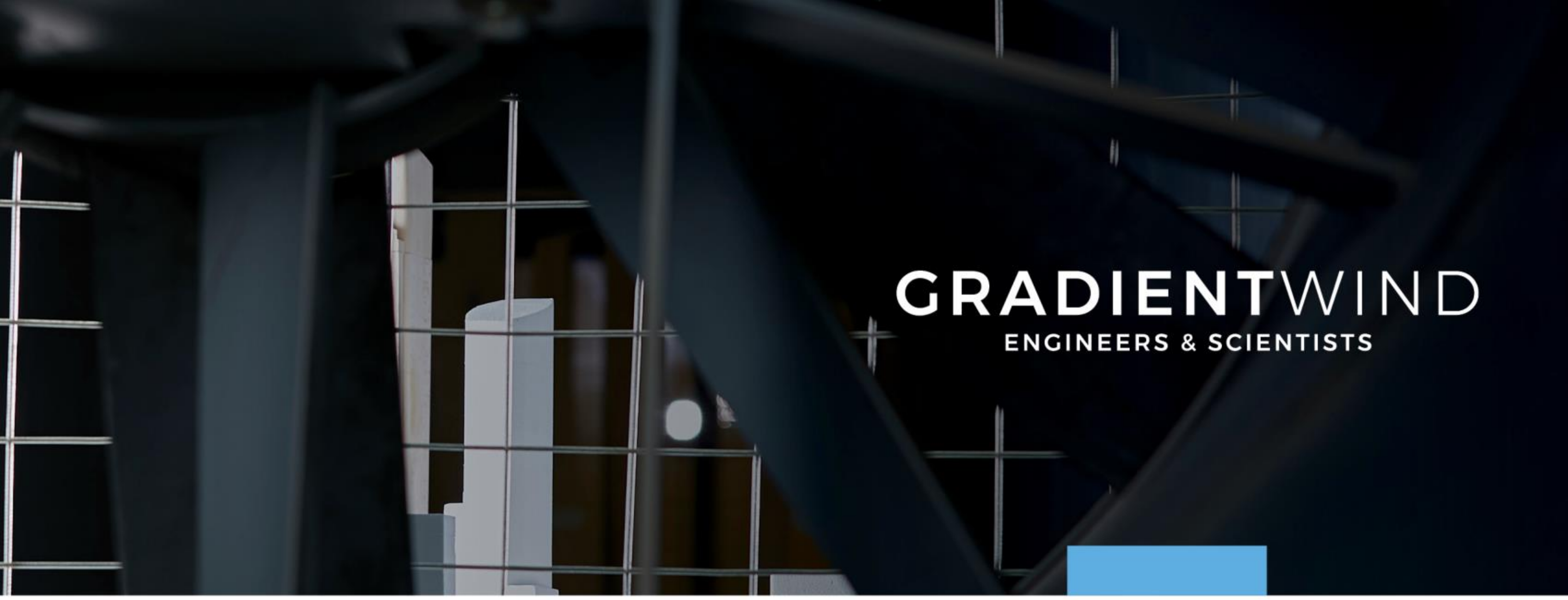
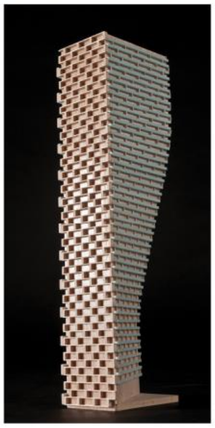
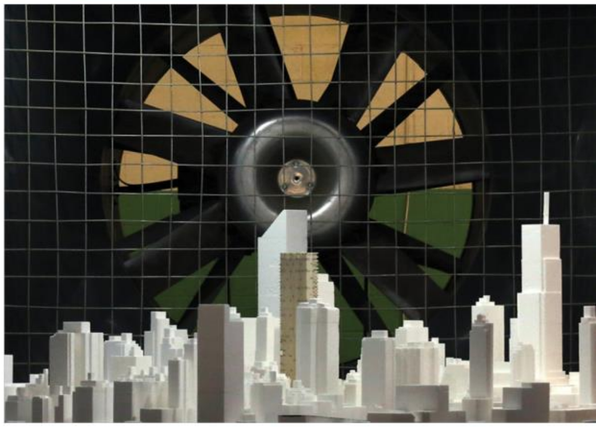


PEDESTRIAN LEVEL WIND STUDY

Yonge and High Tech Master Plan
Richmond Hill, Ontario

Report: 21-439-PLW





January 12, 2022

PREPARED FOR
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EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study for the proposed Yonge and High Tech Master Plan development in Richmond Hill, Ontario (hereinafter referred to as the "subject site"). Our mandate within this study is to investigate wind conditions throughout and surrounding the subject site, and to identify areas where wind conditions may interfere with certain pedestrian activities so that appropriate mitigation measures may be considered, where required.

The study involves simulation of wind speeds for selected wind directions in a three-dimensional (3D) computer model using the computational fluid dynamics (CFD) technique, combined with meteorological data integration, to assess pedestrian wind 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-3D, and is summarized as follows:

1) The majority of sidewalk areas within and surrounding the subject site are predicted to experience conditions that are suitable for walking, or better, throughout the year. Although a limited portion of the greenway to the south of Block 2 will exceed the walking comfort threshold during the winter months, given that the region is very localized, and because wind speeds remain safe based on annual wind statistics, mitigation is not considered necessary.

