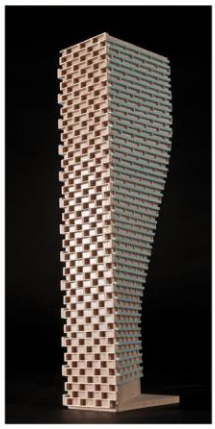
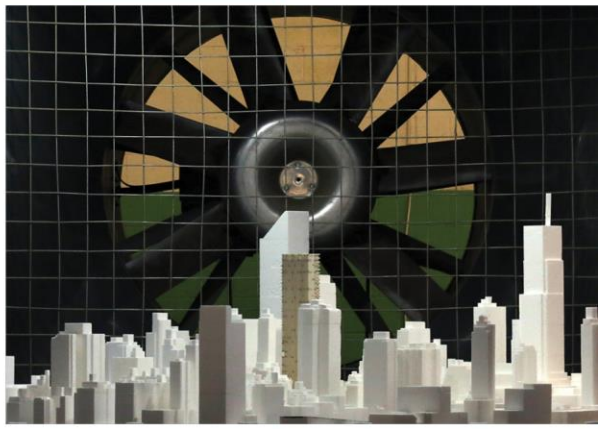
GRADIENTWIND
ENGINEERS & SCIENTISTS

PEDESTRIAN LEVEL WIND STUDY

Greenbank Master Plan
Ottawa, Ontario

Report: 21-299-PLW





September 17, 2021

PREPARED FOR
Claridge Homes
210 Gladstone Avenue
Ottawa, ON K2P 0Y6

PREPARED BY
Daniel Davalos, MESc., Junior Wind Scientist
Justin Ferraro, P.Eng., Principal

127 WALGREEN ROAD, OTTAWA, ON, CANADA K0A 1L0 | 613 836 0934
GRADIENTWIND.COM

EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study to satisfy Zoning By-law Amendment (ZBLA) application requirements for Greenbank Master Plan, a proposed mixed-use residential development located at the intersection of Greenbank Road and Jock River in Ottawa, Ontario (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind comfort and safety within and surrounding the subject site, and to identify areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered.

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 3-6, and is summarized as follows:

1) Most grade-level areas within and surrounding the subject site are predicted to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year. Specifically, wind conditions over surrounding sidewalks, pathways, and in the vicinity of pedestrian building access points are considered acceptable, without mitigation, according to the comfort guidelines in Section 4.4.

    a. Conditions at grade level within the open area formed by the south elevation of Tower A and the north elevation of Tower B are predicted to marginally exceed the walking criterion by 2% of the time during the winter season. Since the area is also predicted to receive safe wind speeds on an annual basis, mitigation is not recommended.

    b. Two potential pedestrian building access points are predicted to receive wind conditions that are suitable for secondary entrances, but not for primary entrances. These locations include the south elevation of Tower B and the north elevation of Tower C. If the noted building elevations are to accommodate primary building entrances, we recommend recessing the entrance within the façade by at least 2 metres (m) to ensure normal and safe door operability throughout the year, particularly during the coldest months.

Alternatively, the entrances could be flanked with 2-m-tall solid wind barriers or replaced with sliding doors.

2) Regarding the existing St. Joseph Catholic High School, as well as the Half Moon Bay District Park, all grade-level areas within and surrounding the noted areas are predicted to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year, without mitigation, according to the comfort criteria in Section 4.4.

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 at grade. During extreme weather events, (e.g., thunderstorms, tornadoes, and downbursts), pedestrian safety is the main concern. However, these events are generally short-lived and infrequent and there is often sufficient warning for pedestrians to take appropriate cover.

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Claridge Homes to undertake a pedestrian level wind (PLW) study to satisfy Zoning By-law Amendment (ZBLA) application requirements for the Greenbank Master Plan, a proposed mixed-use residential development located at the intersection of Greenbank Road and Jock River in Ottawa, Ontario (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind comfort and safety within and surrounding the subject site, and to identify areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, where required.

Our work is based on industry standard computer simulations using the computational fluid dynamics (CFD) technique and data analysis procedures, City of Ottawa wind comfort and safety criteria, architectural drawings prepared by NEUF Architect(e)s in August 2021, surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa, recent satellite imagery, and experience with numerous similar developments.

2. TERMS OF REFERENCE

The master plan is situated on a nominally triangular shaped parcel of land bordered by Greenbank Road to the east, the Jock River to the south, and Darjeeling Avenue to the north.

The subject site comprises seven towers. Towers A, B, C, D, and E are located along the west side of the realigned Greenbank Road, while Towers F and G are located along the east side. All proposed tall buildings within the master plan are arranged north to south.

Tower A rises 30 storeys with a 2-storey podium. The building has a nearly L-shaped planform at grade with a rounded northwest corner. Level 2 steps back from all elevations, while Level 6 steps back from the south elevation. Above Level 6, the building maintains a constant floorplate to Level 30. The main entrance to the building is located at the south elevation.

Tower B rises 21 storeys with a 2-storey podium located to the south of Tower A. The building steps back from all elevations at Level 2 and maintains a constant floorplate to Level 21. The garage and main entrance are accessed at the south elevation of the building.

Towers C and D rise 21 and 6 storeys, respectively, and are connected at Level X. Tower C includes a 2-storey podium, while Tower D includes a 4-storey podium to form an L-shaped planform at grade with the long axis oriented in the north-south direction. The garage and main entrance for Tower C are accessed at the north elevation, while the main entrance for Tower D is located at the west elevation.

Tower E rises 12 storeys with a 4-storey podium that has an L-shaped planform with the long axis oriented in the north-south direction. The main entrance is located at the northwest corner, while the garage can be accessed at the southwest corner.

Tower F rises 6-storeys with a 4-storey podium that forms an L-shaped planform at grade with the long axis oriented in the north-south direction. The building steps back from all elevations at Level 4. The main entrance can be accessed at the east elevation, while the garage entrance is located at the southeast corner.

Tower G rises 6-storeys with an L-shaped planform at grade, with the long axis oriented in the east-west direction. The building steps back from the south elevation at Level 1. The garage can be accessed at the southeast corner, while the main entrance is accessed at the north elevation.

