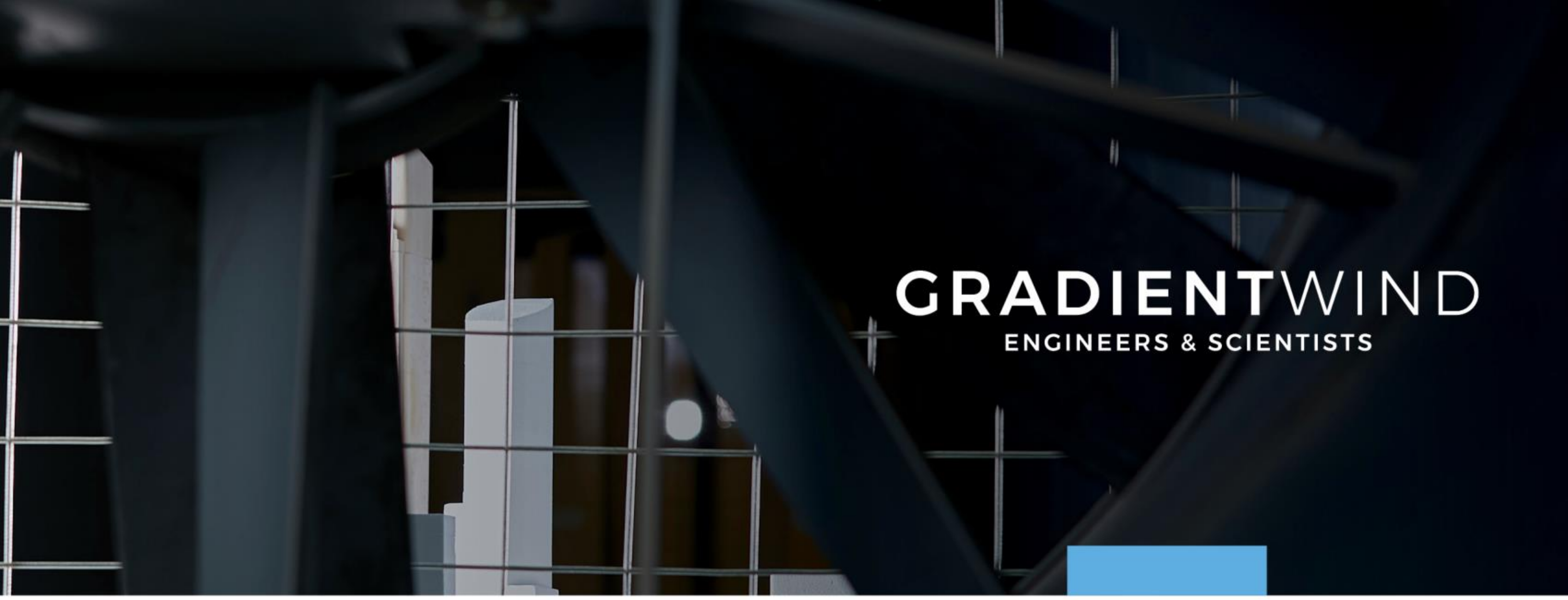
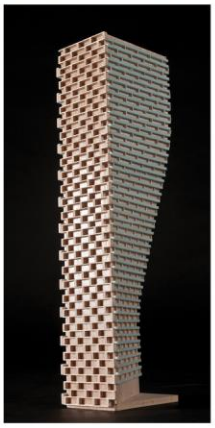


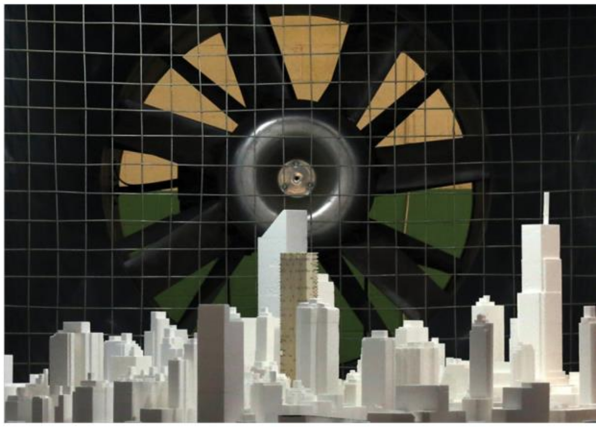
GRADIENTWIND
ENGINEERS & SCIENTISTS

PEDESTRIAN LEVEL WIND STUDY

315 Chapel Street
Ottawa, Ontario

Report: 23-051-PLW





August 8, 2023

PREPARED FOR
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EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study undertaken to satisfy concurrent Zoning By-law Amendment and Site Plan Control application submission requirements for the proposed residential building located at 315 Chapel Street in Ottawa, Ontario (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind conditions within and surrounding the subject site, and to identify areas where conditions may interfere with certain pedestrian activities so that 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 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-8, and summarized as follows:

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

2) Regarding the common amenity terrace serving the proposed development at the roof level, wind conditions during the typical use period are predicted to be suitable for sitting, which is considered acceptable.

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

Addendum: The PLW study was completed with the architectural drawings prepared by Linebox Studio, in May 2023. Updated drawings were distributed to the consultant team in late July 2023 with minor changes to the proposed residential development. At the ground floor, one of the building access points along the south elevation has been recessed into the façade, and the ramp to below-grade parking has been shifted to the south. At Levels 2 and 3, the building has been extended along the south elevation by approximately 1.5 metres. Additionally, the common rooftop amenity terrace serving the proposed development has been relocated to the north. The south portion of the rooftop will accommodate private terraces.

The noted minor changes are not expected to change the main conclusions of the PLW study. As such, the results and recommendations provided in this study are expected to be representative of the current architectural design. Additional simulations to confirm the wind conditions are not required.

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by All Saints Development LP to undertake a pedestrian level wind (PLW) study to satisfy concurrent Zoning By-law Amendment and Site Plan Control application submission requirements for the proposed residential building located at 315 Chapel Street in Ottawa, Ontario (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind conditions within and surrounding the subject site, and to identify areas where 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 Linebox Studio, in May 2023, surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa, as well as recent satellite imagery.

2. TERMS OF REFERENCE

The subject site is located at 315 Chapel Street in Ottawa; situated at the east intersection of Chapel Street and Laurier Avenue, on a parcel of land bounded by Chapel Street to the southwest, Laurier Avenue to the northwest, Blackburn Avenue to the northeast, and low-rise buildings to the southeast. Throughout this report, Chapel Street is referred to as project west. The existing All Saints Anglican Church building is located on the west of the subject site and is to be retained as part of the Ontario Heritage Act. An existing patio is situated to the north of the noted church. The proposed development comprises a nominally rectangular nine-storey residential building and is to be affixed to the polygonal apse to the east of the existing church.

Above two below-grade parking levels, the ground floor of the proposed development includes a lounge at the northeast corner, a main entrance to the east, shared building support spaces and bike storage at the southwest corner, a lobby atrium at the northwest corner and a central elevator core. Access to underground parking is provided by a ramp at the southeast corner via a laneway from Blackburn Avenue. Level 2 extends from the east elevation and includes residential units along the east elevation and to the west, and an indoor amenity to the west. Levels 3-4 are reserved for residential use. The building steps back from the east, south, and west elevations at Level 4 to accommodate private terraces. Levels 5-9 are reserved for residential use and include protruding private terraces to the east, south, and near the southwest corner. The building extends from the west elevation at Level 6 and steps back from the south elevation at Level 7. A floorplate setback from the north and east elevations creates a private terrace at the northeast corner at Level 7. The roof level is reserved for indoor amenities and the building steps back from all elevations to accommodate an amenity terrace around the perimeter of the level.

The near-field surroundings, defined as an area within 200-metres (m) of the subject site, include low-rise massing in all compass directions with high-rise buildings to the north, northeast, and south, and Sir Wilfred Laurier Park to the northwest. Notably, a four-storey apartment development is approved for Zoning By-law Amendment (awaiting Site Plan Control approval) at 326 and 330 Wilbrod Street, approximately 200 m to the northwest. The far-field surroundings, defined as an area beyond the near-field but within a 2-kilometre (km) radius of the subject site, are characterized by low-rise massing with isolated mid- and high-rise buildings in all compass directions. The Rideau River flows from the south to the northwest and the Rideau Canal flows from the south-southwest to the west where it meets the Ottawa River, approximately 1.8 km to the west-northwest.

Site plans for the proposed and existing massing scenarios are illustrated in Figures 1A and 1B, while Figures 2A-2H illustrate the computational models used to conduct the study. The existing massing scenario includes the existing massing and any future developments approved by the City of Ottawa.

3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind 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 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 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 stronger wind speeds.

[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 16 wind directions. The CFD simulation model was centered on the proposed development, complete with surrounding massing within a radius of 480 m. The process was performed for two context massing scenarios, as noted in Section 2.

