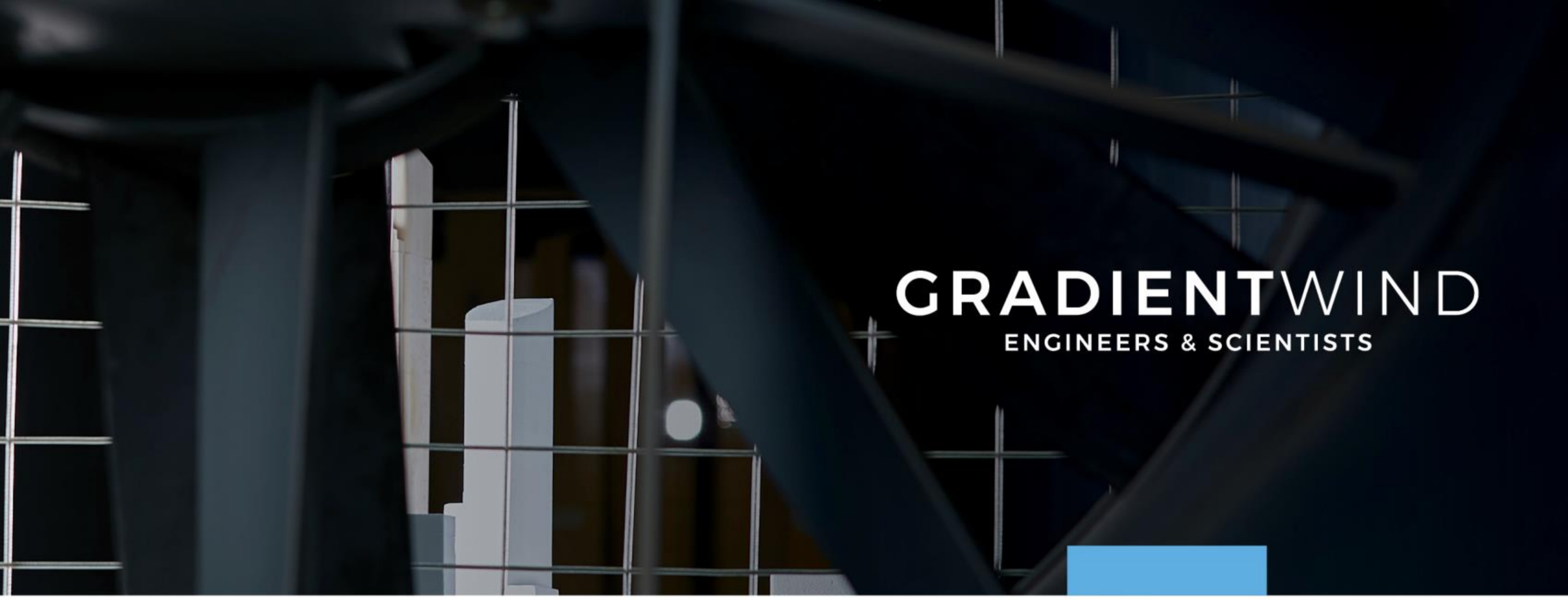
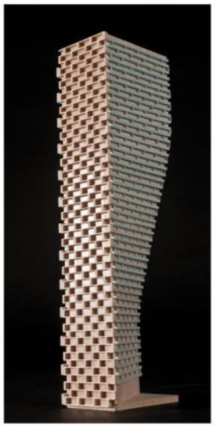
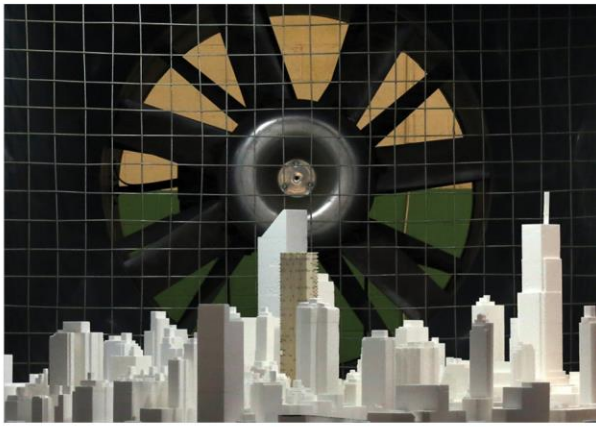


PEDESTRIAN LEVEL WIND STUDY

933 Gladstone Avenue
Ottawa, Ontario

Report: 21-082-PLW





September 23, 2021

PREPARED FOR
Ottawa Community Housing Corporation
39 Auriga Drive
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EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study to satisfy City of Ottawa Site Plan Control application requirements for Gladstone Village Phase 1, a proposed mixed-use residential development located at 933 Gladstone Avenue in Ottawa, Ontario (hereinafter referred to as “subject site”, “proposed development”, or “Phase 1”). Our mandate within this study is to investigate pedestrian wind comfort and safety within and surrounding the subject site, and to identify areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered.

The study involves simulation of wind speeds for selected wind directions in a three-dimensional (3D) computer model using the computational fluid dynamics (CFD) technique, combined with meteorological data integration, to assess pedestrian wind comfort and safety within and surrounding the subject site. A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-8B, and is summarized as follows:

1) Following the introduction of the proposed development, all grade-level areas within and surrounding the subject site are predicted to continue to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year. While the introduction of the proposed development is predicted to increase wind speeds in some areas, conditions over the surrounding sidewalks, building access points, walkways, and the neighbouring Plouffe Park, are predicted to be acceptable for the intended uses on a seasonal basis without mitigation.

2) The amenity terrace and dog park terrace serving the proposed development at Level 4, along the west and east sides of the podium, respectively, are predicted to receive acceptable wind conditions during the typical use period, defined as May to October, inclusive. The dog park terrace is predicted to continue to receive calm conditions during the colder months of the year. These conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

3) The Level 8 roof serving the North Tower is predicted to be suitable for a mix of sitting and standing during the typical use period with the strongest winds concentrated adjacent to the north perimeter of the roof. The boundary of the common amenity terrace atop the roof is situated away from the windiest area on the roof. Conditions within the amenity terrace are predicted to be mostly suitable for sitting during the typical use period; the area that is predicted to be suitable for standing is also predicted to be suitable for sitting for at least 75% of the time during the noted period, where the target is 80%. These conditions are considered acceptable.

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 at grade or on the amenity terraces. 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.

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Ottawa Community Housing (OCH) Corporation to undertake a pedestrian level wind (PLW) study to satisfy City of Ottawa Site Plan Control application requirements for Gladstone Village Phase 1, a proposed mixed-use residential development located at 933 Gladstone Avenue in Ottawa, Ontario (hereinafter referred to as "subject site", "proposed development", or "Phase 1"). 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.

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 Diamond Schmitt Architects and KWC Architects in August and September 2021, surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa, recent satellite imagery, and experience with numerous similar developments.

2. TERMS OF REFERENCE

The master plan is situated on a nominally 32,000 square metre (m^2) trapezoidal-shaped parcel of land in the northwestern portion of the OCH's landholdings, bordered by Gladstone Avenue to the south, existing low-rise housing to the east, Public Works Canada Yard to the north, and the Trillium pathway and light-rail transit corridor to the west. The land will be divided into multiple buildable blocks with new public streets, inclusive of municipal services. The proposed buildings are complemented by new pathways, a street with tree frontage connecting Oak Street to Gladstone Avenue, as well as a new street to the north. Other blocks not forming part of the Phase 1 massing will be developed as subsequent future phases.

Phase 1 comprises two buildings of 18- and 9-storeys connected by a common stepped 5-storey podium including commercial and amenity space. The 18-storey building is referred to as the 'North Tower', while the 9-storey building is referred to as the 'South Mid-Rise'. Phase 1 is also served by below-grade parking with access via a courtyard. The subject site is surrounded by low-rise residential buildings to the east, with light industrial properties to the south, west, and north.

Key areas under consideration include surrounding sidewalks, walkway within and surrounding the subject site, building access points, and common outdoor amenity areas.

Figure 1A illustrates the subject site and surrounding context, representing the proposed future massing scenario, while Figure 1B illustrates the site plan for the existing context. Figures 2A-2F illustrate the computational models used to conduct the comparative study. The existing massing scenario includes the existing massing as well as 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 subject site; (ii) identify areas where wind conditions may interfere with the intended uses of outdoor spaces; and (iii) recommend suitable mitigation measures, where required.

4. METHODOLOGY

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

[1] City of Ottawa Terms of References: Wind Analysis
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 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 proposed landscape elements from the model due to the difficulty of providing accurate seasonal representation of vegetation. The omission of trees and other landscaping elements produces slightly more conservative (i.e., windier) wind speed values.

4.2 Wind Speed Measurements

The PLW analysis was performed by simulating wind flows and gathering velocity data over a CFD model of the subject site for 12 wind directions for the two massing scenarios described in Section 2. The CFD simulation models were centered on the subject site, complete with surrounding massing within a diameter of approximately 820 m.

