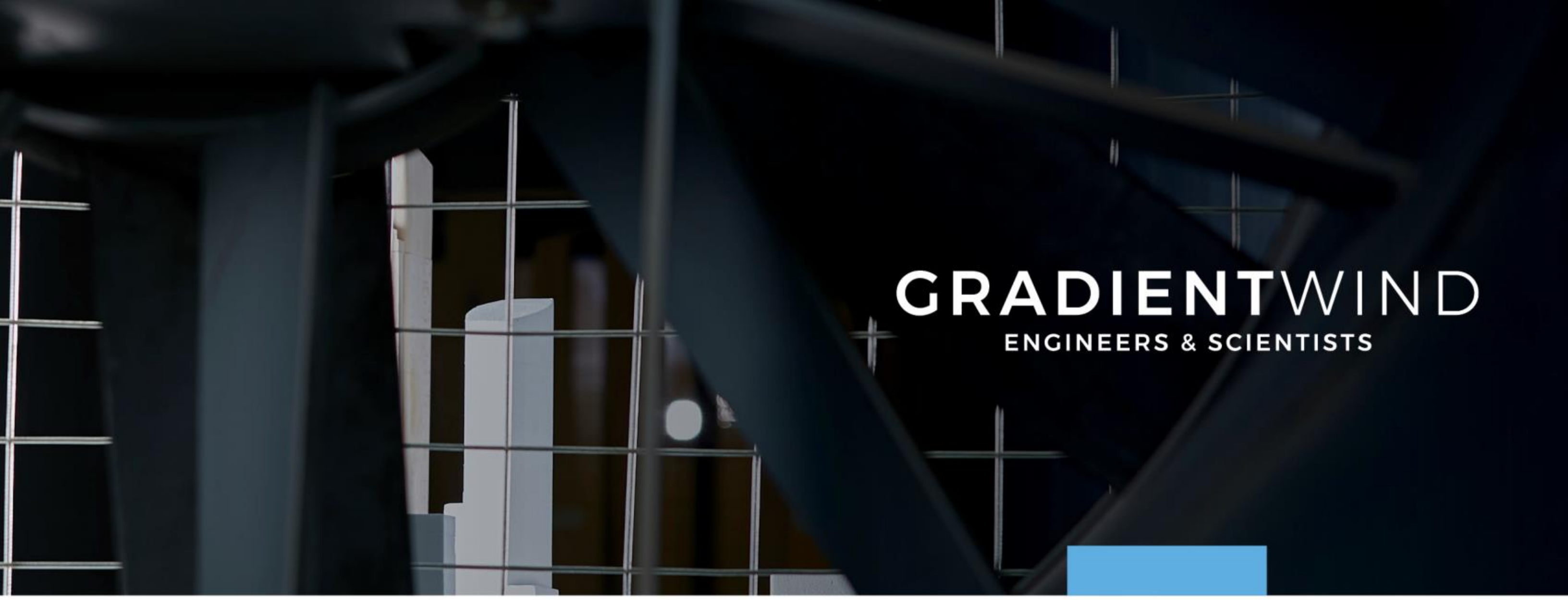
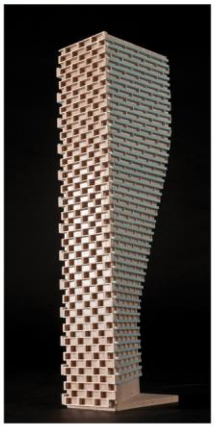
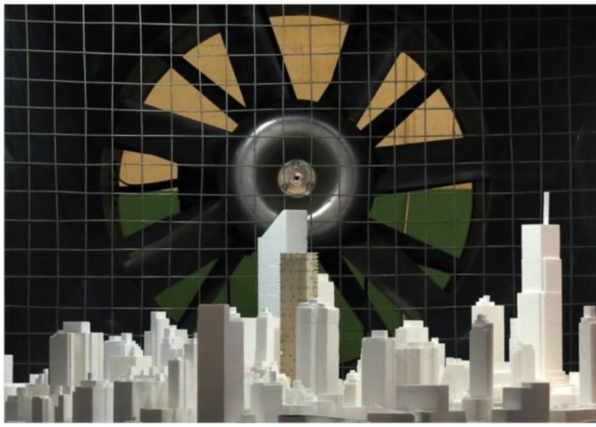


PEDESTRIAN LEVEL WIND STUDY

5160-5170 Ninth Line
Mississauga, Ontario

Report: 21-336-PLW





November 2, 2021

PREPARED FOR
Branthaven Development
720 Oval Court,
Burlington, ON L7L 6A9

PREPARED BY
Edward Urbanski, M.Eng., Wind Scientist
Justin Ferraro, P.Eng., Principal

EXECUTIVE SUMMARY

This report summarizes the results of a comparative computer based pedestrian level wind (PLW) study undertaken to satisfy Zoning By-law Amendment application requirements for the proposed residential development located at 5160-5170 Ninth Line in Mississauga, Ontario. This work is based on industry standard computer simulations using the computational fluid dynamics (CFD) technique and data analysis procedures, City of Mississauga wind comfort and safety criteria, architectural drawings provided by ZO1 Architects, in October 2021, surrounding street layouts and existing and approved future building massing information obtained from the City of Mississauga, as well as recent site imagery.

A complete summary of the predicted wind comfort and safety conditions is provided in Section 5 of this report and illustrated in Figures 3A-5B, following the main text. Based on CFD test results, interpretation, and experience with similar developments, the study concludes the following:

1) All grade level areas within and surrounding the subject site are predicted to be acceptable for the intended pedestrian uses throughout the year. Specifically, wind conditions over surrounding sidewalks, walkways, transit stops, the outdoor amenity area at grade, and in the vicinity of building access points, are considered acceptable.

2) Conditions over the common amenity terrace serving the proposed development at the MPH Level are predicted to be suitable for sitting during the summer, becoming mostly suitable for standing during the winter. The noted conditions are considered acceptable without mitigation.

3) Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas surrounding the subject site were found to experience conditions that could be considered uncomfortable or dangerous.

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Branthaven Development to undertake a comparative pedestrian level wind (PLW) study to satisfy Zoning By-law Amendment application requirements for the proposed development located at 5160-5170 Ninth Line in Mississauga, Ontario (hereinafter referred to as the “subject site”). Our mandate within this study is to investigate pedestrian wind comfort within and surrounding the subject site, and to identify any 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 Mississauga wind comfort and safety criteria, architectural drawings provided by ZO1 Architects, in October 2021, surrounding street layouts and existing and approved future building massing information obtained from the City of Mississauga, as well as recent site imagery.

2. TERMS OF REFERENCE

The subject site is located on a parcel of land encompassed by Ninth Line to the north and proposed future low-rise developments for the remaining elevations of the development. The proposed development comprises a six-storey ‘C’-shaped residential building with one level of below grade parking in addition to surface parking.

Residential units occupy all levels. The primary residential entrance is located to the east, a parking ramp and loading space is to the southwest, while indoor and outdoor amenities are centrally located within the proposed development. The building overhangs grade to the east and southeast at Level 1, while floorplate setbacks are provided to the south at Level 2, and to the east and south at Level 5. The proposed development includes a mechanical penthouse with a rooftop amenity terrace at the north end.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within 200-metres (m) of the subject site) primarily comprise fields of agricultural land except for low-rise residential sectors. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer (km) radius) are characterized by Highway 407 approximately 285 m to the southwest and Highway 403 approximately 1.4 kilometers (km) to the southeast. Agricultural fields are situated to the southeast clockwise to northwest, beyond the noted highways, while low-rise buildings define the remaining compass directions.

Site plans for the proposed and existing massing scenarios are illustrated in Figures 1A and 1B, respectively, while Figures 2A-2H illustrate the computational models used to conduct the study. The existing massing scenario includes the existing massing as well as any changes which have been approved by the City of Mississauga.

3. OBJECTIVES

The principal objectives of this study are to: (i) determine pedestrian level wind comfort and safety conditions at key outdoor areas; (ii) identify areas where future 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 subject site is based on CFD simulations of wind speeds across the subject site within a virtual environment, meteorological analysis of the Mississauga wind climate, and synthesis of computational data with industry-accepted criteria[1]. The following sections describe the analysis procedures, including a discussion of the comfort criteria.

[1] Mississauga, Urban Design Terms of Reference, *Pedestrian Wind Comfort and Safety Studies*, June 2014

4.1 Computer-Based Context Modelling

A computer based PLW wind 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 Lester B. Pearson 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 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 site for 12 wind directions and two massing scenarios, as noted in Section 2. The simulation model was centered on the subject site and included surrounding massing within a radius of 480 m.

