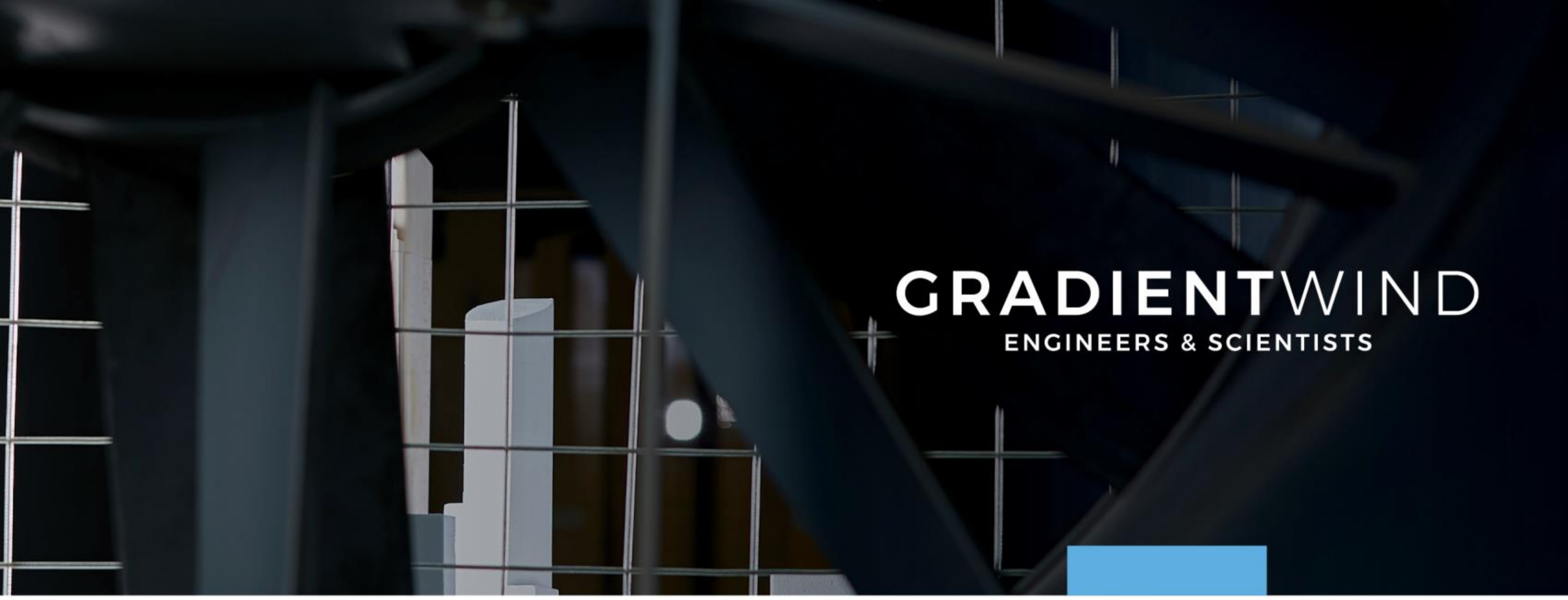
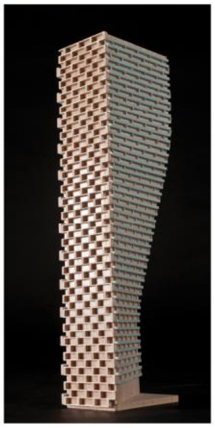
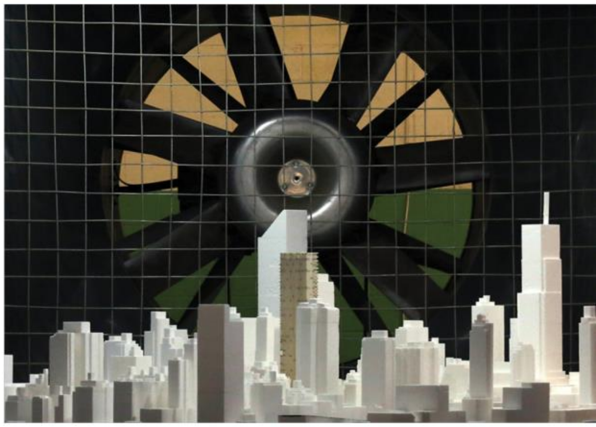


PEDESTRIAN LEVEL WIND STUDY

5687 Ferry Street & 5660 Spring Street
Niagara Falls, Ontario

Report: 22-310-PLW





October 20, 2022

PREPARED FOR
RKO Enterprise Inc.
1225 French Road
Mount Hope, ON L0R 1W0

PREPARED BY
David Huitema, M.Eng., Junior Wind Scientist
Justin Ferraro, P.Eng., Principal

EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study to satisfy Zoning By-law Amendment application requirements for the proposed mixed-use residential development located at 5687 Ferry Street and 5660 Spring Street in Niagara Falls, Ontario (hereinafter referred to as the "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind conditions within and surrounding the subject site, and to identify areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered.

The study involves simulation of wind speeds for twelve (12) 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) All grade-level areas within and surrounding the subject site are predicted to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year. Specifically, conditions over surrounding sidewalks, laneway, walkways, transit stops, surface parking, and in the vicinity of building access points, are considered acceptable.

2) Conditions over the amenity terrace serving the proposed development at Level 8 are predicted to be suitable for a mix of sitting and standing with strolling conditions along the west side of the terrace during the typical use period. The areas that are predicted to be suitable for standing, according to the comfort classification in Section 4.4, are also predicted to be suitable for sitting for at least 72% of the time during the same period to the east, for at least 65% of the time during the same period within the central area, and for at least 60% of the time during the same period along the west side, where the target is 80% to satisfy the sitting comfort class.

    a. To achieve the sitting comfort class in all areas during the typical use period, we recommend implementing a wind screen along the full perimeter of the terrace. The wind screen, typically glazed and preferably solid, is recommended to extend at least 2.0 m above the walking surface of the terrace. Depending on the programming of the terrace, mitigation inboard of the perimeter may also be required and could take the form of wind screens and/or other landscaping features.

3) The foregoing statements and conclusions apply to common weather systems, during which no dangerous wind conditions, as defined in Section 4.4, are expected anywhere over the subject site or within the neighbouring properties. During extreme weather events, (for example, thunderstorms, tornadoes, and downbursts), pedestrian safety is the main concern. However, these events are generally short-lived and infrequent and there is often sufficient warning for pedestrians to take appropriate cover.

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by RKO Enterprise Inc. to undertake a pedestrian level wind (PLW) study to satisfy Zoning By-law Amendment application requirements for the proposed mixed-use residential development located at 5687 Ferry Street and 5660 Spring Street in Niagara Falls, Ontario (hereinafter referred to as the "subject site" or "proposed development"). Our mandate within this study is to investigate wind conditions within and surrounding the subject site, and to identify areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered.

The study is based on industry standard computer simulations using the computational fluid dynamics (CFD) technique and data analysis procedures, architectural drawings provided by DeFilippis Design, in October 2022, surrounding street layouts and existing and approved future building massing information obtained from the City of Niagara Falls, and recent site imagery.

2. TERMS OF REFERENCE

The subject site is located at 5687 Ferry Street and 5660 Spring Street in Niagara Falls; situated centrally on a city block bordered by Spring Street to the north, Gladstone Avenue to the east, Ferry Street to the south, and Temperance Avenue to the west. The proposed development comprises a nominally 'T'-shaped eight-storey mixed-use residential building, with its short axis-oriented along Ferry Street, topped with a mechanical penthouse (MPH).

Above a below-grade parking level, the ground floor of the proposed development comprises a nominally rectangular planform and includes a rental office at the southeast corner, residential main entrance to the south, commercial spaces to the west, residential secondary entrance and staircase to the north, and loading area, garbage room, recycling room, and elevator core at the northeast corner. Surface parking occupies the remaining space to the north of the proposed development, accessed by a north-south laneway extending from Spring Street to Ferry Street, along the east side of the subject site. Access to below-grade parking is provided by a ramp situated central to the subject site via the noted laneway. A stairway is situated to the east of the ramp and provides pedestrian access to the below-grade and Level 2 parking levels. Level 2 comprises a nominally 'T'-shaped planform created by a floorplate extension to the north of the proposed development. This level includes central shared building support spaces, residential units from the east clockwise to the west, and surface parking to the north. Access to Level 2 parking is provided by a ramp to the north, which extends above the surface parking at the ground floor, via the noted laneway. Levels 3-7 include central shared building support spaces and residential units throughout the remainder of the level. Level 5 is served by a private terrace to the south. Level 8 includes shared building support spaces to the north and residential units throughout the remainder of the level. This level is also served by an amenity terrace to the north.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-metre (m) radius of the subject site) comprise a mix of low-rise residential and commercial buildings in all compass directions with a mid-rise government building to the north, mid-rise hotel building to the south, a low-rise hotel to the southwest, and a mid-rise retirement residence to the west. Notably, Don W. Johnson Park is situated to the north and green spaces extend from the northeast clockwise to the southeast. The far-field surroundings (defined as the area beyond the near field and within a two-kilometre (km) radius) primarily comprise a mix of low-rise massing and green spaces with isolated mid-rise buildings from the west clockwise to the south-southwest and isolated high-rise buildings from the east clockwise to the south-southeast. In addition, Goat Island is situated approximately 1.6 km to the southeast, east of the Niagara River, which flows from the south-southeast to the east, approximately 1.2 km to the southeast of the subject site.

