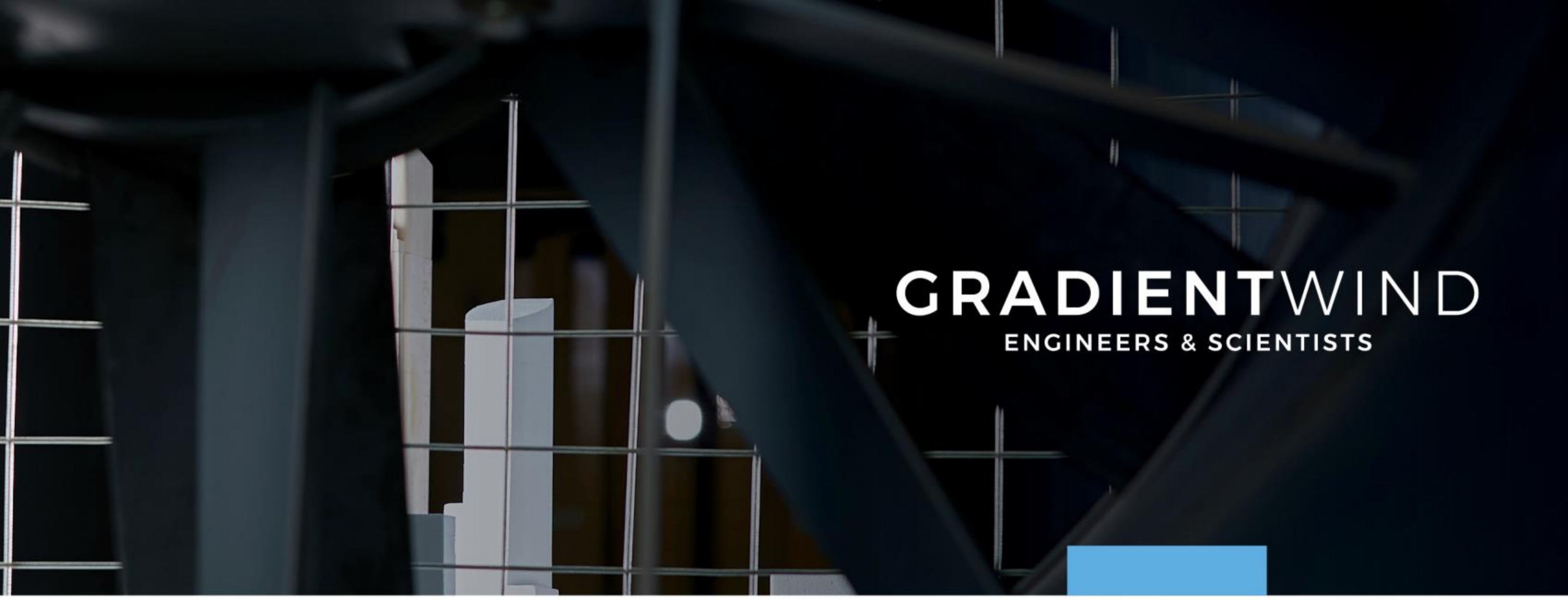
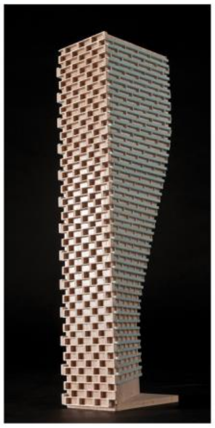
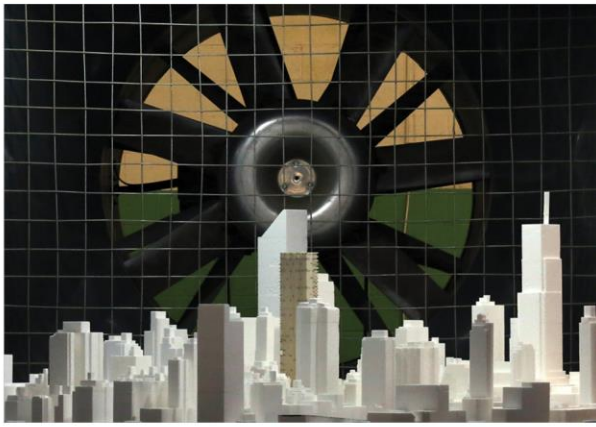



# PEDESTRIAN LEVEL WIND STUDY

384 Arlington Avenue
Ottawa, Ontario

Report: 22-131-PLW-2023





April 13, 2023

PREPARED FOR
Windmill Development Group
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# EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study undertaken to satisfy Zoning By-law Amendment application requirements for the proposed residential development located at 384 Arlington 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 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 conditions 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, the laneway along the east elevation, the landscaped area along the west elevation, and in the vicinity of building access points, are considered acceptable.

2) Regarding the common amenity terraces serving the proposed development, wind conditions during the typical use period and recommendations regarding wind mitigation where required are described as follows:

    a. **Level 4 Common Amenity Terrace**. Wind comfort conditions are predicted to be suitable for sitting within most of the area, with an isolated region suitable for standing near the northwest corner of the terrace. The noted conditions are considered acceptable.

    b. **Level 7 Urban Farming Terrace.** Wind comfort conditions are predicted to be suitable for sitting to the north and south, and suitable for standing throughout the remainder of the terrace. The noted conditions are considered acceptable.

c. **Level 7 Common Amenity Terrace**: Wind comfort conditions are predicted to be suitable for sitting at the northwest and southeast corners, and suitable for standing throughout the remainder of the terrace. During the typical use period, the areas that are predicted to be suitable for standing, according to the comfort criteria in Section 4.4, are also predicted to be suitable for sitting for at least 65% of the time where the target is 80% to achieve the sitting comfort criterion.

- To improve comfort levels within the amenity terrace, it is recommended that tall wind screens, in place of standard height guards, be implemented along the full perimeter, extending at least 2.0 m above the local walking surface. To further improve conditions, mitigation inboard of the perimeter may also be required and could take the form of wind screens and canopies located above designated seating areas.

- The extent of the mitigation measures is dependent on the programming of the terrace. An appropriate mitigation strategy will be developed in collaboration with the building and landscape architects. This work is expected to support the future Site Plan Control application submission.

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, (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 Windmill Development Group to undertake a pedestrian level wind (PLW) study to satisfy Zoning By-law Amendment application requirements for the proposed residential development located at 384 Arlington Avenue in Ottawa, Ontario (hereinafter referred to as “subject site” or “proposed development”). A previous PLW study was conducted in August 2022 for the proposed development. Our mandate within this study is to investigate pedestrian wind conditions 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 March 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 384 Arlington Avenue in Ottawa; situated on a parcel of land bounded by Arlington Avenue to the north, Arthur Lane North to the east, Raymond Street to the south, and Bell Street North to the west. The proposed development comprises a nominally rectangular 24-storey residential tower topped with a mechanical penthouse level (MPH), rising above a six-storey podium.

Above below-grade parking, the ground floor includes a main entrance to the west, activities room, yoga, and gym at the northwest corner, residential units to the east, services at the southeast corner, residential units to the south and west, and a central common space. Access to underground parking is provided by a ramp at the southeast corner from Raymond Street, and a landscaped area is located along the west elevation. Levels 2-24 are reserved for residential use. The building extends from the east elevation at Level 3. The building steps back from the north elevation at Level 4 to accommodate an amenity terrace. At Level 7, the building steps back from the north and east elevations to accommodate an amenity terrace and private terraces, respectively. Of note, the Level 7 amenity terrace is divided between an urban farming terrace (northwest) and common amenity terrace (northeast).

The near-field surroundings, defined as an area within 200-metres (m) of the subject site, include a mix of low-rise residential and commercial buildings in all compass directions with a high-rise mixed-use residential building and a mid-rise residential building to the north, two mid-rise residential buildings to the northeast, two mid-rise commercial buildings to the east, and a church to the northwest. Highway 417 extends from the east to the southwest. Notably, a nine-storey mixed-use residential building is proposed (Zoning By-law Amendment approved, awaiting Site Plan Control approval) at 18 Louisa Street, to the immediate northwest 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 primarily by low-rise buildings with isolated mid- and high-rise buildings from the southwest clockwise southeast, with the Ottawa downtown core approximately 1.2 km to the north, and a mix of low-rise buildings and open exposures (fields and green spaces) to the south. The Ottawa River flows from the northwest to the north, approximately 1.6 km to the northwest, Dow's Lake is situated approximately 820 m to the south, and the Rideau Canal flows from the south to the northeast, approximately 1.3 km to the south 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 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 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 study building, complete with surrounding massing within a radius of 480 m. The process was performed for two context massing scenarios, as noted in Section 2.

