conditions over the common amenity terrace at Level 8. Conditions are presented as continuous contours of wind comfort within and surrounding the subject site. The colour contours indicate predicted regions of the various comfort classes noted in Section 4.4. Conditions suitable for sitting are represented by the colour green, standing by yellow, and walking by blue; uncomfortable conditions are represented by the colour magenta

Wind conditions over the Level 8 amenity terraces are also reported for the typical use period, which is defined as May to October, inclusive. Figure 8A illustrates wind comfort conditions during this period, consistent with the comfort classes in Section 4.4, while Figure 8B illustrates contours indicating the percentage of time the roof areas are predicted to be suitable for sitting. Pedestrian conditions are summarized in the following pages for each area of interest.

5.1 Wind Comfort Conditions – Grade Level

Sidney Street Sidewalk: Following the introduction of the proposed development, the public sidewalks along Sidney Street are predicted to be suitable mostly for standing during the summer and autumn seasons, becoming suitable mostly for a mix of strolling and walking during the spring and winter seasons. The walking comfort class is considered acceptable for public sidewalks.

Prior to the introduction of the proposed development, wind conditions along the Sidney Street public sidewalks are estimated to be suitable mostly for sitting during the summer season, becoming suitable for standing during the remaining three colder seasons. The sidewalk areas at the intersection with Preston Street are also estimated to be suitable for strolling during the coldest months of the year.

Preston Street Sidewalk and Bus Stop: Following the introduction of the proposed development, the public sidewalks along Preston Street are predicted to be suitable mostly for standing during the summer season, a mix of standing and strolling during the autumn season, becoming suitable mostly for strolling during the spring and winter seasons. The noted conditions are considered acceptable for public sidewalks according to the comfort criteria in Section 4.4.

The bus stop to the immediate east of the proposed development is served by a shelter, which provides relief to pedestrians during periods of strong wind activity.

Prior to the introduction of the proposed development, wind conditions along the Preston Street public sidewalks are estimated to be suitable mostly for a mix of sitting and standing during the summer season, suitable for standing during the autumn season, becoming suitable for a mix of standing and strolling during the spring and winter seasons.

Carling Avenue Sidewalk: Following the introduction of the proposed development, the public sidewalks along Carling Avenue are predicted to be suitable mostly for standing during the summer season, becoming suitable mostly for strolling during the remaining three colder seasons. During the winter season, the sidewalk area adjacent to the southwest corner of the proposed development is predicted to be suitable for walking. The noted conditions are considered acceptable for public sidewalks according to the comfort criteria in Section 4.4.

Prior to the introduction of the proposed development, wind conditions along the Carling Avenue public sidewalks are estimated to be suitable for sitting during the summer season, becoming suitable for standing during the spring, autumn, and winter seasons.

Passageway Avenue West Side of Property: Following the introduction of the proposed development, the passageway along the west side of the property is predicted to be suitable for a mix of sitting and standing during the summer season, becoming suitable for standing during the remaining three colder seasons. The noted conditions are considered acceptable according to the comfort criteria in Section 4.4.

5.2 Wind Comfort Conditions – Common Amenity Terrace

The proposed development includes a common amenity terrace at Level 8, along the west and north sides of the podium roof. The areas are predicted to be suitable mostly for a mix of sitting and standing during the summer season, becoming suitable for a mix of sitting, standing, and strolling during the three colder seasons. During the spring and winter seasons, the northwest corner of the roof is predicted to be suitable mostly for walking with a narrow area along the north perimeter that is predicted to be uncomfortable.

During the typical use period, the roof area is predicted to be suitable mostly for a mix of sitting and standing with strolling conditions predicted along most of the perimeter serving the west side of the roof (Figure 8A). The roof areas immediately adjacent to the west and north elevations of the tower are predicted to be suitable for sitting during the typical use period. While comfort levels are expected to be reduced with increasing distance from the tower, the roof is also predicted to be suitable for sitting at least 60% of the time (Figure 8B). To increase wind comfort atop the podium roof, we recommend introducing the following mitigation measures:

a) Wind barriers along the full perimeter of the podium roof rising 1.8 m above the deck.

b) Within the west side of the roof, we recommend introducing a barrier between the northwest corner of the swimming pool building and the west perimeter of the roof. The barrier would need to rise at least 1.8 m above the roof deck to reduce the adverse influence of vortices shed from the northwest corner of the tower.

c) A 1.8-m-tall barrier extending perpendicular from the northwest corner of the tower to the north perimeter of the roof.

d) For items (b) and (c), doors could be provided as part of the wind barrier solution to promote movement between the regions.

e) With the mitigation measures outlined in items (a), (b), and (c), wind conditions are predicted to be suitable for a mix of sitting and standing during the typical use period with the majority of spaces suitable for sitting or lounging. Additionally, the areas that are predicted to be suitable for standing are also predicted to be suitable for sitting at least 70% of the time.

f) Based on the programming of indoor amenities at Level 8, the south end of the floorplan is dedicated mostly to exercise. While the design intent of the adjacent outdoor amenity space has not yet been defined, the area would be suitable for outdoor activities (e.g., yoga, children's play area, etc.).

g) Wind mitigation measures will be revisited and confirmed with the design team, specifically the building and landscape architects, when the programming of the outdoor spaces is defined.

5.3 Wind Safety

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas within or surrounding the subject site at grade level, as well as the Level 8 amenity terrace, were found to experience conditions that could be considered dangerous, as defined in Section 4.4.

5.4 Applicability of Results

Pedestrian wind comfort and safety have been quantified for the specific configuration of existing and foreseeable construction around the subject site. Future changes (i.e., construction or demolition) of these surroundings may cause changes to the wind effects in two ways, namely: (i) changes beyond the immediate vicinity of the subject site would alter the wind profile approaching the subject site; and (ii) development in proximity to the subject site would cause changes to local flow patterns. In general, development in urban centers generally creates reduction in the mean wind speeds and localized increases in the gustiness of the wind.

6. CONCLUSIONS AND RECOMMENDATIONS

A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-8B. Based on computer simulations using the CFD technique, meteorological data analysis of the Ottawa wind climate, City of Ottawa wind comfort and safety criteria, and experience with numerous similar developments, the study concludes that all grade-level areas within and surrounding the subject site are predicted to be acceptable for the intended pedestrian uses throughout the year.

The proposed development includes a common amenity terrace at Level 8, along the west and north sides of the podium roof. Wind mitigation measures, which are presented in Section 5.2, will be required to achieve the sitting comfort class during the typical use period within most areas. For those areas that are predicted to be moderately windy during the same period, it would be prudent to align programming of the spaces with the results in this study. Wind mitigation measures will be revisited and confirmed with the design team when the programming of the outdoor spaces is defined.

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas within or surrounding the subject site at grade level, as well as the Level 8 amenity terrace, were found to experience conditions that could be considered dangerous, as defined in Section 4.4.

Sincerely,

Gradient Wind Engineering Inc.

