

**PEDESTRIAN LEVEL  
WIND STUDY**

403 Richmond Road  
Ottawa, Ontario

Report: 20-174-PLW



April 20, 2022

PREPARED FOR

Westboro L.P.

115 Champagne Avenue South  
Ottawa, ON K1S 5V5

PREPARED BY

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## EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study undertaken to satisfy Site Plan Control requirements for the proposed residential development located 403 Richmond Road 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.

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-8B, 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, walkways, transit stops, exterior terrace, and in the vicinity of building access points, are considered acceptable. A possible exception is described as follows:
  - a. Conditions over the POPS at the intersection of Richmond Road and Roosevelt Avenue are predicted to be suitable for sitting with standing conditions to the west during the typical use period. Within the areas that are predicted to be suitable for standing, conditions are also predicted to be suitable for sitting for at least 76% of the time during the same period, where the target is 80%. Depending on the programming of the space, the noted wind conditions may be considered acceptable. If required, sitting conditions may be extended around sensitive areas with landscaping features such as wind screens and/or coniferous plantings in a dense arrangement.



- 2) Regarding the common amenity terrace serving the proposed development at the MPH Level, wind conditions during the typical use period are predicted to be suitable for sitting within most of the terrace, with standing conditions to the north and at the southwest corner. Within the areas that are predicted to be suitable for standing, conditions are also predicted to be suitable for sitting for at least 65% of the time to the north and 70% of the time at the southwest corner during the same period.
  - a. To achieve the sitting comfort class in all areas during the typical use period, we recommend implementing a perimeter wind screen, typically glazed and preferably solid (i.e., no porosity), extending at least 1.8 m above the walking surface of the terrace.
- 3) 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, (e.g., 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.



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## **1. INTRODUCTION**

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Westboro L.P. to undertake a pedestrian level wind (PLW) study to satisfy Site Plan Control requirements for the proposed residential development located at 403 Richmond Road 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 Roderick Lahey Architect Inc., in February 2022, 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 403 Richmond Road in Ottawa; situated at the northeast intersection of Richmond Road and Roosevelt Avenue. The proposed development comprises a nominally rectangular nine-storey residential building plus a mechanical penthouse with its long axis oriented parallel with Roosevelt Avenue.

Above two below-grade parking levels, the ground floor includes a main entrance at the northwest corner, shipping/receiving space at the northeast corner, an elevator core to the east, retail space and commercial garbage space to the south, central townhouse units, and shared building support spaces throughout the remainder of the level. An exterior terrace is situated to the east, while a privately owned publicly accessible space (POPS) is situated at the southwest corner of the proposed development. Access to below-grade parking is provided by a ramp at the northeast corner of the proposed development via a laneway from Roosevelt Avenue. All upper levels are reserved for residential use. Private terraces are located to the southeast at Level 2, to the south and from the west clockwise to north at Level 5, and to the north and south at Level 9. The MPH Level includes indoor amenities and is served by an exterior terrace from the southeast clockwise to north.



The near-field surroundings (defined as an area within 200 metres (m) of the subject site) include low-rise residential buildings with low- and mid-rise commercial buildings along Richmond Road, extending from the southwest to the east, mid-rise mixed-use residential buildings to the southwest, and a mid-rise residential building to the west. Notably, a mid-rise apartment building comprising 28 units is proposed (awaiting approval) at 398, 402, and 406 Roosevelt Avenue, to the immediate west of the subject site. 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 developments in all compass directions with isolated mid-rise buildings to the northeast, southeast, southwest, and west. In addition, the Ottawa River flows from the west to the northeast, approximately 450 m to the northwest of the subject site.

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 changes which have been approved by the City of Ottawa.

### **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<sup>1</sup>. The following sections describe the analysis procedures, including a discussion of the noted pedestrian wind criteria.

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<sup>1</sup> City of Ottawa Terms of References: Wind Analysis  
[https://documents.ottawa.ca/sites/default/files/torwindanalysis\\_en.pdf](https://documents.ottawa.ca/sites/default/files/torwindanalysis_en.pdf)



#### 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 stronger wind speeds.

#### 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 terrace at the MPH Level 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.

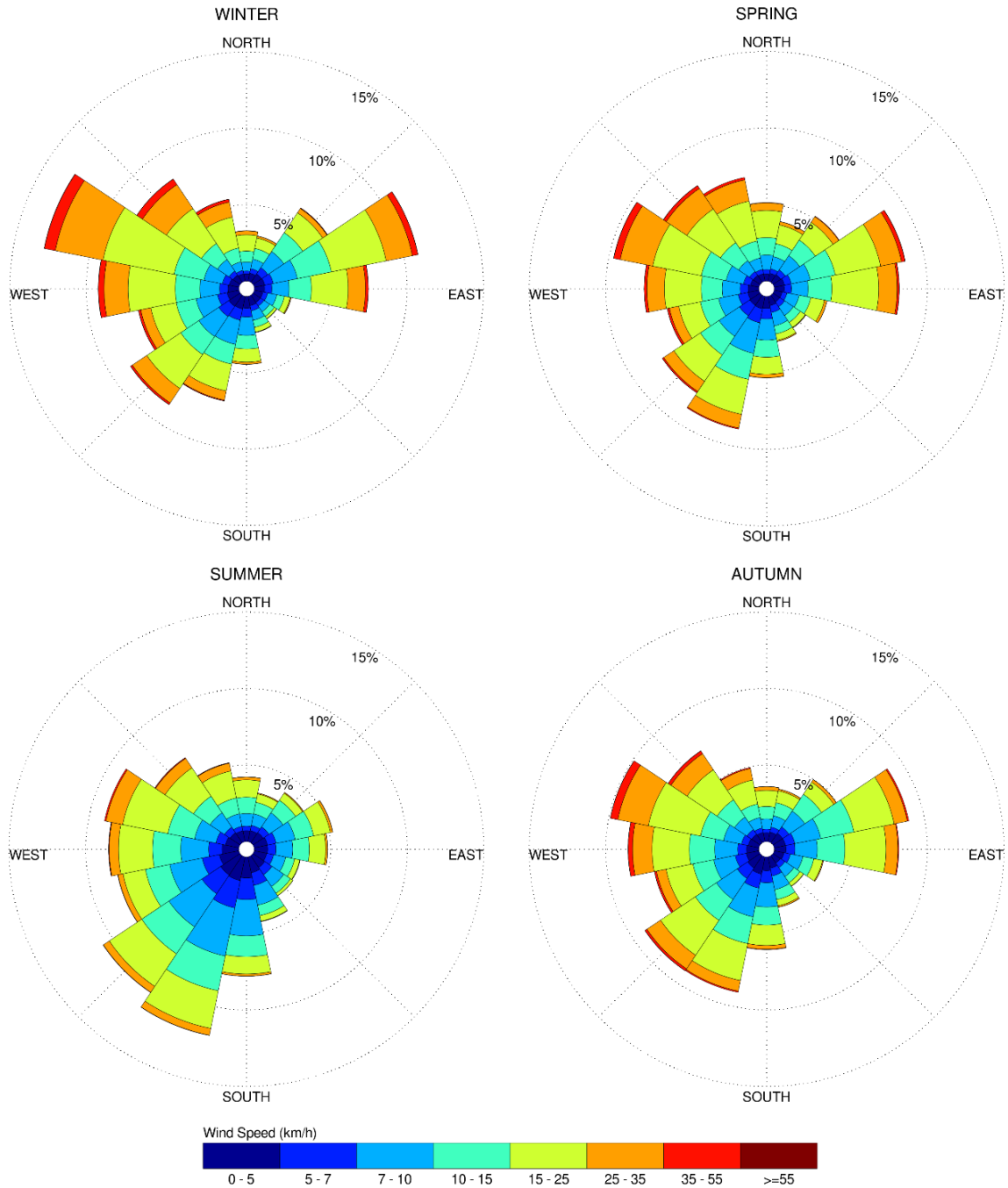
### 4.3 Historical Wind Speed and Direction Data

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 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 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 typical windiest desired comfort classes are summarized on the following page. Depending on the programming of a space, the desired comfort class may differ from this table.

**DESIRED PEDESTRIAN COMFORT CLASSES FOR VARIOUS LOCATION TYPES**

Location Types	Desired Comfort Classes
Primary Building Entrance	Standing
Secondary Building Access Point	Walking
Public Sidewalk / Bicycle Path	Walking
Outdoor Amenity Space	Sitting
Café / Patio / Bench / Garden	Sitting (Summer)
Transit Stop (Without Shelter)	Standing
Transit Stop (With Shelter)	Walking
Public Park / Plaza	Sitting (Summer)
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 Figures 7A-7D, illustrating wind conditions over the common amenity terrace serving the proposed development at the MPH Level. Conditions are presented as continuous contours of wind comfort throughout the subject site and correspond to the comfort classes noted in Section 4.4. 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.

Wind conditions within the common amenity terrace at the MPH Level are also reported for the typical use period, which is defined as May to October, inclusive. Figure 8A illustrates wind comfort conditions consistent with the comfort classes in Section 4.4, while Figure 8B illustrates contours indicating the percentage of time conditions within the terrace are predicted to be suitable for sitting during the same period. The details of these conditions are summarized in the following pages for each area of interest.

## 5.1 Wind Comfort Conditions – Ground Floor

**Sidewalks, Building Access, and Transit Stops along Richmond Road:** Following the introduction of the proposed development, the nearby public sidewalk areas along Richmond Road are predicted to be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing during the remaining three seasons. Conditions in the immediate vicinity of the single building access point along Richmond Road are predicted to be suitable for sitting throughout the year. Conditions over the nearby transit stop to the north of Richmond Road are predicted to be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing during the autumn, and mostly suitable for standing during the winter and spring. Conditions over the nearby transit stop to the south of Richmond Road are predicted to be suitable for sitting during the spring, summer, and autumn, becoming suitable for a mix of sitting and standing during the winter. The noted conditions are considered acceptable according to the City of Ottawa wind criteria in Section 4.4.