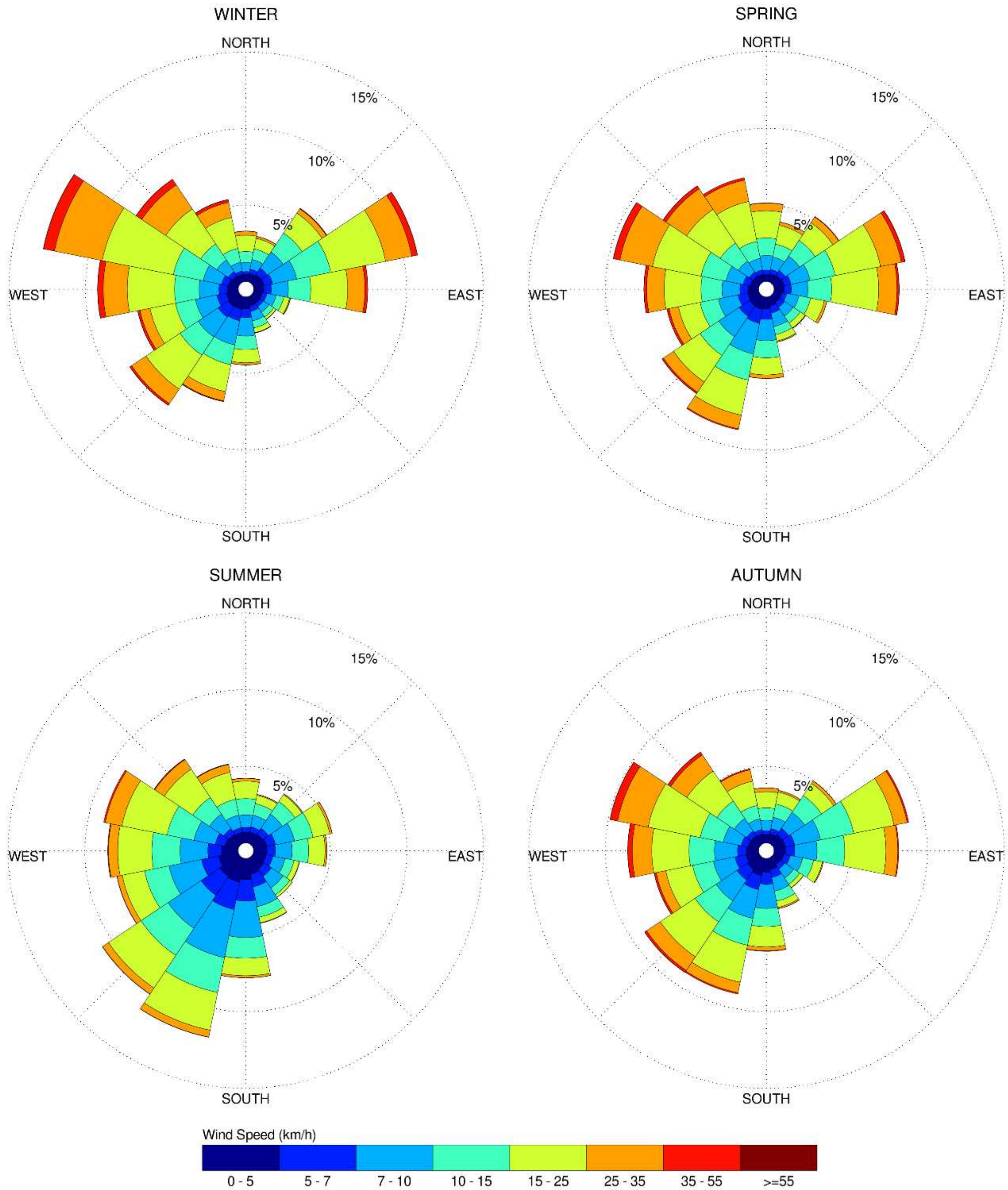
Mean and peak wind speed data obtained over the study site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade and the common amenity terraces were referenced to the wind speed 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 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 comfort and safety criteria are based on the mechanical effects of wind without consideration of other meteorological conditions (that is, 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 (that is, 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 / 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, illustrating wind conditions over the common amenity terraces serving the proposed development at Levels 4 and 7. 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.

Conditions at grade and within the common amenity terraces serving the proposed development are also reported for the typical use period, which is defined as May to October, inclusive. Figures 7 and 9 illustrates wind comfort conditions at grade and over the common amenity terraces, 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 – Ground Floor

**Public Sidewalks Adjacent to the Subject Site:** Following the introduction of the proposed development, the public sidewalks adjacent to the subject site along Arlington Avenue, Raymond Street, and Bell Street North, as well as along Arthur Lane North, are predicted to be suitable for their intended uses throughout the year. Specifically, conditions 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. The only exception is an isolated region near the intersection of Raymond Street and Bell Street North, which is predicted to be suitable for walking during the winter.

Wind conditions along the public sidewalks and laneway with the existing massing are predicted to be suitable for sitting throughout the year. While the introduction of the proposed development produces slightly windier conditions in comparison to existing conditions, wind comfort conditions are nevertheless considered acceptable.

**Landscaped Area West of the Subject Site:** Wind conditions over the landscape area along the west elevation 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. During the typical use period, as illustrated in Figure 7, conditions are predicted to be suitable mostly for sitting, with a small region predicted to be suitable for standing within the south end of the area. The noted conditions are considered acceptable.

**Building Access:** 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

The proposed development is served by several common amenity terraces. Wind comfort conditions during the typical use period and recommendations regarding mitigation, where required, are described as follows:

**Level 4 Common Amenity Terrace**: As illustrated in Figure 9, wind comfort conditions within the amenity terrace serving the proposed development at Level 4 are predicted to be suitable for sitting within most of the area, with an isolated region suitable for standing near the northwest corner of the terrace. The noted conditions are considered acceptable.

**Level 7 Urban Farming Terrace**: As illustrated in Figure 9, wind comfort conditions within the urban farming terrace serving the proposed development at Level 7 to the northwest are predicted to be suitable for sitting to the north and south, and suitable for standing throughout the remainder of the terrace. During the same period, the areas that are predicted to be suitable for standing, according to the comfort criteria in Section 4.4, are also predicted to be suitable for sitting for at least 76% of the time where the target is 80% to achieve the sitting comfort criterion. Since the area is intended to serve as an urban farming terrace, the noted conditions are considered acceptable.

**Level 7 Common Amenity Terrace**: As illustrated in Figure 9, wind comfort conditions within the common amenity terrace serving the proposed development at Level 7 to the northeast are predicted to be suitable for sitting at the northeast and southwest corners, and suitable for standing throughout the remainder of the terrace. During the typical use period, the areas that are predicted to be suitable for standing, according to the comfort criteria in Section 4.4, are also predicted to be suitable for sitting for at least 65% of the time where the target is 80% to achieve the sitting comfort criterion.

To improve comfort levels within the amenity terrace, it is recommended that tall wind screens, in place of standard height guards, be implemented along the full perimeter, extending at least 2.0 m above the local walking surface. To further improve conditions, mitigation inboard of the perimeter may also be required and could take the form of wind screens and canopies located above designated seating areas.

The extent of the mitigation measures is dependent on the programming of the terrace. An appropriate mitigation strategy will be developed in collaboration with the building and landscape architects. This work is expected to support the future Site Plan Control application submission.

## 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, the laneway along the east elevation, the landscaped area along the west elevation, and in the vicinity of building access points, are considered acceptable.

2) Regarding the common amenity terraces serving the proposed development, wind conditions during the typical use period and recommendations regarding wind mitigation where required are described as follows:

    a. **Level 4 Common Amenity Terrace**. Wind comfort conditions are predicted to be suitable for sitting within most of the area, with an isolated region suitable for standing near the northwest corner of the terrace. The noted conditions are considered acceptable.

    b. **Level 7 Urban Farming Terrace.** Wind comfort conditions are predicted to be suitable for sitting to the north and south, and suitable for standing throughout the remainder of the terrace. The noted conditions are considered acceptable.

    c. **Level 7 Common Amenity Terrace**: Wind comfort conditions are predicted to be suitable for sitting at the northwest and southeast corners, and suitable for standing throughout the remainder of the terrace. During the typical use period, the areas that are predicted to be suitable for standing, according to the comfort criteria in Section 4.4, are also predicted to be suitable for sitting for at least 65% of the time where the target is 80% to achieve the sitting comfort criterion.

        - To improve comfort levels within the amenity terrace, it is recommended that tall wind screens, in place of standard height guards, be implemented along the full perimeter, extending at least 2.0 m above the local walking surface. To further improve conditions, mitigation inboard of the perimeter may also be required and could take the form of wind screens and canopies located above designated seating areas.

- The extent of the mitigation measures is dependent on the programming of the terrace. An appropriate mitigation strategy will be developed in collaboration with the building and landscape architects. This work is expected to support the future Site Plan Control application submission.

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, (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
Apr 13, 2023
PROVINCE OF ONTARIO

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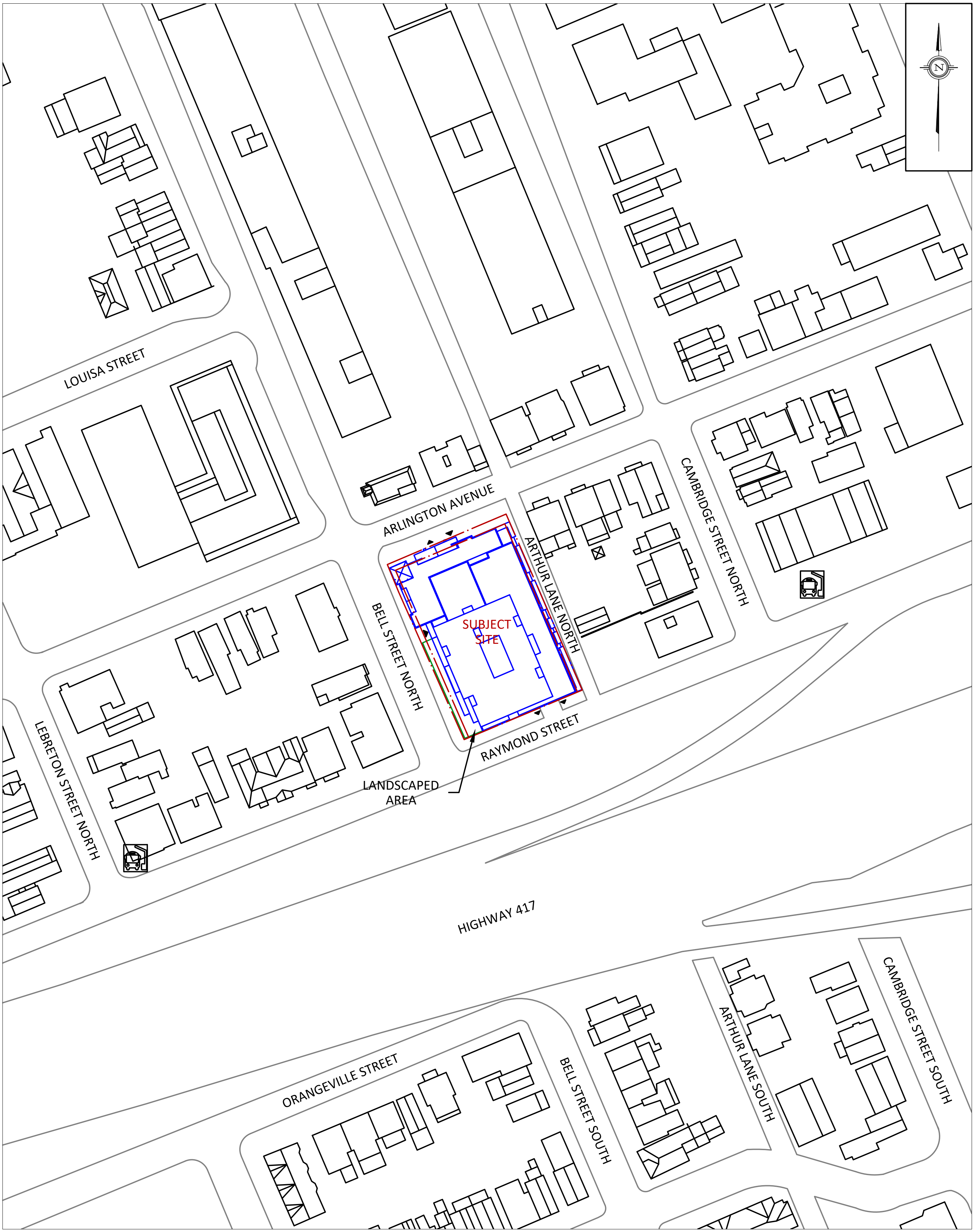


| | | | |
|---|---|---|---|
| GRADIENTWIND ENGINEERS & SCIENTISTS<br>127 WALGREEN ROAD, OTTAWA, ON<br>613 836 0934 • GRADIENTWIND.COM | PROJECT: 384 ARLINGTON AVENUE, OTTAWA<br>PEDESTRIAN LEVEL WIND STUDY | | DESCRIPTION: FIGURE 1A:<br>PROPOSED SITE PLAN AND SURROUNDING CONTEXT |
| | SCALE: 1:1500 | DRAWING NO. 22-131-PLW-2023-1A | |
| | DATE: APRIL 4, 2023 | DRAWN BY: S.K. | |