LICENSED PROFESSIONAL ENGINEER
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Apr 16, 2021
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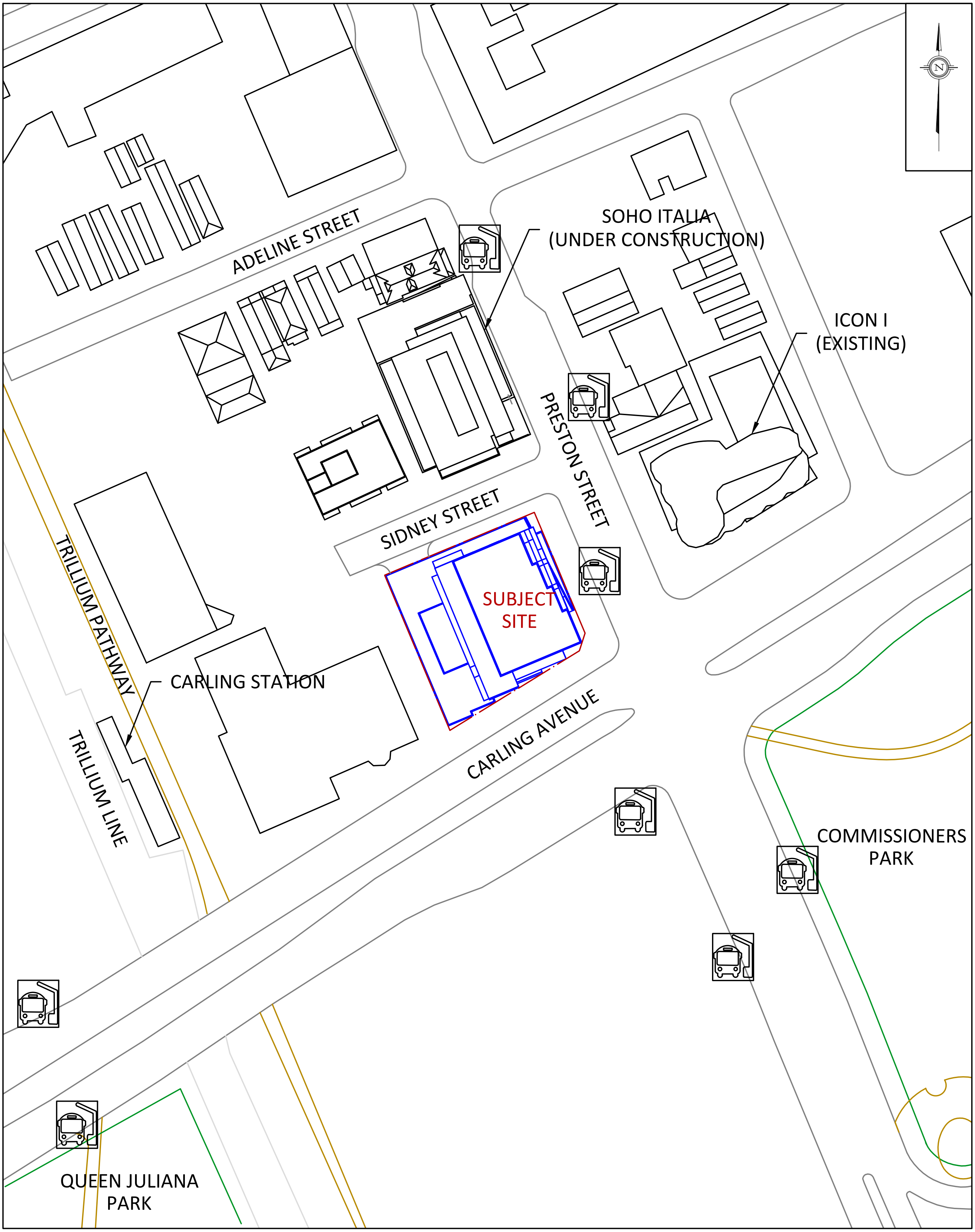

GRADIENTWIND
ENGINEERS & SCIENTISTS

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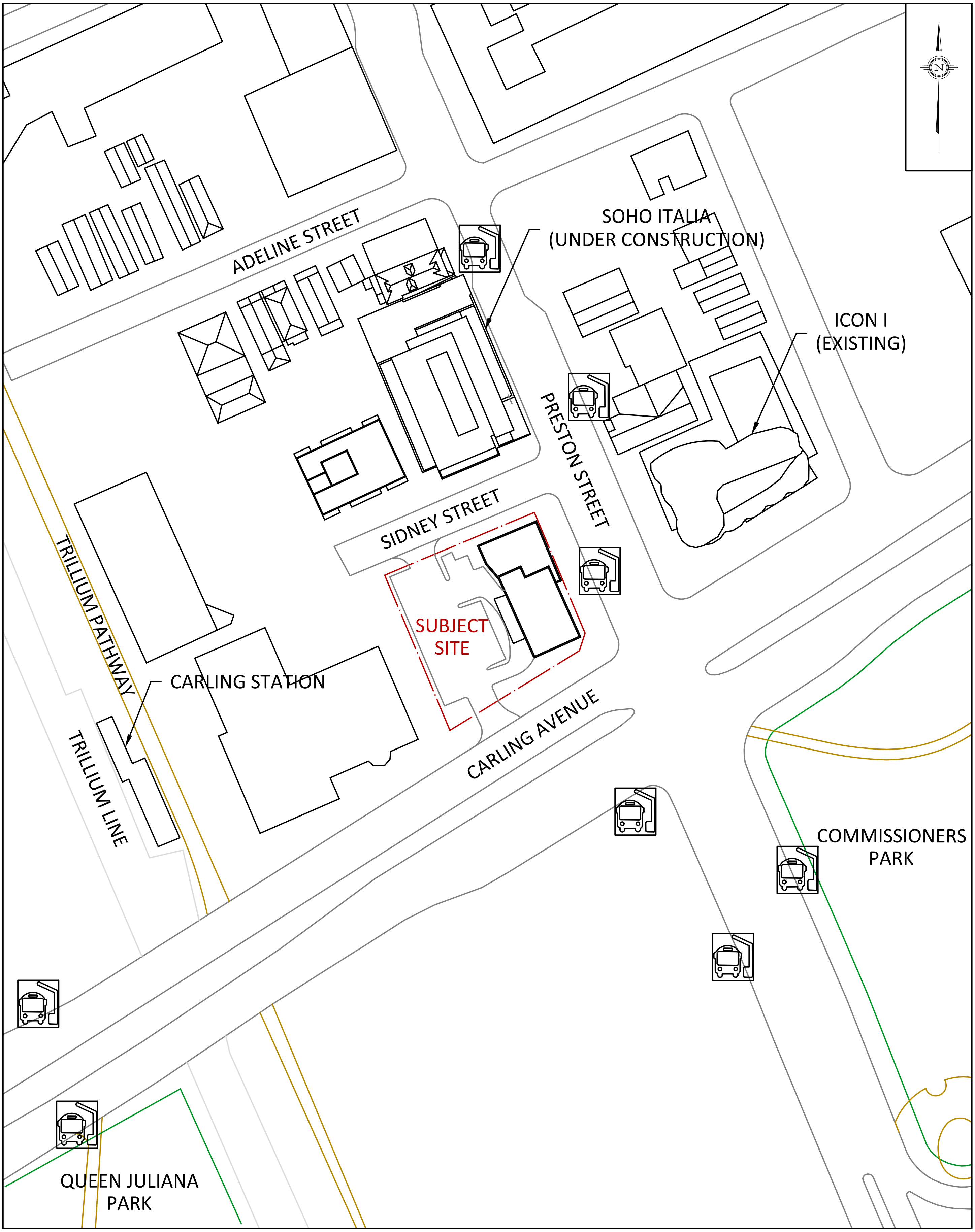
PROJECT: 829 CARLING AVNEUE, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1A: PROPOSED SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:1250	DRAWING NO.: 21-086-PLW-1A	
DATE: APRIL 16, 2021	DRAWN BY: N.M.P.	



GRADIENTWIND ENGINEERS & SCIENTISTS 127 WALGREEN ROAD, OTTAWA, ON 613 836 0934 • GRADIENTWIND.COM	PROJECT: 829 CARLING AVNEUE, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1B: APPROVED SITE PLAN AND SURROUNDING CONTEXT
	SCALE: 1:1250	DRAWING NO.: 21-086-PLW-1B	
	DATE: APRIL 16, 2021	DRAWN BY: N.M.P.	