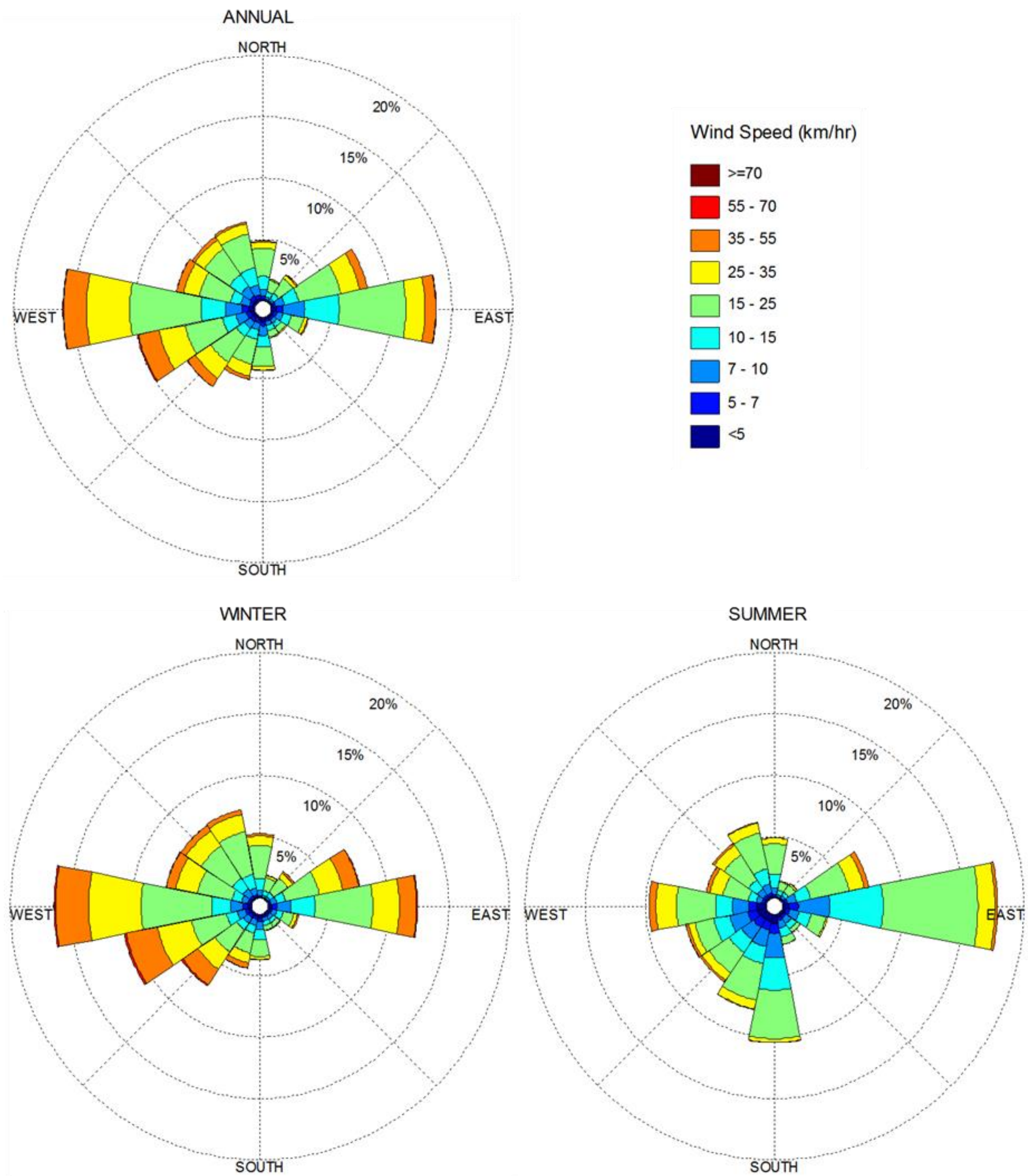
Mean and peak wind speed data obtained over the study site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds on a continuous measurement plane 1.5 m above local grade and the common amenity terraces were referenced to the wind speed at gradient height to generate mean and peak velocity ratios, which were used to calculate full-scale values. The 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 CFD wind flow simulation technique are presented in Appendix A.

4.3 Historical Wind Speed and Direction Data

A statistical model for winds in Mississauga was developed from approximately 40 years of hourly meteorological wind data recorded at Lester B. Pearson International Airport and obtained from Environment and Climate Change Canada. Wind speed and direction data were analyzed during the appropriate hours of pedestrian usage (i.e., 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 Mississauga 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 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 Mississauga (north of the Queen Elizabeth Way, or QEW), the common winds concerning pedestrian comfort occur from the south clockwise to the north, as well as those from the east. The directional preference 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
LESTER B. PEARSON INTERNATIONAL AIRPORT, MISSISSUAGA, ONTARIO



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 Mississauga

Pedestrian wind comfort criteria are based on mechanical wind effects without consideration of other meteorological conditions (i.e., temperature and relative humidity). The criteria provide an assessment of comfort, assuming 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 Mississauga Urban Design Terms of Reference. More 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 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.

Five pedestrian comfort classes and corresponding gust wind speed ranges are used to assess pedestrian comfort: (i) Sitting; (ii) Standing; (iii) Strolling, (iv) Walking; and (v) Uncomfortable. Specifically, the comfort classes, associated wind speed ranges, and limiting criteria are summarized as follows:

(i) **Sitting** – GEM wind speeds no greater than 10 km/h (i.e., 0-10 km/h) occurring at least 80% of the time would be considered acceptable for sedentary activities, including sitting.

(ii) **Standing** – GEM wind speeds no greater than 15 km/h (i.e., 0-15 km/h) occurring at least 80% of the time are acceptable for activities such as standing, strolling or more vigorous activities.

(iii) **Strolling** – GEM wind speeds no greater than 17 km/h (i.e., 0-17 km/h) occurring at least 80% of the time are acceptable for walking or more vigorous activities.

(iv) **Walking** – GEM wind speeds no greater than 20 km/h (i.e., 0-20 km/h) occurring at least 80% of the time are acceptable for walking or more vigorous activities.

(v) **Uncomfortable** – Uncomfortable conditions are characterized by predicted values that fall below the 80% criterion for walking. Brisk walking and exercise, such as jogging, would be 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, 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.

THE BEAUFORT SCALE

Number	Description	Wind Speed (km/h)		Description
		Mean	Gust	
2	Light Breeze	6-11	9-17	Wind felt on faces
3	Gentle Breeze	12-19	18-29	Leaves and small twigs in constant motion; wind extends light flags
4	Moderate Breeze	20-28	30-42	Wind raises dust and loose paper; small branches are moved
5	Fresh Breeze	29-38	43-57	Small trees in leaf begin to sway
6	Strong Breeze	39-49	58-74	Large branches in motion; Whistling heard in electrical wires; umbrellas used with difficulty
7	Moderate Gale	50-61	75-92	Whole trees in motion; inconvenient walking against wind
8	Gale	62-74	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 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 or more sedentary activities. 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 site, the assessment of pedestrian comfort involves determining the suitability of the predicted wind conditions for discrete regions within and surrounding the subject site. This step involves comparing the predicted comfort classes to the desired comfort classes, which are dictated by the location type for each region (i.e., a sidewalk, building entrance, amenity space, or other). An overview of common pedestrian location types and their typical windiest desired comfort classes are summarized on the following page. Depending on the programming of a space, the desired comfort class may differ from this table.

DESIRED PEDESTRIAN COMFORT CLASSES FOR VARIOUS LOCATION TYPES

Location Types	Windiest Desired Comfort Class
Primary Building Entrance	Standing
Secondary Building Access Point	Walking
Public Sidewalks / Pedestrian Walkways	Walking
Outdoor Amenity Spaces	Sitting (During Typical Use Period)
Cafés / Patios / Benches / Gardens	Sitting (Typical Use Period)
Transit Stops (without Shelter)	Standing
Transit Stops (with Shelter)	Walking
Public Parks / Plazas	Sitting (Typical Use Period)
Garage / Service Entrances	Walking
Vehicular Drop-Off Zones	Walking
Laneways / Loading Zones	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 seasonal wind conditions at grade level for the proposed and existing massing scenarios, and Figures 5A-5B, which illustrate seasonal wind conditions over the common amenity terrace serving the proposed development. The wind 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. 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 all areas studied are considered acceptable for the intended pedestrian uses. The details of these conditions are summarized in the following pages for each area of interest.