Figure 1A illustrates the subject site and surrounding context, representing the proposed future massing scenario, while Figure 1B illustrates the subject site and surrounding context, representing the existing massing scenario. Figures 2A-2H illustrate the computational models used to conduct the study.

3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind 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 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 Niagara Falls area wind climate, and synthesis of computational data with industry standard wind comfort and safety guidelines. The following sections describe the analysis procedures, including a discussion of the noted pedestrian wind guidelines.

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 the Niagara Falls International Airport in Niagara County, New York. 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 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 12 wind directions. The CFD simulation model was centered on the proposed development, complete with surrounding massing within a radius of 480 m. The process was performed for two context massing scenarios, as noted in Section 2.

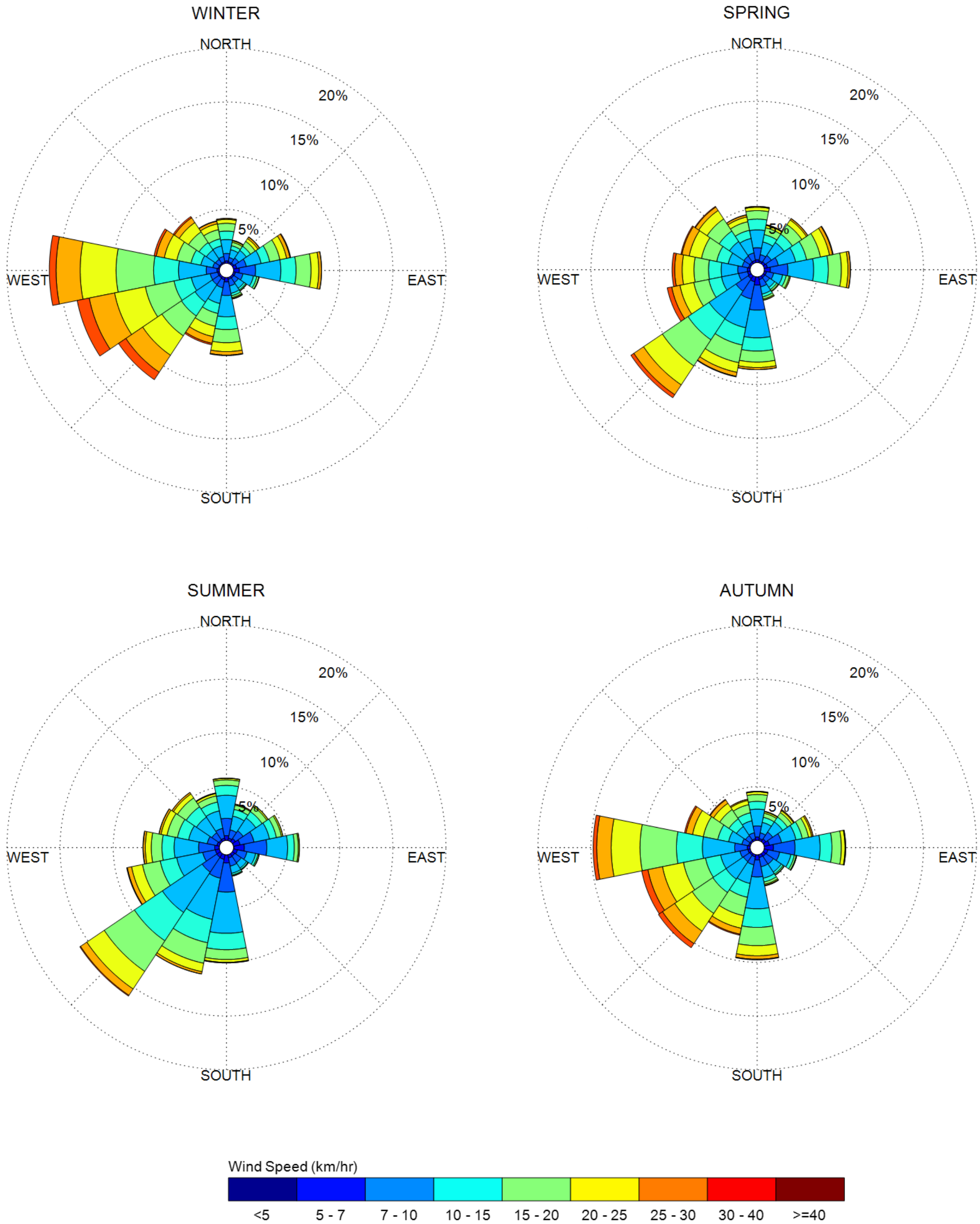
Mean and peak wind speed data obtained over the subject site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade and the Level 8 common amenity terrace serving the proposed development 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 Niagara Falls was developed from approximately 40 years of hourly meteorological wind data recorded at Niagara Falls 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 Niagara Falls 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 Niagara Falls, 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
NIAGARA FALLS INTERNATIONAL AIRPORT, NIAGARA COUNTY, NEW YORK



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 Guidelines

Pedestrian wind comfort and safety guidelines are based on the mechanical effects of wind without consideration of other meteorological conditions, such as temperature and relative humidity. The comfort guidelines 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 target.

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

THE BEAUFORT SCALE

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

Experience and research on people's perception of mechanical wind effects has shown that if the wind speed levels are exceeded for more than 20% of the time, the activity level would be judged to be uncomfortable by most people. For instance, if a mean wind speed of 10 km/h (equivalent gust wind speed of approximately 16 km/h) were exceeded for more than 20% of the time most pedestrians would judge that location to be too windy for sitting. Similarly, if mean wind speed of 20 km/h (equivalent gust wind speed of approximately 32 km/h) at a location were exceeded for more than 20% of the time, walking or less vigorous activities would be considered uncomfortable. As these guidelines are based on subjective reactions of a population to wind forces, their application is partly based on experience and judgment.

Once the pedestrian wind speed predictions have been established throughout the site, the assessment of pedestrian comfort involves determining the suitability of the predicted wind conditions for discrete regions within and surrounding the subject site. This step involves comparing the predicted comfort classes to the desired comfort classes, which are dictated by the location type for each region (that is, a sidewalk, building entrance, amenity space, or other). An overview of common pedestrian location types and their typical windiest desired comfort classes are summarized on the following page. Depending on the programming of a space, the desired comfort class may differ from this table.

DESIRED PEDESTRIAN COMFORT CLASSES FOR VARIOUS LOCATION TYPES

Location Types	Desired Comfort Classes
Primary Building Entrance	Standing
Secondary Building Access Point	Walking
Public Sidewalk / Bicycle Path	Walking
Outdoor Amenity Space	Sitting (Typical Use Period)
Café / Patio / Bench / Garden	Sitting (Typical Use Period)
Transit Stop (Without Shelter)	Standing
Transit Stop (With Shelter)	Walking
Public Park / Plaza	Sitting (Typical Use Period)
Garage / Service Entrance	Walking
Parking Lot	Walking
Vehicular Drop-Off Zone	Walking

5. RESULTS AND DISCUSSION

The following discussion of the predicted pedestrian wind conditions for the subject site is accompanied by Figures 3A-6B, which illustrate wind conditions at grade level for the proposed and existing massing scenarios, and by Figures 7A-7D, which illustrate wind conditions over the common amenity terrace serving the proposed development at Level 8. 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. Wind conditions suitable for sitting are represented by the colour blue, standing by green, strolling by yellow, and walking by orange; uncomfortable conditions are represented by the colour magenta.

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

5.1 Wind Comfort Conditions – Grade Level

Sidewalks Along Spring Street: Following the introduction of the proposed development, the public sidewalk areas along Spring Street are predicted to be mostly suitable for sitting with standing conditions predominantly near the intersection of Spring Street and Gladstone Avenue during the spring, summer, and autumn, becoming suitable for a mix of sitting and standing during the winter. The noted conditions are considered acceptable.

Conditions over the sidewalk areas along Spring Street with the existing massing are predicted to be mostly suitable for sitting during the summer, becoming suitable for a mix of sitting and standing throughout the remainder of the year. Notably, the introduction of the proposed development is predicted to slightly improve comfort levels along Spring Street, in comparison to existing conditions.

North Surface Parking: Following the introduction of the proposed development, conditions over the surface parking to the north of the subject site, adjacent to Spring Street, are predicted to be suitable for sitting during the summer, becoming mostly suitable for sitting throughout the remainder of the year. The noted conditions are considered acceptable.

Conditions over the northern area of the subject site with the existing massing are predicted to be suitable for sitting during the summer, mostly suitable for sitting during the spring, becoming suitable for a mix of sitting and standing during the autumn and winter. Notably, the introduction of the proposed development is predicted to improve comfort levels in the noted area, in comparison to existing conditions.