Conditions over the sidewalks along Richmond Road with the existing massing are predicted to be suitable for sitting throughout the year. Conditions over the nearby transit stops are predicted to be suitable for sitting throughout the year. While the introduction of the proposed development produces windier conditions in comparison to existing conditions, wind comfort conditions with the proposed development are considered acceptable.

**POPS:** Conditions over the POPS are predicted to be suitable for sitting with standing conditions to the west during the typical use period. Within the areas that are predicted to be suitable for standing, conditions are also predicted to be suitable for sitting for at least 76% of the time during the same period, where the target is 80%. Depending on the programming of the space, the noted wind conditions may be considered acceptable. If required, sitting conditions may be extended around sensitive areas with landscaping features such as wind screens and/or coniferous plantings in a dense arrangement.

**Sidewalks and Building Access along Roosevelt Avenue:** Following the introduction of the proposed development, the nearby public sidewalk areas along Roosevelt Avenue are predicted to be suitable for a mix of sitting and standing during the summer and autumn, becoming suitable for a mix of standing and strolling during the winter and spring. Conditions in the immediate vicinity of the building access points along Roosevelt Avenue are predicted to be suitable for sitting during the summer and autumn, becoming

suitable for a mix of sitting and standing during the winter and spring. The noted conditions are considered acceptable according to the City of Ottawa wind criteria.

Conditions over the sidewalks along Roosevelt Avenue with the existing massing are predicted to be suitable for sitting during the spring, summer, and autumn, becoming suitable for a mix of sitting and standing during the winter. While the introduction of the proposed development produces windier conditions in comparison to existing conditions, wind comfort conditions with the proposed development are considered acceptable.

**Walkway and Building Access Along Laneway North of Subject Site:** Conditions over the walkway and in the immediate vicinity of building access points along the laneway to the north of the subject site are predicted to be suitable for sitting throughout the year, with standing conditions at the northeast corner during the spring, autumn, and winter. The noted conditions are considered acceptable according to the City of Ottawa wind criteria.

**Exterior Terrace East of Subject Site:** Conditions over the exterior terrace to the east of the subject site are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable according to the City of Ottawa wind criteria.

## 5.2 Wind Comfort Conditions – Common Amenity Terrace

**MPH Level Common Amenity Terrace:** Conditions over the common amenity terrace serving the proposed development at the MPH Level are predicted to be mostly suitable for sitting with standing conditions to the north and at the southwest corner of the terrace during the typical use period, as illustrated in Figure 8A. Within the areas that are predicted to be suitable for standing, conditions are also predicted to be suitable for sitting for at least 65% of the time to the north and 70% of the time at the southwest corner during the same period, as illustrated in Figure 8B, where the target is 80%.

To achieve the sitting comfort class in all areas during the typical use period, we recommend implementing a perimeter wind screen, typically glazed and preferably solid (i.e., no porosity), extending at least 1.8 m above the walking surface of the terrace.

### 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

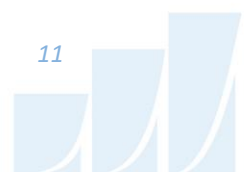
Pedestrian wind comfort and safety have been quantified for the specific configuration of existing and foreseeable construction around the subject site. Future changes (i.e., construction or demolition) of these surroundings may cause changes to the wind effects in two ways, namely: (i) changes beyond 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.

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-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 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, walkways, transit stops, exterior terrace, and in the vicinity of building access points, are considered acceptable. A possible exception is described as follows:
  - a. Conditions over the POPS at the intersection of Richmond Road and Roosevelt Avenue are predicted to be suitable for sitting with standing conditions to the west during the typical use period. Within the areas that are predicted to be suitable for standing,



conditions are also predicted to be suitable for sitting for at least 76% of the time during the same period, where the target is 80%. Depending on the programming of the space, the noted wind conditions may be considered acceptable. If required, sitting conditions may be extended around sensitive areas with landscaping features such as wind screens and/or coniferous plantings in a dense arrangement.

- 2) Regarding the common amenity terrace serving the proposed development at the MPH Level, wind conditions during the typical use period are predicted to be suitable for sitting within most of the terrace, with standing conditions to the north and at the southwest corner. Within the areas that are predicted to be suitable for standing, conditions are also predicted to be suitable for sitting for at least 65% of the time to the north and 70% of the time at the southwest corner during the same period.
  - a. To achieve the sitting comfort class in all areas during the typical use period, we recommend implementing a perimeter wind screen, typically glazed and preferably solid (i.e., no porosity), extending at least 1.8 m above the walking surface of the terrace.
- 3) 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, (e.g., 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.***

*E. Urbanski*

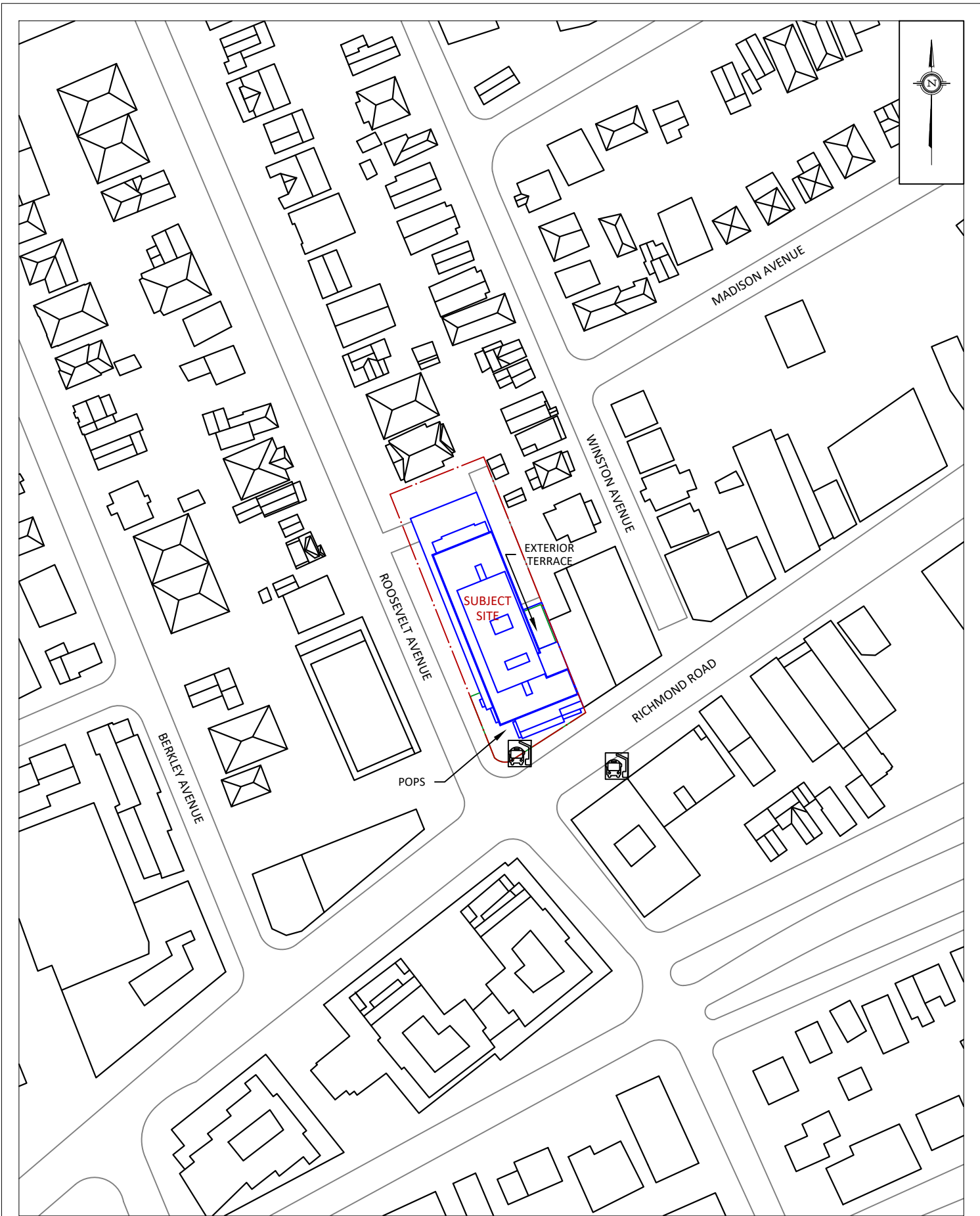
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ENGINEERS & SCIENTISTS

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PROJECT

403 RICHMOND ROAD, OTTAWA  
PEDESTRIAN LEVEL WIND STUDY

SCALE

1:1500

DRAWING NO.