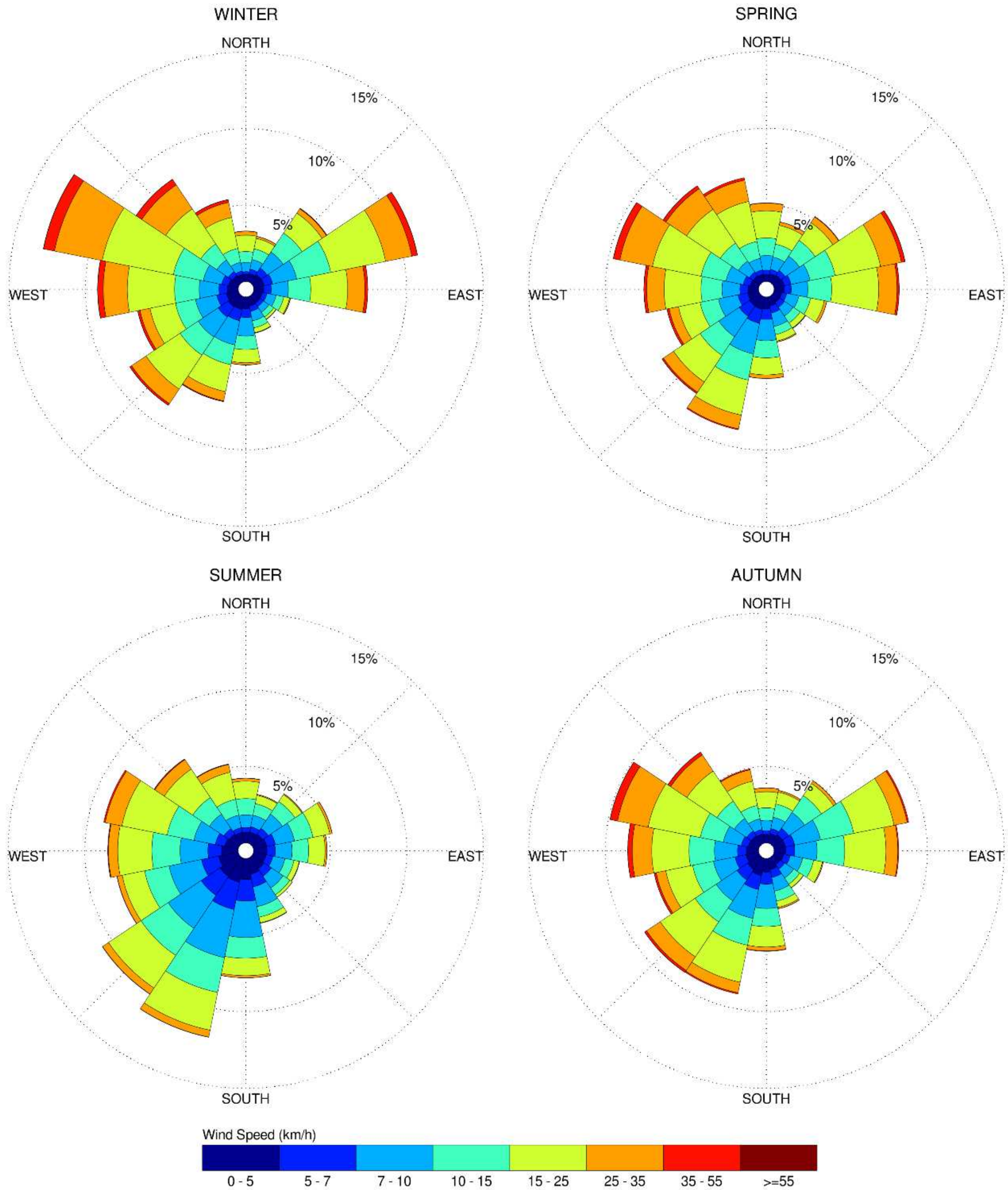
Mean and peak wind speed data obtained over the subject site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade and the rooftop common amenity terrace serving the proposed development were referenced to the wind speed at gradient height to generate mean and peak velocity ratios, which were used to calculate full-scale values. Gradient height represents the theoretical depth of the boundary layer of the earth's atmosphere, above which the mean wind speed remains constant. Further details of the wind flow simulation technique are presented in Appendix A.

4.3 Historical Wind Speed and Direction Data

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

DESIRED PEDESTRIAN COMFORT CLASSES FOR VARIOUS LOCATION TYPES

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

5. RESULTS AND DISCUSSION

The following discussion of the predicted pedestrian wind conditions for the subject site is accompanied by Figures 3A-6B, illustrating wind conditions at grade level for the proposed and existing massing scenarios, and by Figures 7A-7D, illustrating wind conditions over the common amenity terrace serving the proposed development at the roof level. Conditions are presented as continuous contours of wind comfort throughout the subject site and correspond to the comfort classes presented 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.

Wind comfort conditions over the rooftop amenity terrace are also reported for the typical use period, which is defined as May to October, inclusive. Figure 8 illustrates comfort conditions consistent with the comfort classes in Section 4.4. Conditions at all areas studied are considered acceptable for the intended pedestrian uses. The details of these conditions are summarized in the following pages for each area of interest.

5.1 Wind Comfort Conditions – Grade Level

Sidewalks and Transit Stop along Chapel Street, Transit Stop along Laurier Avenue, and Existing Patio North of Subject Site: Prior to the introduction of the proposed development, wind comfort conditions over the public sidewalks and in the vicinity of the nearby transit stop along Chapel Street, in the vicinity of the nearby transit stop along Laurier Avenue, and over the existing patio serving the All Saints Anglican Church are predicted to be suitable for sitting throughout the year. The noted conditions remain unchanged following the introduction of the proposed development. As such, wind conditions with the proposed development are considered acceptable.

Sidewalks along Laurier Avenue: Following the introduction of the proposed development, wind comfort conditions over the public sidewalks along Laurier Avenue are predicted to be suitable for sitting during the summer and autumn, with an isolated region suitable for standing during the autumn, becoming suitable for a mix of sitting and standing during the winter and spring. The noted conditions are considered acceptable.

Wind comfort conditions over the sidewalks along Laurier Avenue with the existing massing are predicted to be suitable for sitting throughout the year with isolated regions suitable for standing during the winter and spring. While the introduction of the proposed development produces slightly windier conditions in comparison to existing conditions, wind comfort conditions are nevertheless considered acceptable.

Sidewalks along Blackburn Avenue: Following the introduction of the proposed development, wind comfort conditions over the public sidewalks along Blackburn Avenue are predicted to be suitable for sitting during the summer, becoming suitable mostly for sitting throughout the remainder of the year. The noted conditions are considered acceptable.

Wind comfort conditions over the sidewalks along Blackburn Avenue with the existing massing are predicted to be suitable for sitting throughout the year. While the introduction of the proposed development produces slightly windier conditions in comparison to existing conditions, wind comfort conditions are nevertheless considered acceptable.

Building Access: Wind comfort conditions in the vicinity of all building access points are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable.

5.2 Wind Comfort Conditions – Common Amenity Terrace

Rooftop Common Amenity Terrace: During the typical use period, wind comfort conditions within the common amenity terrace serving the proposed development at the roof level are predicted to be suitable for sitting, as illustrated in Figure 8. The noted conditions are considered acceptable.

5.3 Wind Safety

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

5.4 Applicability of Results

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

6. CONCLUSIONS AND RECOMMENDATIONS

A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-8. 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) All grade-level areas within and surrounding the subject site are predicted to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year. Specifically, conditions over surrounding sidewalks, transit stops, the existing patio serving the All Saints Anglican Church, and in the vicinity of building access points, are considered acceptable.

2) Regarding the common amenity terrace serving the proposed development at the roof level, wind conditions during the typical use period are predicted to be suitable for sitting, which is considered acceptable.

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

Sincerely,

Gradient Wind Engineering Inc.

