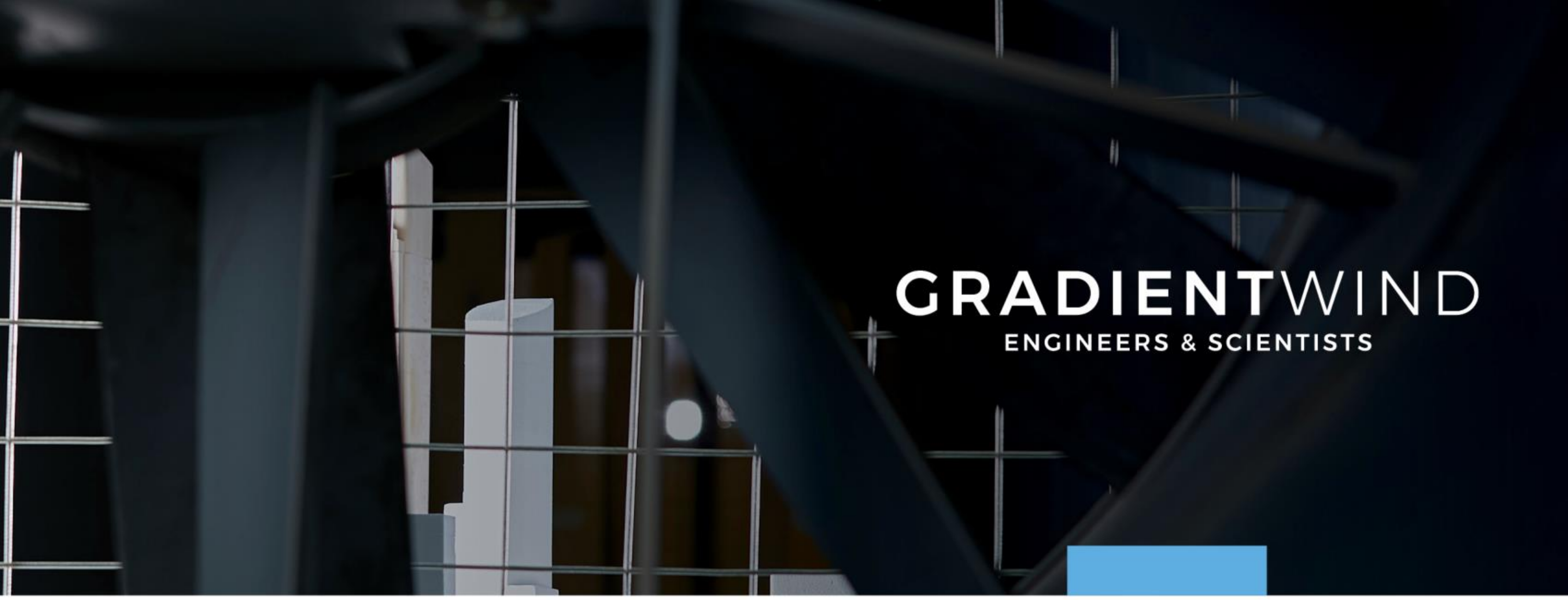
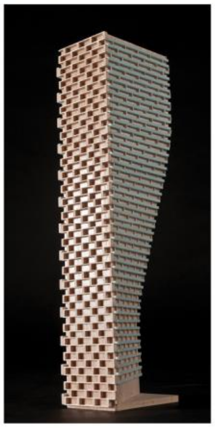
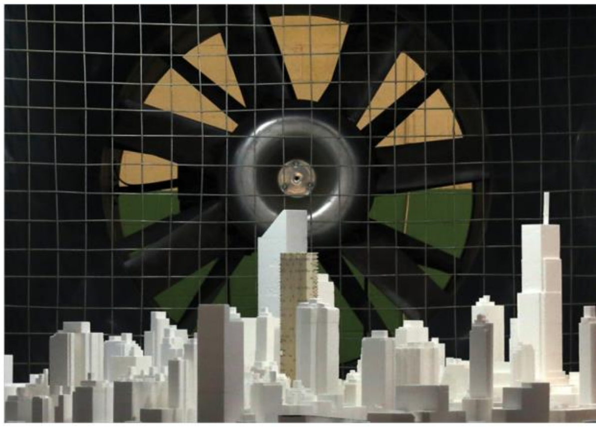


PEDESTRIAN LEVEL WIND STUDY

Brookstreet Apartments
525 Legget Drive
Kanata, Ottawa, Ontario

Report: 21-203-PLW





September 30, 2021

PREPARED FOR
KRP Properties
555 Legget Drive, Tower B, Suite 300
Ottawa, ON K2K 2X3

PREPARED BY
Daniel Davalos, MESc., Junior Wind Scientist
Justin Ferraro, P.Eng., Principal

EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study undertaken to satisfy Site Plan Control application submission requirements for Brookstreet Apartments, a proposed 30-storey residential development located at 525 Legget Drive in Kanata, 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 according to City of Ottawa wind comfort and safety criteria. The results and recommendations derived from these considerations are detailed in the main body of the report (Section 5), illustrated in Figures 3A-13B, and summarized as follows:

1) All grade-level areas within and surrounding the subject site are predicted to be acceptable for the intended pedestrian uses throughout the year, inclusive of all building access points and the existing adjacent parking structure.

2) The proposed development includes common amenity terraces at Level 5, Level 28 (restaurant terrace), and Level 29 (pool terrace). The terraces at Levels 5 and 28 include 2.4-metre (m)-tall wind screens along their full perimeter, while the terrace at Level 29 includes 1.8-m-tall wind screens along its full perimeter. The restaurant terrace at Level 28 also includes 2.4-m-tall dividers at the rounded northeast and southeast corners of the building core. The wind screens for all three terraces resulted from a technical exercise with the design team and ownership group.

    a. During the typical use period, defined as May to October, inclusive, conditions within all three common amenity terraces are predicted to be mostly suitable for sitting. For those roof areas that do not achieve the sitting comfort class, per the wind comfort criteria in Section 4.4, conditions are predicted to be suitable for sitting for at least 75% of the time in most areas. The noted wind conditions are considered acceptable for the intended uses of the terraces.

b. Comparative wind conditions are also provided for the terraces considering standard height wind screens along the perimeter of their roofs. The corresponding wind conditions are predicted to be windy throughout the year and inconsistent with the intended uses of the terraces during the warmer months.

3) Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas within and surrounding the subject site were found to experience conditions that could be considered dangerous.

GRADIENTWIND
ENGINEERS & SCIENTISTS

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by KRP Properties to undertake a pedestrian level wind (PLW) study to satisfy Site Plan Control application submission requirements for Brookstreet Apartments, a proposed 30-storey residential development located at 525 Legget Drive in Kanata, 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 NEUF Architect(e)s, in July, August, and September 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 525 Legget Drive in Kanata, Ottawa, and is flanked by the existing Brookstreet Hotel to the south-southwest, inclusive of its ballroom and above-grade parking structure, and The Marches Golf Club to the east. For ease of description within the present study, the narrow elevation at the northwest corner of the subject site, adjacent to the noted existing parking structure, is defined as project north.

Architectural Rendering, East Perspective
(Prepared by NEUF Architect(e)s)

The proposed development comprises a 30-storey building rising through a 5-storey podium superstructure to a total height of 111.1 metres (m) from average grade to the top of the mechanical penthouse. The typical floorplate for the podium and tall building is 'L'-shaped mirrored about a vertical axis that is oriented nominally north-to-south. The building envelope includes rounded corners at the east and north corners which are constant along the full height of the proposed development. The short dimension of the typical floorplate extends towards the west and abuts the ballroom structure serving the Brookstreet Hotel from the ground floor to Level 3. The ground floor includes the main entrance on the north façade, complete with a vestibule, and pedestrian building access points on the east and south elevations. A stairwell exit is provided on the west façade, between the proposed development and existing parking structure. The north façade is served by a large circular canopy over the main entrance and two oval-shaped canopies. The canopies, which are intended to provide shelter to pedestrians from the elements, are provided at three different heights between the ground floor and Level 2.

The podium elevation abutting the ballroom structure is set back at Level 3, rising to Level 5 with a uniform floorplate. The floorplate sets back at Level 5, rising to Level 28 in a uniform manner. The floorplate at the north end of the building is set back at Level 5 to accommodate a common amenity terrace that includes 2.4-m-tall wind screens along its full perimeter. The proposed development is also served by a restaurant terrace at Level 28 with views to the north clockwise to south, and a south-facing pool terrace at Level 29. The restaurant terrace includes 2.4-m-tall wind screens along its full perimeter, as well as 2.4-m-tall dividers at the rounded northeast and southeast corners of the building core. The pool terrace includes 1.8-m-tall wind screens along its full perimeter.

The near-field surroundings (defined as an area within 200 m of the subject site) include a mix of low and mid-rise buildings, as well as surface parking, from the south clockwise to northwest, with the existing Brookstreet Hotel to the south-southwest and office building complex at 555 Legget Drive (Building B) to the southwest. The remaining compass directions include a pond and The Marches Golf Club. The far-field surroundings (defined as an area beyond the near-field but within a 2-kilometre (km) radius of the subject site) are characterized by mostly open land from the north-northwest clockwise to east-southeast, by low-rise industrial building and surface parking area from the east-southeast clockwise to south-southeast, a mix of industrial and residential developments and surface parking from the south-southeast clockwise to south, a mix of industrial developments and open land from the south clockwise to southwest, and by mostly residential dwellings for the remaining compass directions. The Ottawa River is situated approximately 2.9 km to the northeast of the subject site. Figure 1 illustrates the subject site and surrounding context, while Figures 2A-2D illustrate the computational model used to conduct the study.

3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind comfort and safety conditions at key areas within and surrounding the development 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 study 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 planned 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 radius of 480 m.

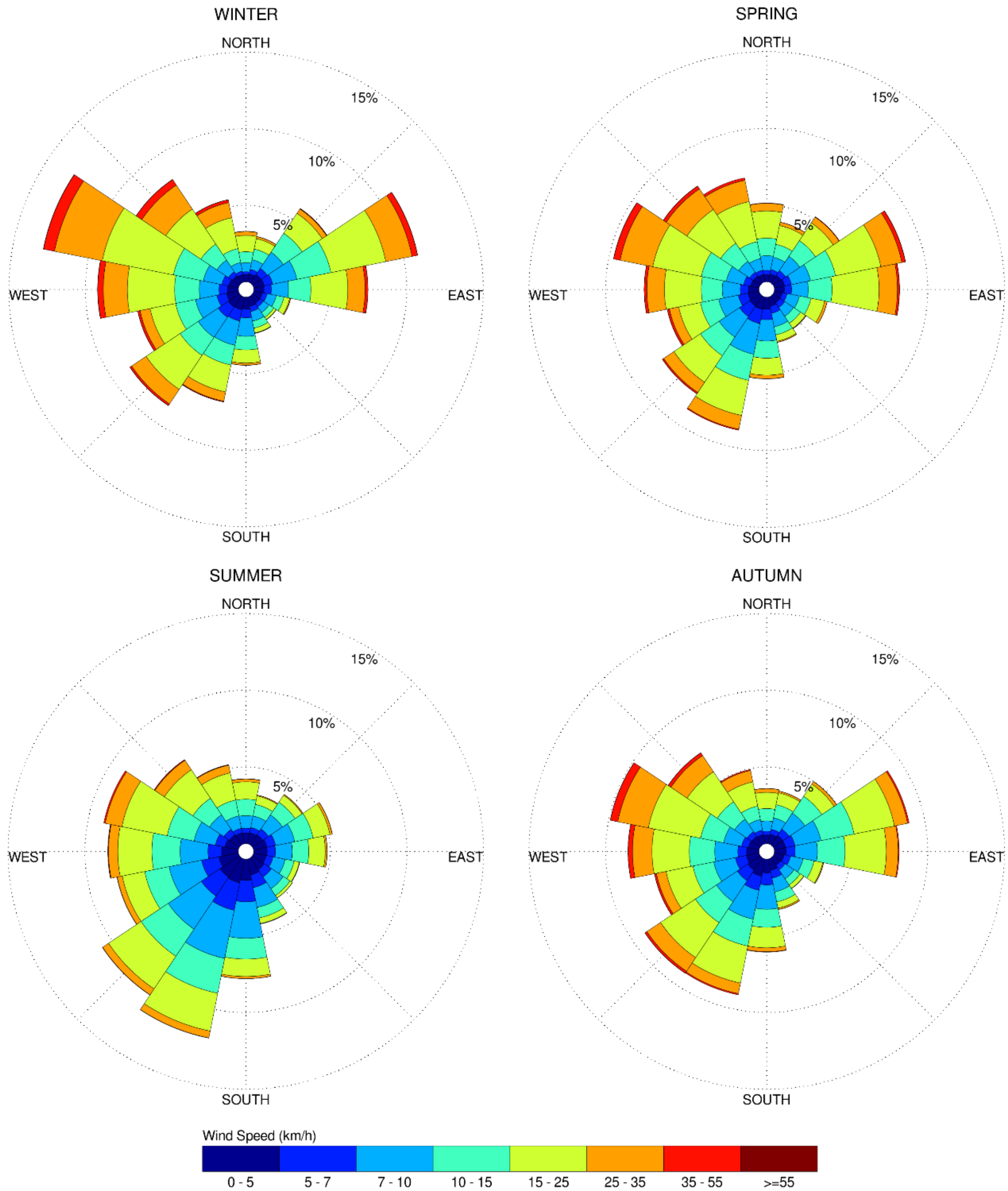
Mean and peak wind speed data obtained over the study site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade and the common amenity terraces were referenced to the wind speed 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 Historical Wind Speed and Direction Data

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	Gust Wind Speed (km/h)	Description
2	Light Breeze	9-17	Wind felt on faces
3	Gentle Breeze	18-29	Leaves and small twigs in constant motion; wind extends light flags
4	Moderate Breeze	30-42	Wind raises dust and loose paper; small branches are moved
5	Fresh Breeze	43-57	Small trees in leaf begin to sway
6	Strong Breeze	58-74	Large branches in motion; Whistling heard in electrical wires; umbrellas used with difficulty
7	Moderate Gale	75-92	Whole trees in motion; inconvenient walking against wind
8	Gale	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 (equivalent gust wind speed of approximately 16 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 (equivalent gust wind speed of approximately 30 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 predicted pedestrian wind conditions is accompanied by Figures 3A-3D illustrating seasonal wind comfort conditions at grade level, as well as by Figures 4A-7B and Figures 9A-12B illustrating seasonal wind conditions over the various common amenity terraces serving the proposed development. 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 blue, standing by green, strolling by yellow, and walking by orange; uncomfortable conditions are represented by the colour magenta.

