

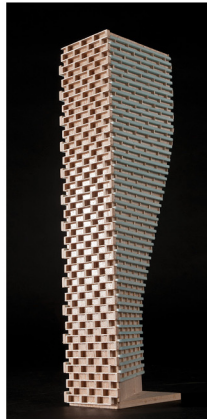
GRADIENTWIND

ENGINEERS & SCIENTISTS

PEDESTRIAN LEVEL WIND STUDY

1356 Clyde Avenue
Ottawa, Ontario

Report: 20-009-PLW



March 31, 2020

PREPARED FOR
Golpro Holdings Inc.
200 – 30 Colonnade Road
Ottawa, ON K2E 7J6

PREPARED BY
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EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study to satisfy the requirements for a zoning by-law amendment (ZBA) application submission for a proposed development located at 1356 Clyde Avenue in Ottawa, Ontario (hereinafter referred to as “subject site”). Our mandate within this study is to investigate pedestrian wind comfort and safety within and surrounding the subject site, and to identify any areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, as 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 according to City of Ottawa wind comfort and safety criteria. The results and recommendations derived from these considerations are detailed in the main body of the report (Section 5), illustrated in Figures 3A-5B, and summarized as follows:

- 1) Wind conditions at the bus stop on the east side of Clyde Avenue will be suitable for strolling during the winter and spring. A bus shelter will be required at this bus stop to ensure vulnerable members of the population can continue to comfortably use the bus stop.
- 2) Conditions within the patio to the north of Phase 2 will be suitable for standing during the summer. We recommend installing tall (minimum 2.0 m) wind barriers along the north and west extents of this patio to ensure conditions are suitable for sitting. These barriers could comprise high-solidity wind screens, dense coniferous plantings, or a combination thereof.
- 3) The Office Lobby entrance at the north elevation of Phase 2 will experience conditions suitable for strolling during the autumn, winter and spring. The mitigation measures described in item (2) above will improve conditions at this entrance to acceptable levels, as long as the recommended wind barrier along the western extent of the patio abuts the northern façade of the building.
- 4) Except for the three locations above, conditions around the subject site at grade level, including along sidewalks and walkways, within the parking lots to the west and north of the buildings, at



all building entrances, within the patio to the south of Phase 2, and at the bus stops to the southeast and southwest, will be acceptable for their intended uses throughout the year.

- 5) Wind conditions within the common amenity terraces at Level 7 of both buildings will be suitable for a mix of sitting and standing during the summer. In order to achieve conditions suitable for sitting during the summer, we recommend installing tall (minimum 2 m) wind screens in place of standard height guard rails along the east and west perimeter of the terrace serving Phase 1, and along the full perimeter of the terraces serving Phase 2. We also recommend local wind barriers inboard of the perimeter, which may take the form of glass architectural wind screens positioned to protect designated seating areas and/or coniferous trees planted in dense arrangement. A mitigation strategy for these terraces can be confirmed during detailed design development.
- 6) Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas surrounding the subject site at grade level or within the common amenity terraces were found to experience conditions that could be considered uncomfortable or dangerous.

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1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Golpro Holdings Inc. to undertake a pedestrian level wind (PLW) study to satisfy the requirements for a zoning by-law amendment (ZBA) submission for a proposed development located at 1356 Clyde Avenue in Ottawa, Ontario (hereinafter referred to as “subject site”). Our mandate within this study is to investigate pedestrian wind comfort and safety within and surrounding the subject site, and to identify any areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, as 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 provided by Roderick Lahey Architect Inc. in March 2020, surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa, as well as recent satellite imagery via Google Earth Pro.

2. TERMS OF REFERENCE

The subject site is situated on a parcel of land bordered by Clyde Avenue to the east, Baseline Road to the south, and existing developments to the west and north.

The proposed two-building development comprises a 24-storey tower (Phase 1) and a 28-storey tower (Phase 2). Phase 1 is located at the north end of the subject site, and has an



*Rendering, East Perspective
(Courtesy of Roderick Lahey Architect Inc)*

L-shaped planform at grade, with the long axis along Clyde Avenue. At Level 3, the building sets back on the west and north elevations while stepping out on the east and south elevations. The building sets back again from the north elevation at Level 7, revealing a large 6-storey podium with a common amenity space. The tower then rises with a uniform planform to Level 22. At Level 23, setbacks from the north and west elevations accommodate private terraces. The Phase 1 building is served by a mechanical penthouse above Level 23.



Similar to the Phase 1 building, the Phase 2 building has an L-shaped planform at grade. The building similarly sets back from the west elevation at Level 3, while also stepping out at the north elevation, creating an overhang. The building then sets back from the north and south elevations at Level 7. The 6-storey podium roof includes common amenity spaces to the north and south of the building. At Level 27, the building sets back from the north elevation and the northern half of the east and west elevations, revealing private terraces. The building is served by a mechanical penthouse above Level 27.

At grade, the buildings include lobby, retail, and amenity space. Primary retail entrances are located along the east elevation, fronting Clyde Avenue, while primary residential entrances are located on the south elevation of each building. Entrances to the office lobbies are located at the north of the east elevation on Phase 1 and in the middle of the north elevation on Phase 2. Secondary entrances are located on the west elevation. Grade-level outdoor amenities include patio/café seating to the north and south of Phase 2. Level 2 comprises office space, while Levels 3 and above comprise residential units. Level 7 on both buildings includes indoor and outdoor amenity space.

Nearby bus stops are located on the east side of Clyde Avenue, at the northwest corner of the intersection of Clyde Avenue and Baseline Road, on the north side of Baseline Road. The latter two include standard bus shelters, while the bus stop on the east side of Clyde Avenue does not.

The near-field surroundings (defined as an area within a radius of 200 metres (m) of the subject site) comprise low-rise residential buildings to the northwest and north, a mid-rise building to the northeast (Laurentian Place), and an existing 12-storey residential building to the west. A two-building 15-storey development is planned to the immediate east at 1357 Baseline Road. The far-field surroundings (defined as an area beyond the near-field but within a 5 kilometer (km) radius of the subject site) contribute primarily suburban wind exposures from all wind directions, although the Ottawa Experimental Farm to the northeast and the Ottawa River to the northwest serve to create slightly more open exposures from these directions.

Key areas under consideration for pedestrian wind comfort include surrounding sidewalks, walkways, building access points, nearby transit stops, and the amenity terraces at Level 7. Figure 1 illustrates the subject site and surrounding context, while 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 development 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 study 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 criteria¹. 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 study site on the surrounding model, and to create suitable atmospheric wind profiles at the model boundary. The wind profiles are designed to have similar mean and turbulent wind properties consistent with actual site exposures.

An industry standard practice is to omit trees, vegetation, and other existing and planned landscape elements from the model due to the difficulty of providing accurate seasonal representation of vegetation. The omission of trees and other landscaping elements produces slightly more conservative (i.e., windier) wind speed values.