Regarding wind exposures, the near-field surroundings of the proposed development (defined as an area falling within a 200-metre (m) radius of the subject site) include a mix of low-rise massing from the west clockwise to the north, a mix of low-rise massing and open fields exposure form the north clockwise to the east, and mostly open fields for the remaining compass directions. The far-field surroundings (defined as the area beyond the near field and within a 2-kilometre (km) radius) are characterized by mostly a mix of low-rise massing and open fields from the northwest clockwise to the southwest and by mostly open fields for the remaining directions. St. Joseph Catholic High School is located to the immediate east of the subject site, across Greenbank Road, while the Chapman Mills Marketplace is approximately 900 m to the north, the Half Moon Bay Park lies approximately 1 km to the south, and the Clarity Park is approximately 1.1 km to the west.

Key areas under consideration include surrounding sidewalks, walkway within and surrounding the subject site, and building access points. Figure 1 illustrates the subject site and surrounding context, representing the proposed future massing scenario. Figures 2A-2D illustrate the computational model used to conduct the study.

3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind comfort and safety 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 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 Ottawa area wind climate, and synthesis of computational data with City of Ottawa wind comfort and safety criteria[1]. The following sections describe the analysis procedures, including a discussion of the noted pedestrian wind criteria.

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 Ottawa Macdonald-Cartier 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 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 slightly more conservative (i.e., windier) wind speed values.

[1] City of Ottawa Terms of References: Wind Analysis
https://documents.ottawa.ca/sites/default/files/torwindanalysis_en.pdf

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 diameter of 1.2 km.

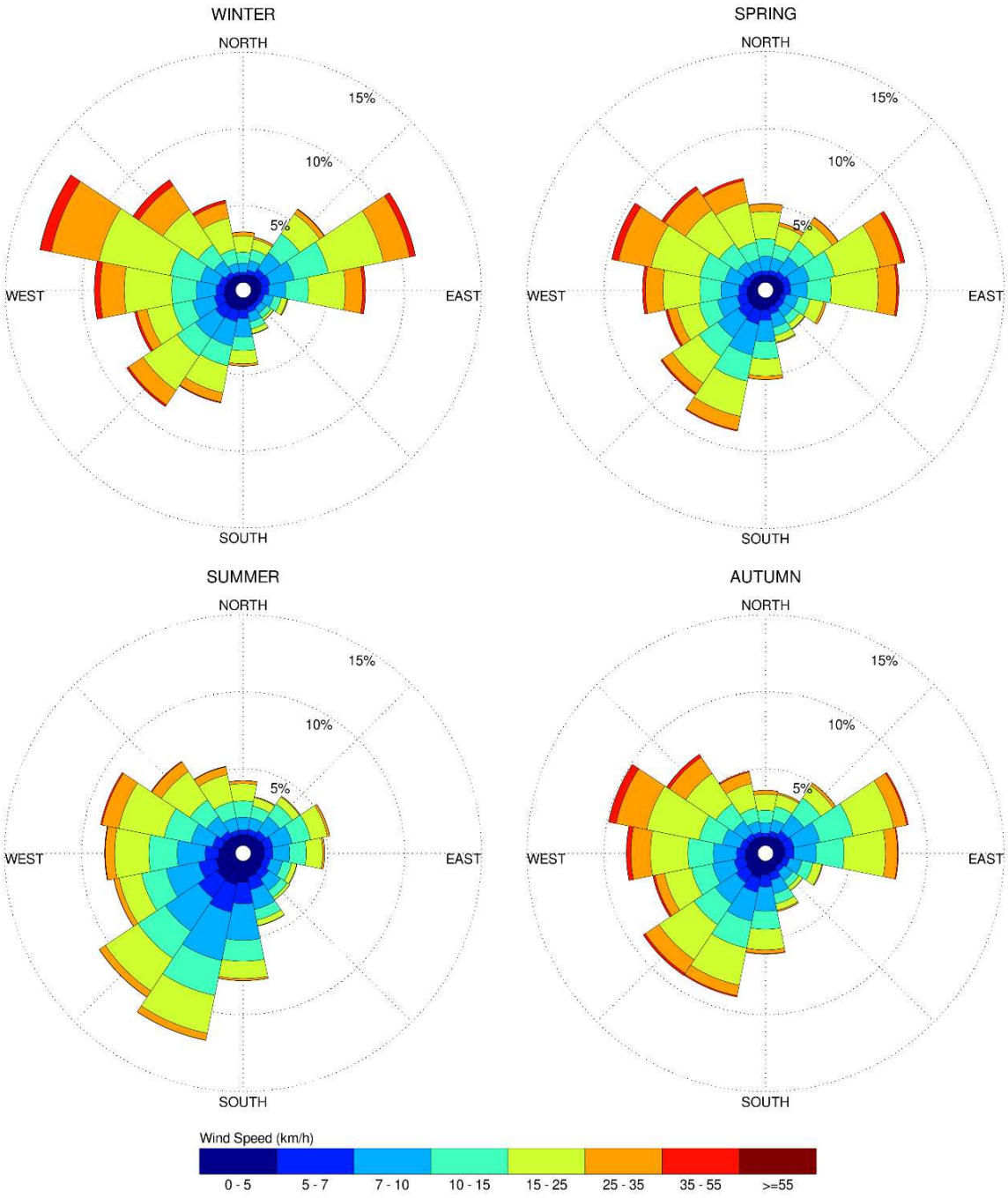
Mean and peak wind speed data obtained over the subject site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade were referenced to the wind speed at gradient height to generate 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 Ottawa was developed from approximately 40 years of hourly meteorological wind data recorded at Ottawa Macdonald-Cartier 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 Ottawa 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 Ottawa, 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
OTTAWA MACDONALD-CARTIER INTERNATIONAL AIRPORT



Notes:

1. Radial distances indicate percentage of time of wind events.
2. Wind speeds are mean hourly in km/h, measured at 10 m above the ground.

4.4 Pedestrian Comfort and Safety Criteria – City of Ottawa

Pedestrian comfort and safety criteria are based on the mechanical effects of wind without consideration of other meteorological conditions (i.e., temperature, relative humidity). The comfort criteria 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 criterion.

The pedestrian safety wind speed criterion 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 criteria are based on subjective reactions of a population to wind forces, their application is partly based on experience and judgment.

Once the pedestrian wind speed predictions have been established throughout the subject site, the assessment of pedestrian comfort involves determining the suitability of the predicted wind conditions for discrete regions within and surrounding the subject site. This step involves comparing the predicted comfort classes to the 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 desired comfort classes are summarized on the following page.

