Pedestrian Level Wind Study

550-568 Booth Street

Ottawa, Ontario

REPORT: GWE18-148-PLW

Prepared For:

Canada Lands Company
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November 20, 2018

EXECUTIVE SUMMARY

This report describes a computer-based pedestrian level wind study in support of a joint Official Plan Amendment (OPA) and Zoning By-law Amendment (ZBA) application for the planned mixed-use residential, retail, and office development located at 550-568 Booth Street in Ottawa, Ontario. 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 comfort and safety within and surrounding the development site. The results and recommendations derived from these considerations are summarized in the following paragraphs and detailed in the subsequent report.

A complete summary of the predicted wind conditions is presented in Section 5 of this report. Wind comfort contours are illustrated in Figures 3A-6B for the future massing configuration, and in Figures 7-10 for the existing massing configuration. Based on CFD test results, interpretation, and experience with similar developments, we conclude the following:

1) All grade-level areas within and surrounding the fully-developed future site massing will be acceptable for the intended pedestrian uses on a seasonal basis in accordance with City of Ottawa wind criteria. Surrounding sidewalks, bus stops, park space, and building access points will experience acceptable wind conditions throughout the year.

2) Further to item (1), and as illustrated in wind comfort contour Figures 3A/4A/5A/6A, wind conditions within the fully-developed future site massing will be suitable for a mix of standing and strolling during the spring season, with pockets of sitting conditions immediately adjacent to most of the buildings. Conditions during the summer season will be suitable for a mix of sitting and standing across the site. Wind conditions during the autumn season will be similar to those predicted for the spring season but with more areas suitable for sitting and standing. Conversely, wind conditions during the winter season will be similar to those predicted for the spring season but with more areas suitable for strolling. Additionally, conditions suitable for walking are predicted to impact the area between Buildings 1 and 14 within the north end of the site during the winter season.

3) Regarding the various rooftop areas serving the fully-developed future site massing, mitigation measures will be required to provide sitting conditions during the typical use period of late spring to early autumn. Mitigation strategies will be explored and confirmed for the Site Plan Control (SPA) application.

4) Further to item (3), the unmitigated wind comfort contours are illustrated in Figures 3B/4B/5B/6B. For the 3rd and 6th floor terraces serving Building 1, the 3rd floor terrace serving Building 2, and the 3rd floor terraces serving Buildings 5 and 12, we recommend that 1.6 m tall high-solidity wind barriers be installed along the full perimeter of each terrace to protect the areas from prominent southwesterly winds. For the 6th floor rooftop terrace serving Building 2, and the 7th floor rooftop terrace serving Building 12, similar barriers are also recommended but at a height of 1.8 m above the walking surface combined with 1.6 m tall high-solidity wind barriers inboard of the perimeter to protect designated seating areas from multiple prominent wind directions. Additionally, for the rooftop terraces situated within the west corner of Buildings 8 and 9, we recommend that 1.6 m tall high-solidity wind barriers also be installed along the perimeters.

5) Grade-level wind conditions for the existing site massing were also quantified and were determined to be suitable for a mix of sitting and standing during the spring season, with pockets of strolling conditions along Rochester Street and Booth Street. Conditions during the summer season will be mostly suitable for sitting, with some smaller areas suitable for standing. Wind conditions during the autumn season will be similar to those predicted for the spring season but with more areas suitable for sitting. Conversely, wind conditions during the winter season will be similar to those predicted for the spring season but with more areas suitable for standing. Additionally, conditions during the winter season along Rochester Street and Booth Street will be suitable for a mix of standing and strolling. The corresponding wind comfort contours are illustrated in Figures 7-10 (following the main text).

6) Wind conditions over surrounding sidewalks beyond the development site, as well as at nearby building entrances, will be comfortable for their intended pedestrian uses during each seasonal period upon the introduction of the planned development. Of particular importance, excluding anomalous localized storm events such as tornadoes and downbursts, no areas over the study site are considered uncomfortable or unsafe.

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1. INTRODUCTION

Gradient Wind Engineering Inc. (GWE) was retained by Canada Lands Company to undertake a pedestrian level wind (PLW) study in support of a joint Official Plan Amendment (OPA) and Zoning By-law Amendment (ZBA) application for the planned mixed-use residential, retail, and office development located at 550-568 Booth Street in Ottawa, Ontario. Our mandate within this study is to investigate pedestrian wind comfort and safety within and surrounding the development site, and to identify any areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, where necessary. Our work is based on industry standard computational fluid dynamic (CFD) simulations and data analysis procedures, City of Ottawa wind criteria, architectural drawings prepared by Stantec and provided by Canada Lands Company in October 2018, as well as surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa.