5.1 Wind Comfort Conditions – Grade Level

Building Access and Grade Level Outdoor Amenity: Wind conditions in the immediate vicinity of all building access points serving the proposed development, as well as within the outdoor amenity space at grade, are predicted to be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing during the winter. The noted conditions are considered acceptable according to the comfort criteria in Section 4.4.

Sidewalk and Transit Stops along Ninth Line: Following the introduction of the proposed building, the sidewalk along Ninth Line is predicted to be suitable mostly for sitting during the summer, becoming suitable for a mix of sitting and standing during the winter. In the vicinity of the transit stop along Ninth Line, conditions are predicted to be suitable for sitting during the summer and for standing during the winter. The noted conditions are considered acceptable according to the comfort criteria in Section 4.4.

Conditions over the sidewalk along Ninth Line with the existing massing are predicted to be suitable mostly for sitting during the summer, becoming mostly suitable for standing during the winter. In the vicinity of the noted transit stop, conditions are predicted to be suitable for sitting during the summer and for standing during the winter. The introduction of the proposed development increases pedestrian comfort in some areas, while maintaining comfort levels in other areas in comparison to existing conditions. As such, conditions with the proposed development are considered acceptable.

Street and Roads Immediately Surrounding Proposed Development: Following the introduction of the proposed building, the street and roads immediately surrounding the subject site are predicted to be suitable for sitting during the summer, becoming suitable for standing during the winter. The noted conditions are considered acceptable according to the comfort criteria in Section 4.4.

Conditions over the street and roads with the existing massing are predicted to be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing during the winter. While the introduction of the proposed development results in similar or slightly windier conditions in comparison to existing conditions, conditions with the proposed development are considered acceptable.

5.2 Wind Comfort Conditions – Common Amenity Terrace

MPH Level, Amenity Terrace: Conditions over the common amenity serving the proposed development at the MPH Level are predicted to be suitable for sitting during the summer, becoming mostly suitable for standing during the winter. The noted conditions are considered acceptable without mitigation.

5.3 Wind Safety

The forgoing statements and conclusions apply to common weather systems, during which no dangerous or consistently strong wind conditions are expected anywhere over the subject site. During extreme weather events, (e.g., thunderstorms, tornadoes, and downbursts), pedestrian safety is the main concern. However, these events are generally short-lived and infrequent and there is often sufficient warning for pedestrians to take appropriate cover.

5.4 Applicability of Results

The introduction of the proposed development is not expected to significantly influence pedestrian wind comfort over neighbouring areas. Nearby building entrances, sidewalks, laneways, parking areas, transit stops, and other pedestrian-sensitive areas beyond the development site are expected to continue to receive wind conditions similar to those that presently exist prior to the introduction of the proposed development.

Pedestrian wind comfort and safety have been quantified for the specific configuration of existing and foreseeable construction around the study 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 site would alter the wind profile approaching the site; and (ii) development in proximity to the site would cause changes to local flow patterns.

Regarding primary and secondary building access points, wind conditions predicted in this study are only applicable to pedestrian comfort and safety. As such, the results should not be construed to indicate wind loading on doors and associated hardware.

6. SUMMARY AND RECOMMENDATIONS

A complete summary of the predicted wind comfort and safety conditions is provided in Section 5 of this report and illustrated in Figures 3A-5B, following the main text. Based on CFD test results, interpretation, and experience with similar developments, the study concludes the following:

1) All grade level areas within and surrounding the subject site are predicted to be acceptable for the intended pedestrian uses throughout the year. Specifically, wind conditions over surrounding sidewalks, walkways, transit stops, the outdoor amenity area at grade, and in the vicinity of building access points, are considered acceptable.

2) Conditions over the common amenity terrace serving the proposed development at the MPH Level are predicted to be suitable for sitting during the summer, becoming mostly suitable for standing during the winter. The noted conditions are considered acceptable without mitigation.

3) Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas surrounding the subject site were found to experience conditions that could be considered uncomfortable or dangerous.

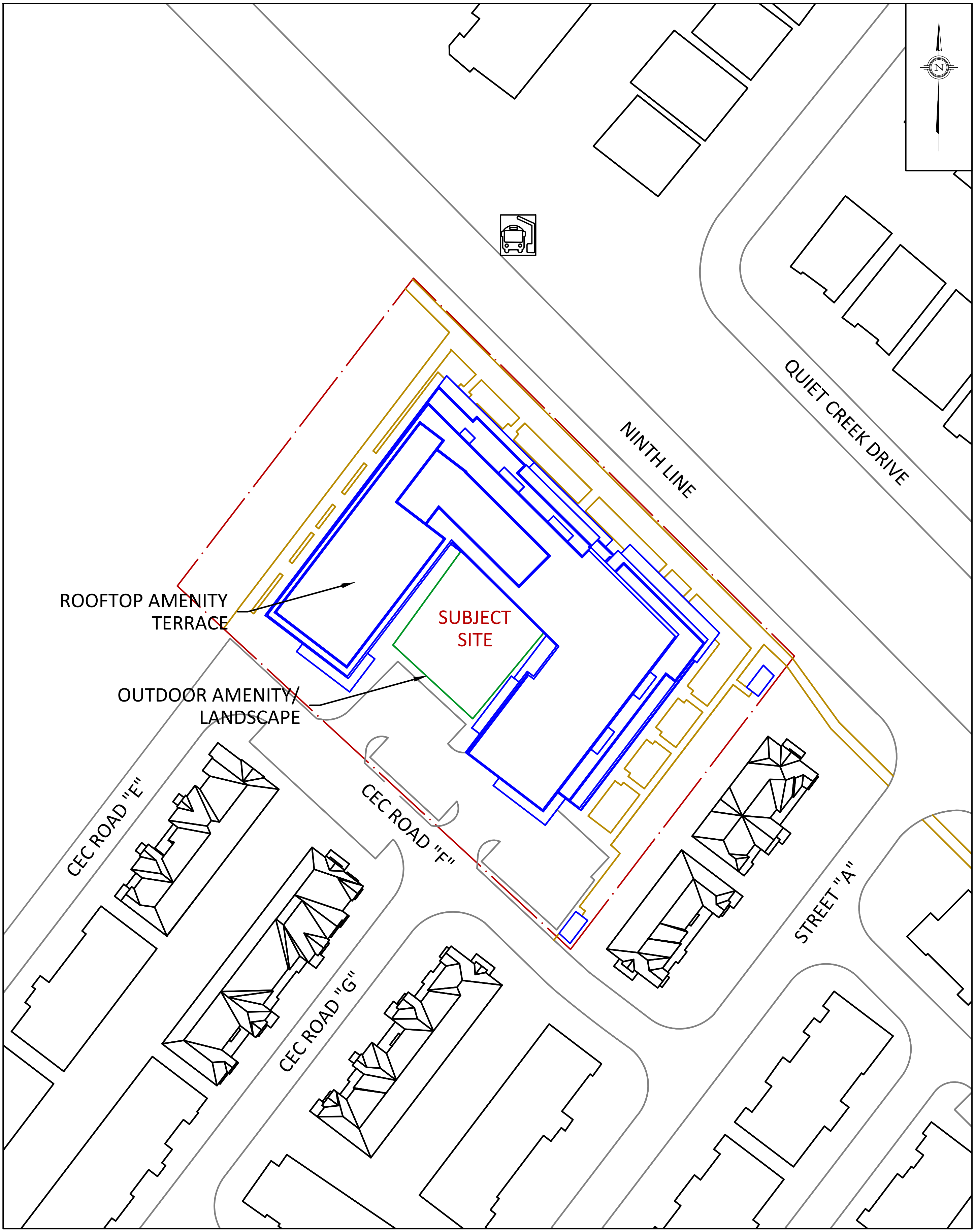
Sincerely,

Gradient Wind Engineering Inc.