DESIRED PEDESTRIAN COMFORT CLASSES FOR VARIOUS LOCATION TYPES

Location Types	Desired Comfort Classes
Primary Building Entrance	Standing
Secondary Building Access Point	Standing / Strolling / Walking
Primary Public Sidewalk	Strolling / Walking
Secondary Public Sidewalk / Bicycle Path	Walking
Outdoor Amenity Space	Sitting / Standing / Strolling
Café / Patio / Bench / Garden	Sitting
Transit Stop	Sitting / Standing
Public Park / Plaza	Standing / Strolling
Garage / Service Entrance	Walking
Parking Lot	Strolling / Walking
Vehicular Drop-Off Zone	Standing / Strolling / Walking

5. RESULTS AND DISCUSSION

The following discussion of the predicted pedestrian wind conditions for the subject site is accompanied by Figures 3-6, which illustrate seasonal wind conditions at grade level with the proposed development present within the existing context. Conditions are presented as continuous contours of wind comfort within and surrounding the subject site.

The colour contours indicate predicted regions of the various comfort classes noted in Section 4.4. 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. Pedestrian conditions are summarized in the following pages for each area of interest.

5.1 Wind Comfort Conditions – Tower A, Grade Level

Sidewalk along North Elevation: Conditions over the sidewalk along the north elevation are predicted to be suitable for standing during the summer, becoming suitable for strolling throughout the remainder of the year. The only exception is the northeast corner of Tower A, which is predicted to be suitable for a mix of strolling and walking during the spring and winter seasons. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Main Entrance along South Elevation: Conditions over the main entrance at the southwest corner of Tower A is predicted to be suitable for sitting during the summer, and a mix of sitting and standing throughout the remainder of the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Open Area along South Elevation: Conditions over the area between the south elevation of Tower A and the north elevation of Tower B are predicted to be suitable for a mix of standing and strolling during the summer, becoming suitable for a mix of strolling and walking throughout the remainder of the year. The only exception are the uncomfortable conditions at the centre of the open area during the winter. However, the area is predicted to be suitable for waking for at least 78% of the time during the winter, where the target is 80%.

Sidewalk and Pathway along West Elevation: Conditions over the sidewalk and pathway along the west elevation of Tower A are predicted to be suitable for a mix of sitting and standing during the summer, and for mostly standing and strolling throughout the remainder of the year. The strolling conditions are located at the southwest and northwest corners of Tower A. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk along East Elevation: Conditions over the sidewalk along the east elevation of Tower A are predicted to be suitable for sitting during the summer, a mix of sitting and standing for the autumn, and becoming suitable for standing during the spring and winter. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

5.2 Wind Comfort Conditions – Tower B, Grade Level

Sidewalk, Pathway, and Entrances along South Elevation: Conditions over the south elevation of Tower B, including in the vicinity of the garage and main entrance, as well as along the adjacent pathway, are predicted to be suitable for standing during the summer, suitable for strolling during the autumn, becoming suitable for a mix of strolling and walking during the spring and winter. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4. The only exception is the main entrance where conditions suitable for standing, or better, are desired throughout the year. To ensure normal and safe door operability throughout the year, particularly during the coldest months, we recommend recessing the entrance within the façade by at least 2 m. Alternatively, the entrance could either be flanked with 2-m-tall solid wind barriers or replaced with sliding doors.

Sidewalk and Pathway along West Elevation: Conditions over the sidewalk and pathway along the west elevation of Tower B are predicted to be suitable for sitting during the summer, becoming suitable for mostly standing throughout the remainder of the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk along East Elevation: Conditions over the sidewalk along the east elevation of Tower B are predicted to be suitable for sitting during the summer and autumn, becoming suitable for a mix of sitting and standing during the spring and winter. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

5.3 Wind Comfort Conditions – Towers C and D, Grade Level

Sidewalk and Entrances along North Elevation: Conditions over the sidewalk, as well as in the vicinity of the garage entrance and main entrance for Tower C along the north elevation of the connected block formed by Towers C and D, are predicted to be suitable for standing during the summer, strolling during the spring and autumn, and a mix of strolling and walking during the winter. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4, expect at the main entrance, as it is desired to be suitable for standing.

Sidewalk and Pathway along South Elevation: Conditions over the sidewalk and pathway along the south elevation of the connected block formed by Towers C and D are predicted to be suitable for a mix of sitting and standing during the summer, for mostly standing during the spring and autumn, and a mix of standing and strolling during the winter. The only exception is the southeast corner where walking conditions are predicted to form. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk and Main Entrance along West Elevation: Wind Conditions over the sidewalk along the west elevation are predicted to be suitable for mostly sitting during the summer, becoming a mix of sitting and standing throughout the remainder of the year. Conditions in the vicinity of the main entrance serving Tower D are predicted to be similar to those along the adjacent sidewalk. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Pathway along West elevation: Conditions over the pathway along the west elevation are predicted to be suitable for a mix of sitting and standing during the summer, becoming suitable for a mix of standing and strolling throughout the remainder of the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk along East Elevation: Conditions over the sidewalk along the east elevation are predicted to be suitable for sitting during the summer, becoming suitable for mostly standing during the remaining three colder seasons. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

5.4 Wind Comfort Conditions – Tower E, Grade Level

Sidewalk along North Elevation: Conditions over the sidewalk along the north elevation of Tower E are predicted to be suitable for mostly sitting during the summer, a mix of sitting and standing during the autumn, and a mix of standing and strolling during the spring and winter. The strolling conditions for the spring and winter are located at the east and west corners of the elevation. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk and Pathway along South Elevation: Conditions over the sidewalk along the south elevation of Tower E are predicted to be suitable for a mix of sitting and standing throughout the year. The only exception is the northeast corner, which is predicted to be suitable for strolling during the winter. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk, Pathway, and Entrances along West Elevation: Wind Conditions over the sidewalk, as well as in the vicinity of the garage and main entrance, and along the pathway, are predicted to be suitable for a mix of sitting and standing during the summer, becoming suitable for standing throughout the remainder of the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk along East Elevation: Conditions over the sidewalk along the east elevation of Tower E are predicted to be suitable for sitting during the summer, becoming a mix of sitting and standing during the remaining three colder seasons. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

5.5 Wind Comfort Conditions – Tower F, Grade Level

Sidewalk along North Elevation: Conditions over the sidewalk along the north elevation of Tower F are predicted to be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing throughout the reminder of the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk and Pathway along South Elevation: Conditions over the sidewalk and pathway along the south elevation are predicted to be suitable for a mix of sitting and standing during the summer, becoming suitable for standing throughout the reminder of the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk along West Elevation: Conditions over the sidewalk along the west elevation are predicted to be suitable for a mix of sitting and standing during the summer. The sitting conditions extend from the southwest corner to the centre of the elevation, while the standing conditions extend from the centre to the northwest corner of the building. Conditions become suitable for mostly standing during the autumn, and a mix of standing and strolling during the spring and winter. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk and Entrances along East Elevation: Conditions over the sidewalk, as well as in the vicinity of the garage and main entrance, along the east elevation are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable according to the wind comfort criteria.

