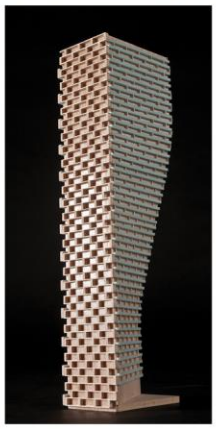
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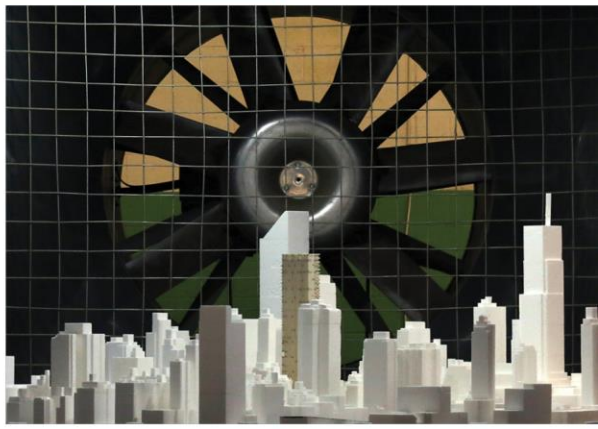
PEDESTRIAN LEVEL WIND STUDY

380 Hagey Boulevard
Waterloo, Ontario

Report: 25-032-PLW







April 16, 2024

PREPARED FOR

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EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study undertaken to satisfy application requirements for the proposed hotel development located at 380 Hagey Boulevard in Waterloo, 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 sixteen (16) 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 Waterloo wind comfort and safety criteria. A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-4B, and is summarized as follows:

1) Most 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 public sidewalks, transit stops, neighbouring existing surface parking lots, proposed drive aisles, the patio adjoining the indoor pool, the loading space, drop-off areas, surface parking, and walkways, and in the vicinity of building access points, are considered acceptable.

2) Regarding the outdoor amenity at the southwest corner of the proposed development, conditions during the summer are predicted to be suitable for a mix of sitting and standing.

    a. The conceptual landscape plans for the amenity incorporate vegetation, shade structures, and other common landscaping elements that are expected to be effective in mitigating windier conditions over this area during the summer, while seating areas are programmed to the southeast where wind conditions are predicted to be suitable for sitting. Marcescent trees may be employed along the south and west perimeters of the noted seating areas to provide further shelter from wind during the summer months.

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 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.

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1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Kothari Group to undertake a pedestrian level wind (PLW) study to satisfy application requirements for the proposed hotel development located at 380 Hagey Boulevard in Waterloo, 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 Waterloo wind comfort and safety criteria, architectural drawings prepared by Chamberlain Architect Services Limited in March 2025, surrounding street layouts and existing and approved future building massing information obtained from the City of Waterloo, recent satellite imagery, and experience with numerous similar developments.

2. TERMS OF REFERENCE

The subject site is located at 380 Hagey Boulevard in Waterloo, situated to the southeast at the intersection of Hagey Boulevard and Wes Graham Way, located on a parcel of land bounded by Hagey Boulevard to the west, Wes Graham Way to the north, and low-rise buildings with surface parking lots to the east and south. The proposed development comprises a 9-storey hotel located at the northwest corner of the subject site. An outdoor amenity is proposed at the southwest corner of the subject site, drop-off areas are located at the rear of the building, and surface parking extends throughout the remainder of the subject site. Access to the noted vehicular areas is provided by internal drive aisles extending from Hagey Boulevard and Wes Graham Way from the southwest and northeast corners of the subject site, respectively.

The ground floor of the proposed development comprises an 'L'-shaped planform with its long axis-oriented along Wes Graham Way. The short-axis comprises conference rooms, while the long-axis includes a central lobby with main entrances to the north and south, a pool at the northeast corner with an adjoining outdoor patio, meeting rooms to the south, a bar/café near the northwest corner, and various indoor amenities and shared building support spaces throughout the remainder of the floor.

At Level 2, the building steps back from all elevations creating a near rectangular planform. Levels 2-9 are reserved for hotel guestrooms.

Regarding wind exposures, the near-field surroundings (defined as an area falling within a 200-metre (m) radius of the subject site) include low-rise buildings with surface parking lots from the east clockwise to the west-northwest and green space from the northwest clockwise to the northeast and to the southeast. The far-field surroundings (defined as the area beyond the near field and within a 2-kilometre (km) radius) are characterized by low-rise suburban massing in all compass directions with isolated clusters of mid- and high-rise buildings along King Street and within the Wilfred Laurier University and University of Waterloo campuses from the east clockwise to the south-southwest. The University of Waterloo Environmental Reserve and other green areas primarily define the southwest to northwest wind directions.

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 approved future developments.

3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind conditions at key areas within and surrounding the development site; (ii) identify areas where wind conditions may interfere with the intended uses of outdoor spaces; and (iii) recommend suitable mitigation measures, where required.

4. METHODOLOGY

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

[1] The City of Waterloo, *Terms of Reference: Wind Study*, 2023
TOR Wind Study (waterloo.ca)

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 Region of Waterloo International Airport in Breslau, Ontario. The general concept and approach to CFD modelling is to represent building and topographic details in the immediate vicinity of the subject site on the surrounding model, and to create suitable atmospheric wind profiles at the model boundary. The wind profiles are designed to have similar mean and turbulent wind properties consistent with actual site exposures.

An industry standard practice is to omit trees, vegetation, and other existing and planned landscape elements from the model due to the difficulty of providing accurate seasonal representation of vegetation. The omission of trees and other landscaping elements produces stronger 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 16 wind directions. The CFD simulation model was centered on the proposed development, complete with surrounding massing within a radius of 490 m. The process was performed for two context massing scenarios, as noted in Section 2.