LICENSED PROFESSIONAL ENGINEER
J. D. FERRARO
100158495
Aug 8, 2023
PROVINCE OF ONTARIO

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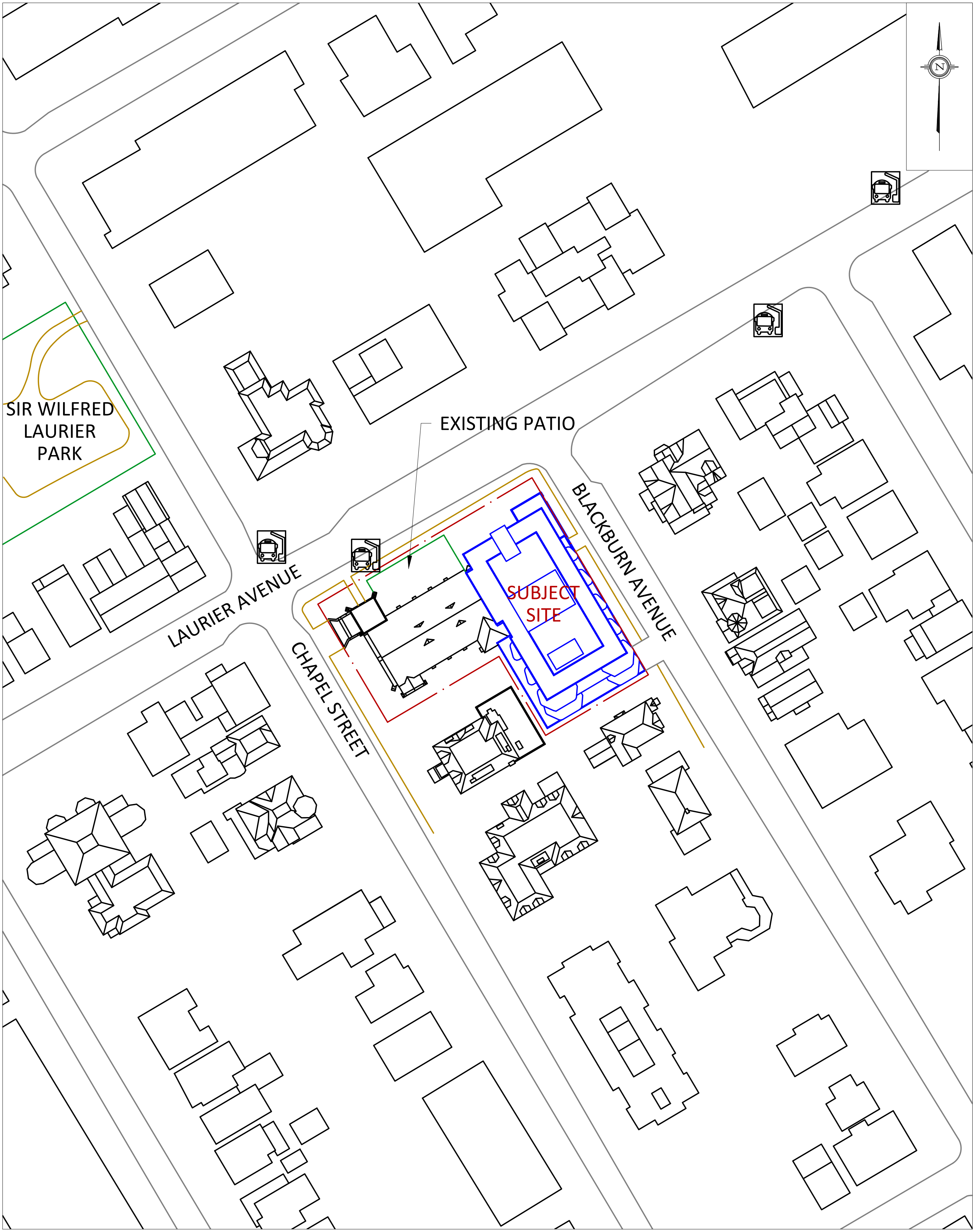

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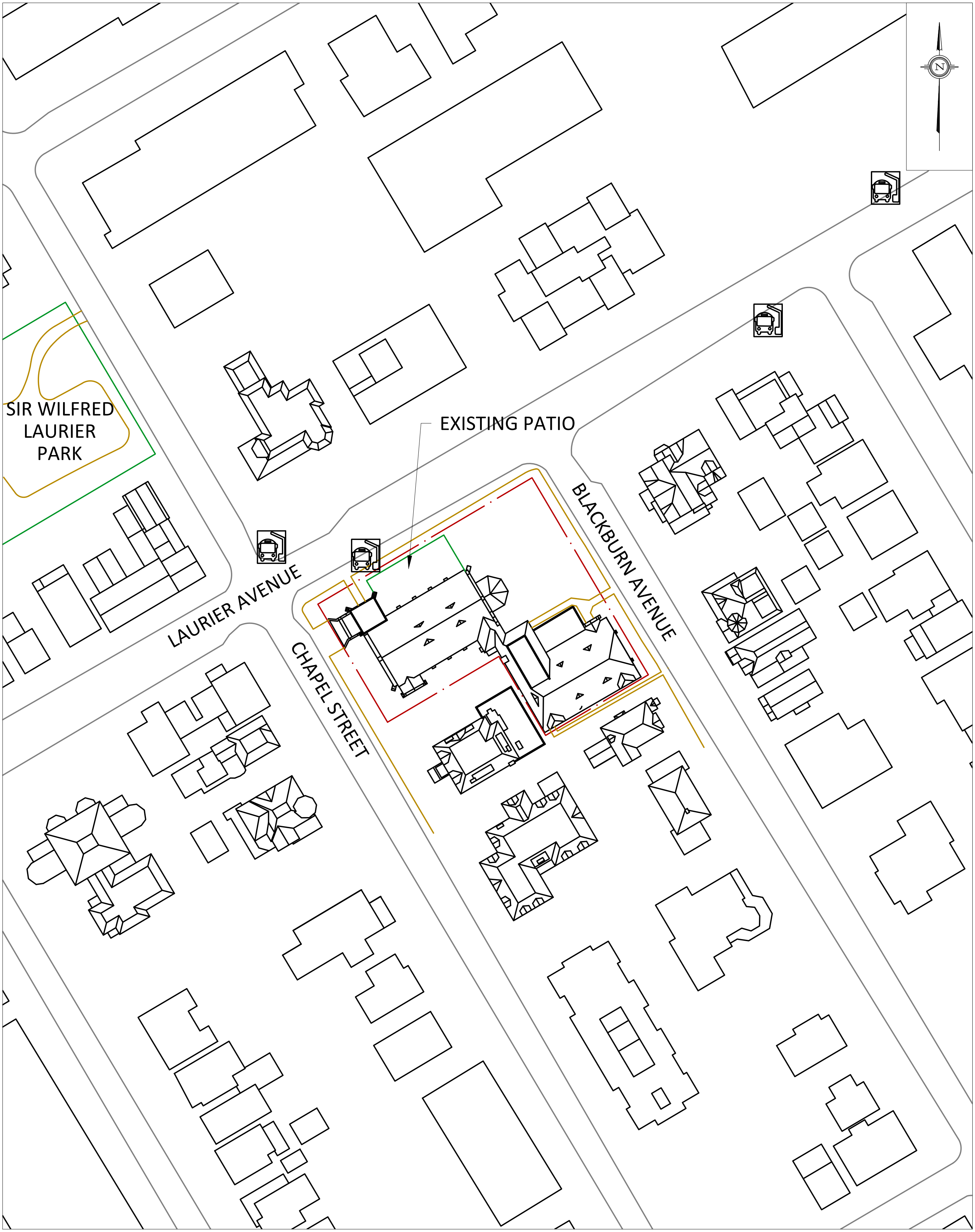
613 836 0934 • GRADIENTWIND.COM

PROJECT	315 CHAPEL STREET - ALL SAINTS, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION FIGURE 1A: PROPOSED SITE PLAN AND SURROUNDING CONTEXT
SCALE 1:1250		DRAWING NO. 23-051-PLW-1A	
DATE JUNE 1, 2023		DRAWN BY N.M.P.	



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PROJECT: 315 CHAPEL STREET - ALL SAINTS, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1B: EXISTING SITE PLAN AND SURROUNDING CONTEXT	
SCALE: 1:1250	DRAWING NO. 23-051-PLW-1B		
DATE: JUNE 1, 2023	DRAWN BY: N.M.P.		