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 site for 12 wind directions. The CFD simulation model was centered on the study building, complete with surrounding massing within a diameter of approximately 820 m. Mean and peak wind speed data obtained over the study site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade and the rooftop amenity terraces were referenced to the wind speed at gradient height to generate mean and peak velocity ratios, which were used to calculate full-scale values. 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.

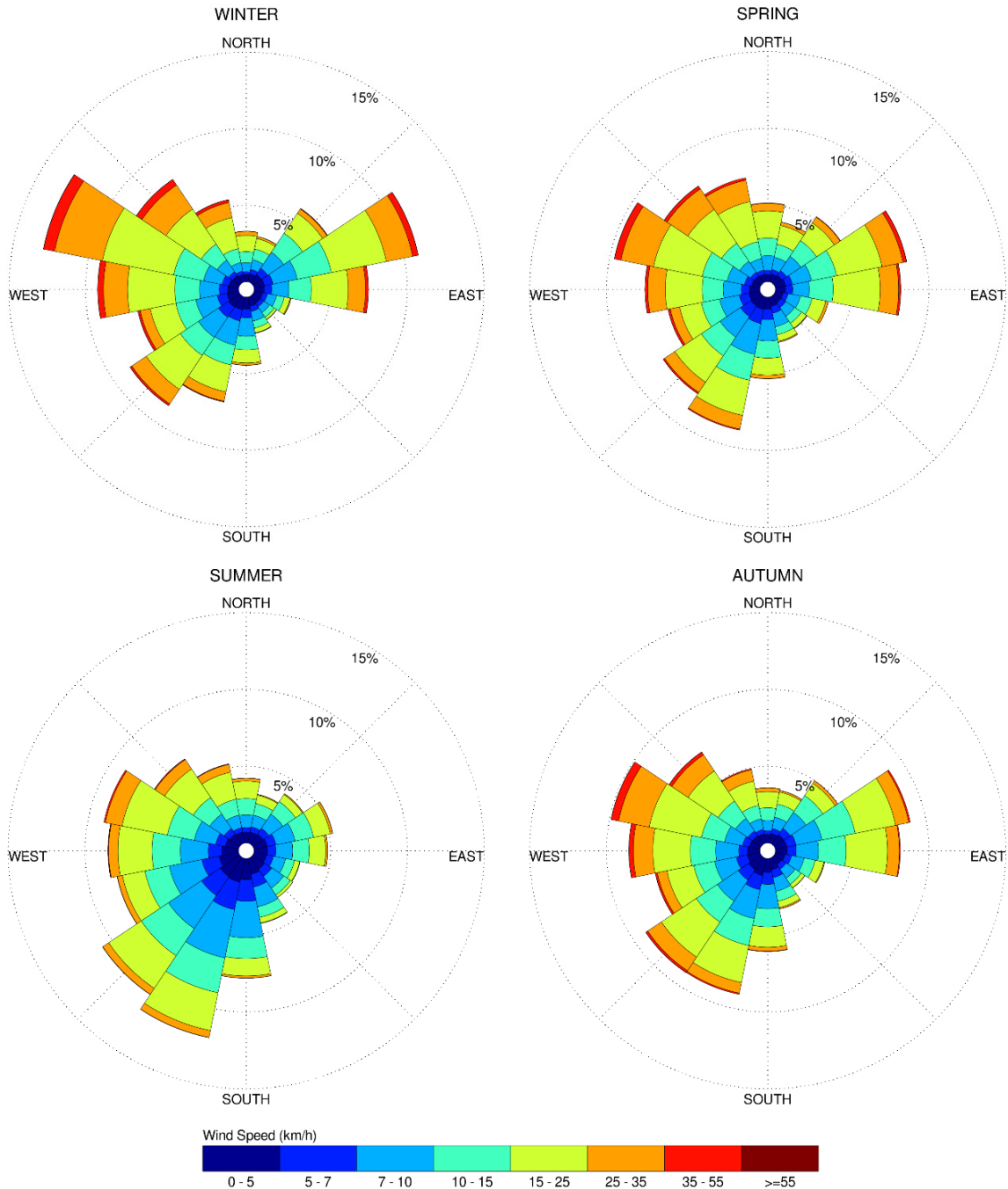
4.3 Meteorological Data Analysis

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 in order to determine the statistically prominent wind directions and corresponding speeds, and to characterize similarities between monthly weather patterns. Based on this portion of analysis, the four seasons are represented by grouping data from consecutive months based on similarity of weather patterns, and not according to the traditional calendar method. The winter season is defined as December-March, spring as April-May, summer as June-September, and autumn as October-November.

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 80% 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 mean gust speed ranges are selected based on 'The Beaufort Scale', which describes the effect of forces produced by varying wind speeds on levels on objects.



THE BEAUFORT SCALE

Number	Description	Wind Speed (km/h)	Description
2	Light Breeze	6-11	Wind felt on faces
3	Gentle Breeze	12-19	Leaves and small twigs in constant motion; Wind extends light flags
4	Moderate Breeze	20-28	Wind raises dust and loose paper; Small branches are moved
5	Fresh Breeze	29-38	Small trees in leaf begin to sway
6	Strong Breeze	39-49	Large branches in motion; Whistling heard in electrical wires; Umbrellas used with difficulty
7	Moderate Gale	50-61	Whole trees in motion; Inconvenient walking against wind
8	Gale	62-74	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 80% 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 (gust equivalent mean wind speed of 16 km/h) was 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 (gust equivalent mean wind speed of 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 most of 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 at tested locations, the assessment of pedestrian comfort involves determining the suitability of the predicted wind conditions for their associated spaces. This step involves comparing the predicted comfort class to the desired comfort class, which is dictated by the location type represented by the sensor (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

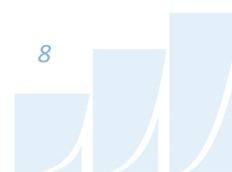
Location Types	Desired Comfort Classes
Primary Building Entrance	Standing
Secondary Building Access Point	Walking
Primary Public Sidewalk	Strolling / Walking
Secondary Public Sidewalk / Bicycle Path	Walking
Outdoor Amenity Space	Sitting / Standing / Strolling
Café / Patio / Bench / Garden	Sitting
Transit 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 predicted pedestrian wind conditions is accompanied by Figures 3A-3D (following the main text) illustrating the seasonal wind conditions at grade level, and Figures 4A-4D illustrating the seasonal wind conditions within the common amenity terraces. The colour contours indicate various comfort classes predicted for certain regions. Wind conditions comfortable for sitting or more sedentary activities are represented by the colour green, standing are represented by yellow, strolling by orange, walking by blue, while uncomfortable conditions are represented by the colour magenta. Pedestrian wind comfort is summarized below for each area of interest. In addition, Figures 5A and 5B illustrate the percentage of time the areas at grade and within the elevated amenity terraces, respectively, will be suitable for sitting during the summer season.