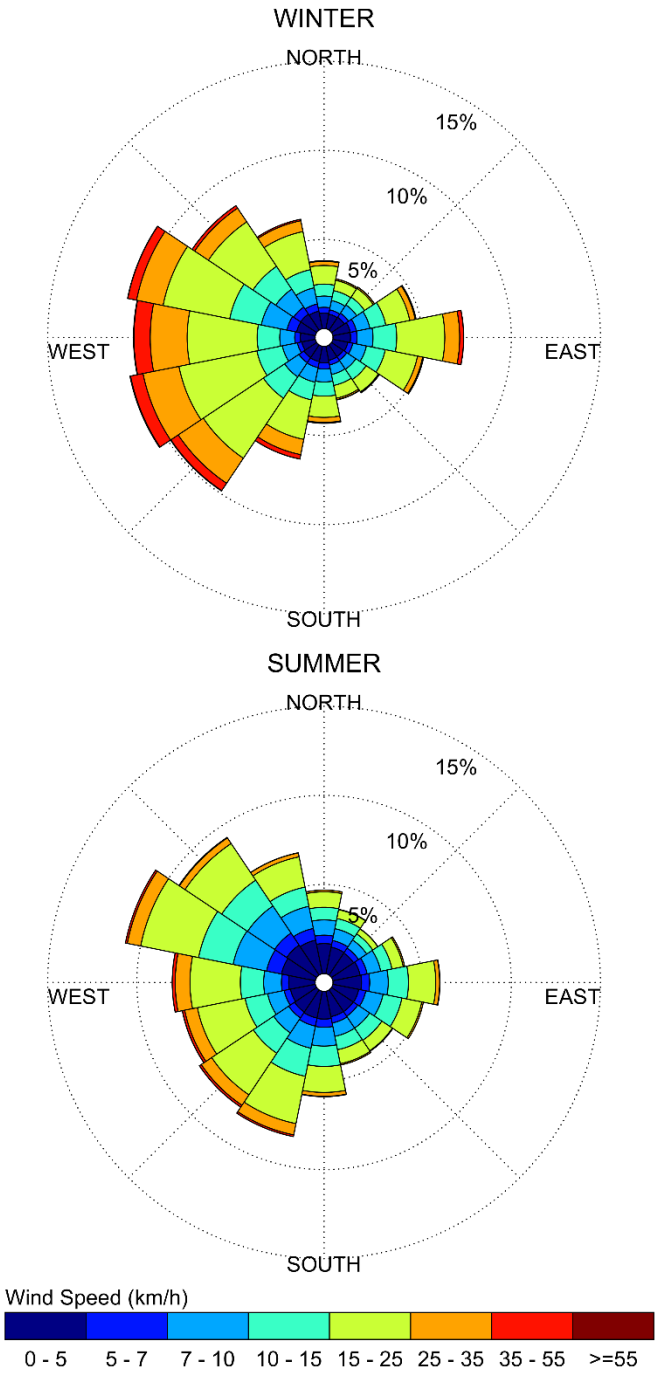
Mean and peak wind speed data obtained over the study site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade were referenced to the wind speed at gradient height to generate 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 Waterloo was developed from 44 years of hourly meteorological wind data recorded at Region of Waterloo International Airport and obtained from Environment and Climate Change Canada. Wind speed and direction data were analyzed during the appropriate hours of pedestrian usage (that is, between 06:00 and 23:00) and divided into two distinct seasons, as stipulated in the wind criteria. Specifically, the summer season is defined as May through October, while the winter season is defined as November through April, inclusive.

The statistical model of the Waterloo 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 shows the frequency distribution of wind speeds for each wind direction during the measurement period. The prominent wind speeds and directions can be identified by the longer length of the bars. For Waterloo, the common winds concerning pedestrian comfort occur from the south-southwest clockwise to north-northwest, as well as those from the east. The directional prominence and relative magnitude of the wind speed varies somewhat from season to season, with the summer months displaying the calmest winds relative to the remaining seasonal periods.

SEASONAL DISTRIBUTION OF WIND
REGION OF WATERLOO 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 Waterloo

Pedestrian wind comfort and safety guidelines are based on the mechanical effects of wind without consideration of other meteorological conditions (that is, temperature and relative humidity). The comfort criteria assume that pedestrians are appropriately dressed for a specified outdoor activity during any given season. Since both mean and gust wind speeds affect pedestrian comfort, their combined effect is defined in the City of Waterloo Pedestrian Level Wind Studies Terms of Reference. Specifically, the criteria are defined as a Gust Equivalent Mean (GEM) wind speed, which is the greater of the mean wind speed or the gust wind speed divided by 1.85.

The wind speed ranges are based on the Beaufort scale, which describes the effects of forces produced by varying wind speed levels on objects. Four pedestrian comfort classes and corresponding gust wind speed ranges are used to assess pedestrian comfort: (1) Sitting; (2) Standing; (3) Walking; and (4) Uncomfortable. Specifically, the comfort classes, associated wind speed ranges, and limiting criteria are summarized as follows:

PEDESTRIAN WIND COMFORT CLASS DEFINITIONS

Wind Comfort Class	GEM Speed (km/h)	Description
SITTING	≤ 10	GEM wind speeds no greater than 10 km/h occurring at least 80% of the time are considered acceptable for sedentary activities, including sitting.
STANDING	≤ 15	GEM wind speeds no greater than 15 km/h occurring at least 80% of the time are considered acceptable for activities such as standing, strolling, or more vigorous activities.
WALKING	≤ 20	GEM wind speeds no greater than 20 km/h occurring at least 80% of the time are considered acceptable for walking or more vigorous activities.
UNCOMFORTABLE	> 20	Uncomfortable conditions are characterized by predicted values that fall below the 80% target for walking. Brisk walking and exercise, such as jogging, are considered acceptable for moderate excesses of this criterion.

Regarding wind safety, gust wind speeds greater than 90 km/h, occurring more than 0.1% of the time on an annual basis (based on wind events recorded for 24 hours a day), are classified as dangerous. From calculations of stability, it can be shown that gust wind speeds of 90 km/h would be the approximate threshold wind speed that would cause an average elderly person in good health to fall.

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

TARGET PEDESTRIAN WIND COMFORT CLASSES FOR VARIOUS LOCATION TYPES

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

5. RESULTS AND DISCUSSION

The following discussion of the predicted pedestrian wind conditions for the subject site is accompanied by Figures 3A-4B, which illustrate wind conditions at grade level for the proposed and existing massing scenarios. Conditions are presented as continuous contours of wind comfort within and surrounding the subject site and correspond to the various comfort classes noted in Section 4.4.

The details of these conditions are summarized below for each area of interest.

5.1 Wind Comfort Conditions

Sidewalks and Transit Stops along Hagey Boulevard: Prior to and following the introduction of the proposed development**,** wind comfort conditions over the nearby public sidewalks along Hagey Boulevard are predicted to be suitable for standing, or better, during the summer, becoming suitable for a mix of standing and walking during the winter. Conditions in the vicinity of the nearby transit stops along Hagey Boulevard are predicted to be suitable for standing, or better, throughout the year. The noted conditions are considered acceptable.

Sidewalks along Wes Graham Way: Prior to and following the introduction of the proposed development**,** wind conditions over the nearby public sidewalks along Wes Graham Way are predicted to be suitable for mostly standing during the summer, becoming suitable for a mix of standing and walking during the winter. The noted conditions are considered acceptable.

Neighbouring Existing Surface Parking Lots: Prior to and following the introduction of the proposed development**,** conditions over the nearby surface parking lots to the east and south of the subject site are predicted to be suitable for standing, or better, during the summer, becoming suitable for walking, or better, during the winter. The noted conditions are considered acceptable.

Outdoor Amenity Serving the Proposed Development: During the summer, wind comfort conditions over the outdoor amenity located at the southwest corner of the proposed development are predicted to be suitable for a mix of sitting and standing.

Specifically, regions of conditions suitable for standing are located at the southwest corner and central to the area and sitting conditions are predicted elsewhere throughout the remainder of the outdoor amenity. Where conditions are suitable for standing, they are also suitable for sitting at least 77% of the time during the same period, where the target is 80% to achieve the sitting comfort class.

The conceptual landscape plans for the space incorporate vegetation, shade structures, and other common landscaping elements that are expected to be effective in mitigating windier conditions over this area during the summer months. Furthermore, the windier areas within the amenity are located to the northwest, whereas seating areas are programmed to the southeast where calmer wind conditions suitable for sitting are mostly predicted. It is recommended to implement marcescent trees along the south and west perimeters of the seating areas to provide further shelter from wind during the summer months.

Pool Patio: Wind conditions during the summer within the patio adjoining the indoor pool are predicted to be suitable for mostly sitting and are considered acceptable.

