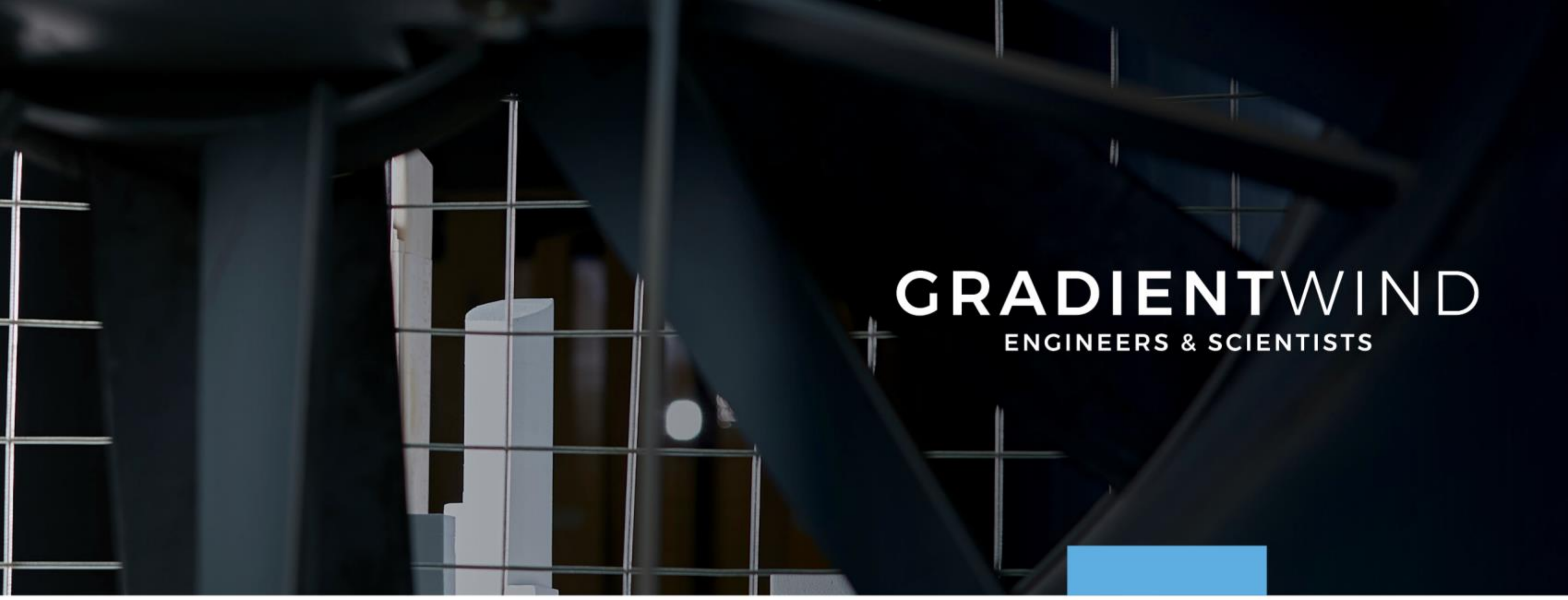
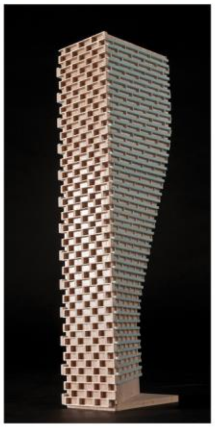


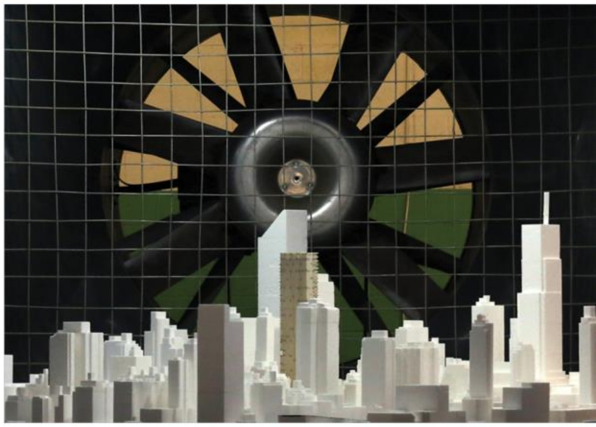
GRADIENTWIND
ENGINEERS & SCIENTISTS

PEDESTRIAN LEVEL WIND STUDY

50 Bayswater Avenue
Ottawa, Ontario

Report: 23-256-PLW





November 22, 2023

PREPARED FOR
Lalit and Anand Aggarwal
c/o Renfroe Land Management
371 Richmond Rd #2
Ottawa, ON K2A 0B7

PREPARED BY
Sunny Kang, B.A.S., Project Coordinator
Omar Rioseco, B.Eng., Junior Wind Scientist
Justin Ferraro, P.Eng., Principal

EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study undertaken to satisfy concurrent Official Plan Amendment, Zoning By-law Amendment, and Site Plan Control application requirements for the proposed mixed-use residential development located at 50 Bayswater Avenue in Ottawa, Ontario (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind conditions within and surrounding the subject site, and to identify areas where conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, where required.

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-9, and summarized as follows:

1) All grade-level areas within and surrounding the subject site are predicted to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year. Specifically, conditions over surrounding sidewalks, transit stops, surface parking, laneways, the existing parking deck, Somerset Square Park, walkways, the grade-level outdoor amenity, and in the vicinity of building access points, are considered acceptable.

2) Regarding the common amenity terrace serving Building A at Level 5, wind conditions are predicted to be suitable for sitting throughout the year, which is considered acceptable.

3) Regarding the rooftop level of Building B, which may be served by a common amenity terrace, conditions during the typical use are predicted to be suitable for mostly standing with regions suitable for sitting to the north, east, and south of the terrace.

    a. Depending on programming, the noted conditions may be considered acceptable. Specifically, if the windier areas of the rooftop where conditions are predicted to be suitable for standing will not accommodate seating or lounging activities, the noted conditions would be considered acceptable.

b. If the programming of the rooftop level is to include seating or more sedentary activities in the noted windier areas, wind comfort conditions may be improved with the implementation of mitigation inboard of the terrace perimeters that is targeted around sensitive areas, in combination with tall wind screens, typically glazed, rising to at least 2 m above the local walking surface along the perimeters of the terrace. This inboard mitigation could take the form of inboard wind screens or other common landscape elements.

c. The extent of the required mitigation measures is dependent on the programming of the space. If required by programming, an appropriate mitigation strategy will be developed in collaboration with the building and landscape architects as the design of the proposed development progresses.

4) The foregoing statements and conclusions apply to common weather systems, during which no dangerous wind conditions, as defined in Section 4.4, are expected anywhere over the subject site. During extreme weather events (for example, thunderstorms, tornadoes, and downbursts), pedestrian safety is the main concern. However, these events are generally short-lived and infrequent and there is often sufficient warning for pedestrians to take appropriate cover.

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Lalit and Anand Aggarwal to undertake a pedestrian level wind (PLW) study to satisfy concurrent Official Plan Amendment, Zoning By-law Amendment, and Site Plan Control application requirements for the proposed mixed-use residential development located at 50 Bayswater in Ottawa, Ontario (hereinafter referred to as “subject site” or “proposed development”). Our mandate within this study is to investigate wind conditions within and surrounding the subject site, and to identify areas where 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 Roderick Lahey Architects in October 2023, 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 50 Bayswater Avenue in Ottawa, situated to the southwest of the intersection of Bayswater Avenue and Somerset Street West. An existing 17-storey residential building (Building C), inclusive of a 2-storey parking deck along its west elevation and two below-grade parking levels, is located at the southeast corner of the subject site and is to be retained. The proposed development comprises two nominally rectangular mixed-use residential buildings: Building A (6 storeys) and Building B (15 storeys) situated to the northwest and north of Building C, respectively. Building A is topped with a mechanical penthouse (MPH) and Buildings A and B share below-grade parking with Building C. An existing north-south laneway is located between Buildings A and B. Access to the parking deck is provided via the noted laneway and access to the below-grade parking is provided by a ramp at the southeast corner of Building C via a laneway from Bayswater Avenue.

The ground floor of Building A includes a commercial space to the north, a residential lobby to the east with a main entrance near the northeast corner, and an indoor amenity to the south. An outdoor amenity is located to the south and surface parking is located near the southeast corner. Levels 2-6 are reserved for residential occupancy. The building steps back from the south elevation at Level 5, which is considered in the current study to accommodate a common amenity terrace.

The ground floor of Building B includes a central residential lobby with a main entrance to the north, commercial spaces at the northwest corner and to the east, and a garbage space at the southwest corner. Levels 2-15 are reserved for residential occupancy. The building extends from the west elevation at Level 2 and steps back from the north and west elevations at Level 14. The rooftop level is considered in this study to serve as a potential common amenity terrace.

The near-field surroundings, defined as an area within 200 m of the subject site, include low-rise buildings in all compass directions with isolated mid-rise buildings to the east, southeast, and west, and a high-rise building to the northwest. Somerset Square Park is located approximately 40 m to the west of the proposed development. Notably, a 39-storey mixed-use residential building is under construction at 1040 Somerset Street West, approximately 125 m to the east. In addition, a 28-storey mixed-use residential building is approved at 1050 Somerset Street West, approximately 60 m to the east, a 6-storey residential building is approved at 54, 56, & 60 Bayswater Ave, to the immediate south, and a 12-storey mixed-use residential building is approved at 979 Wellington Street West, approximately 80 m to the west.

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 low-rise suburban massing with isolated mid- and high-rise buildings in all compass directions, a cluster of mid- and high-rise buildings approximately 1.4 km to the northeast which define the edge of Ottawa's downtown core, and a mix of suburban massing and the open exposure of the Ottawa River Valley from the northwest clockwise to the northeast. The Ottawa Hospital Civic Campus is located approximately 1.3 km to the south. Dow's Lake is situated approximately 1.5 km to the southeast and the Ottawa River flows from the northwest to the northeast approximately 700 m to the north of the proposed development.

Site plans for the proposed and existing massing scenarios are illustrated in Figures 1A and 1B, while Figures 2A-2H illustrate the computational models used to conduct the study. The existing massing scenario includes the existing massing and any future developments approved by the City of Ottawa.

3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind 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 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 subject 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 stronger wind speeds.

[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 proposed development, complete with surrounding massing within a radius of 480 m. The process was performed for two context massing scenarios, as noted in Section 2.