Wind conditions over the various amenity terraces are also reported for the typical use period, which is defined as May to October, inclusive. Figures 8A and 13A illustrate wind comfort conditions during this period, consistent with the comfort classes in Section 4.4, while Figures 8B and 13B illustrate contours indicating the percentage of time the noted 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 – Ground Floor

Wind conditions around the subject site at the ground floor are predicted to be suitable for a mix of sitting and standing during the summer, mostly suitable for standing during the autumn, becoming mostly suitable for a mix of standing and strolling during the winter and spring. The noted wind conditions are considered acceptable according to the City of Ottawa wind criteria.

Conditions in the vicinity of the main entrance at the north end of the proposed development are predicted to be suitable for sitting during the summer, becoming suitable for standing during the remaining three colder seasons. Wind conditions in the vicinity of all remaining pedestrian building access points serving the proposed development are predicted to be suitable for sitting during the summer, becoming suitable for standing, or better, during the remaining three colder seasons. The noted wind conditions are considered acceptable according to the City of Ottawa wind criteria.

Wind conditions within the ground floor of the adjacent parking structure are predicted to be calm during the spring, summer, and autumn seasons, becoming moderately windy during the winter season. While the strongest wind speeds are predicted to occur within the east corner of the parking structure, wind conditions are considered acceptable within all areas according to the City of Ottawa wind criteria.

5.2 Wind Comfort Conditions – Common Amenity Terraces

Level 5: With 2.4-m-tall wind screens along the full perimeter of the terrace, wind conditions are predicted to be suitable for a mix of sitting and standing during the summer, becoming mostly suitable for standing during the spring and autumn, and suitable for a mix of standing and strolling during the winter. During the typical use period, conditions are predicted to be suitable for a mix of sitting and standing (Figure 8A). For those roof areas that do not achieve the sitting comfort class, per the wind comfort criteria in Section 4.4, conditions are predicted to be suitable for sitting for at least 75% of the time in most areas, as illustrated in Figure 8B. The noted wind conditions are considered acceptable for the intended uses of the terrace.

With standard height wind screens along the perimeter of the roof (i.e., 1.07 m), wind conditions atop the terrace are predicted to be windy throughout the year and inconsistent with the intended uses of the terrace. For completeness, the corresponding seasonal wind conditions are illustrated in Figures 4B, 5B, 6B, and 7B.

Level 28, Restaurant Terrace: With 2.4-m-tall wind screens along the full perimeter of the terrace, as well as 2.4-m-tall dividers at the rounded northeast and southeast corners of the building core, wind conditions within the south end of the terrace are predicted to be suitable for sitting throughout the year. The remaining terrace area is predicted to be suitable for mostly sitting during the summer, becoming suitable for a mix of sitting and standing during the autumn. Conditions during the spring are predicted to be suitable for a mix of sitting, standing, and strolling, while windier conditions are predicted during the winter. During the typical use period, conditions within the north end of the terrace are predicted to be suitable for a mix of sitting and standing (Figure 8A). For those roof areas that do not achieve the sitting comfort class, per the wind comfort criteria in Section 4.4, conditions are predicted to be suitable for sitting for at least 75% of the time in all areas, as illustrated in Figure 8B. The noted wind conditions are considered acceptable for the intended uses of the terrace.

With standard height wind screens along the perimeter of the roof (i.e., 1.07 m), wind conditions atop the restaurant terrace are predicted to be windy throughout the year and inconsistent with the intended uses of the terrace. Of importance, dangerous conditions are also predicted at the northeast corner of the building core. For completeness, the corresponding seasonal wind conditions are illustrated in Figures 4B, 5B, 6B, and 7B.

Level 29, Pool Terrace: With 1.8-m-tall wind screens along the full perimeter of the terrace, wind conditions within the south end of the terrace are predicted to be suitable for sitting during the summer, a mix of sitting and standing during and autumn, and mostly for standing during the winter and spring. During the typical use period, conditions within the terrace are predicted to be mostly suitable for sitting (Figure 13A). For those roof areas that do not achieve the sitting comfort class, per the wind comfort criteria in Section 4.4, conditions are predicted to be suitable for sitting for at least 75% of the time in all areas, as illustrated in Figure 13B. The noted wind conditions are considered acceptable for the intended uses of the terrace.

With standard height wind screens along the perimeter of the roof (i.e., 1.07 m), wind conditions atop the pool terrace are predicted to be windy throughout the year and inconsistent with the intended uses of the terrace during the warmer months. For completeness, the corresponding seasonal wind conditions are illustrated in Figures 9B, 10B, 11B, and 12B.

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 and surrounding the subject site were found to experience conditions that could be considered dangerous, as defined in Section 4.4.

5.4 Applicability of Results

Wind conditions over surrounding sidewalks beyond the subject site, as well as at nearby primary building entrances, will be acceptable for their intended pedestrian uses during each seasonal period upon the introduction of the subject site. Pedestrian wind comfort and safety have been quantified for the specific configuration of existing and foreseeable construction around the study 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 site would alter the wind profile approaching the site; and (ii) development in proximity to the site would cause changes to local flow patterns.

Regarding primary and secondary building access points, wind conditions predicted in this study are only applicable to pedestrian comfort and safety. As such, the results should not be construed to indicate wind loading on doors and associated hardware.

6. CONCLUSIONS AND RECOMMENDATIONS

A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-13B. 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 the following:

1) All grade-level areas within and surrounding the subject site are predicted to be acceptable for the intended pedestrian uses throughout the year, inclusive of all building access points and the existing adjacent parking structure.

2) The proposed development includes common amenity terraces at Level 5, Level 28 (restaurant terrace), and Level 29 (pool terrace). The terraces at Levels 5 and 28 include 2.4-m-tall wind screens along their full perimeter, while the terrace at Level 29 includes 1.8-m-tall wind screens along its full perimeter. The restaurant terrace at Level 28 also includes 2.4-m-tall dividers at the rounded northeast and southeast corners of the building core. The wind screens for all three terraces resulted from a technical exercise with the design team and ownership group.

    a. During the typical use period, defined as May to October, inclusive, conditions within all three common amenity terraces are predicted to be mostly suitable for sitting. For those roof areas that do not achieve the sitting comfort class, per the wind comfort criteria in Section 4.4, conditions are predicted to be suitable for sitting for at least 75% of the time in most areas. The noted wind conditions are considered acceptable for the intended uses of the terraces.

    b. Comparative wind conditions are also provided for the terraces considering standard height wind screens along the perimeter of their roofs. The corresponding wind conditions are predicted to be windy throughout the year and inconsistent with the intended uses of the terraces during the warmer months.

3) Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas within and surrounding the subject site were found to experience conditions that could be considered dangerous.

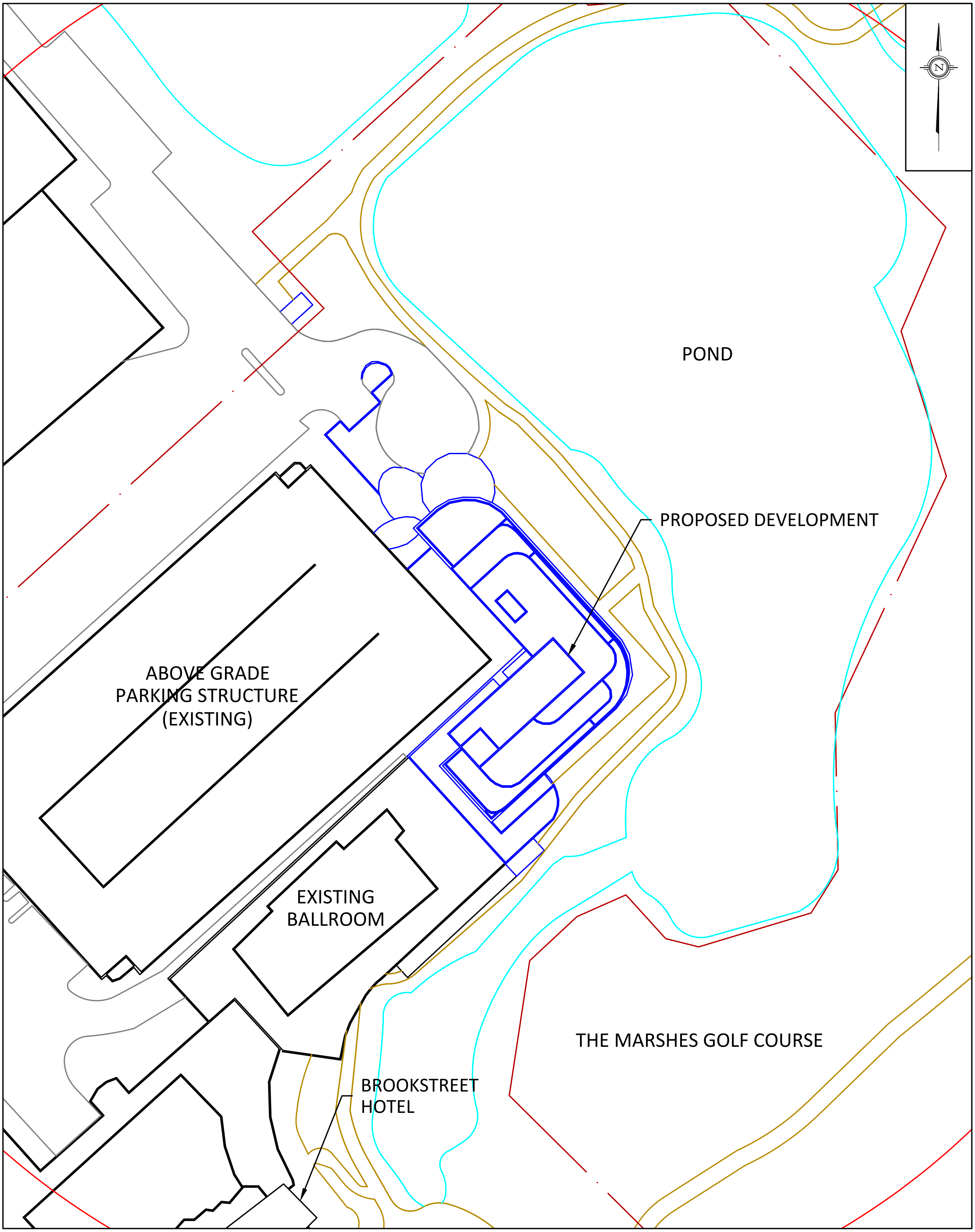
Sincerely,

Gradient Wind Engineering Inc.

Oct 1, 2021

Daniel Davalos, MESc.
Junior Wind Scientist

Justin Ferraro, P.Eng.
Principal



GRADIENTWIND
ENGINEERS & SCIENTISTS

127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM

PROJECT		DESCRIPTION
BROOKSTREET APARTMENTS, OTTAWA PEDESTRIANS LEVEL WIND STUDY		FIGURE 1: SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:1000	DRAWING NO.: 21-203-PLW-1	
DATE: SEPTEMBER 30, 2021	DRAWN BY: O.R.	