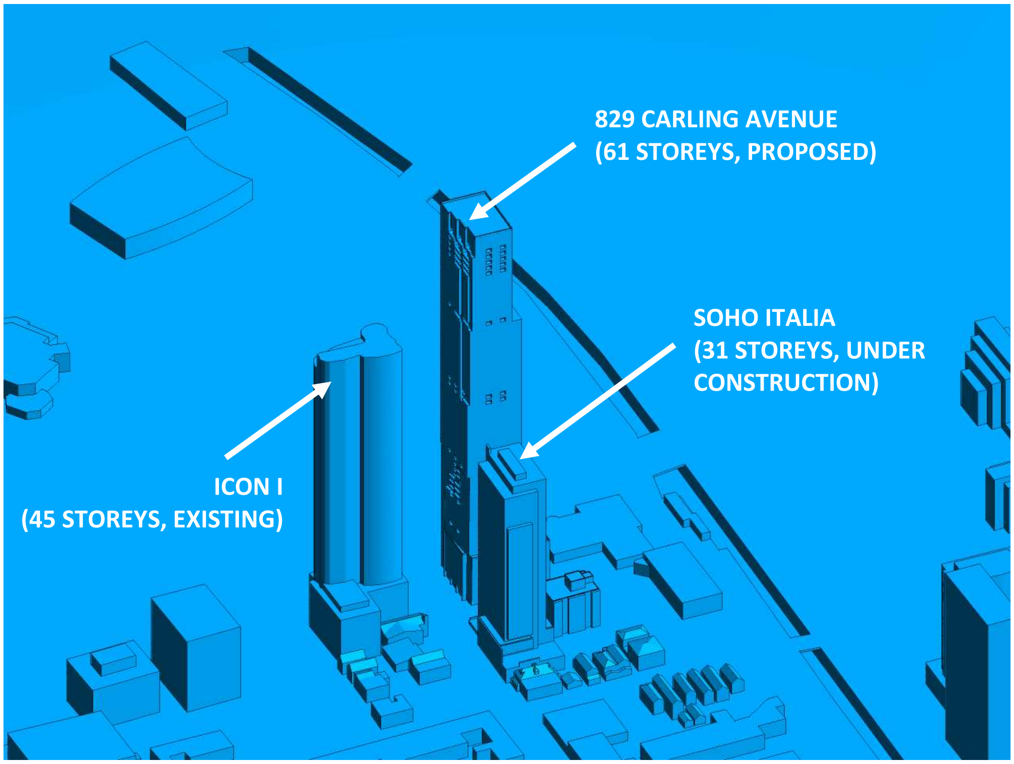


FIGURE 2A: COMPUTATIONAL MODEL, NORTH PERSPECTIVE – PROPOSED MASSING

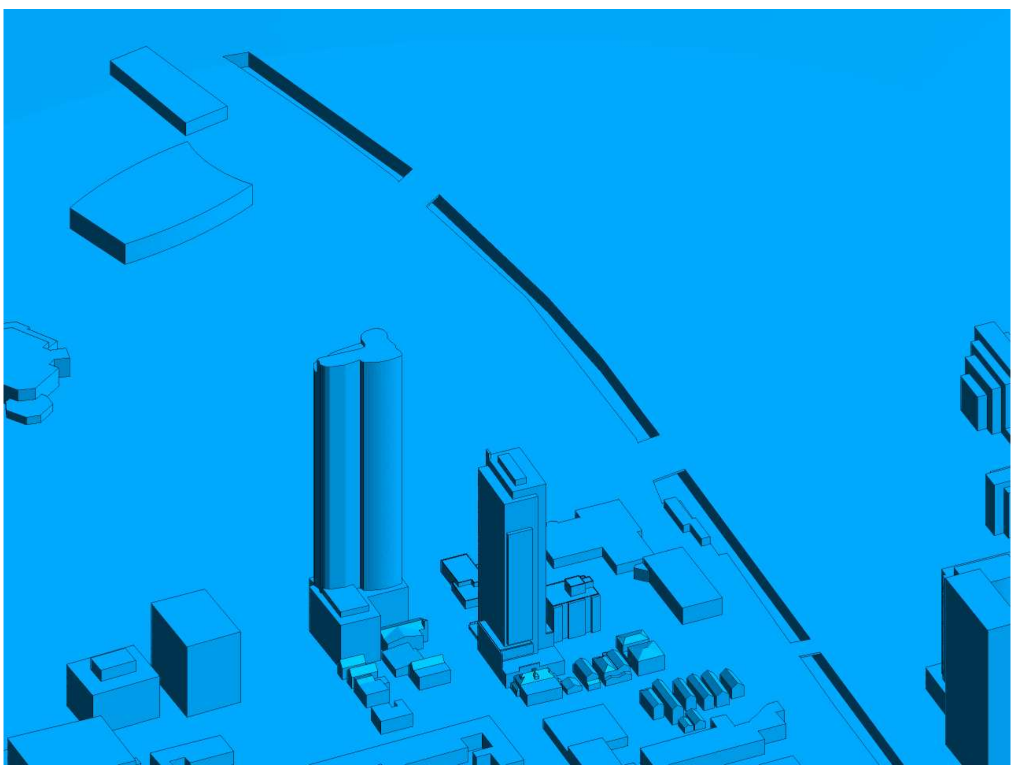


FIGURE 2B: COMPUTATIONAL MODEL, NORTH PERSPECTIVE – APPROVED MASSING

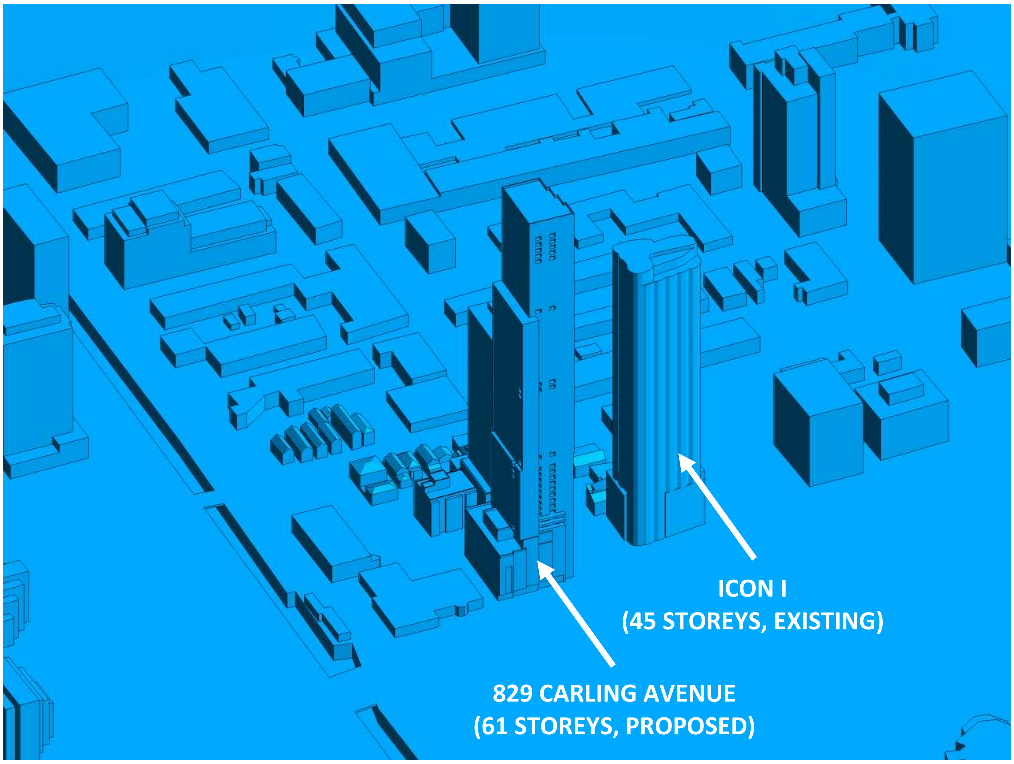


FIGURE 2C: COMPUTATIONAL MODEL, SOUTH PERSPECTIVE – PROPOSED MASSING

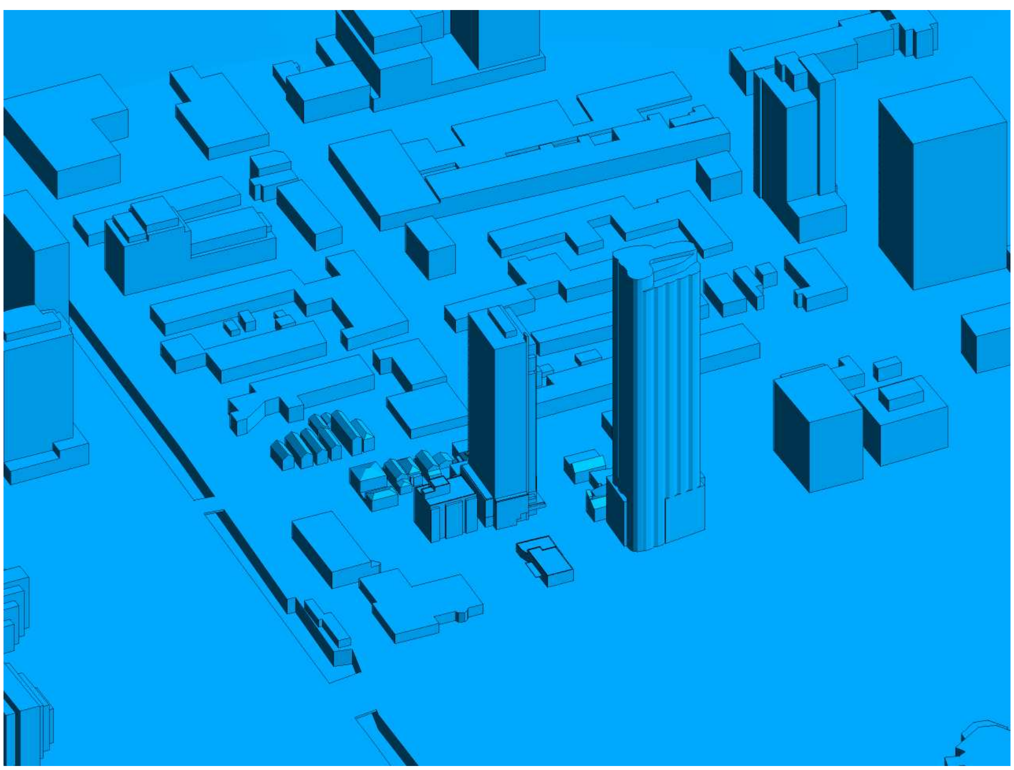


FIGURE 2D: COMPUTATIONAL MODEL, SOUTH PERSPECTIVE – APPROVED MASSING

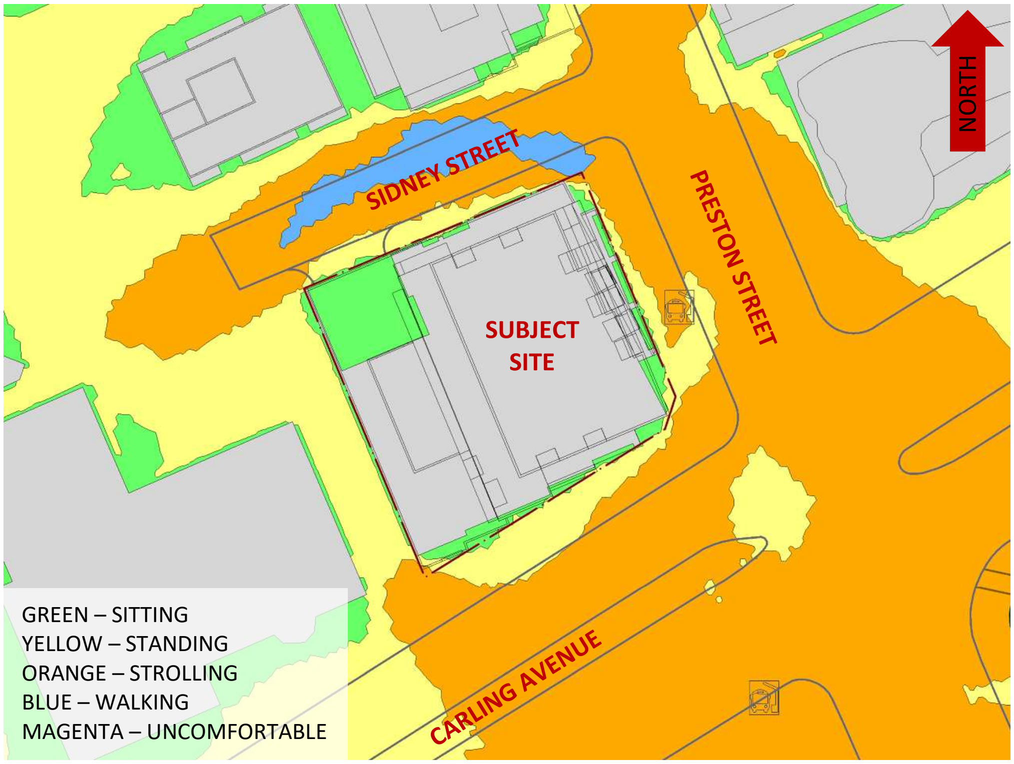


FIGURE 3A: SPRING – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

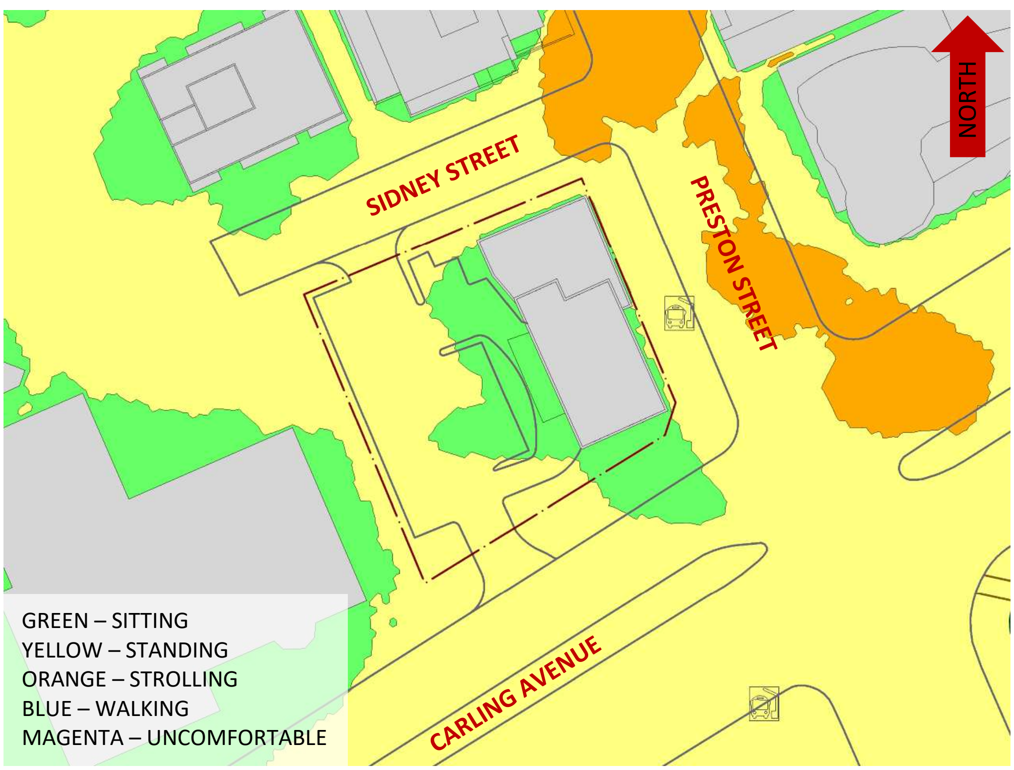


FIGURE 3B: SPRING – WIND COMFORT, GRADE LEVEL – APPROVED MASSING

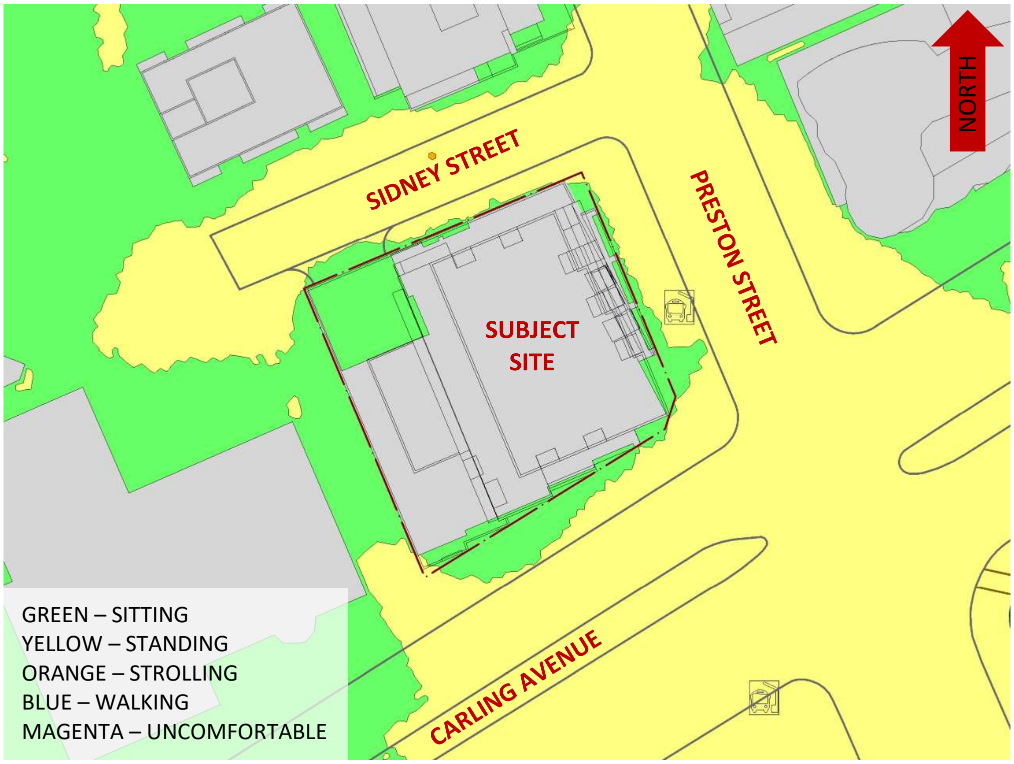


FIGURE 4A: SUMMER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

FIGURE 4B: SUMMER – WIND COMFORT, GRADE LEVEL – APPROVED MASSING

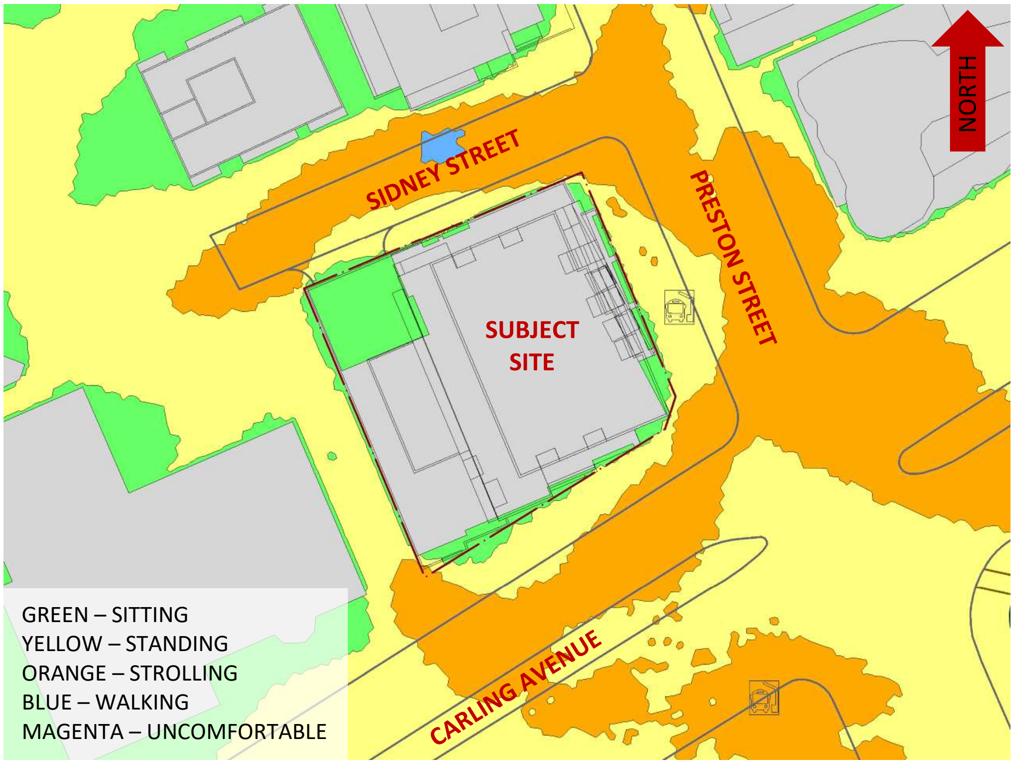


FIGURE 5A: AUTUMN – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