Central Surface Parking: Following the introduction of the proposed development, conditions over the central surface parking, situated to the north of the proposed development, are predicted to be suitable for a mix of sitting and standing during the summer, becoming suitable for strolling or better during the spring and autumn, with an isolated region of standing during the autumn, and suitable for a mix of standing, strolling and walking during the winter. The noted conditions are considered acceptable.

Conditions over the central area of the subject site with the existing massing are predicted to be suitable for sitting during the spring, summer, and autumn, becoming mostly suitable for sitting during the winter.

While the introduction of the proposed development produces windier conditions in comparison to existing conditions, wind comfort conditions are nevertheless considered acceptable.

Laneway East of Subject Site: Conditions over the north-south laneway extending from Spring Street to Ferry Street, along the east side of the subject site, are predicted to be suitable for sitting during the summer, mostly suitable for sitting during the spring and autumn, becoming suitable for a mix of sitting and standing during the winter. The noted conditions are considered acceptable.

Walkway North of Proposed Development: Conditions over the walkway along the north elevation of the proposed development are predicted to be suitable for sitting during the summer, suitable for a mix of sitting and standing during the spring and autumn, becoming mostly suitable for standing during the winter. The noted conditions are considered acceptable.

Building Access North of Proposed Development: Conditions in the vicinity of building access points to the north of the proposed development 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.

Building Access Northeast of Proposed Development: Conditions in the vicinity of the single building access point near the northeast corner of the proposed development are predicted to be suitable for sitting during the summer and autumn, becoming suitable for a mix of sitting and standing during the winter and spring. The noted conditions are considered acceptable.

Sidewalks, Transit Stops, and Building Access Along Ferry Street: Following the introduction of the proposed development, the public sidewalk areas along Ferry Street are predicted to be mostly suitable for sitting during the summer, suitable for a mix of sitting and standing during the spring and autumn, becoming mostly suitable for standing with an isolated region of strolling during the winter. Conditions over the transit stop north of Ferry Street are predicted to be suitable for sitting during the summer, suitable for a mix of sitting and standing during the spring and autumn, becoming mostly suitable for standing during the winter. Conditions over the transit stop south of Ferry Street are predicted to be suitable for sitting during the summer, becoming suitable for standing throughout the remainder of the year. The noted conditions are considered acceptable.

Conditions over the sidewalk areas along Ferry Street with the existing massing are predicted to be mostly suitable for sitting during the spring, summer, and autumn, becoming suitable for a mix of sitting and standing with an isolated region of strolling during the winter. Conditions over the transit stop north of Ferry Street are predicted to be suitable for sitting throughout the year. Conditions over the transit stop south of Ferry Street are predicted to be suitable for sitting during the summer, becoming suitable for standing throughout the remainder of the year. While the introduction of the proposed development produces windier conditions over Ferry Street in comparison to existing conditions, wind comfort conditions are nevertheless considered acceptable.

Walkway West of Proposed Development: Conditions over the walkway situated along the west elevation of the proposed development are predicted to be suitable for sitting during the summer, suitable for a mix of sitting and standing during the spring and autumn, becoming mostly suitable for standing during the winter. The noted conditions are considered acceptable.

5.2 Wind Comfort Conditions – Common Amenity Terrace

Level 8 Common Amenity Terrace: Wind comfort conditions over the amenity terrace serving the proposed development at Level 8 are predicted to be suitable for a mix of sitting and standing with isolated strolling conditions along the west side of the terrace during the typical use period, as illustrated in Figure 8A.

The areas that are predicted to be suitable for standing, according to the comfort classification in Section 4.4, are also predicted to be suitable for sitting for at least 72% of the time during the typical use period to the east of the terrace, for at least 65% of the time during the same period within the central area of the terrace, and for at least 60% of the time during the same period along the west side of the terrace, as illustrated in Figure 8B, where the target is 80% to satisfy the sitting comfort class.

To achieve the sitting comfort class in all areas during the typical use period, we recommend implementing a wind screen along the full perimeter of the terrace. The wind screen, typically glazed and preferably solid, is recommended to extend at least 2.0 m above the walking surface of the terrace. Depending on the programming of the terrace, mitigation inboard of the perimeter may also be required and could take the form of wind screens and/or other landscaping features.

5.3 Wind Safety

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas within or surrounding the subject site are expected to experience conditions that could be considered dangerous, as defined in Section 4.4.

5.4 Applicability of Results

Pedestrian wind comfort and safety have been quantified for the specific configuration of existing and foreseeable construction around the subject site. Future changes (that is, construction or demolition) of these surroundings may cause changes to the wind effects in two ways, namely: (i) changes beyond the immediate vicinity of the subject site would alter the wind profile approaching the subject site; and (ii) development in proximity to the subject site would cause changes to local flow patterns.

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 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, and experience with numerous similar developments, the study concludes the following:

1) All grade-level areas within and surrounding the subject site are predicted to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year. Specifically, conditions over surrounding sidewalks, laneway, walkways, transit stops, surface parking, and in the vicinity of building access points, are considered acceptable.

2) Conditions over the amenity terrace serving the proposed development at Level 8 are predicted to be suitable for a mix of sitting and standing with strolling conditions along the west side of the terrace during the typical use period. The areas that are predicted to be suitable for standing, according to the comfort classification in Section 4.4, are also predicted to be suitable for sitting for at least 72% of the time during the same period to the east, for at least 65% of the time during

the same period within the central area, and for at least 60% of the time during the same period along the west side, where the target is 80% to satisfy the sitting comfort class.

a. To achieve the sitting comfort class in all areas during the typical use period, we recommend implementing a wind screen along the full perimeter of the terrace. The wind screen, typically glazed and preferably solid, is recommended to extend at least 2.0 m above the walking surface of the terrace. Depending on the programming of the terrace, mitigation inboard of the perimeter may also be required and could take the form of wind screens and/or other landscaping features.

3) The foregoing statements and conclusions apply to common weather systems, during which no dangerous wind conditions, as defined in Section 4.4, are expected anywhere over the subject site or within the neighbouring properties. During extreme weather events, (for example, thunderstorms, tornadoes, and downbursts), pedestrian safety is the main concern. However, these events are generally short-lived and infrequent and there is often sufficient warning for pedestrians to take appropriate cover.

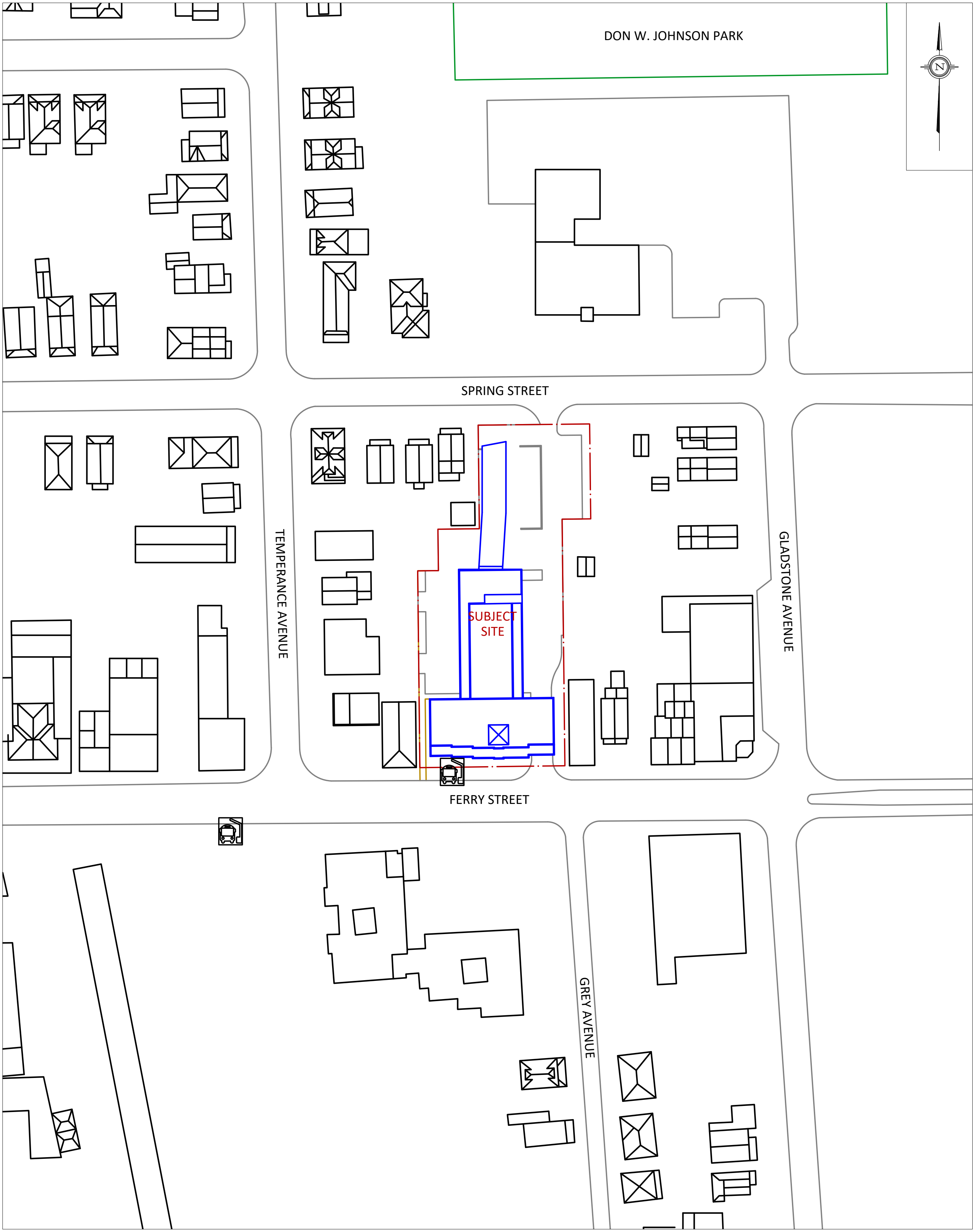
Sincerely,

Gradient Wind Engineering Inc.