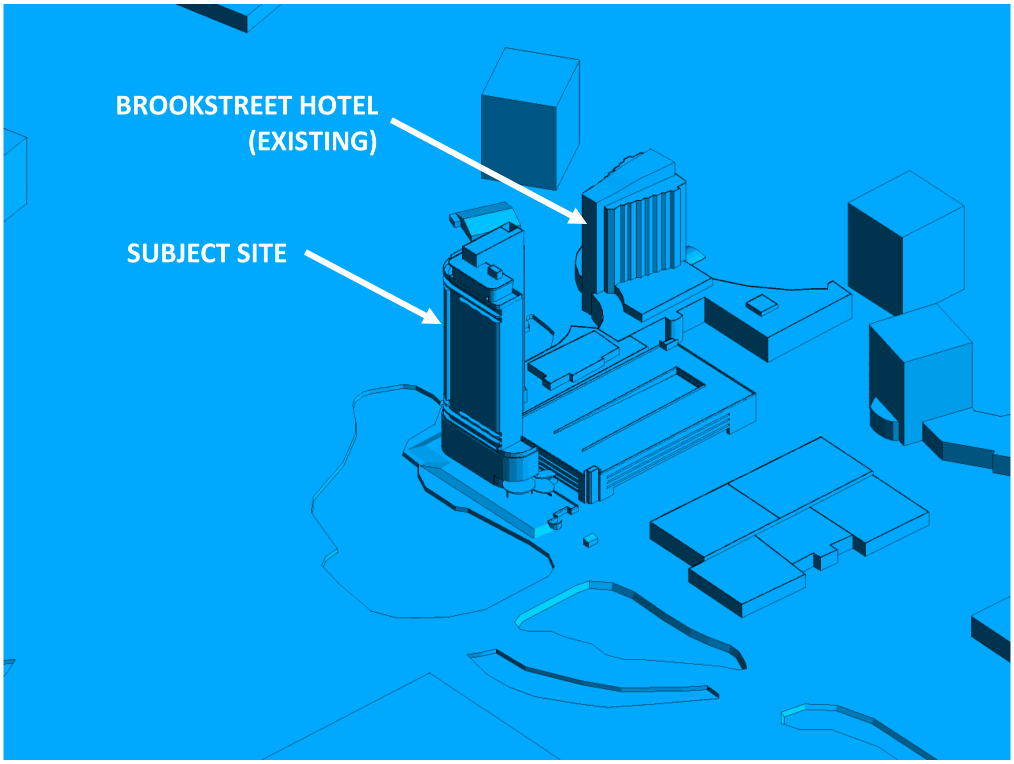


FIGURE 2A: COMPUTATIONAL MODEL, NORTH PERSPECTIVE

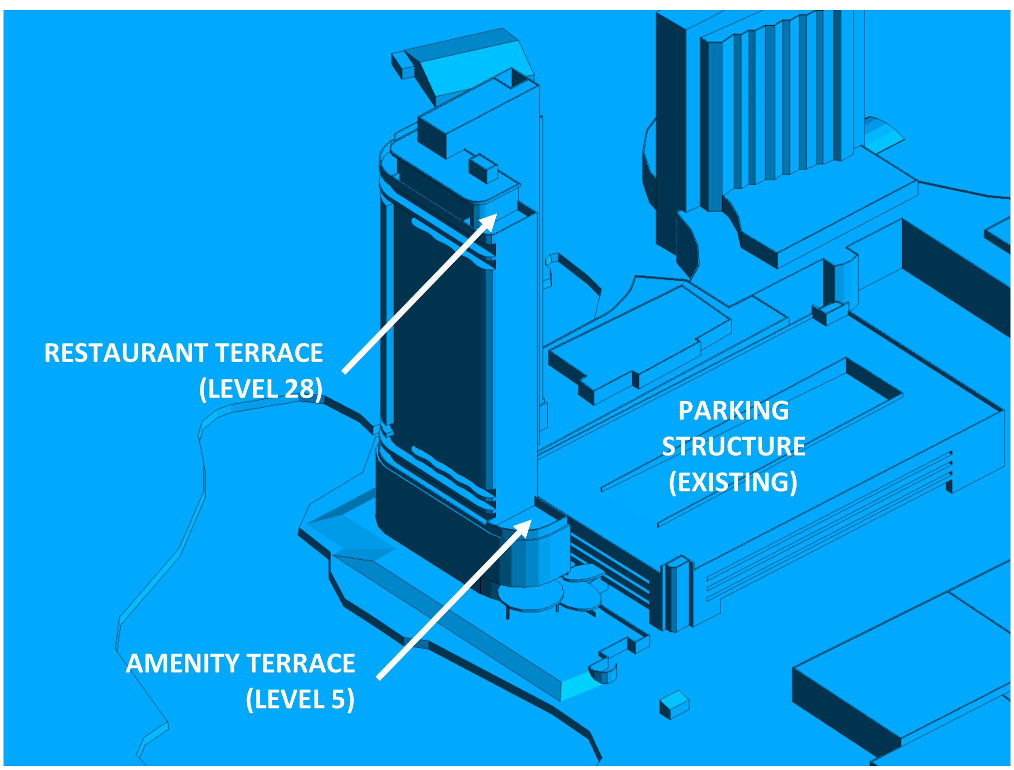


FIGURE 2B: CLOSE UP OF FIGURE 2A

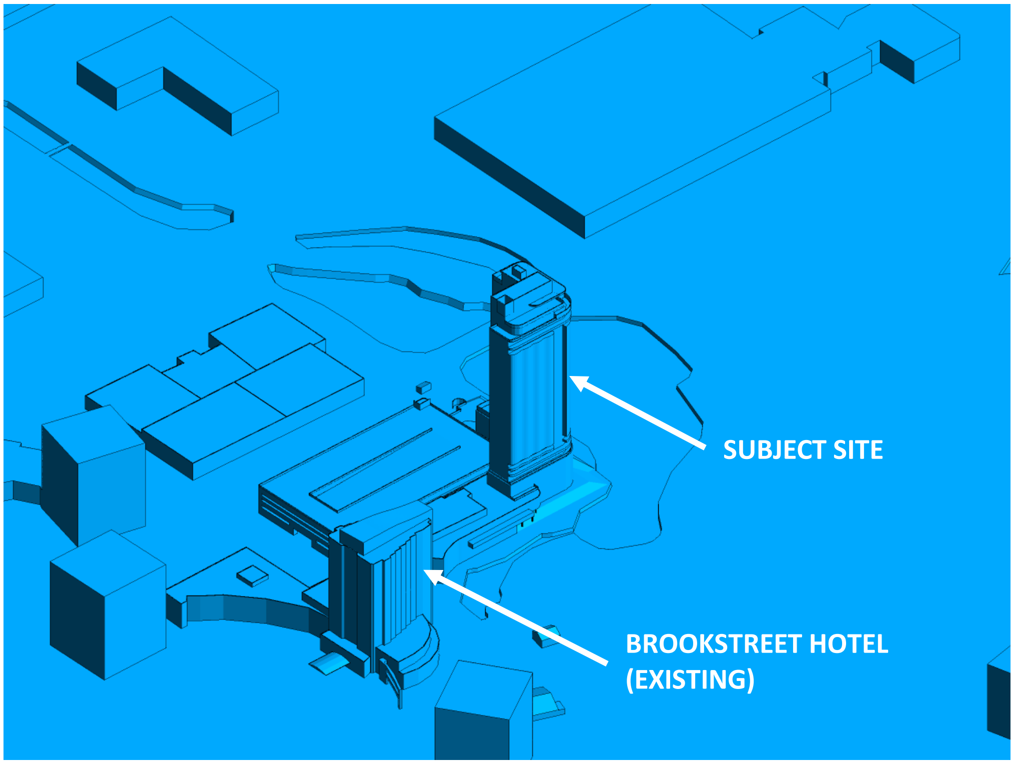


FIGURE 2C: COMPUTATIONAL MODEL, SOUTH PERSPECTIVE

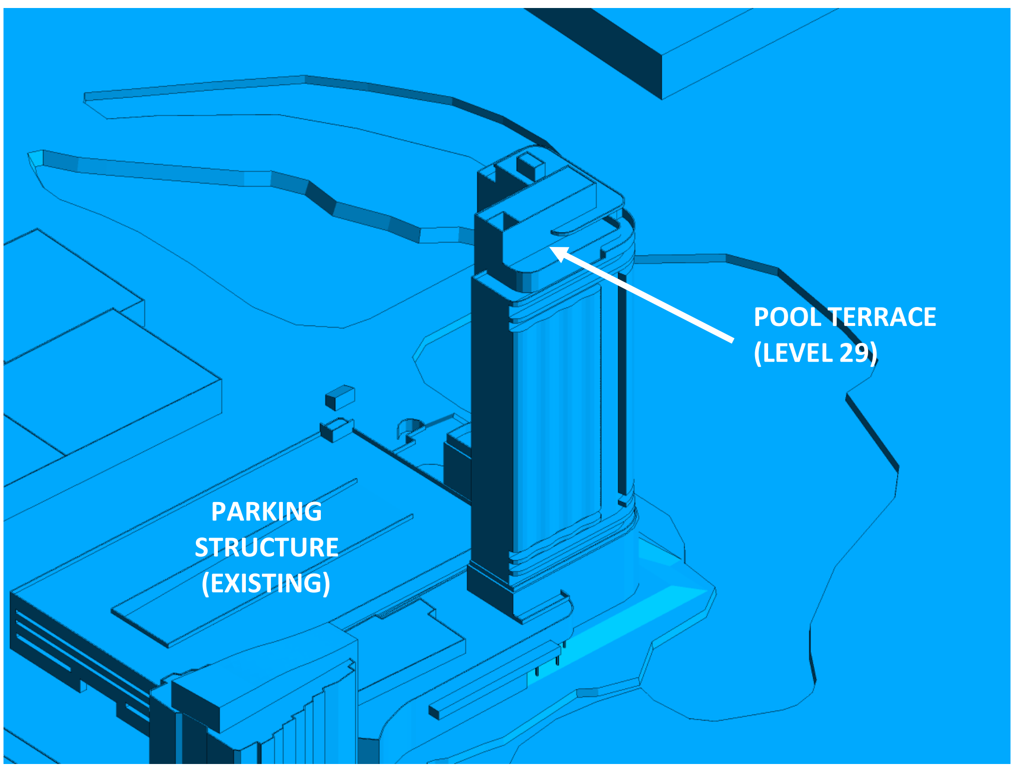


FIGURE 2D: CLOSE UP OF FIGURE 2C

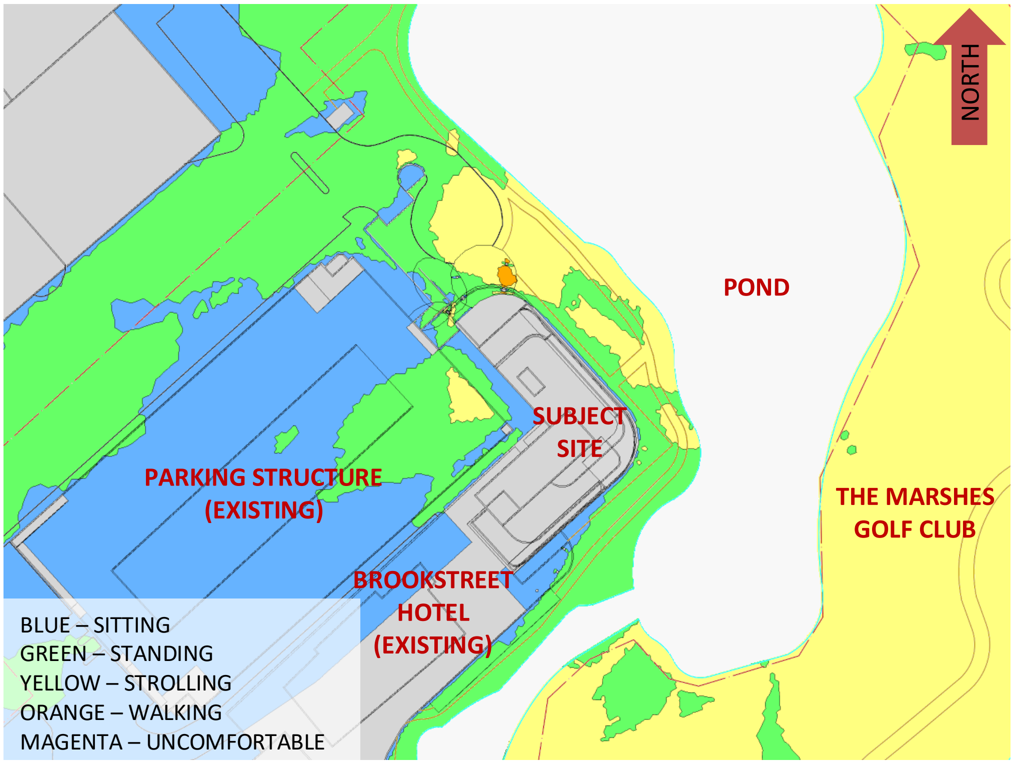


FIGURE 3A: SPRING – WIND COMFORT, GRADE LEVEL

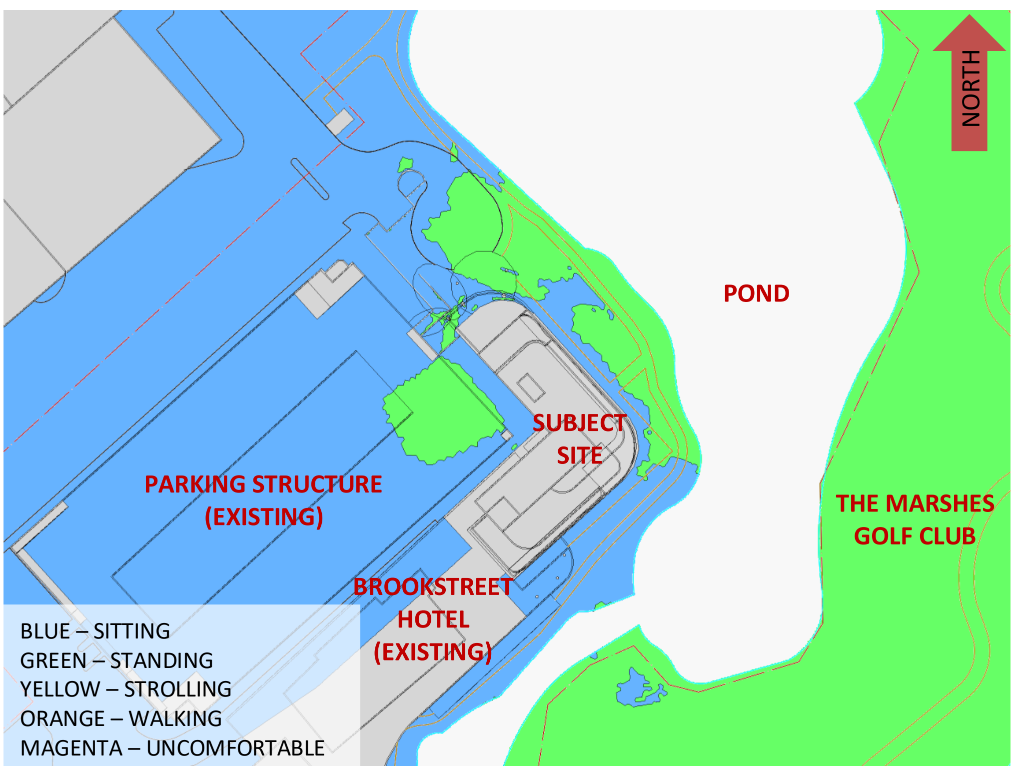


FIGURE 3B: SUMMER – WIND COMFORT, GRADE LEVEL

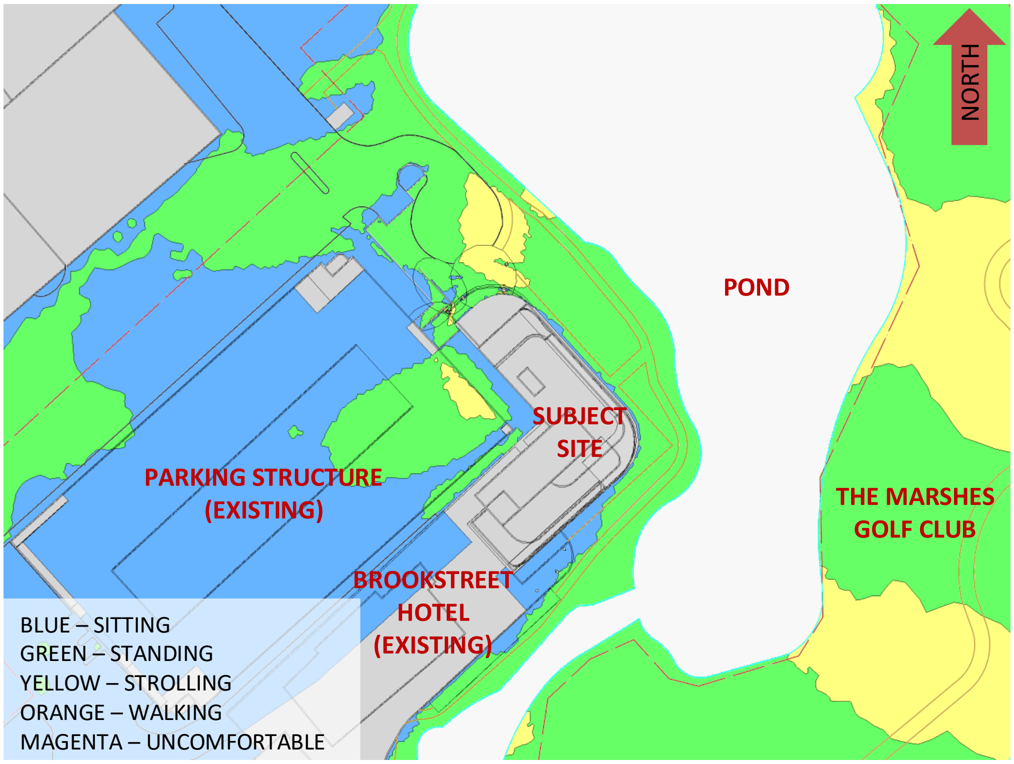