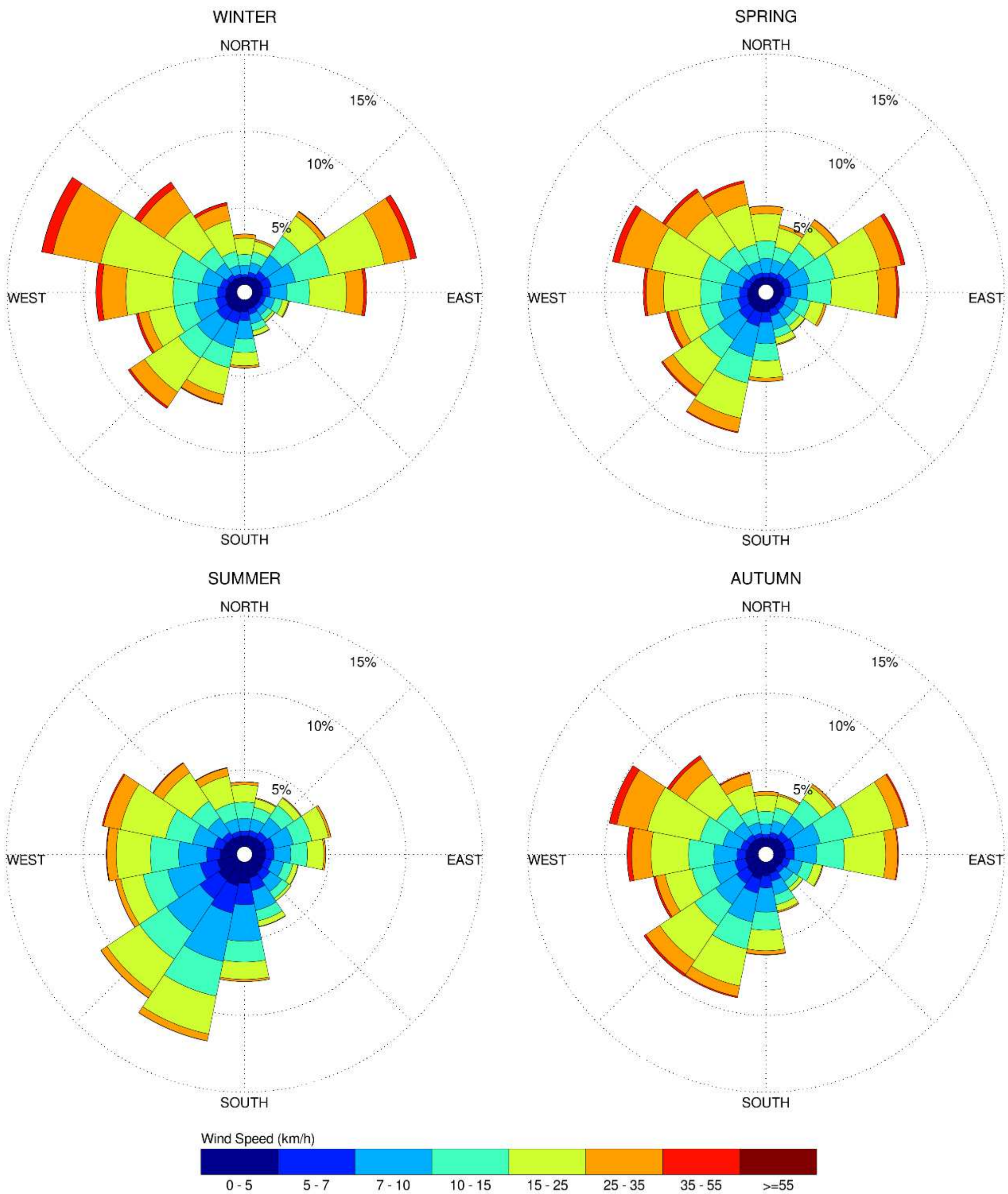
Mean and peak wind speed data obtained over the subject site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade and above the common elevated amenity terraces were referenced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

4.3 Historical Wind Speed and Direction Data

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

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

SEASONAL DISTRIBUTION OF WIND
OTTAWA MACDONALD-CARTIER INTERNATIONAL AIRPORT



Notes:

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

4.4 Pedestrian Comfort and Safety Criteria – City of Ottawa

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

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

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

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

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

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

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

THE BEAUFORT SCALE

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

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

Once the pedestrian wind speed predictions have been established throughout the 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 desired comfort classes, which are dictated by the location type for each region (i.e., a sidewalk, building entrance, amenity space, or other). An overview of common pedestrian location types and their desired comfort classes are summarized on the following page.

DESIRED PEDESTRIAN COMFORT CLASSES FOR VARIOUS LOCATION TYPES

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

5. RESULTS AND DISCUSSION

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

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

5.1 Wind Comfort Conditions – Grade Level

Sidewalk along Street A: Conditions over the sidewalk along Street A 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 noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Walkway along North Elevation: Conditions over the walkway along the north elevation of the proposed development 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 only exception is the northeast and northwest corners of the proposed development, which are predicted to be suitable for strolling during the spring and winter seasons. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Trillium Pathway along West Elevation: Following the introduction of the proposed development, the Trillium Pathway is predicted to be suitable for a mix of sitting and standing during the summer, for standing during the autumn, becoming suitable for strolling, or better, during the spring and winter. The strolling conditions during the spring and winter are located near the southwest corner of the proposed development. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Conditions over the Trillium Pathway with the existing massing are predicted to be suitable for sitting during the summer, becoming suitable for standing during the remaining three colder seasons. While the introduction of the proposed development results in slightly windier conditions in comparison to existing conditions, wind conditions with the proposed development present are considered acceptable.

Amenity Area along West Elevation: Conditions over the amenity space along the west elevation of the proposed development are predicted to be suitable for sitting during the summer and autumn seasons, becoming mostly suitable for sitting during the remaining two colder seasons. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Walkway and Private Patios along South Elevation: Conditions over the walkway along the south elevation are predicted to be suitable for mostly sitting during the summer and autumn, becoming suitable for a mix of sitting and standing throughout the remainder of the year. Within the private patios, conditions are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Plouffe Park North of Proposed Development: Conditions over Plouffe Park, situated to the north of the proposed development, are predicted to be suitable for sitting during the summer, becoming suitable for standing during the remaining three colder seasons. Conditions over Plouffe Park with the existing massing are predicted to be similar to those with the proposed development present. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Building Entrances: Wind conditions in the vicinity of all building entrances serving Phase 1 are predicted to be suitable for sitting during the summer and autumn, and suitable for standing, or better, during the spring and winter. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

5.2 Wind Comfort Conditions – Common Amenity Terraces

Podium, Level 4 Amenity Terrace: Conditions over the Level 4 amenity terrace, located on the west side of the podium, are predicted to be mostly suitable for sitting during the typical use period, as illustrated in Figure 8A. There is one small area which is predicted to be suitable for sitting between 70-75% of the typical use period, as illustrated in Figure 8B. Since the area is small and immediately adjacent to the perimeter guard, and since conditions are close to the target threshold of 80%, it is recommended that these conditions may be considered satisfactory.

Podium, Level 4 Dog Park Terrace: Conditions over the Level 4 dog park terrace, located on the east side of the podium, are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

North Tower, Level 8 Amenity Terrace: Conditions over the Level 8 amenity terrace are predicted to be mostly suitable for sitting during the typical use period; the area that is predicted to be suitable for standing is also predicted to be suitable for sitting for at least 75% of the time during the noted period, as illustrated in Figure 8B, where the target is 80%. These conditions are considered acceptable.

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, including areas at grade and over the amenity terraces, 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. For example, development in urban centers generally creates reduction in the mean wind speeds and localized increases in the gustiness of the wind.

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 of this report 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) Following the introduction of the proposed development, all grade-level areas within and surrounding the subject site are predicted to continue to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year. While the introduction of the proposed development is predicted to increase wind speeds in some areas, conditions over the surrounding sidewalks, building access points, walkways, and the

neighbouring Plouffe Park, are predicted to be acceptable for the intended uses on a seasonal basis without mitigation.

2) The amenity terrace and dog park terrace serving the proposed development at Level 4, along the west and east sides of the podium, respectively, are predicted to receive acceptable wind conditions during the typical use period. The dog park terrace is predicted to continue to receive calm wind conditions during the colder months of the year. These conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

3) The Level 8 roof serving the North Tower is predicted to be suitable for a mix of sitting and standing during the typical use period with the strongest winds concentrated adjacent to the north perimeter of the roof. The boundary of the common amenity terrace atop the roof is situated away from the windiest area on the roof. Conditions within the amenity terrace are predicted to be mostly suitable for sitting during the typical use period; the area that is predicted to be suitable for standing is also predicted to be suitable for sitting for at least 75% of the time during the noted period, where the target is 80%. These conditions are considered acceptable.

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 at grade or on the amenity terraces. 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.