20-174-PLW-1A

DATE

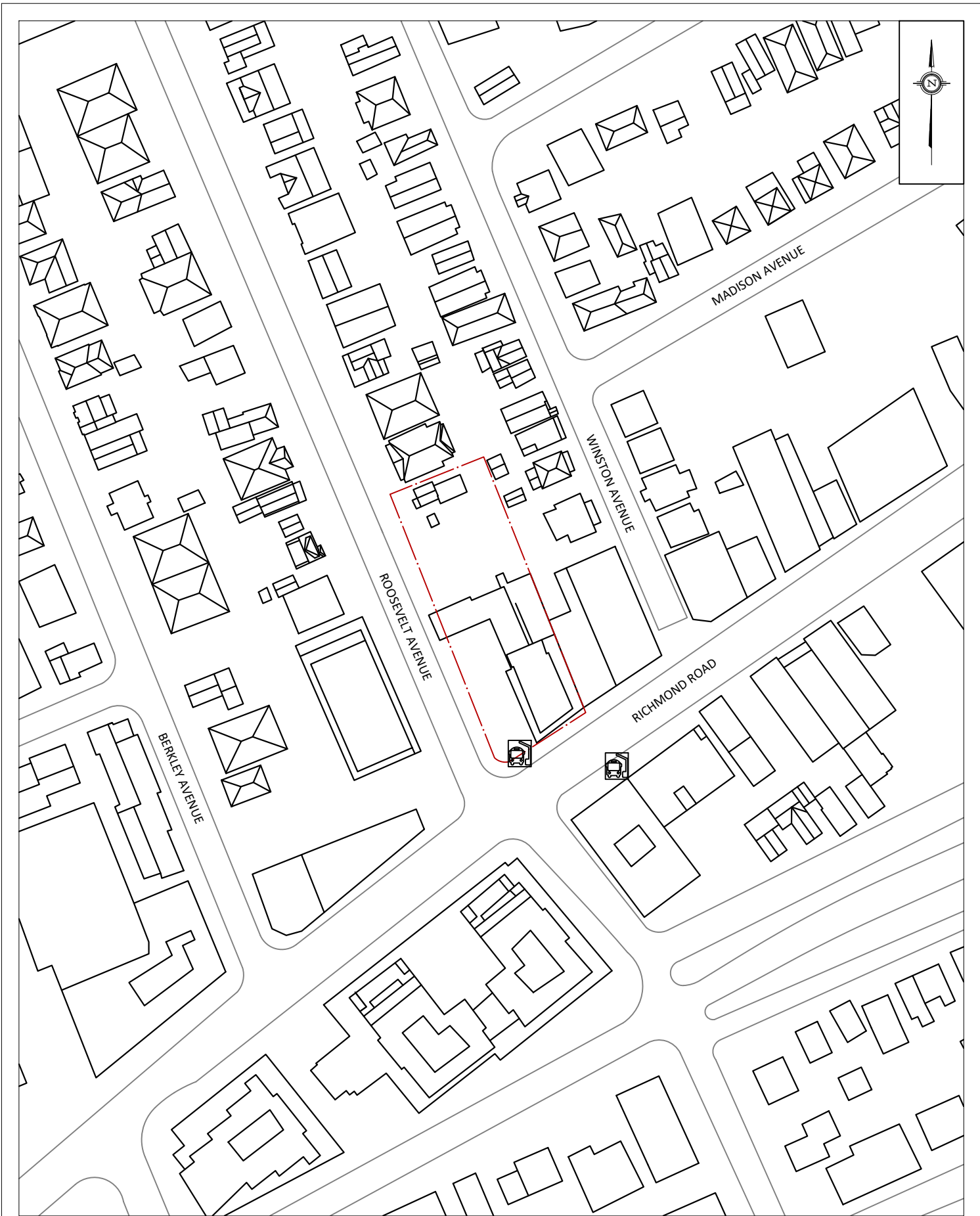
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DESCRIPTION

FIGURE 1A:  
PROPOSED SITE PLAN AND SURROUNDING CONTEXT



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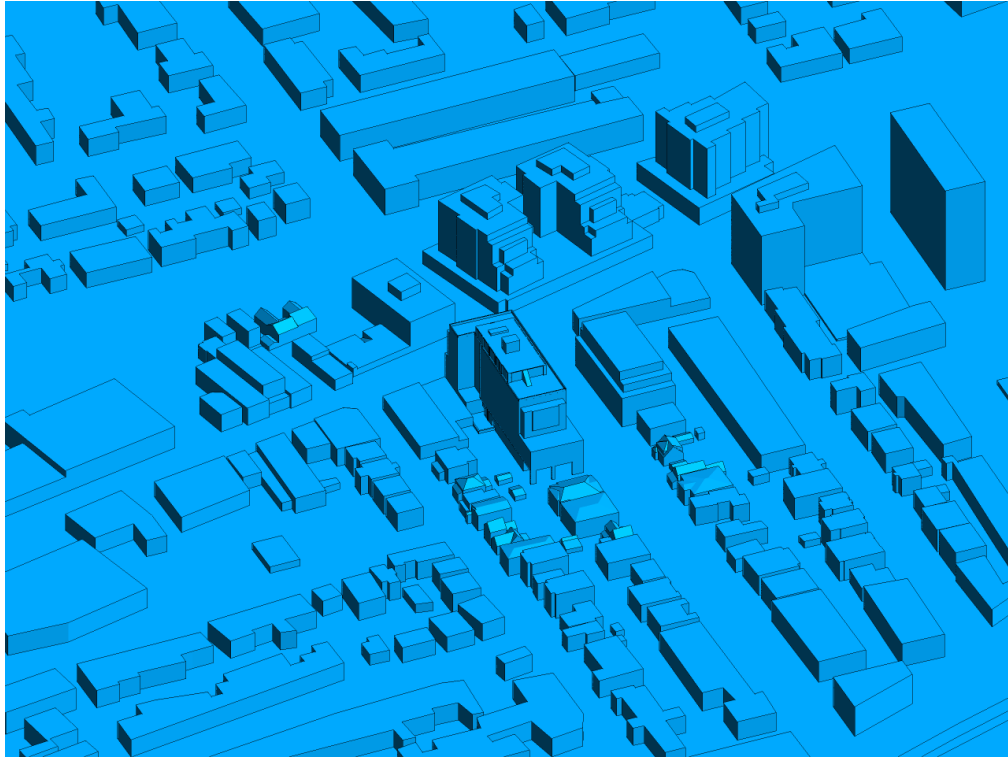
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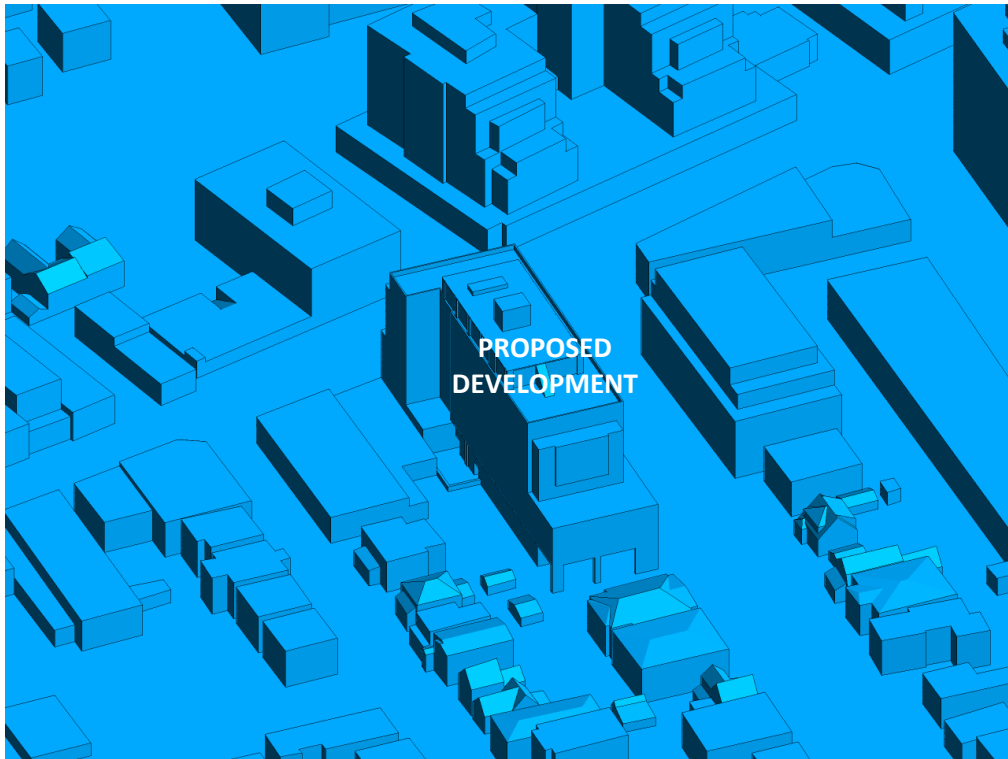
S.K.