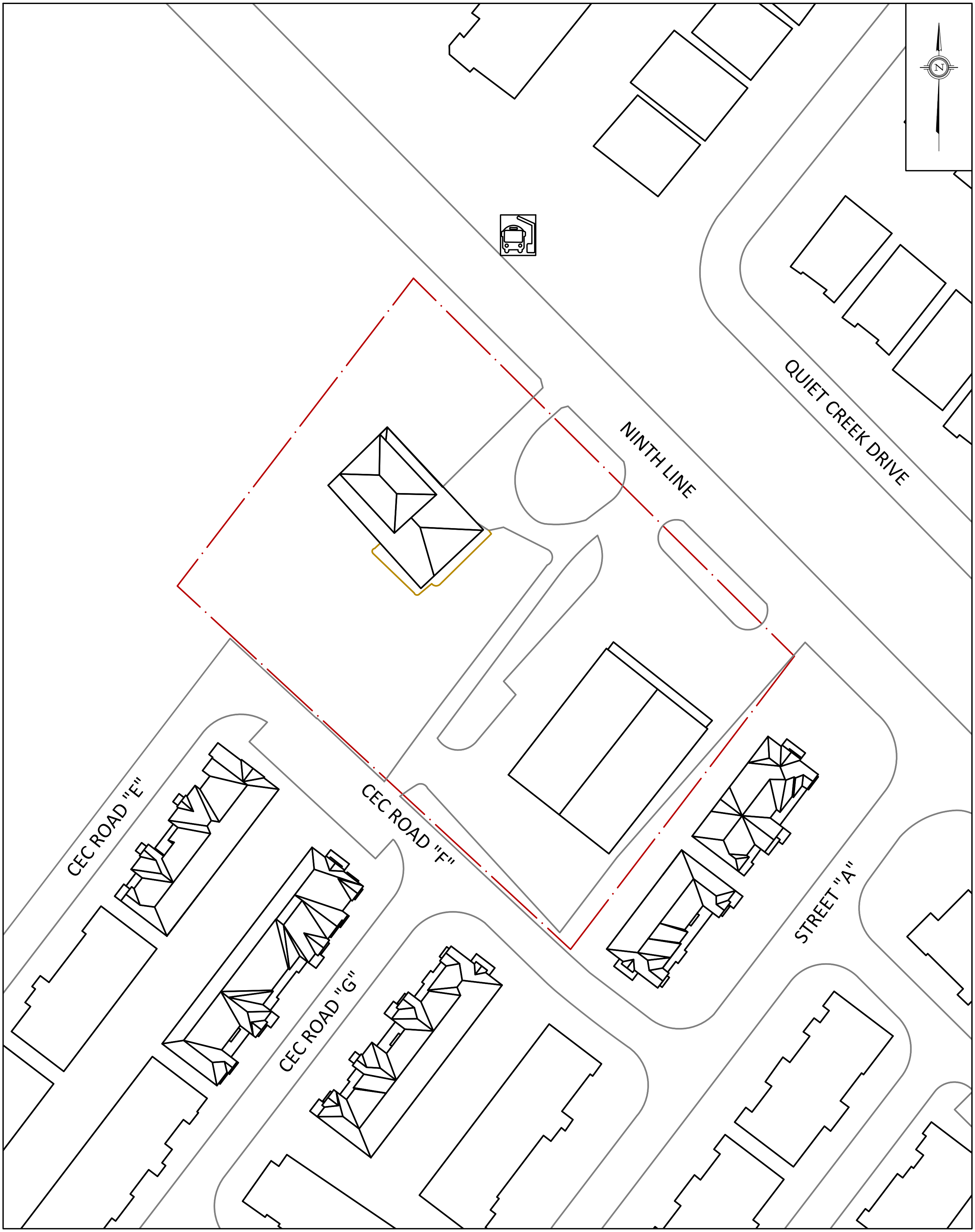
LICENSED PROFESSIONAL ENGINEER
J. D. FERRARO
100158495
Dec 16, 2021
PROVINCE OF ONTARIO

Edward Urbanski, M.Eng.
Wind Scientist

Justin Ferraro, P.Eng.
Principal



GRADIENTWIND ENGINEERS & SCIENTISTS 127 WALGREEN ROAD, OTTAWA, ON 613 836 0934 • GRADIENTWIND.COM	PROJECT 5160-5170 NINTH LINE, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION FIGURE 1A: PROPOSED SITE PLAN AND SURROUNDING CONTEXT
	SCALE 1:1000	DRAWING NO. 21-336-PLW-1A	
	DATE NOVEMBER 2, 2021	DRAWN BY N.M.P	



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PROJECT	5160-5170 NINTH LINE, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:1000	DRAWING NO.	21-336-PLW-1B
DATE	NOVEMBER 2, 2021	DRAWN BY	N.M.P