5.1 Wind Comfort Conditions – Grade Level

Clyde Avenue: The sidewalks along Clyde Avenue are predicted to be suitable for a mix of sitting and standing during the summer season, becoming suitable for a mix of standing and strolling during the autumn, and including regions suitable for walking during the winter and spring. Generally, the sidewalks on the west side of Clyde Avenue (near the study buildings) are calmer than the sidewalks on the east



side. Conditions near the gap between the buildings are somewhat windier due to channeling of prominent westerly and easterly winds between Phases 1 and 2, and between the planned 15-storey building at 1357 Baseline Road and Laurentian Place. These conditions are considered acceptable.

Baseline Road: The sidewalks along Baseline Road will be suitable for a mix of sitting and standing during the summer, mostly suitable for standing during the autumn, and suitable for a mix of sitting, standing and strolling during the winter and spring. These conditions are considered acceptable.

Bus Stops: Three bus stops are located near the study site. The bus stop on the east side of Clyde Avenue will experience conditions suitable for standing during the summer and autumn, and suitable for strolling during the winter and spring. The two bus stops to the southeast and southwest of Phase 2 will experience conditions suitable for sitting during the summer and suitable for standing during the remaining seasons.

The bus stop on the east side of Clyde Avenue will require a bus shelter to ensure vulnerable members of the population can continue to comfortably use the bus stop. This is particularly crucial given the planned seniors' residence at 1357 Baseline Road, as many seniors are more likely to be adversely affected by stronger wind flows and correspondingly reduced comfort conditions.

Parking Lot, North of Phase 1: The parking lot to the north of Phase 1 will experience wind conditions suitable for sitting during the summer, and mostly suitable for standing during the remaining seasons. Areas near the northeast and northwest corners of Phase 1 will be suitable for strolling during the winter. These conditions are considered acceptable.

Parking Lot, West of Subject Site: The parking spaces to the west of the buildings will be suitable for a mix of sitting and standing during the summer, becoming suitable for a mix of standing and strolling during the remaining seasons. Areas near the building corners are generally slightly windier than areas near the centre of the west façades. These conditions are considered acceptable.

Patio, South of Phase 2: The patio/café seating to the south of Phase 2 will be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing during the remaining seasons. Figure 5A shows that most of this patio seating area will be suitable for sitting at least 85% of the time during the summer season. These conditions are acceptable.



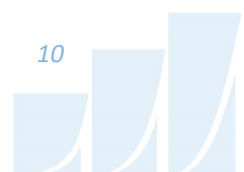
Driveway, Walkways, and Patio Between Phase 1 and Phase 2: The area to the north of Phase 2 and south of Phase 1 will be suitable for standing during the summer, mostly suitable for strolling during the spring and autumn, and will include a region suitable for walking during the winter. Figure 5A shows that the patio area will be suitable for sitting at least 65% of the time during the summer season. The noted conditions during the summer are not acceptable for a patio/café area and will require mitigation. We recommend positioning wind barriers at the western and northern extents of the patio area. The barriers could comprise tall (minimum 2.0 m) high-solidity wind screens, tall dense coniferous plantings, or a combination thereof.

Office Lobby Entrances: The office lobby entrance serving Phase 1 will be suitable for sitting year-round. The office lobby entrance serving Phase 2 is predicted to be suitable for standing during the summer, becoming suitable for strolling during the colder seasons. This does not meet the desired pedestrian comfort class for primary building entrances (standing).

If the mitigation steps recommended for the patio to the north of Phase 2 are followed, and the wind barrier at the western extent of the patio abuts the northern façade of the building, the wind conditions at the office lobby entrance serving Phase 2 will improve to acceptable levels. If these mitigation steps are not taken, it is recommended to recess the entrance at least 1 m into the façade. This is necessary to ensure pedestrian safety when using the door and to preserve door hardware.

Retail Entrances: The retail entrances along Clyde Avenue will be suitable for sitting during the summer, suitable for a mix of sitting and standing during the autumn, and mostly suitable for standing during the winter and spring. These conditions are acceptable.

Residential Entrances: The residential entrances at the south of both buildings are recessed into the façade and protected from strong winds by walls on either side. This is a positive design feature which will ensure that wind conditions at the entrances will be acceptable during all seasons. Conditions are predicted to be suitable for sitting year-round. These conditions are acceptable.



5.2 Wind Comfort Conditions – Common Amenity Terraces

Level 7 Terraces: Wind conditions within the common amenity terraces at Level 7 will be suitable for a mix of sitting and standing during the summer season, suitable for a mix of standing and strolling during the autumn, and suitable for walking or better during the spring and winter. Figure 5B shows that the terrace serving Phase 1 will be suitable for sitting at least 70% of the time during the summer, while the terraces serving Phase 2 will be suitable for sitting at least 65% of the time.

Windy conditions on the terraces are caused by a combination of downwash from the buildings and acceleration of prominent westerly and easterly winds around the building corners. We recommend installing tall (minimum 2 m) wind screens in place of standard height guardrails along the east and west perimeters of the terrace serving Phase 1, and along the full perimeter of the terraces serving the Phase 2 building. Since the terraces are large, local wind barriers inboard of the perimeter will likely also be required. These may take the form of glass architectural wind screens positioned to protect designated seating areas and/or coniferous trees planted in dense arrangement. A mitigation strategy for these terraces can be confirmed during detailed design development.

5.3 Wind Comfort Conditions – Surrounding Area

Wind conditions over surrounding sidewalks beyond the subject site, as well as at nearby primary building entrances, will be acceptable for their intended pedestrian uses during each seasonal period upon the introduction of the subject site. Pedestrian wind comfort and safety have been quantified for the specific configuration of existing and foreseeable construction around the study site. Future changes (i.e., construction or demolition) of these surroundings may cause changes to the wind effects in two ways, namely: (i) changes beyond the immediate vicinity of the site would alter the wind profile approaching the site; and (ii) development in proximity to the site would cause changes to local flow patterns. In general, development in urban centers generally creates reduction in the mean wind and localized increases in the gustiness of the wind.