2) Conditions surrounding the future subway station are expected to be comfortable for walking, or better, during all seasonal periods, which is acceptable.

3) In general, all future park areas within the subject site will be calm and suitable for sitting during the warmer months, which is acceptable.

4) Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience conditions that could be considered unsafe.

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Yonge Bayview Holdings Inc., Saltwhistle Bay Properties Inc., Carondelet Holdings Inc., and Condor York Holdings Inc. to undertake a pedestrian level wind (PLW) study for the proposed Yonge and High Tech Master Plan development in Richmond Hill, Ontario (hereinafter referred to as the “subject site”). Our mandate within this study is to investigate wind conditions throughout 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 necessary.

The study is based on industry standard computer simulations using the computational fluid dynamics (CFD) technique and data analysis procedures, a master plan concept provided by BDP Quadrangle in December 2021, surrounding street layouts and existing and approved future building massing information obtained, recent site imagery, and experience with similar developments in the Greater Toronto Area (GTA).

2. TERMS OF REFERENCE

The master plan site encompasses an approximately L-shaped parcel of land bounded by Yonge Street to the west, Beresford Drive to the north, the future Street A North along the east side of the north portion of the subject site, Red Maple Road along the east side of the south portion of the site, and a utility/hydro corridor and Connector Road to the south. The CN and future subway corridor border the north portion of the site to the east, and bisect the south portion. A future subway station will be located at the intersection of High Tech Road and the future Street A.

The proposal comprises numerous residential towers and associated mixed-use podia, ranging is height from 40- to 80-storeys in height. The taller buildings are clustered near the future subway station at the centre of the site, with the shorter building around the perimeters. The master plan also contains parks at the north and east sides of the site, and a large plaza near the centre, adjacent to the future subway station.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-metre radius of the site), are characterized by low- and medium-rise buildings and surface parking to the north and east, an open exposure of the Highway 407 corridor to the south, and mostly low-rise suburban development to the west. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer radius) include primarily low-rise buildings and open space in all directions. The site plan for the proposed massing scenario is illustrated in Figure 1, while Figures 2A and 2B illustrate the computational model used to conduct the study.

3. OBJECTIVES

The principal objectives of this study are to: (i) outline wind flow patterns and associated predicted 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 site is based on CFD simulations of wind speeds across the subject site within a virtual environment, meteorological analysis of the Richmond Hill wind climate, and synthesis of computational data with industry-accepted guidelines. The following sections describe the analysis procedures, including a discussion of the comfort guidelines.

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 subject 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 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 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. The CFD simulation models were centered on the subject site, complete with surrounding massing within a radius of 1000 m (480 m).

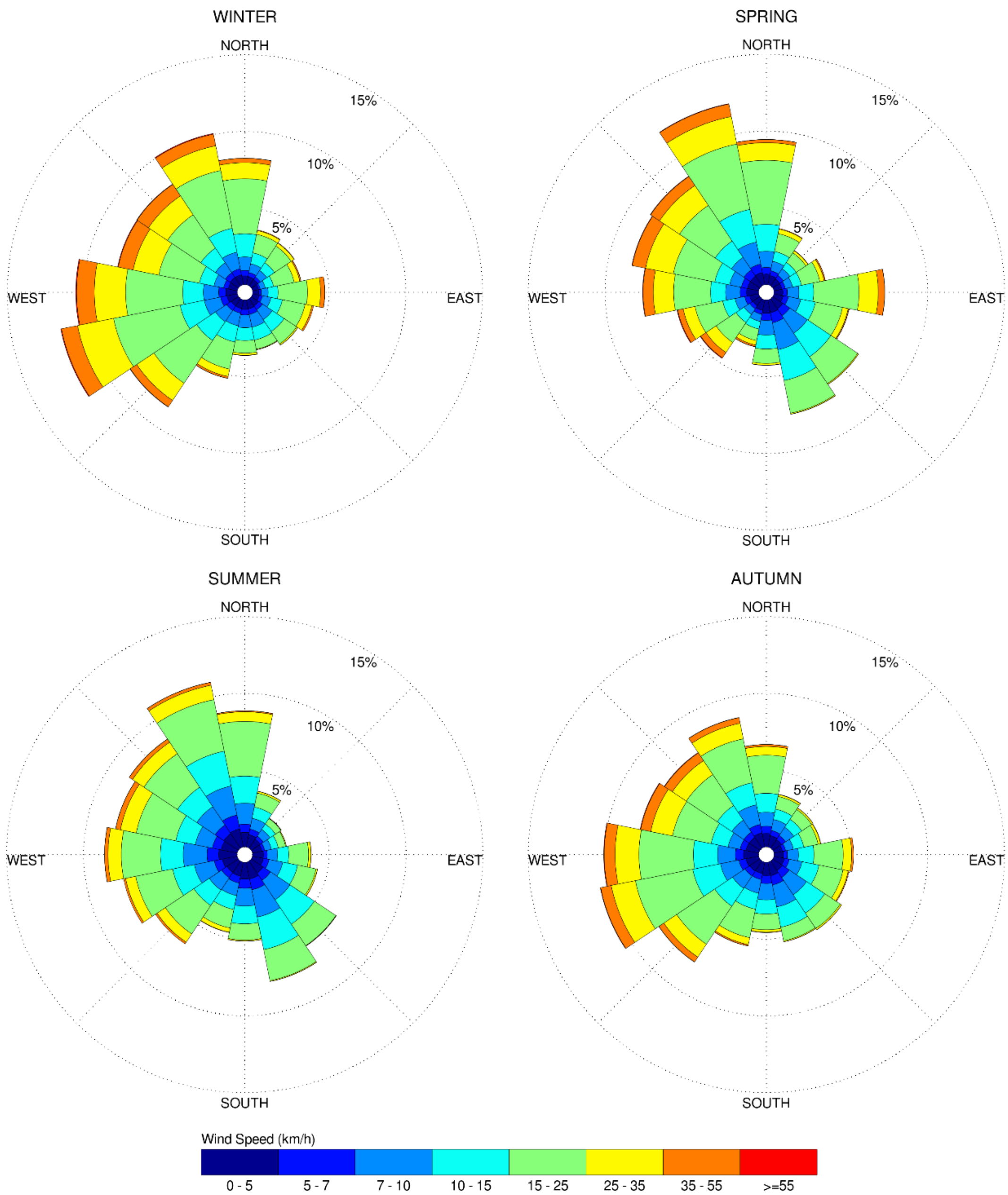
Mean and peak wind speed data obtained over the subject site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds on a continuous measurement plane 1.5 m above local grade were referenced to the wind speed at gradient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