DESCRIPTION

FIGURE 1B:
EXISTING SITE PLAN AND SURROUNDING CONTEXT

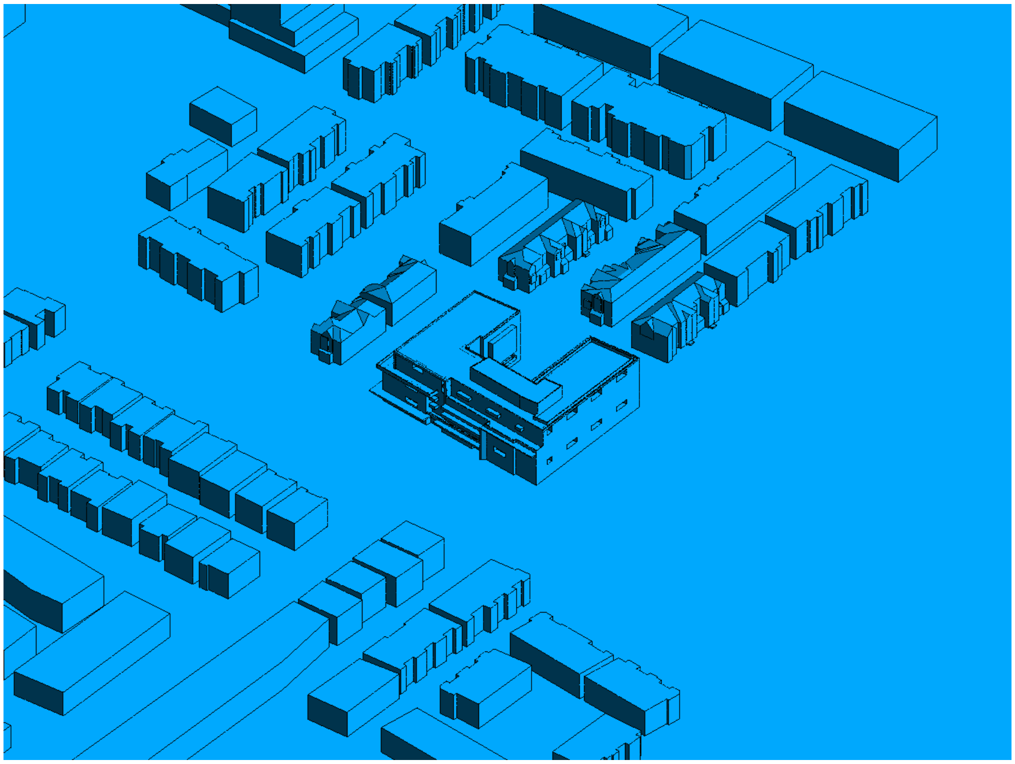


FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTH PERSPECTIVE

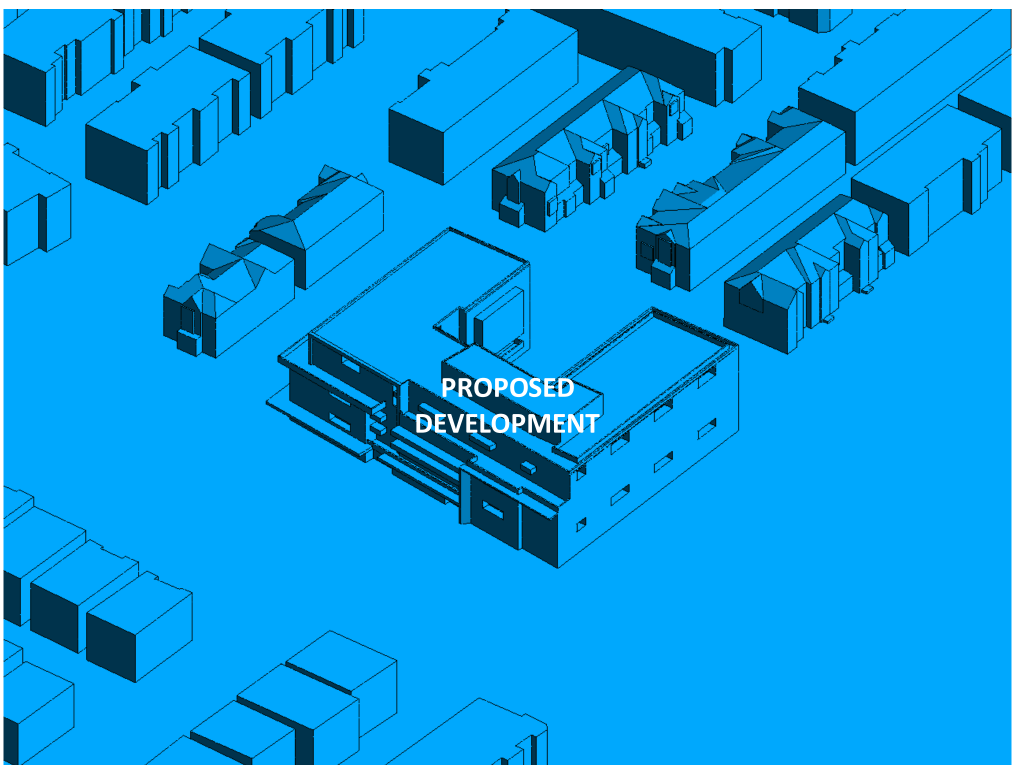


FIGURE 2B: CLOSE-UP VIEW OF FIGURE 2A

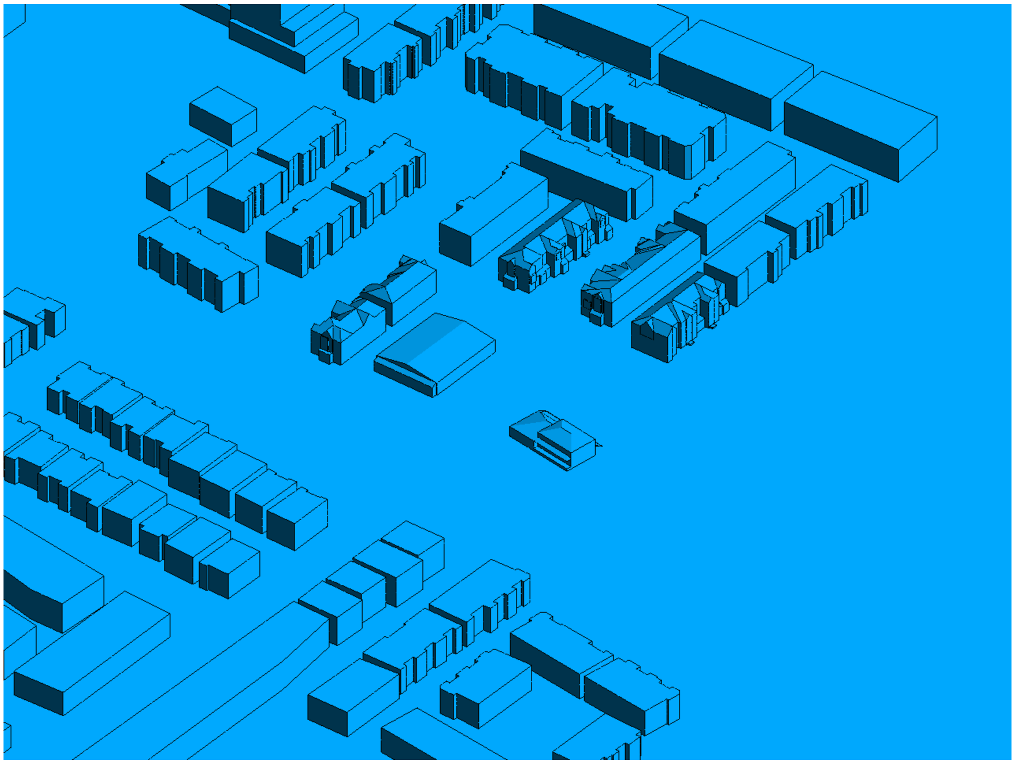


FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, NORTH PERSPECTIVE

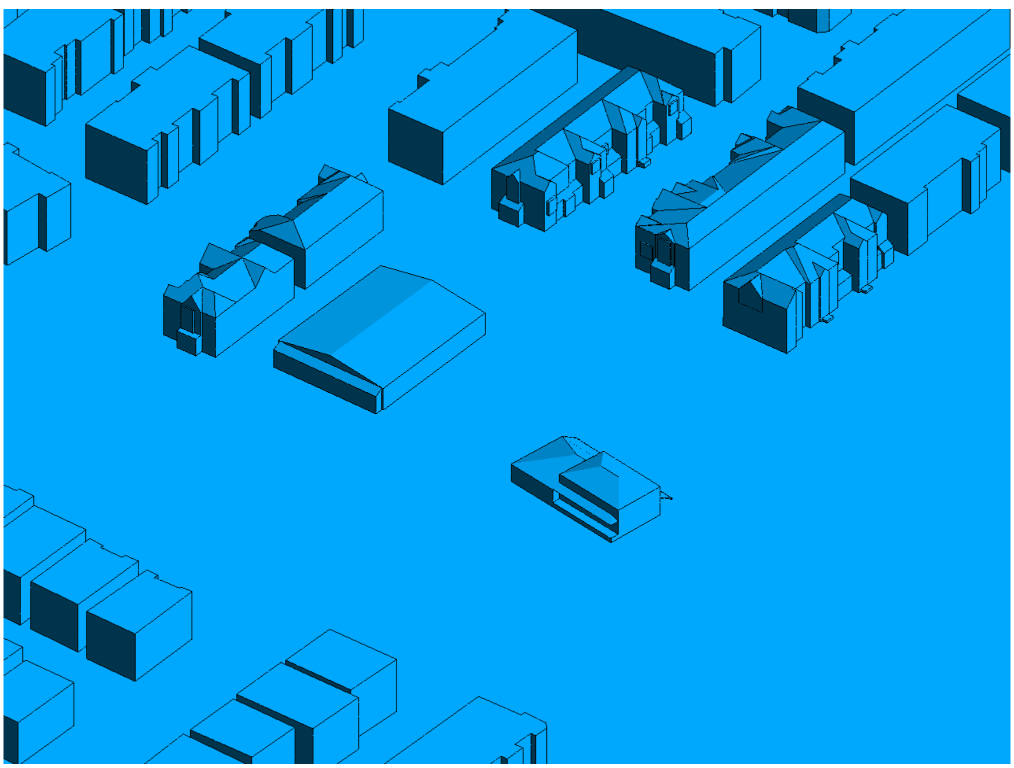


FIGURE 2D: CLOSE-UP VIEW OF FIGURE 2C