6. CONCLUSIONS AND RECOMMENDATIONS

A complete summary of the predicted wind comfort and safety conditions is provided in Section 5 and illustrated in Figures 3A-5B. 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 similar developments in Ottawa, we conclude the following:

- 1) Wind conditions at the bus stop on the east side of Clyde Avenue will be suitable for strolling during the winter and spring. A bus shelter will be required at this bus stop to ensure vulnerable members of the population can continue to comfortably use the bus stop.
- 2) Conditions within the patio to the north of Phase 2 will be suitable for standing during the summer. We recommend installing tall (minimum 2.0 m) wind barriers along the north and west extents of this patio to ensure conditions are suitable for sitting. These barriers could comprise high-solidity wind screens, dense coniferous plantings, or a combination thereof.
- 3) The office lobby entrance at the north elevation of Phase 2 will experience conditions suitable for strolling during the autumn, winter and spring. The mitigation measures described in item (2) above will improve conditions at this entrance to acceptable levels, as long as the recommended wind barrier along the western extent of the patio abuts the northern façade of the building.
- 4) Except for the three locations above, conditions around the subject site at grade level, including along sidewalks and walkways, within the parking lots to the west and north of the buildings, at all building entrances, within the patio to the south of Phase 2, and at the bus stops to the southeast and southwest, will be acceptable for their intended uses throughout the year.
- 5) Wind conditions within the common amenity terraces at Level 7 of both buildings will be suitable for a mix of sitting and standing during the summer. In order to achieve conditions suitable for sitting during the summer, we recommend installing tall (minimum 2 m) wind screens in place of standard height guard rails along the east and west perimeter of the terrace serving Phase 1, and along the full perimeter of the terraces serving Phase 2. We also recommend local wind barriers inboard of the perimeter, which may take the form of glass architectural wind screens positioned



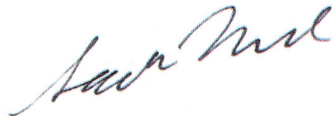
to protect designated seating areas and/or coniferous trees planted in dense arrangement. A mitigation strategy for these terraces can be confirmed during detailed design development.

- 6) Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas surrounding the subject site at grade level or within the common amenity terraces were found to experience conditions that could be considered uncomfortable or dangerous.

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

Sincerely,

Gradient Wind Engineering Inc.

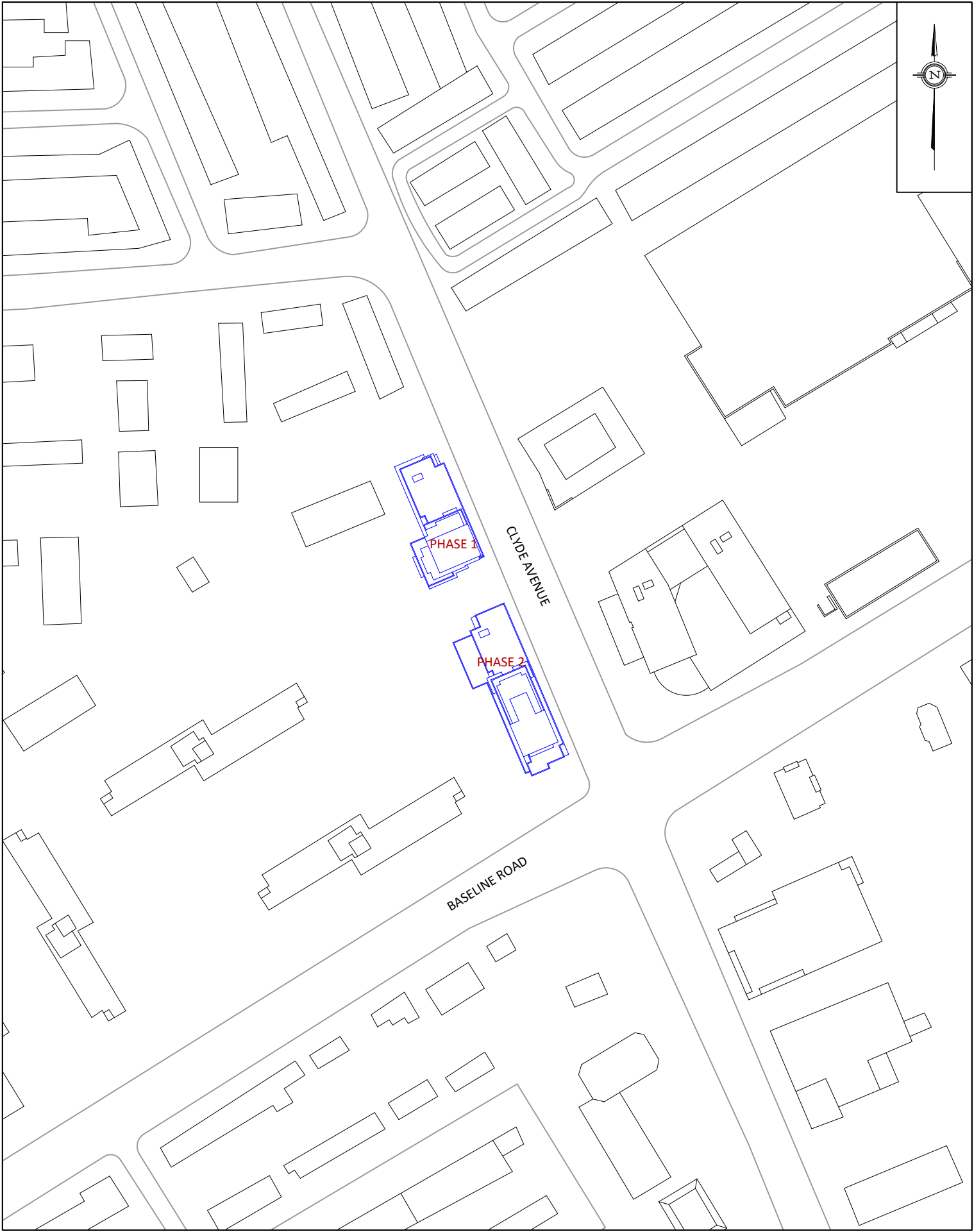


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PROJECT

1356 CLYDE AVENUE, OTTAWA
PEDESTRIAN LEVEL WIND STUDY

SCALE

1:2500 (APPROX.)

DRAWING NO.

20-009-PLW-1

DATE

MARCH 27, 2020

DRAWN BY

C.E.