FIGURE 3C: AUTUMN – WIND COMFORT, GRADE LEVEL

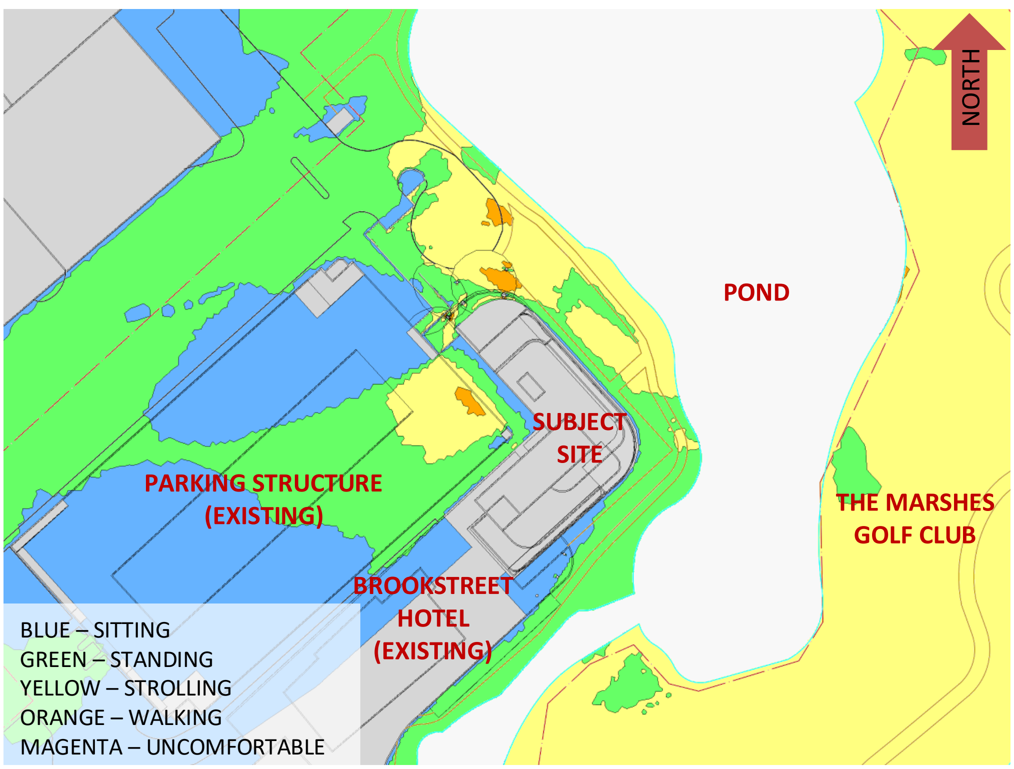


FIGURE 3D: WINTER – WIND COMFORT, GRADE LEVEL

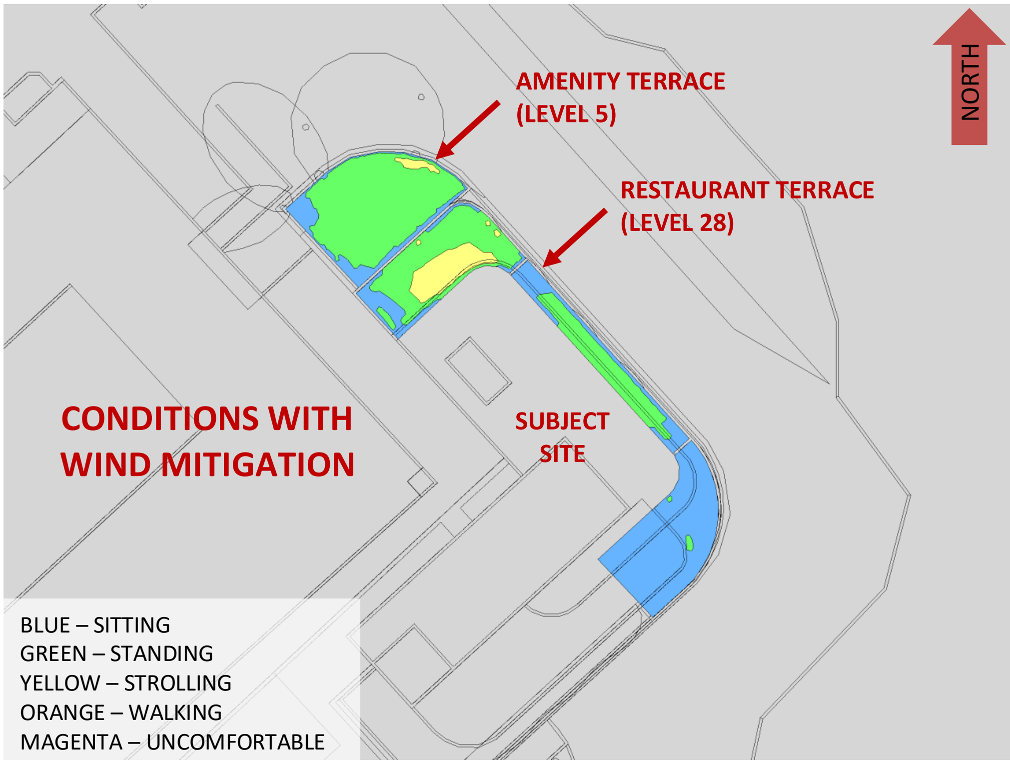


FIGURE 4A: SPRING – WIND COMFORT, AMENITY TERRACES

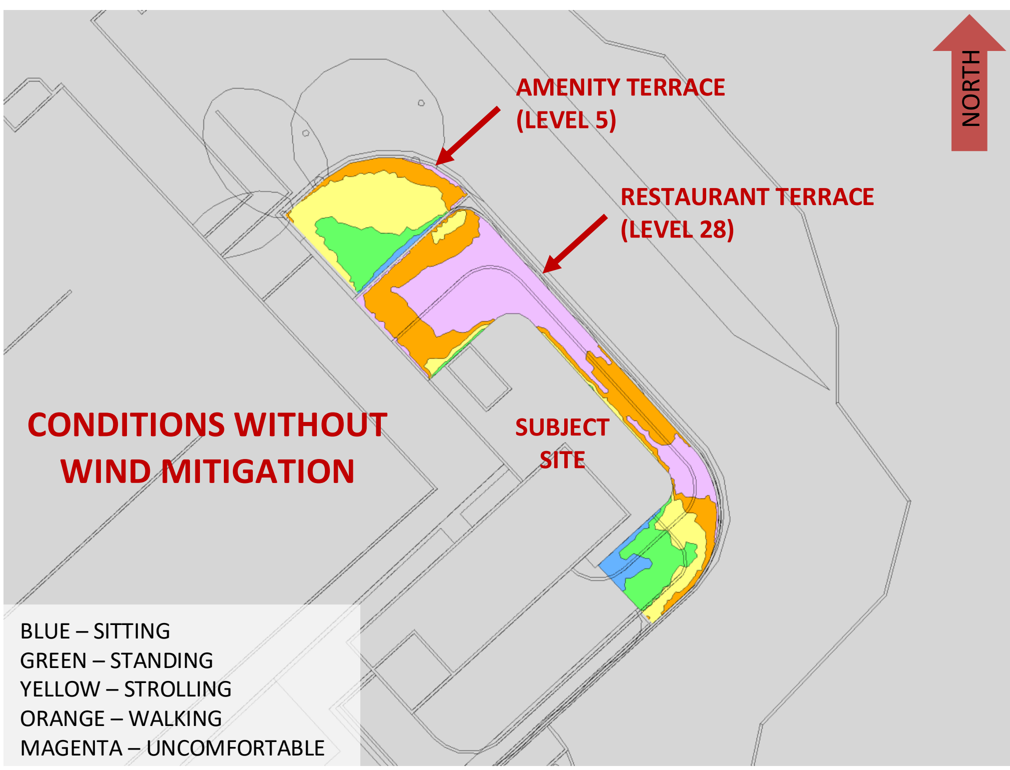


FIGURE 4B: SPRING – WIND COMFORT, AMENITY TERRACES

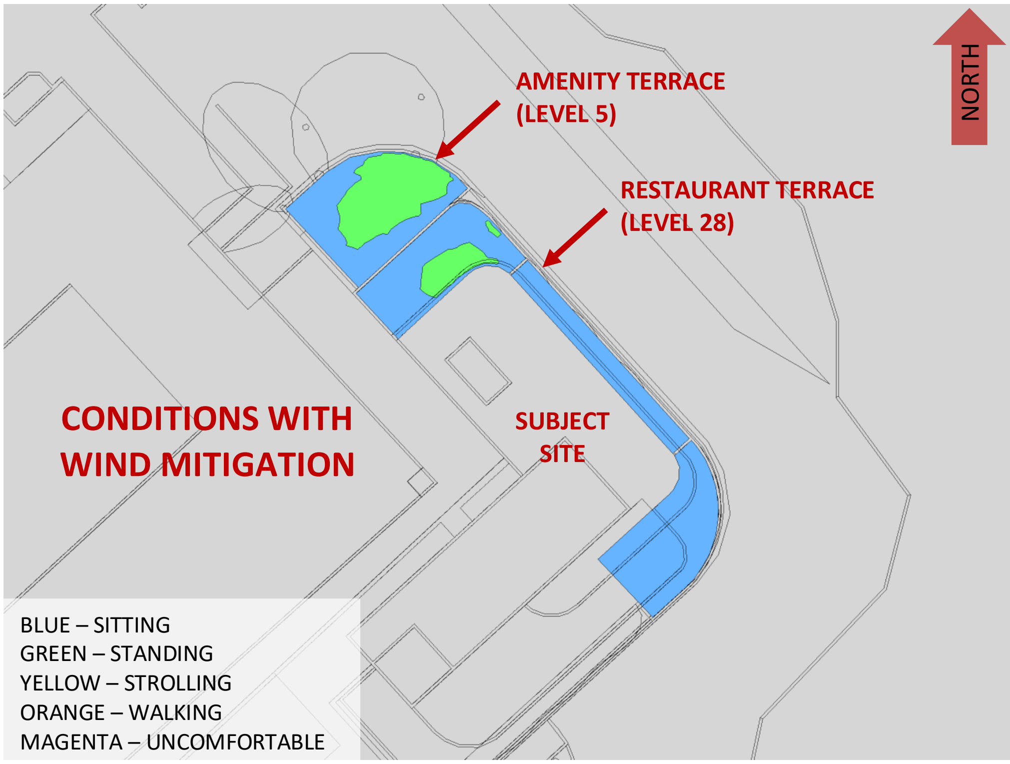


FIGURE 5A: SUMMER – WIND COMFORT, AMENITY TERRACES

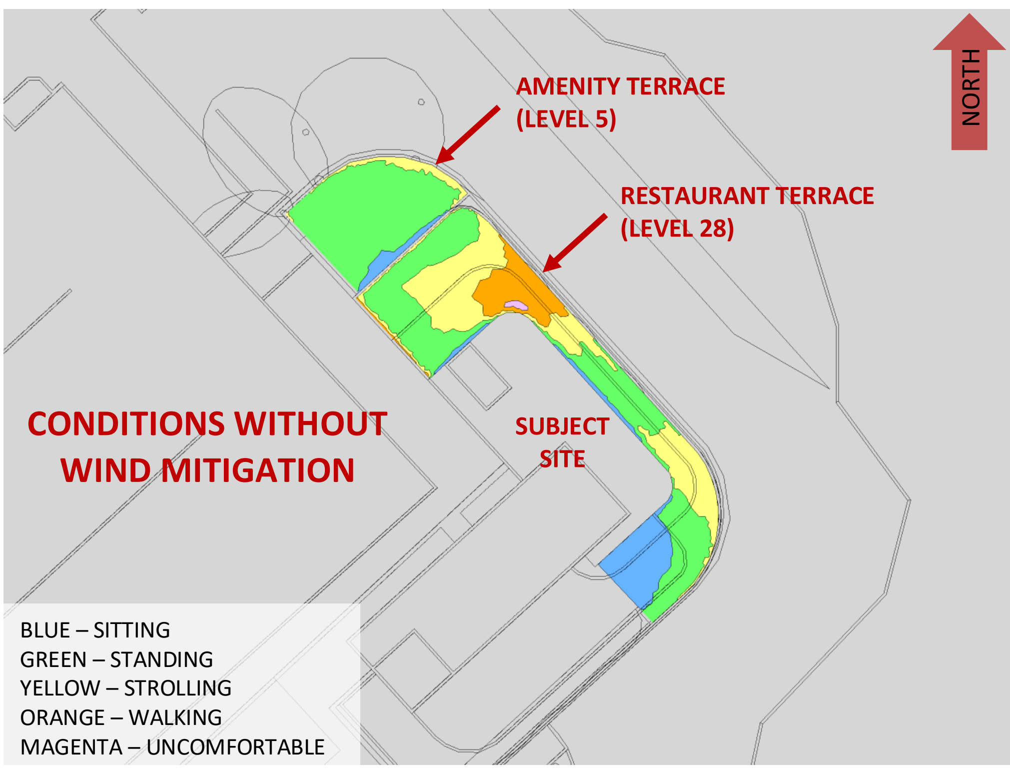


FIGURE 5B: SUMMER – WIND COMFORT, AMENITY TERRACES

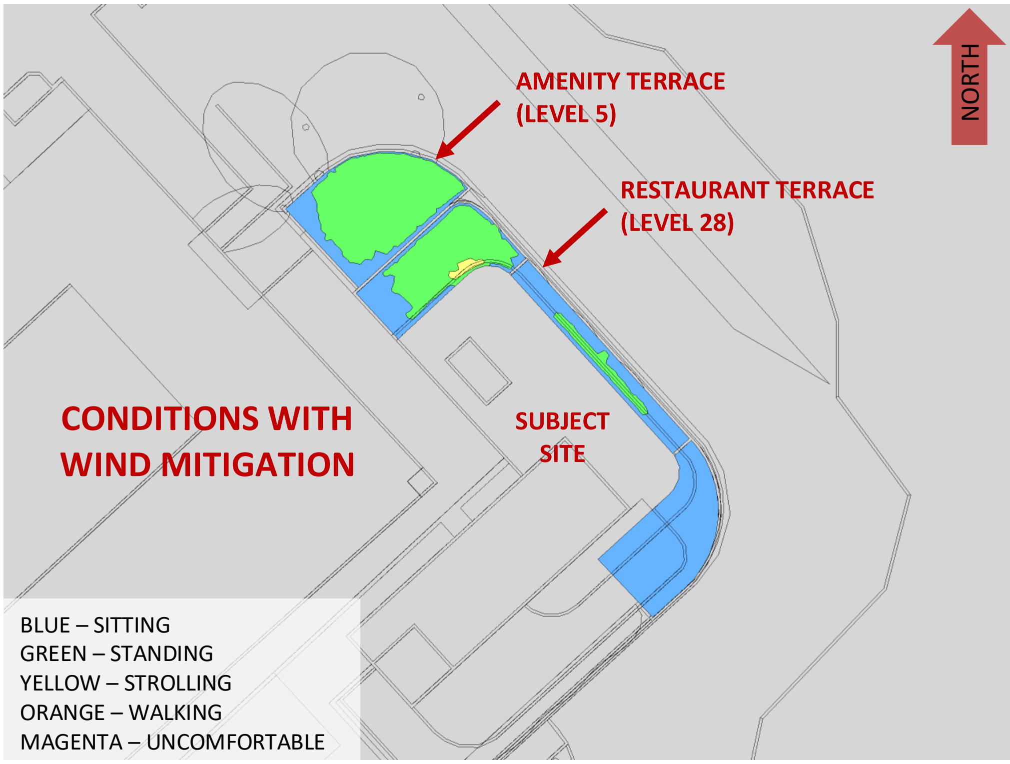


