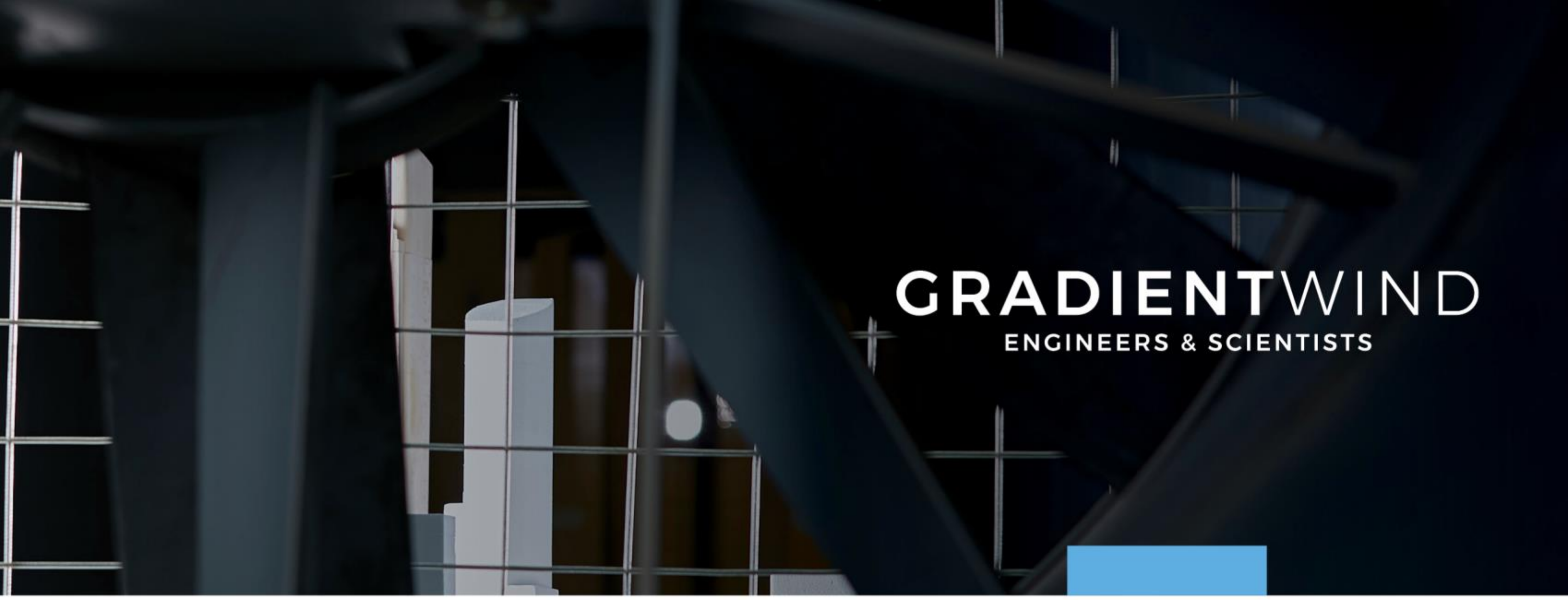
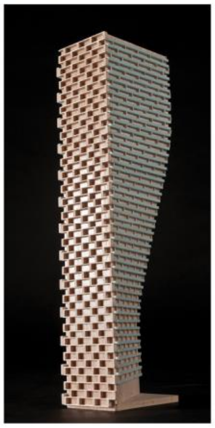
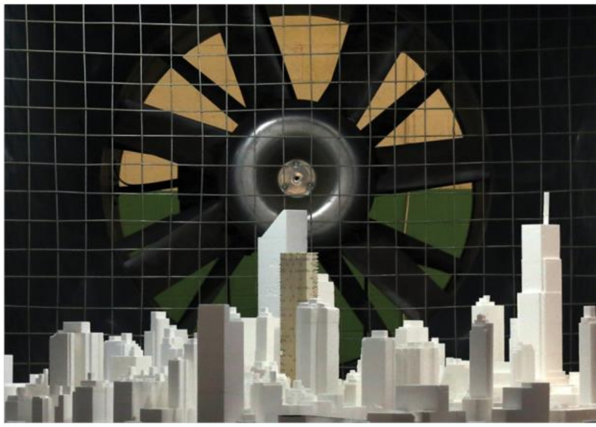


PEDESTRIAN LEVEL WIND STUDY

Bridge Station Master Plan
Markham, Ontario

Report: 21-438-PLW





January 19, 2022

PREPARED FOR
Markham Gateway LP
1500 Highway 7
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PREPARED BY
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EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study for the proposed Bridge Station Master Plan development in Markham, 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. For the area along South Boulevard between buildings W01 and W13 to the north and W04 to the south, mitigation is recommended to reduce channelling and acceleration of prominent westerly winds. Such mitigation should comprise a combination of vertical elements (e.g. wind screening) and horizontal elements (e.g. podium projection at the base of the tower and/or canopies), as described in Section 5.