LICENSED PROFESSIONAL ENGINEER
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Sep 23, 2021
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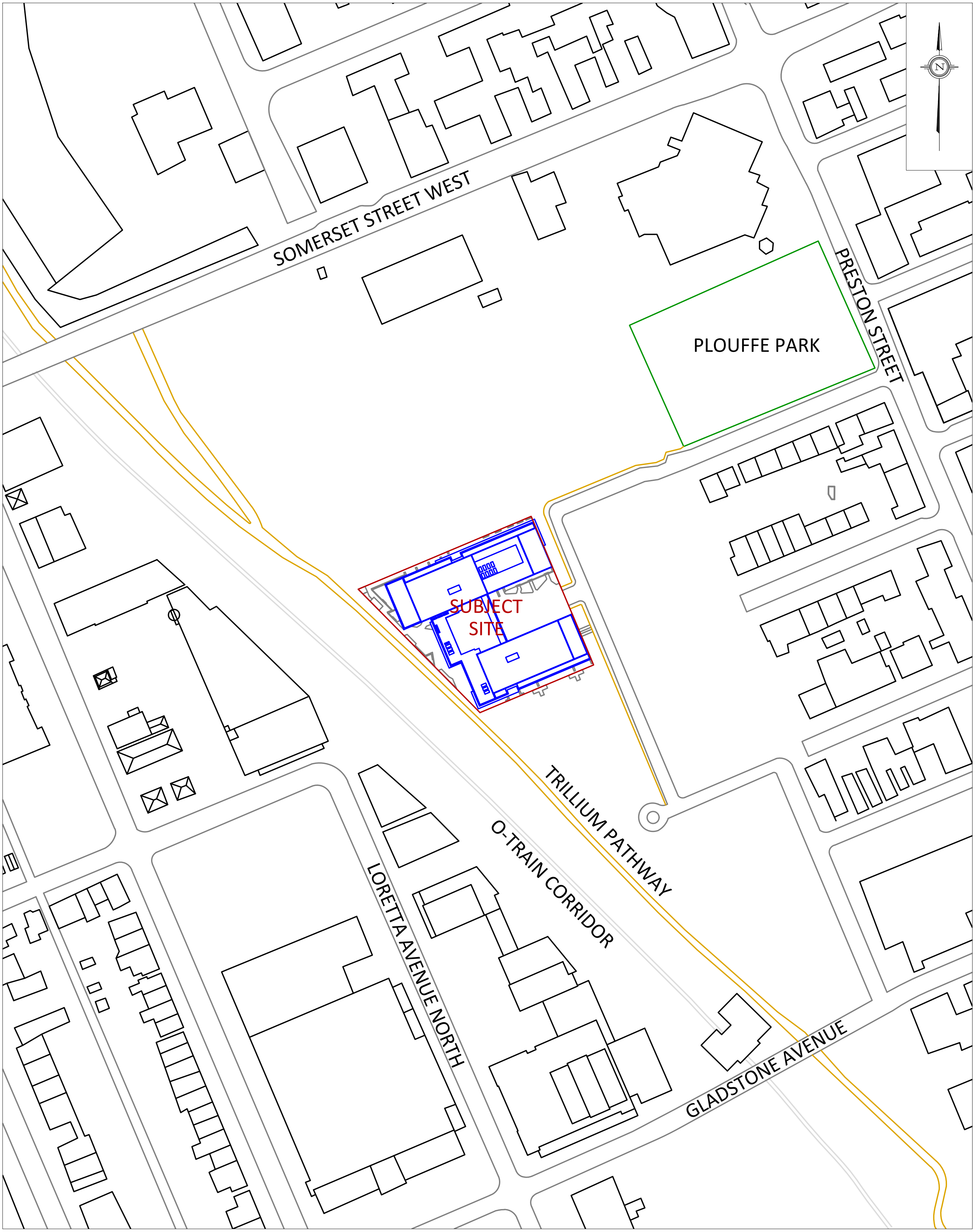

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PROJECT: 933 GLADSTONE AVENUE, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1A: PROPOSED SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:2500	DRAWING NO.: 21-082-PLW-1A	
DATE: SEPTEMBER 23, 2021	DRAWN BY: O.R.	

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PROJECT: 933 GLADSTONE AVENUE, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1B: EXISTING SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:2500	DRAWING NO.: 21-082-PLW-1B	
DATE: SEPTEMBER 23, 2021	DRAWN BY: O.R.	