Proposed Drive Aisles, Loading Space, Drop-off Areas, Surface Parking, and Walkways: Wind conditions over the proposed drive aisles, loading space, drop-off areas, and surface parking within the subject site are predicted to be suitable for mostly standing, or better, throughout the year, with isolated regions suitable for walking. The noted conditions are considered acceptable.

Building Access Points: Owing to the protection of the building façade, conditions in the vicinity of the building access points serving the proposed development are predicted to be suitable for sitting during the summer, becoming suitable for standing, or better, during the winter. The noted conditions are considered acceptable.

5.2 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.

5.3 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 of this report and illustrated in Figures 3A-4B. Based on computer simulations using the CFD technique, meteorological data analysis of the Waterloo area wind climate, City of Waterloo wind comfort and safety criteria, and experience with numerous similar developments, the study concludes the following:

1) Most 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 public sidewalks, transit stops, neighbouring existing surface parking lots, proposed drive aisles, the patio adjoining the indoor pool, the loading space, drop-off areas, surface parking, and walkways, and in the vicinity of building access points, are considered acceptable.

2) Regarding the outdoor amenity at the southwest corner of the proposed development, conditions during the summer are predicted to be suitable for a mix of sitting and standing.

    a. The conceptual landscape plans for the amenity incorporate vegetation, shade structures, and other common landscaping elements that are expected to be effective in mitigating windier conditions over this area during the summer, while seating areas are programmed to the southeast where wind conditions are predicted to be suitable for sitting. Marcescent trees may be employed along the south and west perimeters of the noted seating areas to provide further shelter from wind during the summer months.

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 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,

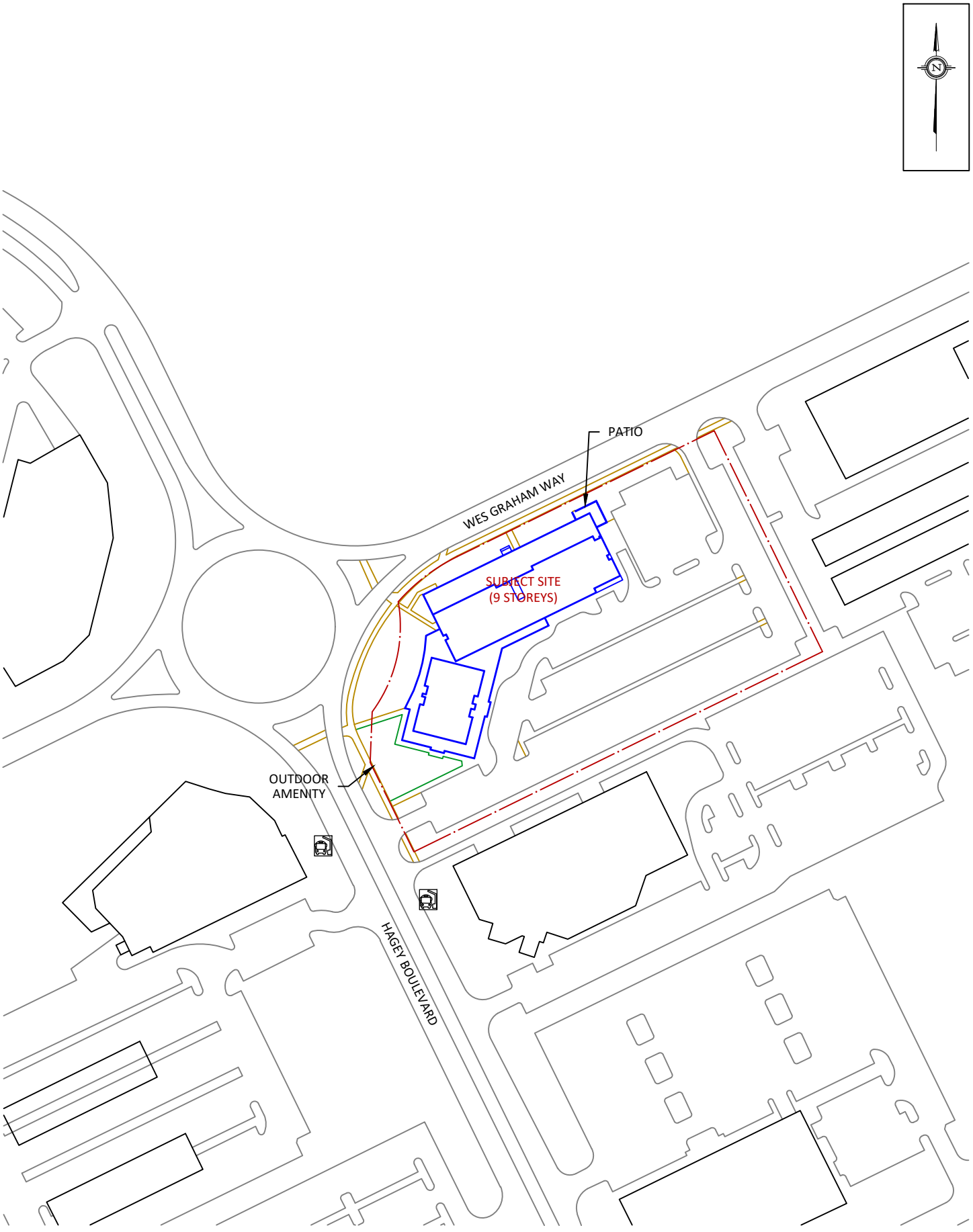
Gradient Wind Engineering Inc.