DESCRIPTION

FIGURE 1B:  
EXISTING SITE PLAN AND SURROUNDING CONTEXT

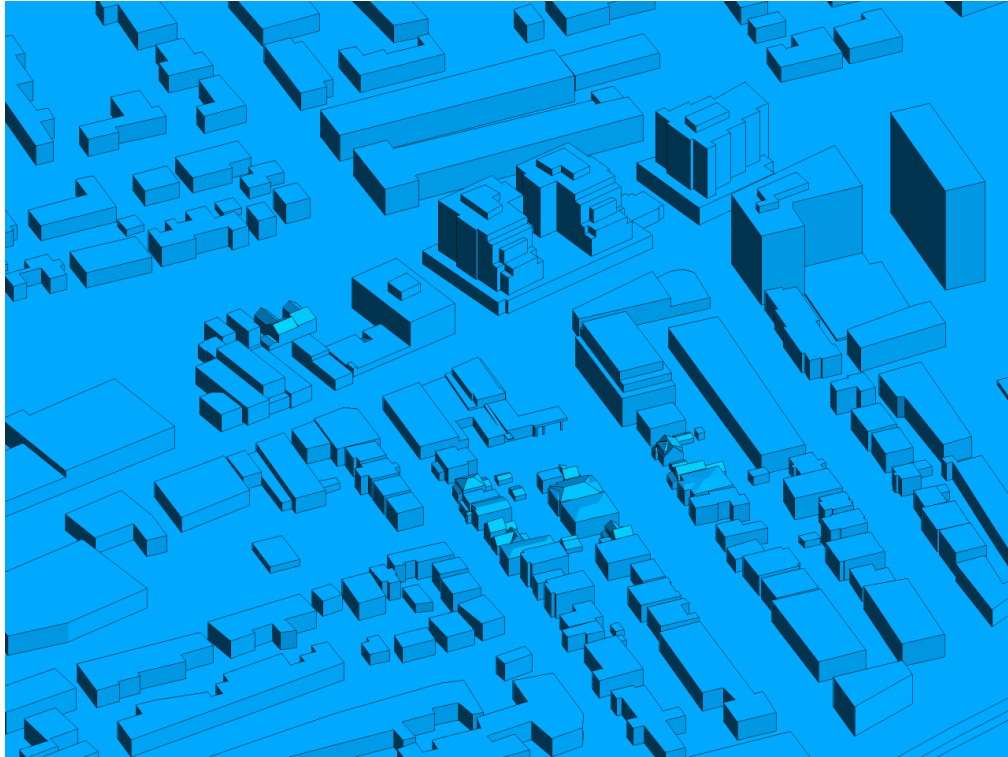


**FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTH PERSPECTIVE**

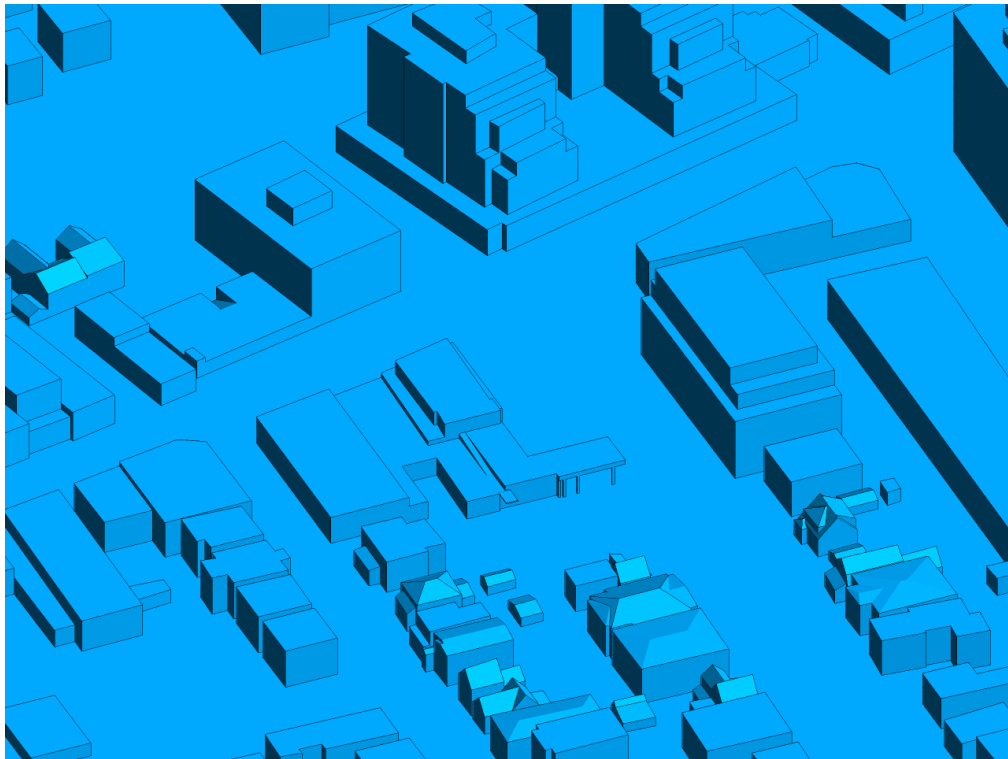


**FIGURE 2B: CLOSE UP OF FIGURE 2A**



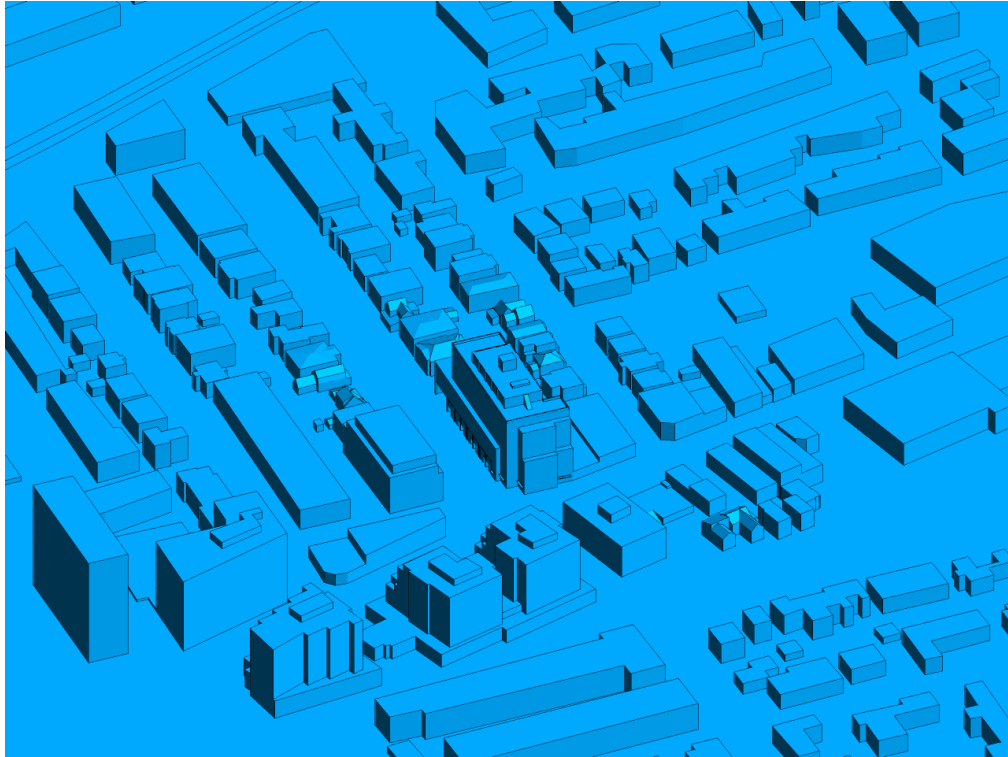


**FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, NORTH PERSPECTIVE**

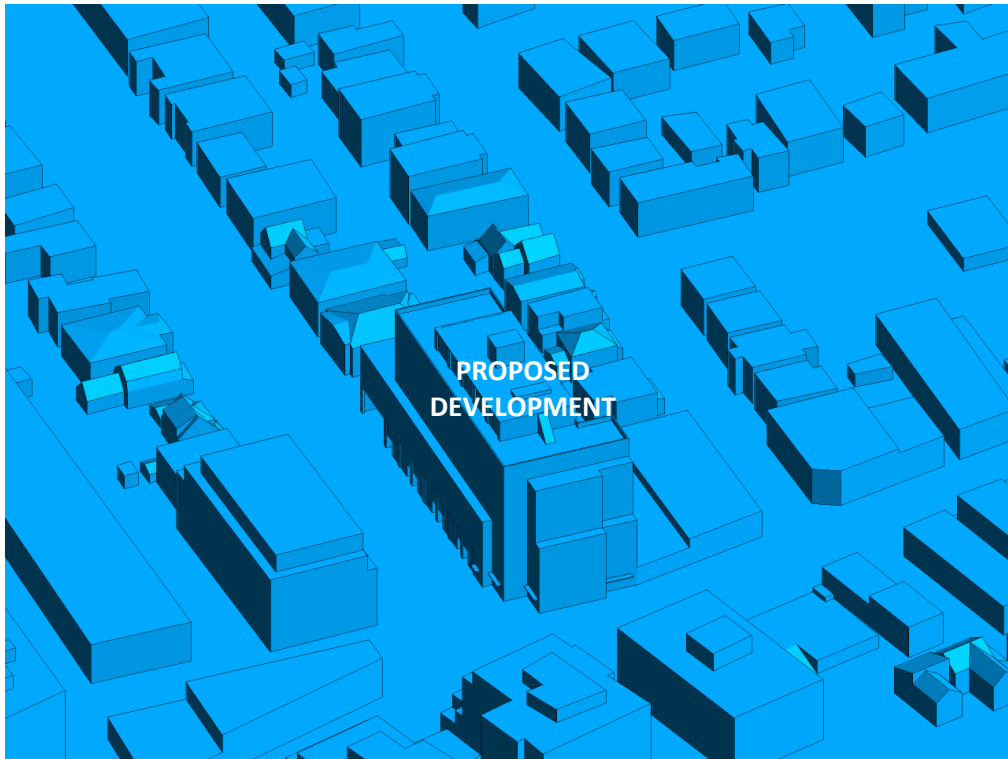