LICENSED PROFESSIONAL ENGINEER
J. D. FERRARO
100158495
Oct 20, 2022
PROVINCE OF ONTARIO

David Huitema, M.Eng.
Junior Wind Scientist

Justin Ferraro, P.Eng.
Principal



GRADIENTWIND
ENGINEERS & SCIENTISTS

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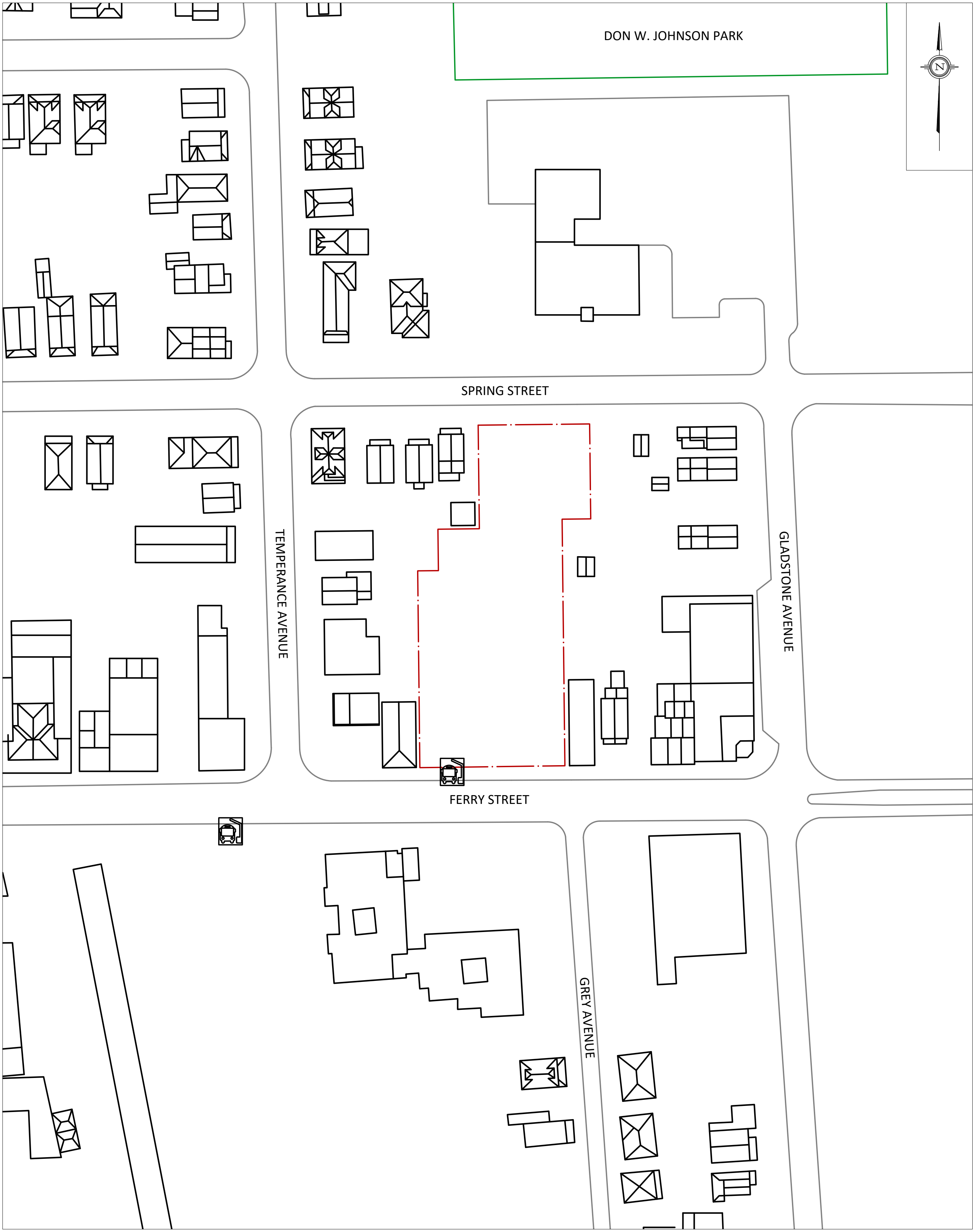
613 836 0934 • GRADIENTWIND.COM

PROJECT 5687 FERRY STREET & 5660 SPRING STREET, NIAGARA FALLS PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION FIGURE 1A: PROPOSED SITE PLAN AND SURROUNDING CONTEXT
SCALE 1:1500	DRAWING NO. 22-310-PLW-1A	
DATE OCTOBER 13, 2022	DRAWN BY S.K.	



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PROJECT	5687 FERRY STREET & 5660 SPRING STREET, NIAGARA FALLS PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:1500	DRAWING NO.	22-310-PLW-1B
DATE	OCTOBER 13, 2022	DRAWN BY	S.K.