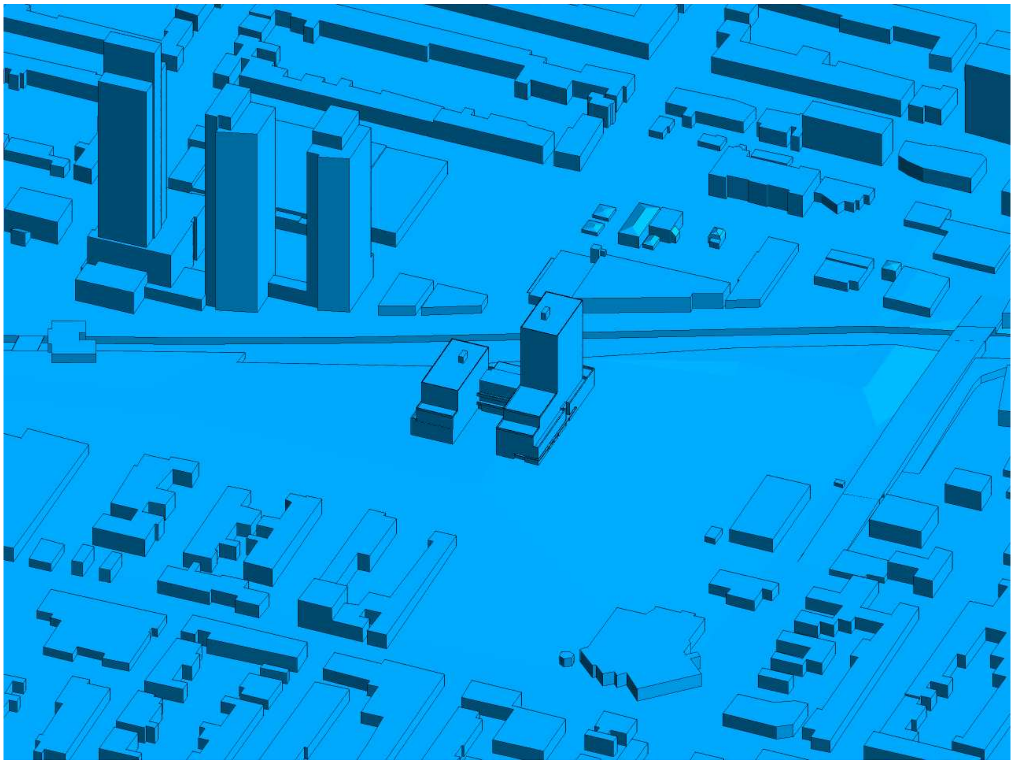


FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTHEAST PERSPECTIVE

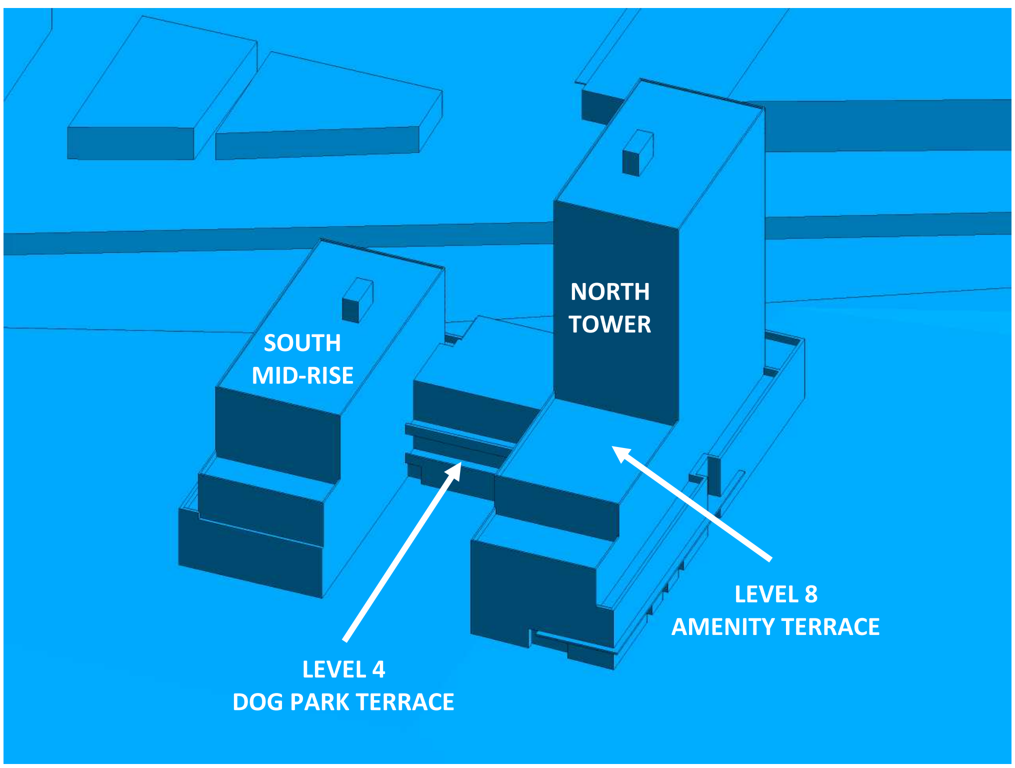


FIGURE 2B: CLOSE-UP VIEW OF FIGURE 2A

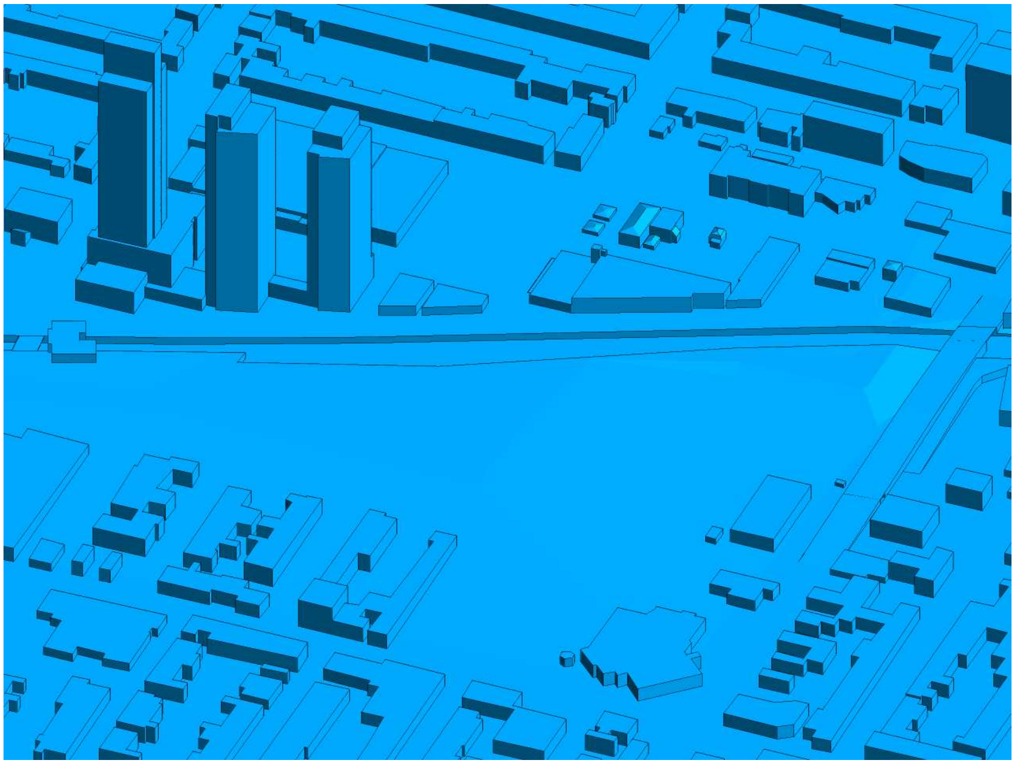


FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, NORTHEAST PERSPECTIVE

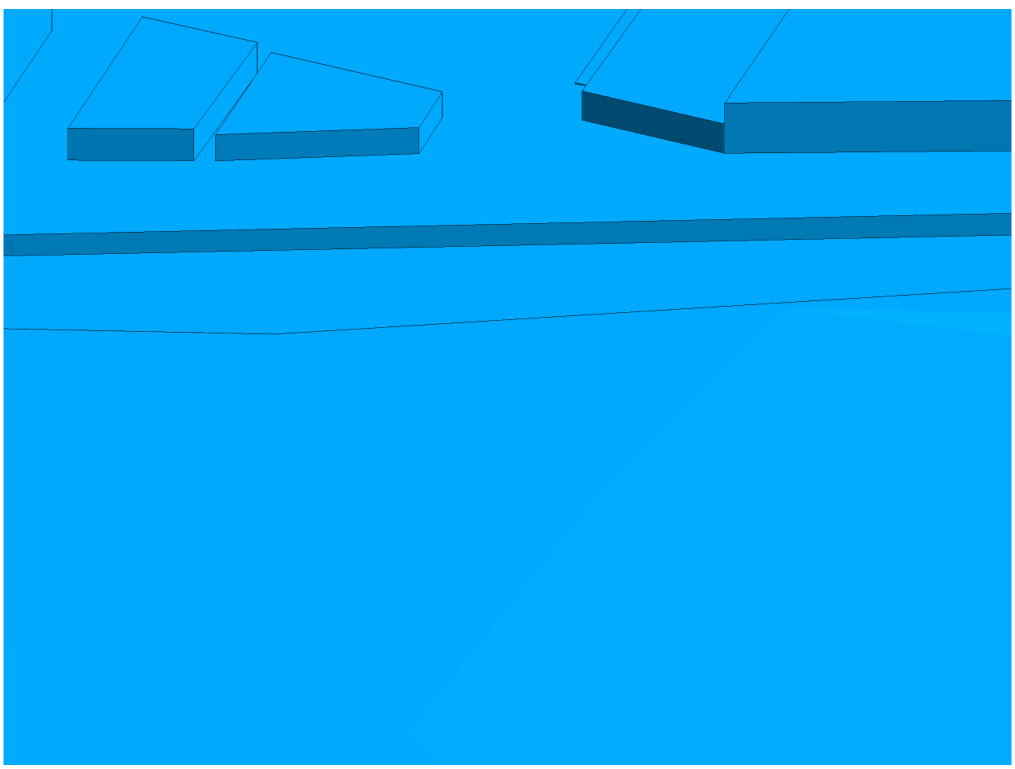


FIGURE 2D: CLOSE-UP VIEW OF FIGURE 2C

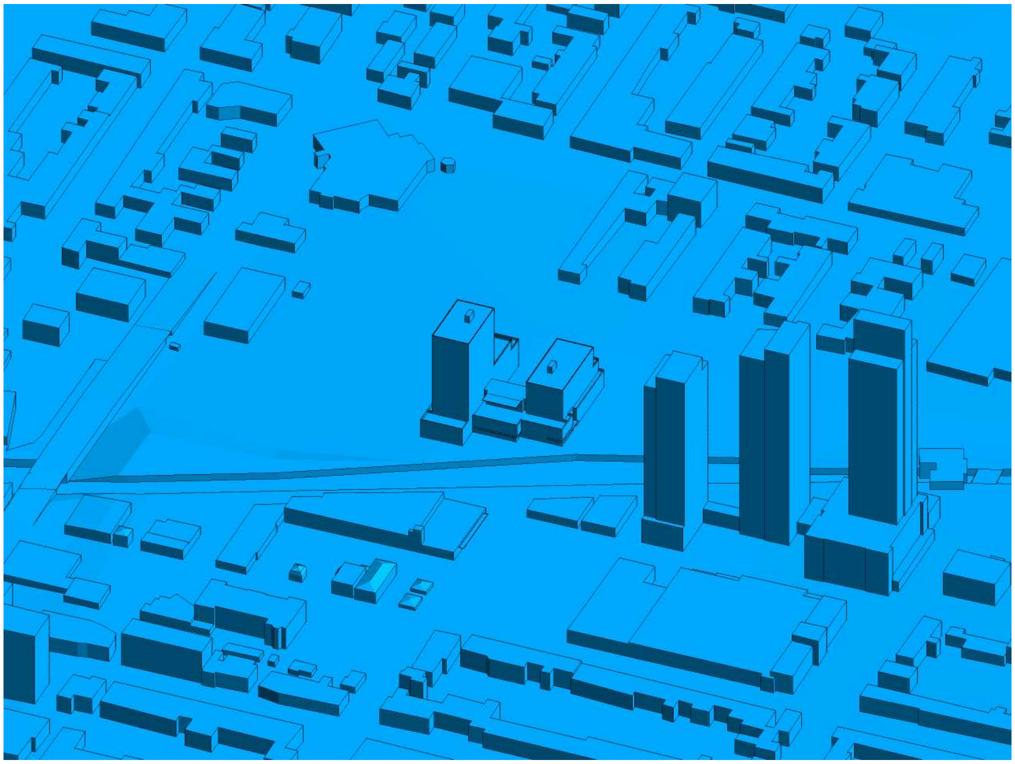


FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTHWEST PERSPECTIVE

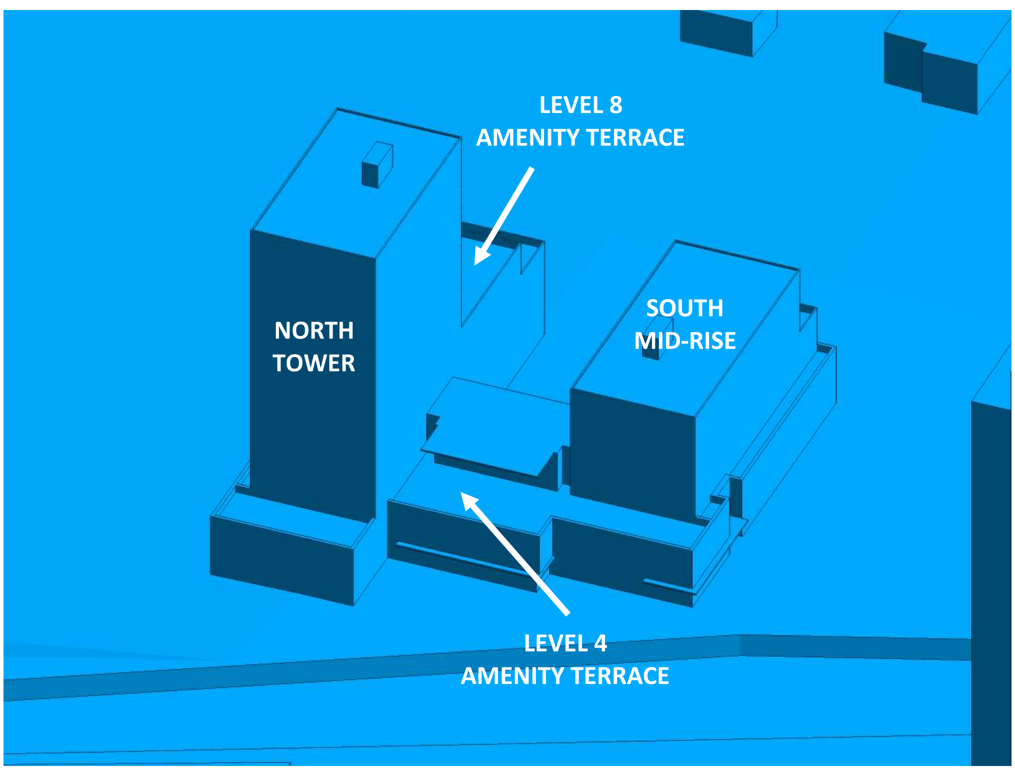


FIGURE 2F: CLOSE-UP VIEW OF FIGURE 2E

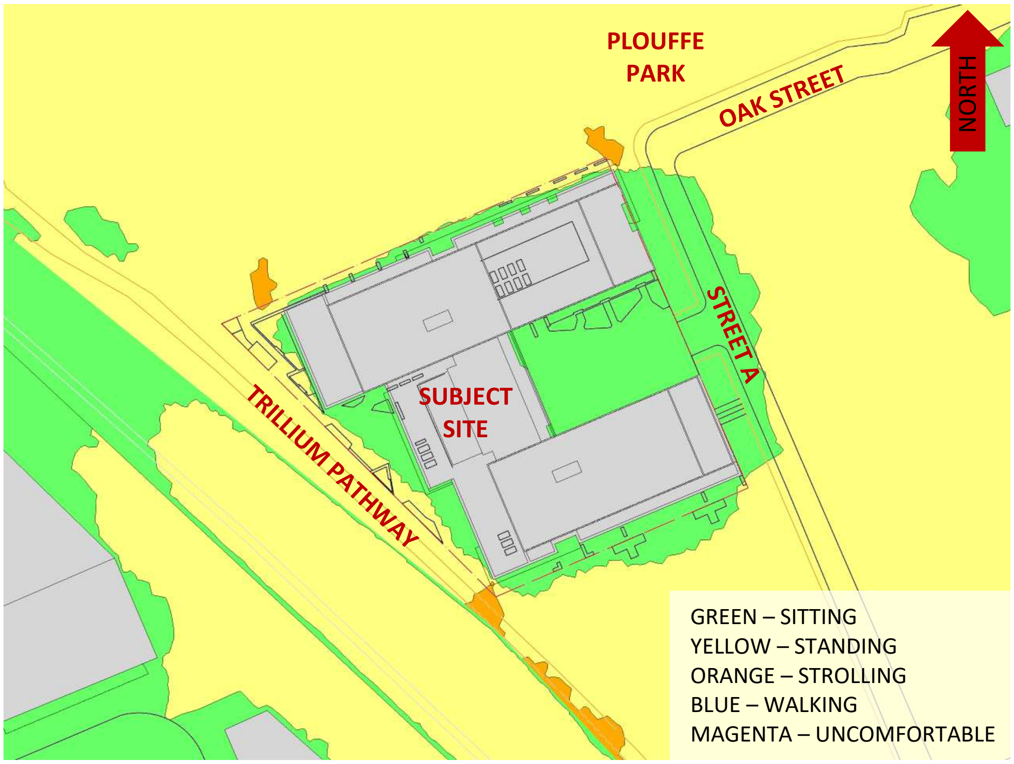