**FIGURE 2D: CLOSE UP OF FIGURE 2C**



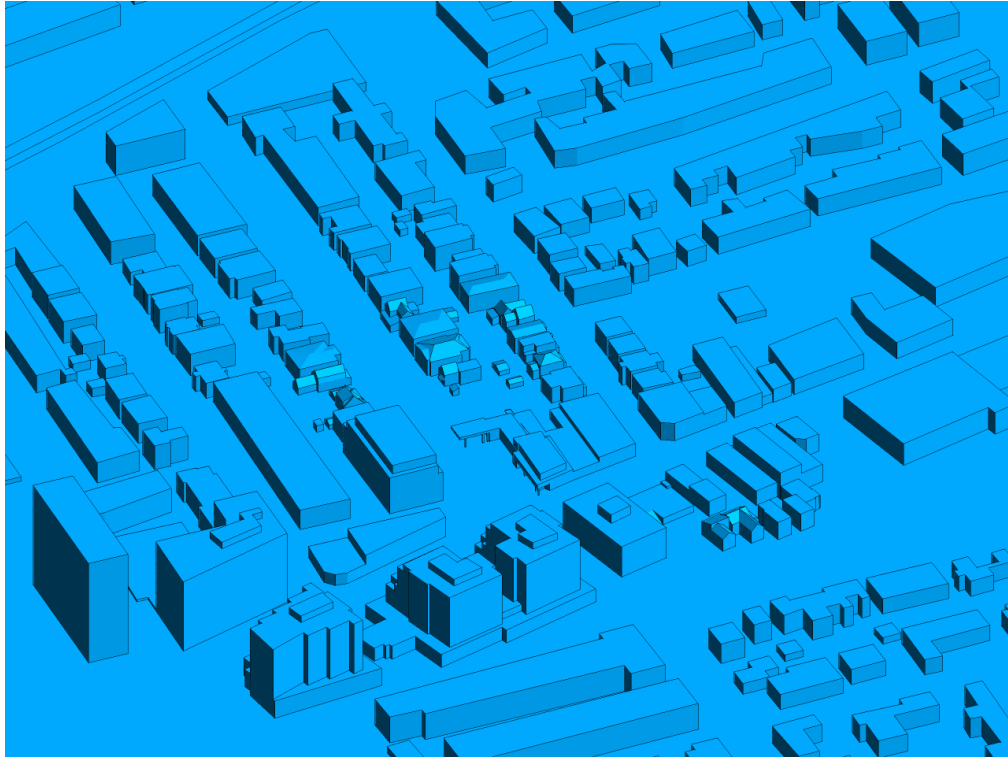


**FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTH PERSPECTIVE**

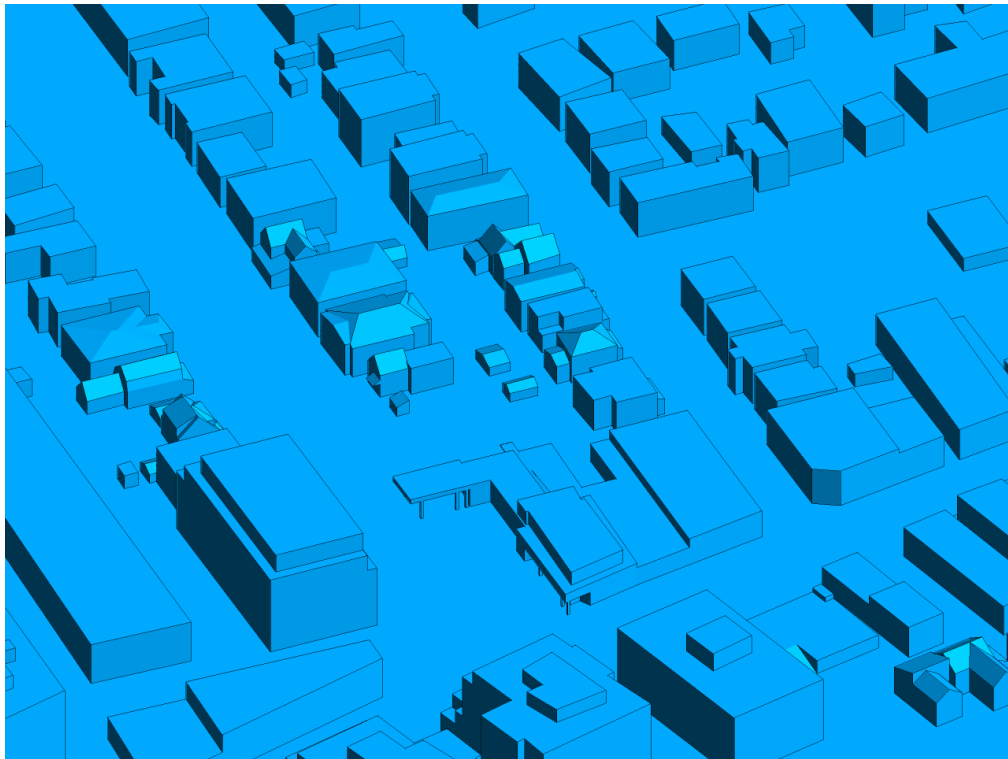


**FIGURE 2F: CLOSE UP OF FIGURE 2E**



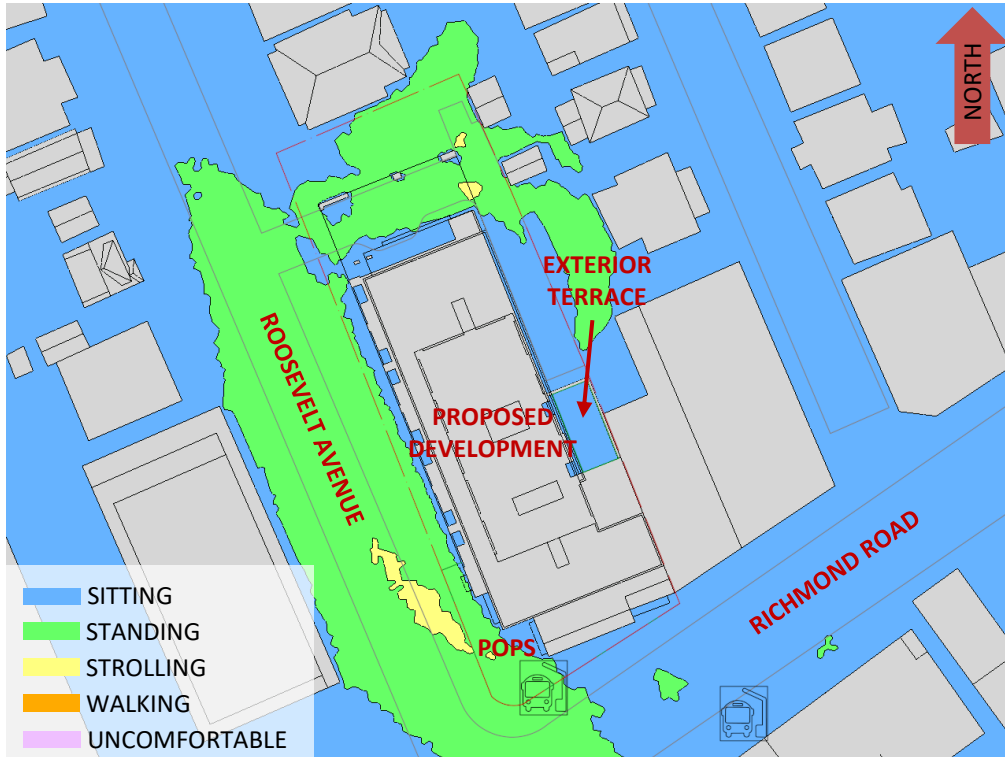


**FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, SOUTH PERSPECTIVE**

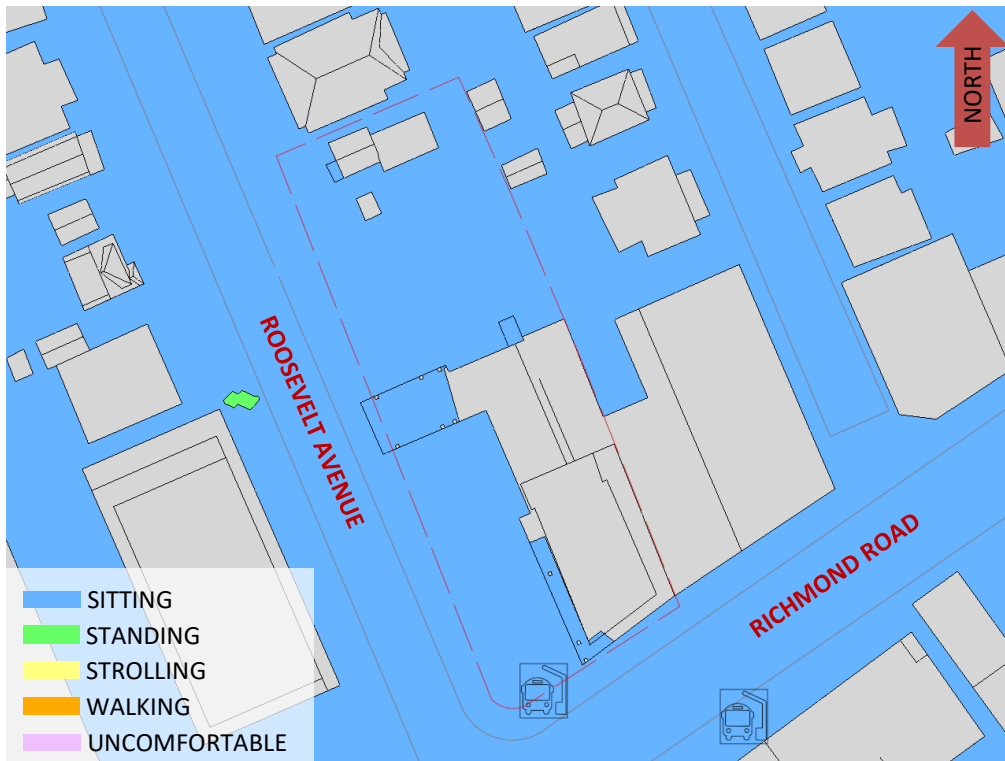