4.3 Historical Wind Speed and Direction Data

A statistical model for winds in the GTA was developed from approximately 40 years of hourly meteorological wind data recorded at Lester B. Pearson International Airport in Mississauga 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 GTA 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 shows the frequency distribution of wind speeds for each wind direction during the measurement period. The preferred wind speeds and directions can be identified by the longer length of the bars. For the GTA, the most common winds concerning pedestrian comfort occur from the southwest 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 Comfort and Safety Guidelines

Pedestrian comfort and safety guidelines are based on the mechanical effects of wind without consideration of other meteorological conditions (i.e., temperature, 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) Walking; and (5) Uncomfortable. More specifically, the comfort classes and associated mean wind speed ranges are summarized as follows:

(i) **Sitting:** A wind speed below 16 km/h (i.e. 0 – 16 km/h) would be considered acceptable for sedentary activities, including sitting.

(ii) **Standing:** A wind speed below 22 km/h (i.e. 16 km/h – 22 km/h) is acceptable for activities such as standing or leisurely strolling.

(iii) **Walking:** A wind speed below 30 km/h (i.e. 22 km/h– 30 km/h) is acceptable for walking or more vigorous activities.

(iv) **Uncomfortable:** A wind speed over 30 km/h is classified as uncomfortable from a pedestrian comfort standpoint. Brisk walking and exercise, such as jogging, would be acceptable for moderate excesses of this criterion.

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 greater than 90 km/h is classified as dangerous.

The wind speeds associated with the above categories are gust wind speeds. Corresponding mean wind speeds are approximately calculated as gust wind speed minus 1.5 times the root-mean-square (rms) of the wind speed measurements. Gust speeds are used in the guidelines because people 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 cause problems for pedestrians. The gust 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.

THE BEAUFORT SCALE

Number	Description	Guts 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 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 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 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 (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 Classes
Primary Building Entrance	Standing
Secondary Building Access Point	Walking
Public Sidewalks / Pedestrian Walkways	Walking
Outdoor Amenity Spaces	Sitting / Standing
Cafés / Patios / Benches / Gardens	Sitting / Standing
Plazas	Standing / Walking
Transit Stops	Standing
Public Parks	Sitting / Walking
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-3D, which illustrate wind conditions at grade level. 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, and walking by orange; uncomfortable conditions are represented by the colour magenta. The details of these conditions are summarized in the following pages for areas of interest.

Sidewalk and Greenway Areas: The majority of sidewalk and greenway areas within and surrounding the subject site are predicted to be suitable for walking, or better, throughout the year, which is considered acceptable. Towards the north side of the site, along the south elevation of Block B, an area of greenway will exceed the walking threshold during the winter months. Given the limited region of uncomfortable conditions, and because conditions remain safe based on annual wind statistics, mitigation is not considered necessary for this area.

Future Subway Station: Wind speeds surrounding the future subway station are predicted to generally be comfortable for sitting or standing during all seasonal periods. Somewhat windier conditions suitable for standing or walking are expected for the area between the station buildings along High Tech Road. The noted conditions are considered acceptable.

Primary Building Access Points: It is desirable for main entrances to buildings to be suitable for standing, or better, throughout the year. If building entrances are planned at building façade areas where conditions exceed the standing threshold (orange), conditions can be locally improved by either recessing the doorways within the façade or providing vertical wind barriers flanking the entrance and a canopy above. Alternatively, relocating entrances to calmer façade locations is another option. As part of the future detailed wind tunnel studies to be performed for the individual development phases, more specific guidance related to building entrances will be provided.

Future Parks: Towards the north side of the site, the future park at the northwest corner of Block A will generally be comfortable for sitting or more sedentary activities during the summer season, without the need for mitigation.

To the west of the intersection of High Tech Road and future Street A, the Northwest Plaza and Southwest Plaza will be mostly calm and suitable for sitting during the summer owing, in part, to protection from prominent west quadrant winds by the Phase 1 buildings along the west perimeter of the site and the south portion of Phase 2A buildings and the Phase 3C buildings. Should the phasing order for the master plan build-out change in the future, and the Plaza area be more exposed to westerly wind directions, additional testing would be warranted to confirm the wind conditions in this area.