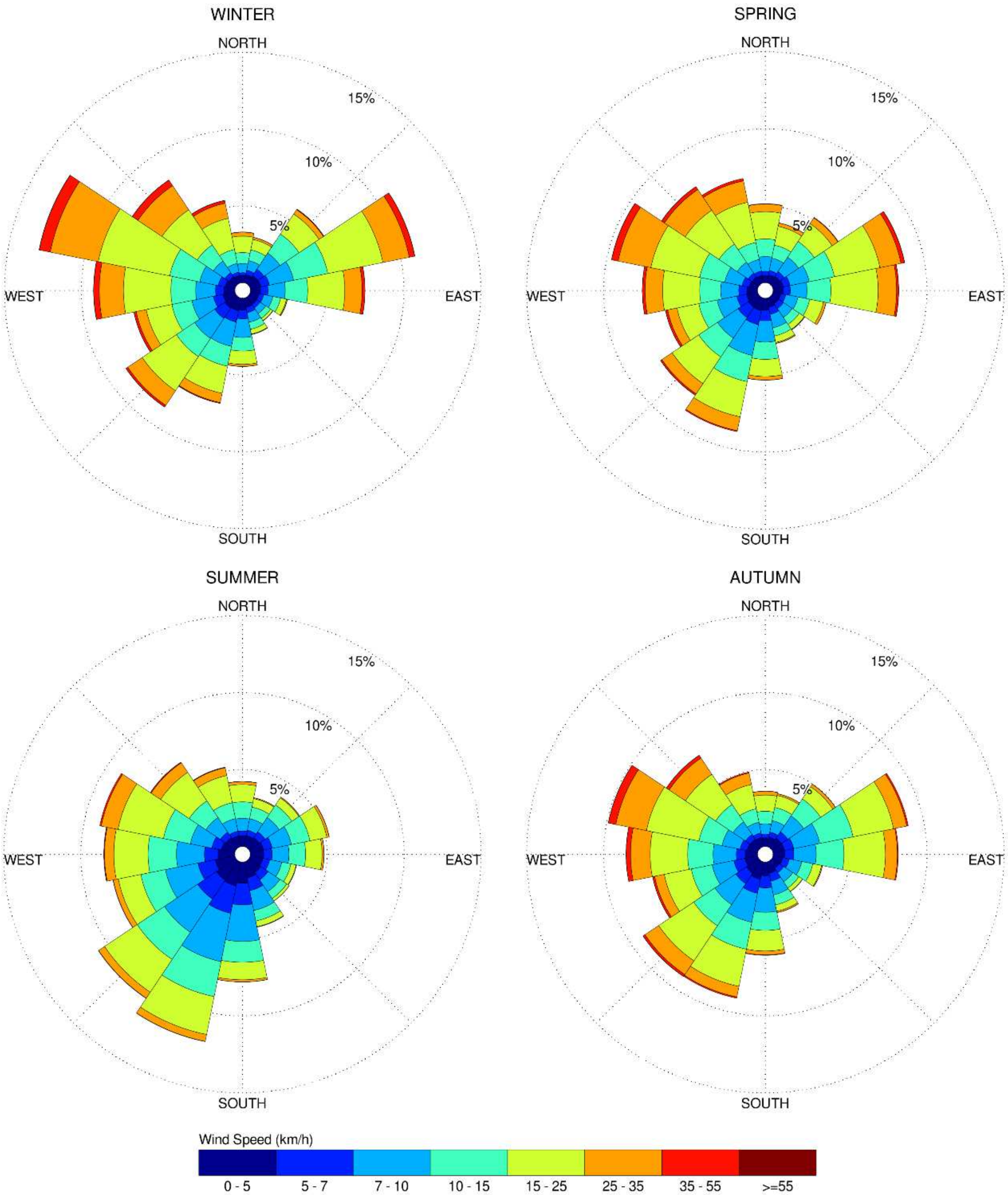
Mean and peak wind speed data obtained over the subject site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade and over the common amenities serving the proposed development 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 prominent 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 prominence 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 Wind Comfort and Safety Criteria – City of Ottawa

Pedestrian wind comfort and safety criteria are based on the mechanical effects of wind without consideration of other meteorological conditions (that is, temperature and relative humidity). The comfort criteria assume that pedestrians are appropriately dressed for a specified outdoor activity during any given season. Five pedestrian comfort classes based on 20% non-exceedance mean wind speed ranges are used to assess pedestrian comfort: (1) Sitting; (2) Standing; (3) Strolling; (4) Walking; and (5) Uncomfortable. The gust speeds, and equivalent mean speeds, are selected based on the Beaufort scale, which describes the effects of forces produced by varying wind speed levels on objects. Wind 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. Specifically, the comfort classes, associated wind speed ranges, and limiting criteria are summarized as follows:

PEDESTRIAN WIND COMFORT CLASS DEFINITIONS

Wind Comfort Class	GEM Speed (km/h)	Description
SITTING	≤ 10	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.
STANDING	≤ 14	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.
STROLLING	≤ 17	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.
WALKING	≤ 20	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.
UNCOMFORTABLE	> 20	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.

Regarding wind safety, 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. From calculations of stability, it can be shown that gust wind speeds of 90 km/h would be the approximate threshold wind speed that would cause an average elderly person in good health to fall. Notably, 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.

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 32 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 subject 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 target comfort classes, which are dictated by the location type for each region (that is, a sidewalk, building entrance, amenity space, or other). An overview of common pedestrian location types and their typical windiest target comfort classes are summarized on the following page. Depending on the programming of a space, the desired comfort class may differ from this table.

TARGET PEDESTRIAN WIND COMFORT CLASSES FOR VARIOUS LOCATION TYPES

Location Types	Comfort Classes
Primary Building Entrance	Standing
Secondary Building Access Point	Walking
Public Sidewalk / Bicycle Path	Walking
Outdoor Amenity Space	Sitting / Standing
Café / Patio / Bench / Garden	Sitting / Standing
Transit Stop (Without Shelter)	Standing
Transit Stop (With Shelter)	Walking
Public Park / Plaza	Sitting / Standing
Garage / Service Entrance	Walking
Parking Lot	Walking
Vehicular Drop-Off Zone	Walking

5. RESULTS AND DISCUSSION

The following discussion of the predicted pedestrian wind conditions for the subject site is accompanied by Figures 3A-6B, illustrating wind conditions at grade level for the proposed and existing massing scenarios, and by Figures 8A-8D, which illustrate conditions over the common amenity terraces serving Building A at Level 5 and Building B at the rooftop level. Conditions are presented as continuous contours of wind comfort throughout the subject site and correspond to the comfort classes presented in Section 4.4.

Wind comfort conditions are also reported for the typical use period, which is defined as May to October, inclusive. Figures 7 and 9 illustrate comfort conditions at grade level and over the noted common amenity terraces serving the proposed development, respectively, consistent with the comfort classes in Section 4.4. The details of these conditions are summarized in the following pages for each area of interest.

5.1 Wind Comfort Conditions – Grade Level

Sidewalks and Transit Stops along Somerset Street West: Following the introduction of the proposed development, wind comfort conditions over the nearby public sidewalks along Somerset Avenue West are predicted to be suitable for mostly sitting during the summer, becoming suitable for a mix of sitting and standing throughout the remainder of the year, with isolated regions suitable for strolling during the winter and spring. Conditions in the vicinity of the nearby transit stops along Somerset Street West are predicted to be suitable for sitting during the summer, becoming suitable for standing, or better, throughout the remainder of the year. The noted conditions are considered acceptable.

Wind conditions over the sidewalks and nearby transit stops along Somerset Avenue West with the existing massing are predicted to be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing throughout the remainder of the year. While the introduction of the proposed development produces slightly windier conditions over Somerset Avenue West in comparison to existing conditions, conditions along Somerset Avenue West with the proposed development are nevertheless considered acceptable for public sidewalks and transit stops.

Sidewalks along Bayswater Avenue: Following the introduction of the proposed development, wind conditions over the nearby public sidewalks along Bayswater Avenue are predicted to be suitable for mostly sitting during the summer, becoming suitable for a mix of sitting and standing during the autumn, and suitable for strolling, or better, during the winter and spring. The noted conditions are considered acceptable.

Conditions along Bayswater Avenue with the existing massing are predicted to be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing during the autumn, and suitable for strolling, or better, during the winter and spring. Notably, as compared to existing conditions, wind conditions remain similar following the introduction of the proposed development, and the predicted wind conditions with the proposed development are nevertheless considered acceptable.

Neighbouring Existing Surface Parking Lots: Following the introduction of the proposed development, wind conditions over the nearby neighbouring existing surface parking lots around the subject site are predicted to be suitable for sitting during the summer, becoming suitable for mostly standing, or better, throughout the remainder of the year. The noted conditions are considered acceptable.

Conditions over the neighbouring existing surface parking lots with the existing massing are predicted to be suitable for sitting during the summer, becoming suitable for standing, or better, throughout the remainder of the year. Notably, conditions over these surface parking areas are predicted to be mostly unchanged under the proposed massing scenario as compared to existing conditions and are nevertheless considered acceptable.

Laneway and Parking Deck: Following the introduction of the proposed development, conditions over the north-south laneway situated between Buildings A and B and over the parking deck to the west of Building C are predicted to be suitable for mostly sitting during the summer, becoming suitable for a mix of sitting and standing throughout the remainder of the year. The noted conditions are considered acceptable.

With the existing massing, wind conditions over the noted laneway are predicted to be suitable for sitting during the summer, autumn, and spring, becoming suitable for standing, or better, during the winter. Conditions over the noted parking deck with the existing massing are predicted to be suitable for mostly sitting during the summer, becoming suitable for standing, or better, throughout the remainder of the year. While the introduction of the proposed development produces windier conditions over the noted laneway, conditions over the noted parking deck are predicted to improve in comparison to existing conditions, and wind conditions with the proposed development are nevertheless considered acceptable.

Somerset Square Park: Prior to the introduction of the proposed development, wind comfort conditions within the Somerset Square Park situated to the northwest of the subject site are predicted to be suitable for sitting during the typical use period. The noted conditions remain unchanged following the introduction of the proposed development and the wind conditions with the proposed development are considered acceptable.

Outdoor Amenity South of Building A: Conditions within the outdoor amenity area situated to the south of Building A are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable.

Surface Parking and Walkways Within Subject Site: Wind conditions over the surface parking near the southeast corner of the Building A are predicted to be suitable for mostly sitting throughout the year. Conditions over the walkways serving the proposed development are predicted to be suitable for sitting during the summer, becoming suitable for standing, or better, throughout the remainder of the year.

Building Access Points: Wind conditions in the vicinity of the building access points serving the proposed development are predicted to be suitable for standing, or better, throughout the year. The noted conditions are considered acceptable.

5.2 Wind Comfort Conditions – Common Amenity Terraces

Building A, Level 5 Amenity Terrace: Conditions over the common amenity terrace serving Building A at Level 5 are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable.