5.6 Wind Comfort Conditions – Tower G, Grade Level

Sidewalk along North Elevation: Conditions over the sidewalk along the north elevation of Tower G are predicted to be suitable for sitting during the summer, except for the east and west corners, which are predicted to be suitable for standing. Wind conditions become suitable for mostly standing throughout the reminder of the year. The only exception is the northwest corner of Tower G, which is predicted to be suitable for strolling during the winter. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Main Entrance along North Elevation: Conditions in the vicinity of the main entrance along the north elevation are predicted to be suitable for sitting during the summer, becoming suitable for mostly standing throughout the reminder of the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Pathway along South Elevation: Conditions over the pathway along the south elevation of Tower G are predicted to be suitable for mostly sitting during the summer, becoming suitable for a mix of sitting and standing throughout the reminder of the year, except for the southwest corner, which is predicted to be suitable for strolling during the spring and winter. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Garage Entrance along South Elevation: Conditions in the vicinity of the garage entrance along the west elevation are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk along West Elevation: Conditions over the sidewalk along the west elevation are predicted to be suitable for a mix of sitting and standing during the summer, becoming a suitable for mostly standing during the remaining three colder seasons. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk along East Elevation: Conditions over the sidewalk along the east elevation are predicted to be suitable for a mix of sitting and standing throughout the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

5.7 Wind Comfort Conditions – St. Joseph Catholic High School, Grade Level

Parking Area and Secondary Entrance along North Elevation: Conditions over the parking area within the north end of the school grounds are predicted to be suitable for sitting during the summer, becoming suitable for mostly standing throughout the reminder of the year. Conditions in the vicinity of the secondary entrance are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Vehicular Drop-Off Zone along South Elevation: Conditions over the vehicular drop-off zone along the south elevation are predicted to be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing throughout the reminder of the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Sidewalk and Main Entrance along West Elevation: Conditions over the sidewalk along the west elevation are predicted to be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing throughout the reminder of the year. Conditions in the vicinity of the main entrance are predicted to be similar to those along the adjacent sidewalk. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Secondary Entrances along East Elevation: Conditions in the vicinity of both secondary entrances along the east elevation are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

Pathway along East Elevation: Conditions along the pathway are predicted to be suitable for sitting during the summer and autumn, becoming suitable for a mix of sitting and standing for the spring and winter. The noted conditions are considered acceptable according to the wind comfort criteria in Section 4.4.

5.8 Wind Comfort Conditions – Half Moon Bay District Park, Grade Level

Half Moon Bay District Park: Conditions at the northwest portion of the park near the subject site are predicted to be suitable mostly sitting during the summer, becoming suitable for a mix of sitting, standing, and strolling during the reminding three colder seasons.

5.9 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 at grade level were found to experience conditions that could be considered dangerous, as defined in Section 4.4.

5.10 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 (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 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. CONCLUSIONS AND RECOMMENDATIONS

A complete summary of the predicted wind conditions is provided in Section 5 of this report and illustrated in Figures 3-6. Based on computer simulations using the CFD technique, meteorological data analysis of the Ottawa wind climate, City of Ottawa wind comfort and safety criteria, and experience with numerous similar developments, the study concludes the following:

1) Most grade-level areas within and surrounding the subject site are predicted to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year. Specifically, wind conditions over surrounding sidewalks, pathways, and in the vicinity of pedestrian building access points are considered acceptable, without mitigation, according to the comfort guidelines in Section 4.4.

    a. Conditions at grade level within the open area formed by the south elevation of Tower A and the north elevation of Tower B are predicted to marginally exceed the walking

criterion by 2% of the time during the winter season. Since the area is also predicted to receive safe wind speeds on an annual basis, mitigation is not recommended.

b. Two potential pedestrian building access points are predicted to receive wind conditions that are suitable for secondary entrances, but not for primary entrances. These locations include the south elevation of Tower B and the north elevation of Tower C. If the noted building elevations are to accommodate primary building entrances, we recommend recessing the entrance within the façade by at least 2 m to ensure normal and safe door operability throughout the year, particularly during the coldest months. Alternatively, the entrances could be flanked with 2-m-tall solid wind barriers or replaced with sliding doors.

2) Regarding the existing St. Joseph Catholic High School, as well as the Half Moon Bay District Park, all grade-level areas within and surrounding the noted areas are predicted to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year, without mitigation, according to the comfort criteria in Section 4.4.