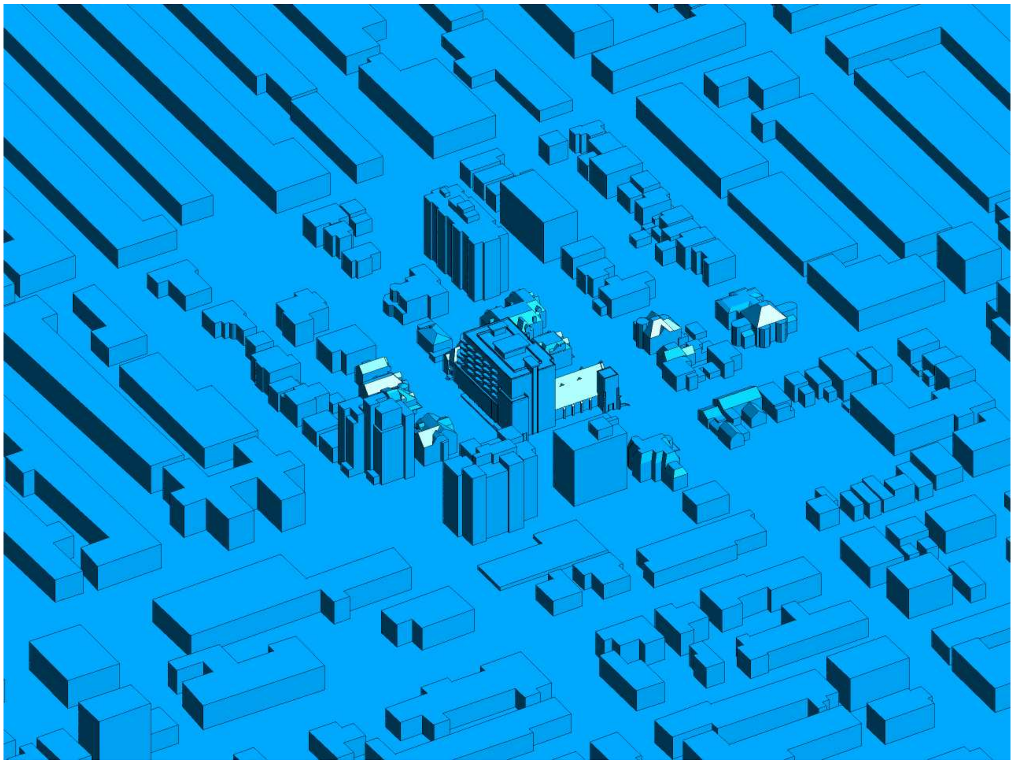


FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTH PERSPECTIVE

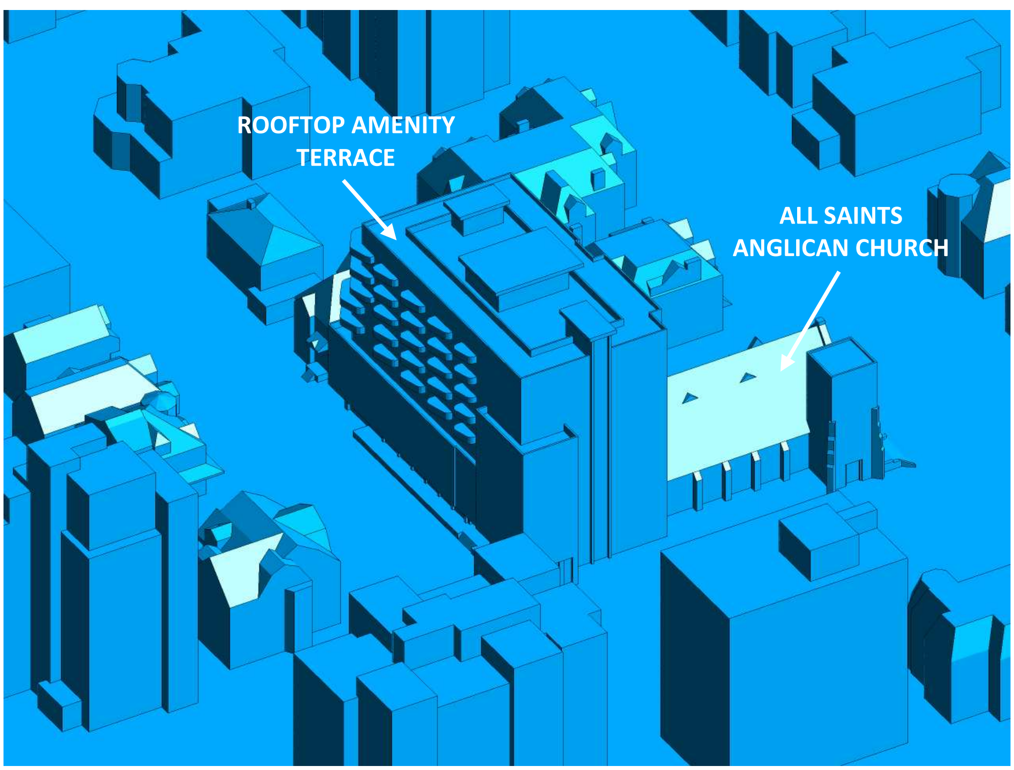


FIGURE 2B: CLOSE UP OF FIGURE 2A

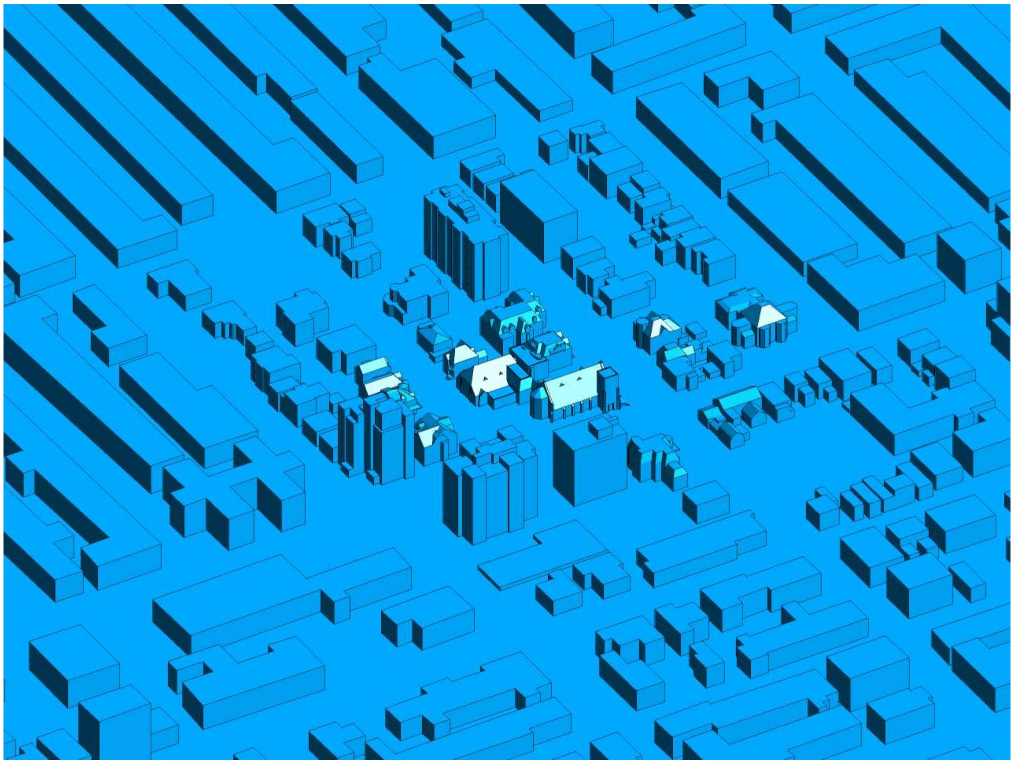


FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, NORTH PERSPECTIVE

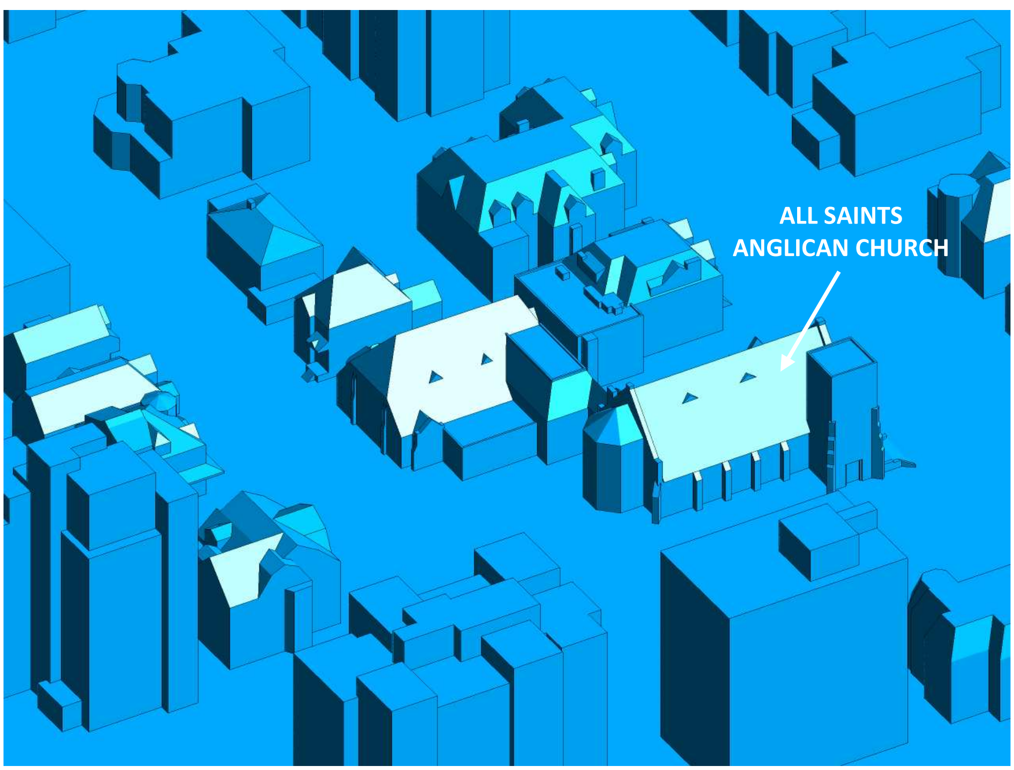


FIGURE 2D: CLOSE UP OF FIGURE 2C

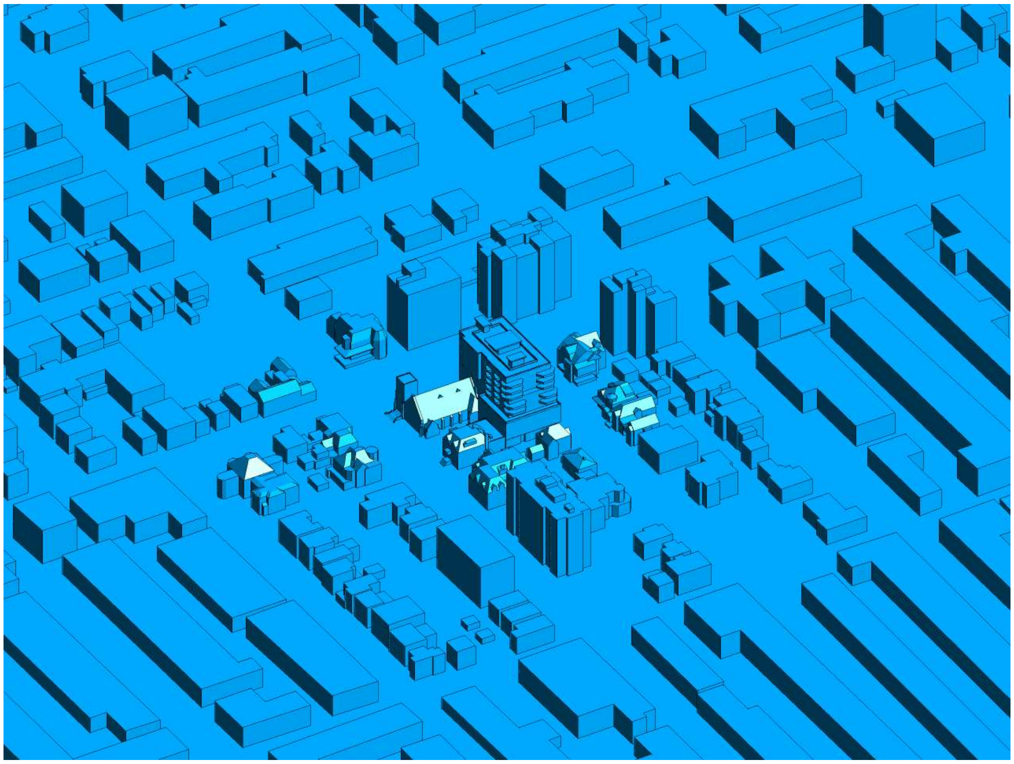


FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTH PERSPECTIVE

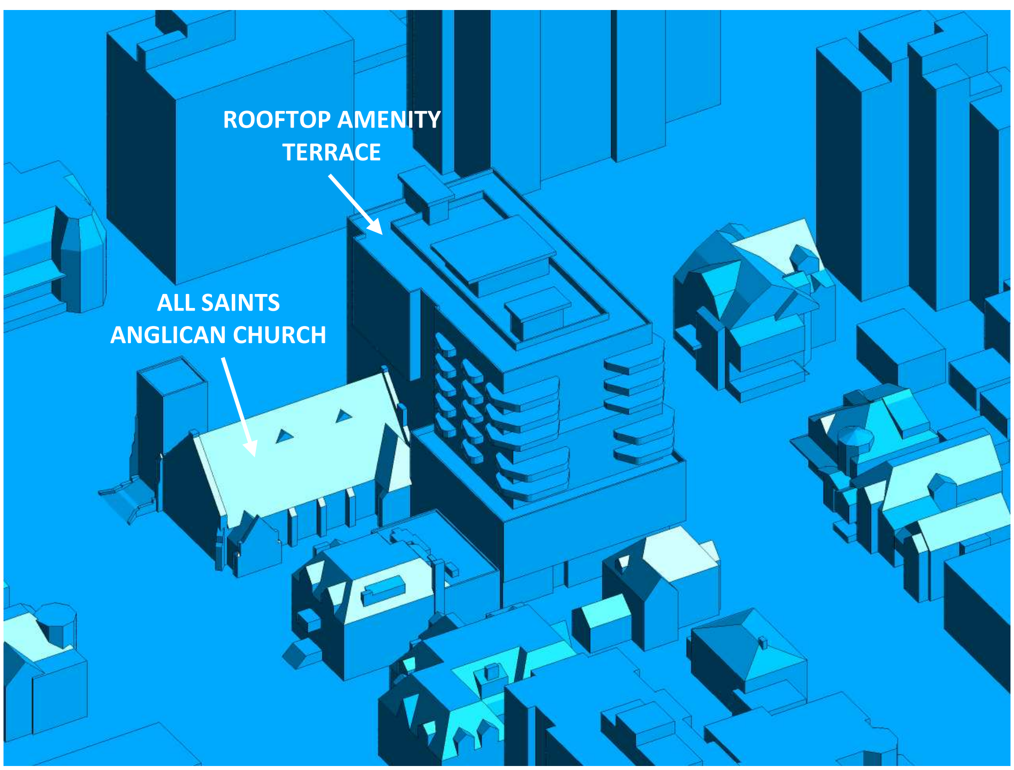


FIGURE 2F: CLOSE UP OF FIGURE 2E

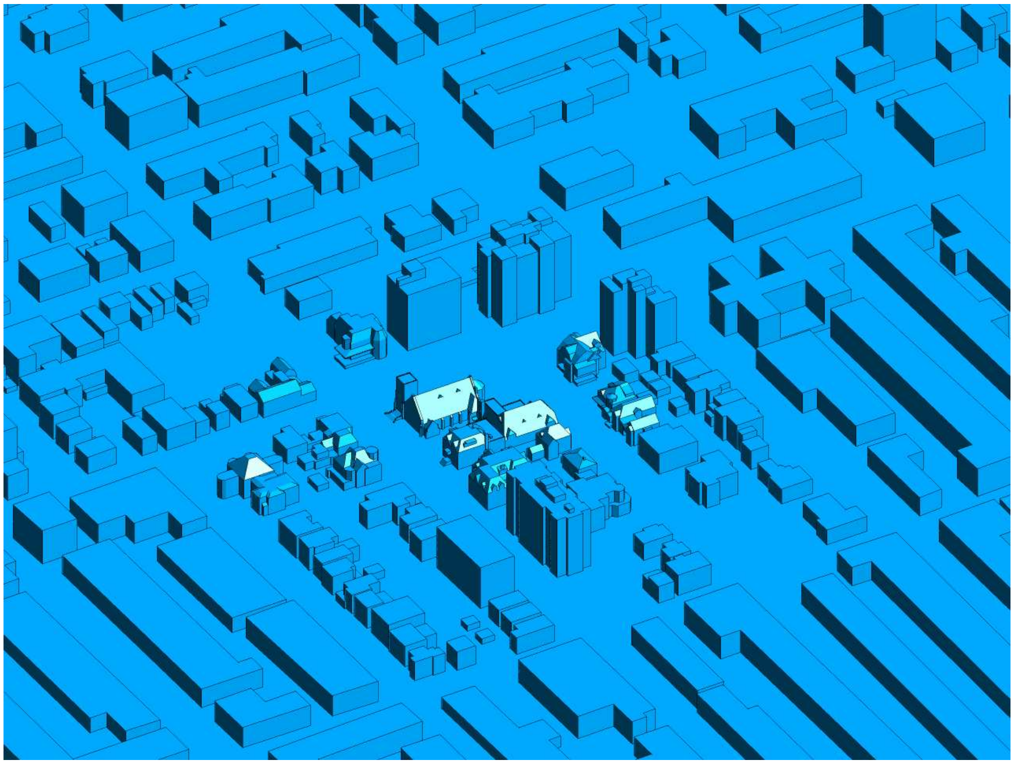


FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, SOUTH PERSPECTIVE

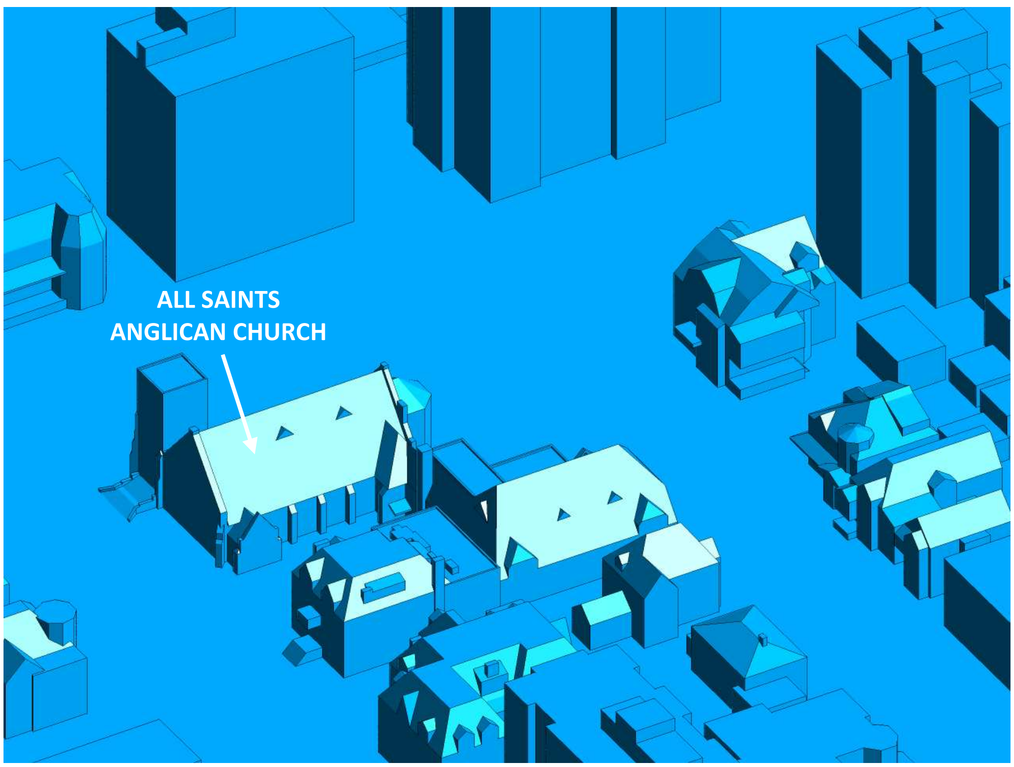


FIGURE 2H: CLOSE UP OF FIGURE 2G

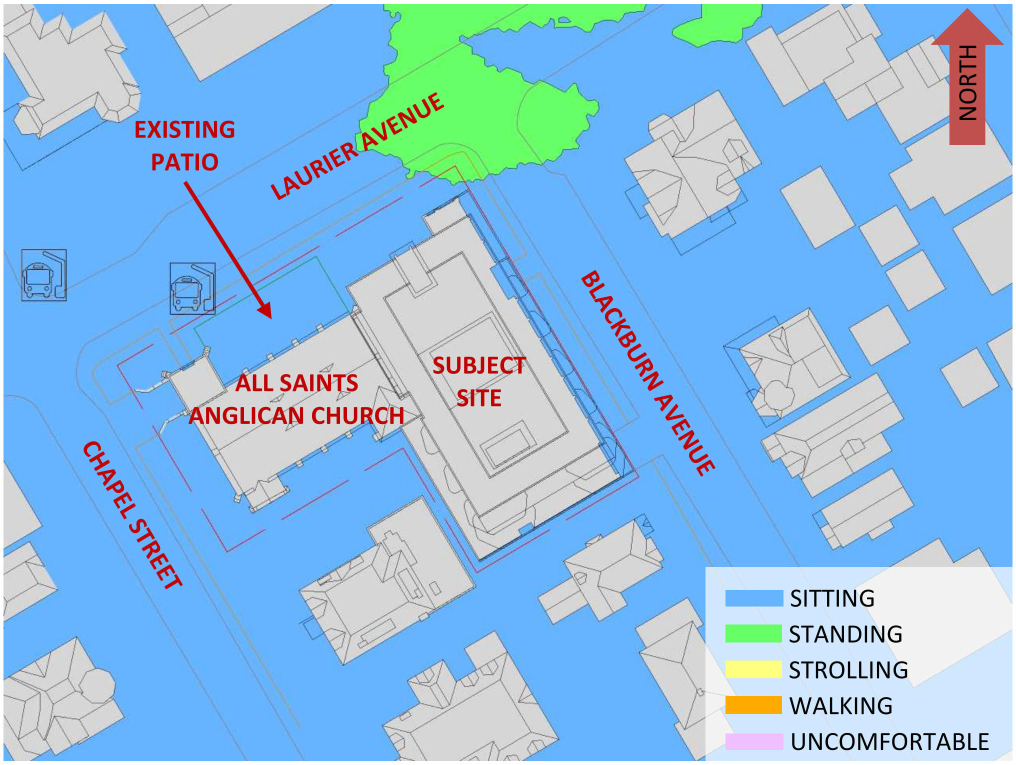


FIGURE 3A: SPRING – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

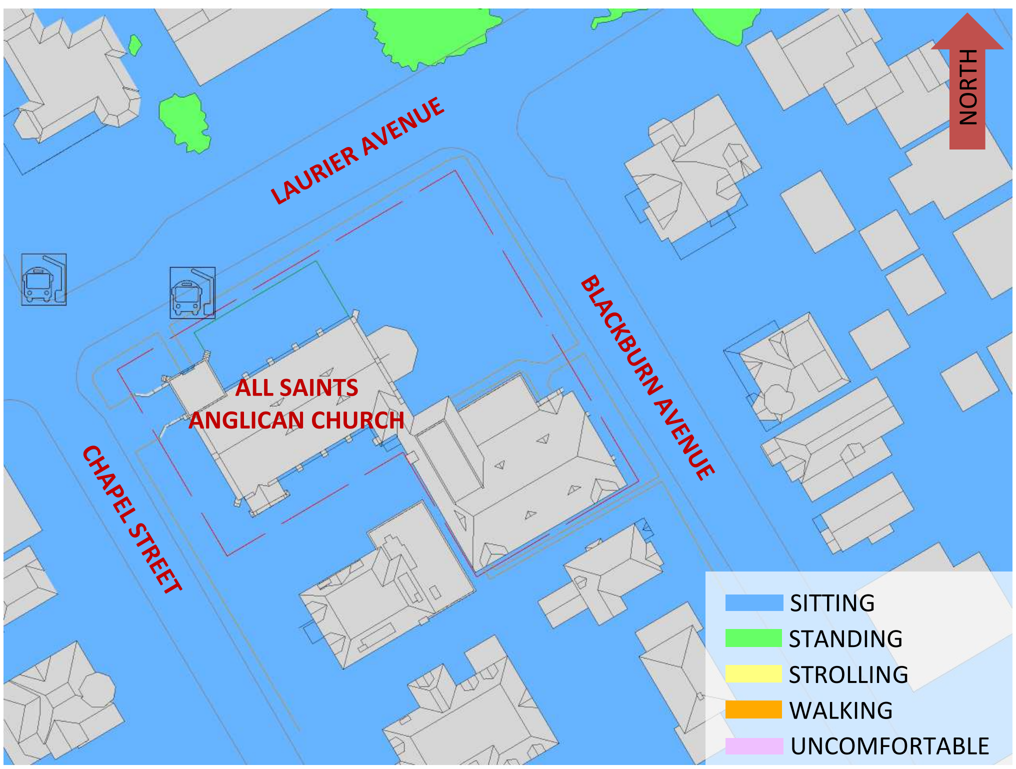


FIGURE 3B: SPRING – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

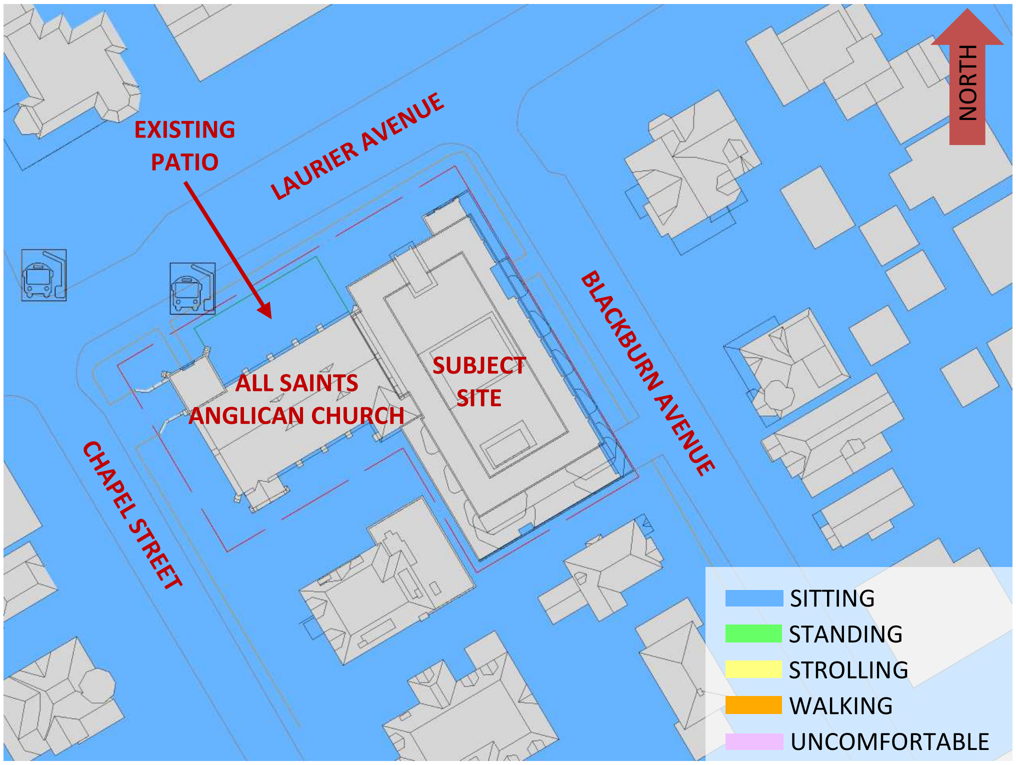


FIGURE 4A: SUMMER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

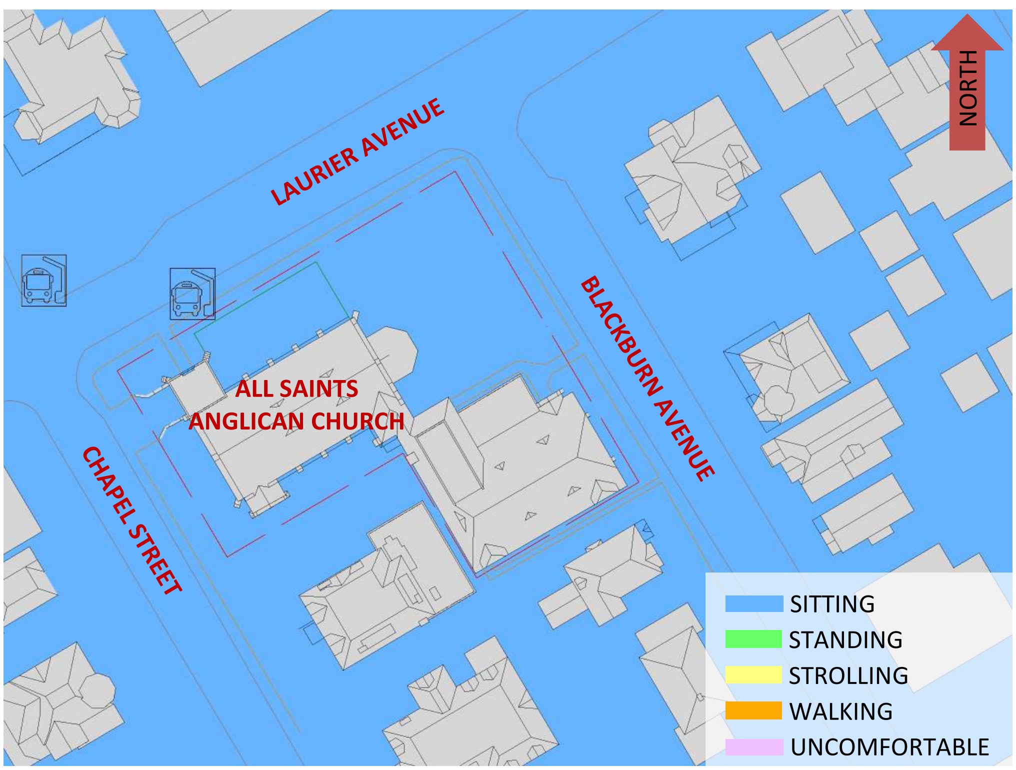