Building B, Rooftop Level Amenity Terrace: Conditions during the typical use period over the common amenity terrace serving Building B at the rooftop level are predicted to be suitable for mostly standing with regions suitable for sitting to the north, east, and south of the terrace, as illustrated in Figure 9. Where conditions are suitable for standing, they are also suitable for sitting for at least 73% of the time during the same period, where the target is 80% to achieve the sitting comfort class.

Depending on programming, the noted conditions may be considered acceptable. Specifically, if the windier areas of the rooftop where conditions are predicted to be suitable for standing will not accommodate seating or lounging activities, the noted conditions would be considered acceptable.

If the programming of the rooftop level is to include seating or more sedentary activities in the noted windier areas, wind conditions may be improved with the implementation of mitigation inboard of the terrace perimeter that is targeted around sensitive areas, in combination with tall wind screens, typically glazed, rising to at least 2 m above the local walking surface along the perimeters of the terrace. This inboard mitigation could take the form of inboard wind screens or other common landscape elements.

The extent of the required mitigation measures is dependent on the programming of the space. If required by programming, an appropriate mitigation strategy will be developed in collaboration with the building and landscape architects as the design of the proposed development progresses.

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 are expected 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 (that is, 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.

6. CONCLUSIONS AND RECOMMENDATIONS

A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-9. 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 experience conditions that are considered acceptable for the intended pedestrian uses throughout the year. Specifically, conditions over surrounding sidewalks, transit stops, surface parking, laneways, the existing parking deck, Somerset Square Park, walkways, the grade-level outdoor amenity, and in the vicinity of building access points, are considered acceptable.

2) Regarding the common amenity terrace serving Building A at Level 5, wind conditions are predicted to be suitable for sitting throughout the year, which is considered acceptable.

3) Regarding the rooftop level of Building B, which may be served by a common amenity terrace, conditions during the typical use are predicted to be suitable for mostly standing with regions suitable for sitting to the north, east, and south of the terrace.

    a. Depending on programming, the noted conditions may be considered acceptable. Specifically, if the windier areas of the rooftop where conditions are predicted to be suitable for standing will not accommodate seating or lounging activities, the noted conditions would be considered acceptable.

b. If the programming of the rooftop level is to include seating or more sedentary activities in the noted windier areas, wind comfort conditions may be improved with the implementation of mitigation inboard of the terrace perimeters that is targeted around sensitive areas, in combination with tall wind screens, typically glazed, rising to at least 2 m above the local walking surface along the perimeters of the terrace. This inboard mitigation could take the form of inboard wind screens or other common landscape elements.

c. The extent of the required mitigation measures is dependent on the programming of the space. If required by programming, an appropriate mitigation strategy will be developed in collaboration with the building and landscape architects as the design of the proposed development progresses.

4) The foregoing statements and conclusions apply to common weather systems, during which no dangerous wind conditions, as defined in Section 4.4, are expected anywhere over the subject site. During extreme weather events (for example, thunderstorms, tornadoes, and downbursts), pedestrian safety is the main concern. However, these events are generally short-lived and infrequent and there is often sufficient warning for pedestrians to take appropriate cover.

Sincerely,

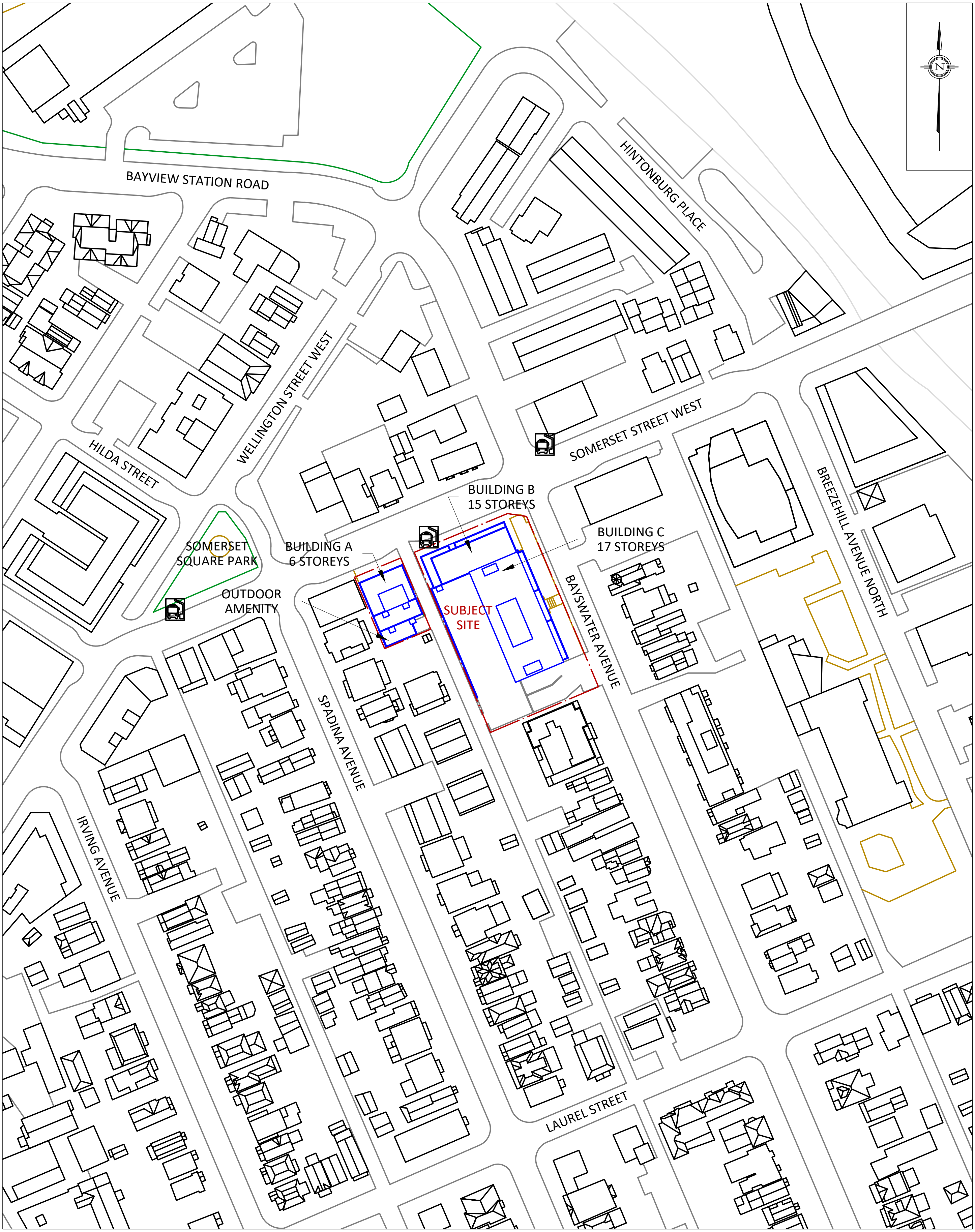
Gradient Wind Engineering Inc.

LICENSED PROFESSIONAL ENGINEER
J. D. FERRARO
100158495
Nov 22, 2023
PROVINCE OF ONTARIO

Omar Rioseco, B.Eng.
Junior Wind Scientist

Justin Ferraro, P.Eng.
Principal

Sunny Kang, B.A.S.
Project Coordinator



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

PROJECT	50 BAYSWATER AVENUE, OTTAWA PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:2000	DRAWING NO.	23-256-PLW-1A
DATE	NOVEMBER 20, 2023	DRAWN BY	N.M.P.

DESCRIPTION

FIGURE 1A:
PROPOSED SITE PLAN AND SURROUNDING CONTEXT

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PROJECT: 50 BAYSWATER AVENUE, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1B: EXISTING SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:2000	DRAWING NO.: 23-256-PLW-1B	
DATE: NOVEMBER 20, 2023	DRAWN BY: N.M.P.	

FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTHEAST PERSPECTIVE

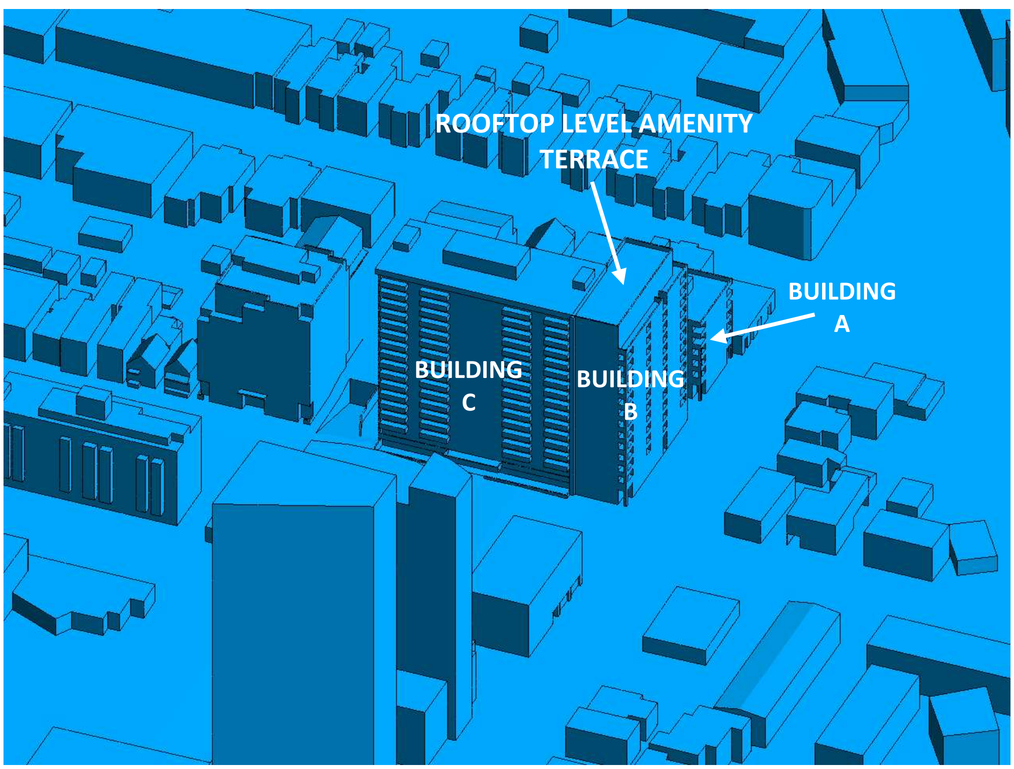


FIGURE 2B: CLOSE UP OF FIGURE 2A

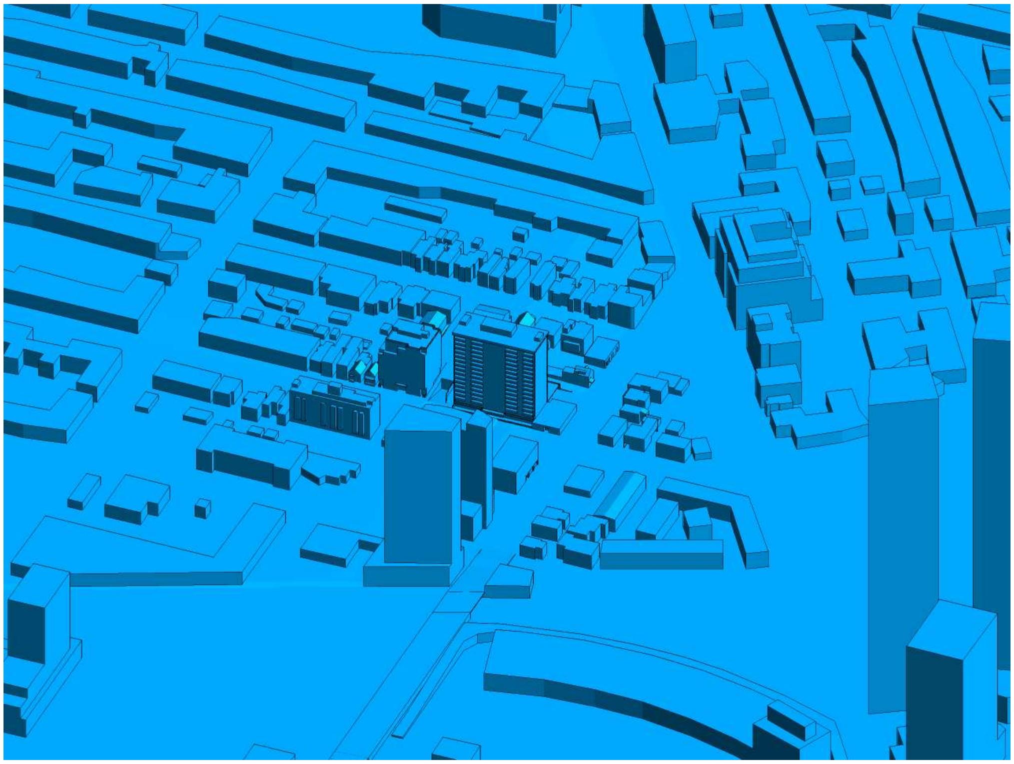


FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, NORTHEAST PERSPECTIVE

FIGURE 2D: CLOSE UP OF FIGURE 2C

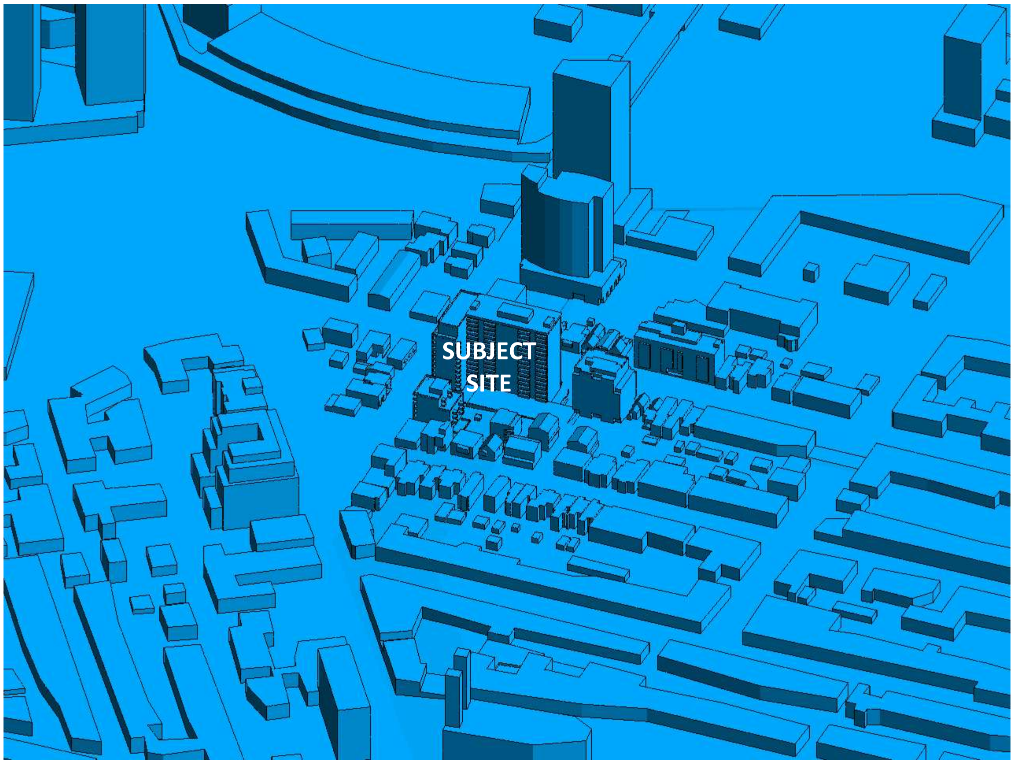


FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTHWEST PERSPECTIVE

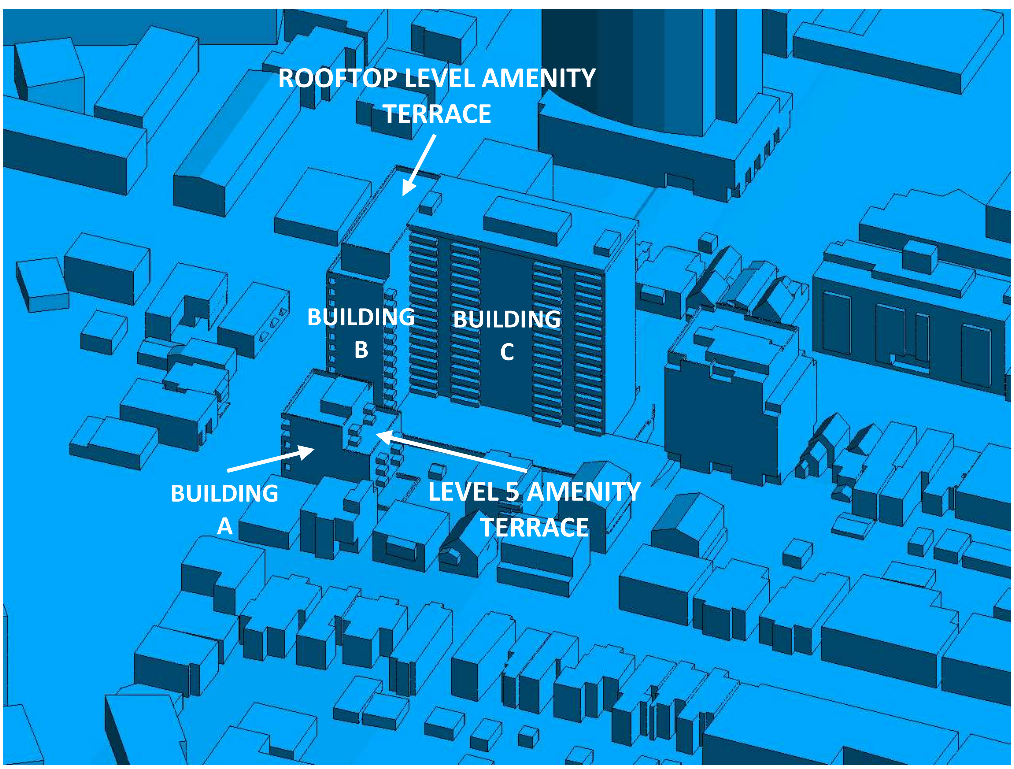


FIGURE 2F: CLOSE UP OF FIGURE 2E

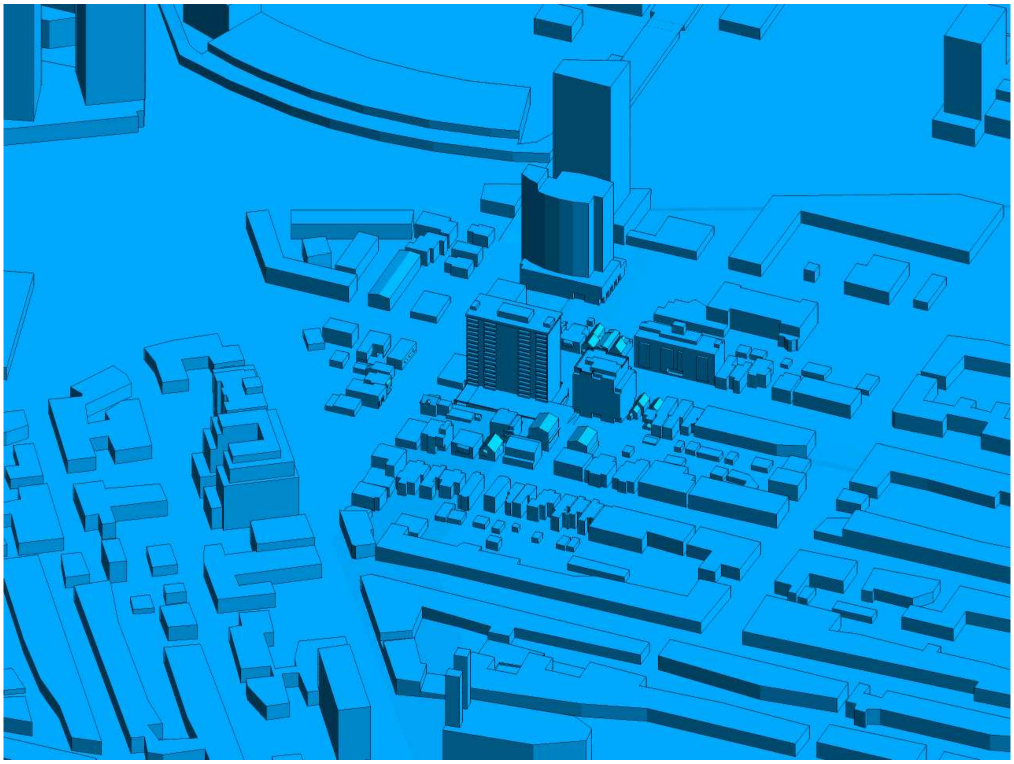


FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, SOUTHWEST PERSPECTIVE