DESCRIPTION

FIGURE 1B:
EXISTING SITE PLAN AND SURROUNDING CONTEXT

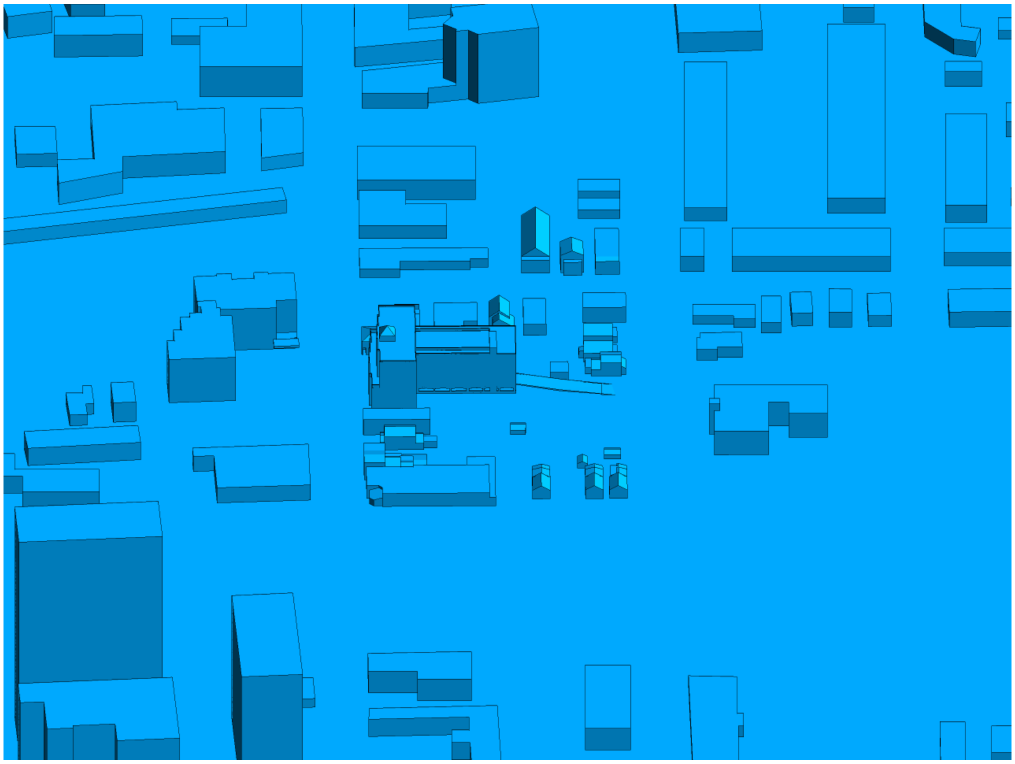


FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, EAST PERSPECTIVE

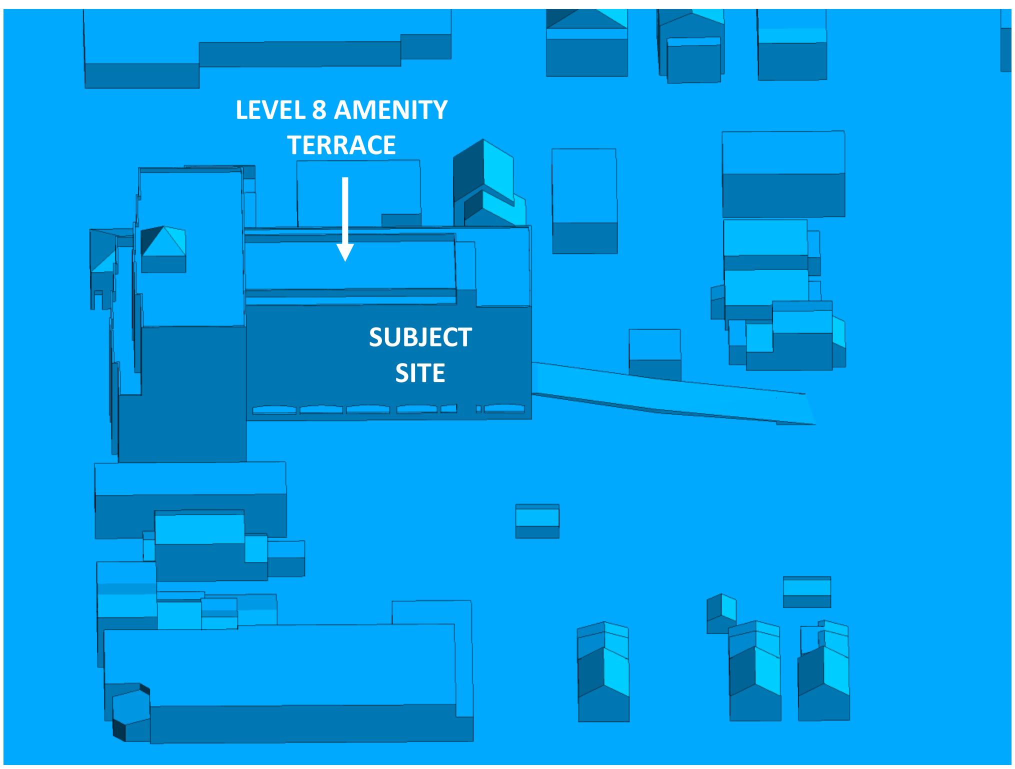


FIGURE 2B: CLOSE-UP VIEW OF FIGURE 2A

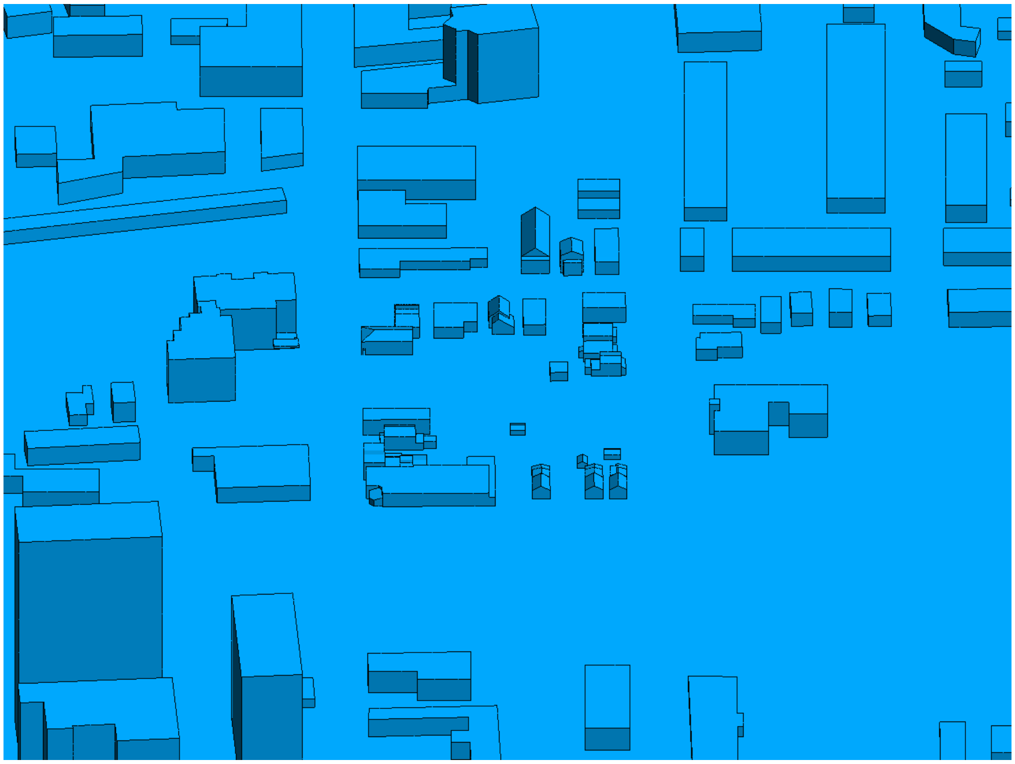


FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, EAST PERSPECTIVE

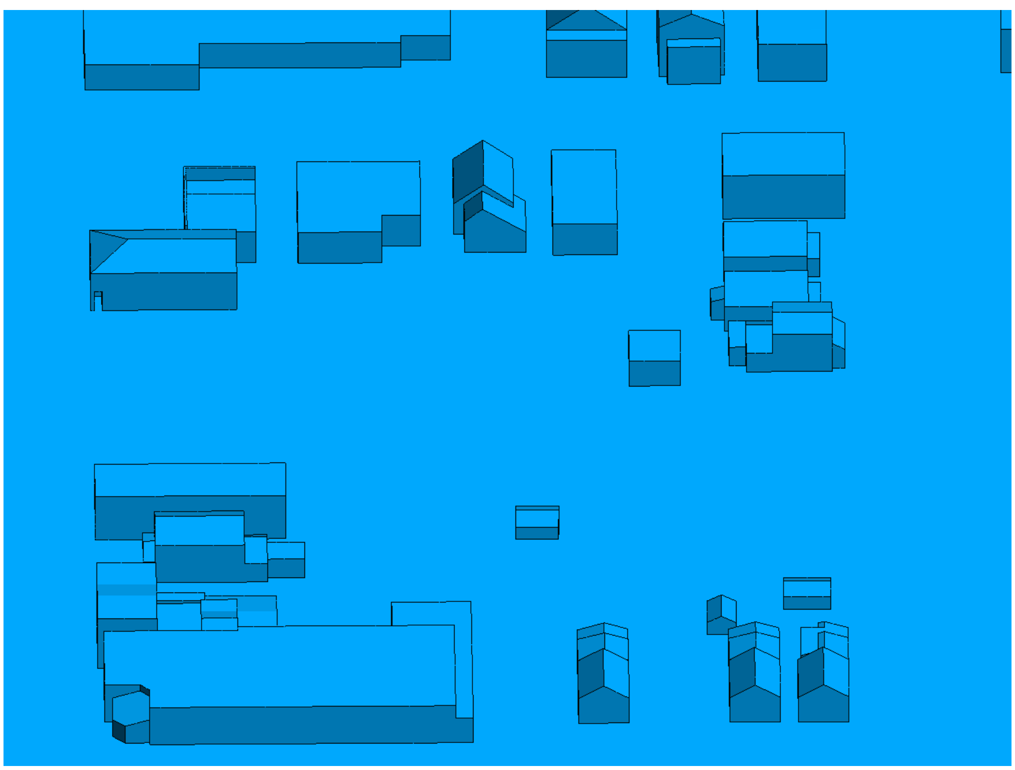


FIGURE 2D: CLOSE-UP VIEW OF FIGURE 2C

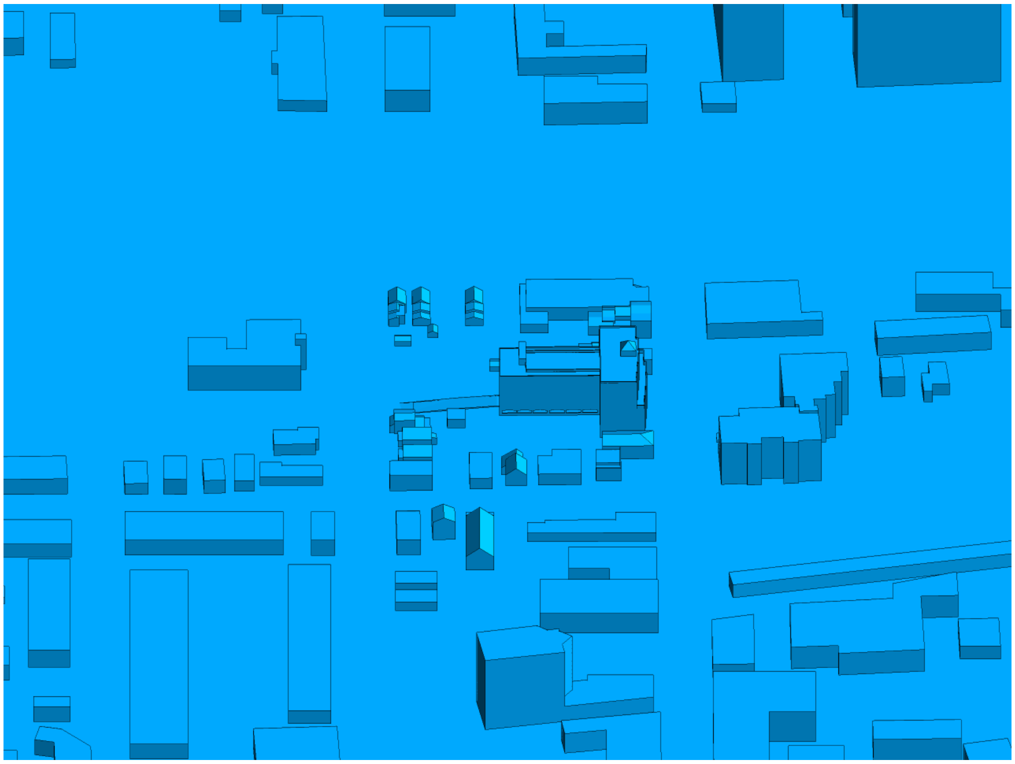


FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, WEST PERSPECTIVE

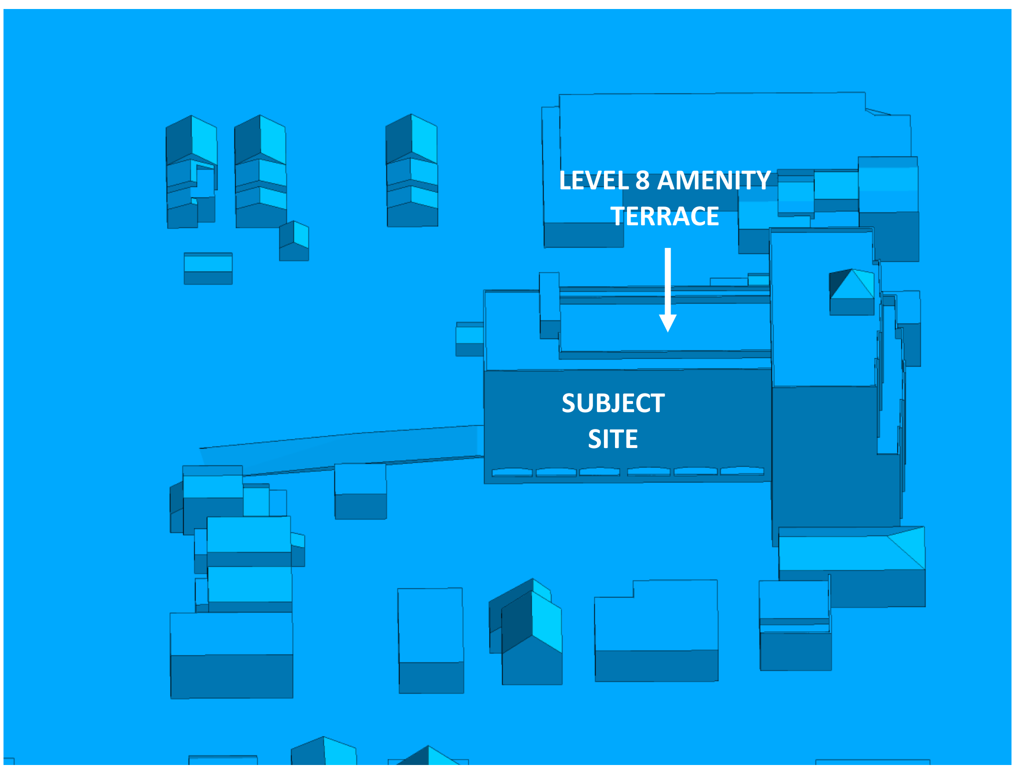


FIGURE 2F: CLOSE-UP VIEW OF FIGURE 2E

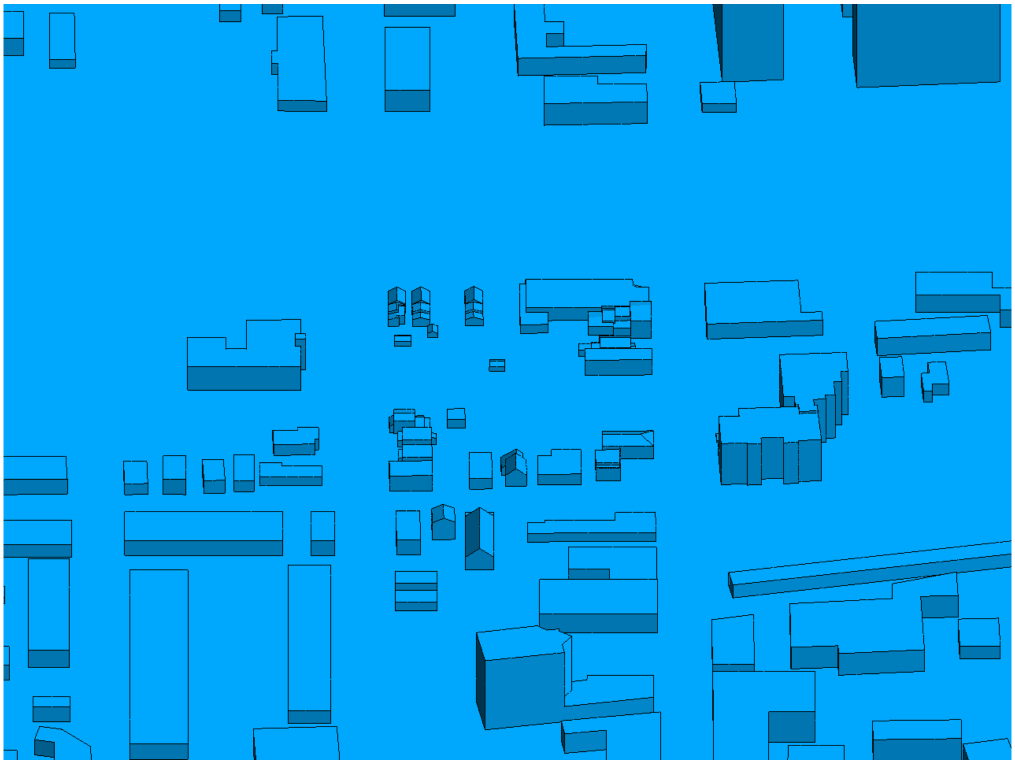


FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, WEST PERSPECTIVE

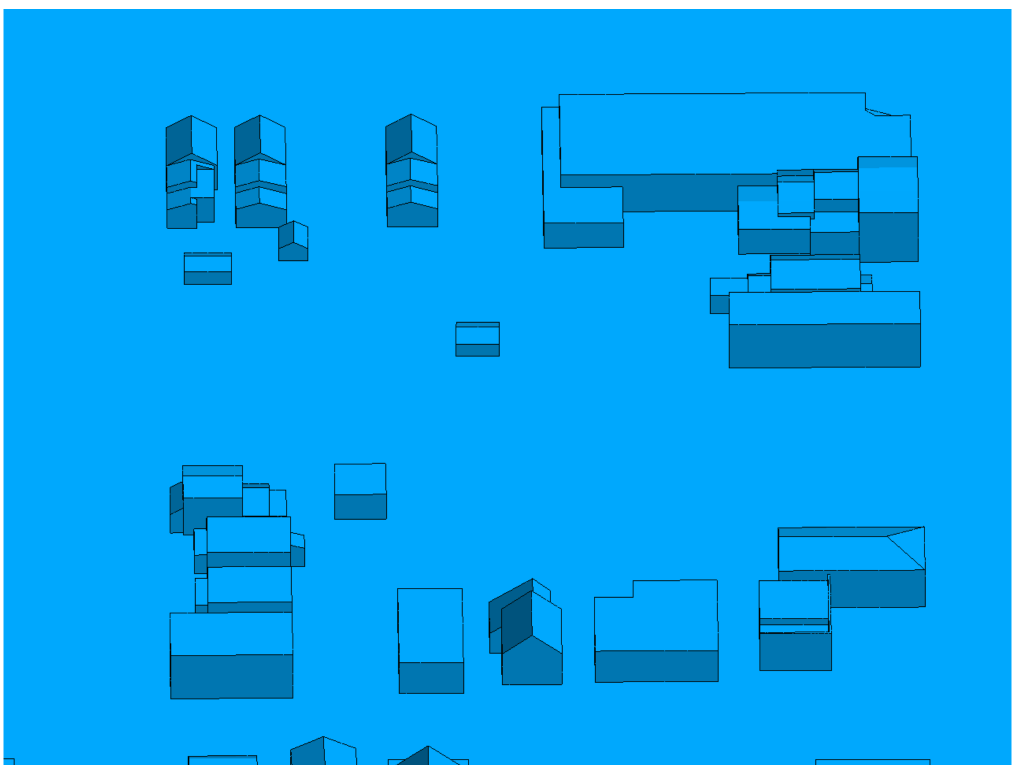