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| GRADIENTWIND<br>ENGINEERS & SCIENTISTS<br>127 WALGREEN ROAD, OTTAWA, ON<br>613 836 0934 • GRADIENTWIND.COM | PROJECT<br>384 ARLINGTON AVENUE, OTTAWA<br>PEDESTRIAN LEVEL WIND STUDY | | DESCRIPTION<br>FIGURE 1B:<br>EXISTING SITE PLAN AND SURROUNDING CONTEXT |
| | SCALE<br>1:1500 | DRAWING NO.<br>22-131-PLW-2023-1B | |
| | DATE<br>APRIL 4, 2023 | DRAWN BY<br>S.K. | |

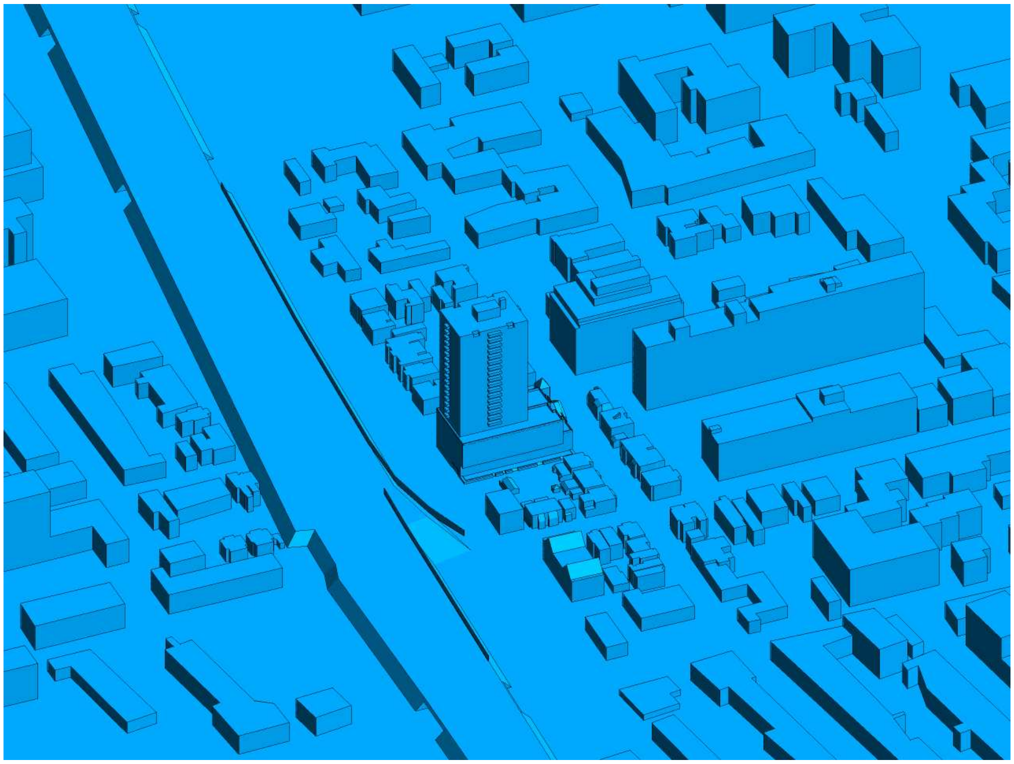


**FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, EAST PERSPECTIVE**

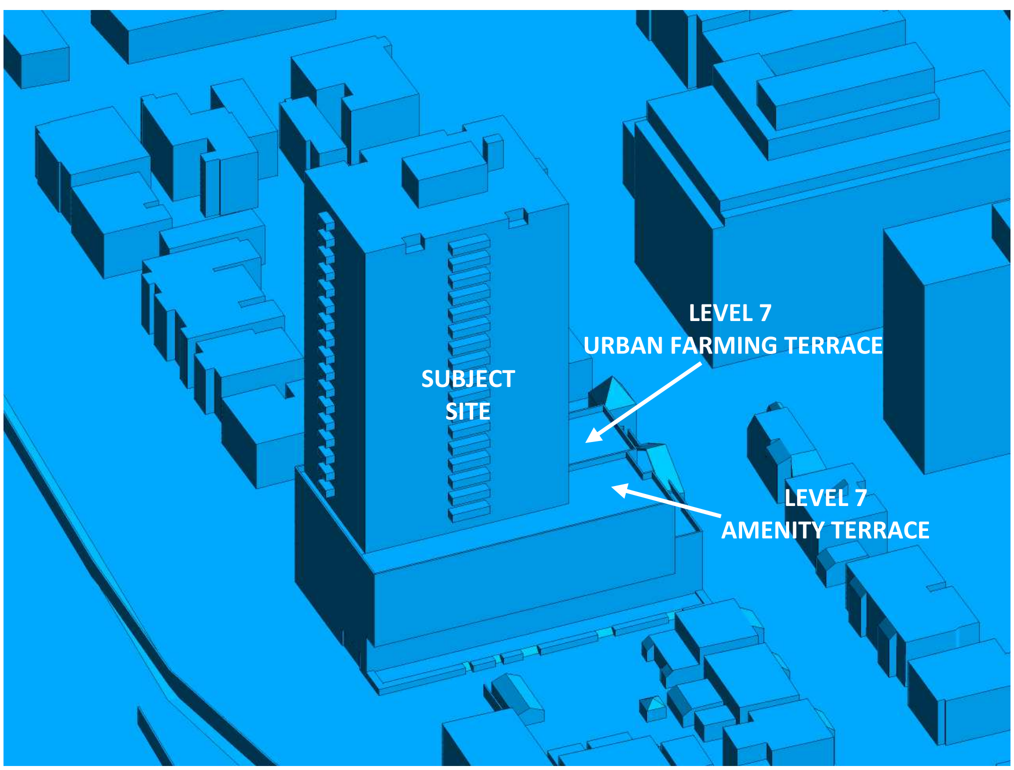



**FIGURE 2B: CLOSE UP OF FIGURE 2A**

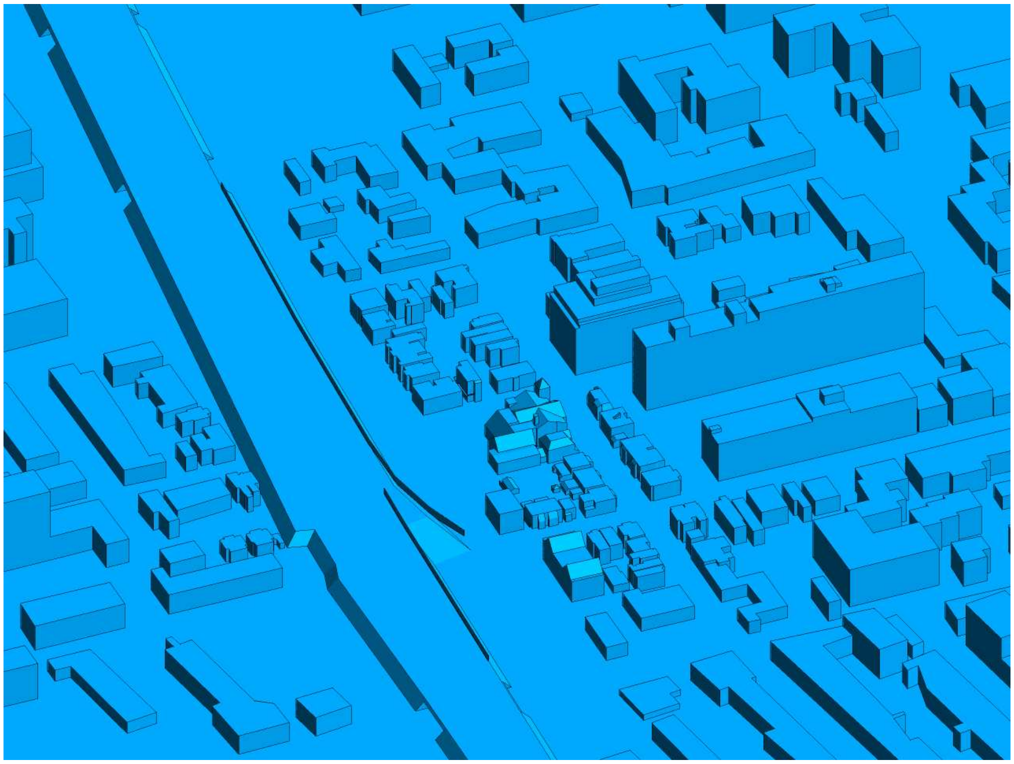


FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, EAST PERSPECTIVE

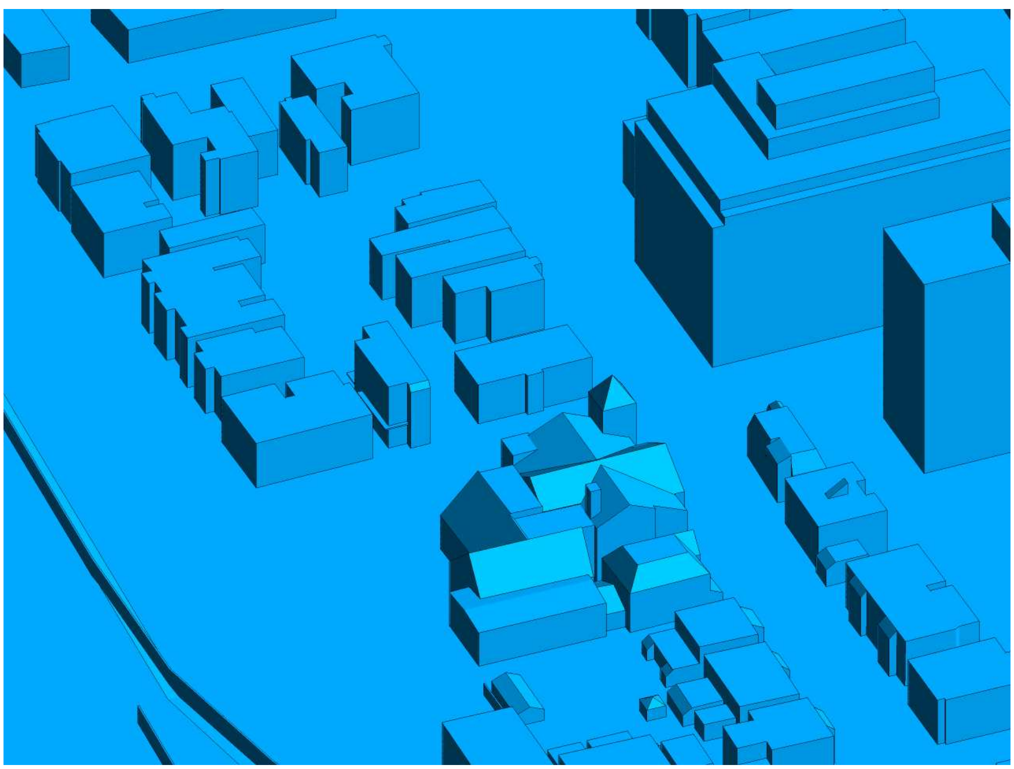


FIGURE 2D: CLOSE UP OF FIGURE 2C

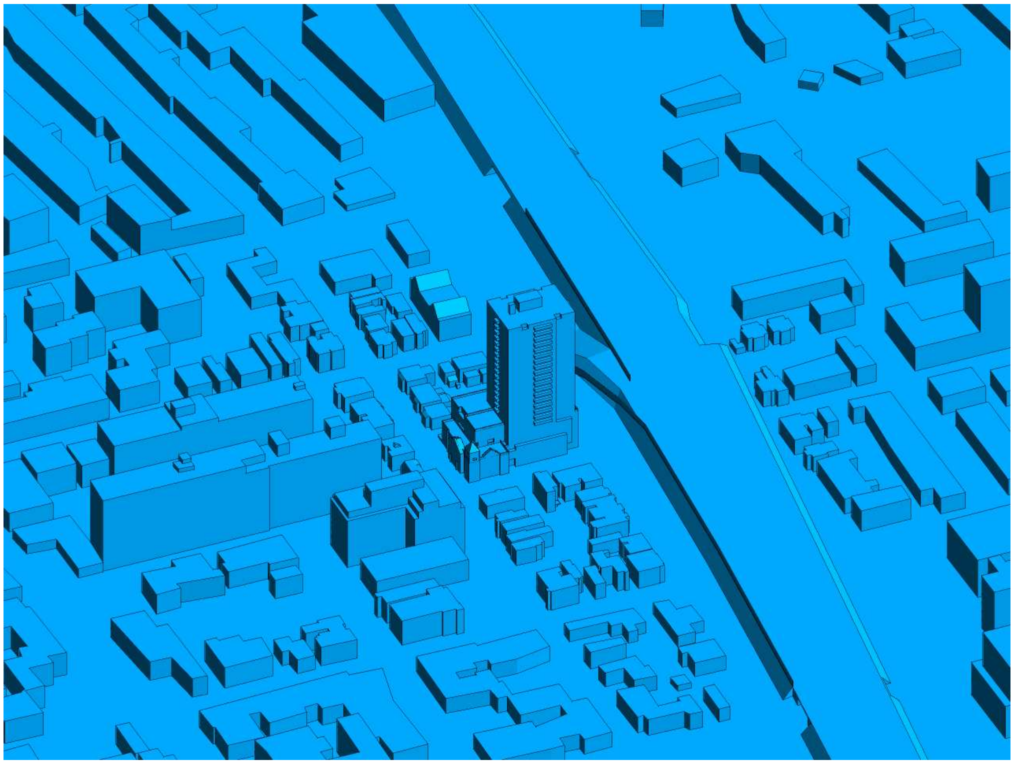


**FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, WEST PERSPECTIVE**

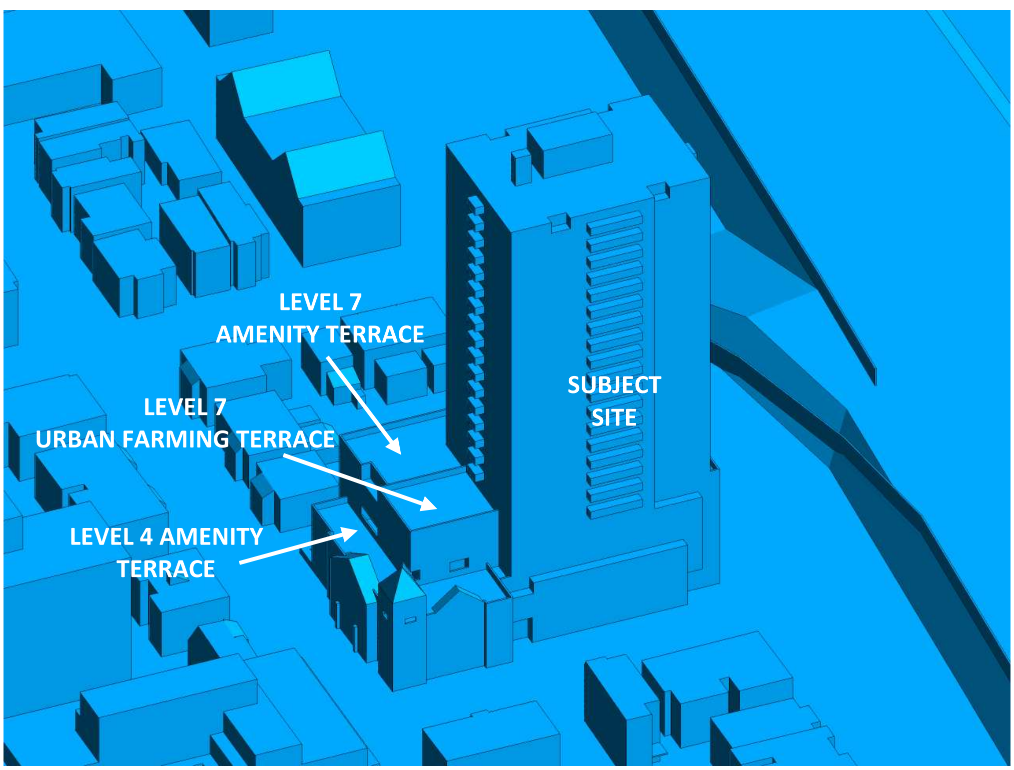