2) In general, Romeo Park is predicted to be comfortable for sitting or more sedentary activities during the summer months. To achieve similar sitting conditions in Bridge Park and Cedar Park, it will be necessary to reduce the channelling of prominent winds through these spaces. The inclusion of coniferous or marcescent plantings within the park – and particularly at the north portion of Bridge Park and the west portion of Cedar Park, as well as providing canopies along the park-facing tower elevations, is recommended.

3) 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.

GRADIENTWIND
ENGINEERS & SCIENTISTS

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Markham Gateway LP to undertake a pedestrian level wind (PLW) study for the proposed Bridge Station Master Plan development in Markham, 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 IBI Group Architects in December 2021, surrounding street layouts and existing and approved future building massing information obtained, recent site imagery, and experience with numerous similar developments in the Greater Toronto Area (GTA).

2. TERMS OF REFERENCE

The master plan site encompasses a parcel of land bounded by Yonge Street to the west, Highway 407 and a GO Transit station to the north, Cedar Avenue to the east, and Holy Cross Cemetery to the south. The site topography gently slopes up from west to east, and contains a step change at the south side of the site bordering Holy Cross Cemetery.

The proposal comprises numerous mixed-use and office towers and associated podia, up to 80-storeys in height. The buildings are organized around the perimeter of the master plan area and along future internal roads. The master plan also contains several large parks (Romeo Park, Bridge Park, and Cedar Park), as well as several other smaller parks. Bridge Park will cover the existing CN Railway line and future subway line at the east side of the site.

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 open exposures of vacant land and highway corridors to the west and north, existing low-rise industrial spaces to the east, and an open exposure of the cemetery to the south. 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, with the Highway 407 corridor east-to-west to the north of the site.

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 Markham area 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 Buttonville Municipal 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 480 m.

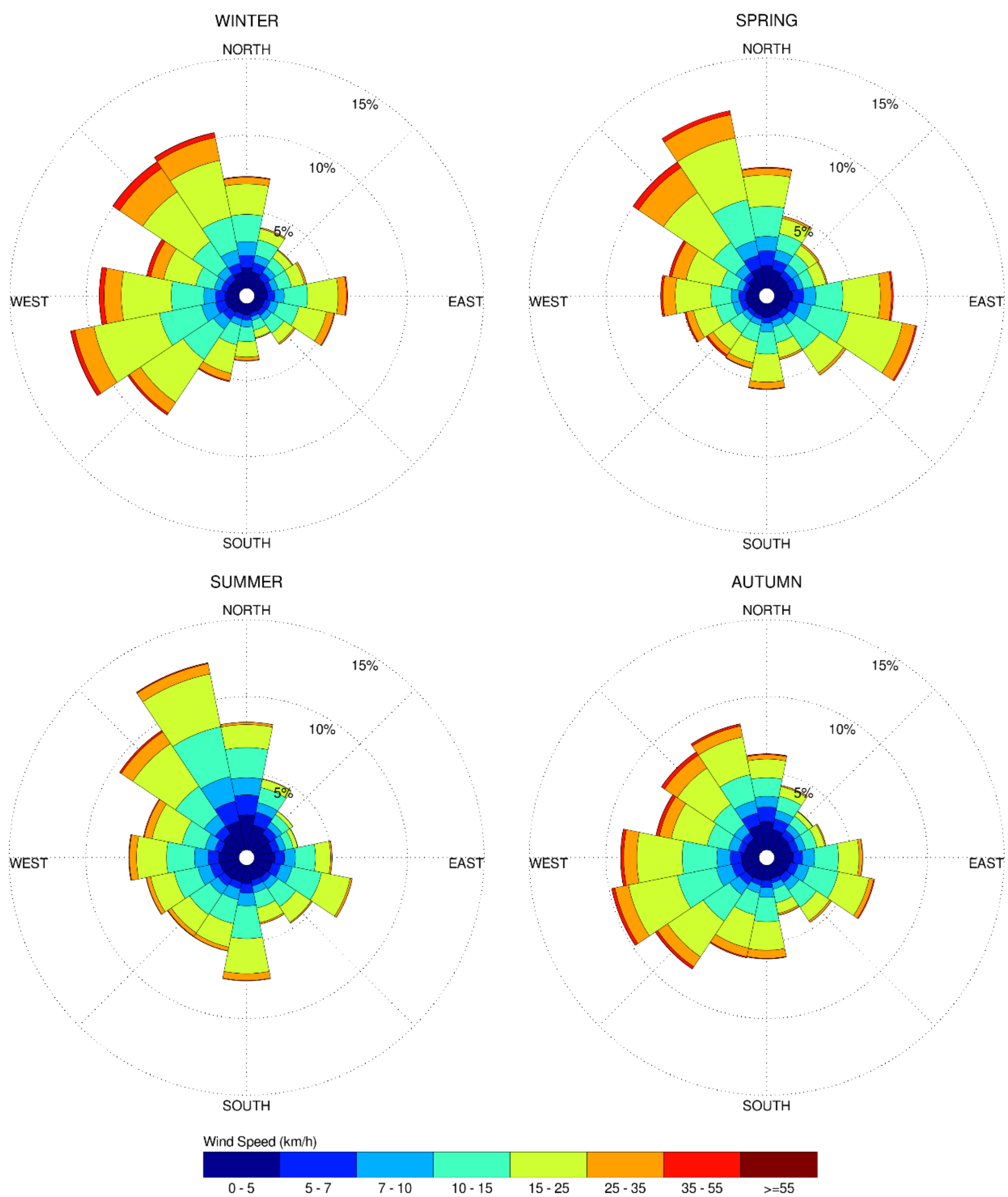
Mean and peak wind speed data obtained over the subject site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds on a continuous measurement plane 1.5 m above local grade and the amenity terrace were referenced 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 Markham was developed from approximately 30-years of hourly meteorological wind data recorded at Buttonville Municipal 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 Markham 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 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 Markham, the most common winds concerning pedestrian comfort occur from the northwest and southwest, followed by 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 WINDS FOR VARIOUS PROBABILITIES
BUTTONVILLE MUNICIPAL AIRPORT, MARKHAM, 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. 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.