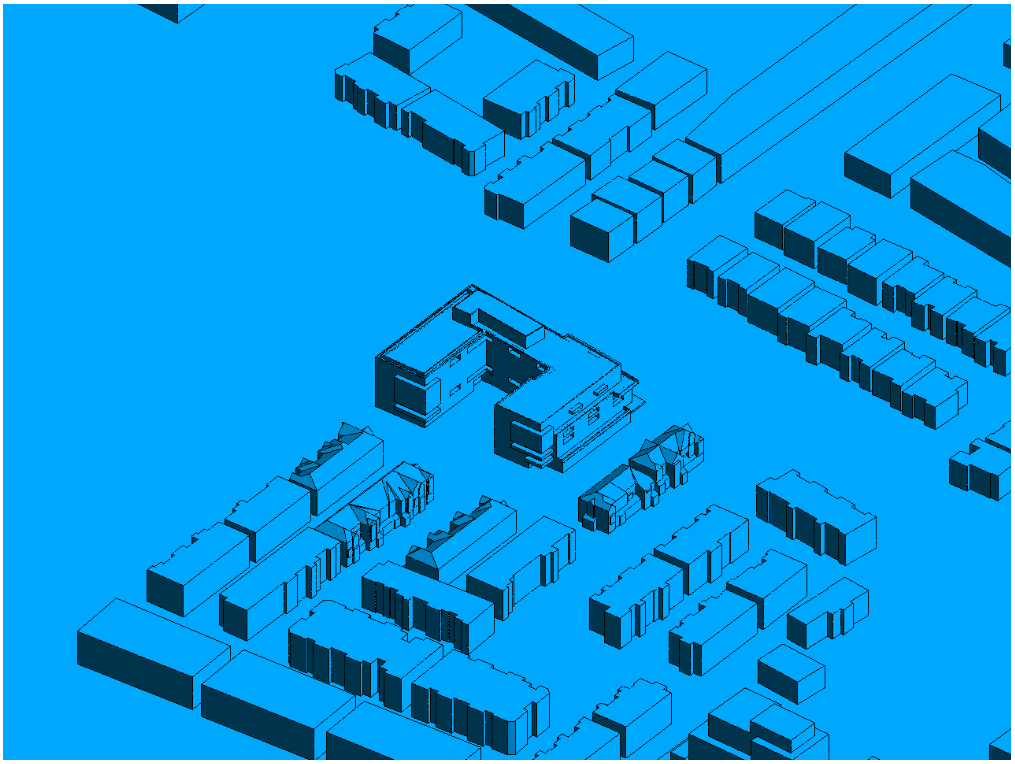


FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTH PERSPECTIVE

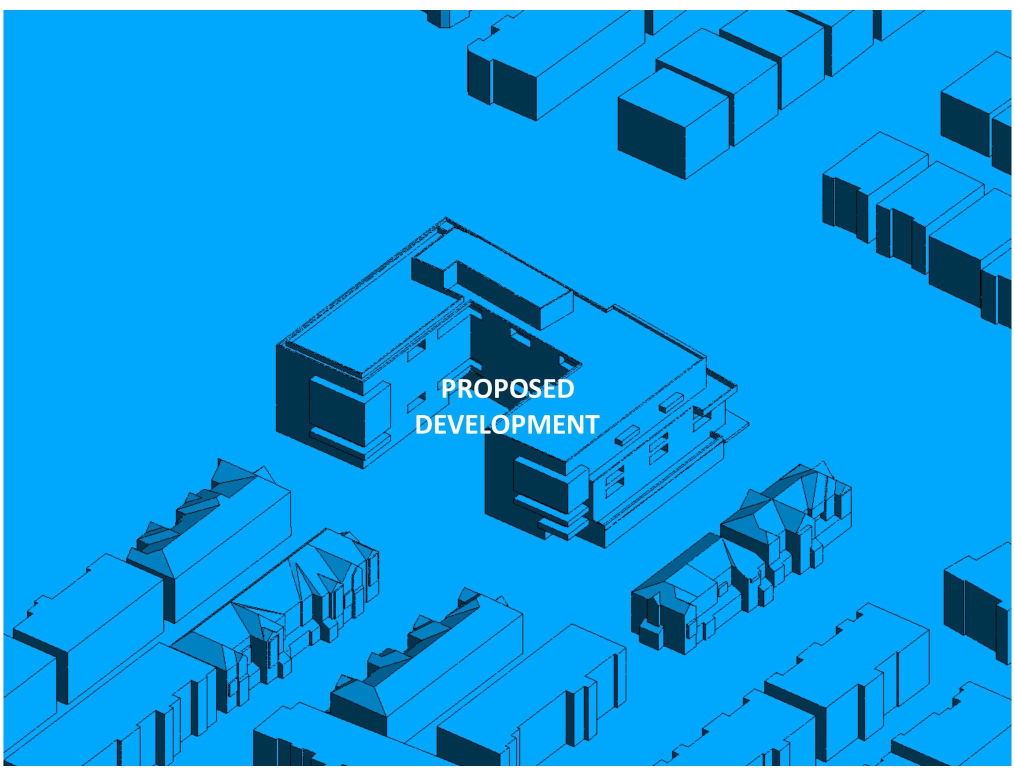


FIGURE 2F: CLOSE-UP VIEW OF FIGURE 2E

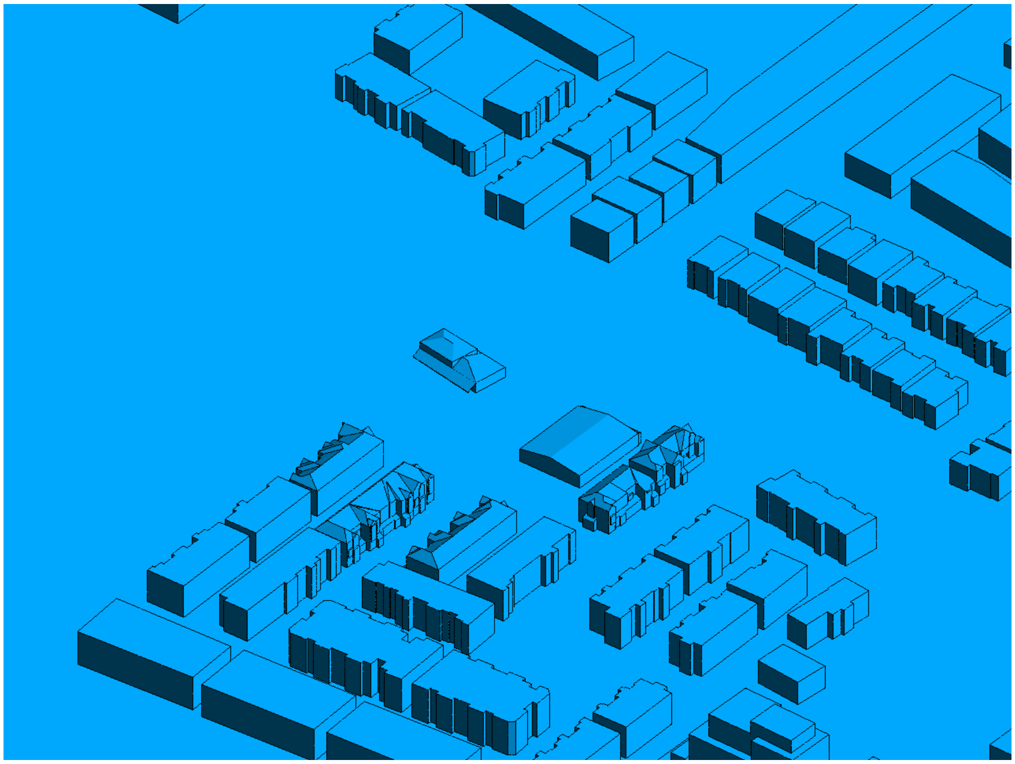


FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, SOUTH PERSPECTIVE

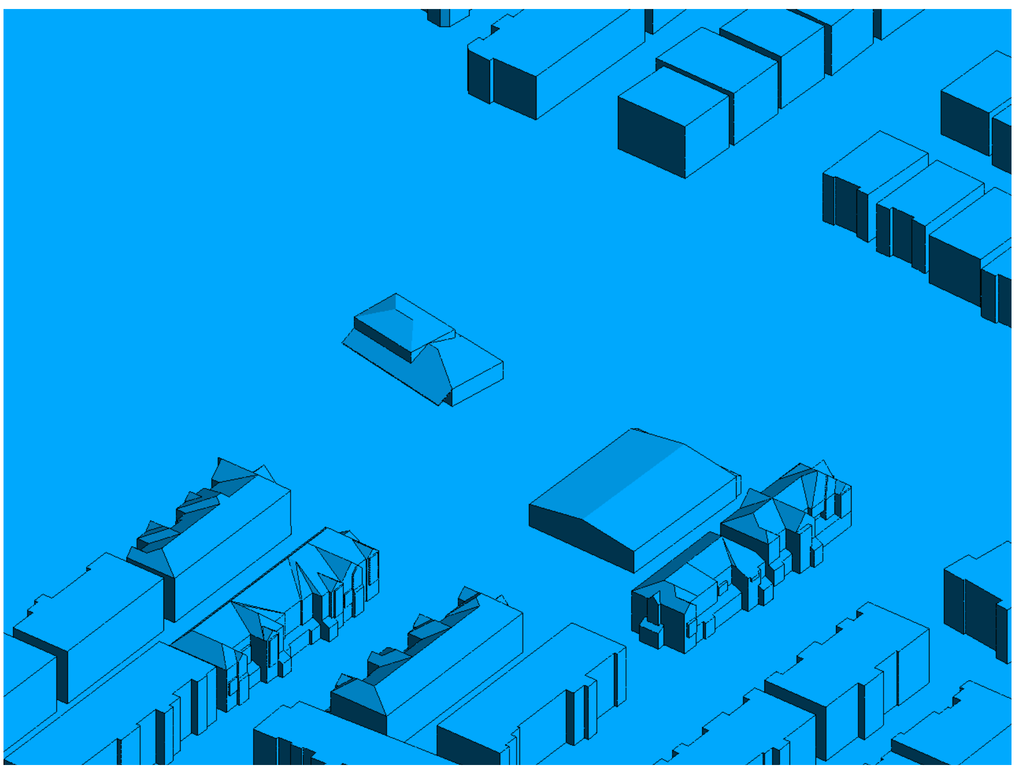


FIGURE 2H: CLOSE-UP VIEW OF FIGURE 2G

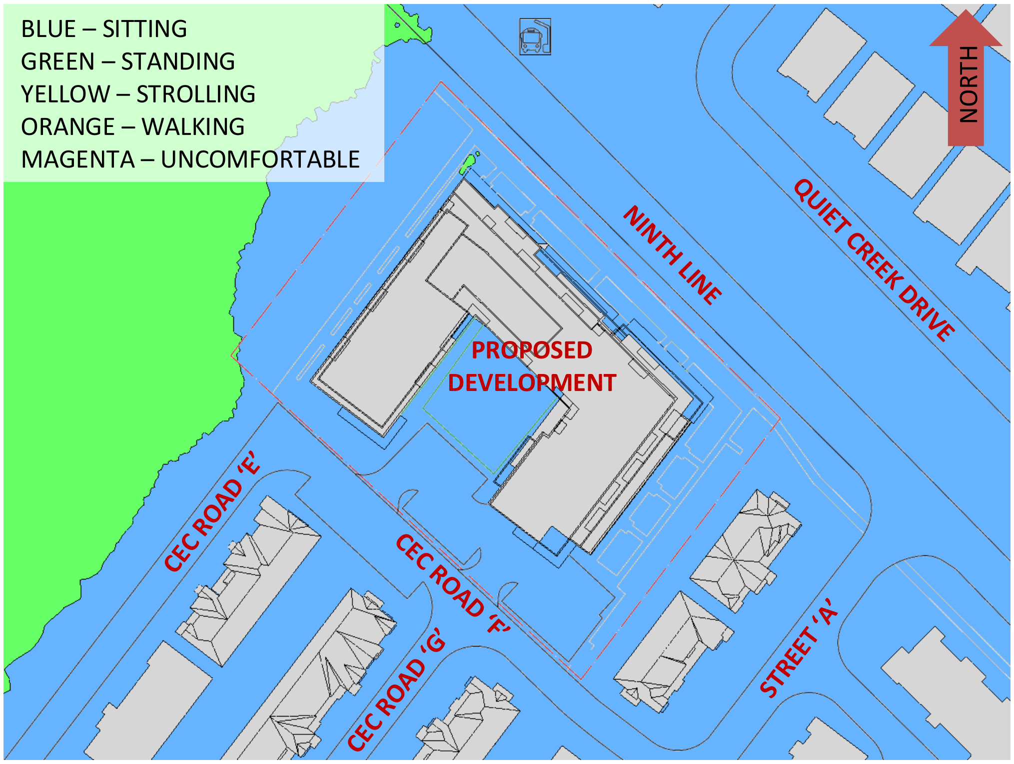