FIGURE 3A: SPRING – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

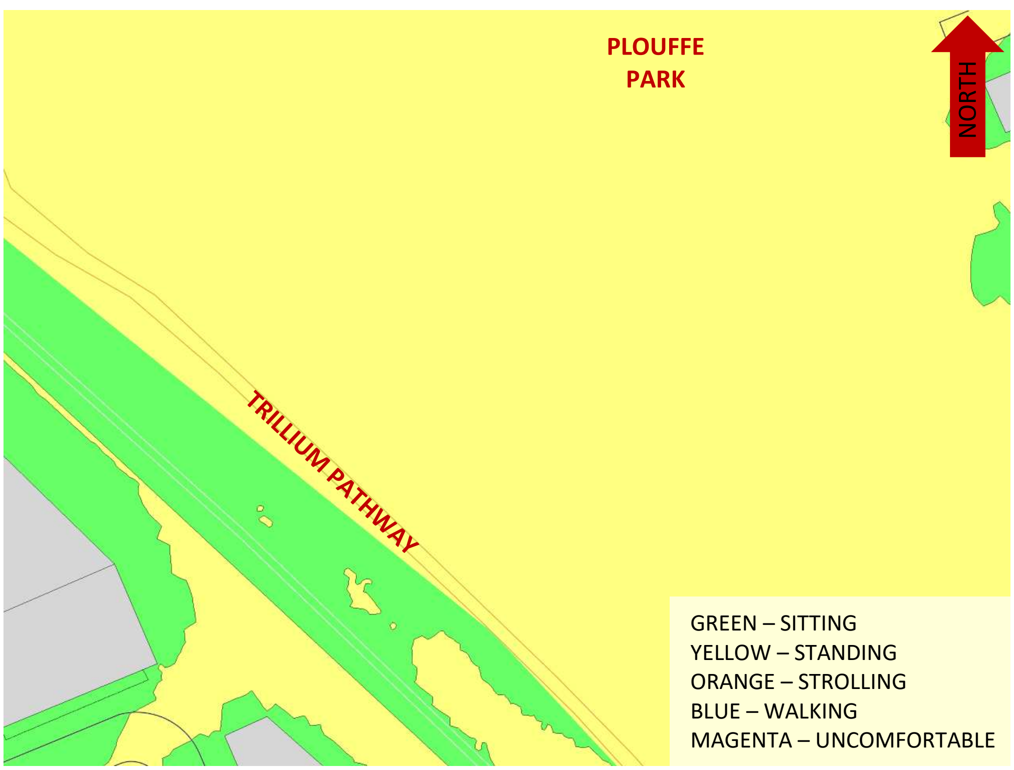


FIGURE 3B: SPRING – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

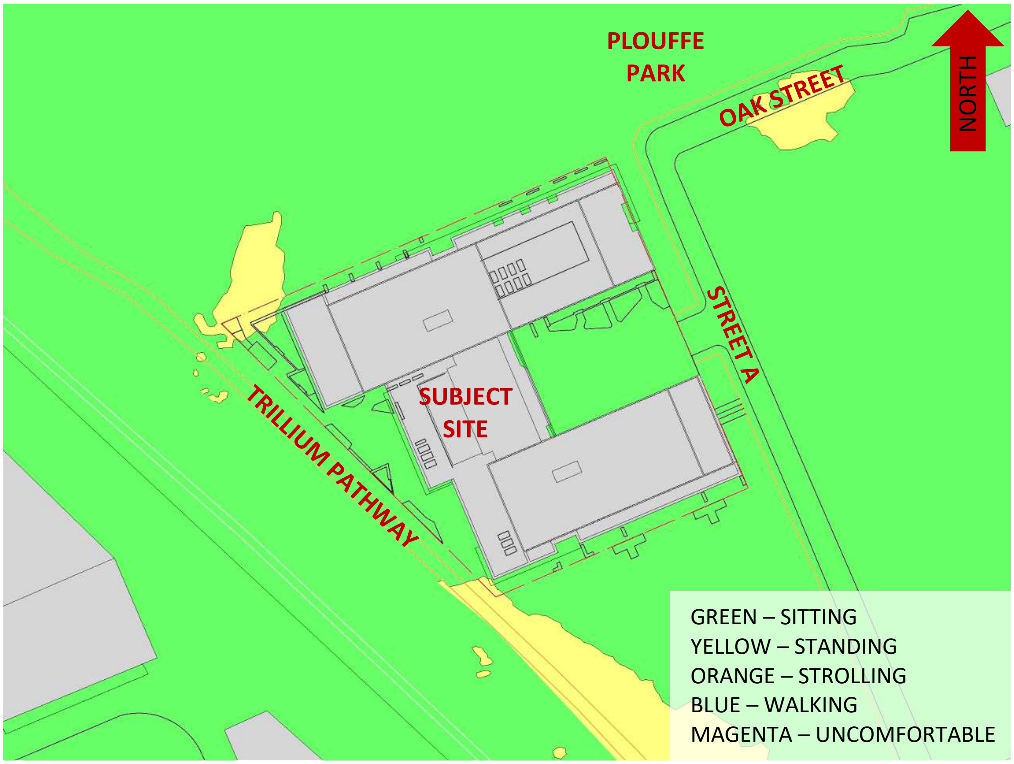


FIGURE 4A: SUMMER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

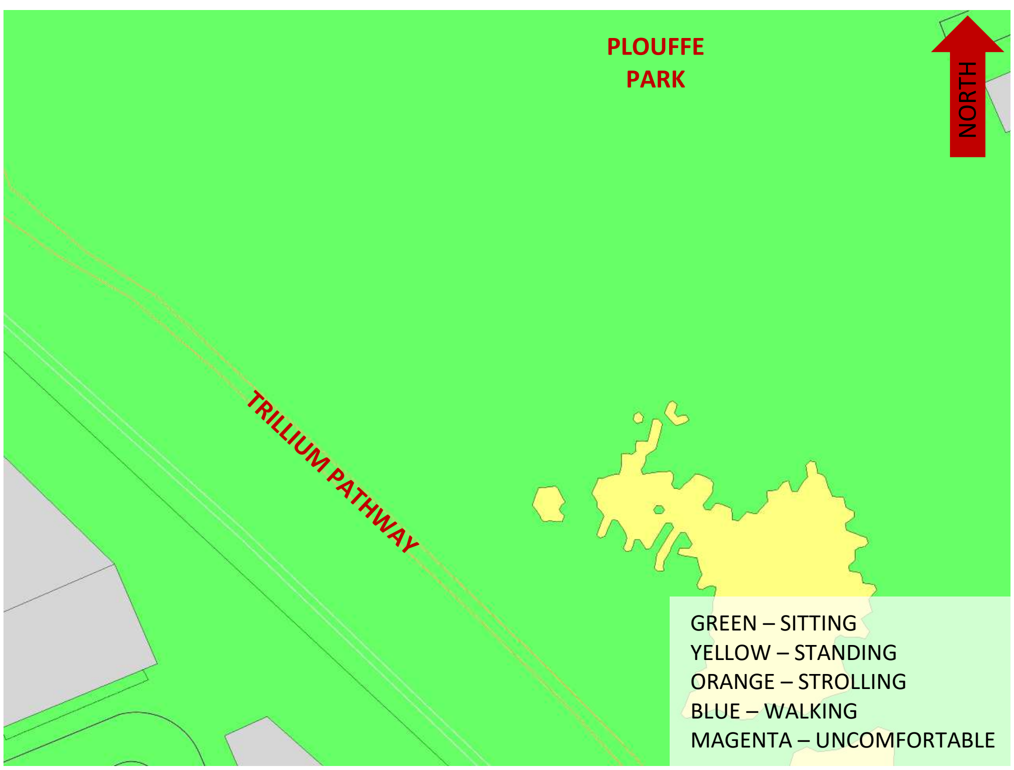


FIGURE 4B: SUMMER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

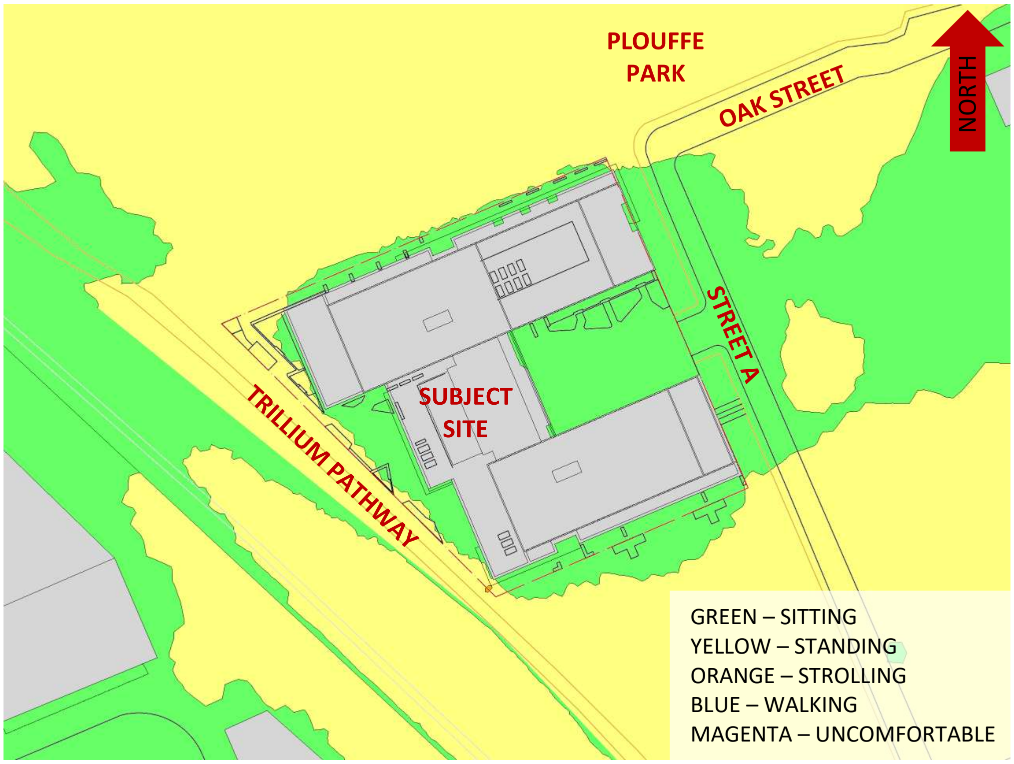


FIGURE 5A: AUTUMN – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

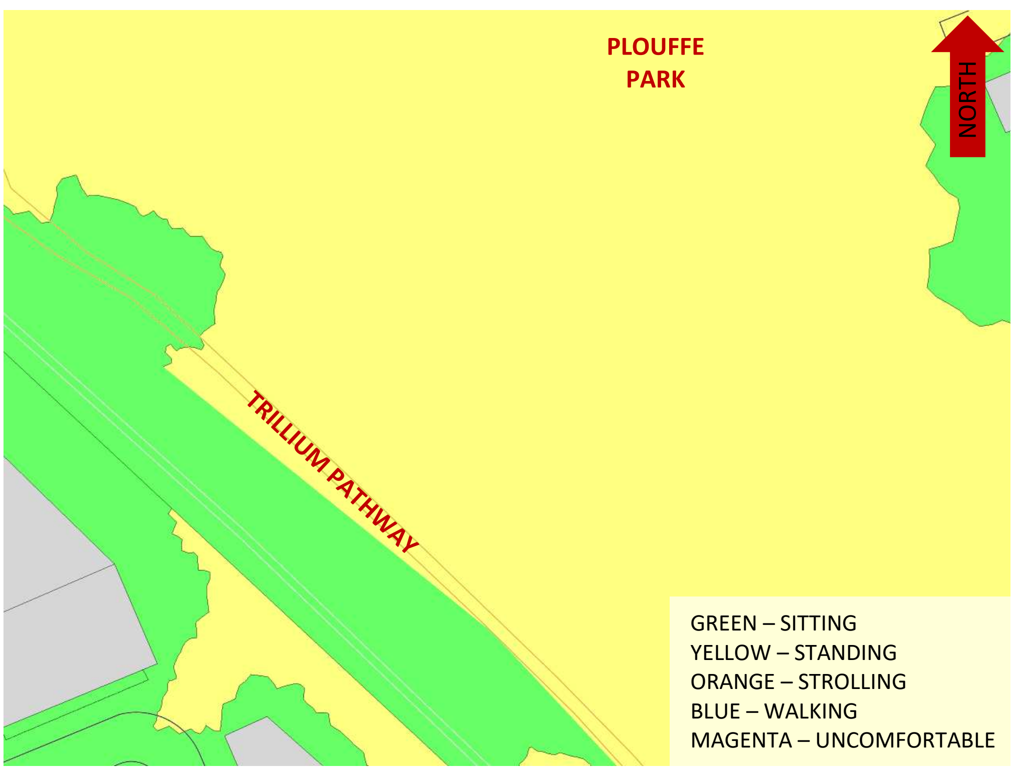


FIGURE 5B: AUTUMN – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

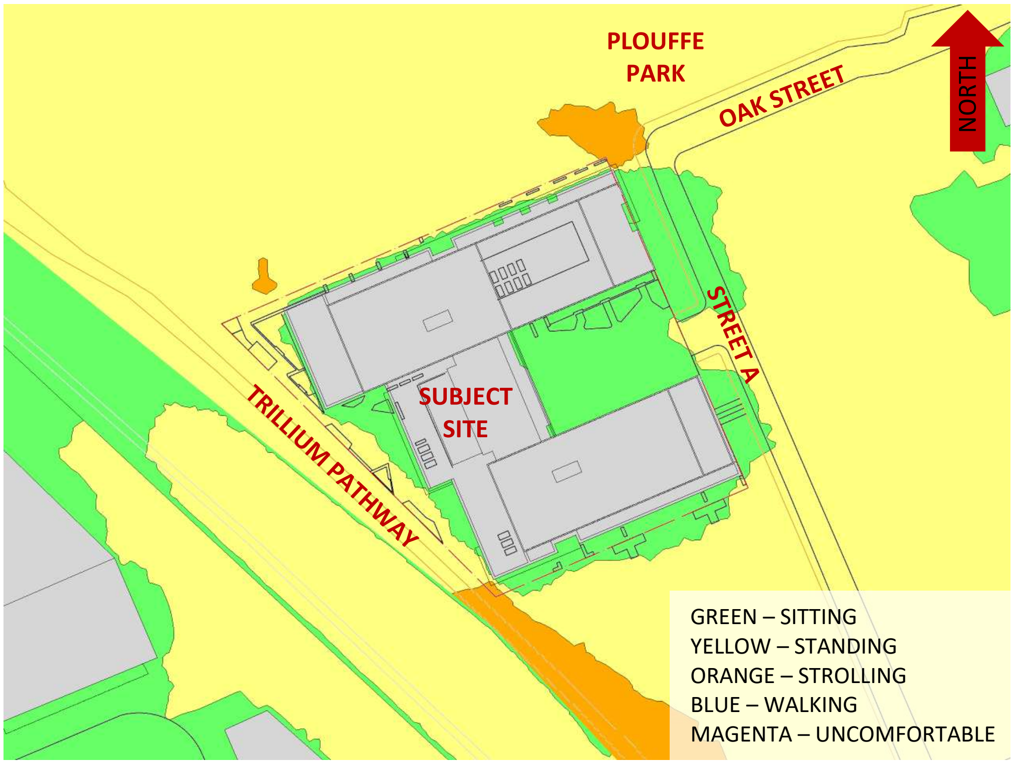