**FIGURE 2H: CLOSE UP OF FIGURE 2G**



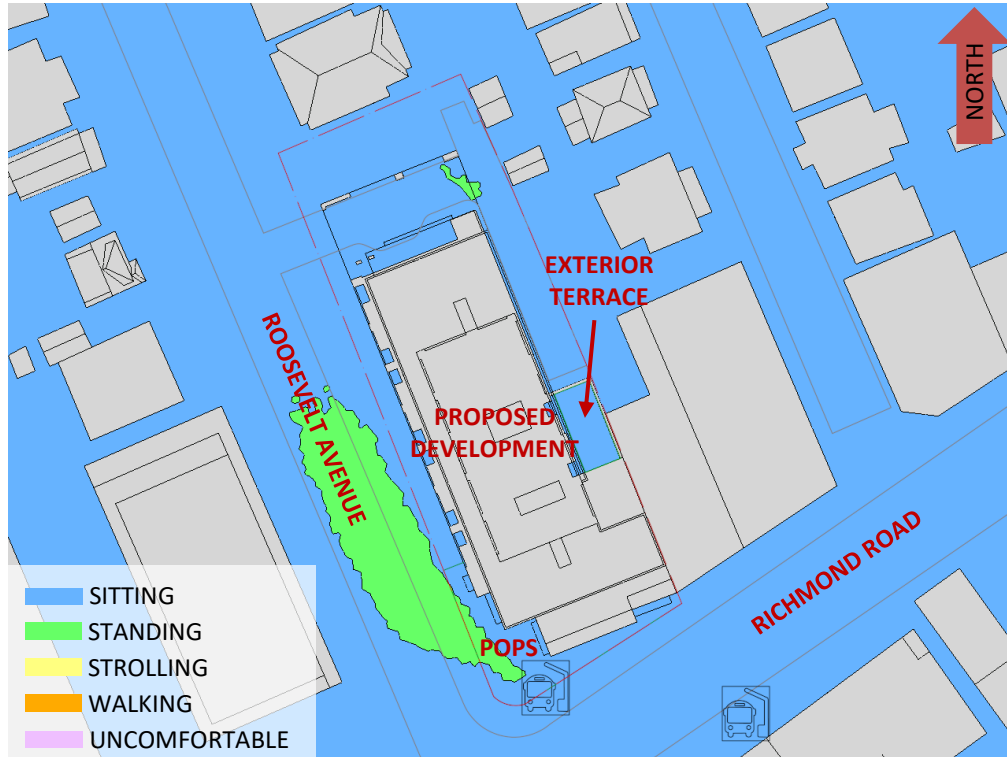


**FIGURE 3A: SPRING – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING**

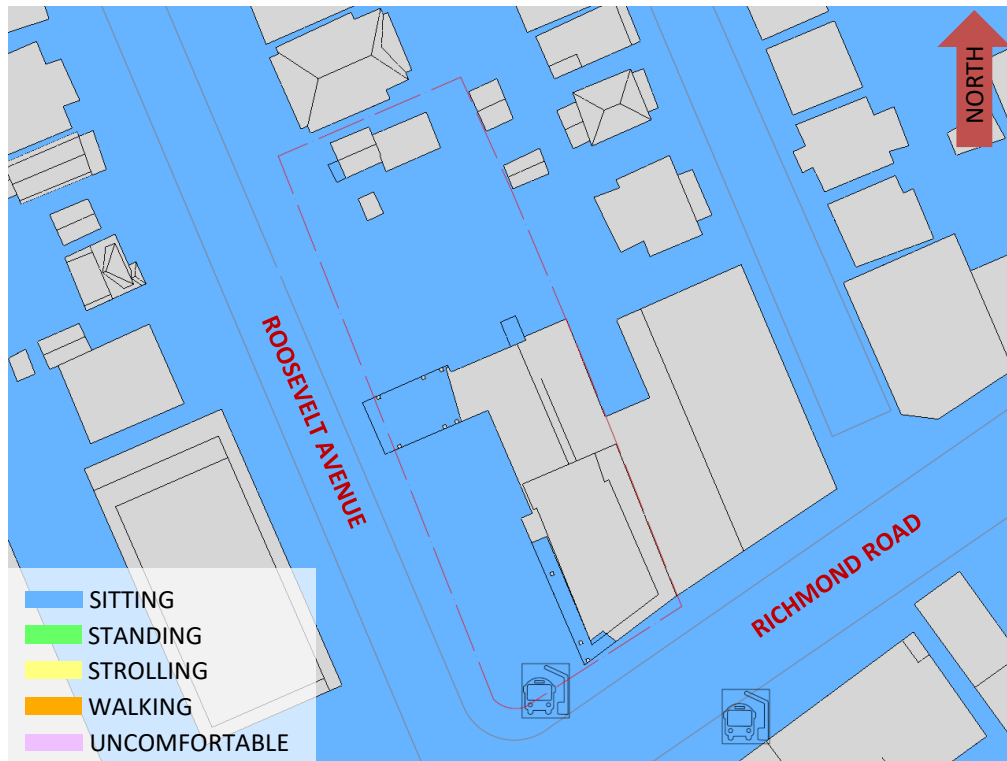


**FIGURE 3B: SPRING – WIND COMFORT, GRADE LEVEL– EXISTING MASSING**





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



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