**FIGURE 2F: CLOSE UP OF FIGURE 2E**

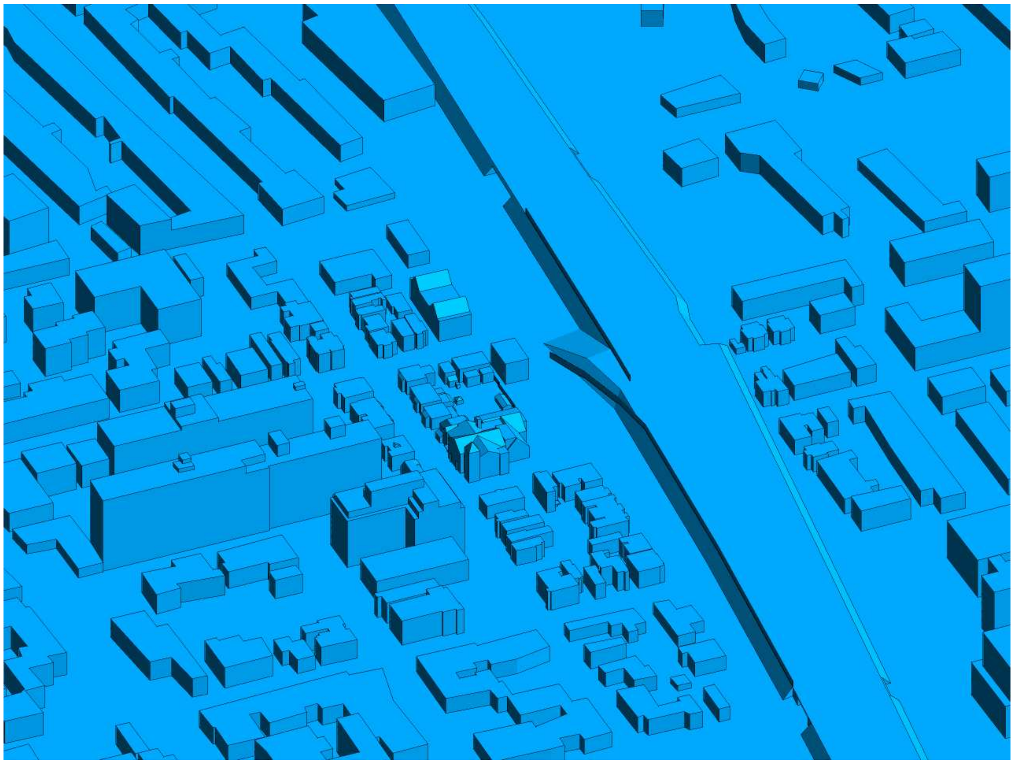


**FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, WEST PERSPECTIVE**

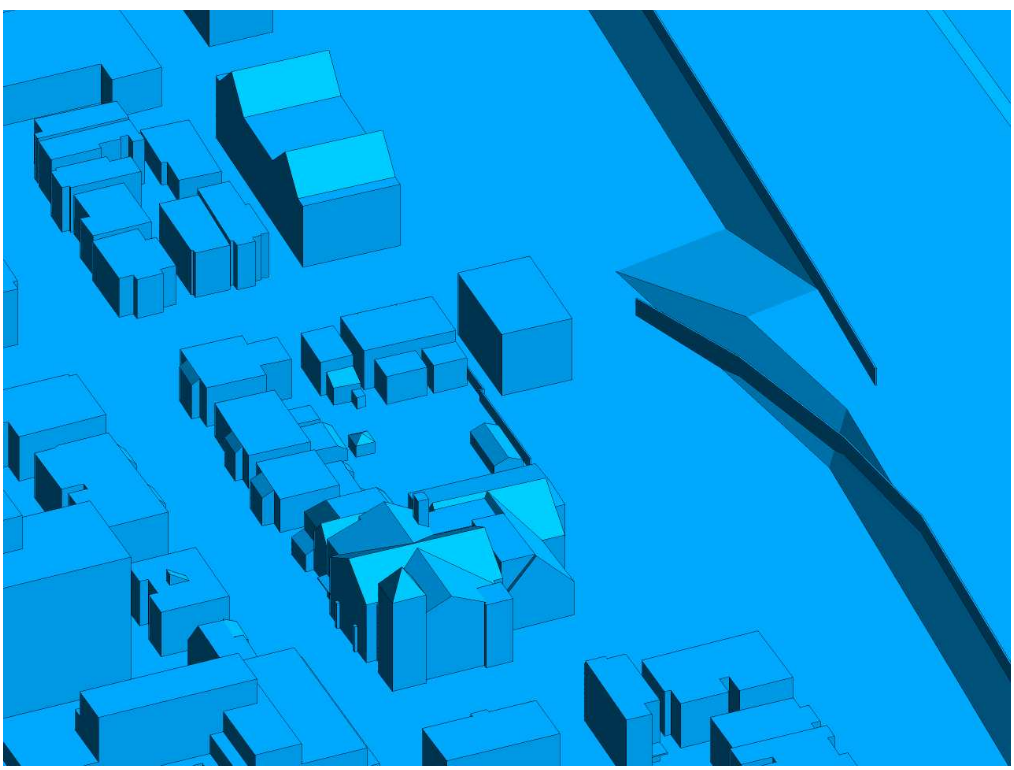


**FIGURE 2H: CLOSE UP OF FIGURE 2G**

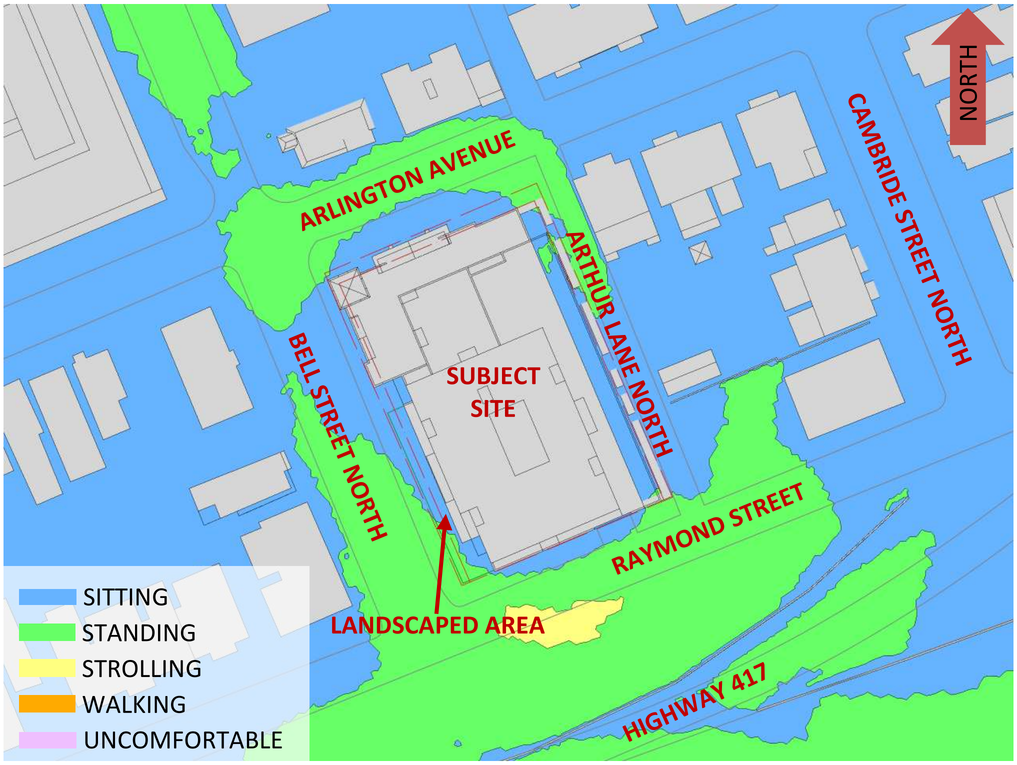



**FIGURE 3A: SPRING – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING**

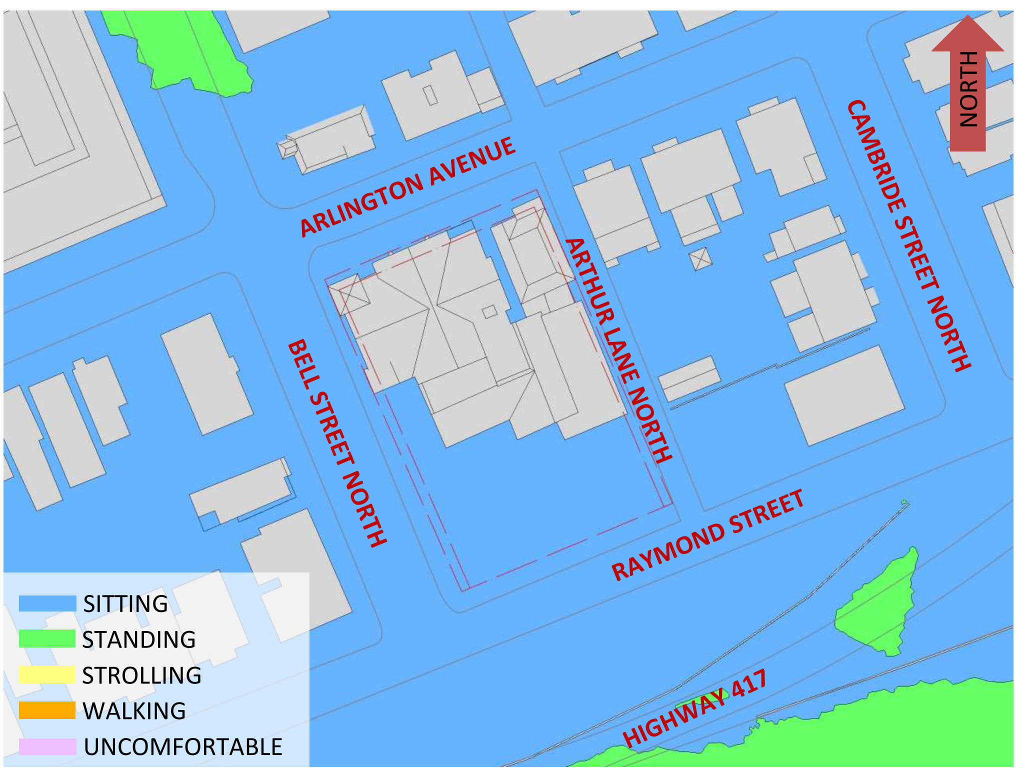
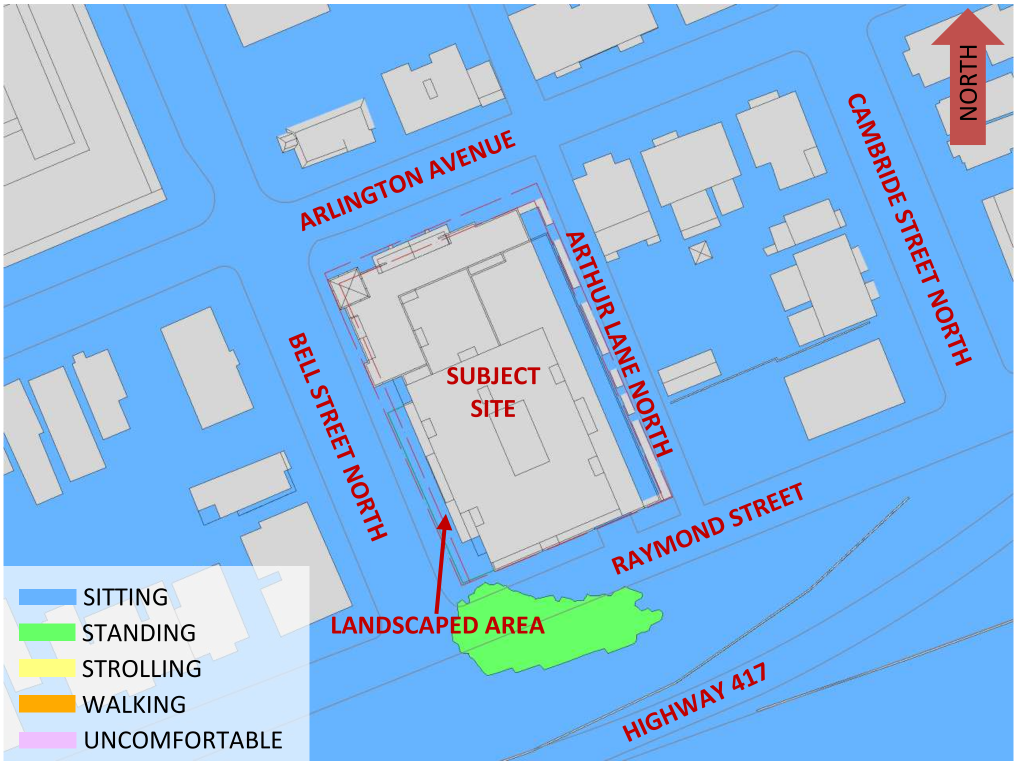