FIGURE 6A: WINTER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

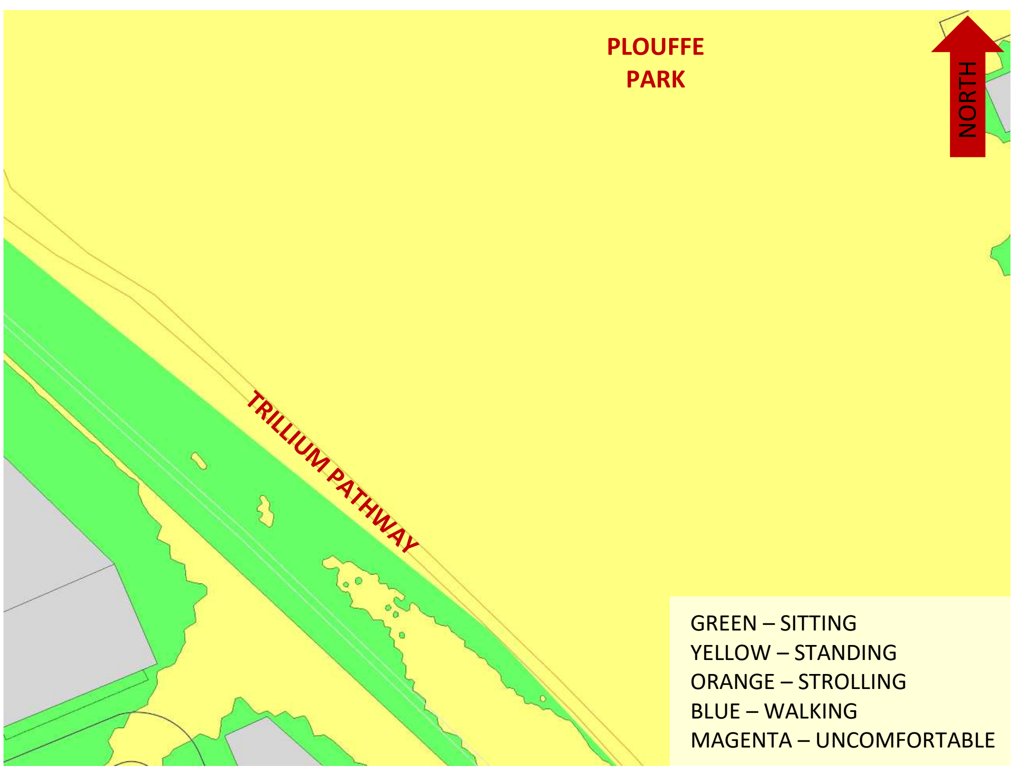


FIGURE 6B: WINTER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

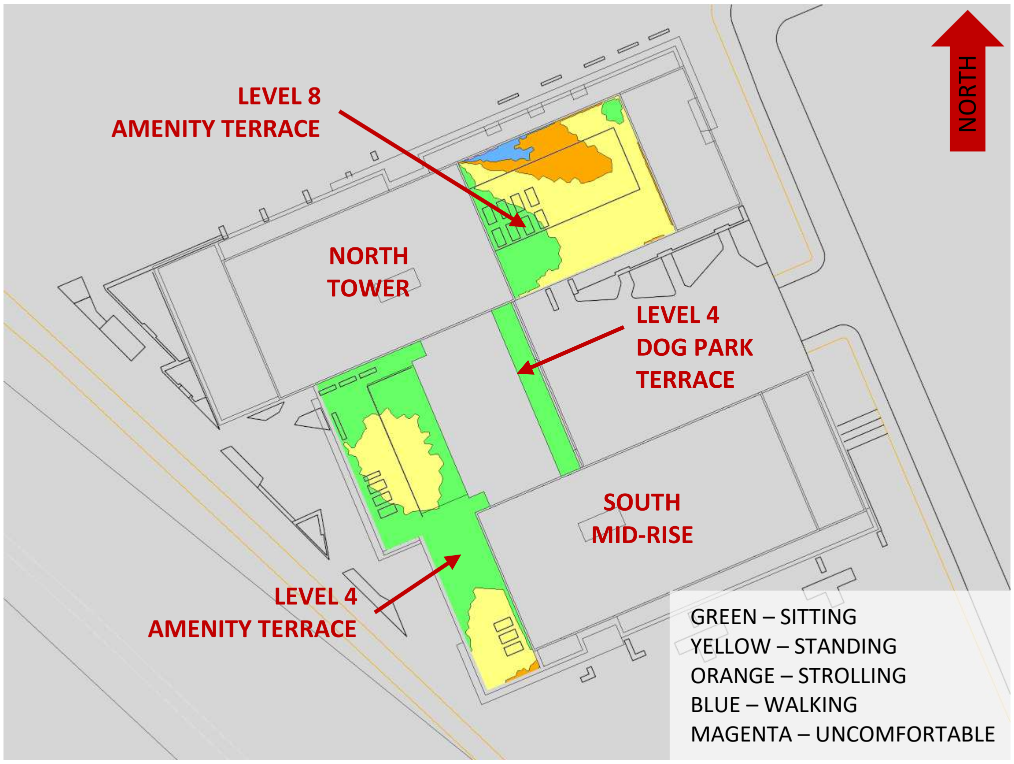


FIGURE 7A: SPRING – WIND COMFORT, AMENITY TERRACES

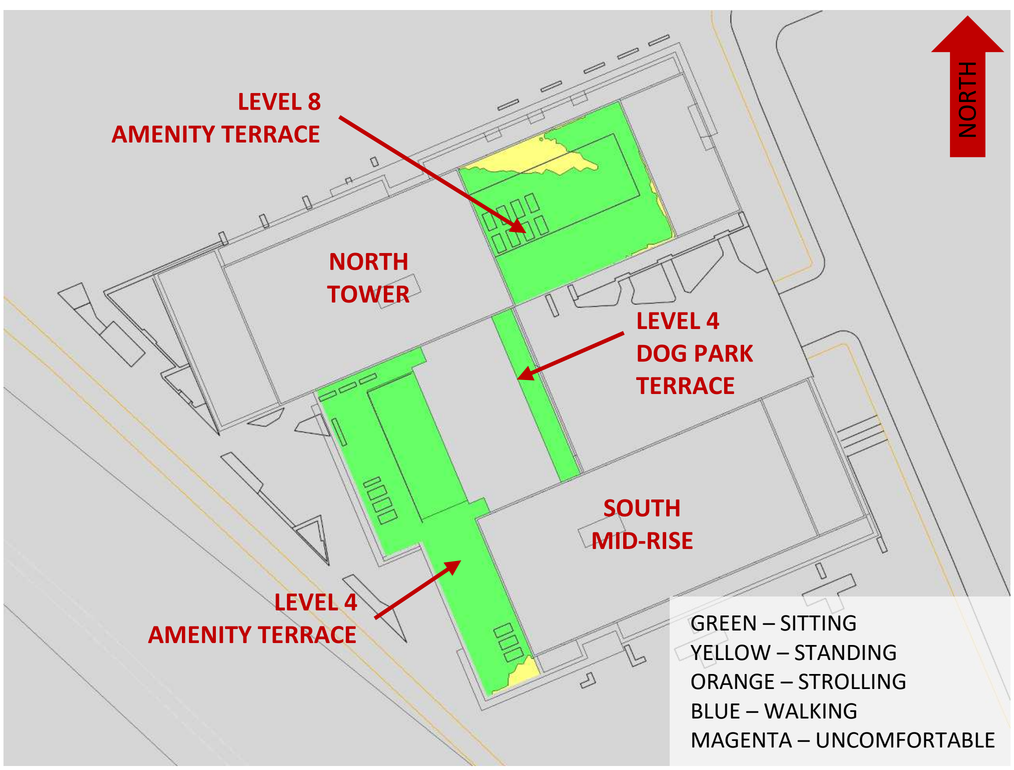


FIGURE 7B: SUMMER – WIND COMFORT, AMENITY TERRACES

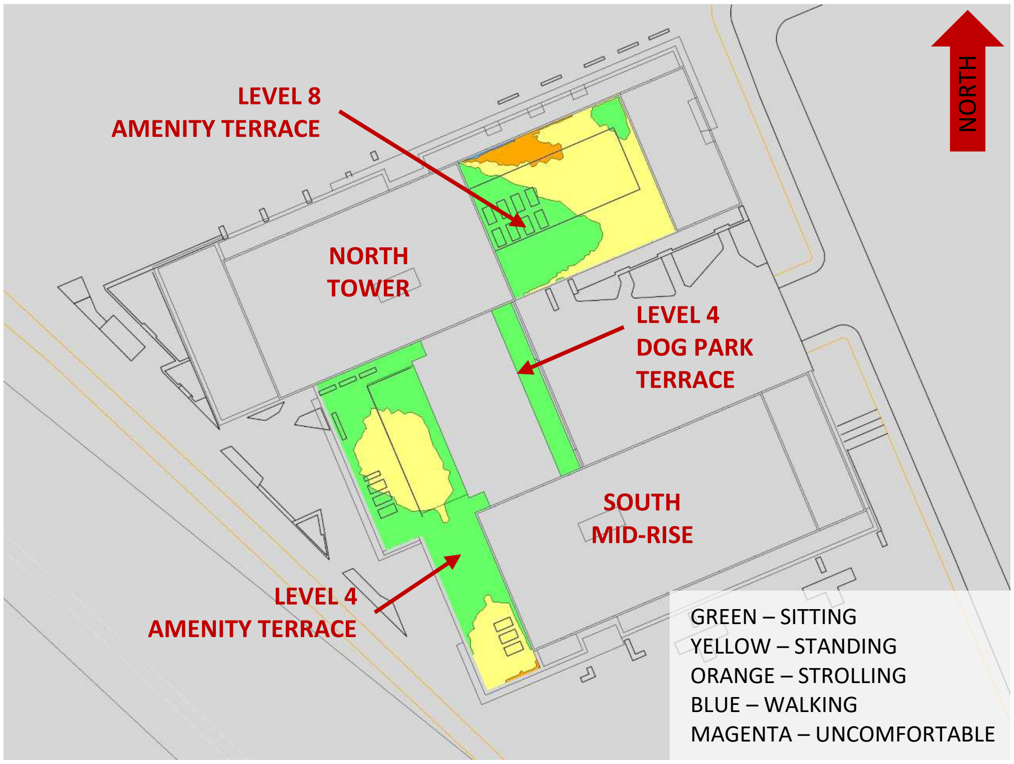


FIGURE 7C: AUTUMN – WIND COMFORT, AMENITY TERRACES

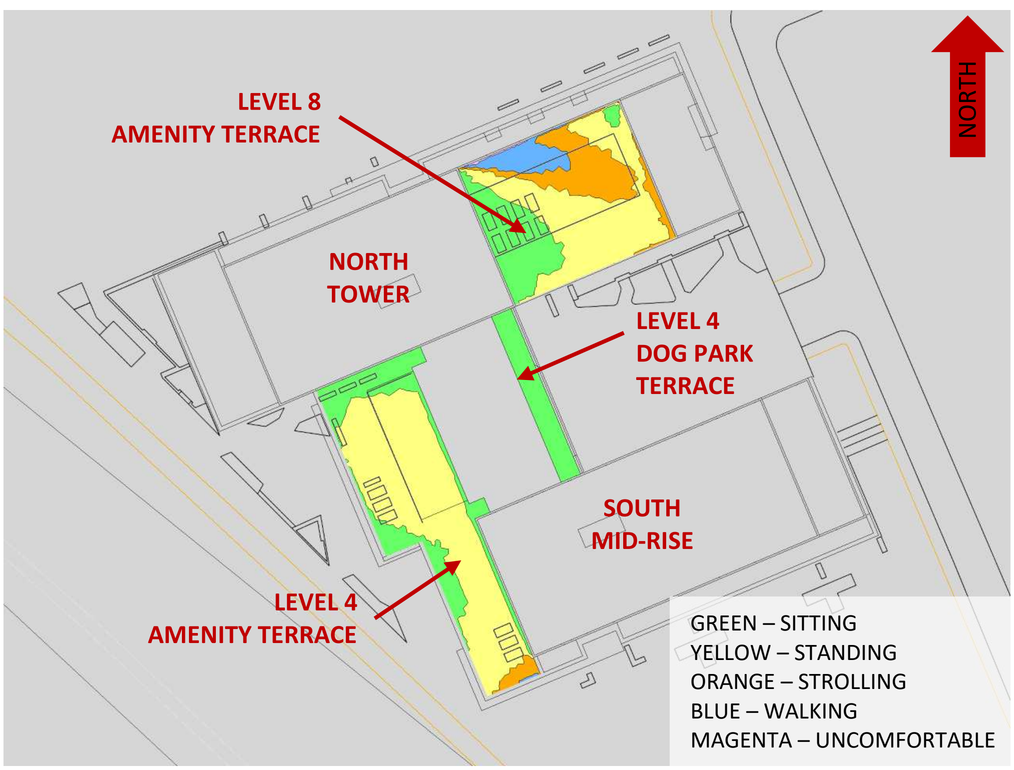


FIGURE 7D: WINTER – WIND COMFORT, AMENITY TERRACES

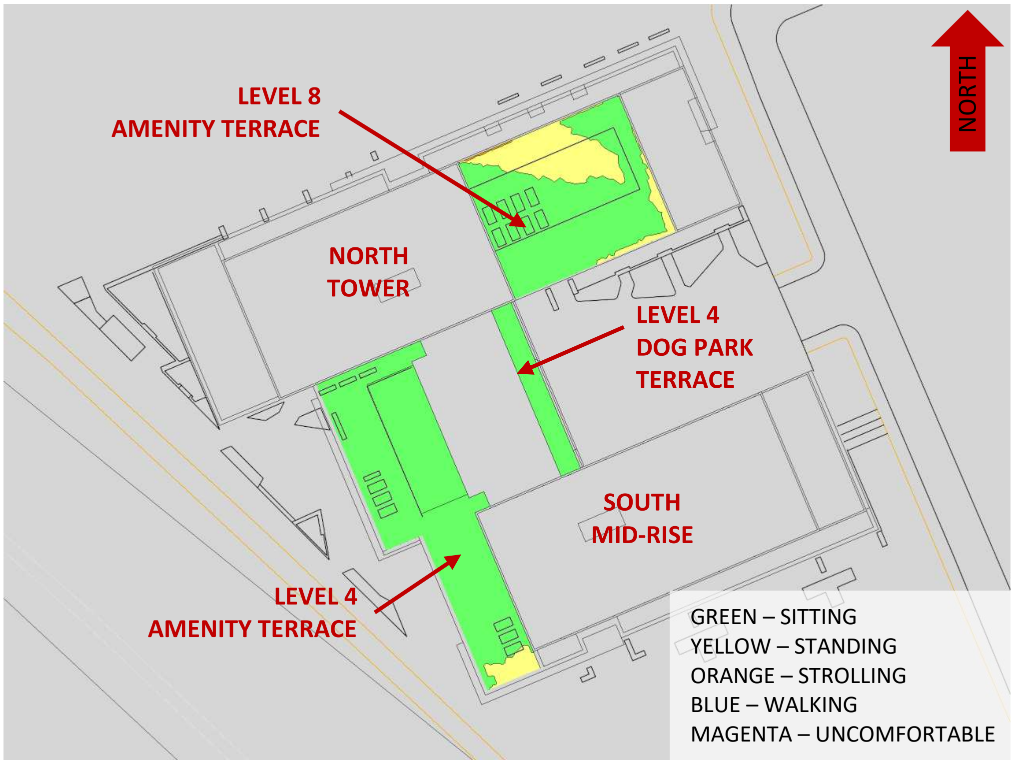