Four pedestrian comfort classes and corresponding GEM wind speed ranges are used to assess pedestrian comfort, which include: (i) Sitting; (ii) Standing; (iii) Walking; and (iv) Uncomfortable. More specifically, the comfort classes, wind speed ranges, and limiting criteria are summarized as follows:

(i) **Sitting** – GEM wind speeds below 10 km/h occurring more than 80% of the time would be considered acceptable for sedentary activities, including sitting.

(ii) **Standing** – GEM wind speeds below 15 km/h (i.e. 10-15 km/h) occurring more than 80% of the time are acceptable for activities such as standing, strolling or more vigorous activities.

(iii) **Walking** – GEM wind speeds below 20 km/h (i.e. 15-20 km/h) occurring more than 80% of the time are acceptable for walking or more vigorous activities.

(iv) **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.

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 a vulnerable member of the population to fall.

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 Areas: At the west side of the subject site, prominent west quadrant winds approaching with limited upwind resistance will tend to accelerate along South Boulevard between buildings W01 and W13 to the north and W04 to the south, resulting in limited areas of uncomfortable wind conditions during the winter and spring months. To improve wind comfort in this area, it is recommended to provide mitigation to reduce downwash effects from the west elevation of W13. This can be achieved by either providing a podium projection along the west side of W13 at the base of the building and/or installing canopies along the west elevation and wrapping around the south elevation. A canopy along the north elevation of W04 would also benefit wind conditions in this area. To reduce channelling of grade-level winds along the west side of South Boulevard, providing coniferous or marcescent plantings in this area would be an effective strategy.

The remainder of sidewalk locations within and surrounding the subject site are predicted to be suitable for walking, or better, throughout the year, which is 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, 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: Romeo Park, in the west portion of the subject site, is well-protected from prominent westerly and northerly wind directions by the surrounding tower and podia massing. During the warmer months, conditions will generally be calm and suitable for sitting or more sedentary activities, without the need for mitigation.