2. TERMS OF REFERENCE

The proposed development is located at 550-568 Booth Street in Ottawa. The development is situated on a parcel of land bounded by Orangeville Street to the north, Booth Street to the east, Norman Street to the south, and Rochester Street to the west. The development is situated on uneven topography that gently slopes downward to the south.

The development comprises a total of fourteen (14) buildings, identified as Buildings ‘1’ through ‘14’ and are located clockwise beginning at the northeast corner of the site. Buildings 1, 2, 5, 8, 9, 12, and 13 are proposed buildings that are amid low-rise existing buildings with expected green roof additions. Buildings 1 and 2 are connected by a two-storey link on the fourth-floor creating a pedestrian throughway below, while Building 8, 12, and 13 are fully connected at grade to existing buildings. All remaining buildings are stand-alone structures. A grade-level park is located at the southwest corner of the site. Building 1 (20 storeys) and Building 2 (6 storeys) are of rectangular planform with the long axis parallel to Orangeville Street. The floorplan for both building’s steps back at the third floor, which is consistent on all sides except for where the buildings are connected creating rooftop terraces. The floor plan for Building 1 steps back again, in all directions at the sixth floor and continues upward. Building 5 (18 storeys) is of rectangular planform with the short axis parallel to Booth Street. The floor plan sets back at the third floor on all elevations creating a rooftop terrace and a green roof area. Building 8 (10 storeys) is of rectangular planform with the long axis parallel to Booth Street and incorporates a portion of the existing site massing within the two-storey podium. A green roof is inset on the south side of the building within the two-storey podium. The floor plan sets back at the third floor on the northwest corner creating a rooftop terrace. Building 9 (17 storeys) is of rectangular planform with the long axis parallel to Norman Street. The floor plan sets back at the third floor on the northwest corner and the east elevation of the building creating rooftop terraces. Building 12 (24 storeys) is of rectangular planform with the long axis parallel to Rochester Street and includes a covered pedestrian throughway from east to west in the centre. The building is also connected to an existing building to the south. The floorplan steps back at the third floor on the north, south and west sides. The step back creates rooftop terraces on the north and south elevations of the building. The floor plan steps back again at the seventh floor on the south side creating a rooftop terrace. Building 13 (4 storeys) is of square planform facing Rochester Street. The building is connected to an existing building to the east.

The immediate surroundings of the development site comprise of a mix of suburban and industrial low-rise developments in all directions, with an open undeveloped area west of the site. Two high-rise buildings, Preston Square and Natural Resources Canada are located just west and south of the development, respectively. The Queensway intersects the area immediately north of the development site and runs east to west. At greater distances from the study site, the surroundings comprise primarily low-rise suburban developments, with the Ottawa River beginning approximately 1.5 kilometres (km) to the north, and Dow's Lake and the Central Experimental Farm beginning approximately 500 metres (m) to the south and 1 km to the southwest, respectively.

Key areas under consideration for pedestrian wind comfort include; surrounding sidewalks, laneways, parking areas, outdoor amenity areas, building access points, bus stops, and grade-level parks. Figures 1A and 1B illustrate the future site plan and existing site plan, respectively, while Figures 2A and 2B illustrate the computational model used to conduct the study.

3. OBJECTIVES

The principal objectives of this study are to: (i) determine pedestrian level comfort and safety conditions at key outdoor areas; (ii) identify areas where future wind conditions may interfere with the intended uses of outdoor spaces; and (iii) recommend suitable mitigation measures, where required.

4. METHODOLOGY

The approach followed to quantify pedestrian wind conditions over the site is based on Computational Fluid Dynamics (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 criteria[1]. The following sections describe the analysis procedures, including a discussion of the pedestrian comfort guidelines.

4.1 Computer-Based Context Modelling

A computer-based PLW study is 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, are determined by combining measured wind speed data from CFD simulations with statistical weather data obtained from 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 computational model due to the difficulty of providing accurate seasonal representation of vegetation. The omission of trees and other landscaping elements produces slightly more conservative wind speed values.

4.2 Wind Speed Measurements

The PLW analysis was performed by simulating wind flows and gathering velocity data over a CFD model of the site for 12 wind directions. The CFD simulation model was centered on the study building, complete with surrounding massing within a diameter of approximately 840 meters (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 select elevated surfaces were referenced to the wind speed at gradient height to generate mean and peak velocity ratios, which were used to calculate full-scale values. The gradient height represents the theoretical depth of the boundary layer of the Earth's atmosphere, above which the mean wind speed remains constant. Appendices A and B provide greater detail of the theory behind wind speed measurements.