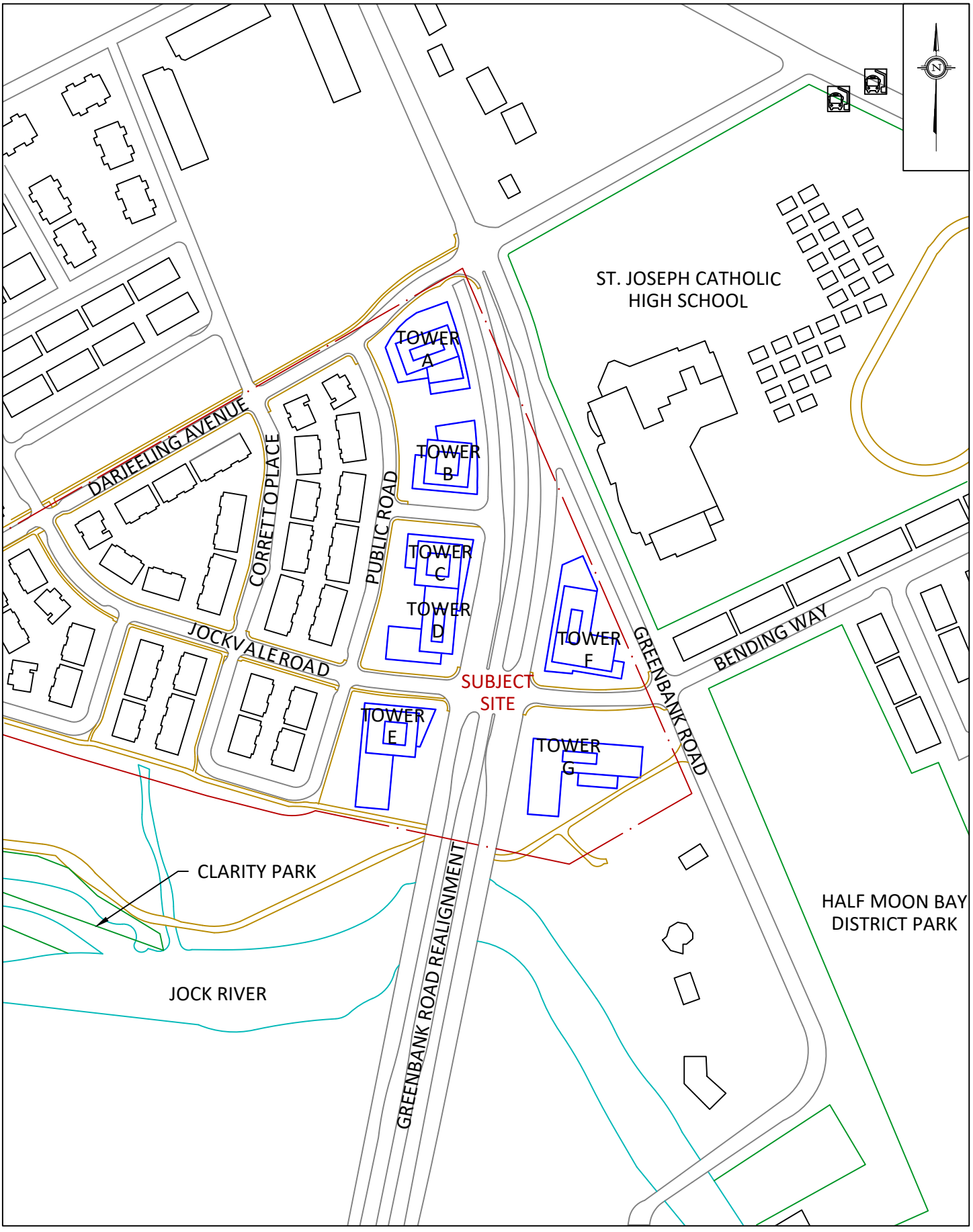
3) The foregoing statements and conclusions apply to common weather systems, during which no dangerous wind conditions, as defined in Section 4.4, are expected anywhere over the subject site at grade. During extreme weather events, (e.g., thunderstorms, tornadoes, and downbursts), pedestrian safety is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

Sincerely,

Gradient Wind Engineering Inc.

Daniel Davalos, MESc.
Junior Wind Scientist

Justin Ferraro, P.Eng.
Principal



GRADIENTWIND
ENGINEERS & SCIENTISTS
127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM

PROJECT	GREENBANK MASTER PLAN, OTTAWA PEDESTRIAN LEVEL WIND STUDY
SCALE	1:3250
DRAWING NO.	21-299-PLW-1
DATE	SEPTEMBER 17, 2021
DRAWN BY	N.M.P.