At the east portion of the site, the future park at the present location of the Home Depot will be well-protected from oncoming winds by the surrounding massing, and conditions will be comfortable for sitting during the warmer months.

Wind Safety: Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience conditions that are considered unsafe.

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

6. SUMMARY AND RECOMMENDATIONS

A complete summary of the predicted wind conditions for the proposed Bridge Station Master Plan development in Richmond Hill, Ontario is provided in Section 5 of this report and illustrated in Figures 3A-3D. Based on computer simulations using the CFD technique, meteorological data analysis, and experience with numerous similar developments in the GTA, the study concludes the following:

1) The majority of sidewalk areas within and surrounding the subject site are predicted to experience conditions that are suitable for walking, or better, throughout the year. Although a limited portion of the greenway to the south of Block 2 will exceed the walking comfort threshold during the winter months, given that the region is very localized, and because wind speeds remain safe based on annual wind statistics, mitigation is not considered necessary.

2) Conditions surrounding the future subway station are expected to be comfortable for walking, or better, during all seasonal periods, which is acceptable.

3) In general, all future park areas within the subject site will be calm and suitable for sitting during the warmer months, which is acceptable.

4) Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience conditions that could be considered unsafe.

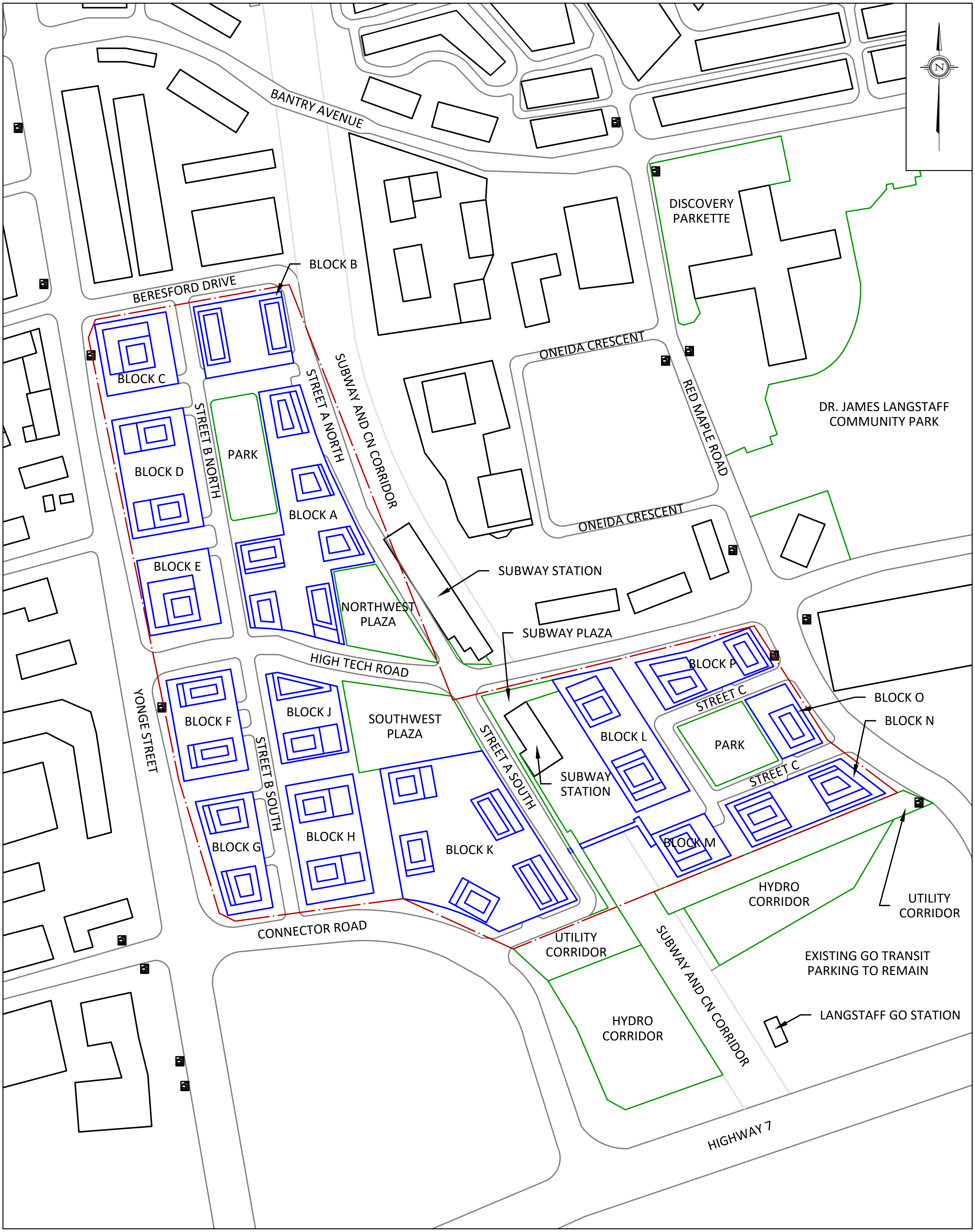
This concludes our pedestrian level wind study and report. Please advise the undersigned of any questions or comments.

Sincerely,

Gradient Wind Engineering Inc.