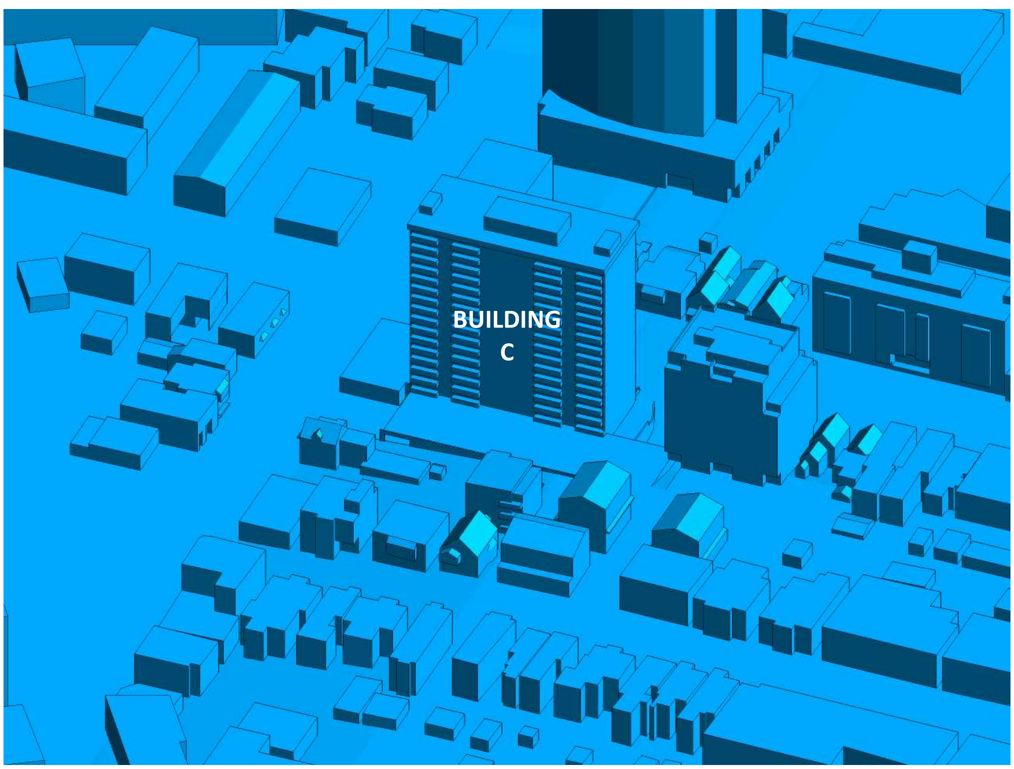


FIGURE 2H: CLOSE UP OF FIGURE 2G

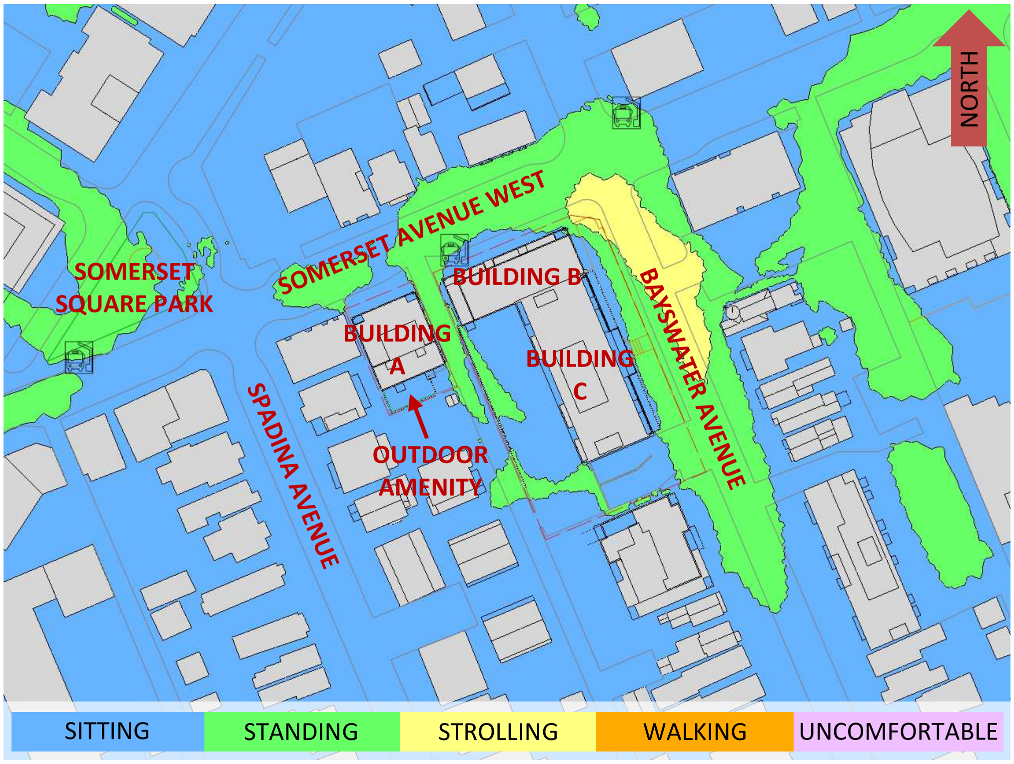


FIGURE 3A: SPRING – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

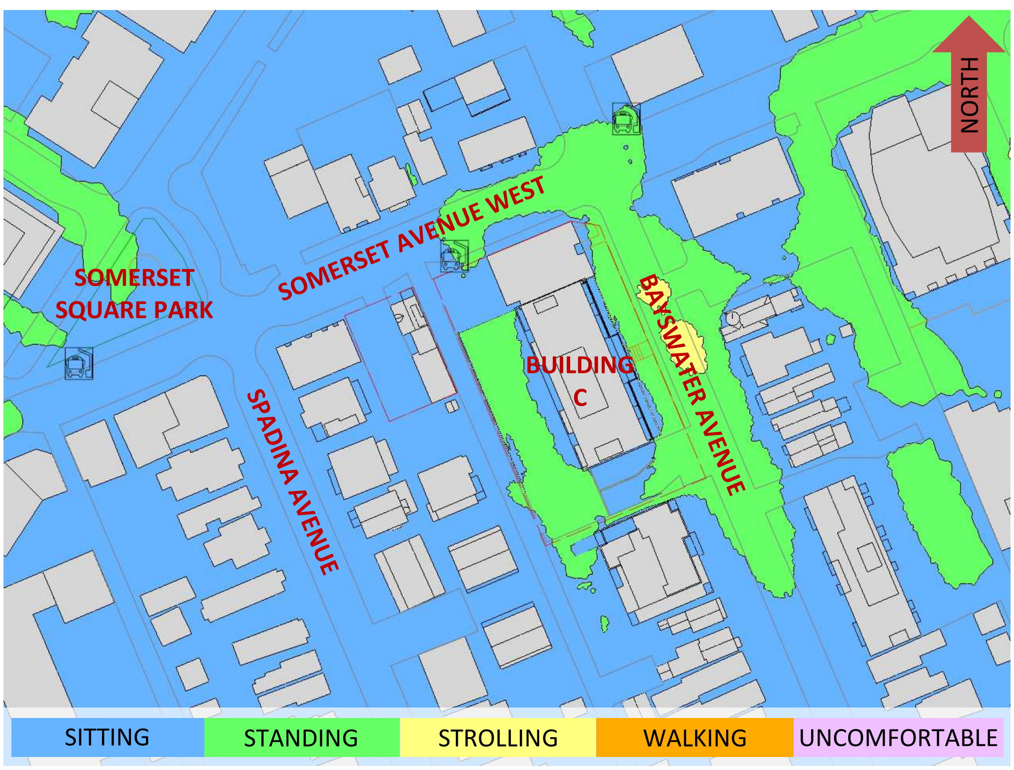


FIGURE 3B: SPRING – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

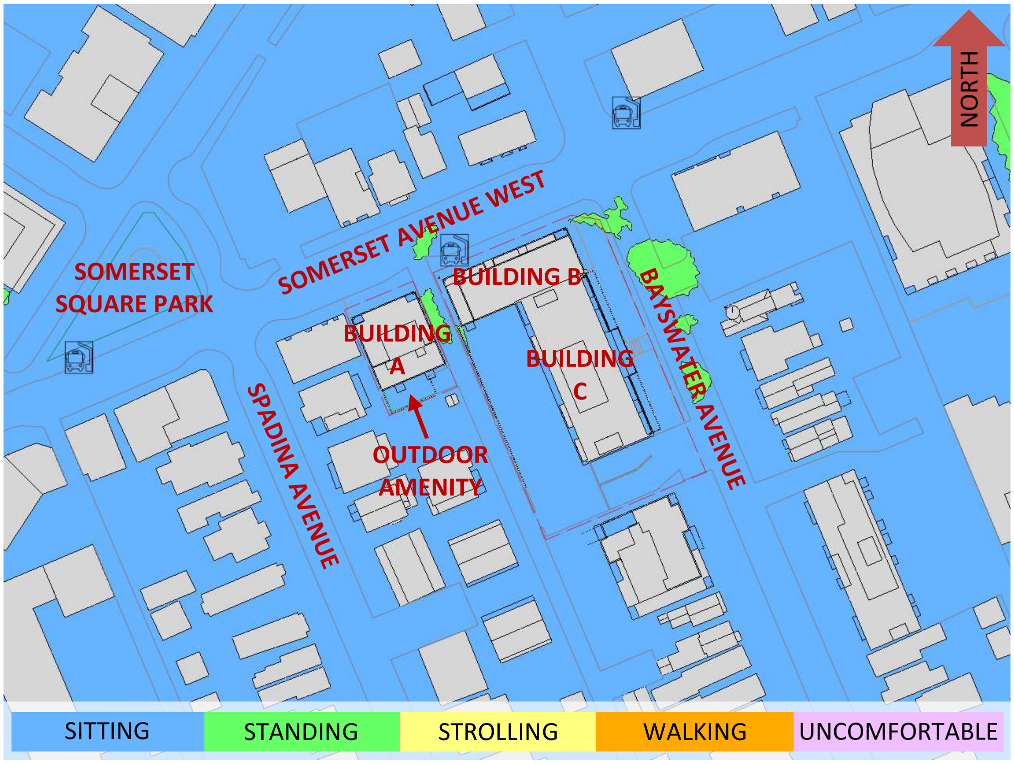


FIGURE 4A: SUMMER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

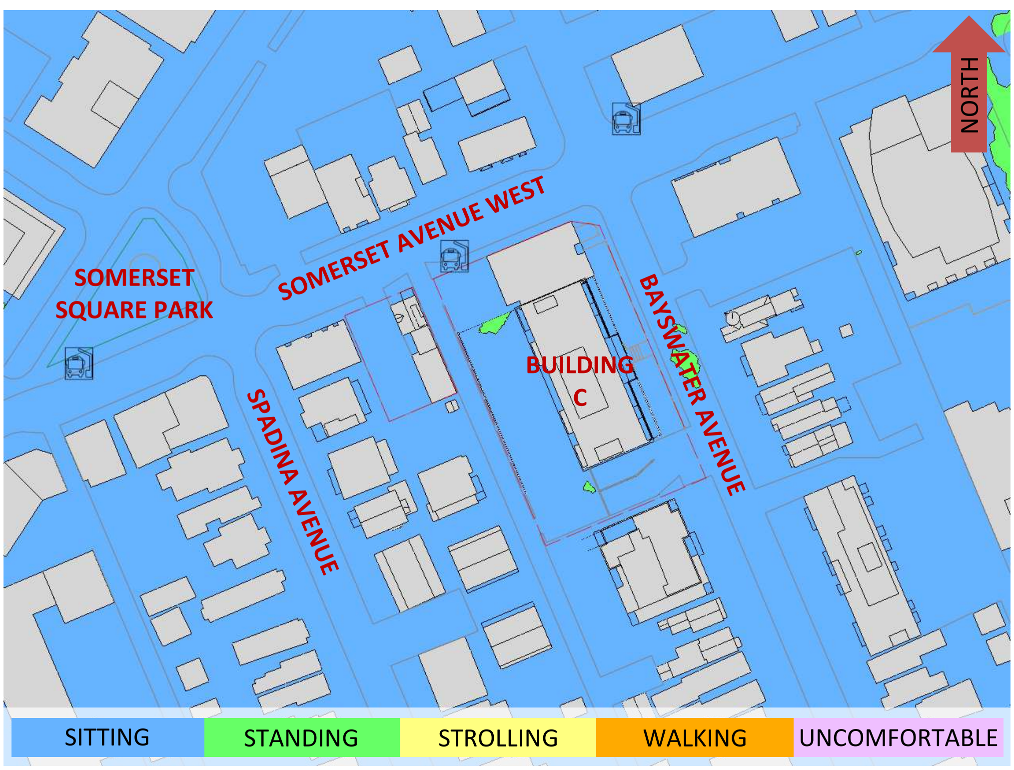


FIGURE 4B: SUMMER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