**FIGURE 3B: SPRING – WIND COMFORT, GRADE LEVEL – EXISTING MASSING**




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

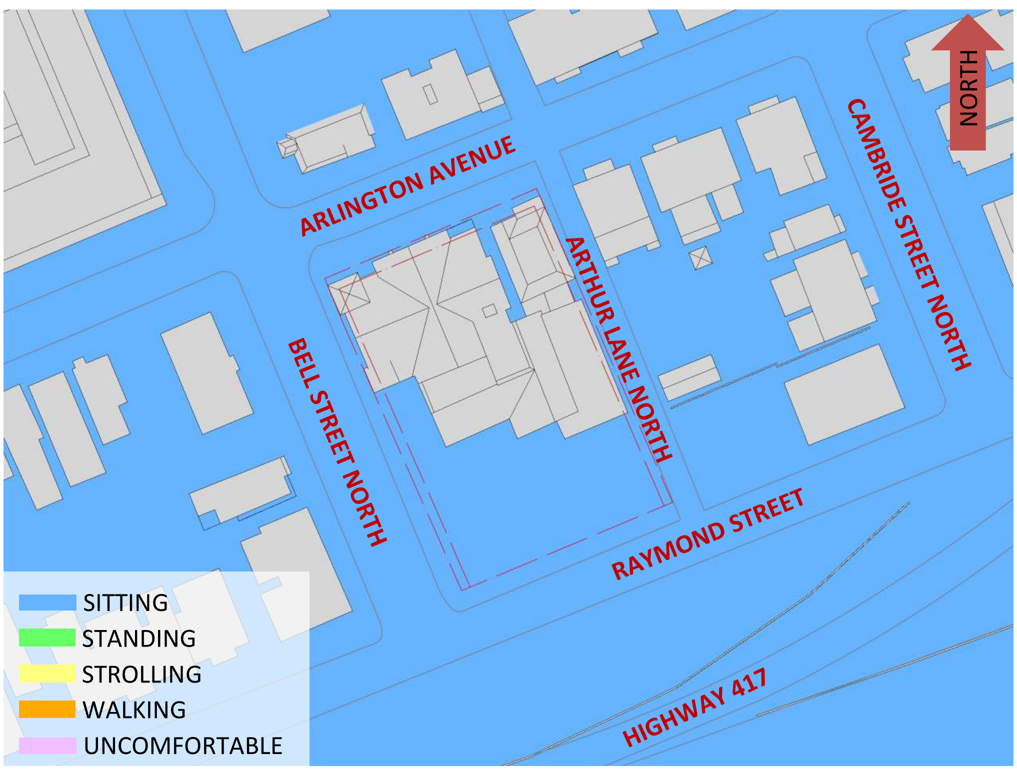



**FIGURE 4B: SUMMER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING**

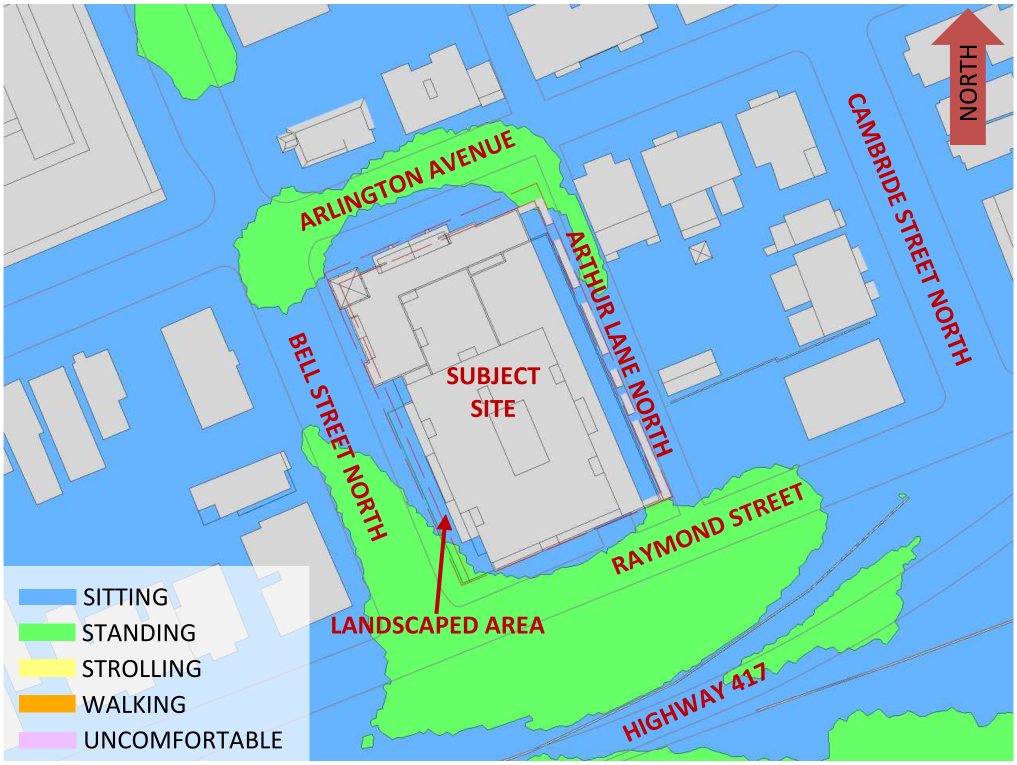



**FIGURE 5A: AUTUMN – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING**

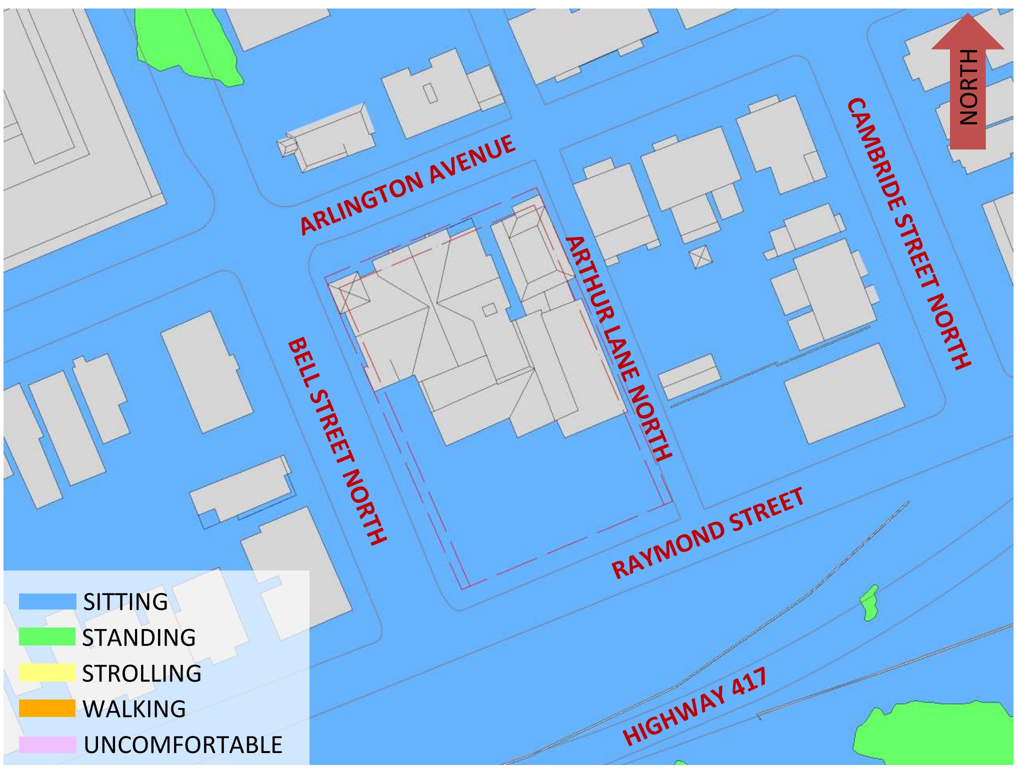



**FIGURE 5B: AUTUMN – WIND COMFORT, GRADE LEVEL – EXISTING MASSING**

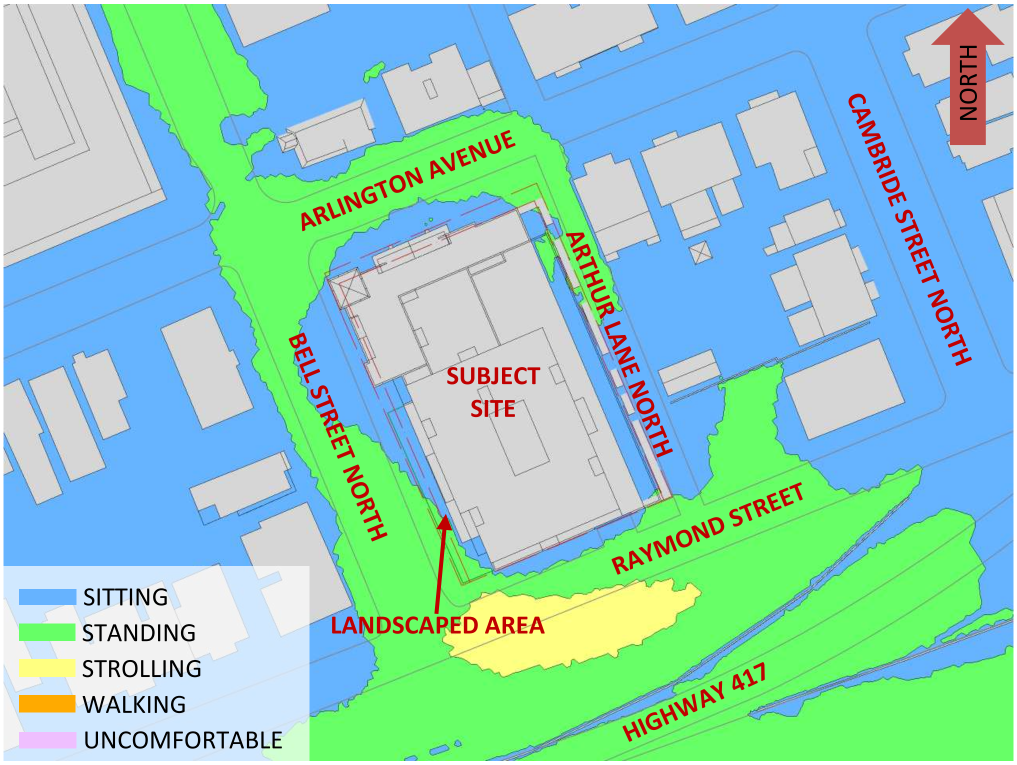



**FIGURE 6A: WINTER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING**

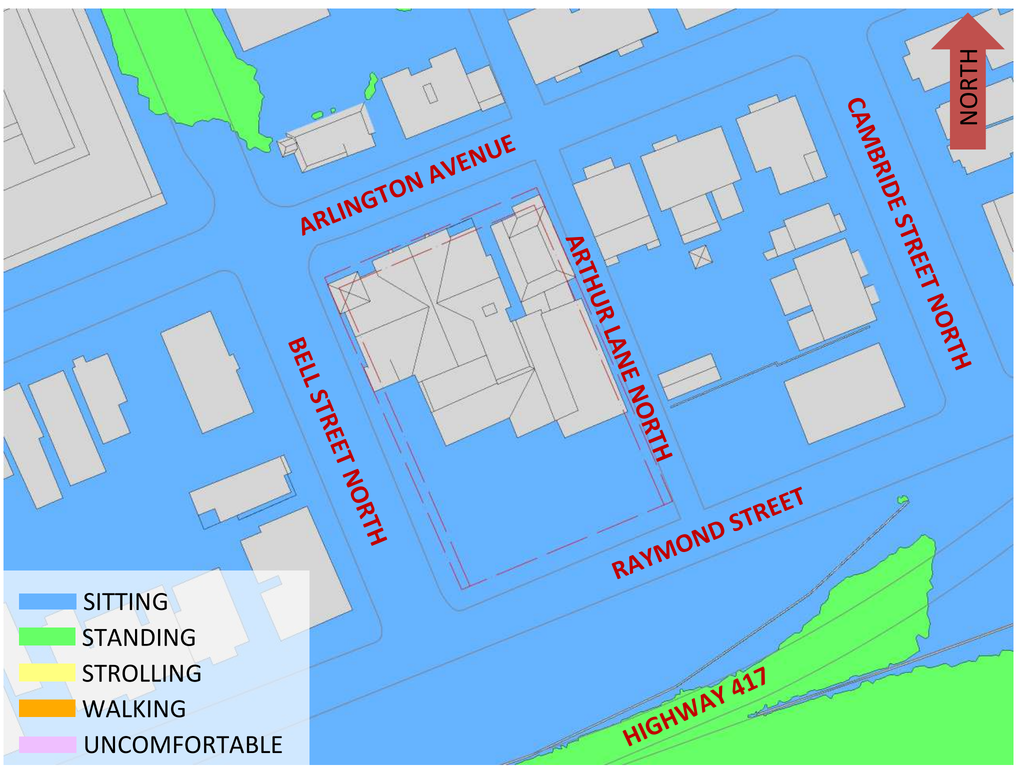