Daniel Davalos, MESc.
Junior Wind Scientist

Andrew Sliasas, M.A.Sc., P.Eng.,
Principal



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PROJECT	YONGE STREET AND HIGH TECH ROAD, RICHMOND HILL PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:4500	DRAWING NO.	21-439-PLW-1
DATE	JANUARY 10, 2022	DRAWN BY	S.K.

DESCRIPTION

FIGURE 1:
PROPOSED SITE PLAN AND SURROUNDING CONTEXT

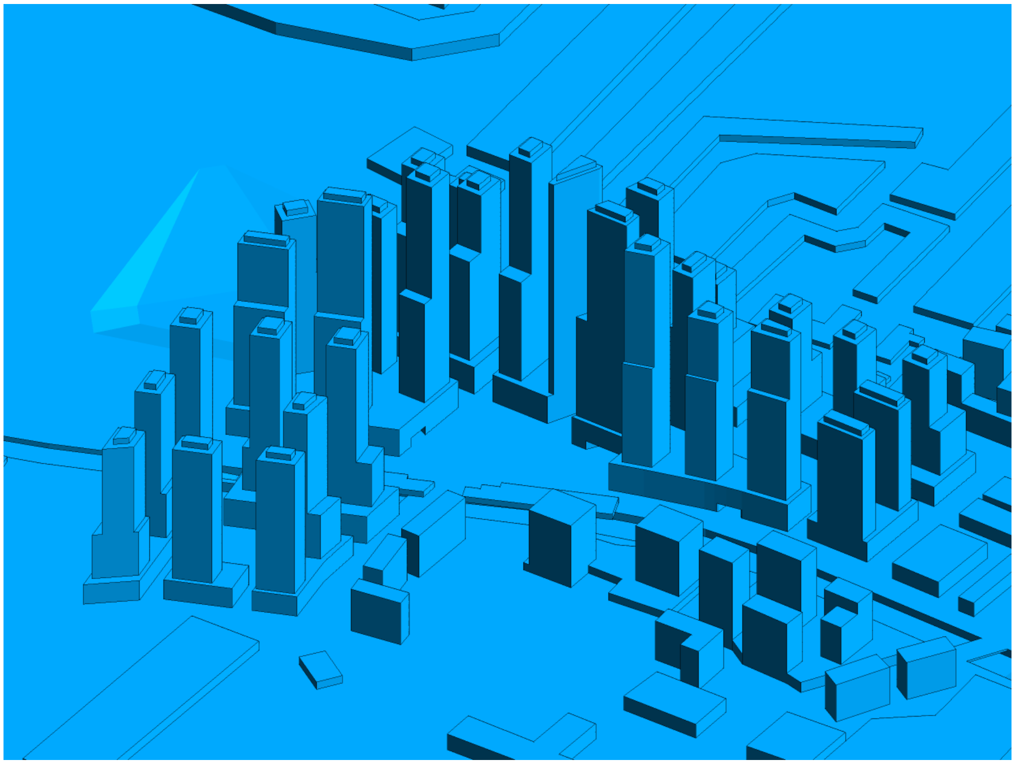


FIGURE 2A: COMPUTATIONAL MODEL OF MASTER PLAN, NORTHEAST PERSPECTIVE