Near the centre of the site, Bridge Park will be affected by northwesterly winds concentrating and flowing through the park with little upwind resistance. Without mitigation, the park area will be suitable for a mix of standing and walking during the summer, with areas to the south somewhat calmer and suitable for standing. To improve wind comfort within this space, it will be necessary to both reduce grade-level winds channelling through the park, as well as limit downwash from the adjacent towers. Grade-level winds can be effectively mitigated by providing vertical wind screening (high-solidity wind barriers and/or dense coniferous/marcescent plantings) throughout the park, and in particular to the north of designated seating or other sedentary-use areas. Downwash winds from the inward-facing elevations of the towers along Bridge Park can be reduced by providing wide and continuous canopies along the podium elevations at the base of the buildings.

Cedar Park, at the east side of the site, will generally be comfortable for standing during the summer months. If seating areas will be provided within this space, it will be necessary to reduce west quadrant winds flowing between buildings E02 and E04. Providing vertical wind screening at the west side of the park – particularly near the southwest corner of E02 and the northwest corner of E04, as well as reducing downwash from Tower "A" of both buildings through the use of canopies along the inward-facing elevations, will improve wind conditions within Cedar Park.

The Transit Green space at the west side of the site will be mostly suitable for sitting during the summer months, with some areas suitable for standing. If desired, the inclusion of landscape plantings within this space can be used to diffuse winds flowing through the area and improve wind comfort. The park space between E01 and E03, to the east of Bridge Park, will be comfortable for standing during the summer months. If seating areas will be provided in this park, similar mitigation as described for Cedar Park is recommended. Specifically, reducing westerly winds flowing between Tower "B" of E01 and Tower "A" of E03 through the use of canopies, as well as vertical wind mitigation at the west side of the park is recommended.

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 Markham, 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. For the area along South Boulevard between buildings W01 and W13 to the north and W04 to the south, mitigation is

recommended to reduce prominent westerly winds. Such mitigation should comprise a combination of vertical elements (e.g. wind screening) and horizontal elements (e.g. podium projection at the base of the tower and/or canopies), as described in Section 5.

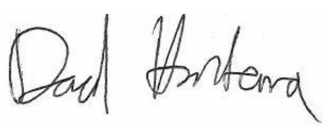
2) In general, Romeo Park is predicted to be comfortable for sitting or more sedentary activities during the summer months. To achieve similar sitting conditions in Bridge Park and Cedar Park, it will be necessary to reduce the channelling of prominent winds through these spaces. The inclusion of coniferous or marcescent plantings within the park – and particularly at the north portion of Bridge Park and the west portion of Cedar Park, as well as providing canopies for the park-facing tower elevations, is recommended.

3) 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.



David Huitema, M.Eng.
Junior Wind Scientist

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

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PROJECT	THE BRIDGE, MARKHAM PEDESTRIAN LEVEL WIND STUDY
SCALE	1:5000
DRAWING NO.	21-438-PLW-1
DATE	JANUARY 4, 2021
DRAWN BY	S.K.
DESCRIPTION	FIGURE 1: PROPOSED SITE PLAN AND SURROUNDING CONTEXT