FIGURE 3A: SUMMER – PROPOSED MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

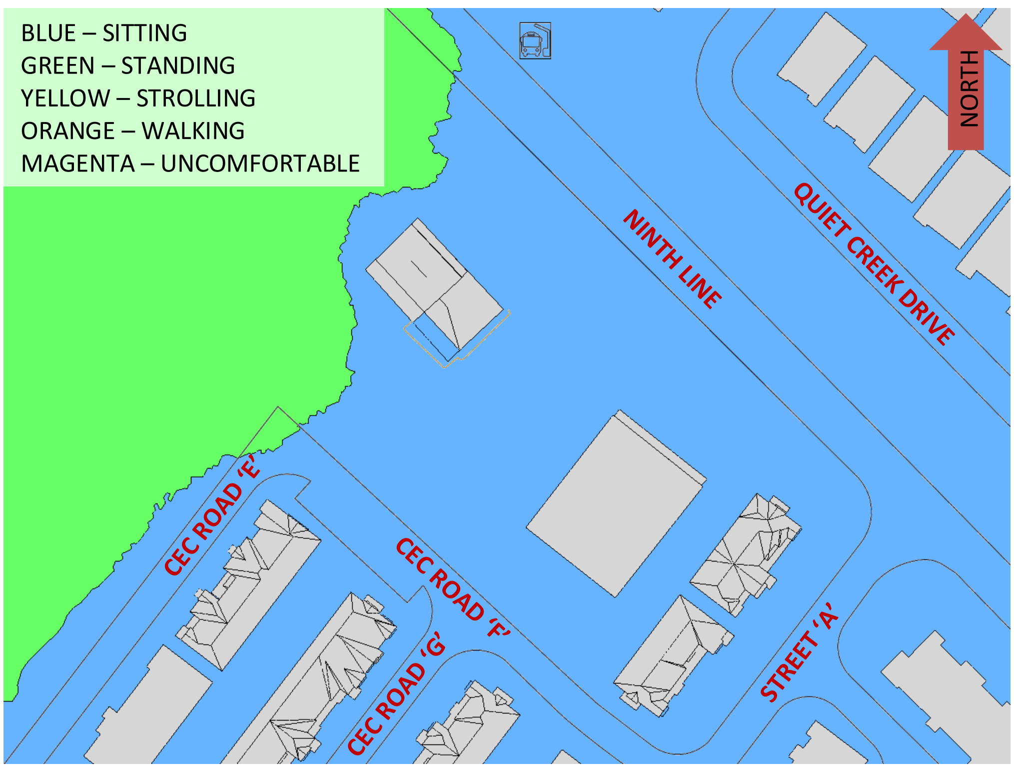


FIGURE 3B: SUMMER – EXISTING MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

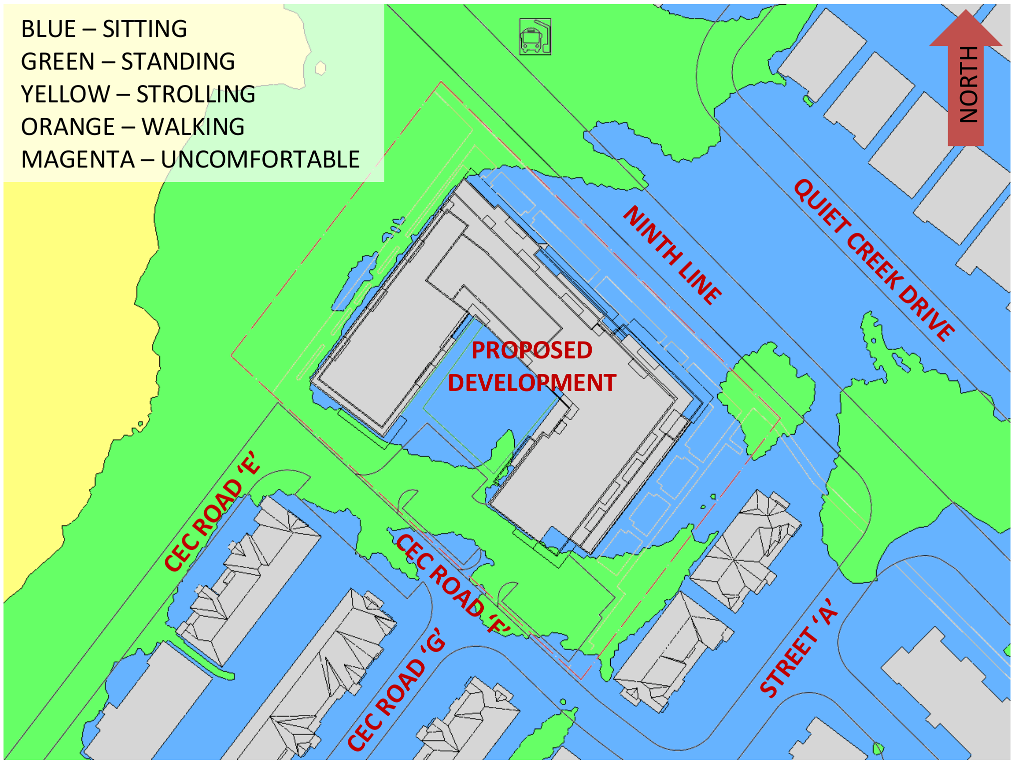


FIGURE 4A: WINTER – PROPOSED MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

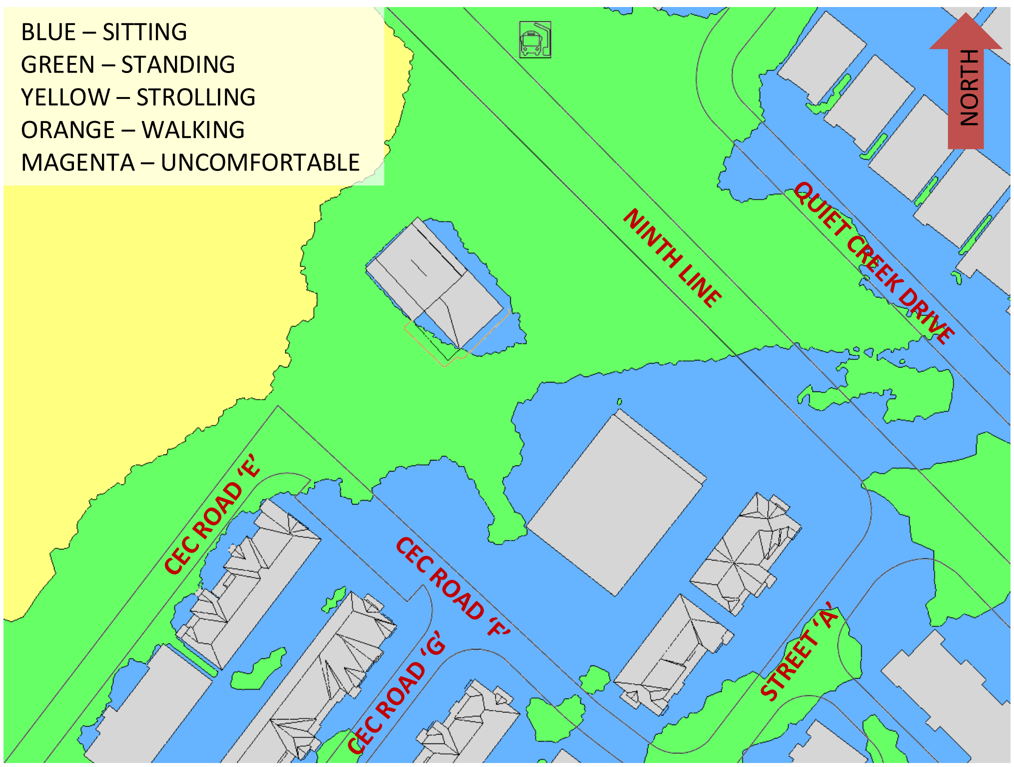


FIGURE 4B: WINTER – EXISTING MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