FIGURE 4B: SUMMER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

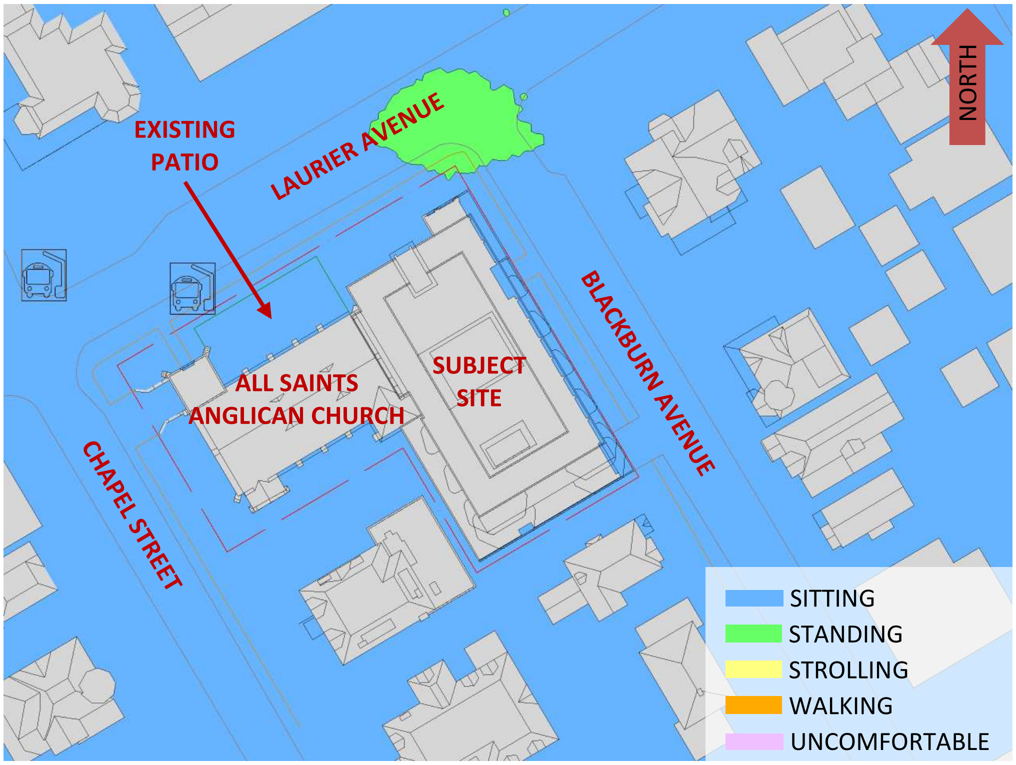


FIGURE 5A: AUTUMN – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

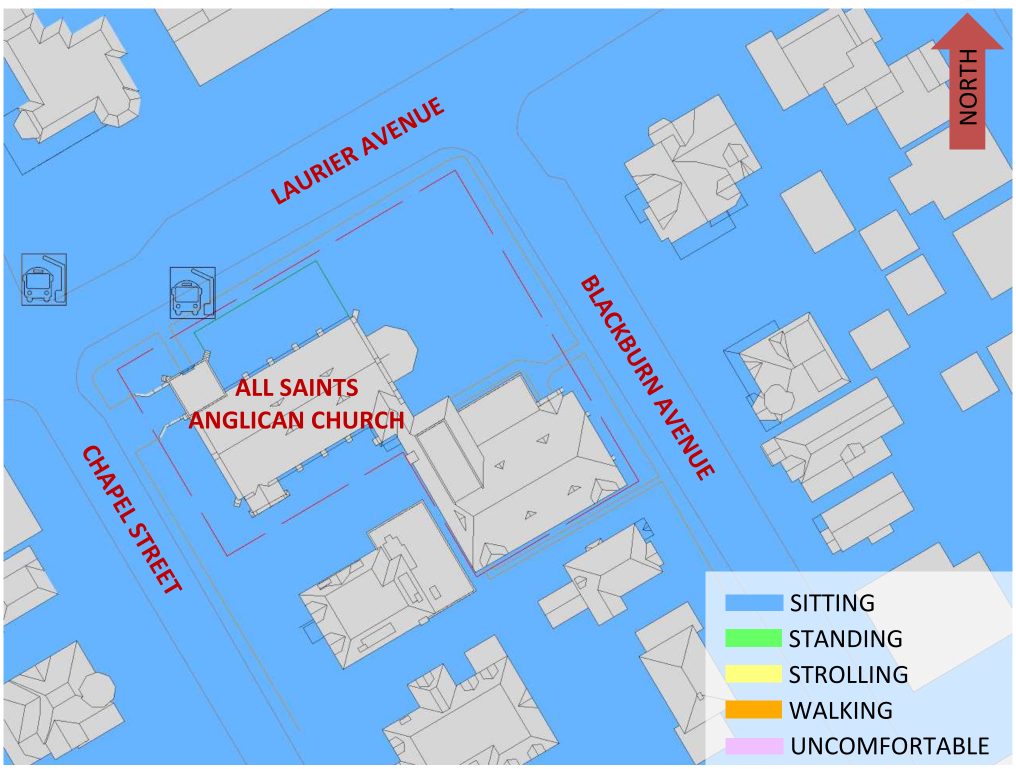


FIGURE 5B: AUTUMN – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

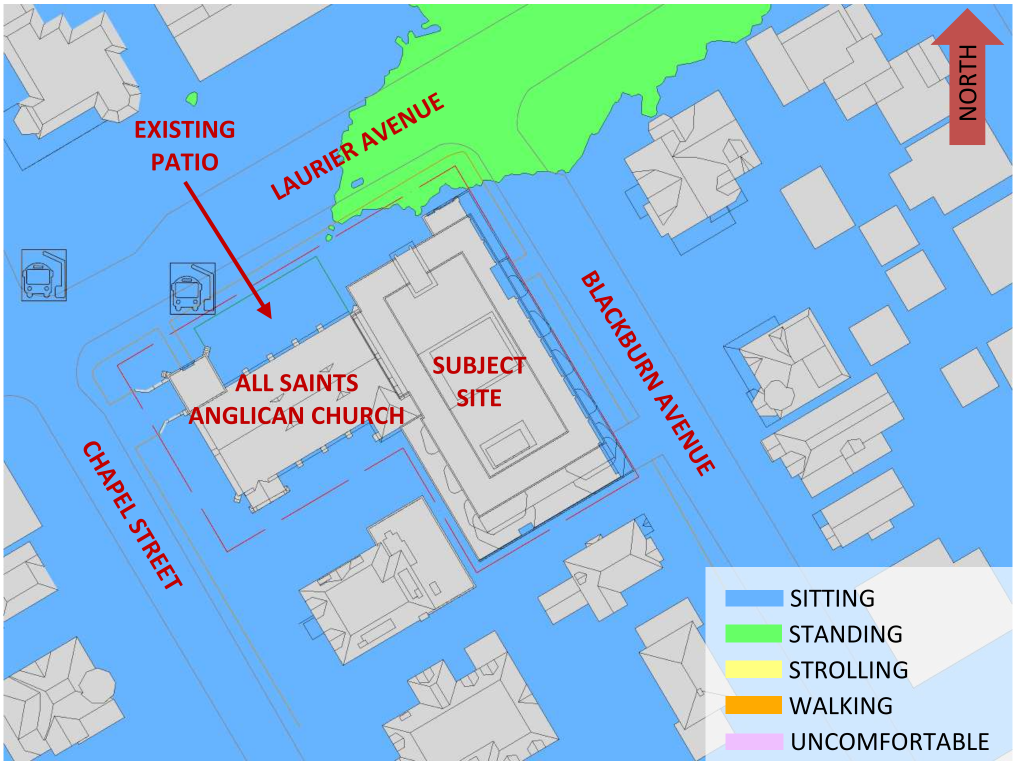


FIGURE 6A: WINTER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING

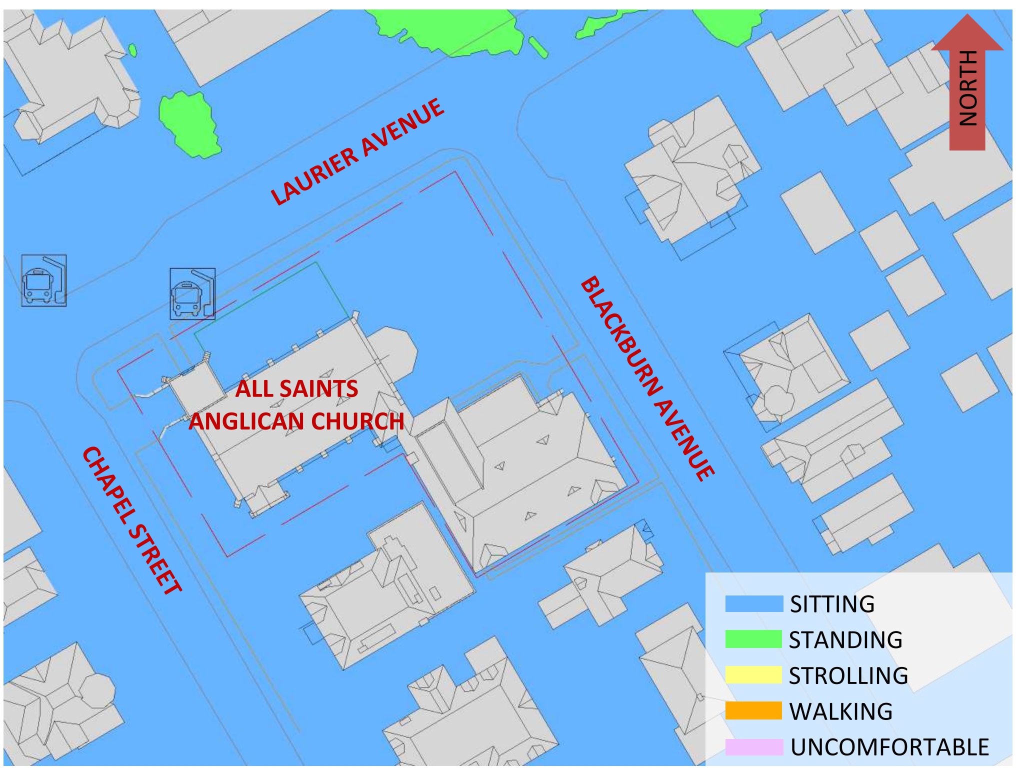


FIGURE 6B: WINTER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING

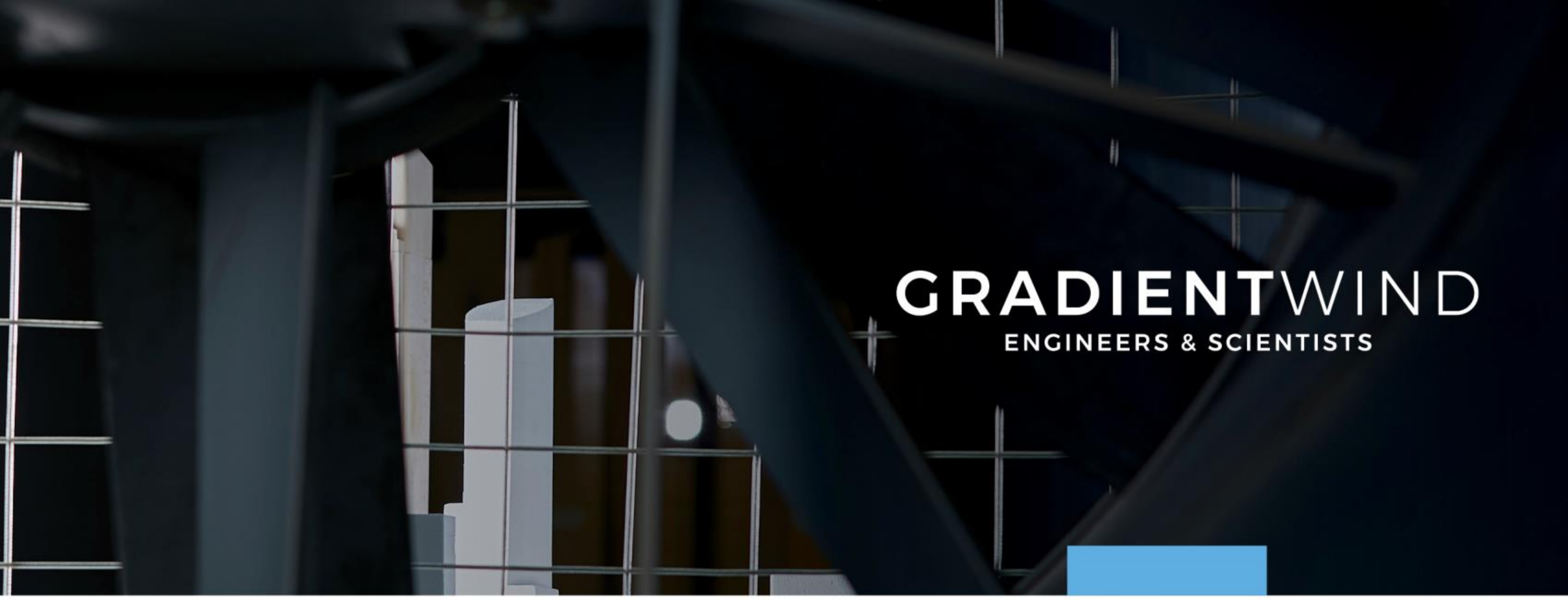
FIGURE 7A: SPRING – WIND COMFORT, ROOFTOP COMMON AMENITY TERRACE