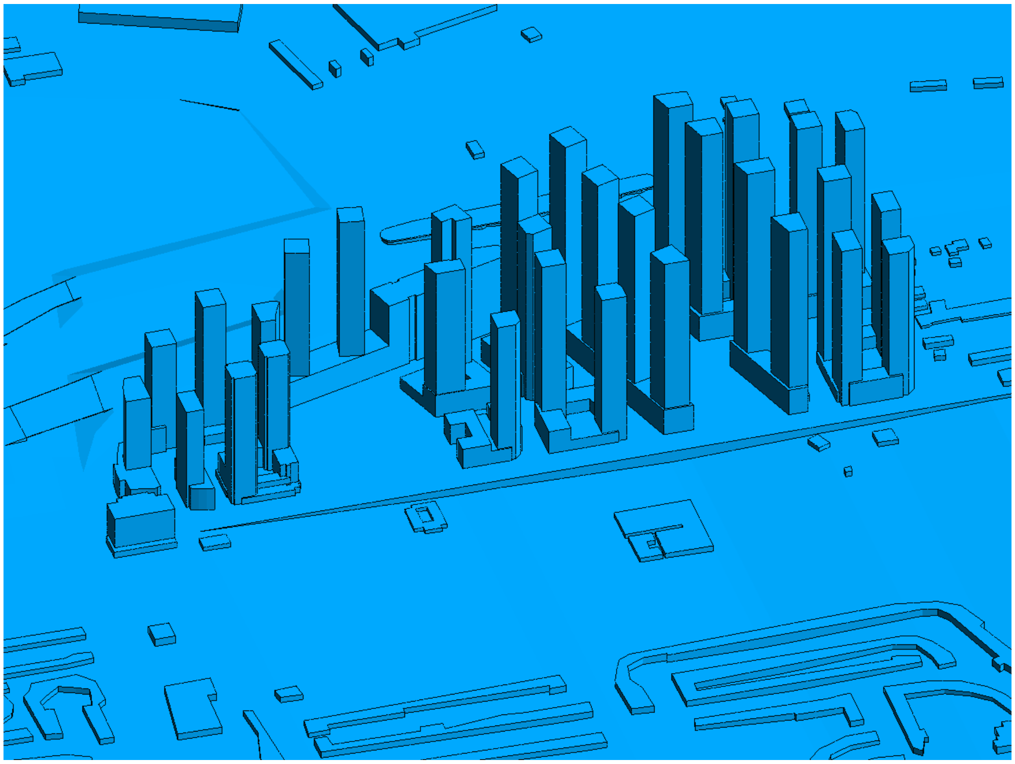


FIGURE 2A: COMPUTATIONAL MODEL OF MASTER PLAN, SOUTH PERSPECTIVE

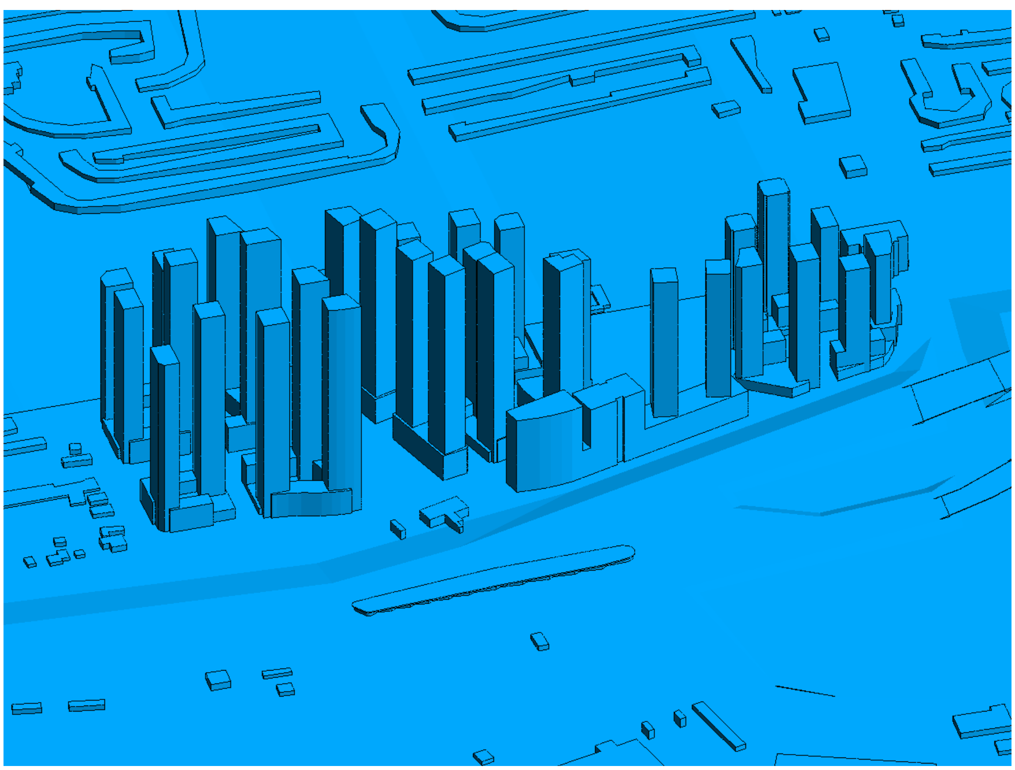


FIGURE 2B: COMPUTATIONAL MODEL OF MASTER PLAN, NORTH PERSPECTIVE

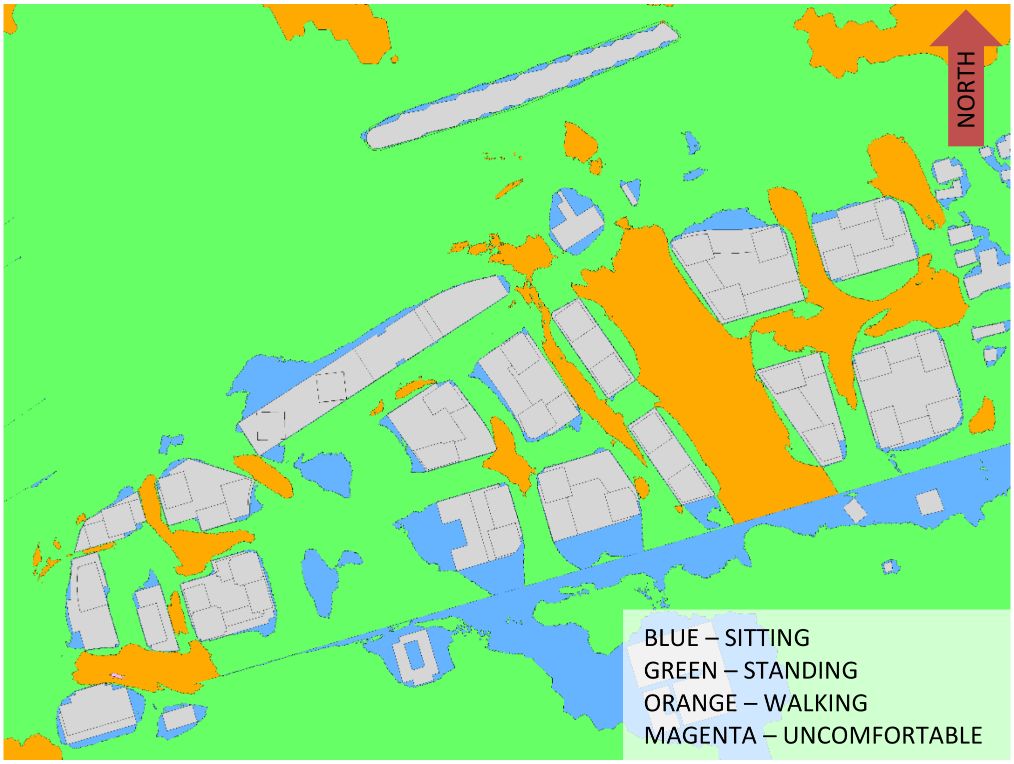


FIGURE 3A: SPRING – WIND COMFORT CONDITIONS, GRADE LEVEL