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Wind Scientist

David Huitema, M.Eng., P.Eng.
CFD Lead Engineer

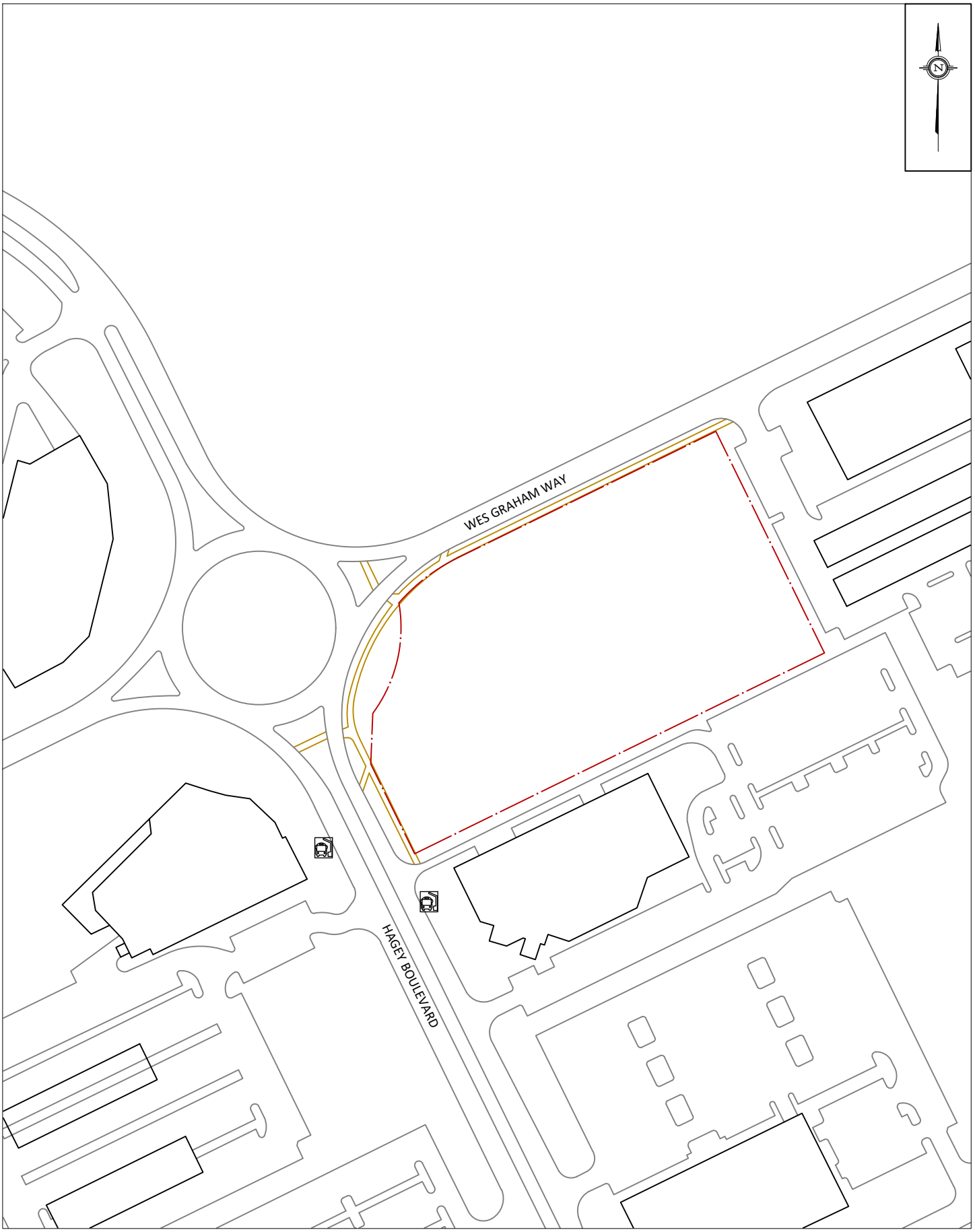
Sunny Kang, B.A.S.
Project Coordinator



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PROJECT	380 HAGEY BOULEVARD, WATERLOO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION
SCALE	1:2000	DRAWING NO. 25-032-PLW-1A	FIGURE 1A: PROPOSED SITE PLAN AND SURROUNDING CONTEXT
DATE	APRIL 16, 2025	DRAWN BY S.K.	



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PROJECT	380 HAGEY BOULEVARD, WATERLOO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION
SCALE	1:2000	DRAWING NO. 25-032-PLW-1B	FIGURE 1B: EXISTING SITE PLAN AND SURROUNDING CONTEXT
DATE	APRIL 16, 2025	DRAWN BY S.K.	