FIGURE 6A: AUTUMN – WIND COMFORT, AMENITY TERRACES

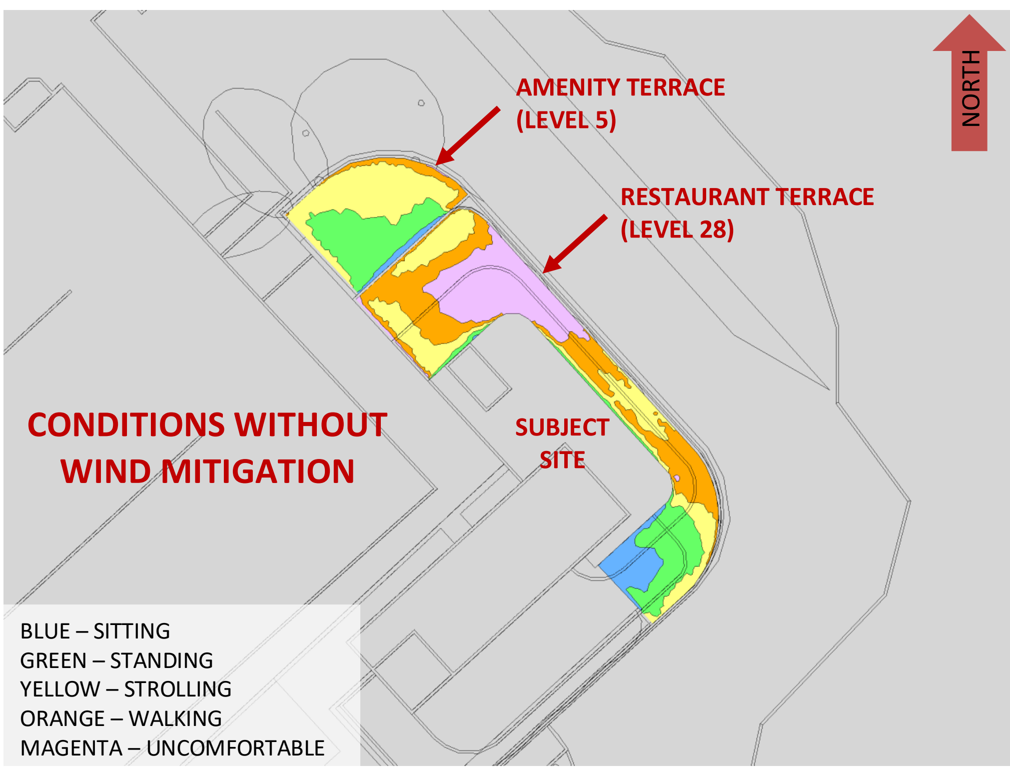


FIGURE 6B: AUTUMN – WIND COMFORT, AMENITY TERRACES

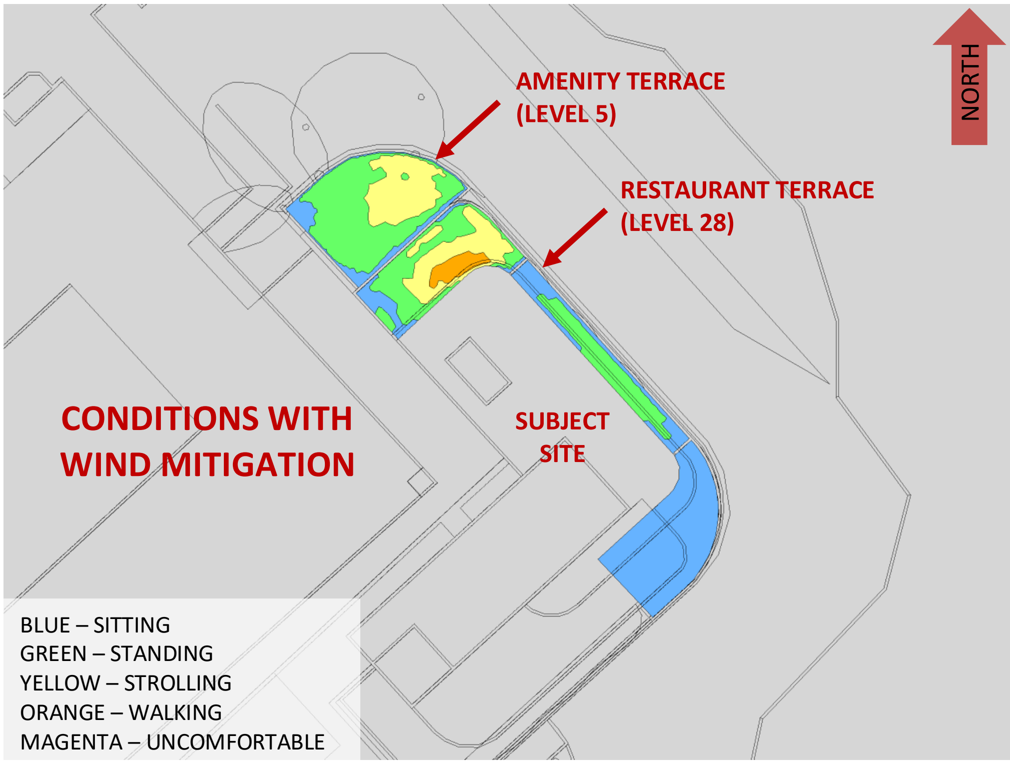


FIGURE 7A: WINTER – WIND COMFORT, AMENITY TERRACES

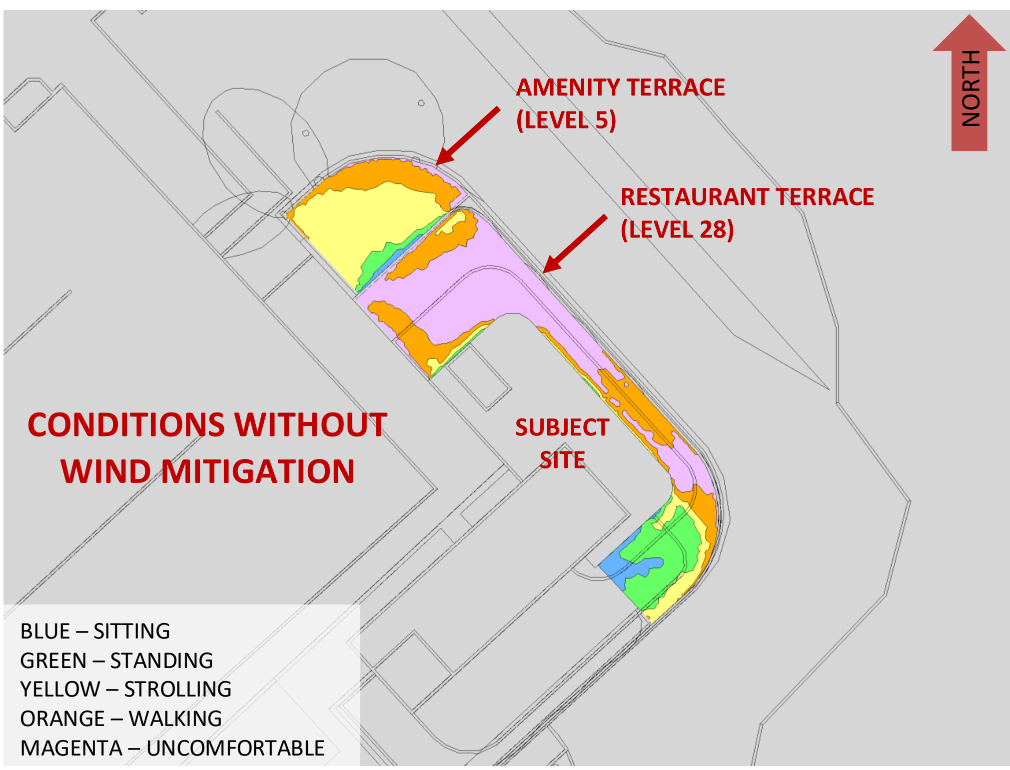


FIGURE 7B: WINTER – WIND COMFORT, AMENITY TERRACES

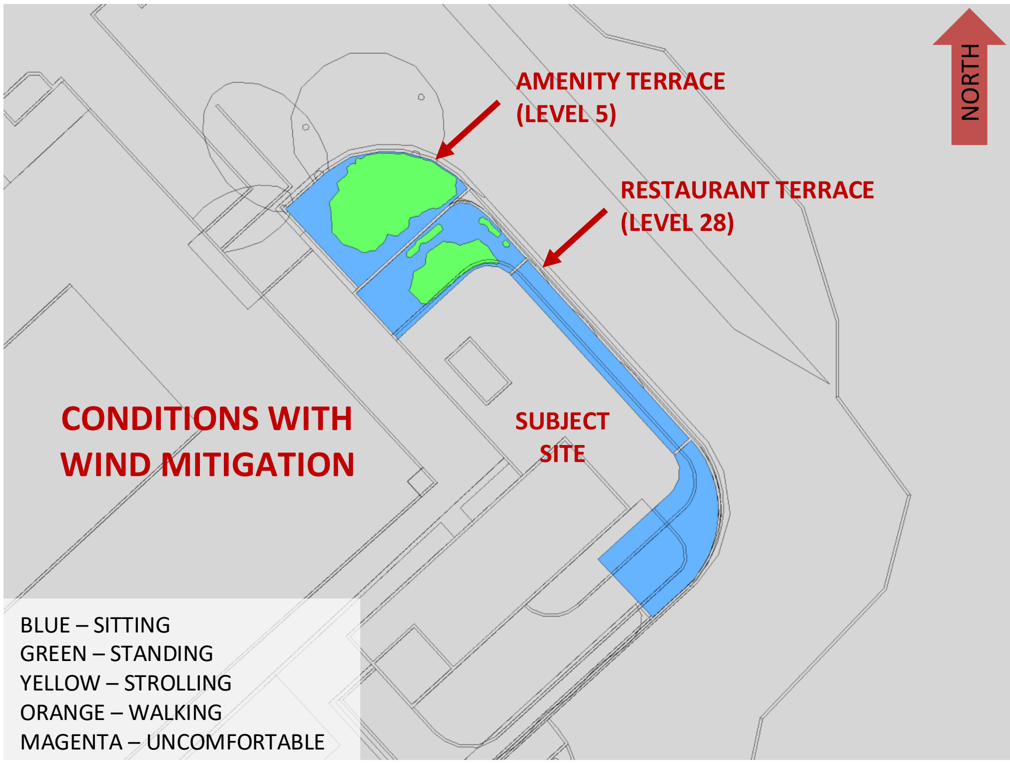


FIGURE 8A: TYPICAL USE PERIOD – WIND COMFORT, AMENITY TERRACES

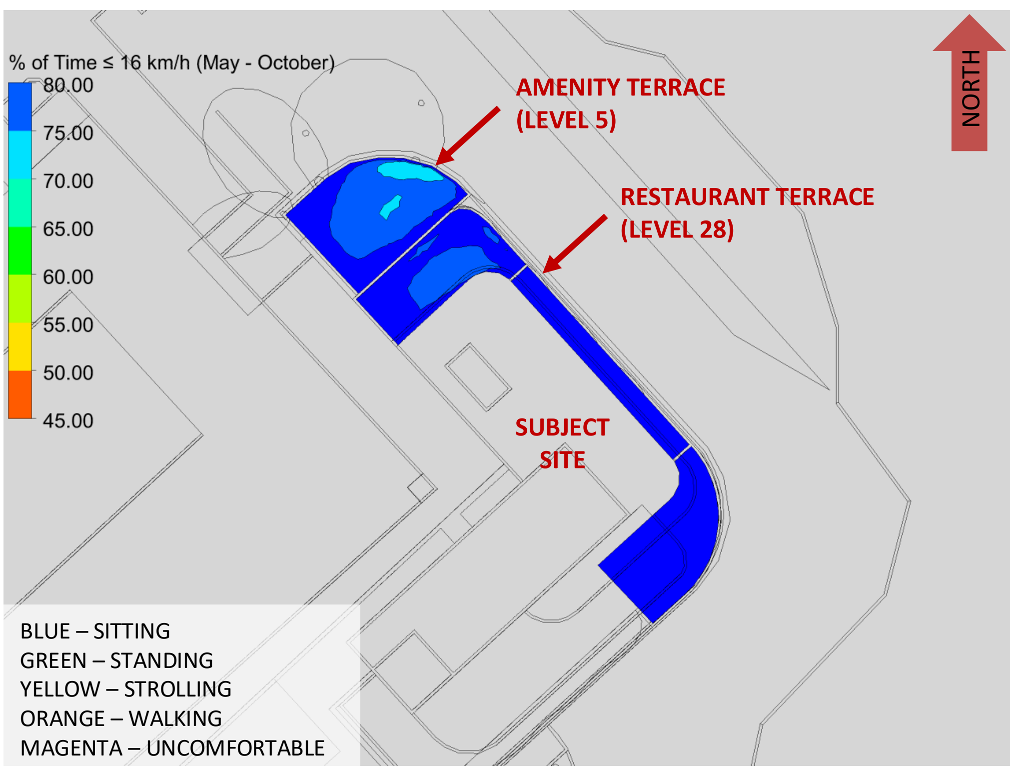


FIGURE 8B: % OF TIME SUITABLE FOR SITTING CORRESPONDING TO FIGURE 8A

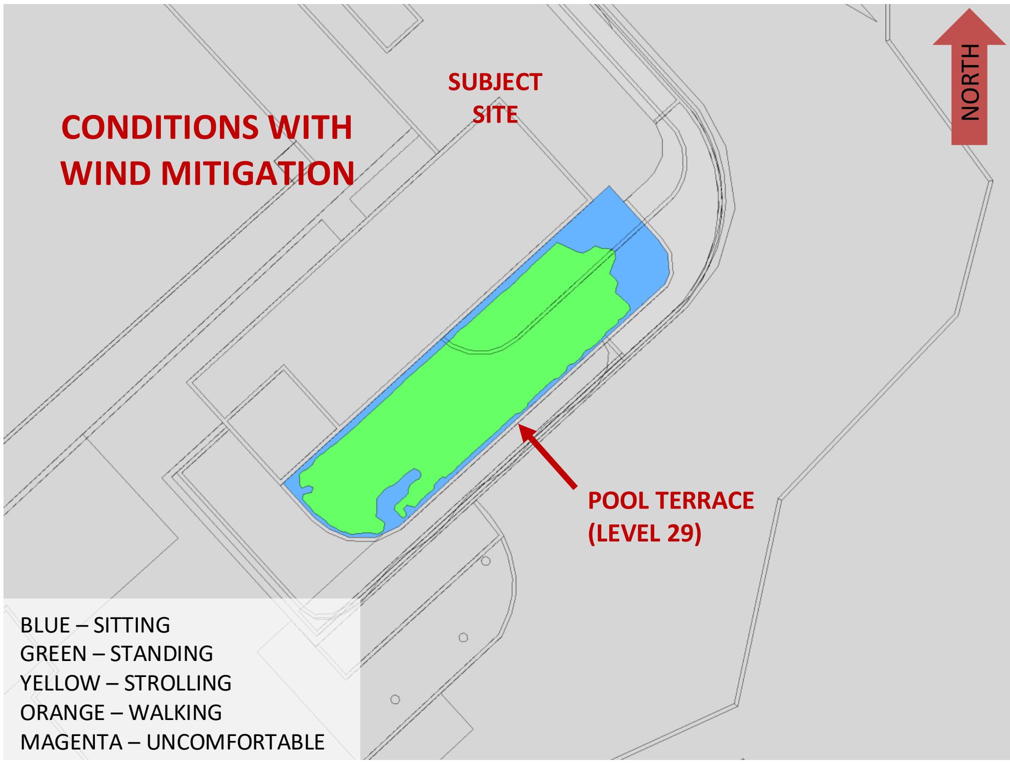