**FIGURE 6B: WINTER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING**

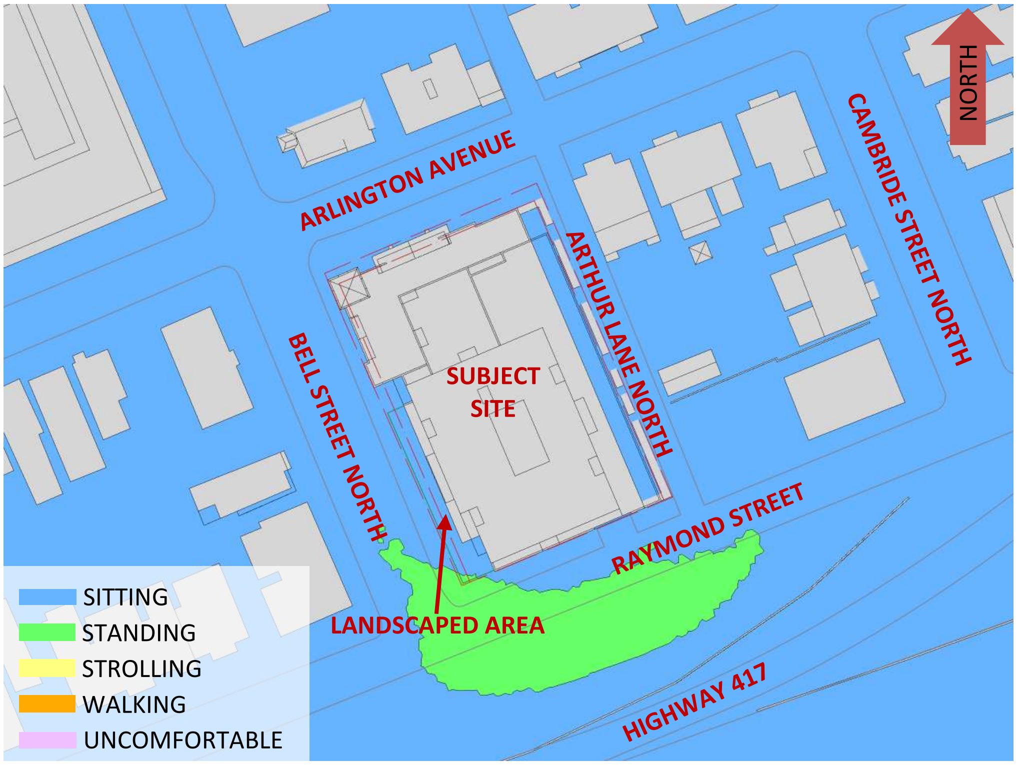



**FIGURE 7: TYPICAL USE PERIOD – WIND COMFORT, GRADE LEVEL**

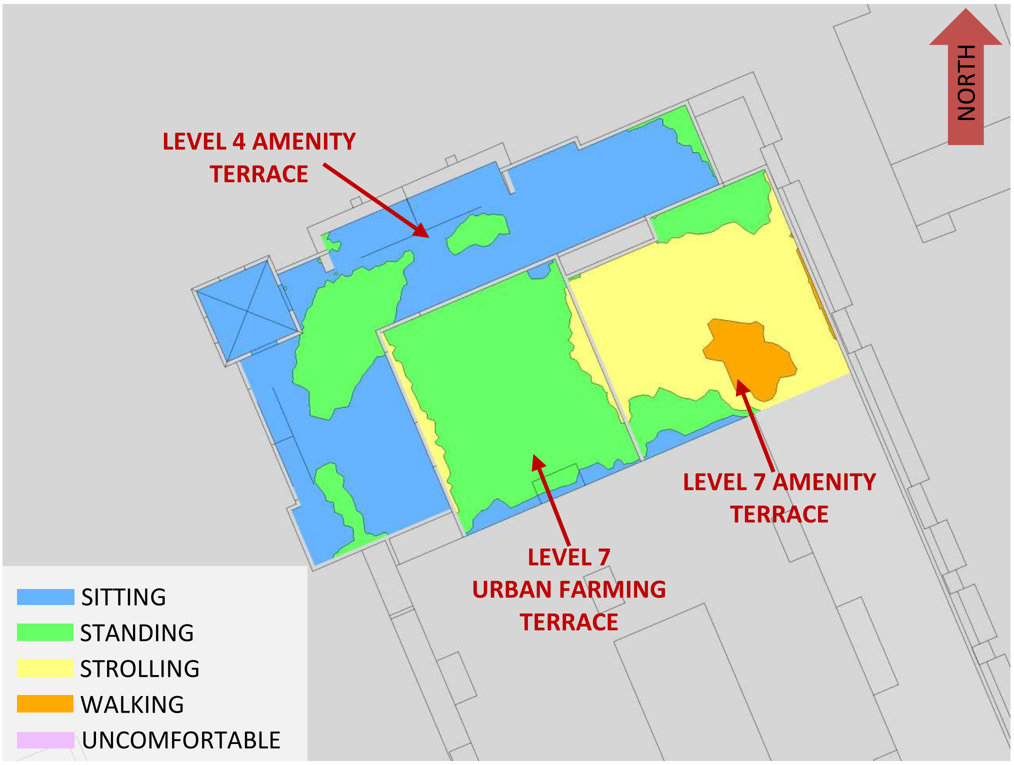



**FIGURE 8A: SPRING – WIND COMFORT, COMMON AMENITY TERRACES**

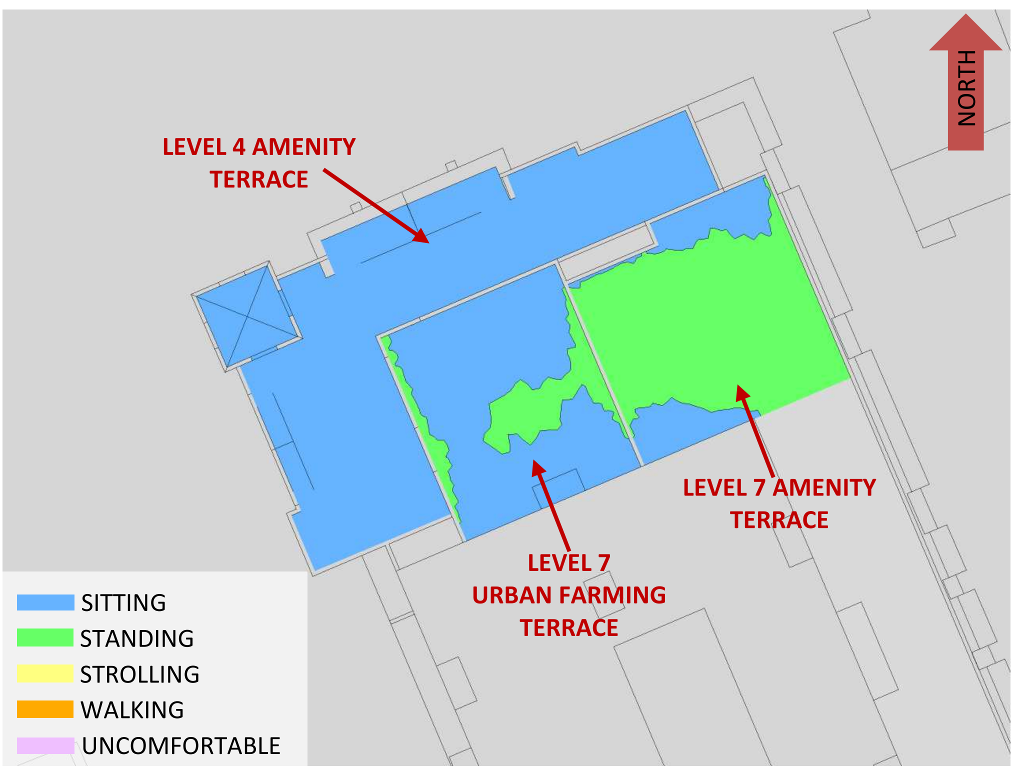



**FIGURE 8B: SUMMER – WIND COMFORT, COMMON AMENITY TERRACES**

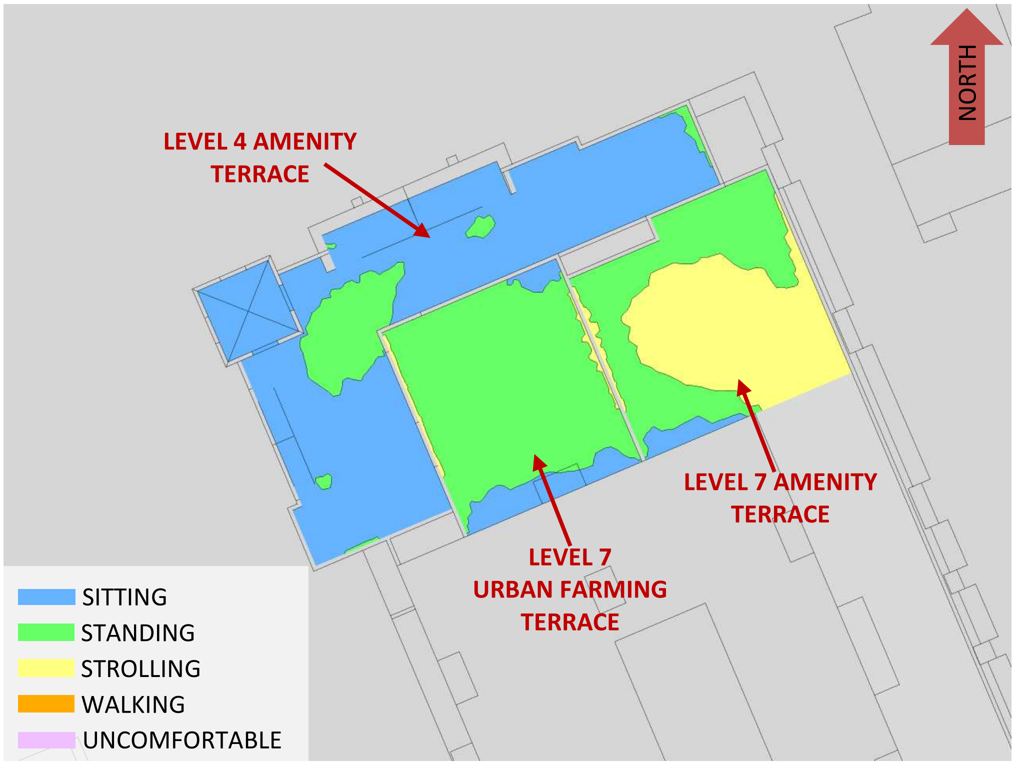



**FIGURE 8C: AUTUMN – WIND COMFORT, COMMON AMENITY TERRACES**

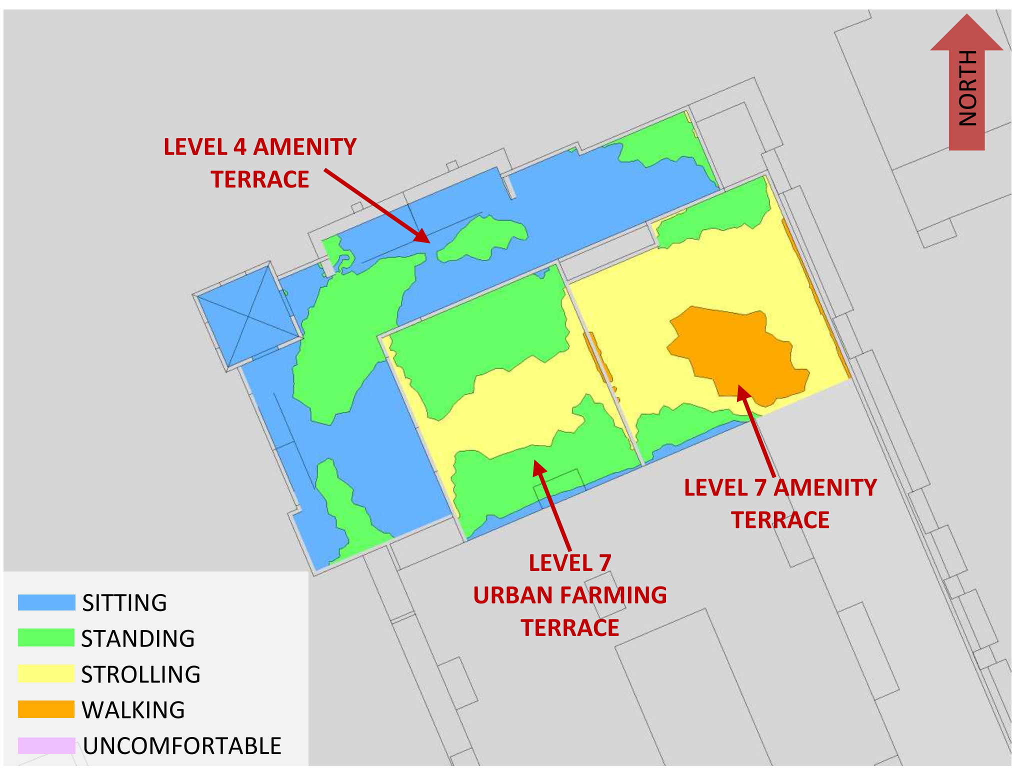



**FIGURE 8D: WINTER – WIND COMFORT, COMMON AMENITY TERRACES**

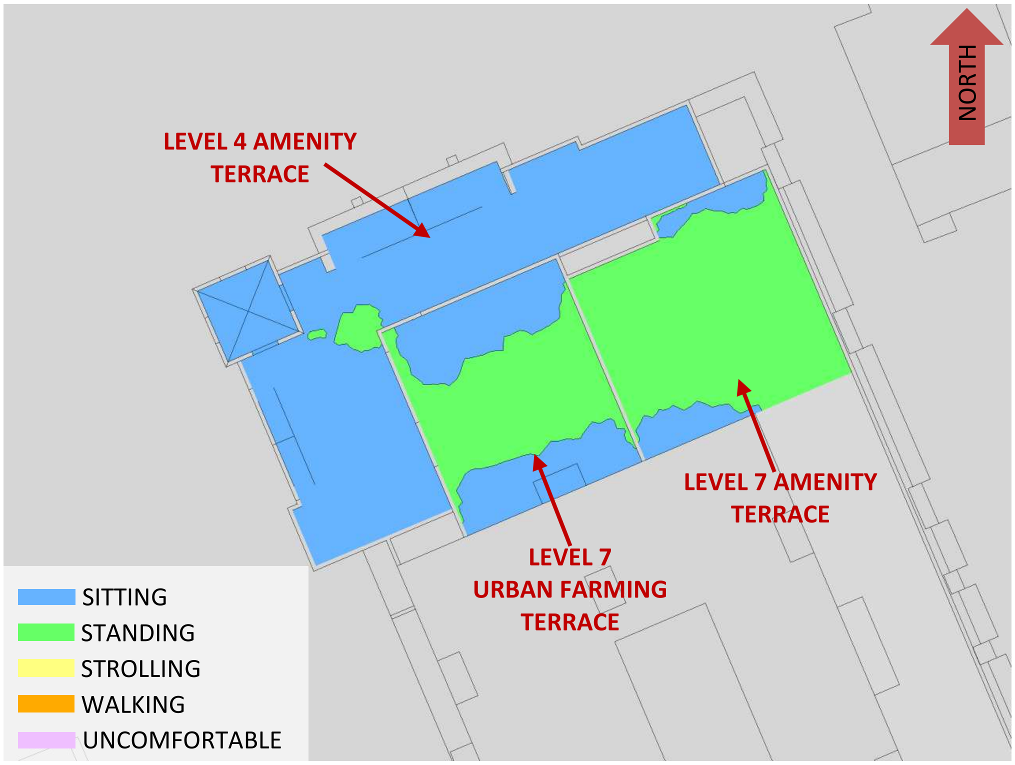
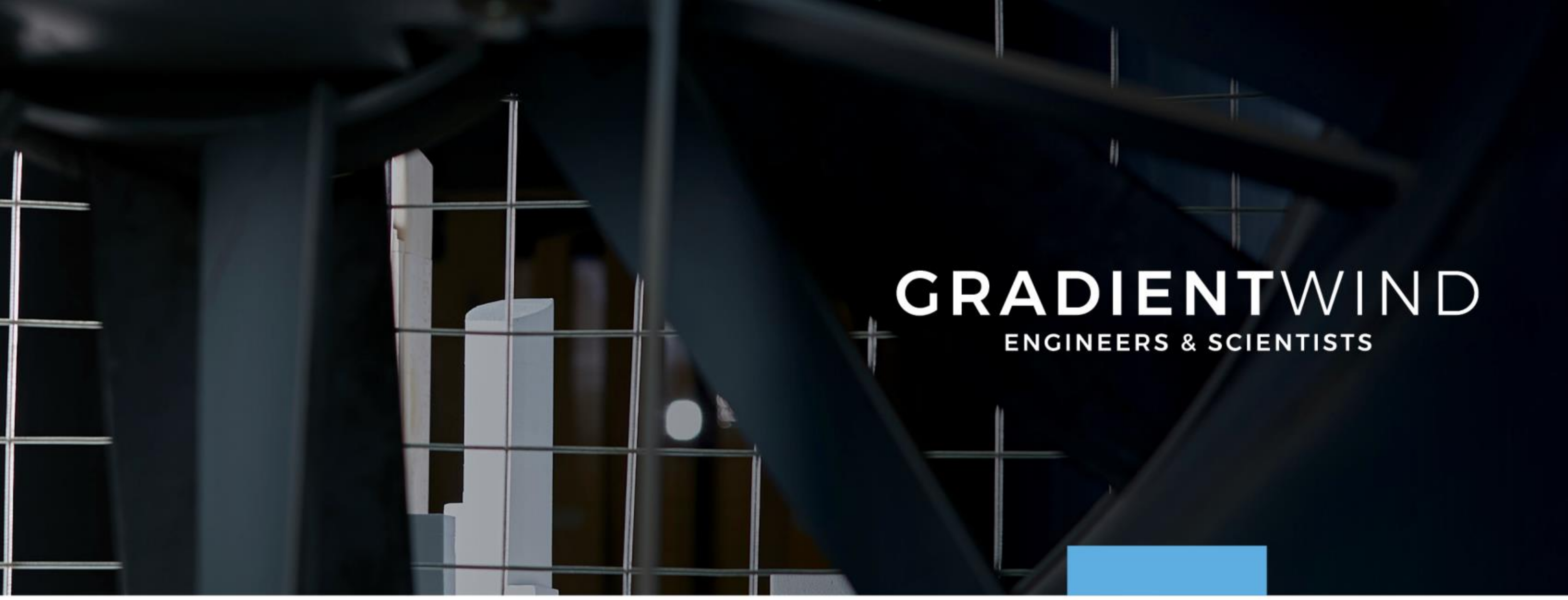
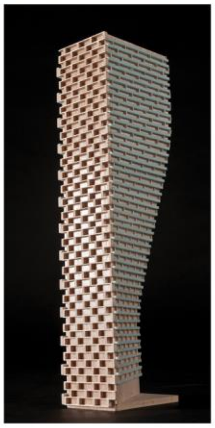
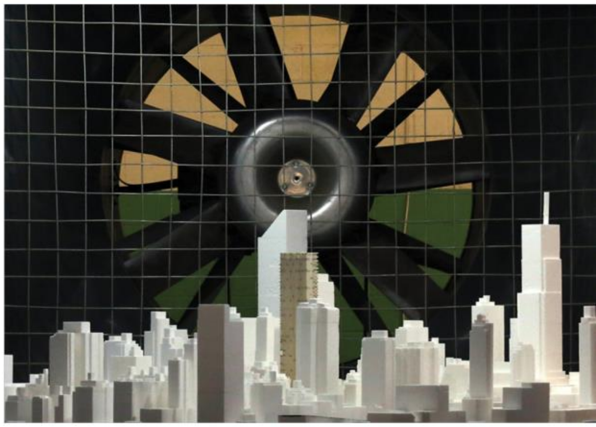



**FIGURE 9: TYPICAL USE PERIOD – WIND COMFORT, COMMON AMENITY TERRACES**





# 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 $\alpha$ 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.

$\alpha$ 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 | 0.27 |
| 49 | 0.26 |
| 74 | 0.25 |
| 103 | 0.25 |
| 167 | 0.23 |
| 197 | 0.21 |
| 217 | 0.22 |
| 237 | 0.25 |
| 262 | 0.25 |
| 282 | 0.23 |
| 301 | 0.22 |
| 324 | 0.24 |

### 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).

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

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

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

[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.