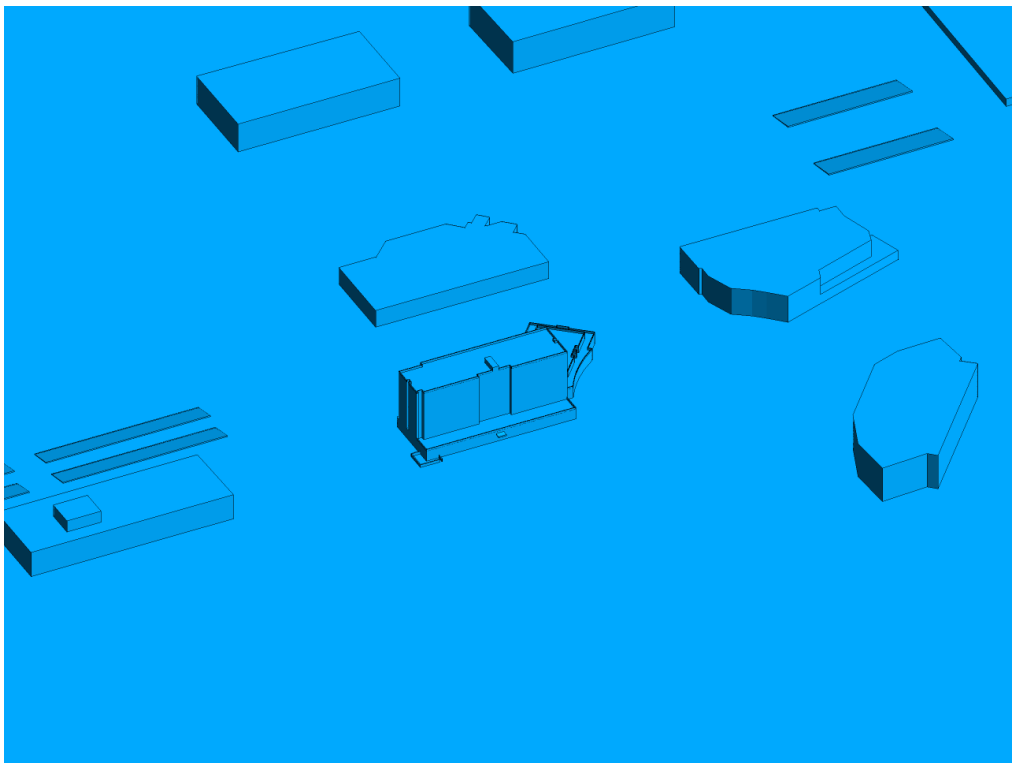


FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTH PERSPECTIVE

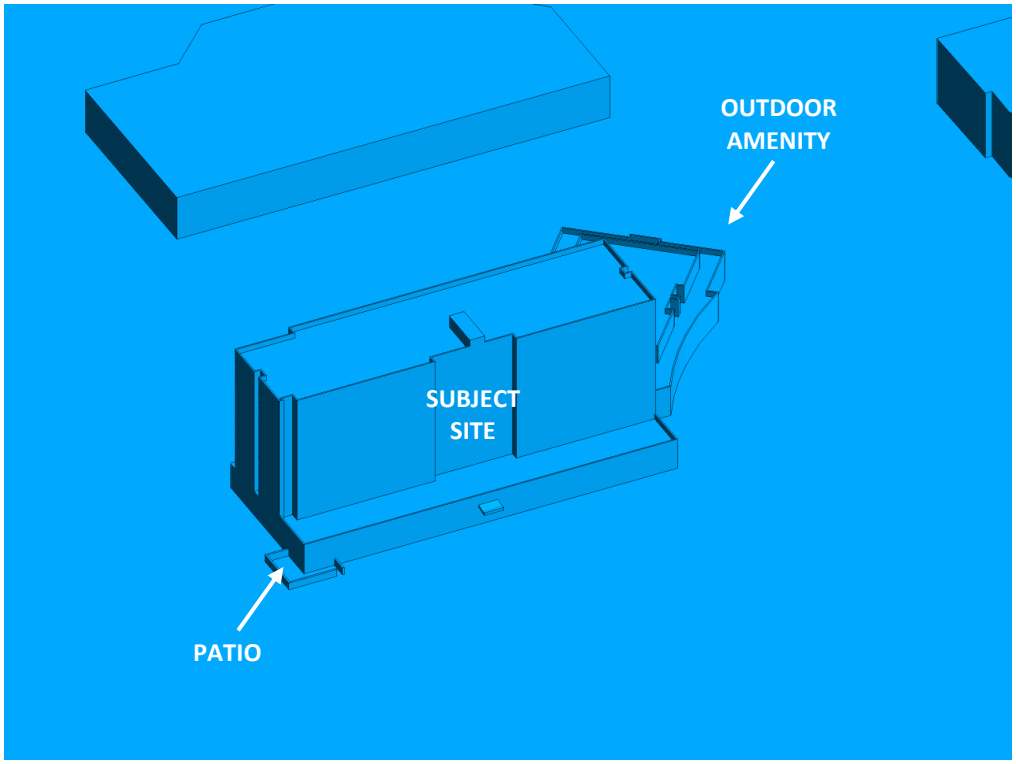


FIGURE 2B: CLOSE-UP VIEW OF FIGURE 2A

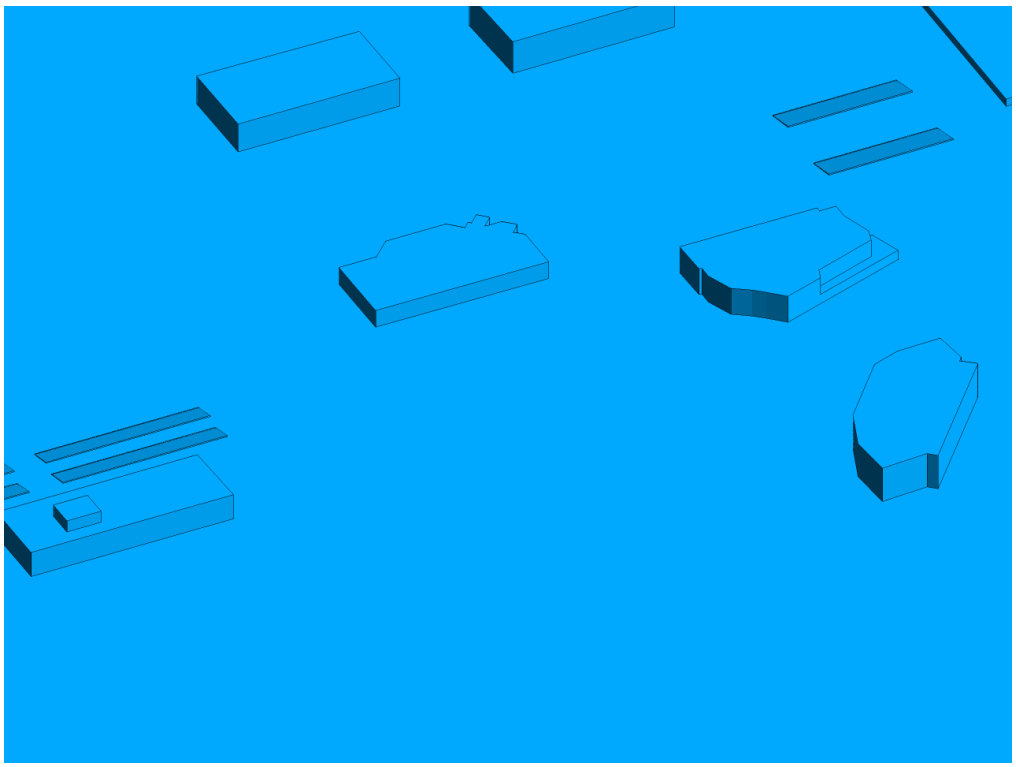


FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, NORTH PERSPECTIVE

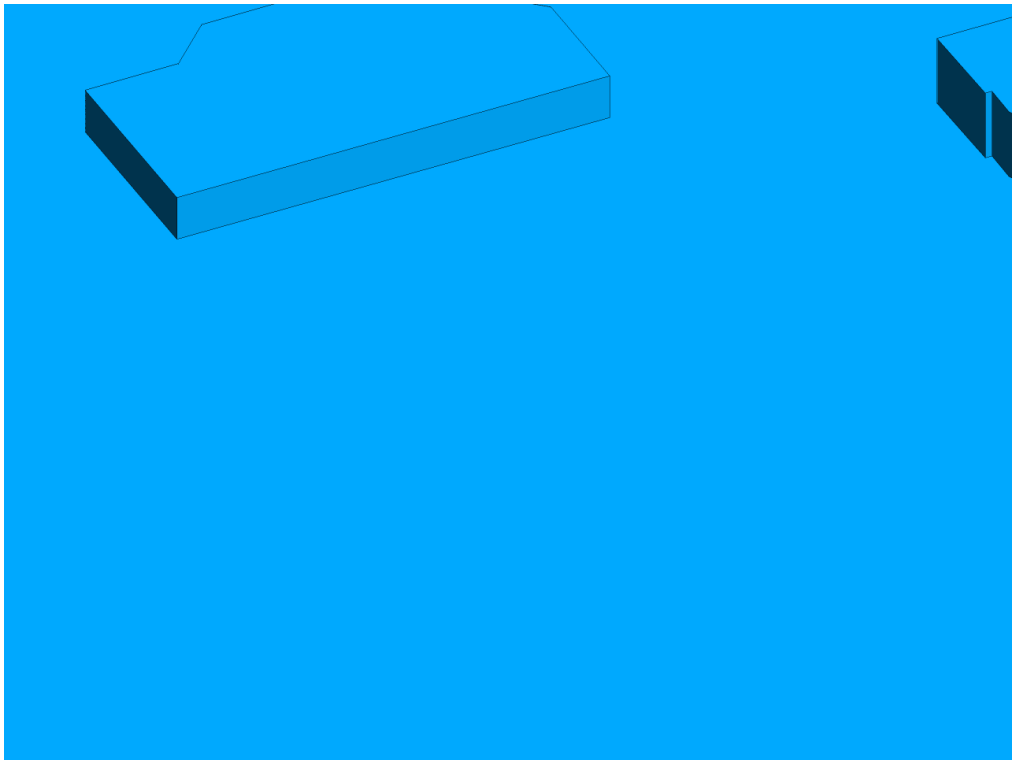


FIGURE 2D: CLOSE-UP VIEW OF FIGURE 2C

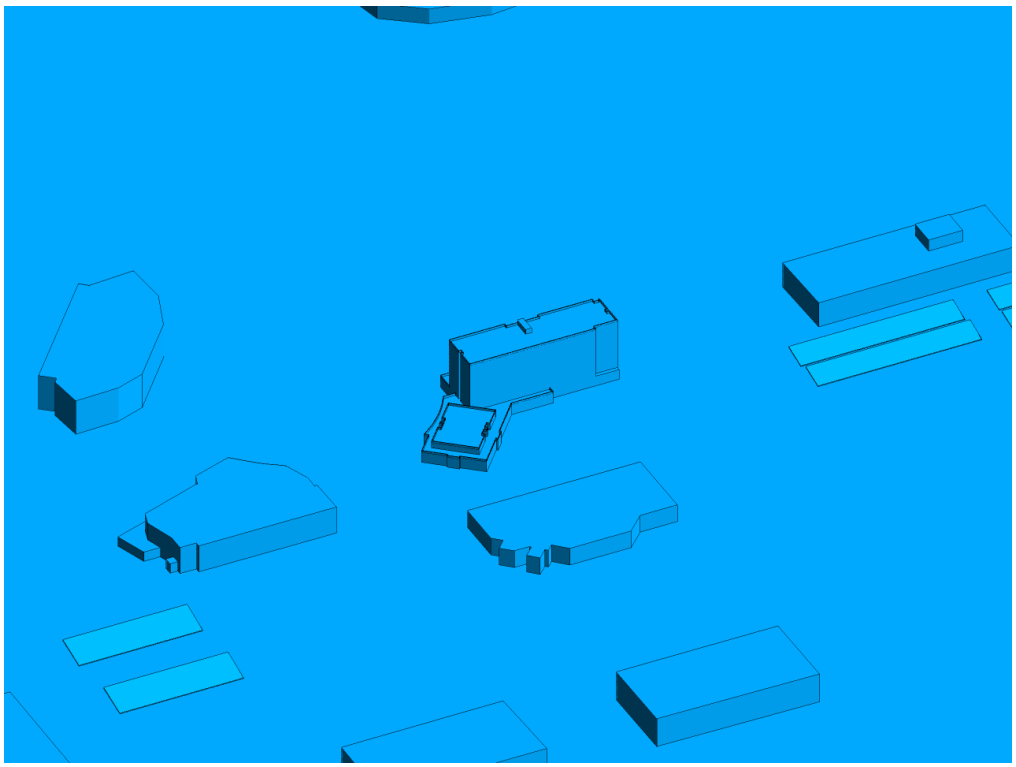


FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTH PERSPECTIVE

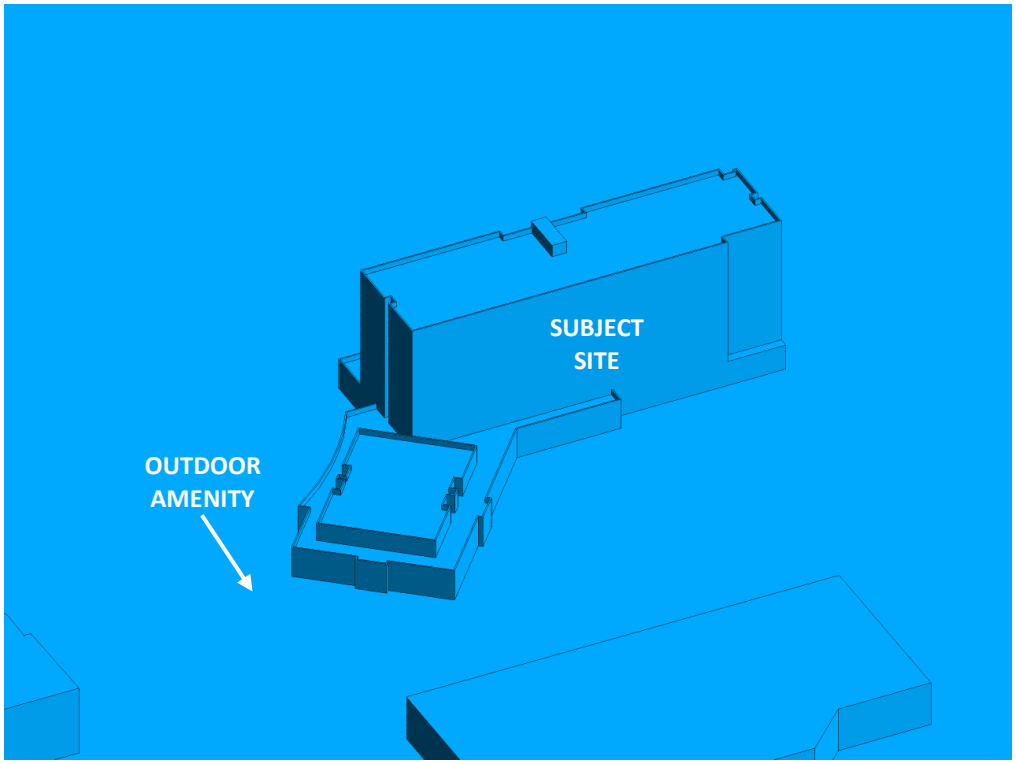


FIGURE 2F: CLOSE-UP VIEW OF FIGURE 2E