DESCRIPTION

FIGURE 1:
SITE PLAN AND SURROUNDING CONTEXT

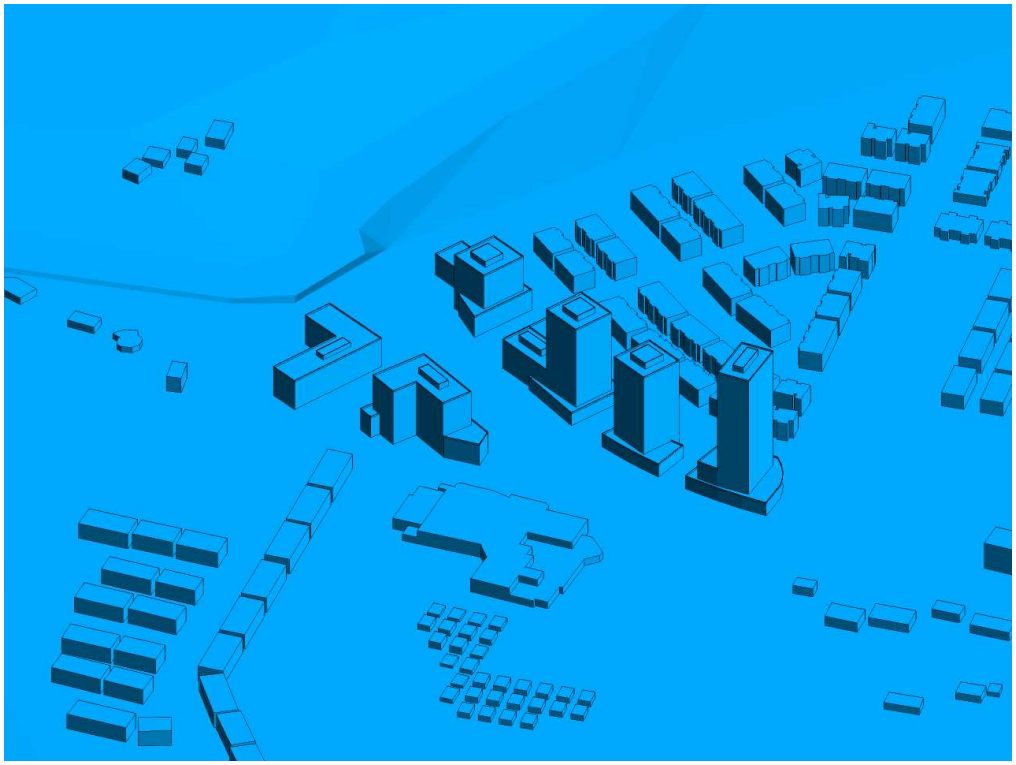


FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTHEAST PERSPECTIVE

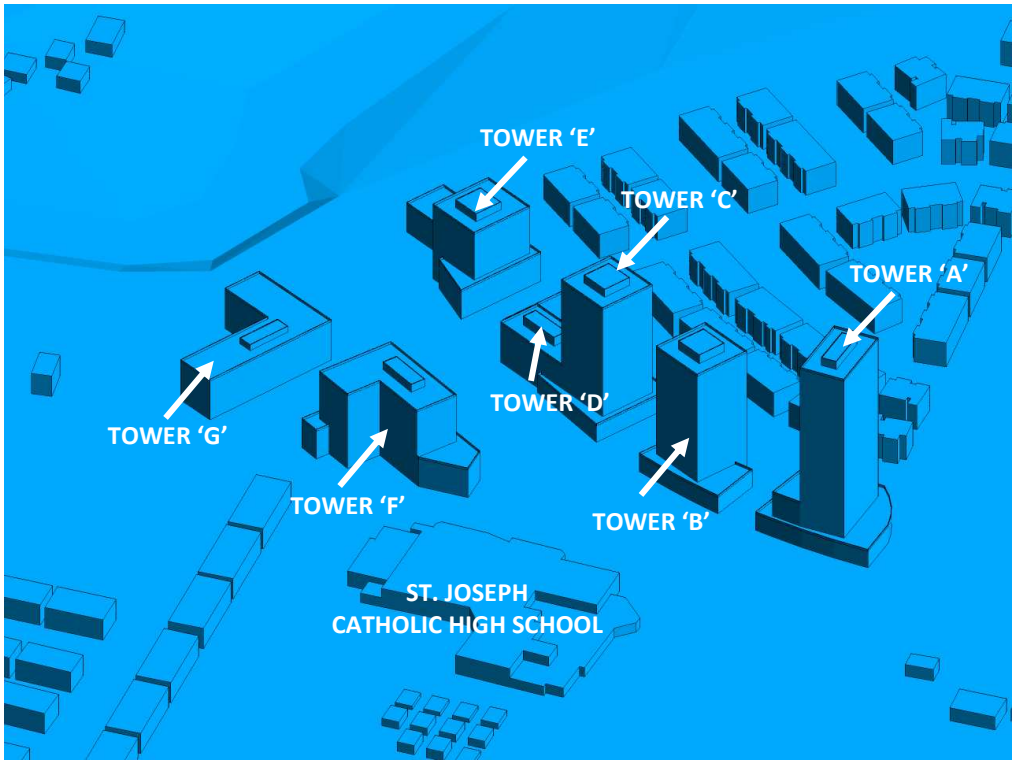


FIGURE 2B: CLOSE-UP VIEW OF FIGURE 2A

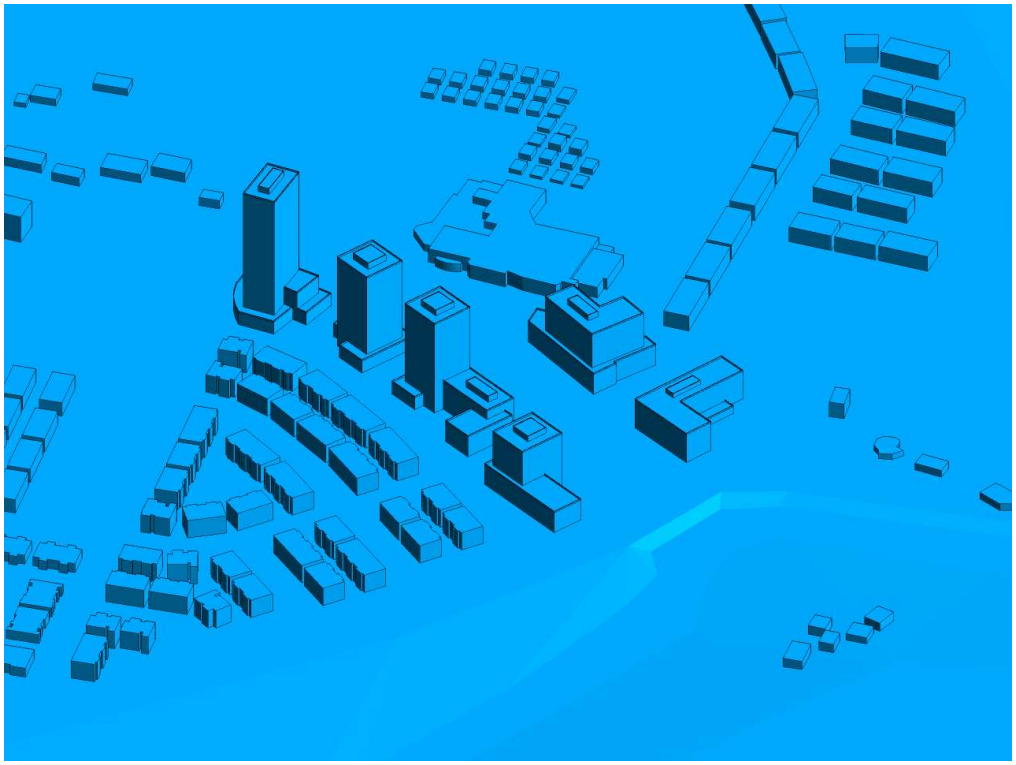


FIGURE 2C: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTHWEST PERSPECTIVE