FIGURE 8A: TYPICAL USE PERIOD (MAY-OCTOBER) – WIND COMFORT, AMENITY TERRACES

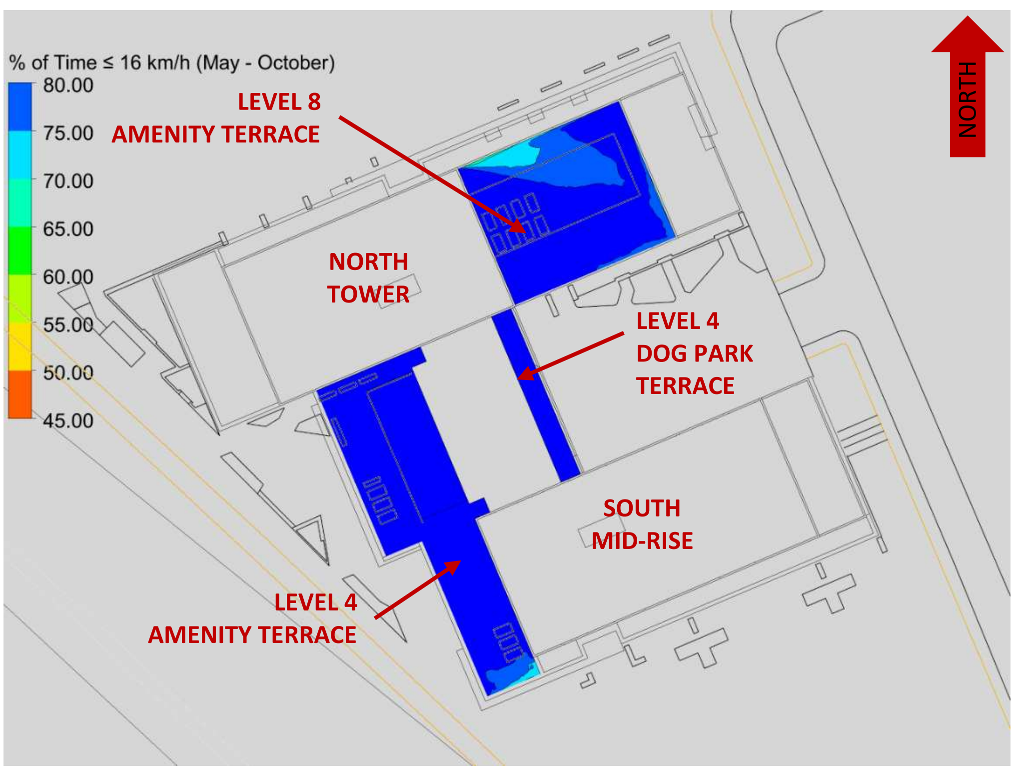
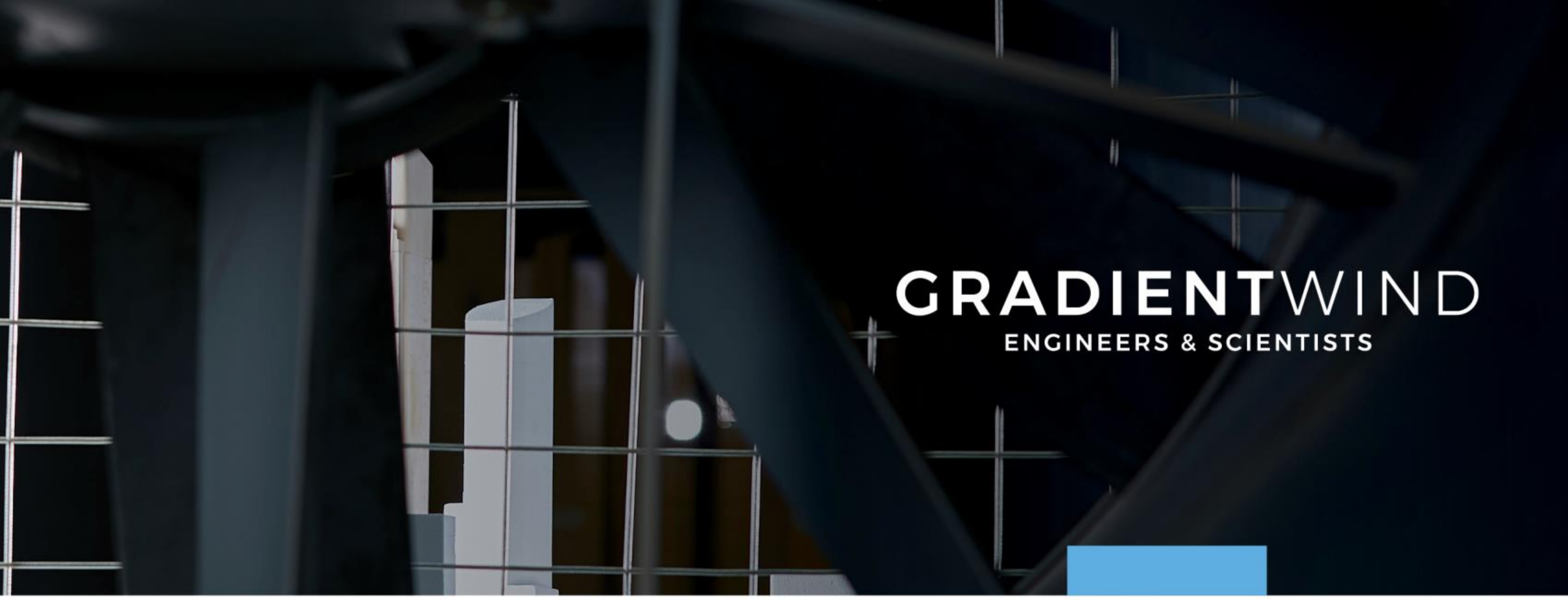


FIGURE 8B: TYPICAL USE PERIOD – % OF TIME SUITABLE FOR SITTING, AMENITY TERRACES



APPENDIX A

SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

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

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

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

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

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

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

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

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

Wind Direction (Degrees True)	Alpha Value (α)
0	0.25
49	0.27
74	0.25
103	0.25
167	0.22
197	0.24
217	0.25
237	0.25
262	0.25
282	0.24
302	0.22
324	0.22

TABLE 2: DEFINITION OF UPSTREAM EXPOSURE (ALPHA VALUE)

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

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

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

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

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

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

REFERENCES

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