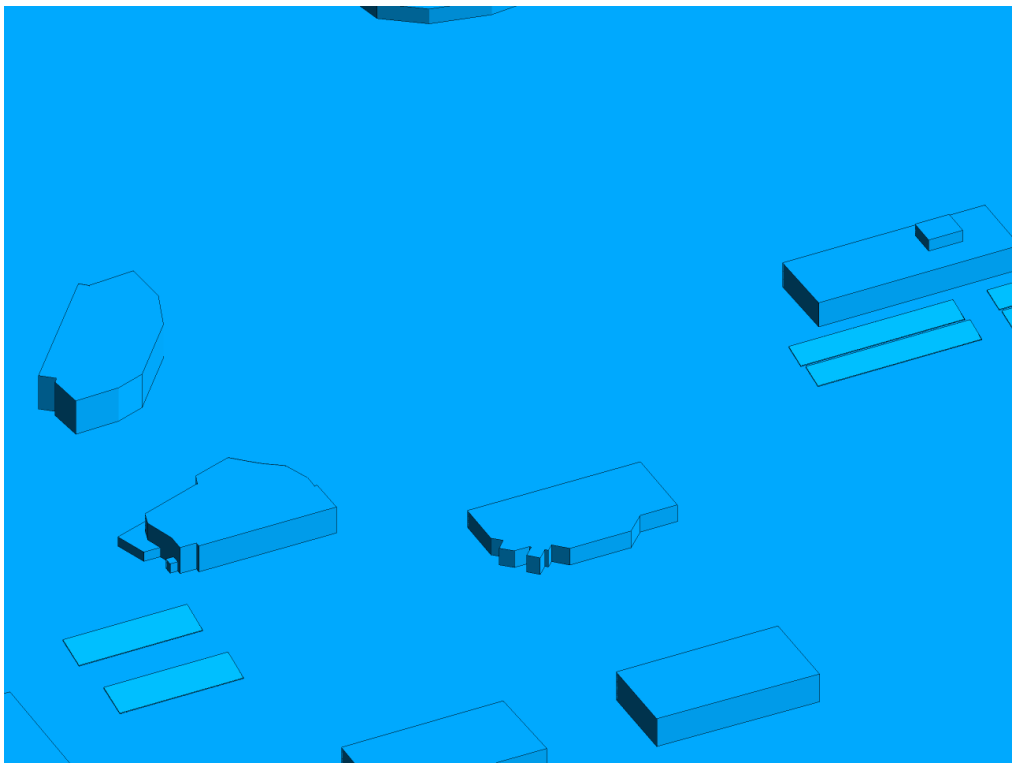


FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, SOUTH PERSPECTIVE



FIGURE 2H: CLOSE-UP VIEW OF FIGURE 2G

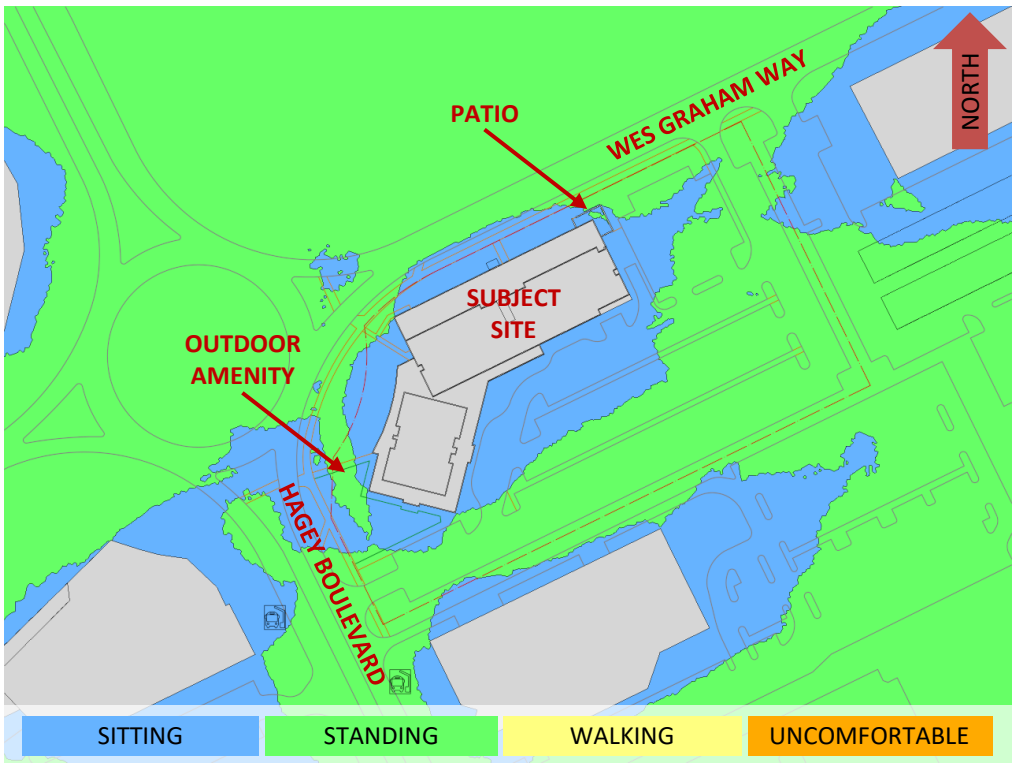


FIGURE 3A: SUMMER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

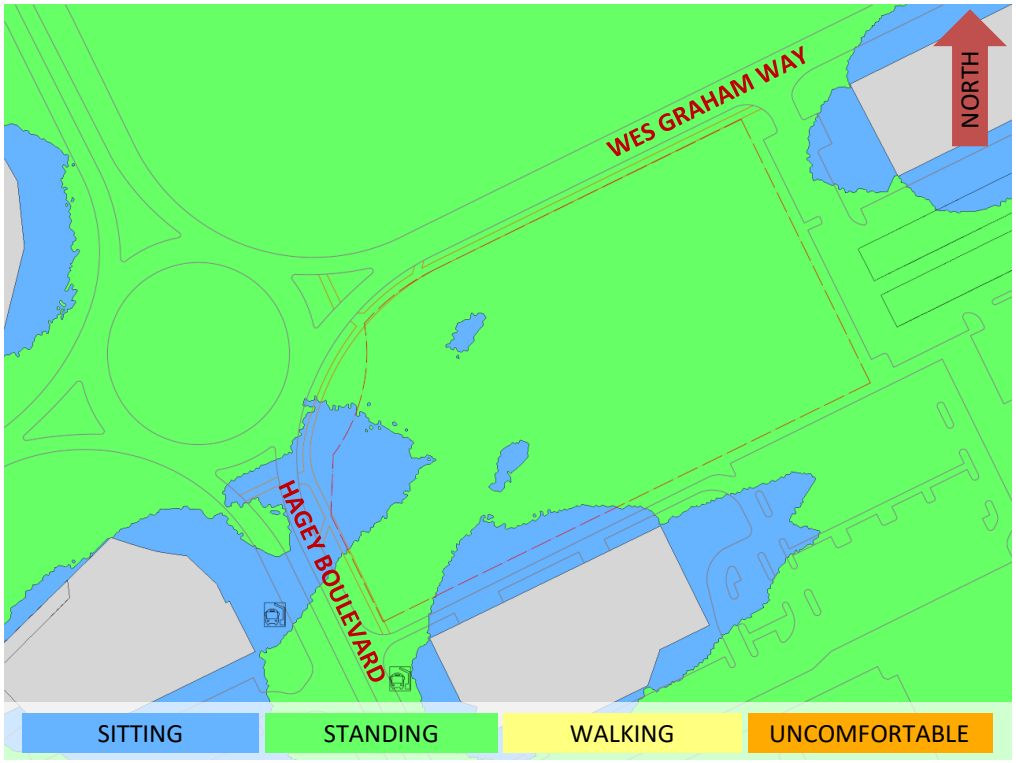


FIGURE 3B: SUMMER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

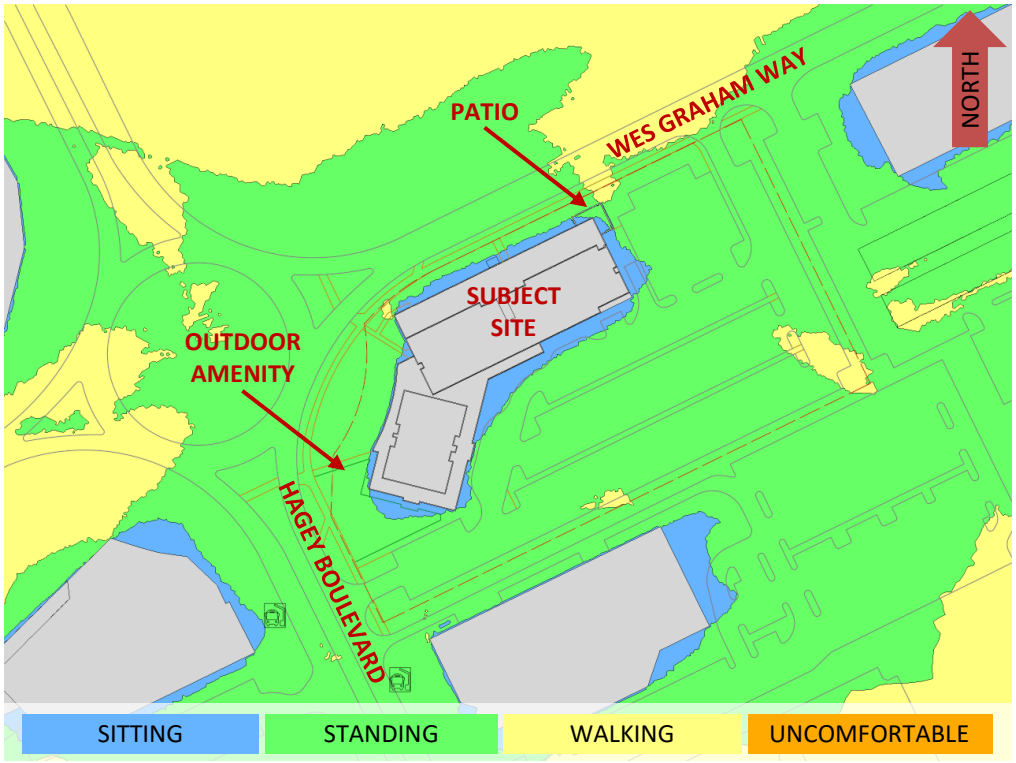


FIGURE 4A: WINTER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

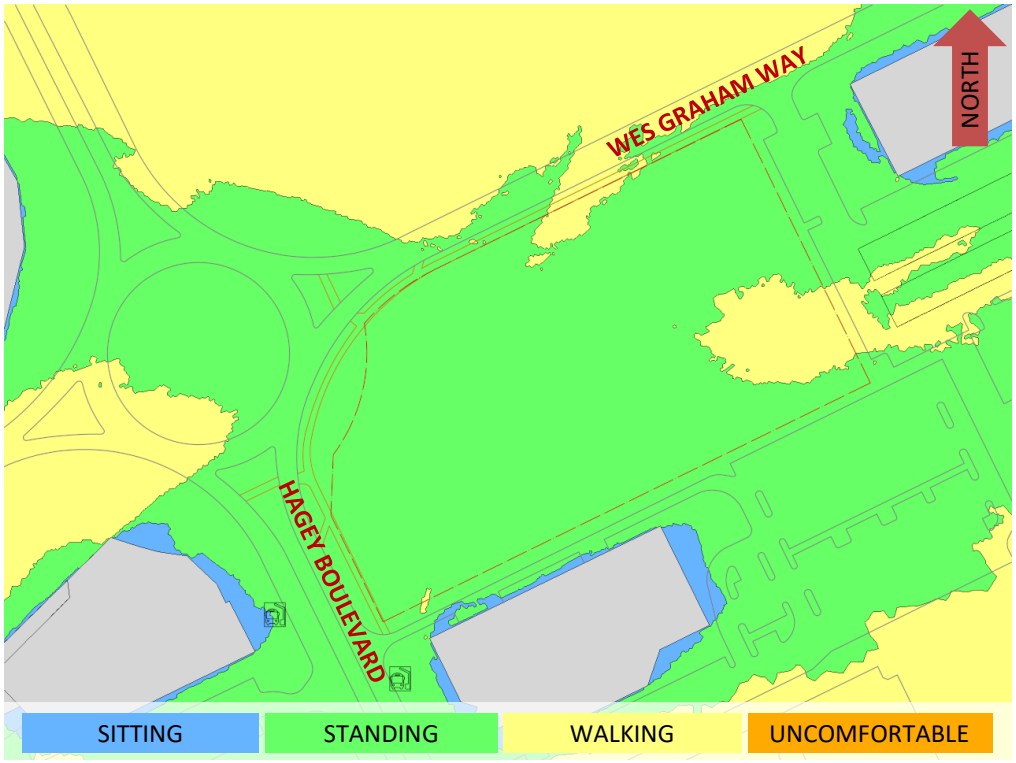
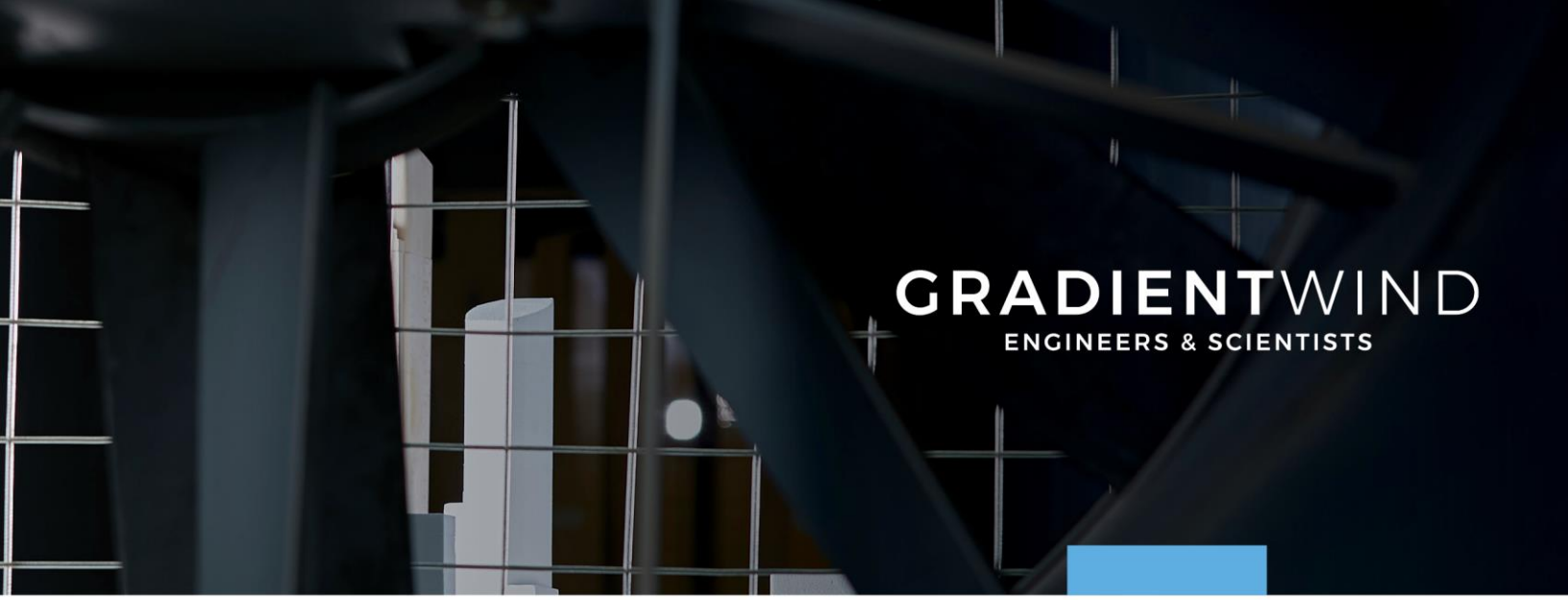