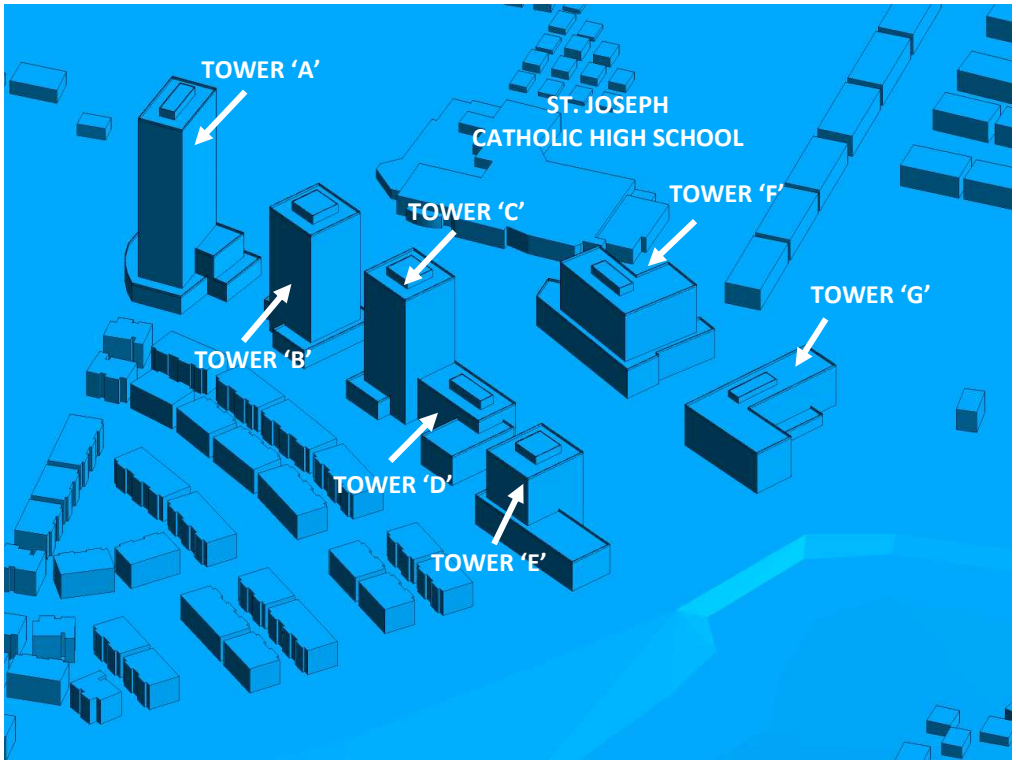


FIGURE 2D: CLOSE-UP VIEW OF FIGURE 2C

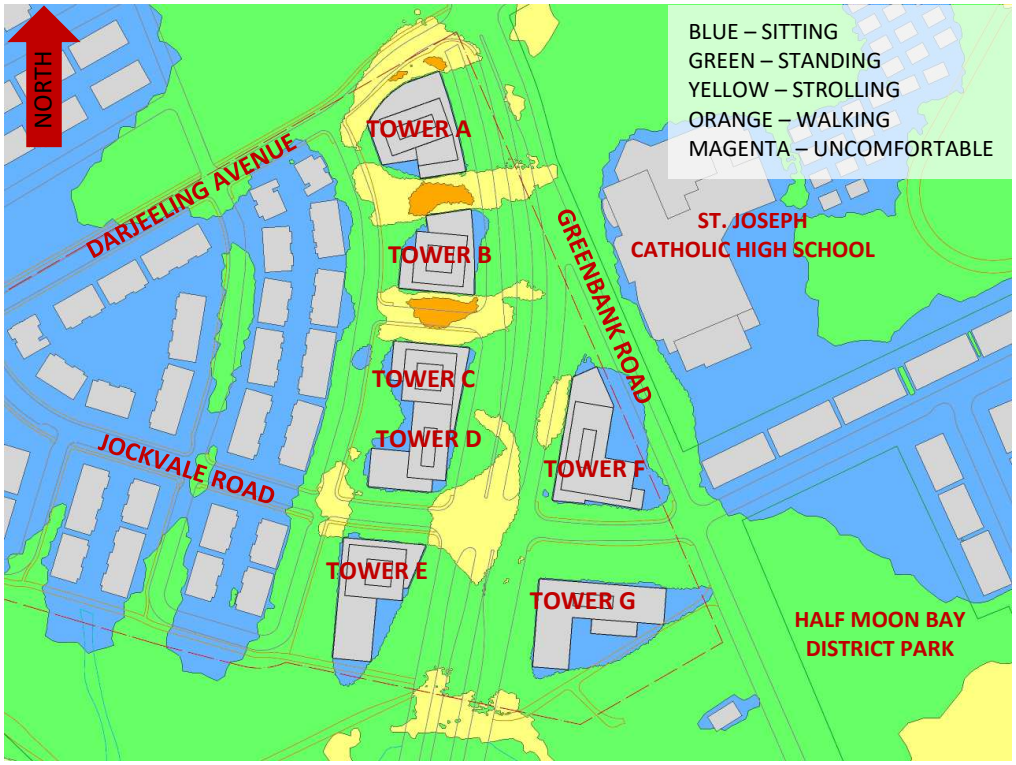


FIGURE 3: SPRING – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

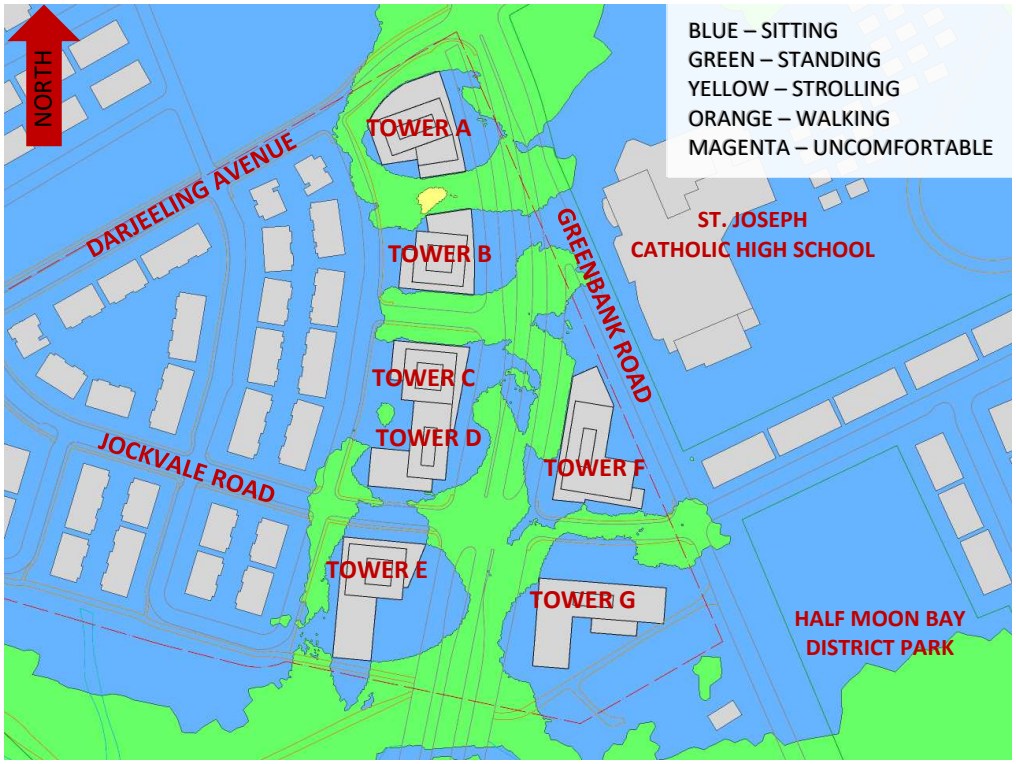


FIGURE 4: SUMMER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

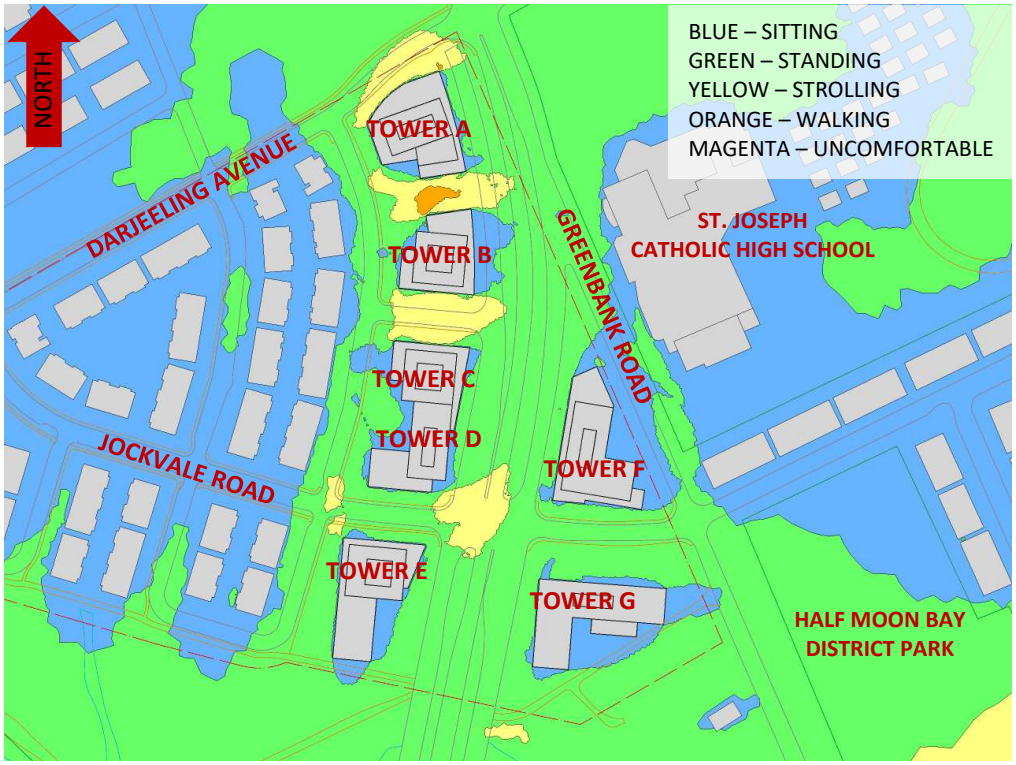


FIGURE 5: AUTUMN – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

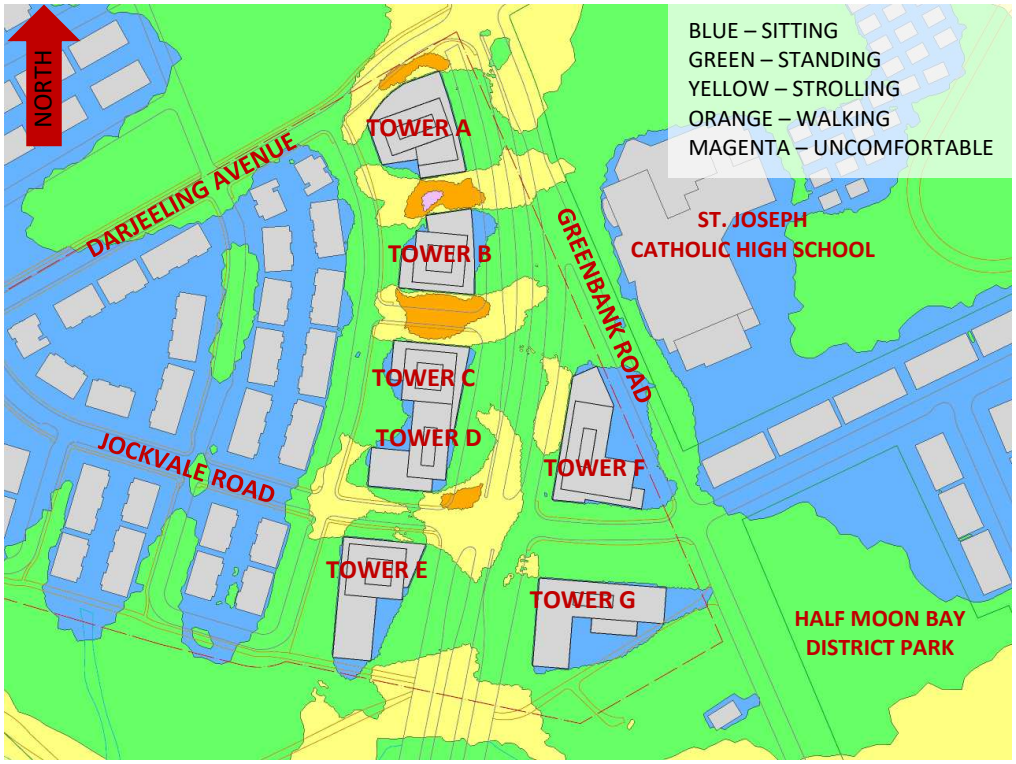


FIGURE 6: WINTER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

APPENDIX A

SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

127 WALGREEN ROAD, OTTAWA, ON, CANADA K0A 1L0 | 613 836 0934
GRADIENTWIND.COM

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 60% mean wind speed for Ottawa based on historical climate data and statistical analyses. When the results are normalized by this velocity, they are relatively insensitive to the selection of gradient wind speed.

Z_g is set to 540 m. The selection of gradient height is relatively unimportant, so long as it exceeds the building heights surrounding the subject site. The value has been selected to correspond to our physical wind tunnel reference value.

α is determined based on the upstream exposure of the far-field surroundings (i.e., the area that it not captured within the simulation model).

Table 1 presents the values of α used in this study, while Table 2 presents several reference values of α. When the upstream exposure of the far-field surroundings is a mixture of multiple types of terrain, the α values are a weighted average with terrain that is closer to the subject site given greater weight.

TABLE 1: UPSTREAM EXPOSURE (ALPHA VALUE) VS TRUE WIND DIRECTION

Wind Direction (Degrees True)	Alpha Value (α)
0	0.23
49	0.23
74	0.22
103	0.22
167	0.22
197	0.21
217	0.20
237	0.19
262	0.20
282	0.21
302	0.23
324	0.23

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