FIGURE 9A: SPRING – WIND COMFORT, POOL TERRACE

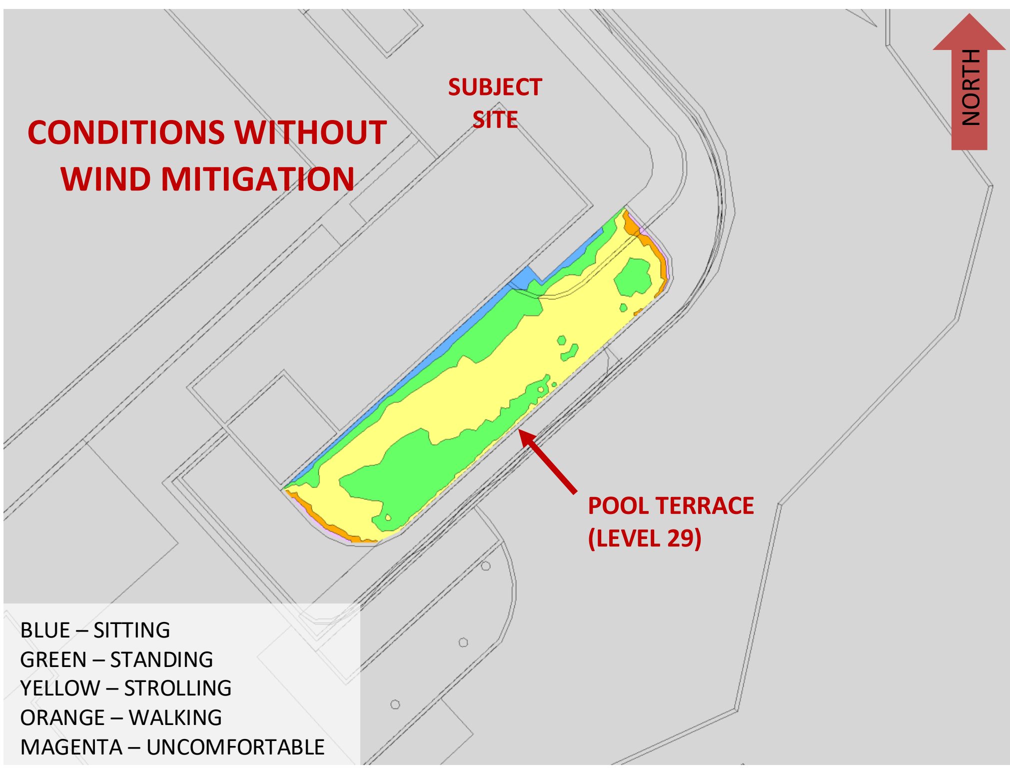


FIGURE 9B: SPRING – WIND COMFORT, POOL TERRACE

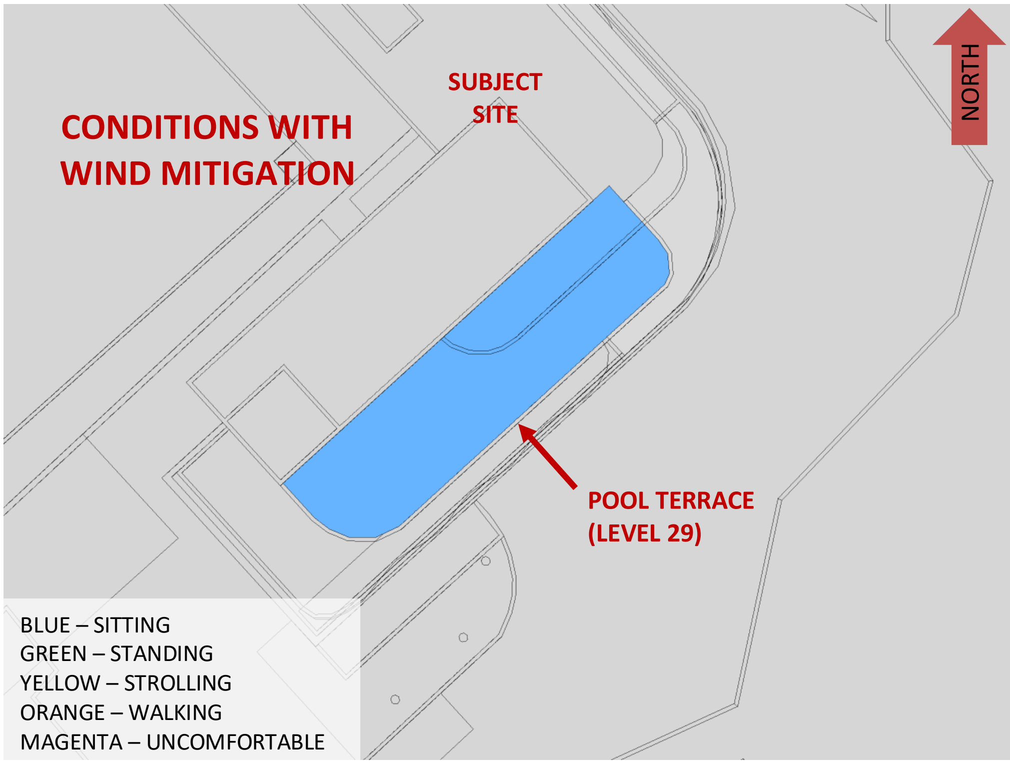


FIGURE 10A: SUMMER – WIND COMFORT, POOL TERRACE

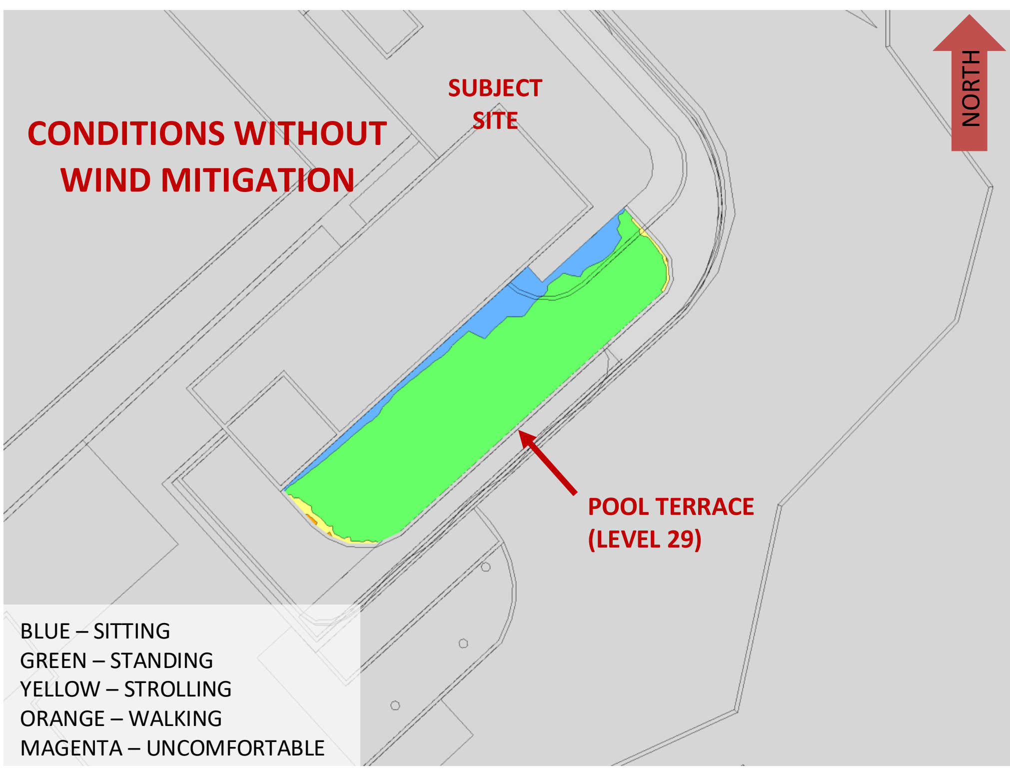


FIGURE 10B: SUMMER – WIND COMFORT, POOL TERRACE

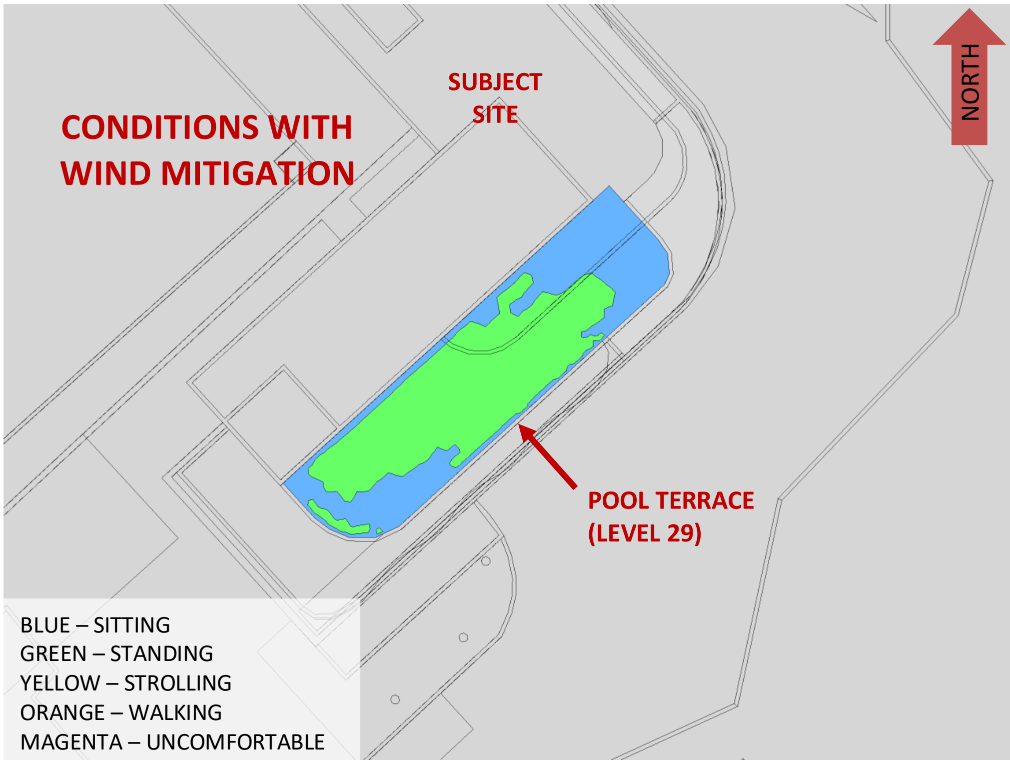


FIGURE 11A: AUTUMN – WIND COMFORT, POOL TERRACE

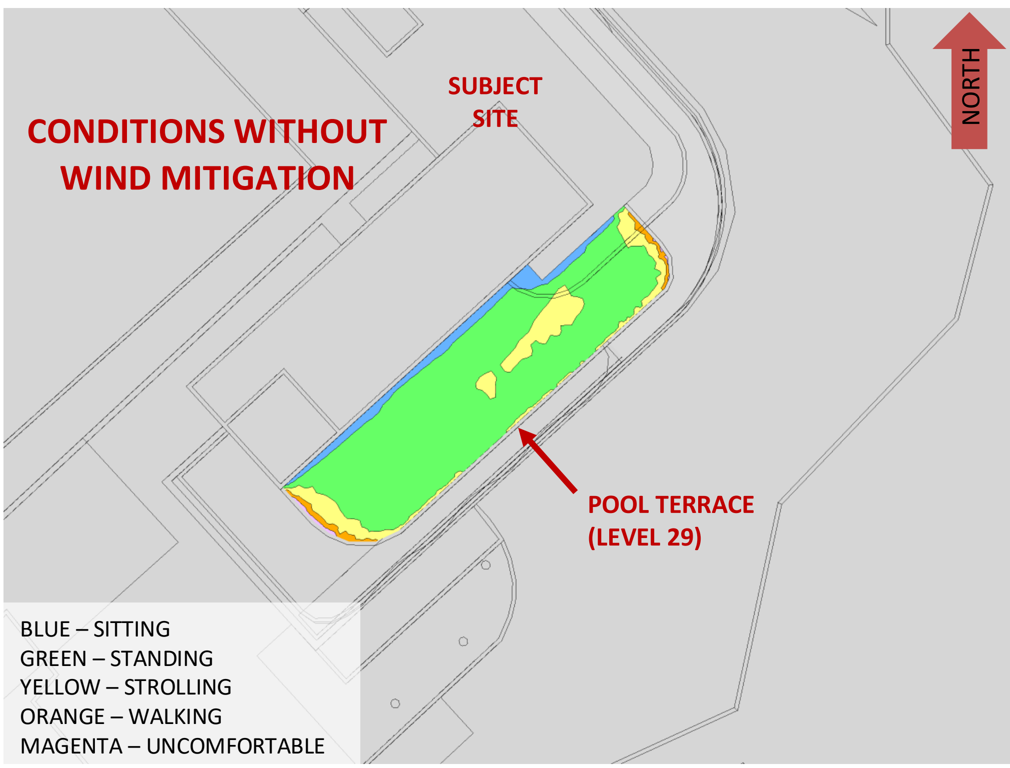


FIGURE 11B: AUTUMN – WIND COMFORT, POOL TERRACE

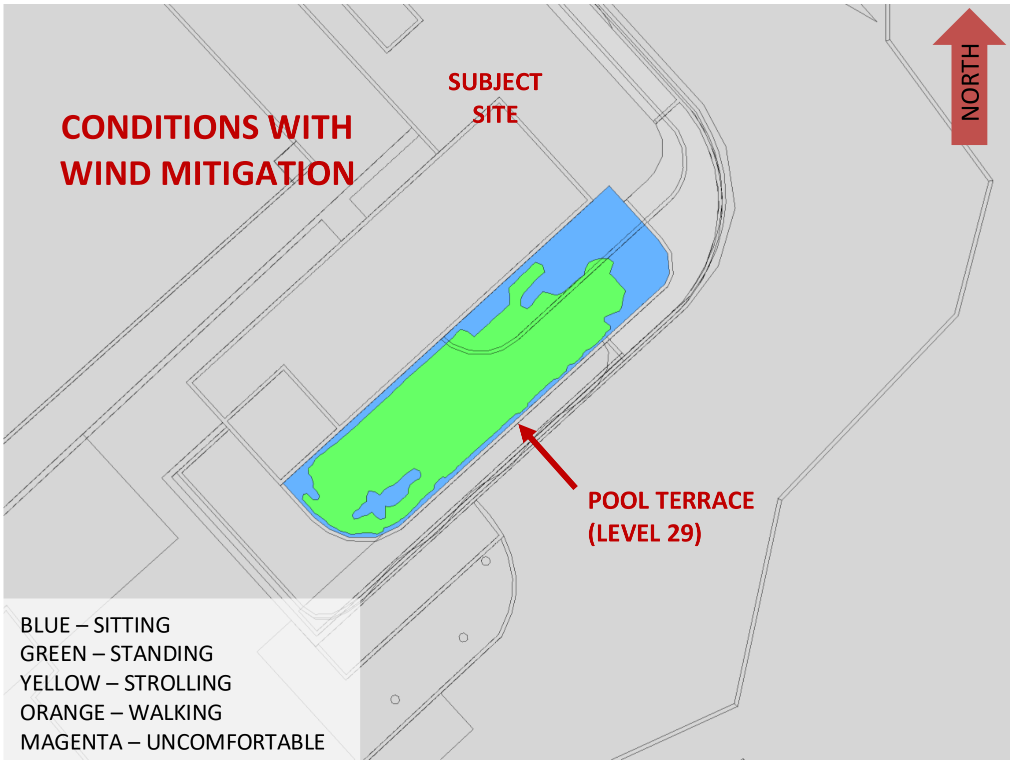