DESCRIPTION

FIGURE 1:
SITE PLAN AND SURROUNDING CONTEXT

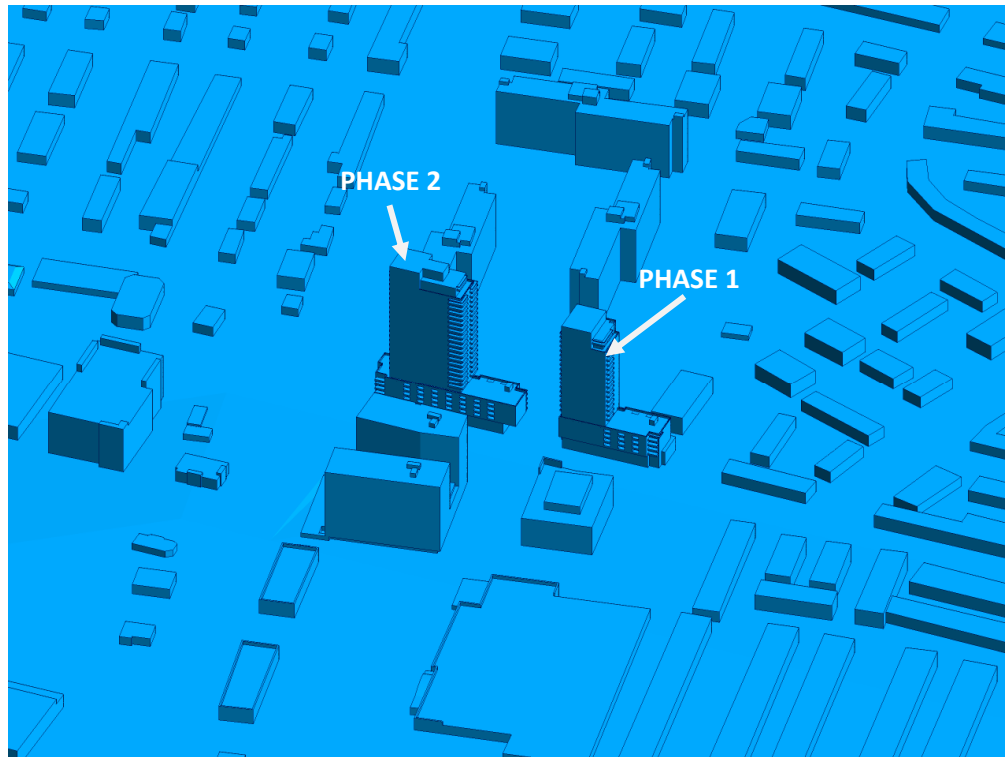


FIGURE 2A: COMPUTATIONAL MODEL, NORTHEAST PERSPECTIVE



FIGURE 2B: CLOSE UP OF FIGURE 2A



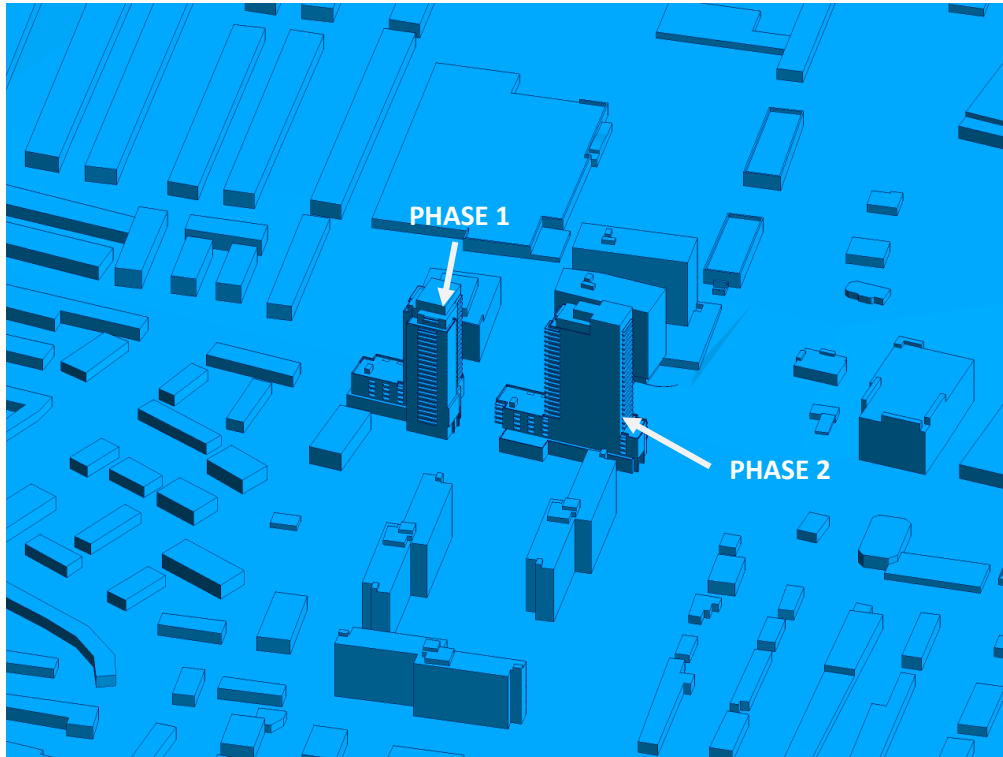


FIGURE 2C: COMPUTATIONAL MODEL, SOUTHWEST PERSPECTIVE

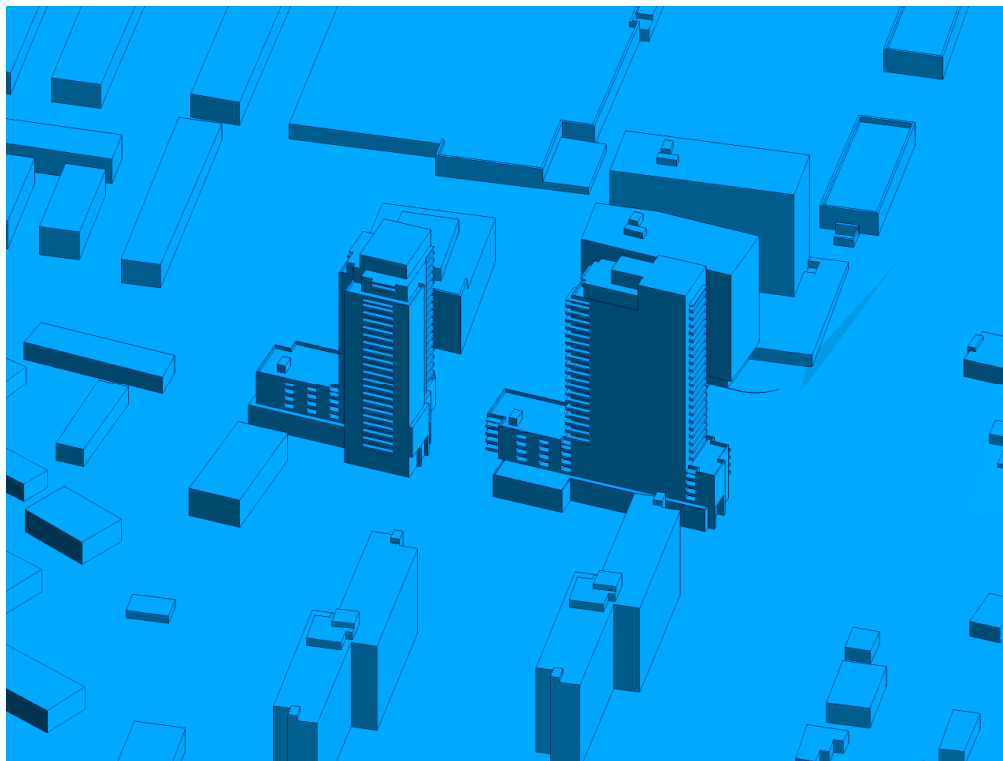


FIGURE 2D: CLOSE UP OF FIGURE 2C





FIGURE 3A: SPRING – WIND CONDITIONS AT GRADE LEVEL

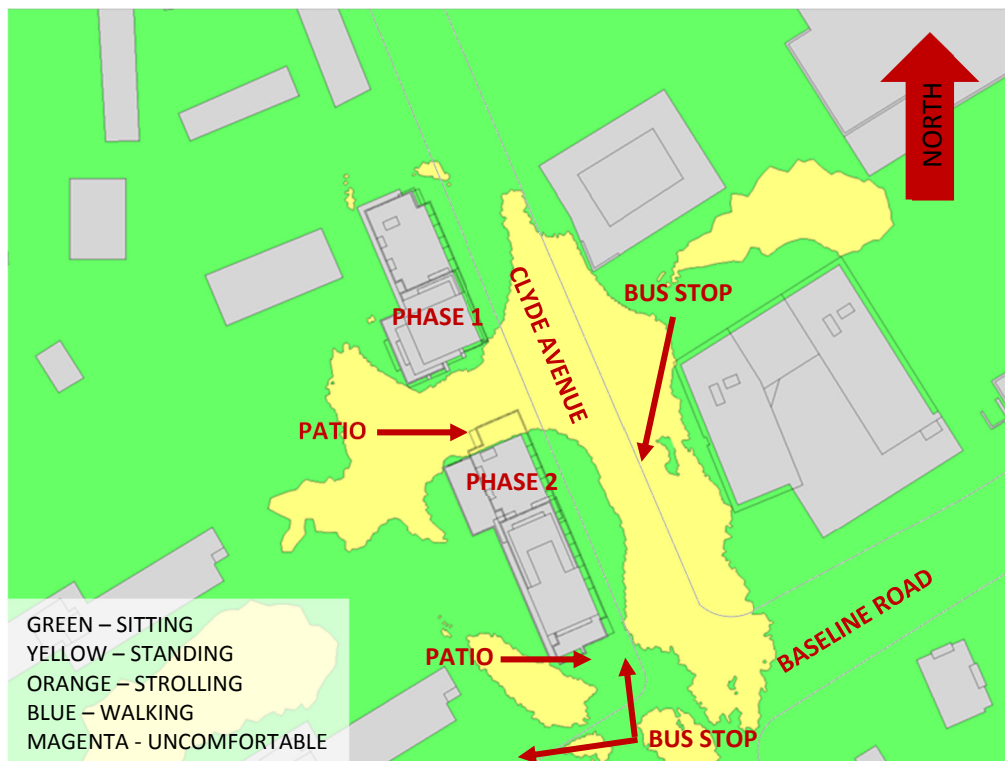


FIGURE 3B: SUMMER – WIND CONDITIONS AT GRADE LEVEL





FIGURE 3C: AUTUMN – WIND CONDITIONS AT GRADE LEVEL

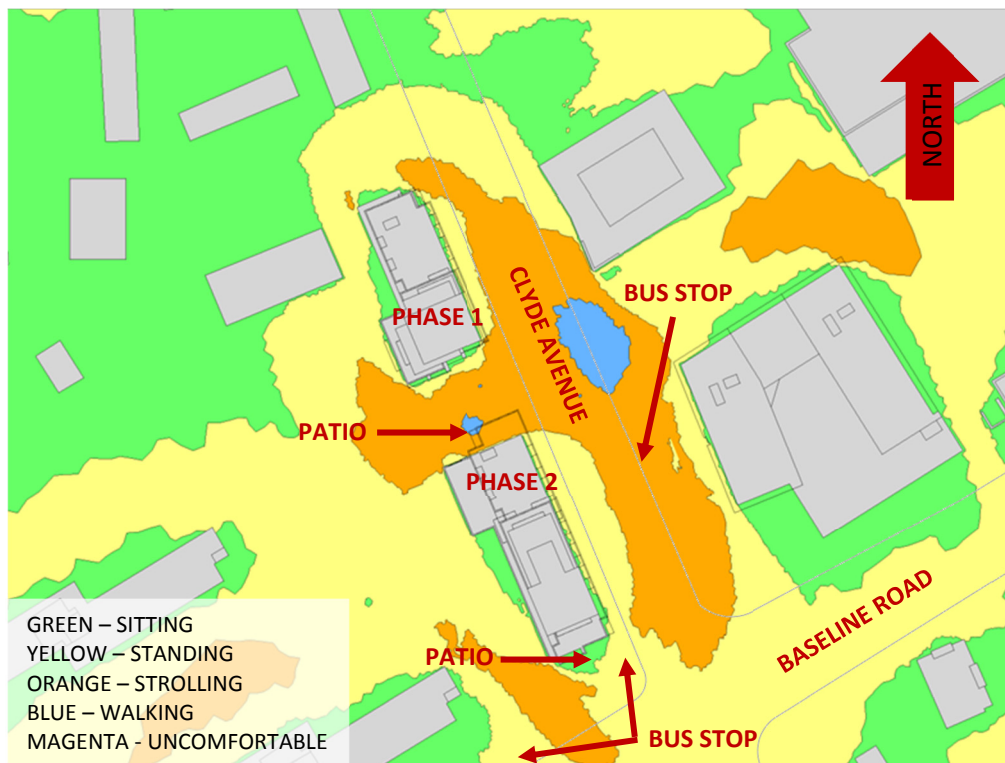