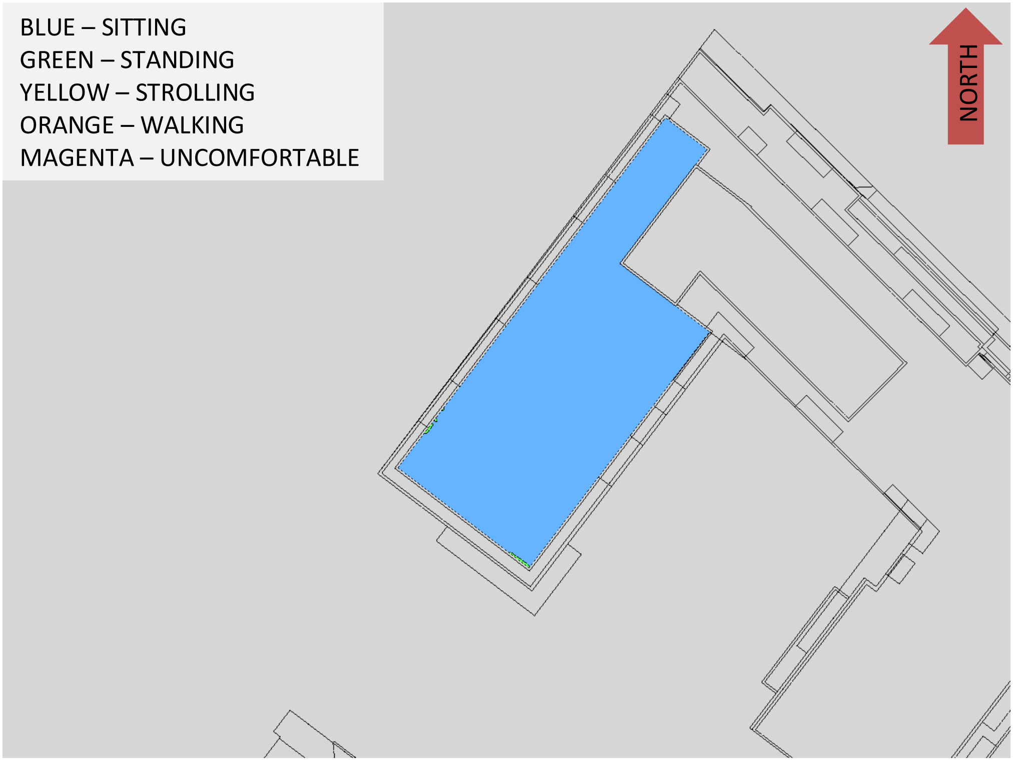
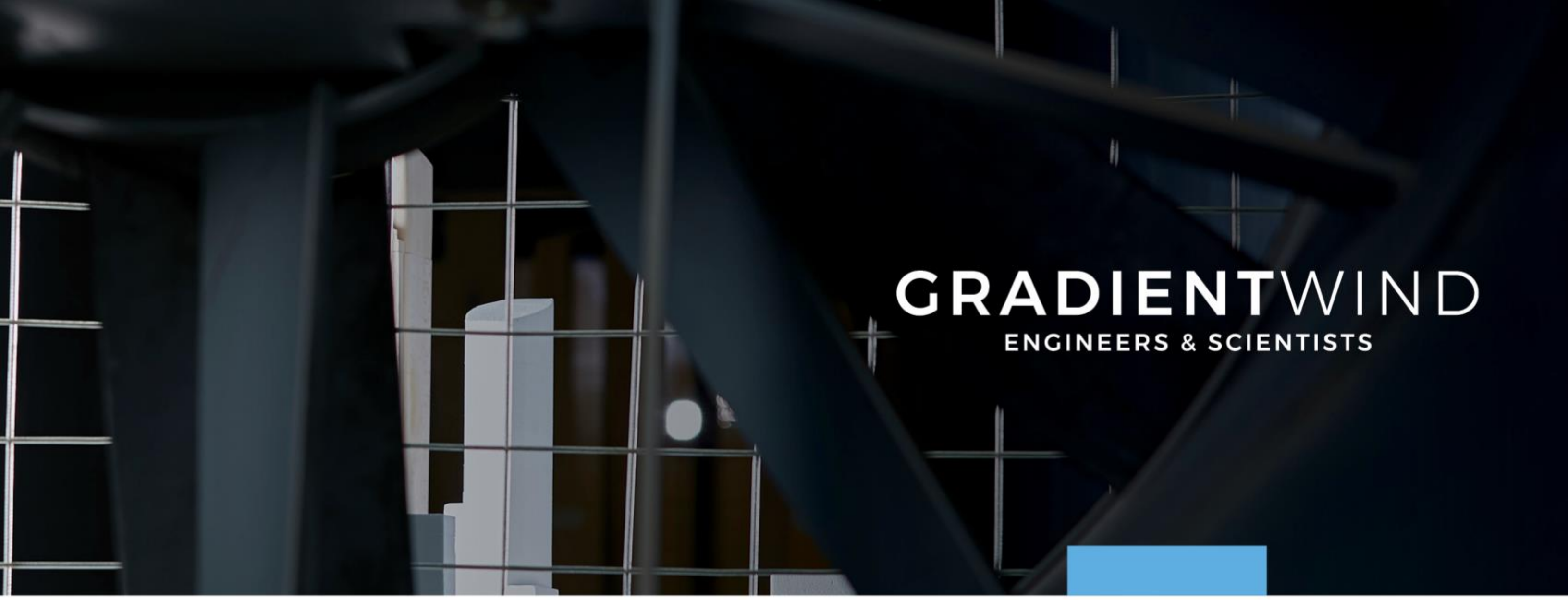
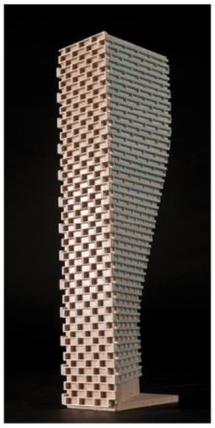
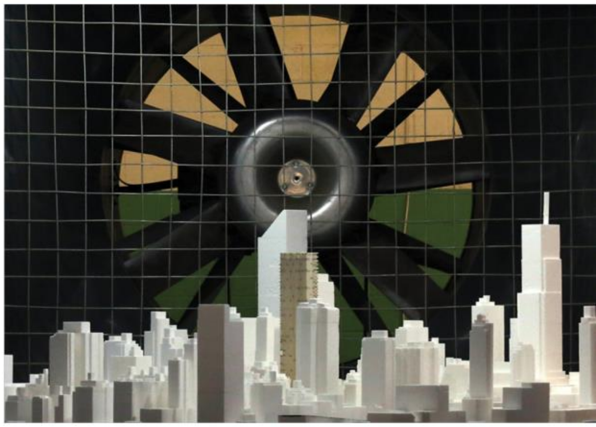


FIGURE 5A: SUMMER –WIND COMFORT CONDITIONS, AMENITY TERRACE AT MPH LEVEL

FIGURE 5B: WINTER –WIND COMFORT CONDITIONS, AMENITY TERRACE AT MPH LEVEL







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 50% mean wind speed for Mississauga based on historical 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
40	0.23
97	0.23
136	0.22
170	0.19
210	0.19
237	0.19
258	0.19
278	0.19
300	0.20
322	0.22
341	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].

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

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

where, $\boldsymbol{I}$ = turbulence intensity, $\boldsymbol{L_t}$ = turbulence length scale, $\boldsymbol{Z}$ = 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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