FIGURE 12A: WINTER – WIND COMFORT, POOL TERRACE

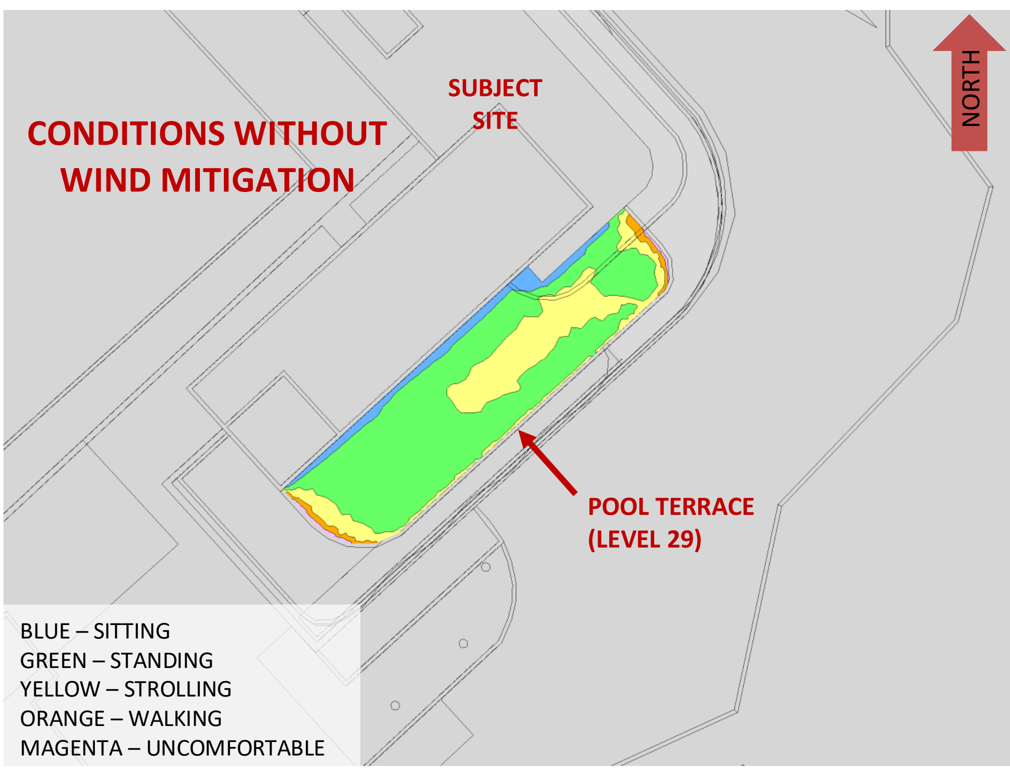


FIGURE 12B: WINTER – WIND COMFORT, POOL TERRACE

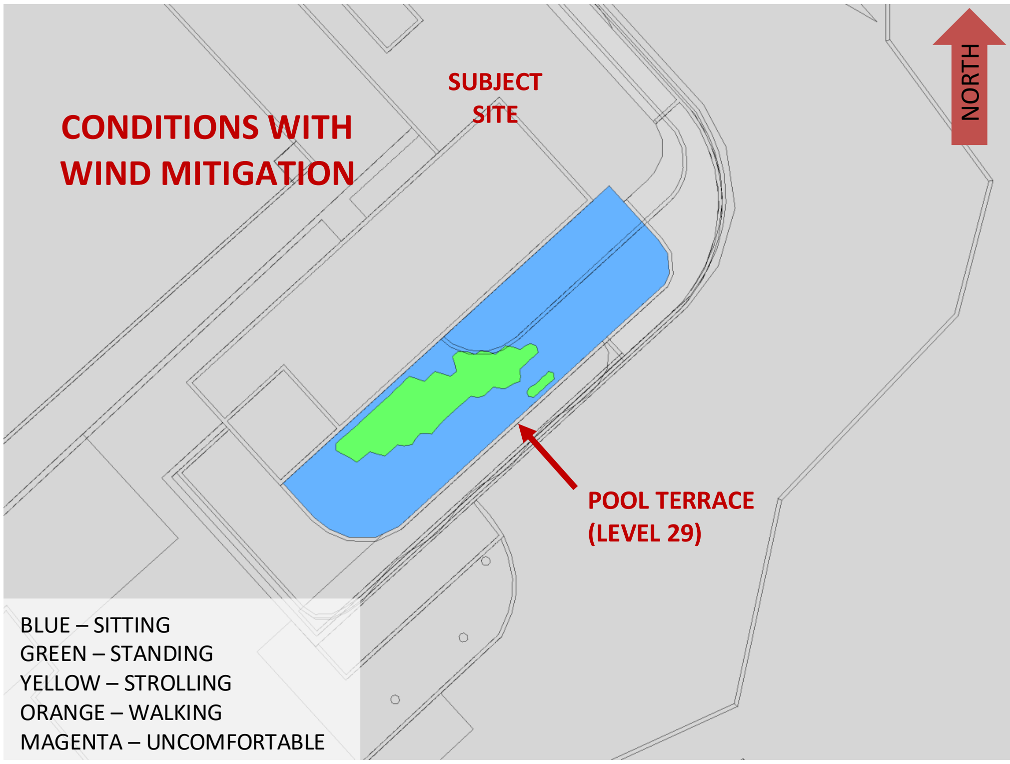


FIGURE 13A: TYPICAL USE PERIOD – WIND COMFORT, POOL TERRACE

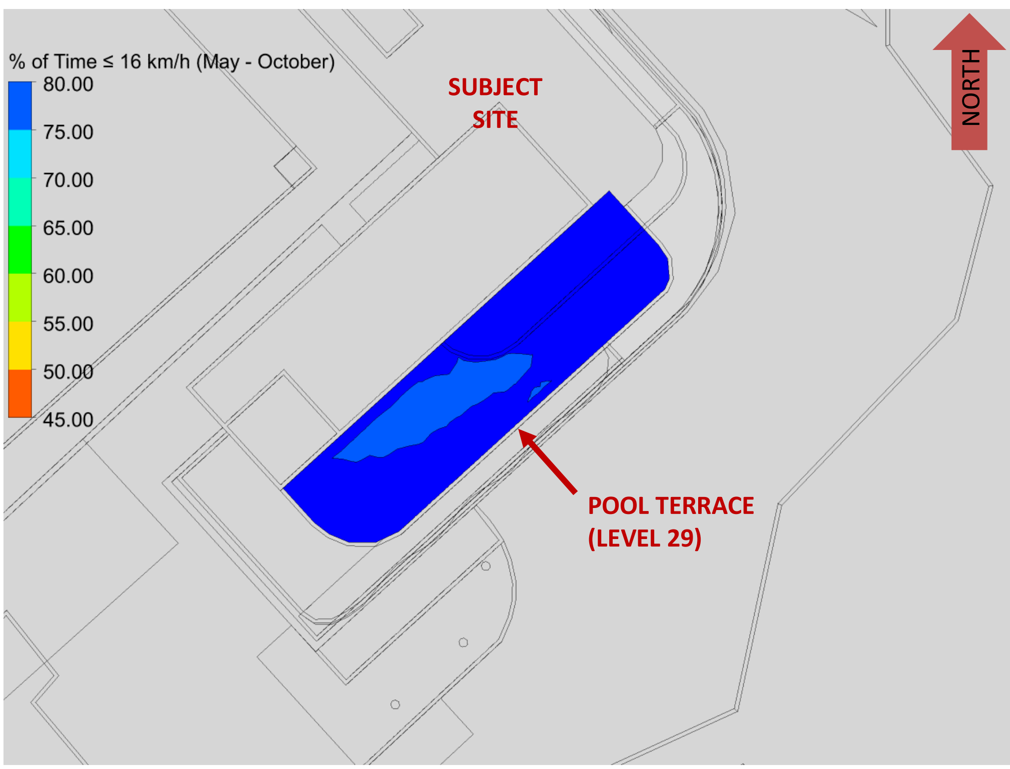
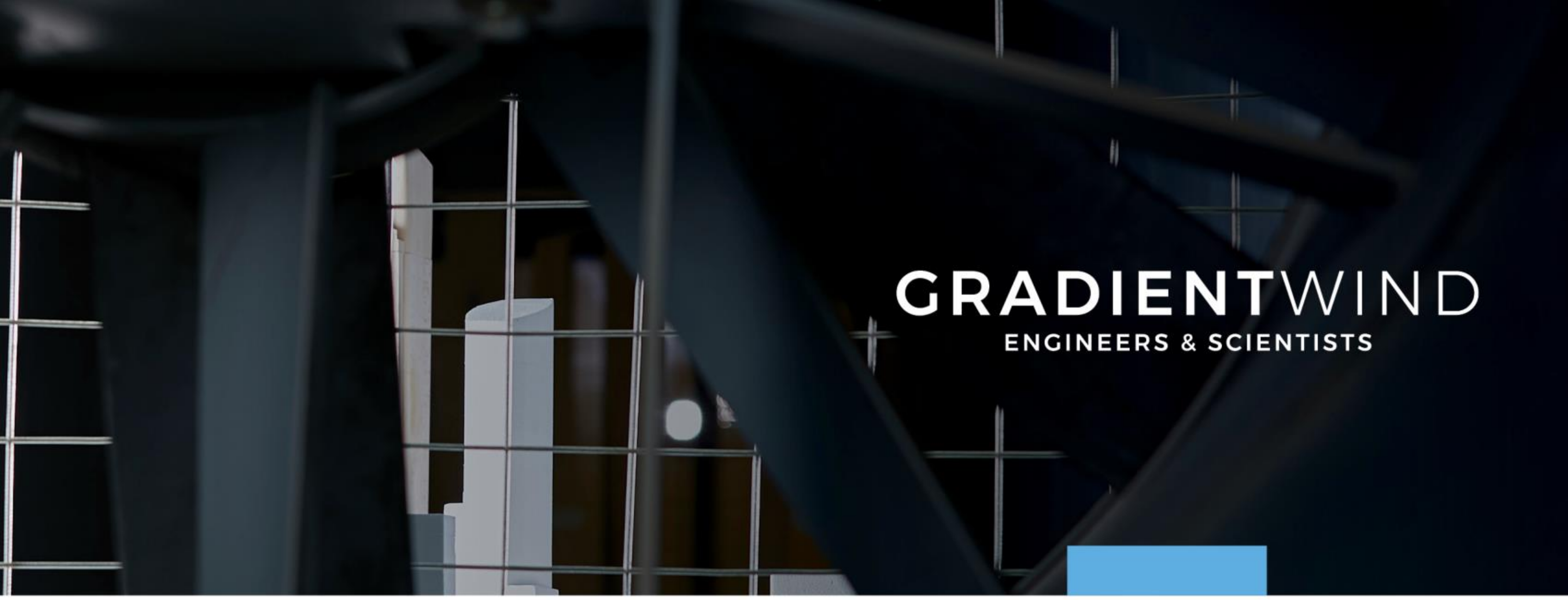
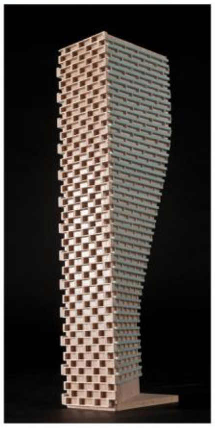
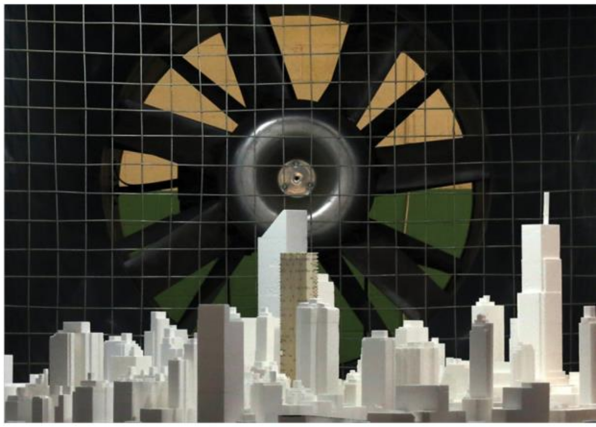


FIGURE 13B: % OF TIME SUITABLE FOR SITTING CORRESPONDING TO FIGURE 8A







APPENDIX A

SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

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	0.20
49	0.19
74	0.19
103	0.21
167	0.23
197	0.22
217	0.22
237	0.23
262	0.24
282	0.24
302	0.22
324	0.22

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

[1] P. Arya, "Chapter 10: Near-neutral Boundary Layers," in *Introduction to Micrometeorology*, San Diego, California, Academic Press, 2001.

[2] S. A. Hsu, E. A. Meindl and D. B. Gilhousen, "Determining the Power-Law WInd Profile Exponent under Near-neutral Stability Conditions at Sea," vol. 33, no. 6, 1994.

[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.