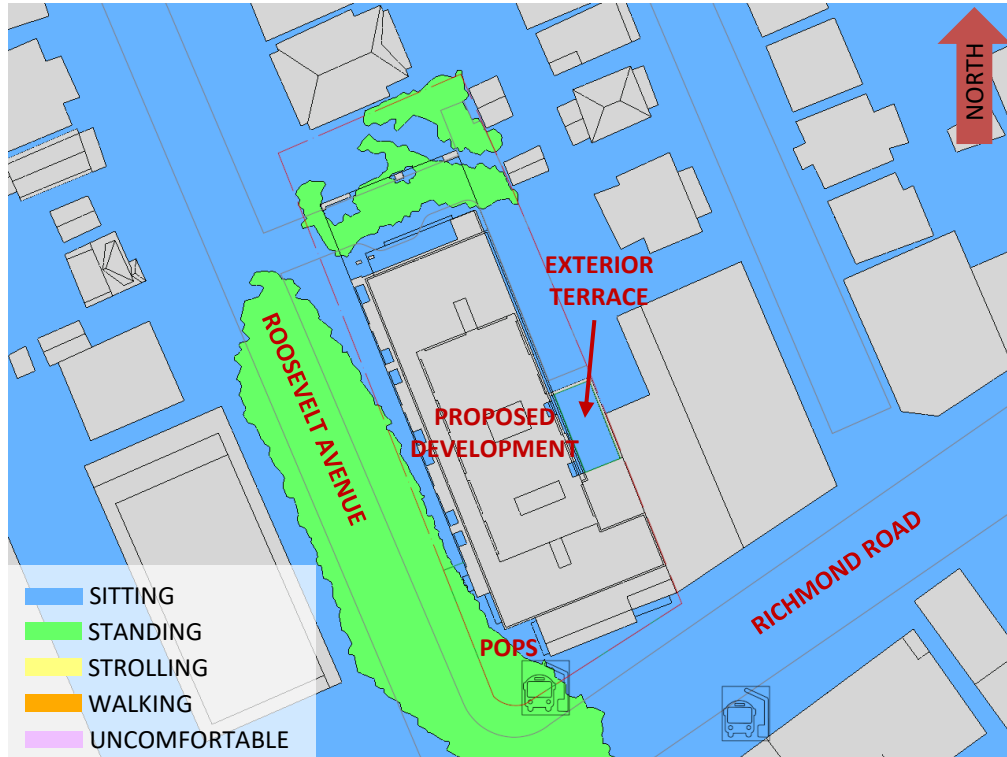


FIGURE 5A: AUTUMN – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING



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



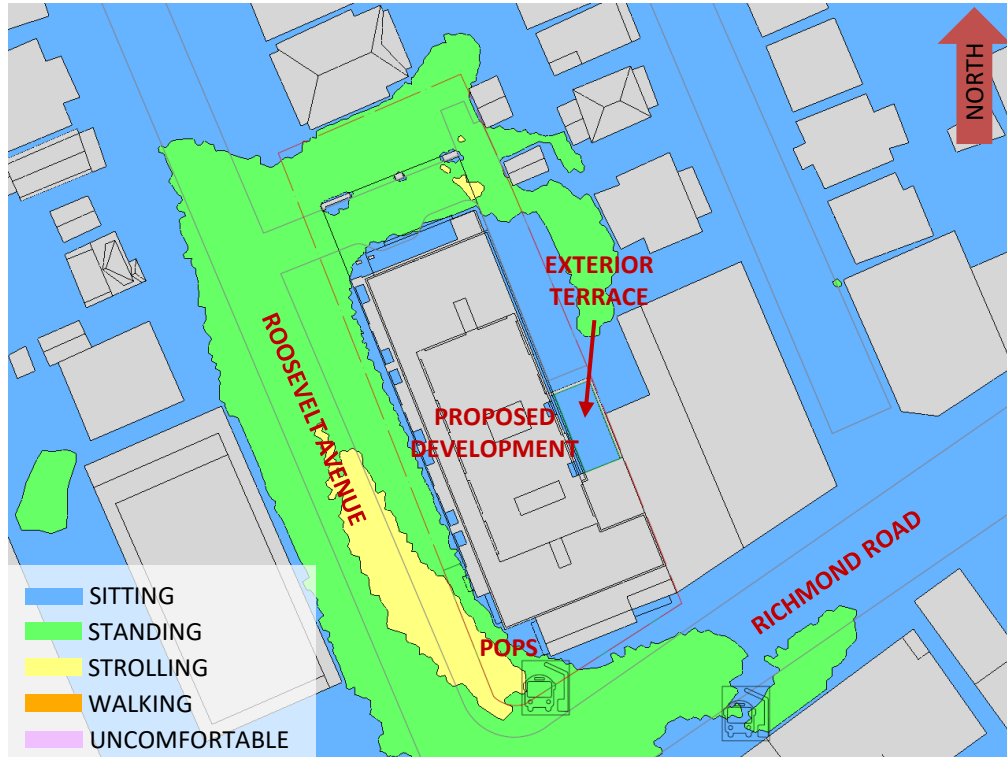


FIGURE 6A: WINTER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

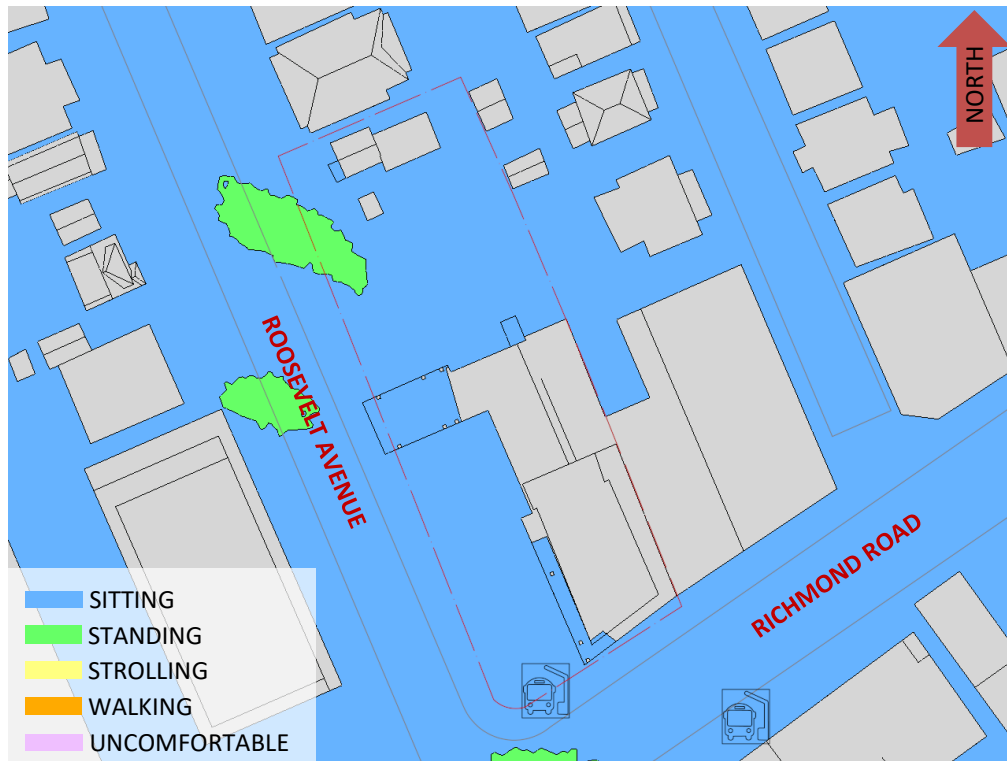
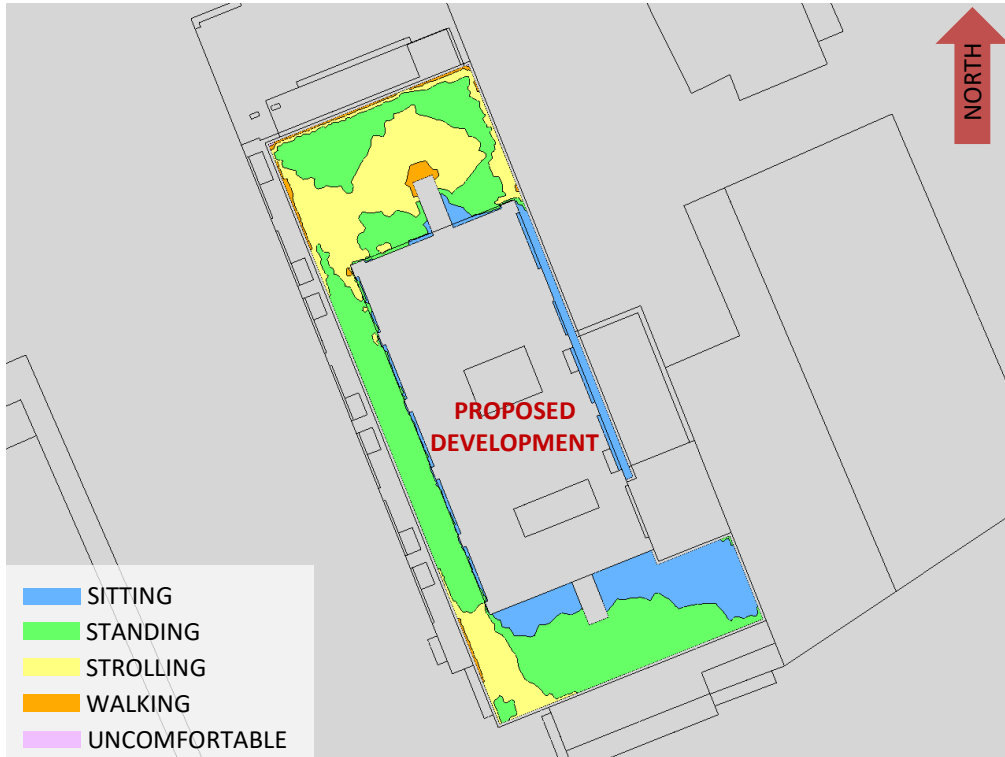
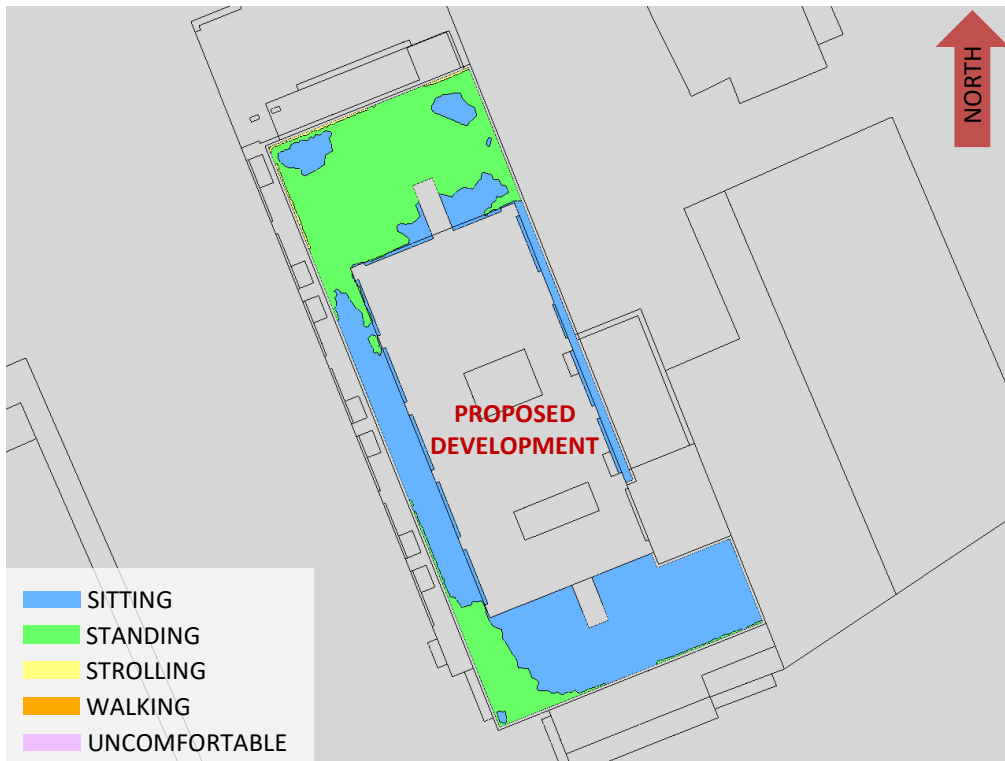