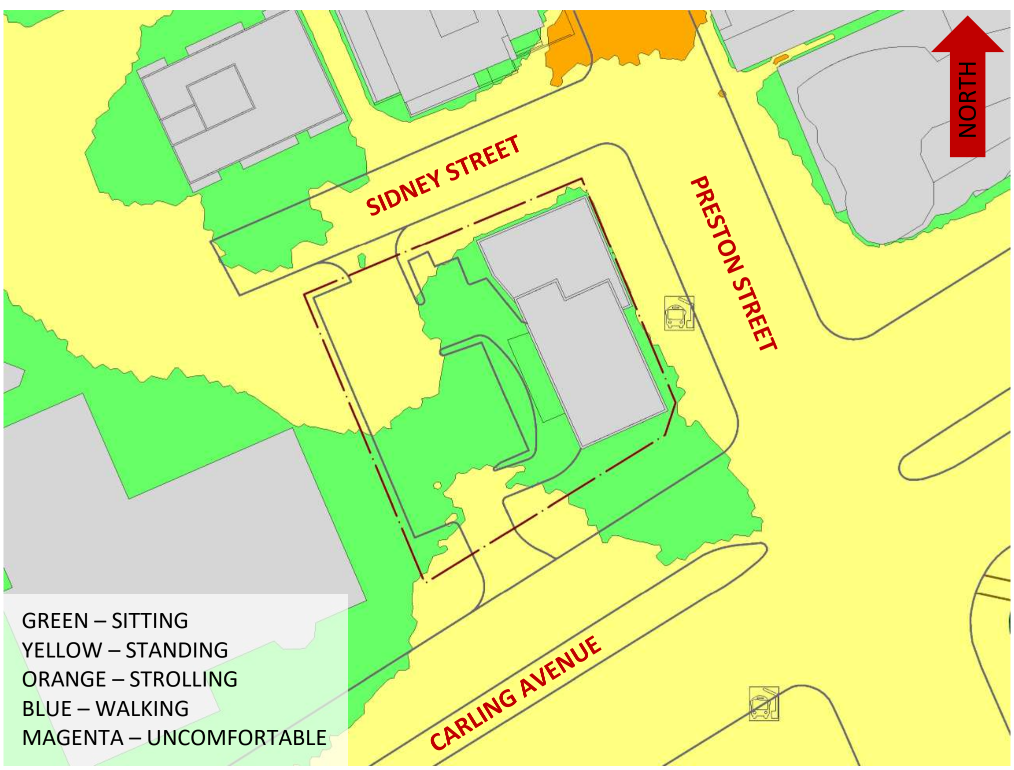


FIGURE 5B: AUTUMN – WIND COMFORT, GRADE LEVEL – APPROVED MASSING

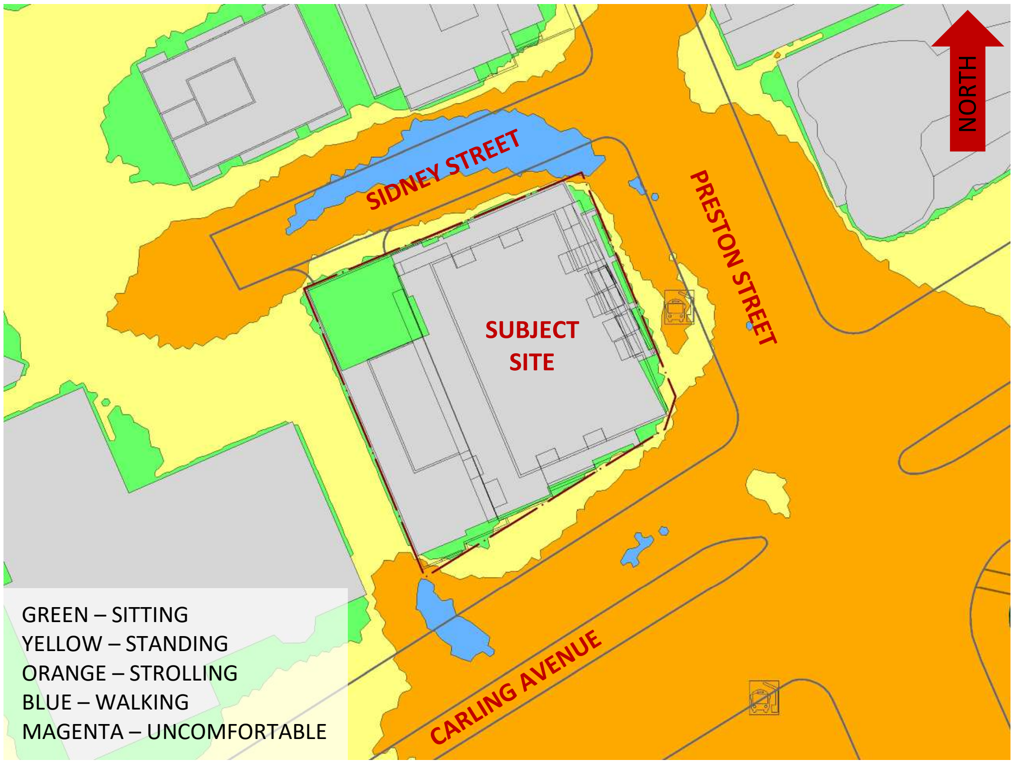


FIGURE 6A: WINTER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

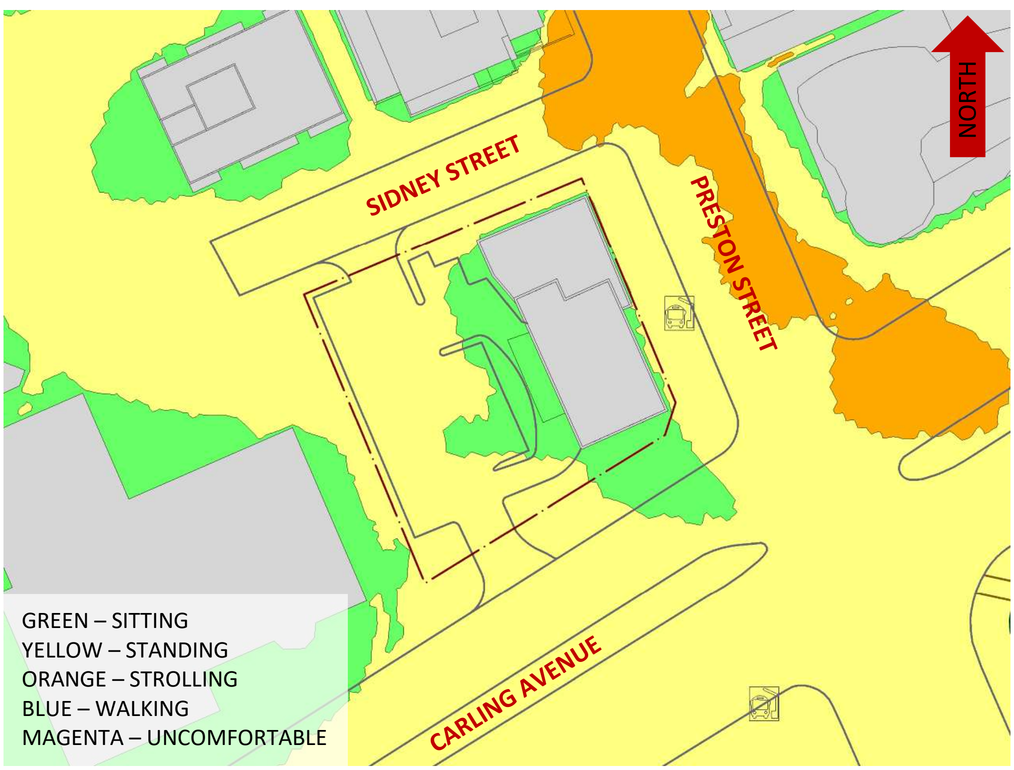


FIGURE 6B: WINTER – WIND COMFORT, GRADE LEVEL – APPROVED MASSING

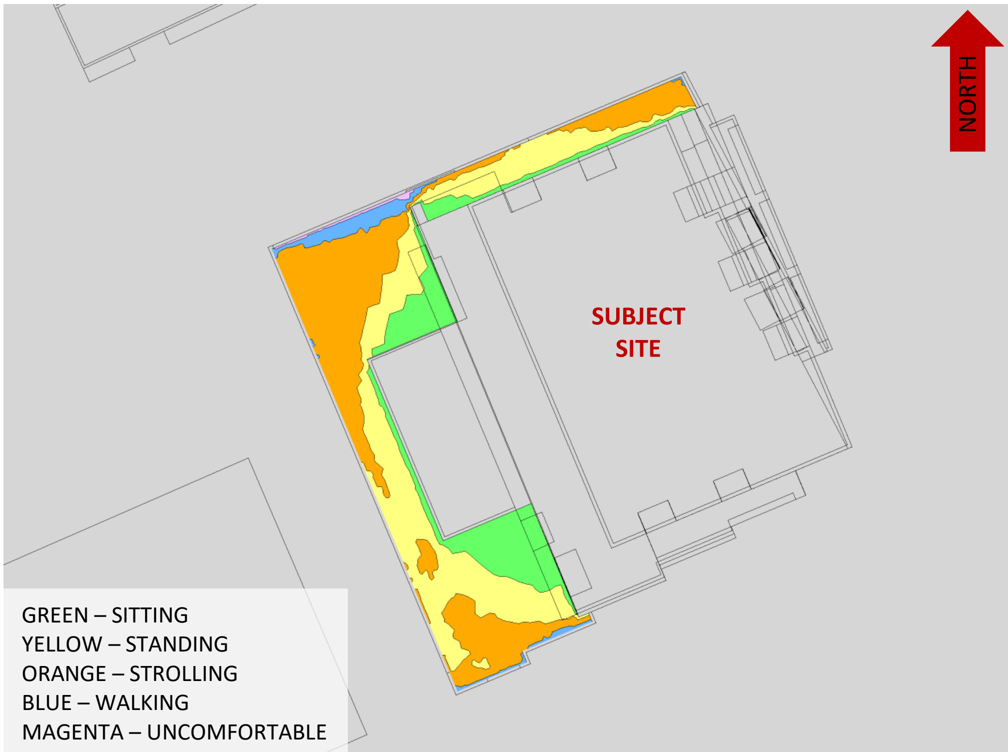


FIGURE 7A: SPRING – WIND COMFORT, LEVEL 8 AMENITY TERRACE

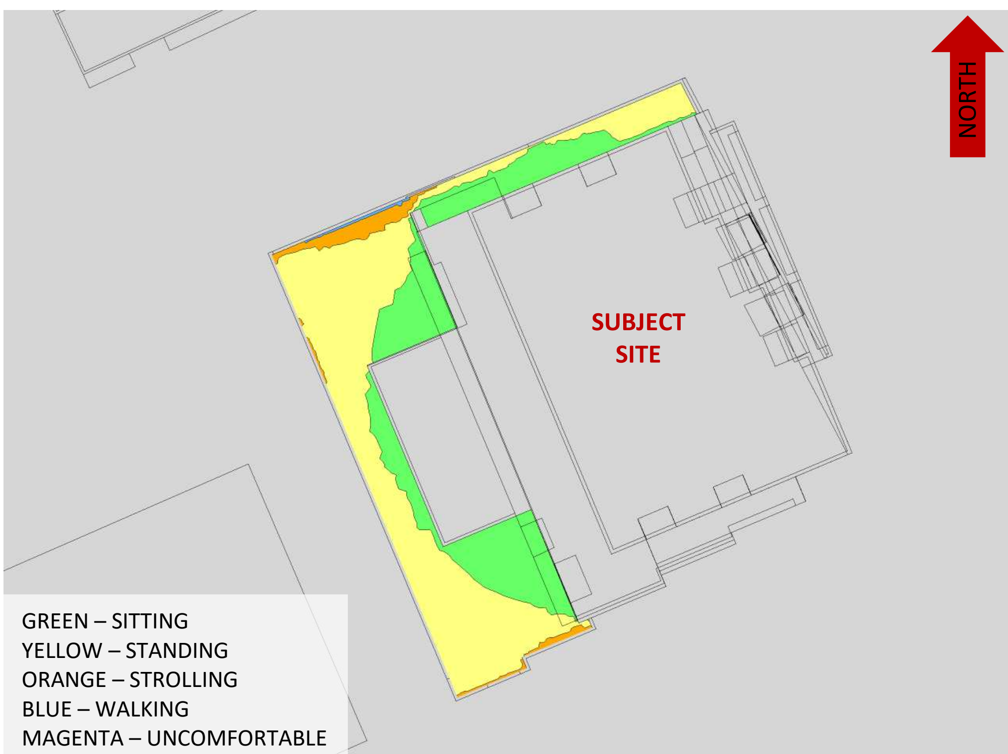


FIGURE 7B: SUMMER – WIND COMFORT, LEVEL 8 AMENITY TERRACE

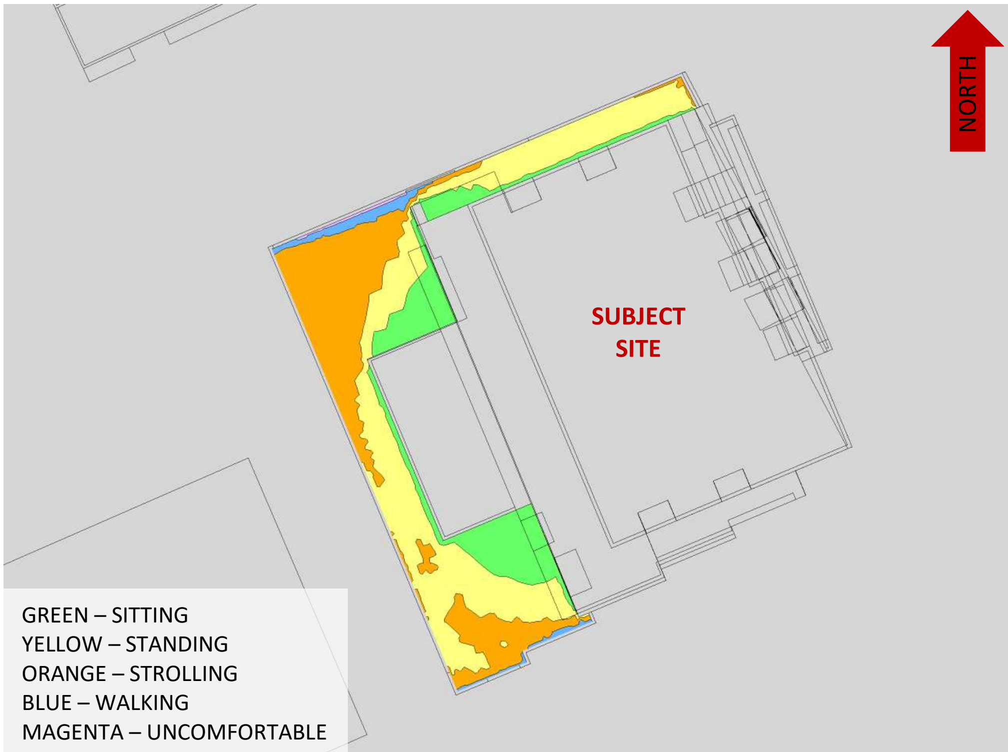


FIGURE 7C: AUTUMN – WIND COMFORT, LEVEL 8 AMENITY TERRACE

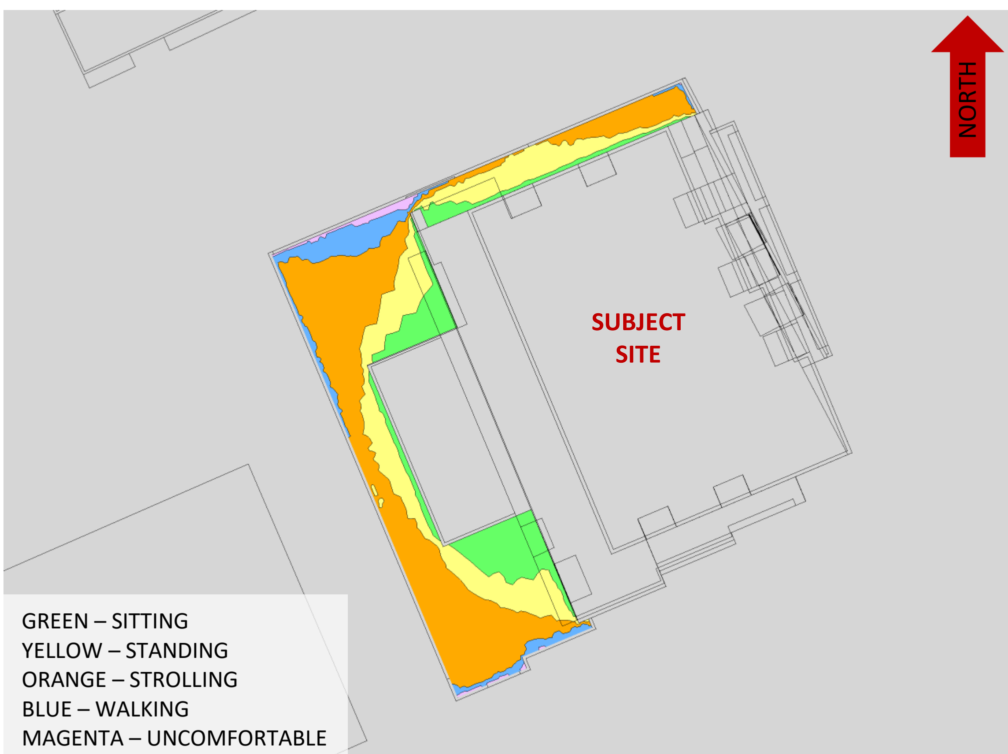


FIGURE 7D: WINTER – WIND COMFORT, LEVEL 8 AMENITY TERRACE

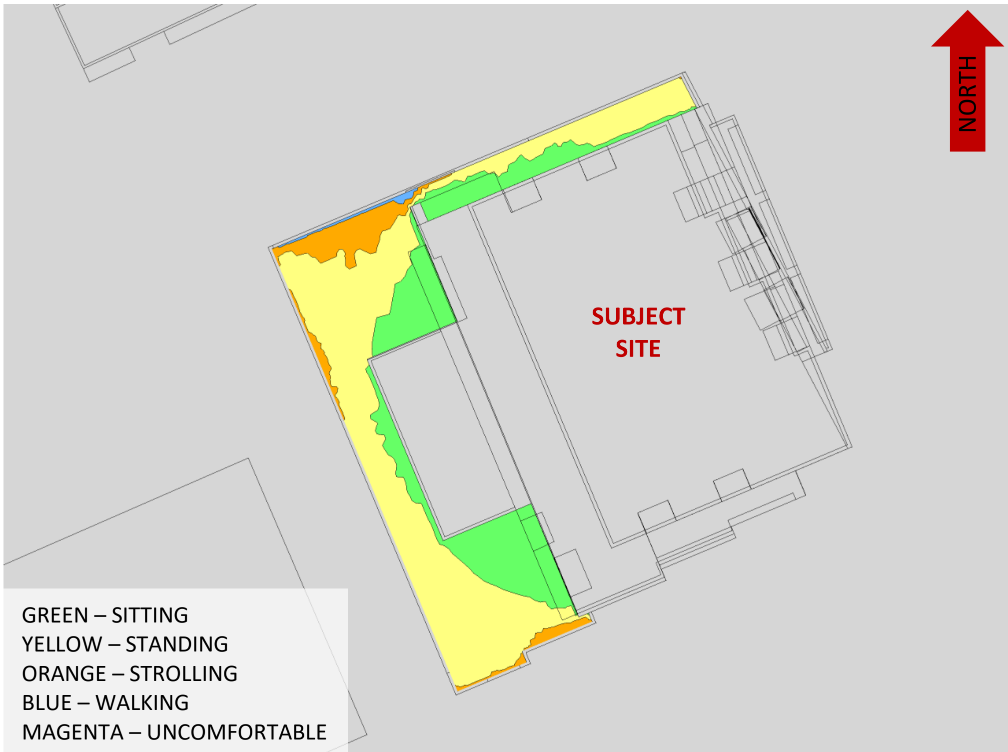
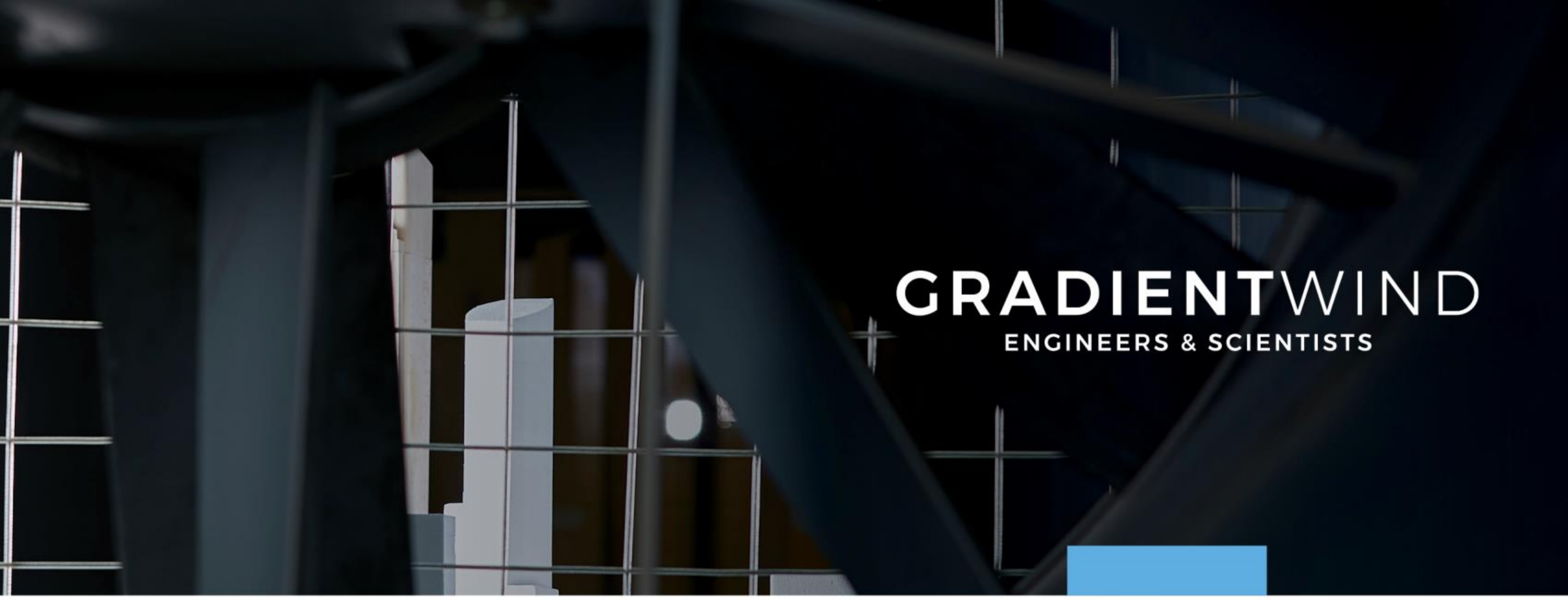


FIGURE 8A: TYPICAL USE PERIOD (MAY-OCTOBER) – WIND COMFORT, AMENITY TERRACE