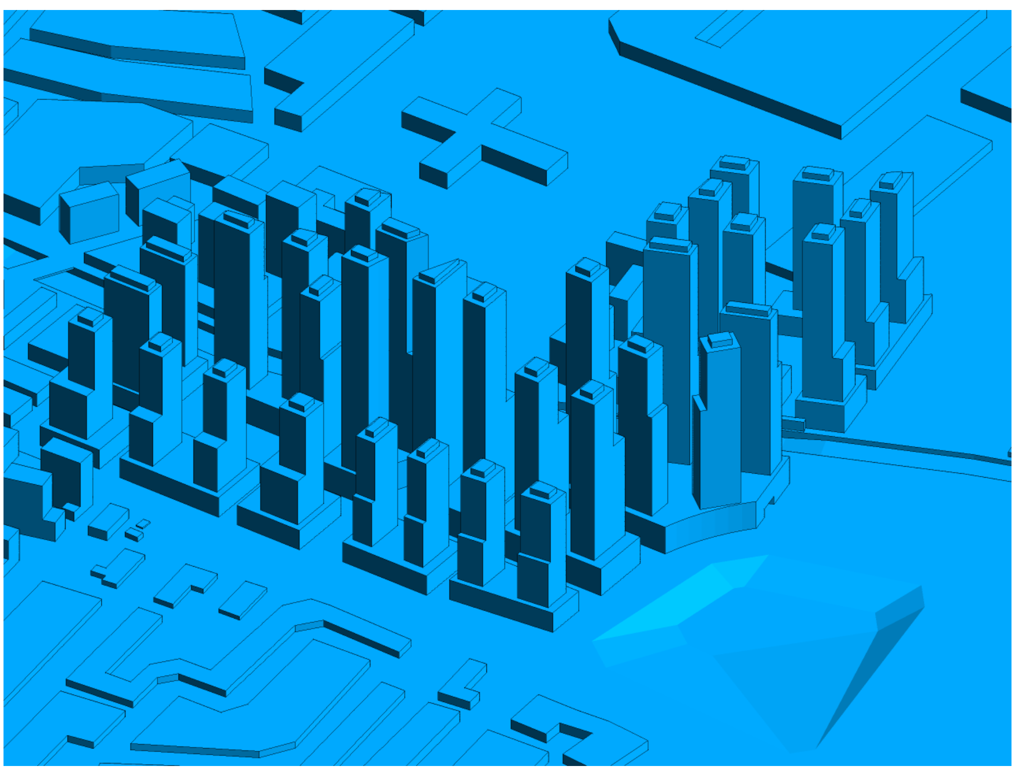


FIGURE 2B: COMPUTATIONAL MODEL OF MASTER PLAN, SOUTHWEST PERSPECTIVE

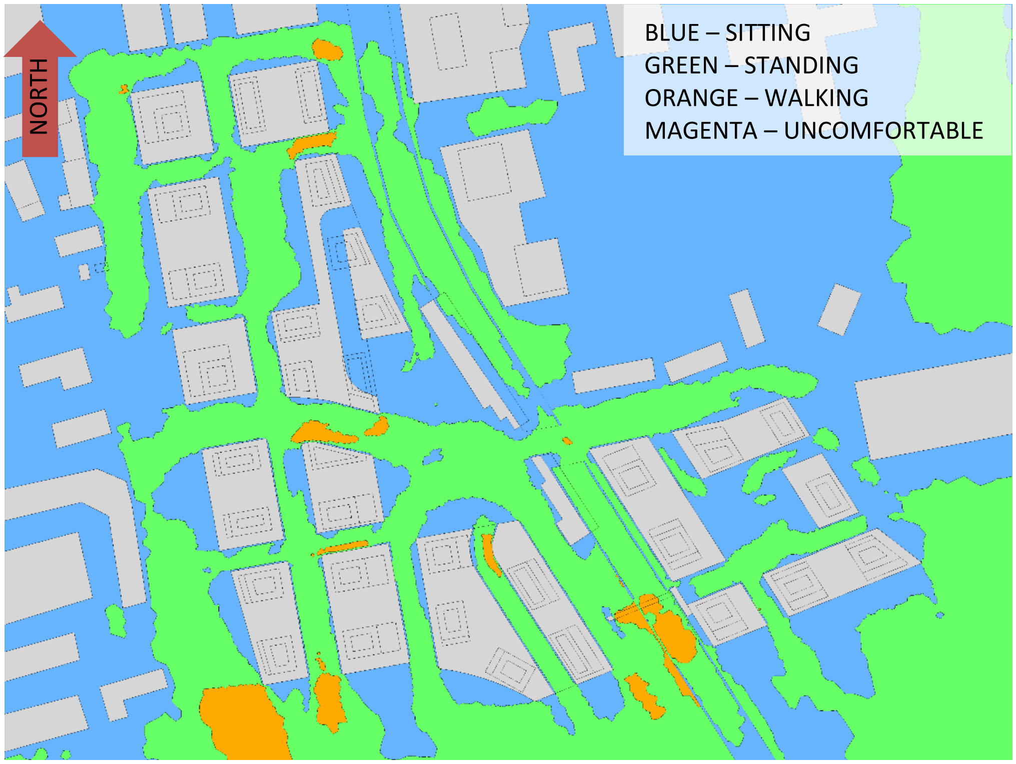


FIGURE 3A: SPRING – WIND COMFORT CONDITIONS, GRADE LEVEL

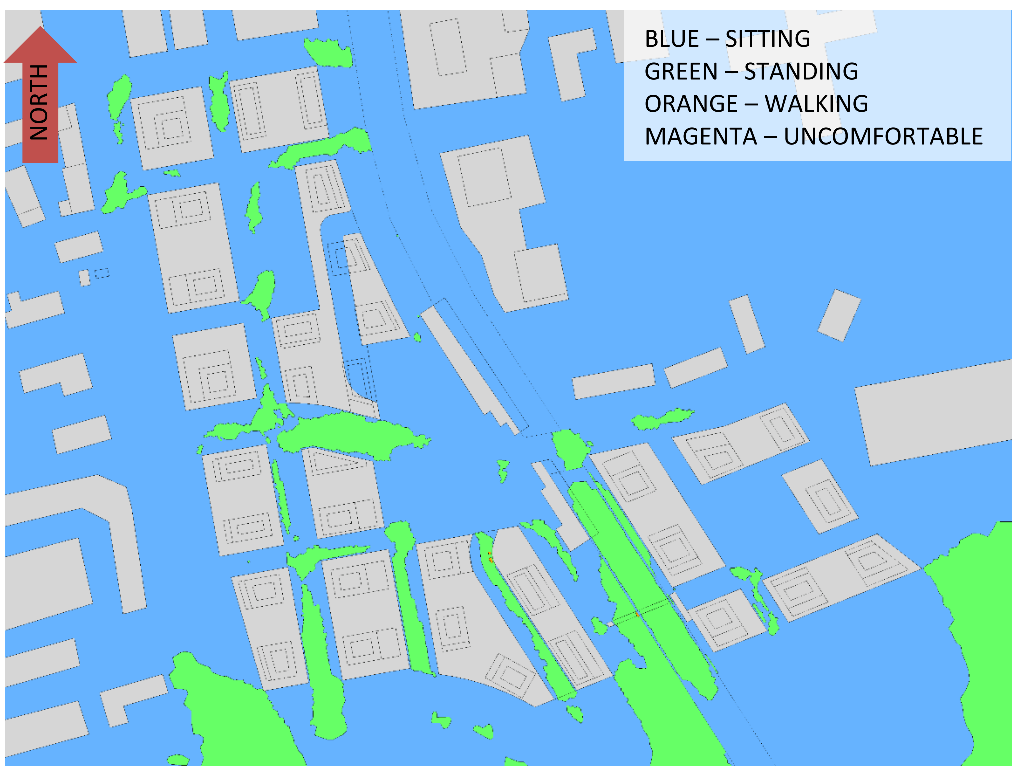


FIGURE 3B: SUMMER – WIND COMFORT CONDITIONS, GRADE LEVEL

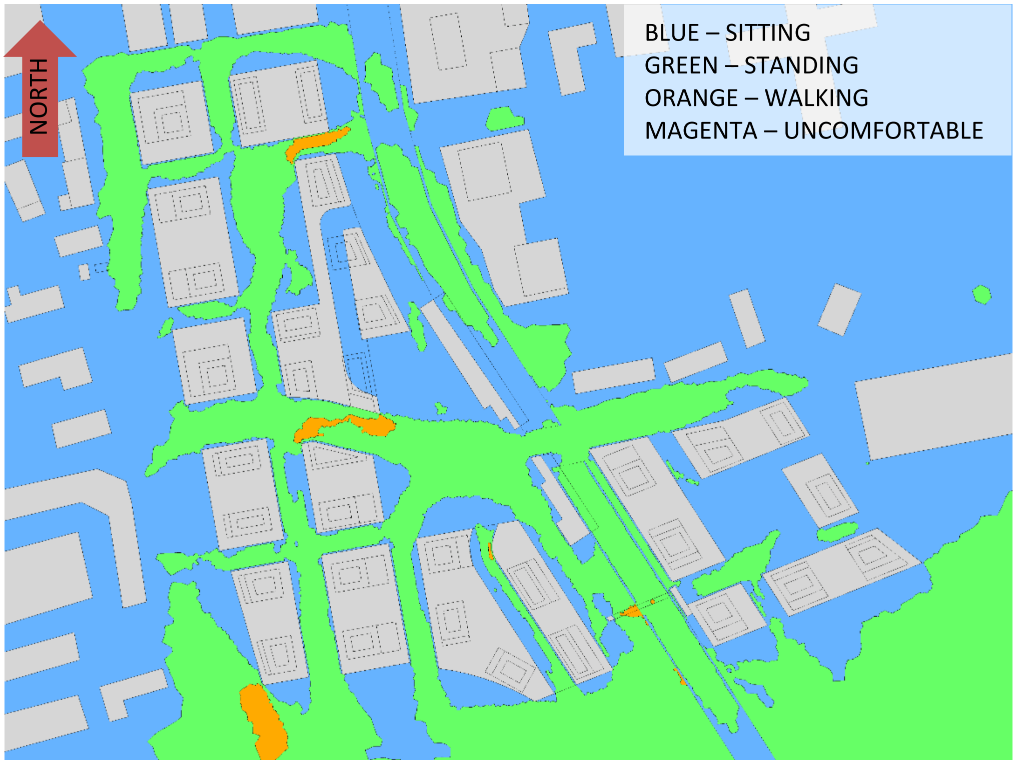


FIGURE 3C: AUTUMN – WIND COMFORT CONDITIONS, GRADE LEVEL

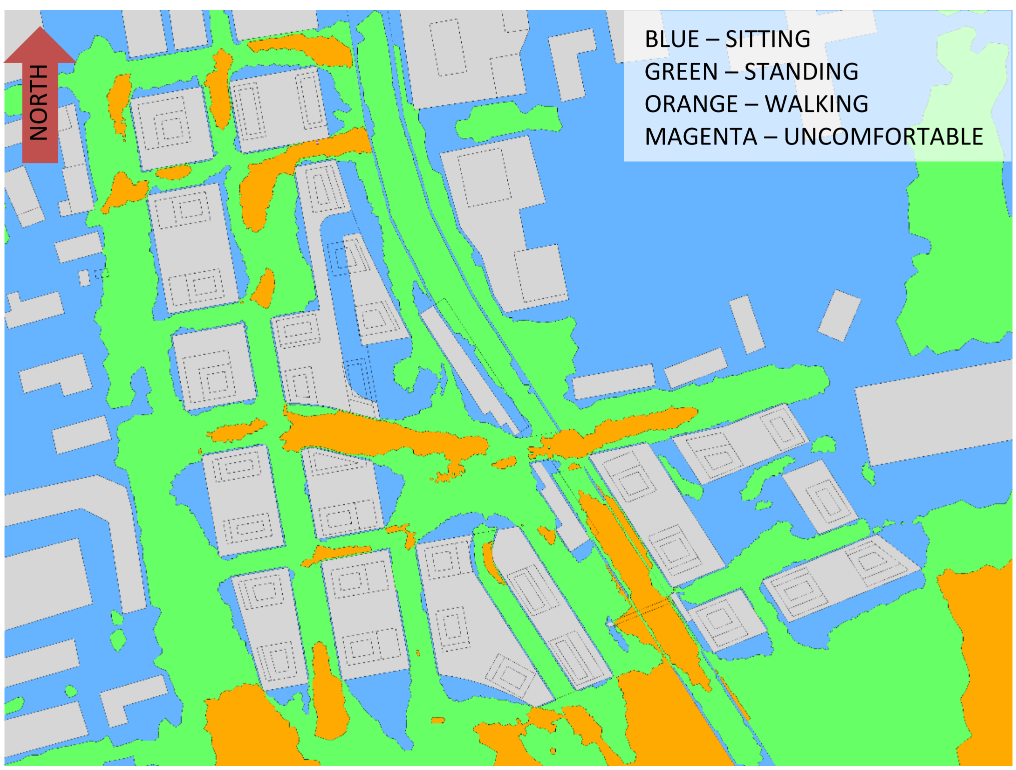