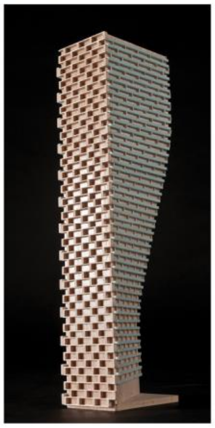
FIGURE 7B: SUMMER – WIND COMFORT, ROOFTOP COMMON AMENITY TERRACE

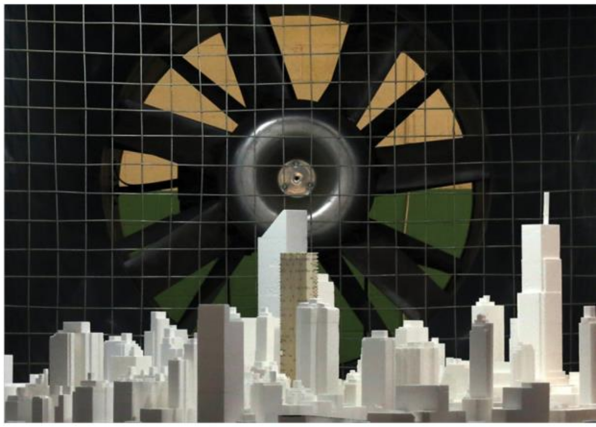
FIGURE 7C: AUTUMN – WIND COMFORT, ROOFTOP COMMON AMENITY TERRACE

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

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







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, 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 (that is, 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	0.25
22.5	0.25
45	0.24
67.5	0.24
90	0.24
112.5	0.23
135	0.24
157.5	0.24
180	0.25
202.5	0.27
225	0.27
247.5	0.29
270	0.28
292.5	0.27
315	0.25
337.5	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).

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

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

where, ***I*** = turbulence intensity, L_t = turbulence length scale, ***Z*** = height above ground, and α is the power law exponent used for the velocity profile in Equation (1).

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

REFERENCES

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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.