FIGURE 8B: TYPICAL USE PERIOD – % OF TIME SUITABLE FOR SITTING, AMENITY TERRACE



APPENDIX A

SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

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SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

The atmospheric boundary layer (ABL) is defined by the velocity and turbulence profiles according to industry standard practices. The mean wind profile can be represented, to a good approximation, by a power law relation, Equation (1), giving height above ground versus wind speed (1), (2).

$$U = U_g \left(\frac{Z}{Z_g}\right)^{\alpha} \qquad \text{Equation (1)}$$

where, $\boldsymbol{U}$ = mean wind speed, $\boldsymbol{U_g}$ = gradient wind speed, $\boldsymbol{Z}$ = height above ground, $\boldsymbol{Z_g}$ = depth of the boundary layer (gradient height), and α is the power law exponent.

For the model, U_g is set to 6.5 metres per second (m/s), which approximately corresponds to the 60% mean wind speed for Ottawa based on historical climate data and statistical analyses. When the results are normalized by this velocity, they are relatively insensitive to the selection of gradient wind speed.

Z_g is set to 540 m. The selection of gradient height is relatively unimportant, so long as it exceeds the building heights surrounding the subject site. The value has been selected to correspond to our physical wind tunnel reference value.

α is determined based on the upstream exposure of the far-field surroundings (i.e., the area that it not captured within the simulation model).

Table 1 presents the values of α used in this study, while Table 2 presents several reference values of α. When the upstream exposure of the far-field surroundings is a mixture of multiple types of terrain, the α values are a weighted average with terrain that is closer to the subject site given greater weight.