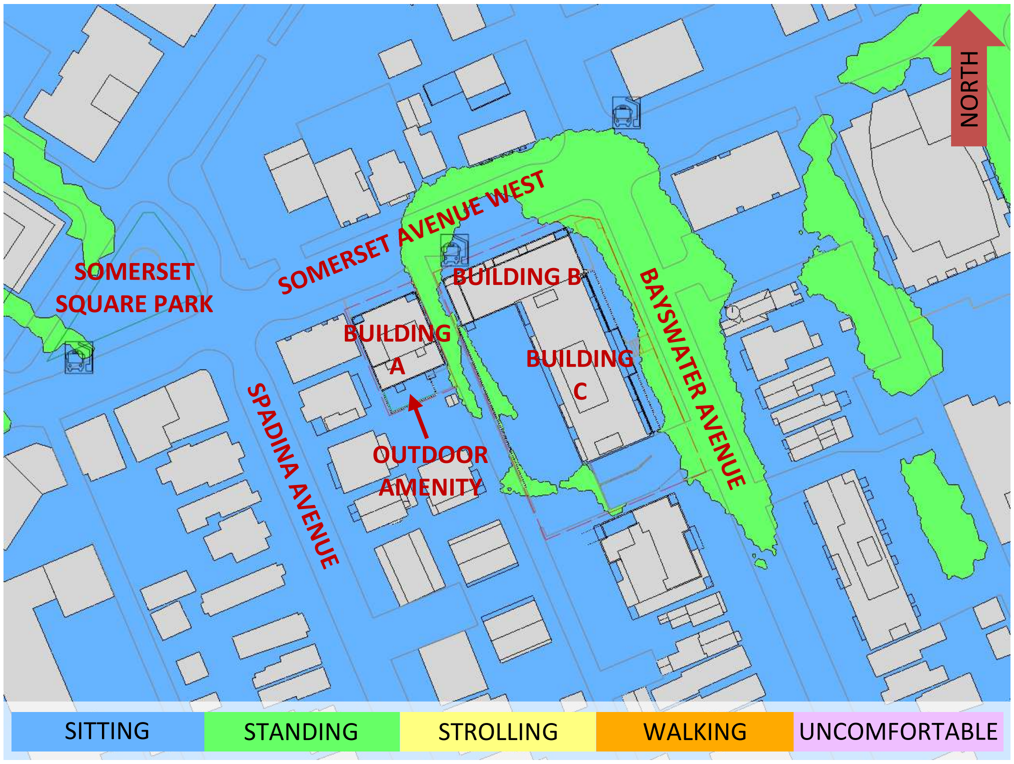


FIGURE 5A: AUTUMN – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

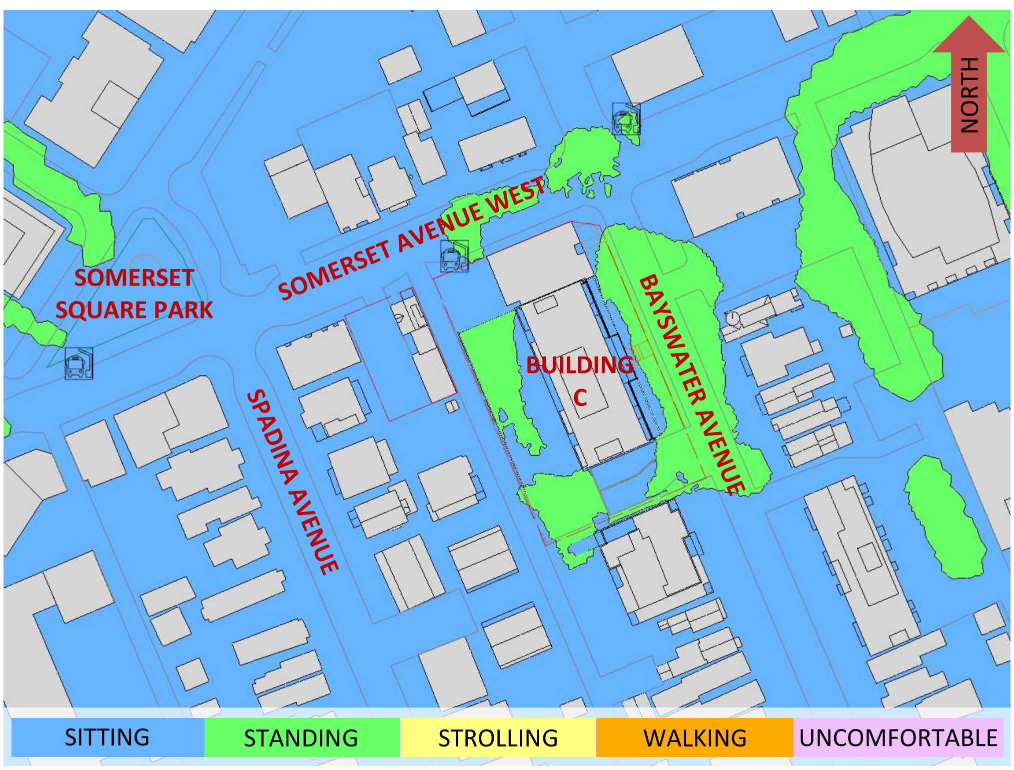


FIGURE 5B: AUTUMN – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

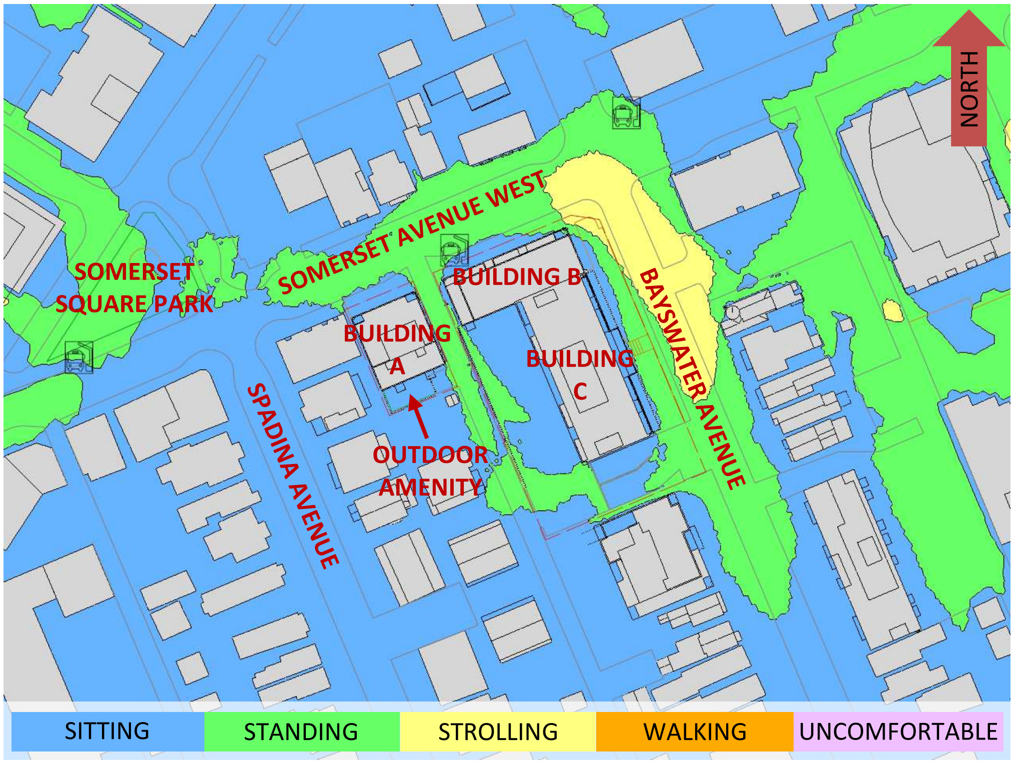


FIGURE 6A: WINTER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

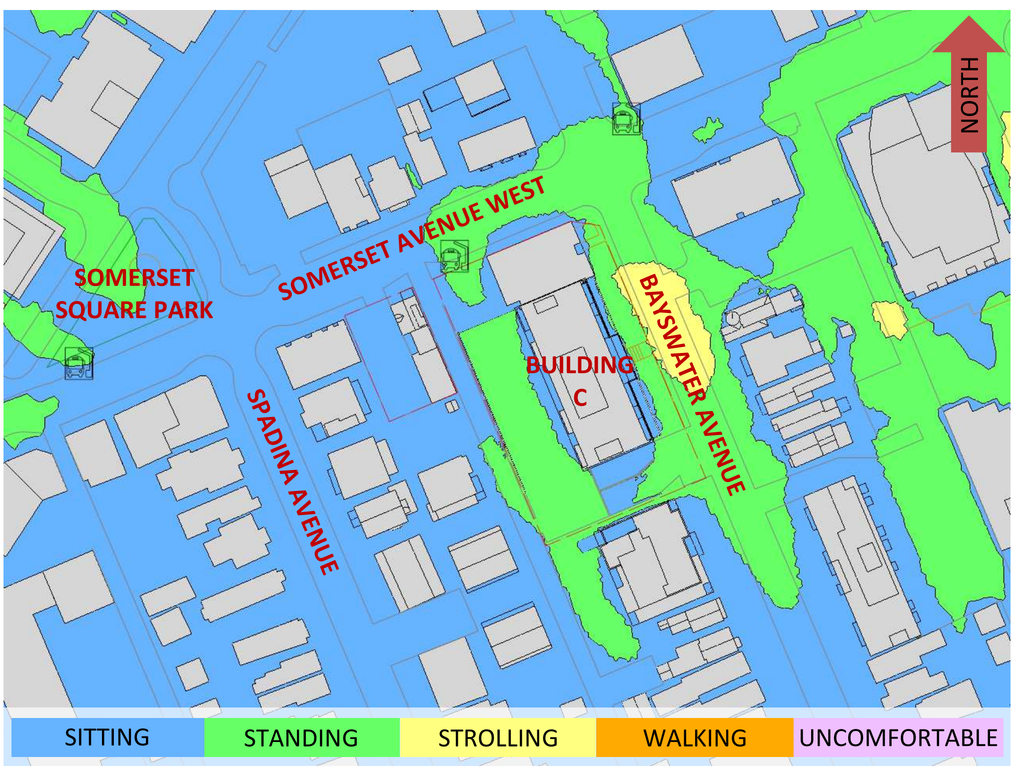


FIGURE 6B: WINTER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

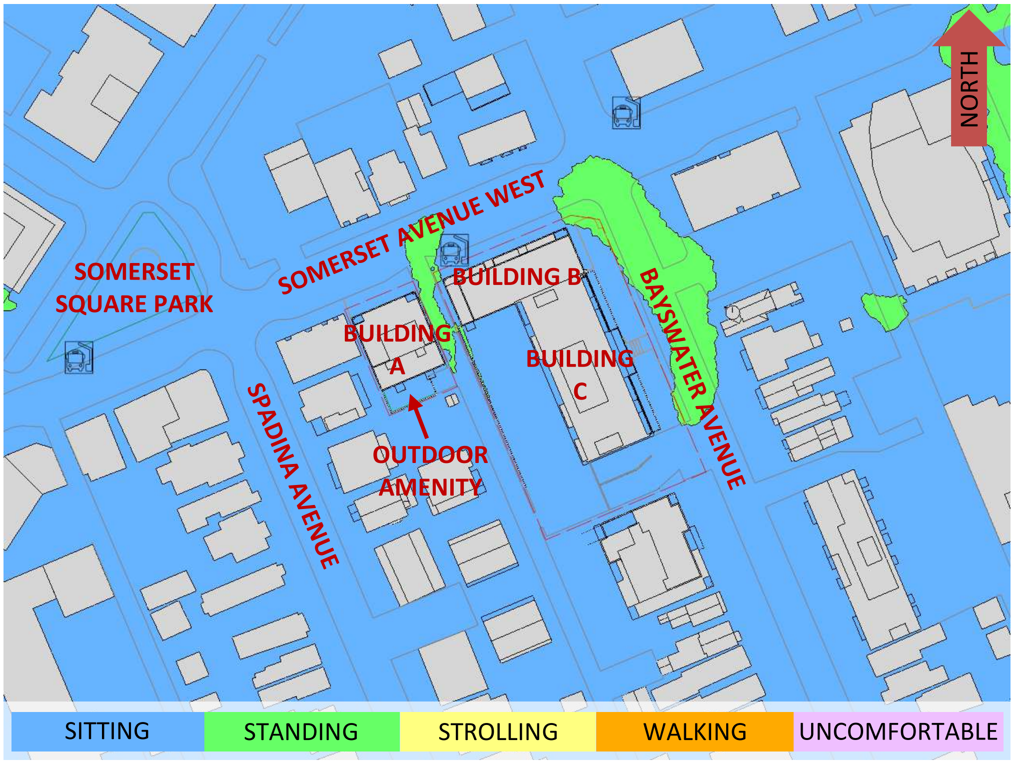


FIGURE 7: TYPICAL USE PERIOD – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