FIGURE 2H: CLOSE-UP VIEW OF FIGURE 2G

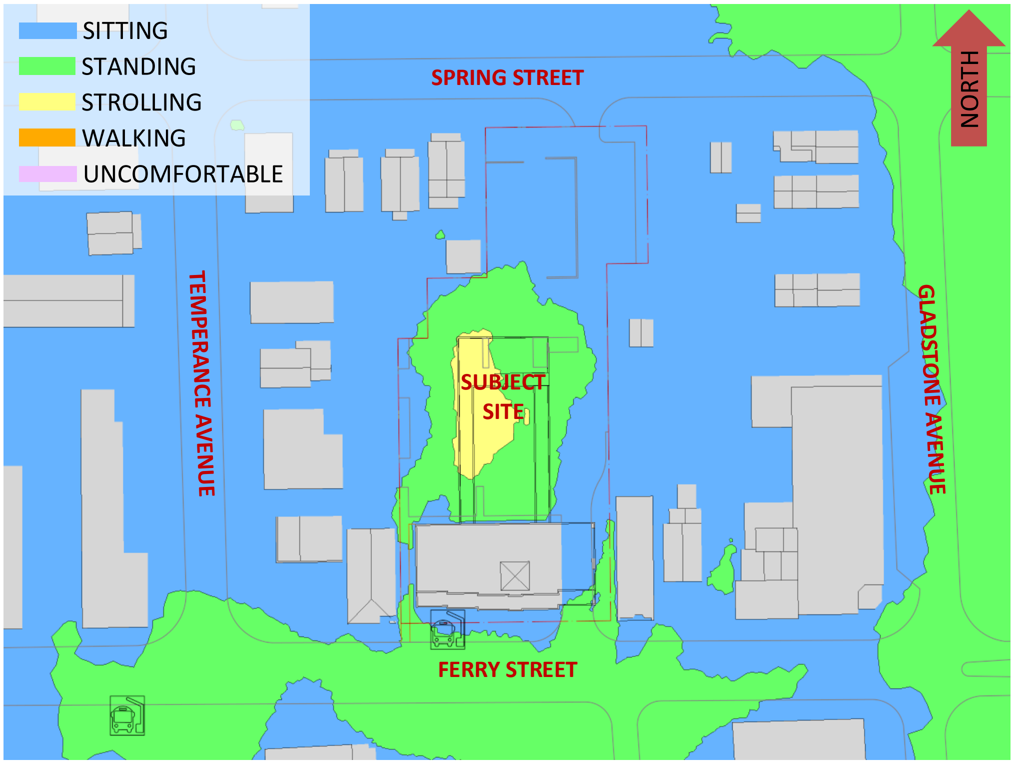


FIGURE 3A: SPRING – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

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

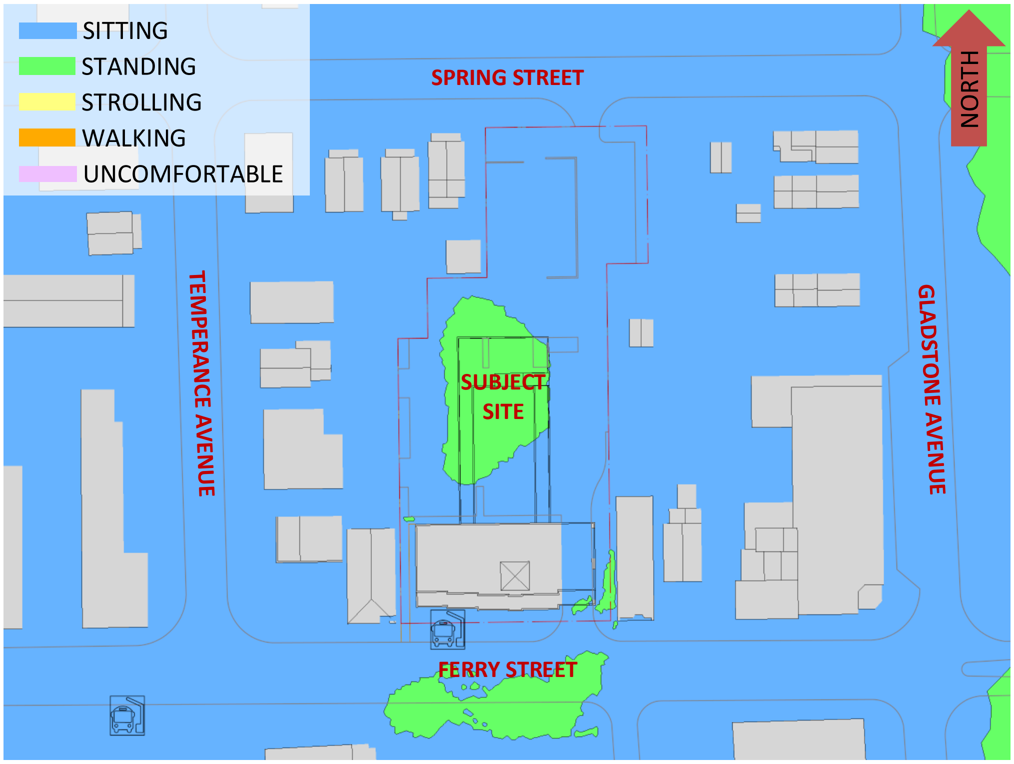


FIGURE 4A: SUMMER – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

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

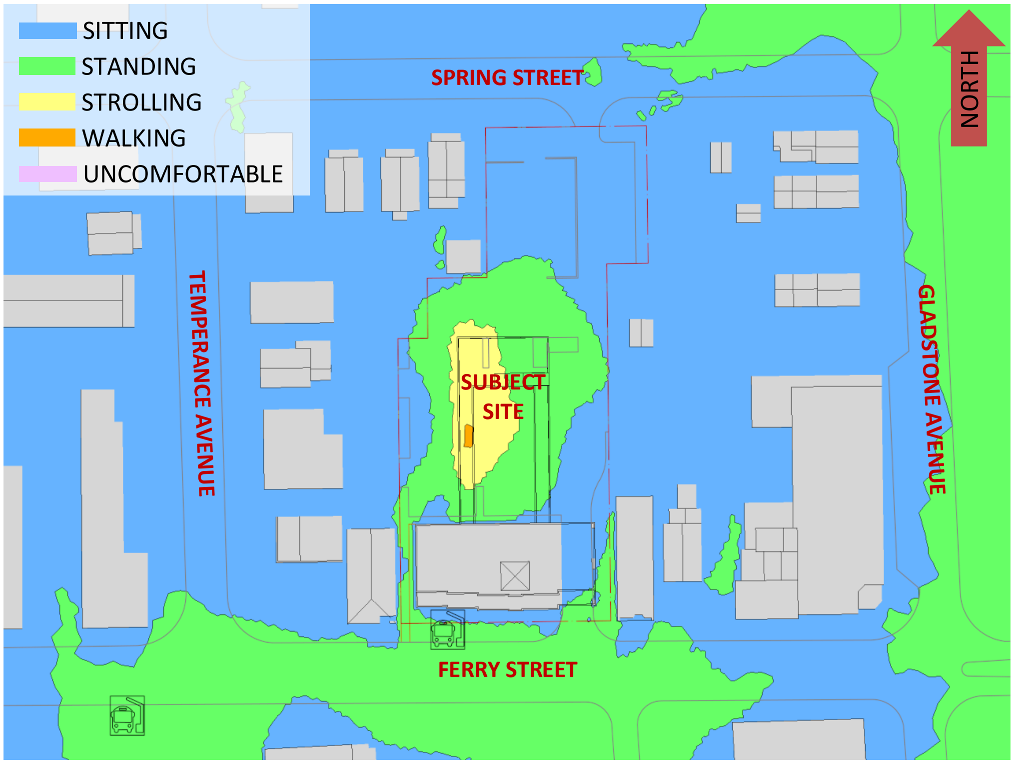


FIGURE 5A: AUTUMN – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

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

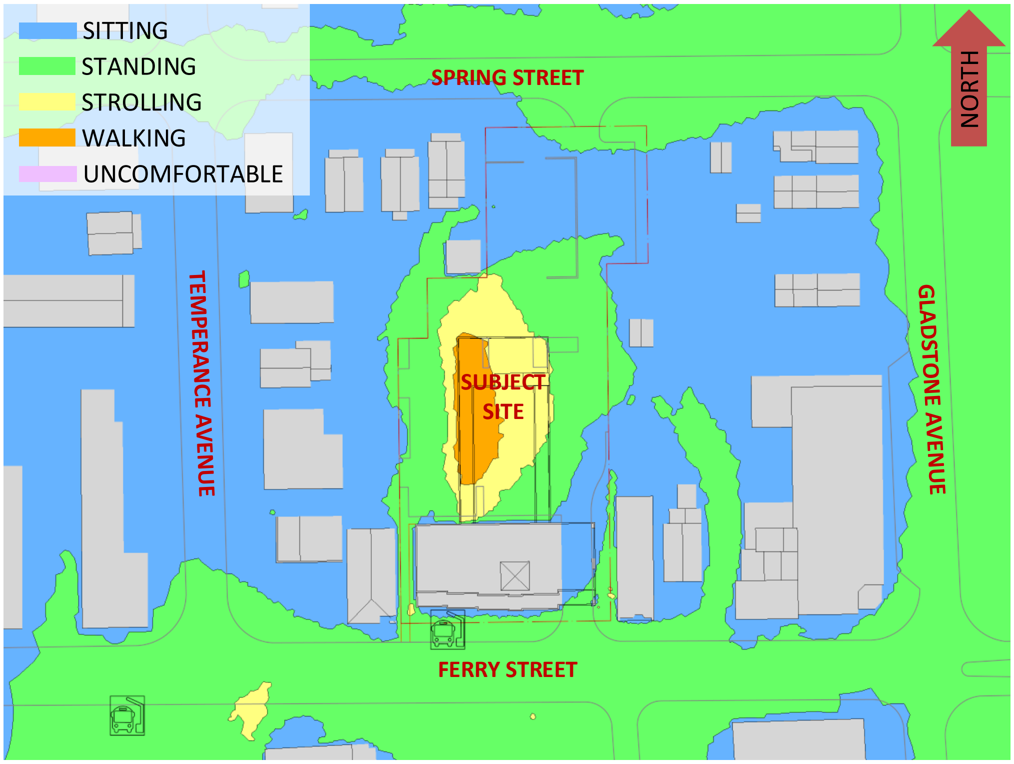


FIGURE 6A: WINTER – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

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

FIGURE 7A: SPRING – WIND COMFORT, LEVEL 8 COMMON AMENITY TERRACE

FIGURE 7B: SUMMER – WIND COMFORT, LEVEL 8 COMMON AMENITY TERRACE