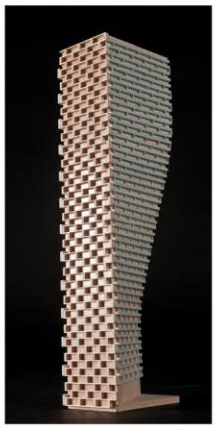


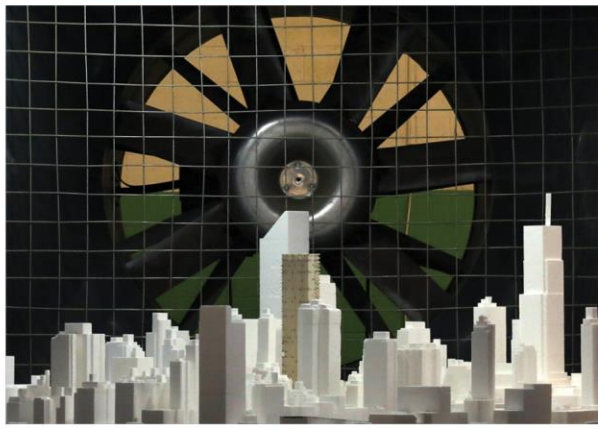
FIGURE 4B: WINTER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING











APPENDIX A

SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

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SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

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

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

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

For the model, U_g is set to 6.5 metres per second (m/s), which approximately corresponds to the 85% mean wind speed for Waterloo 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	0.24
22.5	0.24
45	0.24
67.5	0.24
90	0.25
112.5	0.26
135	0.26
157.5	0.26
180	0.25
202.5	0.23
225	0.22
247.5	0.22
270	0.21
292.5	0.22
315	0.23
337.5	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).

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

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

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

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

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