TABLE 1: UPSTREAM EXPOSURE (ALPHA VALUE) VS TRUE WIND DIRECTION

Wind Direction (Degrees True)	Alpha Value (α)
0	0.27
49	0.26
74	0.25
103	0.23
167	0.21
197	0.19
217	0.20
237	0.23
262	0.25
282	0.25
302	0.25
324	0.25

TABLE 2: DEFINITION OF UPSTREAM EXPOSURE (ALPHA VALUE)

Upstream Exposure Type	Alpha Value (α)
Open Water	0.14-0.15
Open Field	0.16-0.19
Light Suburban	0.21-0.24
Heavy Suburban	0.24-0.27
Light Urban	0.28-0.30
Heavy Urban	0.31-0.33

The turbulence model in the computational fluid dynamics (CFD) simulations is a two-equation shear-stress transport (SST) model, and thus the ABL turbulence profile requires that two parameters be defined at the inlet of the domain. The turbulence profile is defined following the recommendations of the Architectural Institute of Japan for flat terrain (3).

$$I(Z) = \begin{cases} 0.1\left(\frac{Z}{Z_g}\right)^{-\alpha-0.05}, & Z > 10 \text{ m} \\ 0.1\left(\frac{10}{Z_g}\right)^{-\alpha-0.05}, & Z \leq 10 \text{ m} \end{cases}$$ Equation (2)

$$L_t(Z) = \begin{cases} 100 \text{ m}\sqrt{\frac{Z}{30}}, & Z > 30 \text{ m} \\ 100 \text{ m}, & Z \leq 30 \text{ m} \end{cases}$$ Equation (3)

where, ***I*** = turbulence intensity, L_t = turbulence length scale, ***Z*** = height above ground, and α is the power law exponent used for the velocity profile in Equation (1).

Boundary conditions on all other domain boundaries are defined as follows: the ground is a no-slip surface; the side walls of the domain have a symmetry boundary condition; the top of the domain has a specified shear, which maintains a constant wind speed at gradient height; and the outlet has a static pressure boundary condition.

REFERENCES

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[3] Y. Tamura, H. Kawai, Y. Uematsu, K. Kondo and T. Okhuma, "Revision of AIJ Recommendations for Wind Loads on Buildings," in *The International Wind Engieering Symposium, IWES 2003*, Taiwan, 2003.