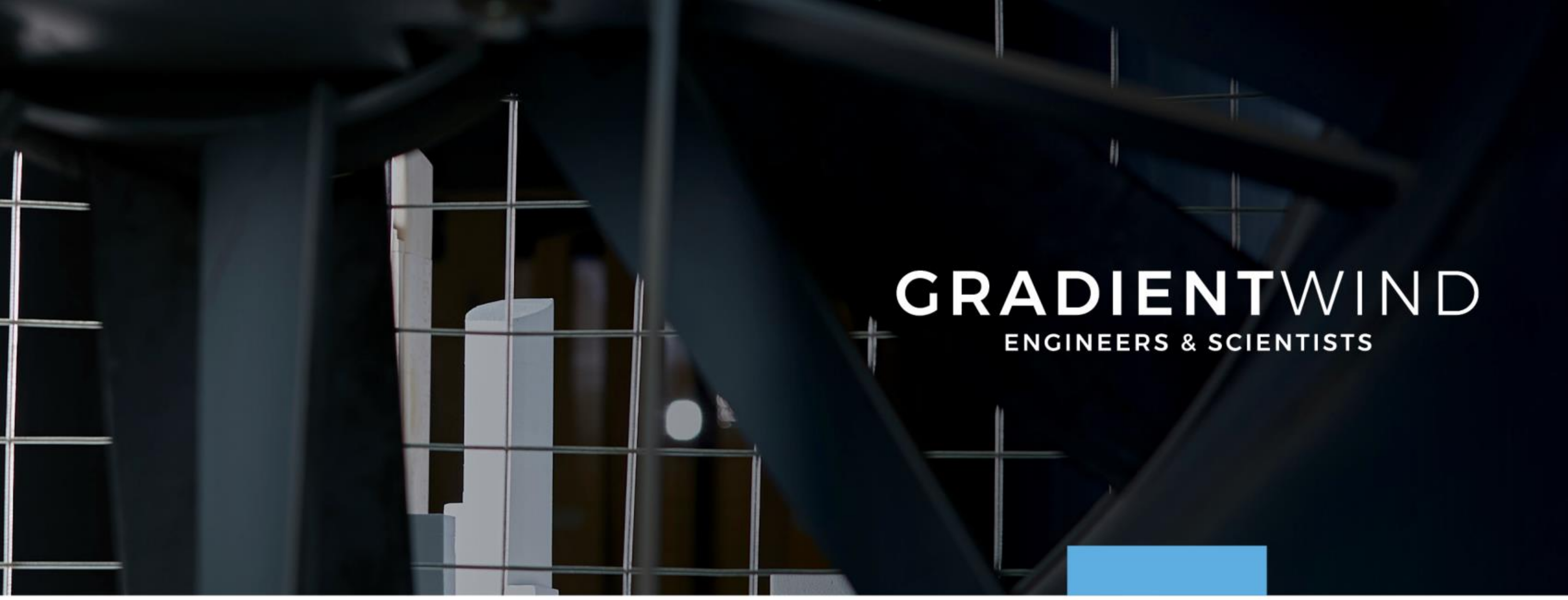
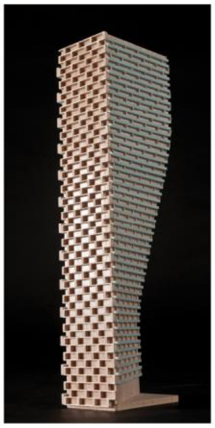
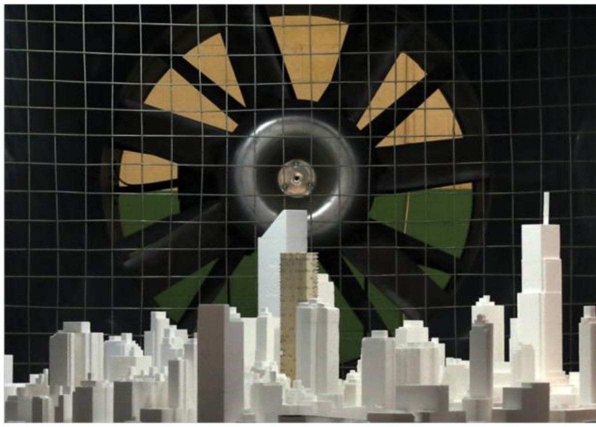


FIGURE 3D: WINTER – WIND COMFORT CONDITIONS, GRADE LEVEL







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 50% mean wind speed for Toronto 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 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
40	0.24
97	0.22
136	0.24
170	0.24
210	0.22
237	0.22
258	0.23
278	0.23
300	0.24
322	0.24
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, ***I*** = turbulence intensity, $\boldsymbol{L_t}$ = turbulence length scale, ***Z*** = height above ground, and α is the power law exponent used for the velocity profile in Equation (1).

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

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[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 Engieering Symposium, IWES 2003*, Taiwan, 2003.