FIGURE 3D: WINTER – WIND CONDITIONS AT GRADE LEVEL



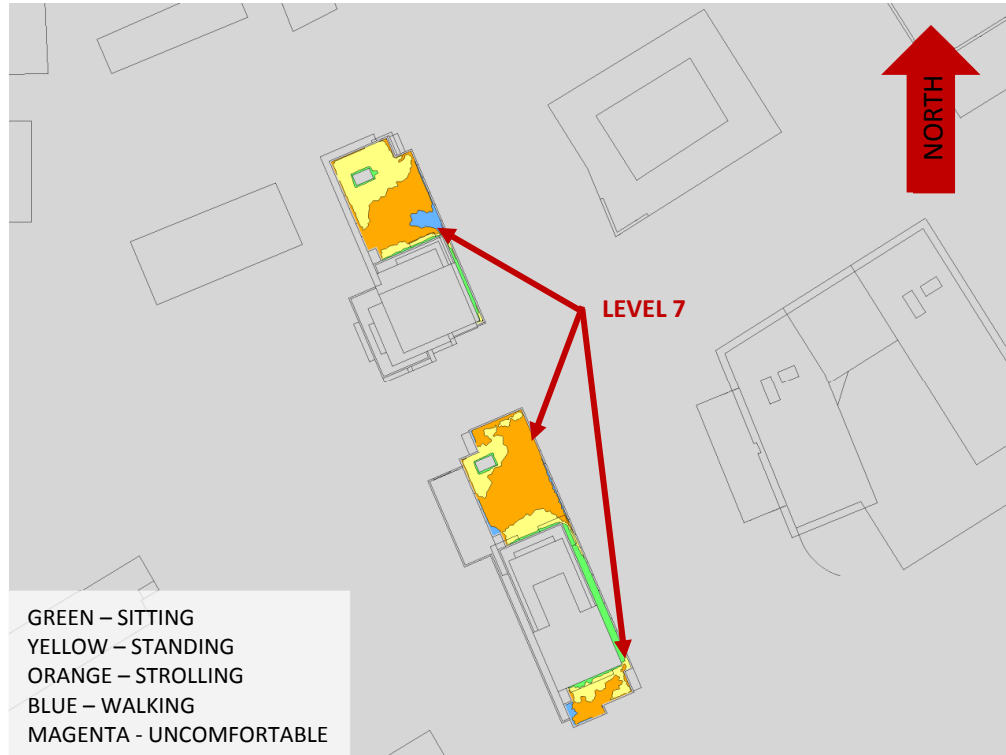


FIGURE 4A: SPRING – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES



FIGURE 4B: SUMMER – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES



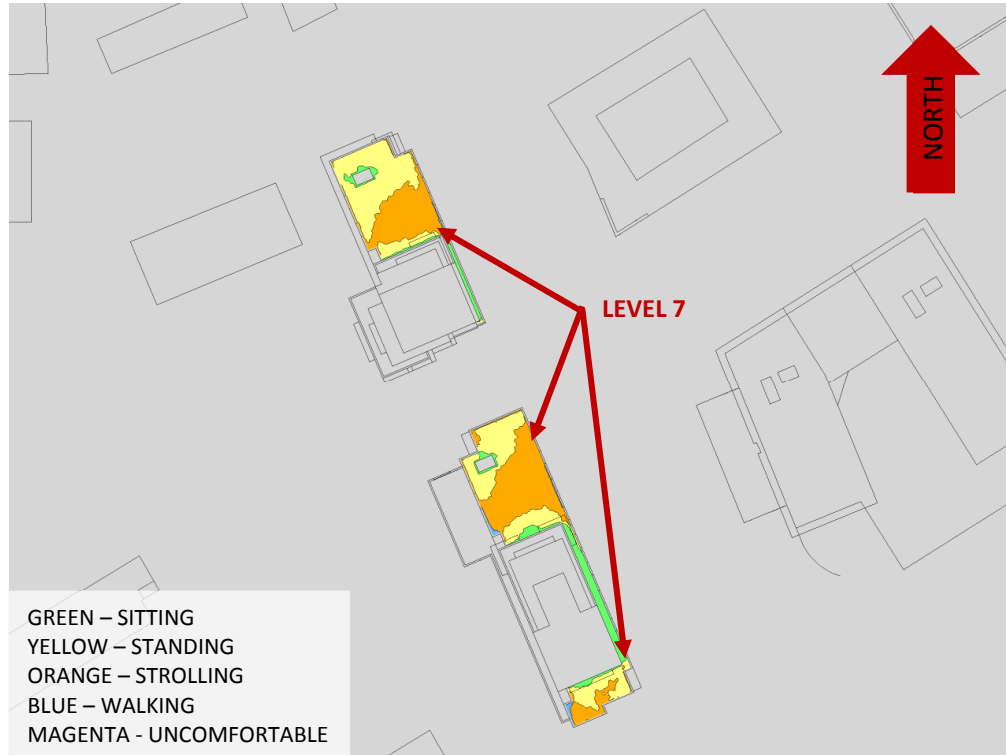


FIGURE 4C: AUTUMN – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES

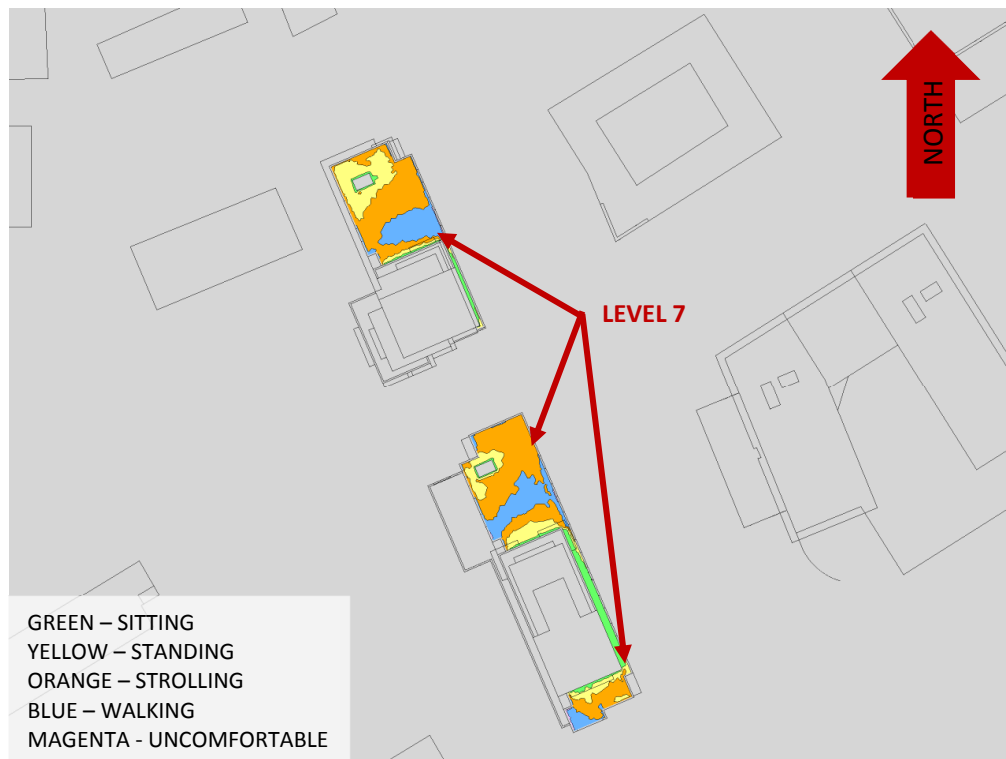


FIGURE 4D: WINTER – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES



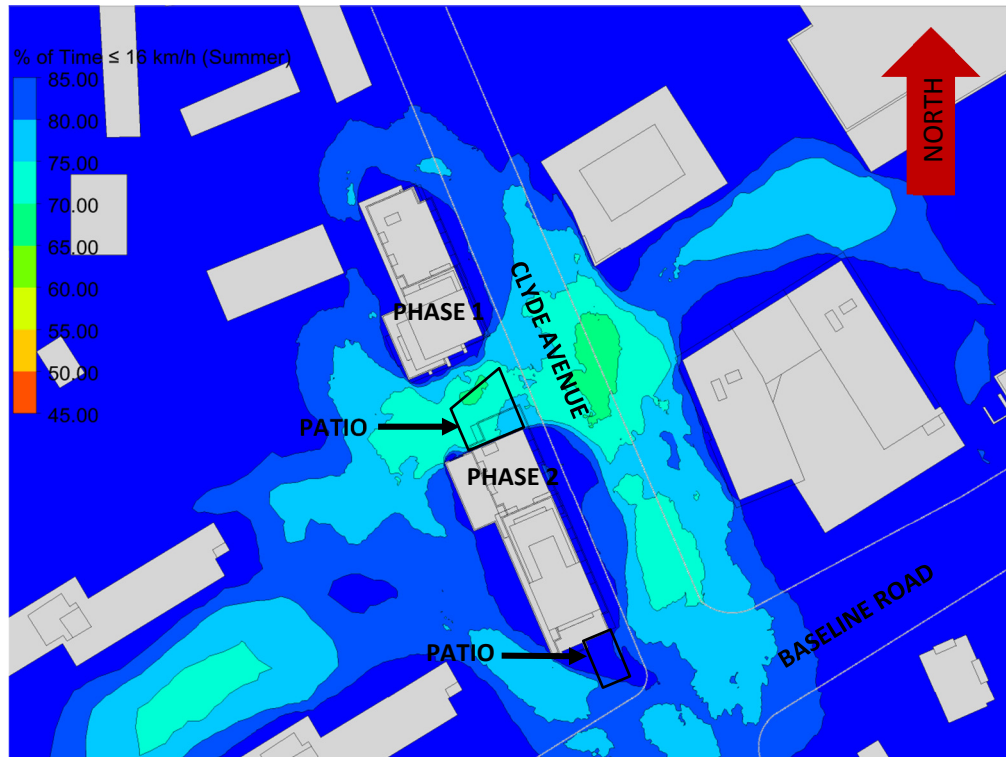


FIGURE 5A: SUMMER – PERCENTAGE OF TIME SUITABLE FOR SITTING (GRADE)

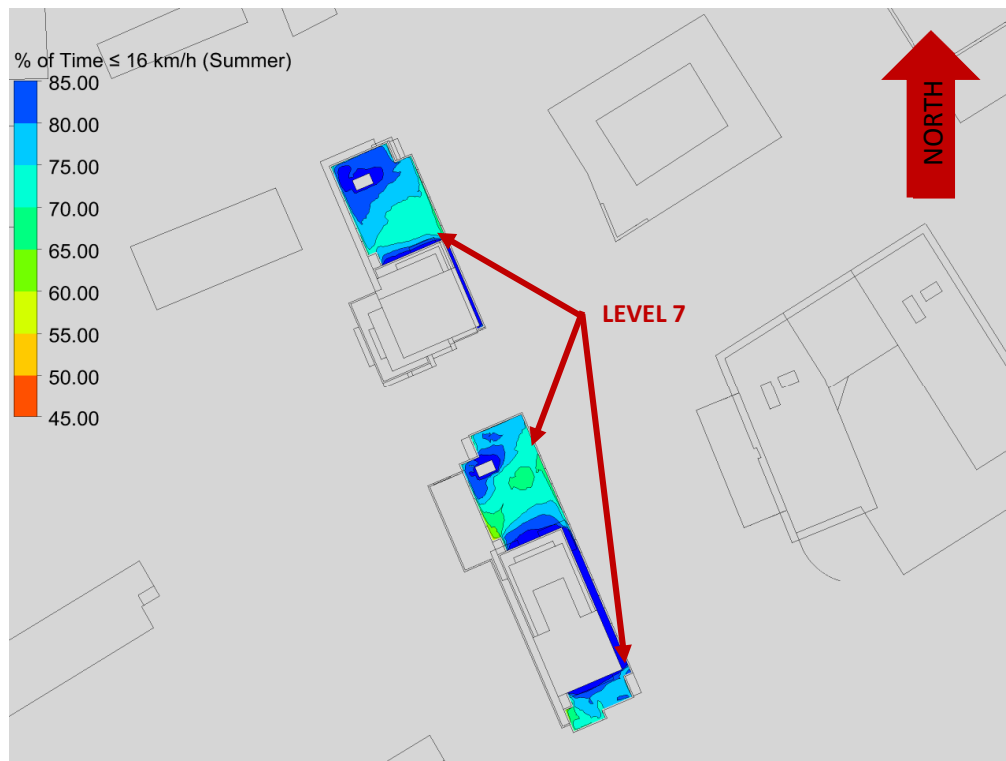