FIGURE 6B: WINTER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING



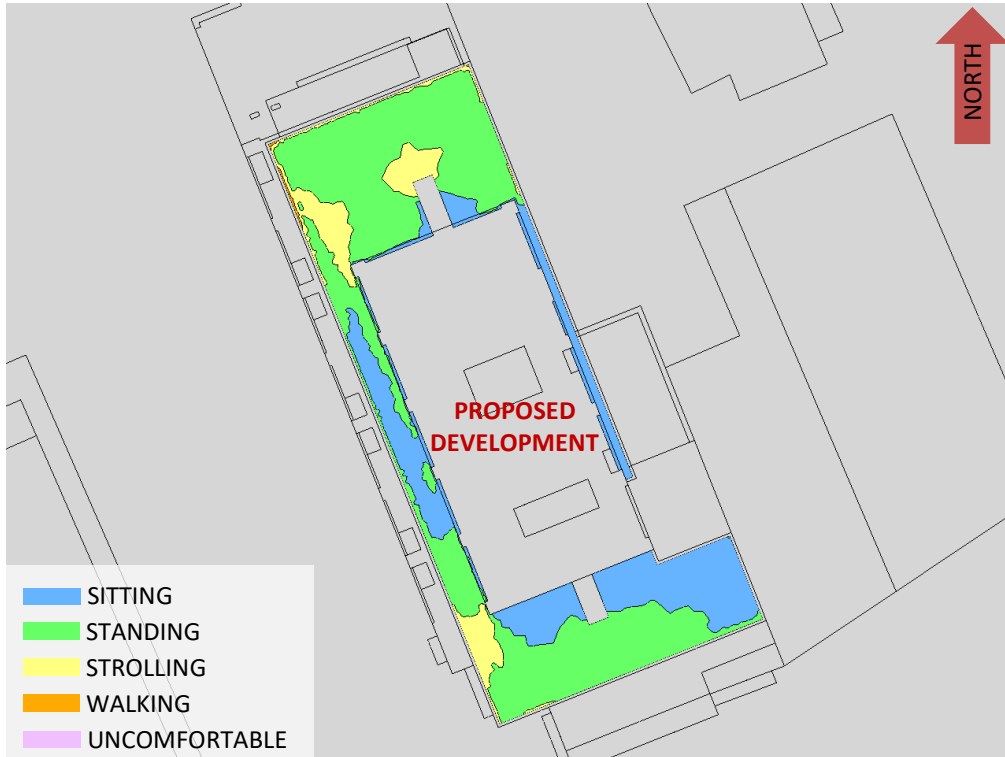


**FIGURE 7A: SPRING – WIND COMFORT, MPH LEVEL AMENITY TERRACE**

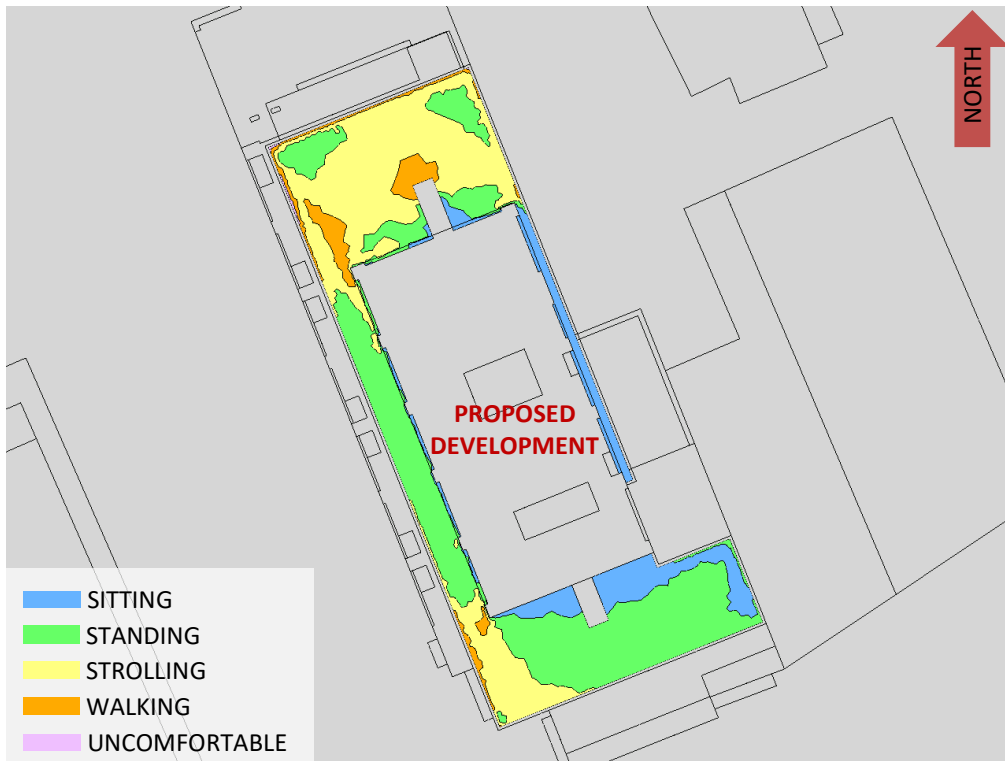


**FIGURE 7B: SUMMER – WIND COMFORT, MPH LEVEL AMENITY TERRACE**



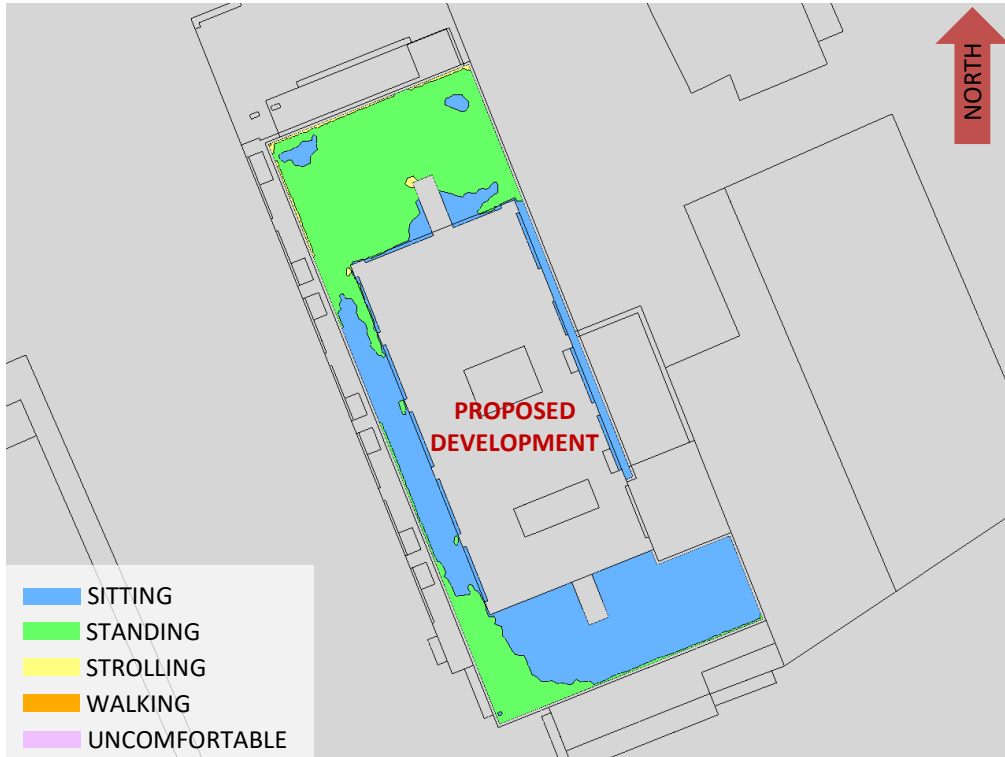


**FIGURE 7C: AUTUMN – WIND COMFORT, MPH LEVEL AMENITY TERRACE**

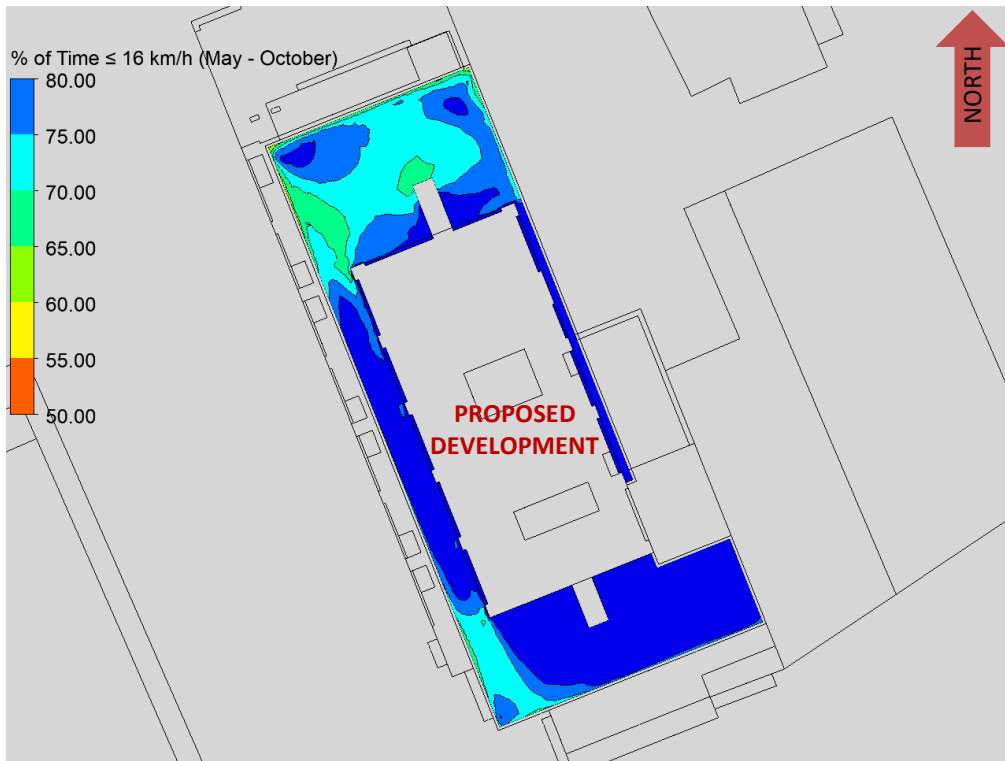


**FIGURE 7D: WINTER – WIND COMFORT, MPH LEVEL AMENITY TERRACE**





**FIGURE 8A: TYPICAL USE PERIOD – WIND COMFORT, MPH LEVEL AMENITY TERRACE**



**FIGURE 8B: TYPICAL USE PERIOD – % OF TIME SUITABLE FOR SITTING IN FIGURE 8A**



# GRADIENTWIND

ENGINEERS & SCIENTISTS



## 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).

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

where,  $U$  = mean wind speed,  $U_g$  = gradient wind speed,  $Z$  = height above ground,  $Z_g$  = depth of the boundary layer (gradient height), and  $\alpha$  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.

$\alpha$  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  $\alpha$  used in this study, while Table 2 presents several reference values of  $\alpha$ . When the upstream exposure of the far-field surroundings is a mixture of multiple types of terrain, the  $\alpha$  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 ( $\alpha$ )
0	0.20
49	0.25
74	0.24
103	0.23
167	0.24
197	0.25
217	0.25
237	0.18
262	0.16
282	0.16
301	0.18
324	0.18

**TABLE 2: DEFINITION OF UPSTREAM EXPOSURE (ALPHA VALUE)**

Upstream Exposure Type	Alpha Value ( $\alpha$ )
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).

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

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

where,  $I$  = turbulence intensity,  $L_t$  = turbulence length scale,  $Z$  = height above ground, and  $\alpha$  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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