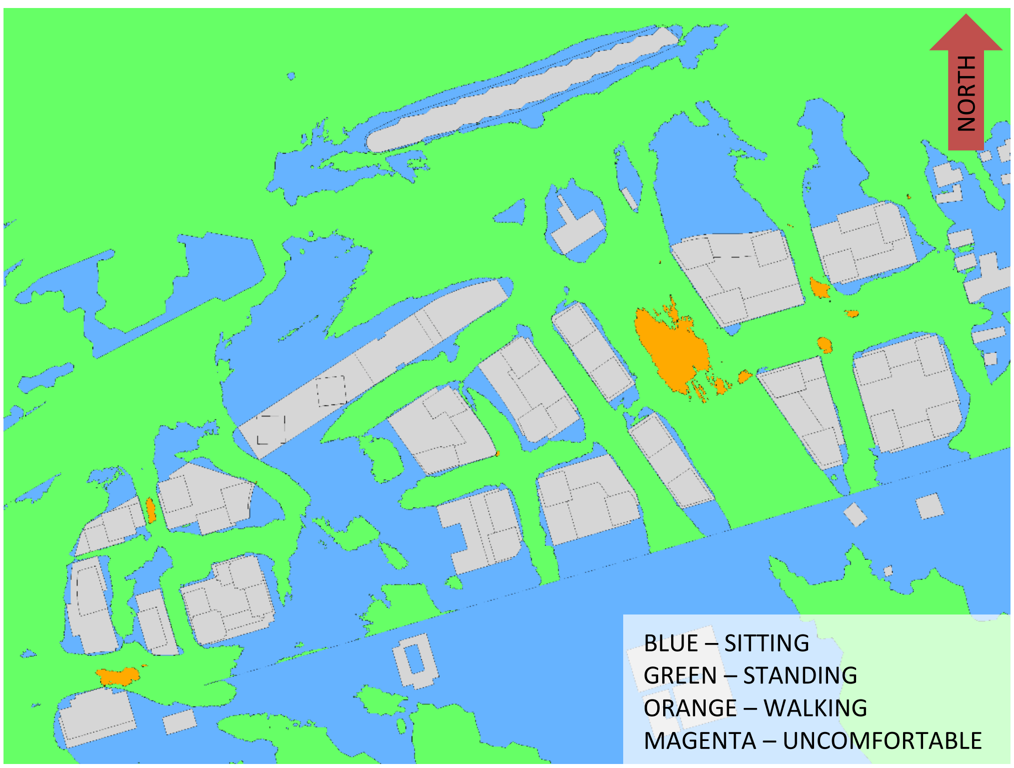


FIGURE 3B: SUMMER – WIND COMFORT CONDITIONS, GRADE LEVEL

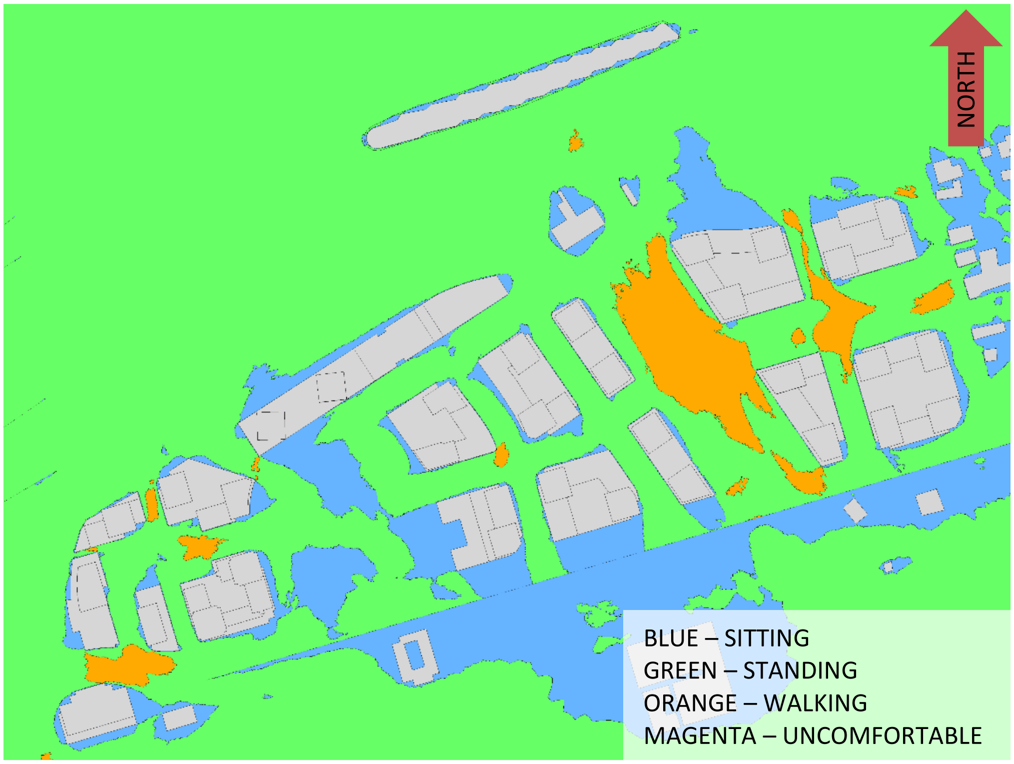


FIGURE 3C: AUTUMN – WIND COMFORT CONDITIONS, GRADE LEVEL

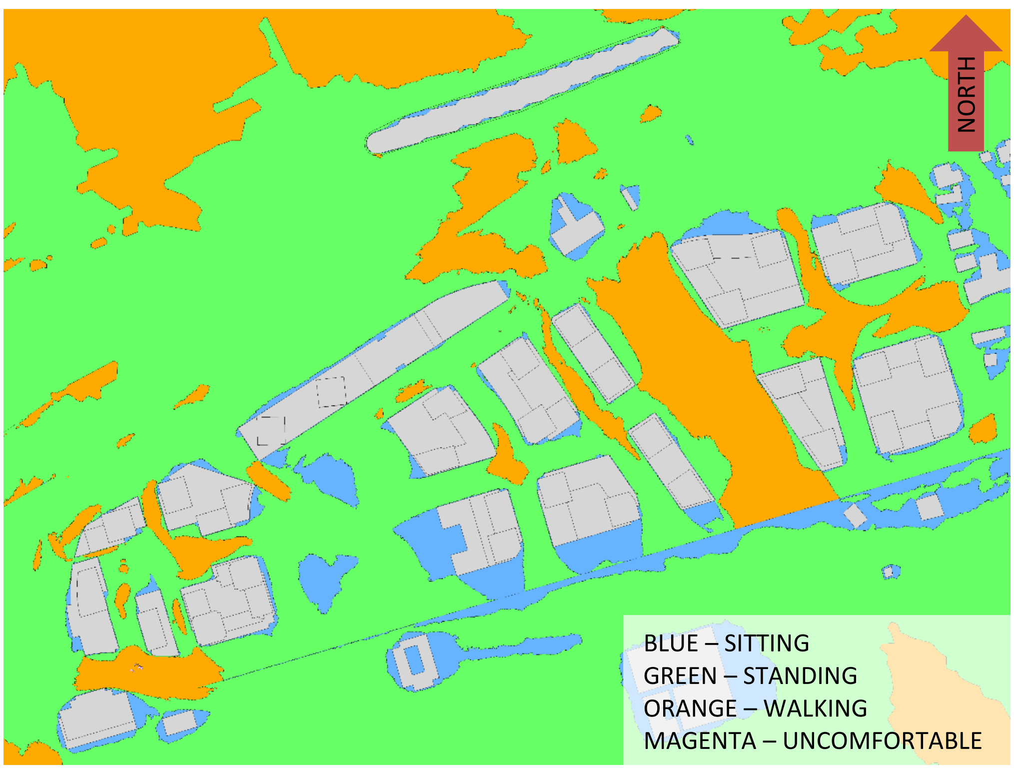
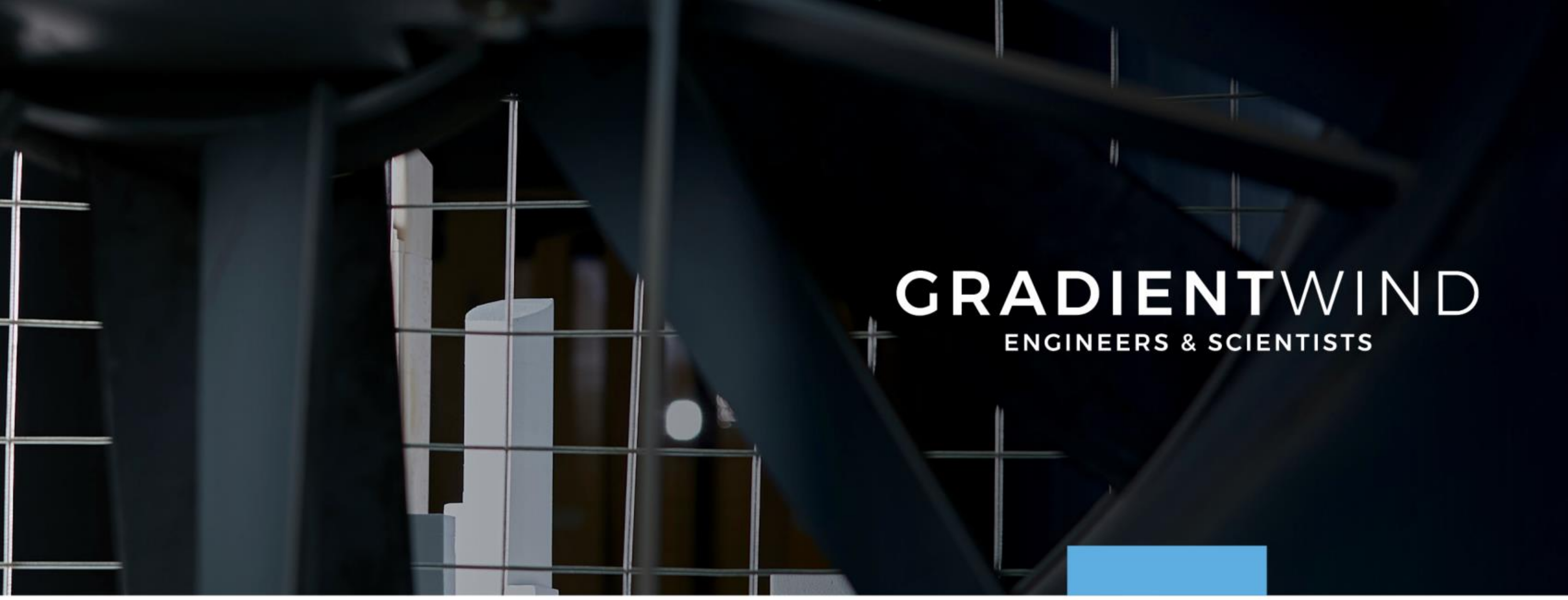


FIGURE 3D: WINTER – WIND COMFORT CONDITIONS, GRADE LEVEL



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
37	0.24
90	0.22
120	0.24
166	0.24
202	0.24
234	0.24
254	0.22
277	0.24
304	0.24
324	0.24
340	0.25

TABLE 2: DEFINITION OF UPSTREAM EXPOSURE (ALPHA VALUE)

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

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

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

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

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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