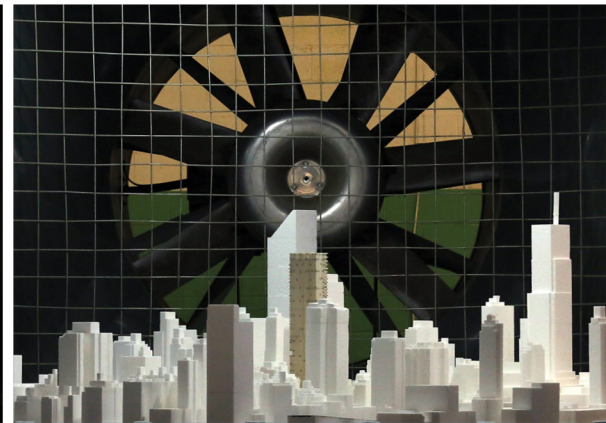
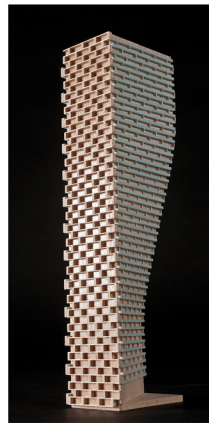


FIGURE 5B: SUMMER – PERCENTAGE OF TIME SUITABLE FOR SITTING (TERRACES)



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APPENDIX A

SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

The atmospheric boundary layer (ABL) is defined by the velocity and turbulence profiles according to industry standard practices. The mean wind profile can be represented, to a good approximation, by a power law relation, Equation (1), giving height above ground versus wind speed [1], [2].

$$U = U_g \left(\frac{Z}{Z_g} \right)^\alpha \quad \text{Equation (1)}$$

where, U = mean wind speed, U_g = gradient wind speed, Z = height above ground, 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 (° True)	Alpha (α) Value
0	0.23
49	0.21
74	0.24
103	0.24
167	0.24
197	0.24
217	0.24
237	0.24
262	0.24
282	0.24
302	0.24
324	0.23

TABLE 2: DEFINITION OF UPSTREAM EXPOSURE (ALPHA VALUE)

Upstream Exposure Type	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].

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

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

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

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