FIGURE 7C: AUTUMN – WIND COMFORT, LEVEL 8 COMMON AMENITY TERRACE

FIGURE 7D: WINTER – WIND COMFORT, LEVEL 8 COMMON AMENITY TERRACE

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

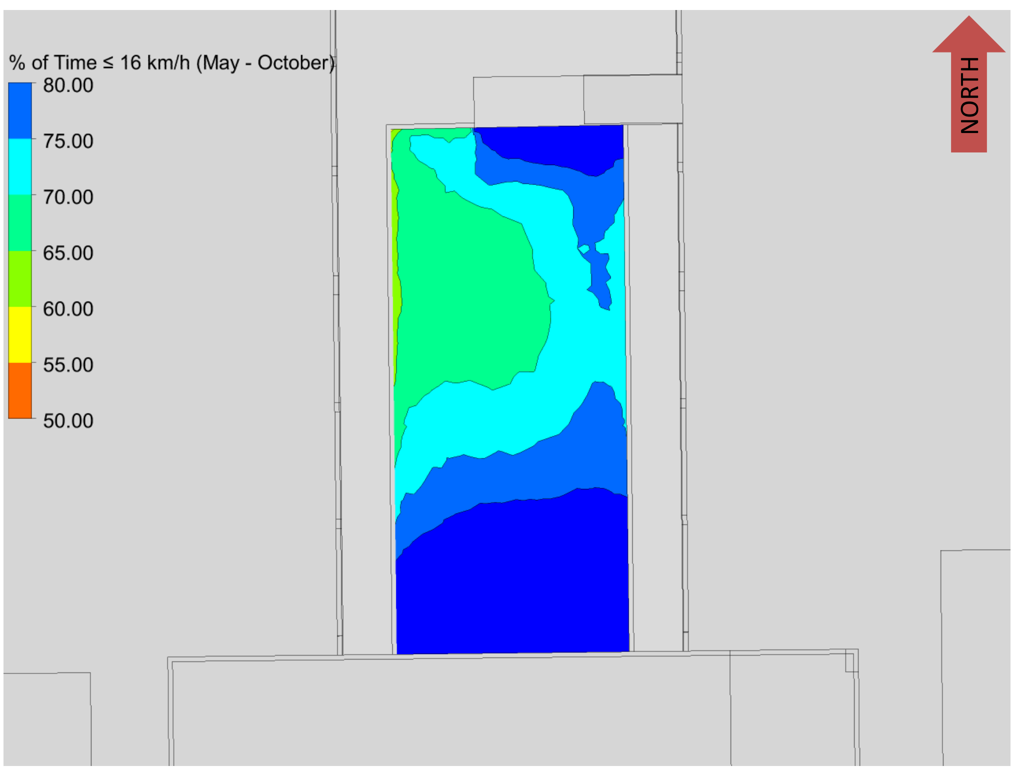
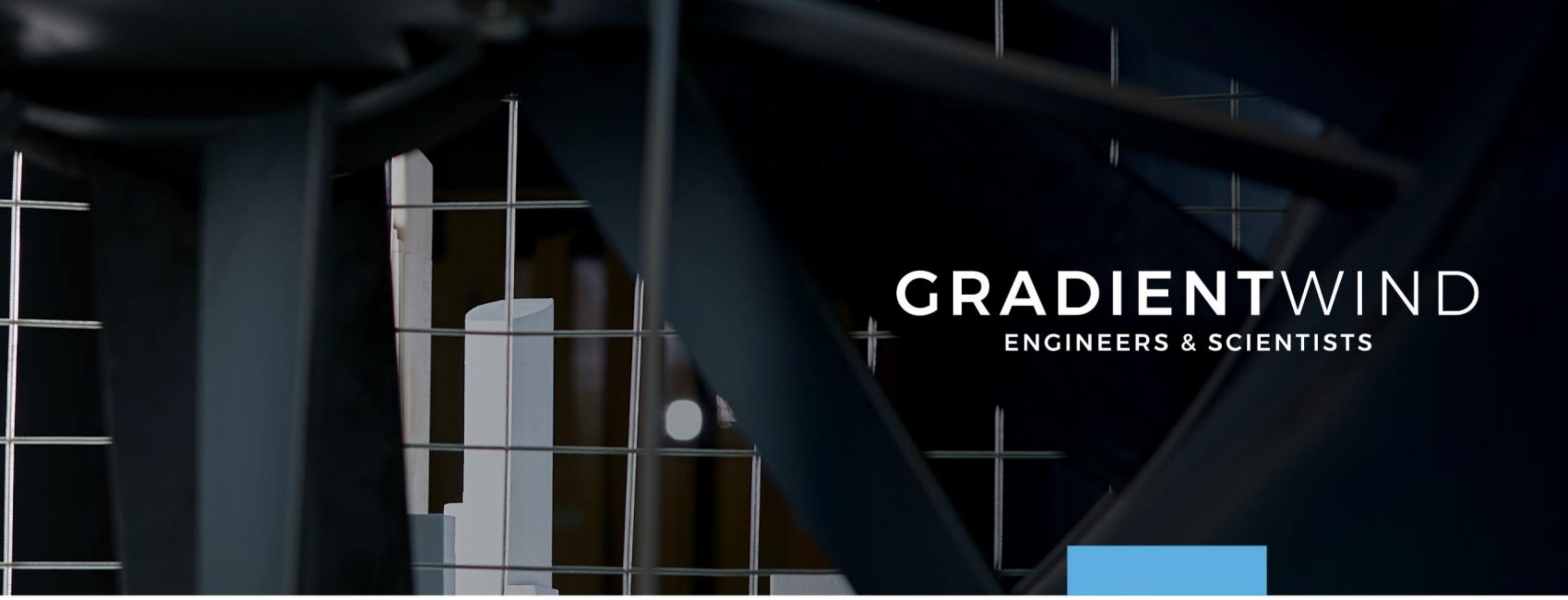
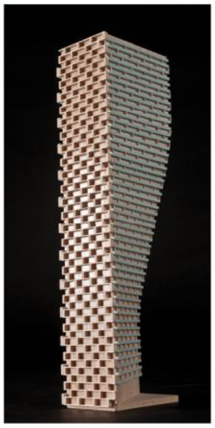
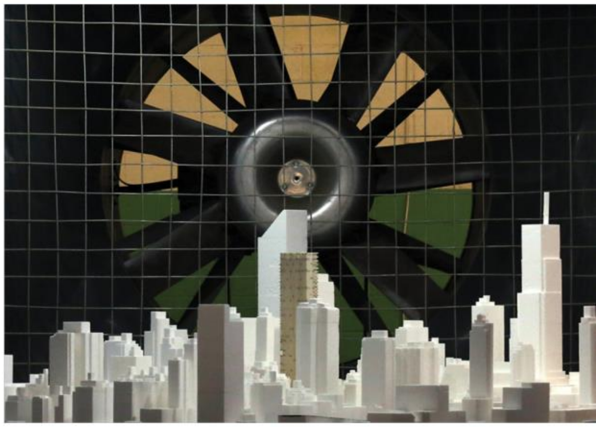


FIGURE 8B: TYPICAL USE PERIOD – % OF TIME SUITABLE FOR SITTING IN FIGURE 8A







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 35% mean wind speed for Niagara Falls 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 (that is, the area that is 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
38	0.24
70	0.24
123	0.22
190	0.23
210	0.24
224	0.24
236	0.24
250	0.24
270	0.24
294	0.24
322	0.24

TABLE 2: DEFINITION OF UPSTREAM EXPOSURE (ALPHA VALUE)

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

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

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

Equation (2)

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

Equation (3)

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

[1] P. Arya, "Chapter 10: Near-neutral Boundary Layers," in *Introduction to Micrometeorology*, San Diego, California, Academic Press, 2001.

[2] S. A. Hsu, E. A. Meindl and D. B. Gilhousen, "Determining the Power-Law WInd Profile Exponent under Near-neutral Stability Conditions at Sea," vol. 33, no. 6, 1994.

[3] Y. Tamura, H. Kawai, Y. Uematsu, K. Kondo and T. Okhuma, "Revision of AIJ Recommendations for Wind Loads on Buildings," in *The International Wind Engineering Symposium, IWES 2003*, Taiwan, 2003.