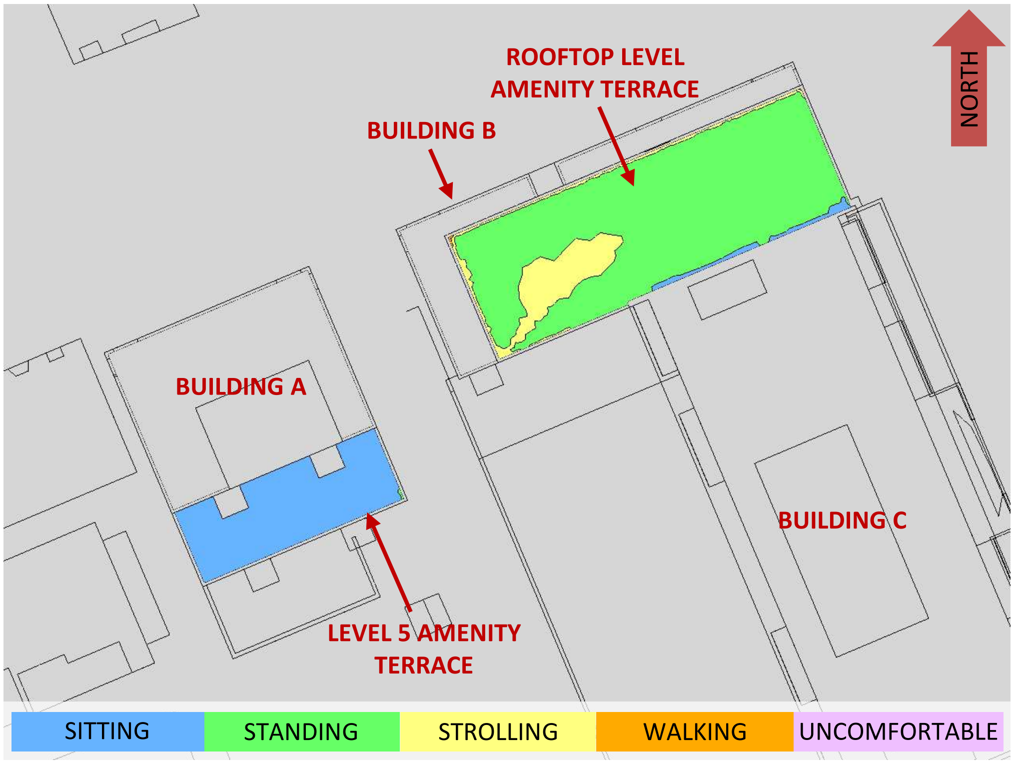


FIGURE 8A: SPRING – WIND COMFORT, COMMON AMENITY TERRACES

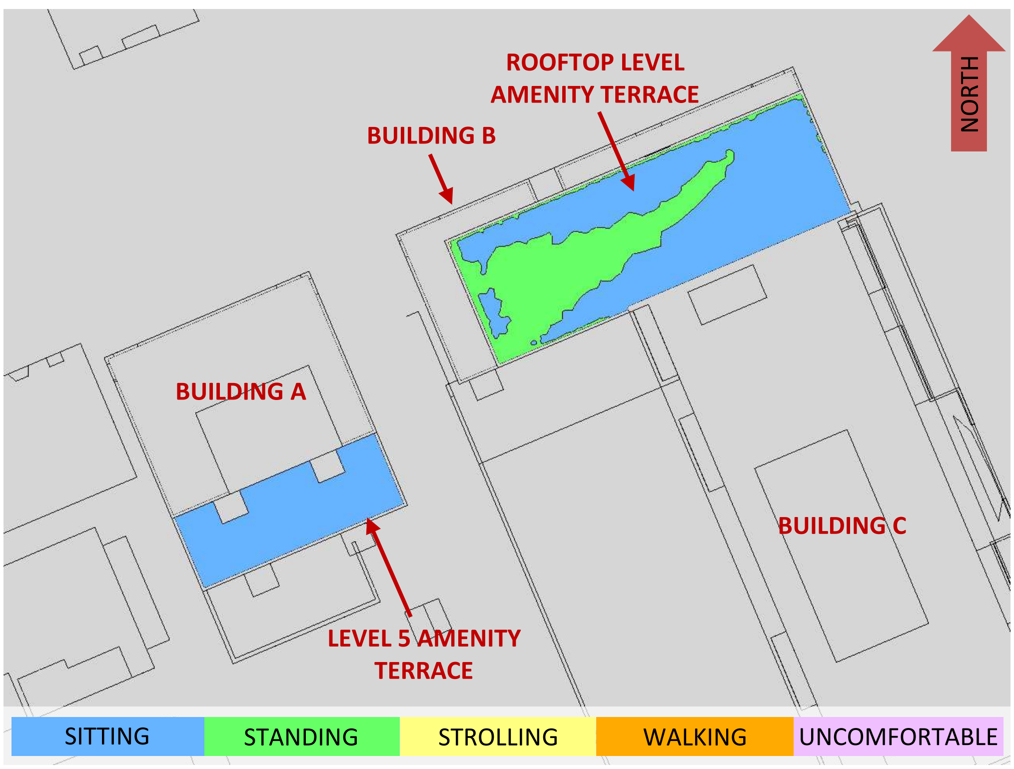


FIGURE 8B: SUMMER – WIND COMFORT, COMMON AMENITY TERRACES

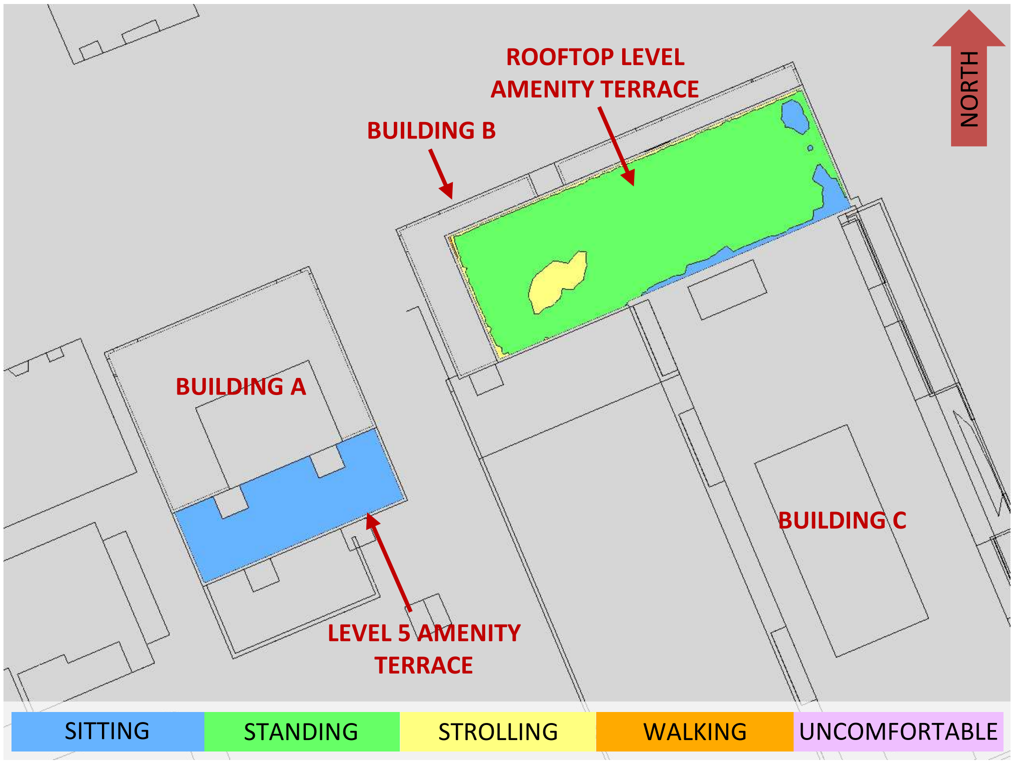


FIGURE 8C: AUTUMN – WIND COMFORT, COMMON AMENITY TERRACES

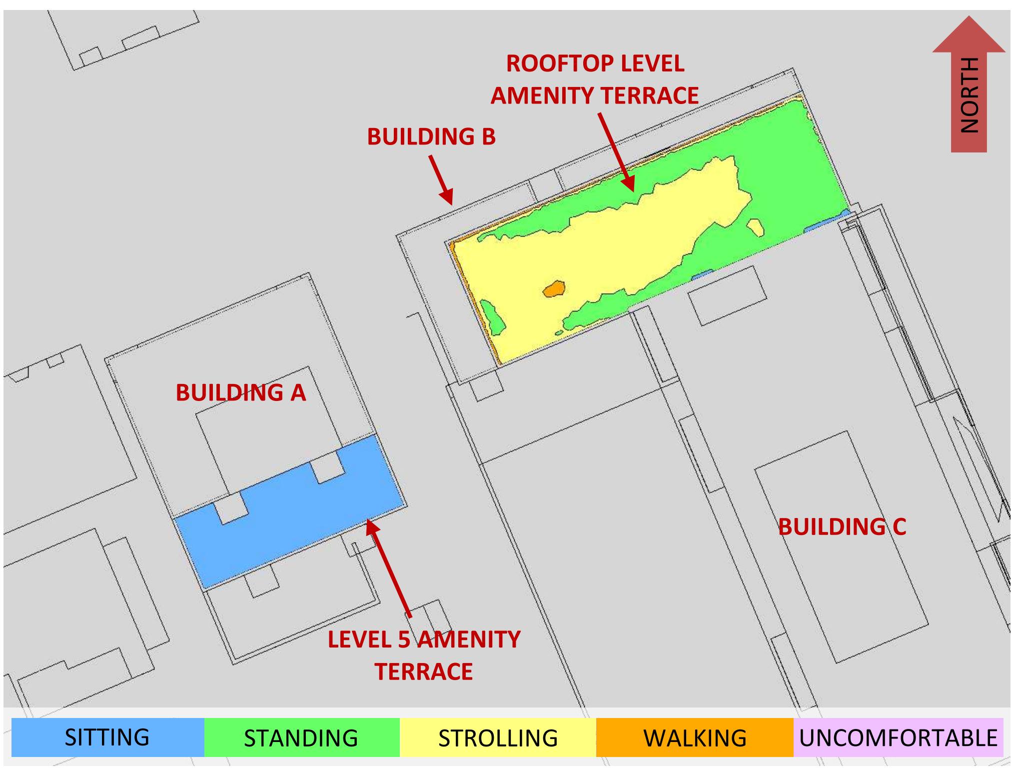


FIGURE 8D: WINTER – WIND COMFORT, COMMON AMENITY TERRACES

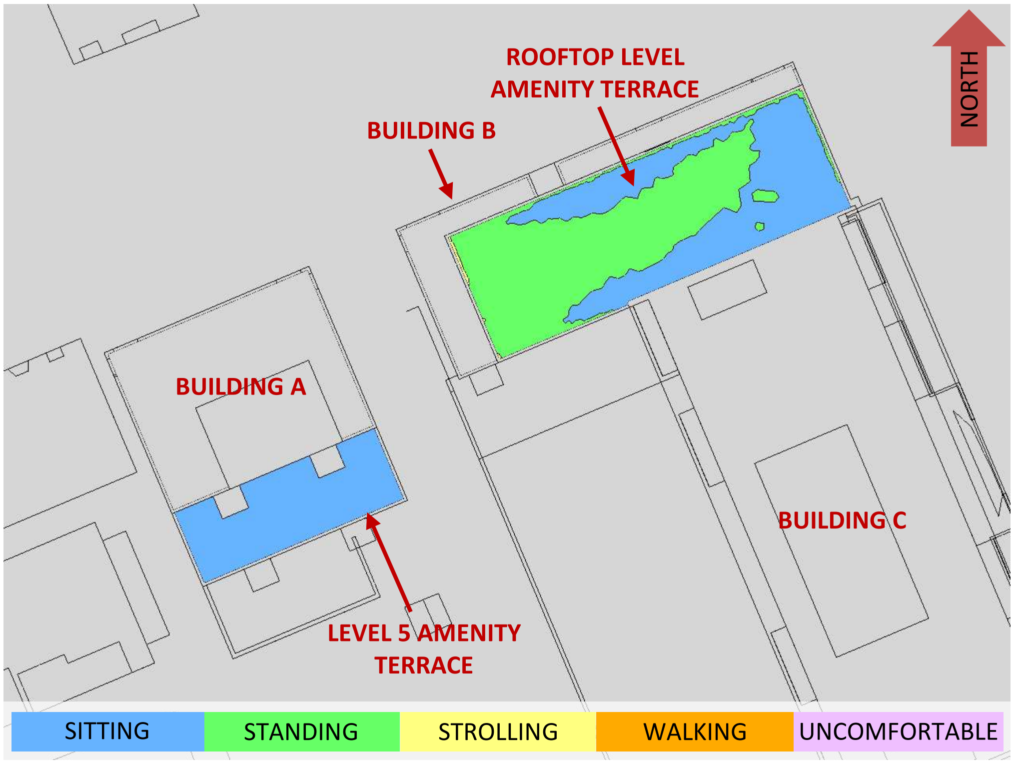
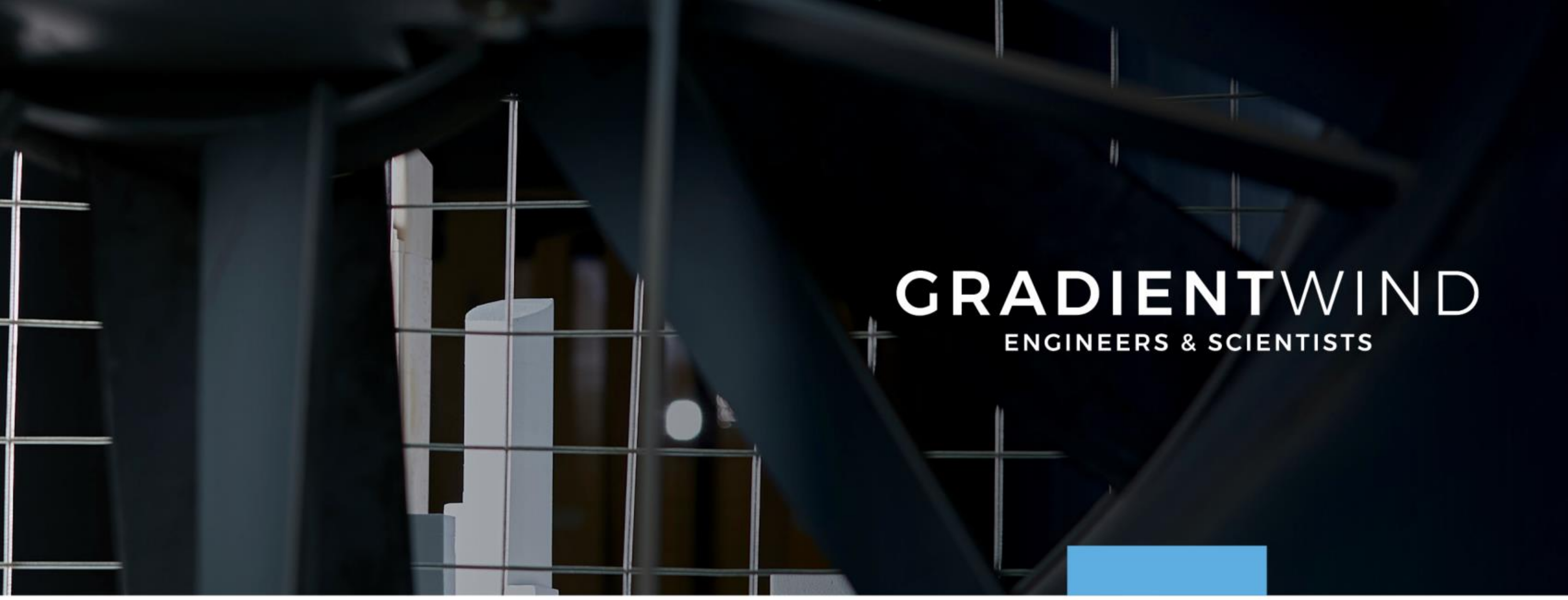
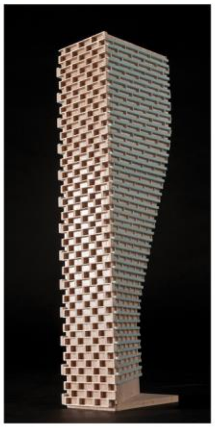
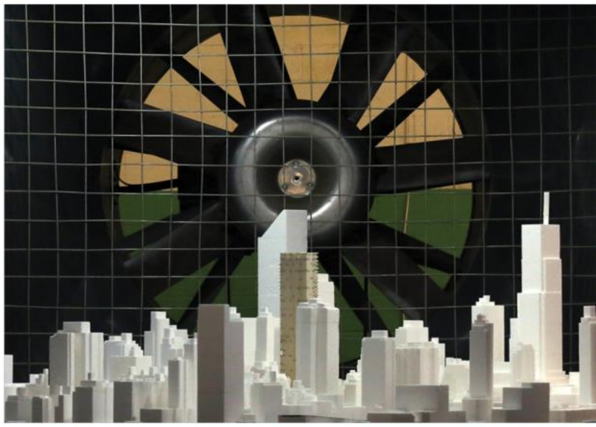


FIGURE 9: TYPICAL USE PERIOD – WIND COMFORT, COMMON AMENITY TERRACES







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, 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 (that is, 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	0.23
49	0.27
74	0.25
103	0.25
167	0.23
197	0.25
217	0.25
237	0.25
262	0.22
282	0.21
301	0.20
324	0.21

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.

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[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 Engineering Symposium, IWES 2003*, Taiwan, 2003.