[1] City of Ottawa Terms of Reference – Wind Analysis (Undated)

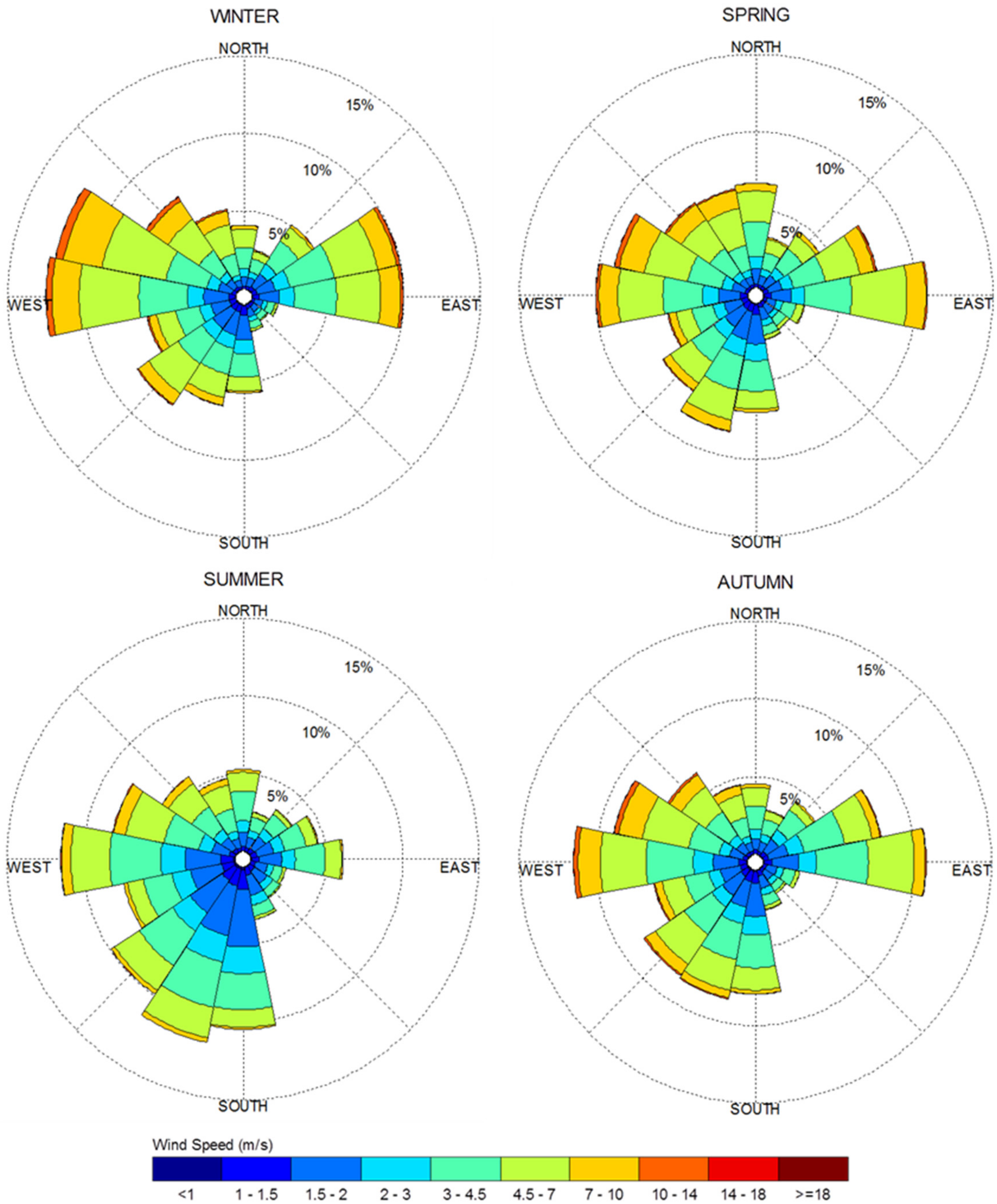
4.3 Meteorological Data Analysis

A statistical model for winds in Ottawa was developed from approximately forty (40) years of hourly meteorological wind data recorded at Macdonald-Cartier International Airport and obtained from the local branch of Atmospheric Environment Services of Environment 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 the 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 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 metres per second (m/s). 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 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 10 m/s [36 kilometers per hour].

The directional preference and relative magnitude of wind speed changes somewhat from season to season. By convention in microclimate studies, wind direction refers to the wind origin (e.g., a north wind blows from north to south).

SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES MACDONALD-CARTIER INTERNATIONAL AIRPORT, OTTAWA, ONTARIO



Notes:

1. Radial distances indicate percentage of time of wind events.
2. Mean hourly wind speeds in m/s measured at 10 m above the ground.
3. Apply a factor of 3.6 to convert m/s to km/h (e.g., 10 m/s is equivalent to 36 km/h).

4.4 Pedestrian Comfort Criteria – City of Ottawa

Pedestrian comfort criteria are based on mechanical wind effects without consideration of other meteorological conditions (i.e., temperature, relative humidity). The City of Ottawa criteria provide an assessment of comfort, assuming pedestrians are appropriately dressed for a specified outdoor activity during any given season. Five pedestrian comfort classes and corresponding gust wind speed ranges are used to assess pedestrian comfort, which include: (i) Sitting; (ii) Standing; (iii) Strolling; (iv) Walking; and (v) Uncomfortable. Specifically, the comfort classes, associated wind speed ranges, and limiting criteria are summarized as follows:

(i) **Sitting:** Mean wind speeds less than or equal to 10 km/h, occurring at least 80% of the time. The gust equivalent mean wind speed is approximately 14 km/h.

(ii) **Standing:** Mean wind speeds less than or equal to 14 km/h, occurring at least 80% of the time. The gust equivalent mean wind speed is approximately 20 km/h.

(iii) **Strolling:** Mean wind speeds less than or equal to 17 km/h, occurring at least 80% of the time. The gust equivalent mean wind speed is approximately 25 km/h.

(iv) **Walking:** Mean wind speeds less than or equal to 20 km/h, occurring at least 80% of the time. The gust equivalent mean wind speed is approximately 30 km/h.

(v) **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.

** **Dangerous:** Gust equivalent mean wind speeds greater than or equal to 90 km/h, occurring more often than 0.1% of the time, are classified as dangerous. From calculations of stability, it can be shown that gust wind speeds of 90 km/h would be the approximate threshold wind speed that would cause an average elderly person in good health to fall.

Gust speeds are used in the criteria because people tend to be more sensitive to wind gusts than to steady winds for lower wind speed ranges. For strong winds approaching dangerous levels, this effect is less important because the mean wind can also cause problems for pedestrians. The 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	4-8	Wind felt on faces.
3	Gentle Breeze	8-15	Leaves and small twigs in constant motion; Wind extends light flags.
4	Moderate Breeze	15-22	Wind raises dust and loose paper; Small branches are moved.
5	Fresh Breeze	22-30	Small trees in leaf begin to sway.
6	Strong Breeze	30-40	Large branches in motion; Whistling heard in electrical wires; Umbrellas used with difficulty.
7	Moderate Gale	40-50	Whole trees in motion; Inconvenient walking against wind.
8	Gale	50-60	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 gust wind speeds of 14 km/h were exceeded for more than 20% of the time, most pedestrians would judge that location to be too windy for sitting or more sedentary activities. Similarly, if 30 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 across the study site, 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. 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
Building Entrances	Standing
Public Sidewalks, Bicycle Paths	Strolling / Walking
Outdoor Amenity Spaces	Sitting
Cafés / Patios / Benches / Gardens	Sitting
Transit Shelters	Standing
Public Parks / Plazas	Sitting / Standing / Strolling
Garage / Service Entrances / Parking Lots	Strolling / Walking
Vehicular Drop-Off Zones	Walking

5. RESULTS AND DISCUSSION

The foregoing discussion of the predicted pedestrian wind conditions for the study site is accompanied by Figures 3A through 6B (following the main text), which illustrate seasonal wind conditions at grade level and on select elevated surfaces. The colour contours indicate predicted regions of the various comfort classes, as dictated by City of Ottawa criteria. Wind conditions suitable for sitting are represented by the colour green, standing by yellow, strolling by orange, and walking by blue.

5.1 Future Wind Conditions

Orangeville Street, **Building Entrances, and Pedestrian Throughway (Tags A-D, Figures 3A/4A/5A/6A):** The sidewalk along Orangeville Street (Tag A) will be comfortable for sitting during the summer season, becoming suitable for standing, or better, during the remaining colder seasons. Wind conditions near the north corner of Building 2 (Tag B) will be somewhat windier, and comfortable for standing during the summer, becoming suitable for strolling, or better, during the three colder seasons. Wind conditions at the entrances along the north elevation (Tag C) will be comfortable for sitting during the summer season, becoming suitable for standing during the remaining colder seasons. The pedestrian throughway (Tag D) will be comfortable for standing during the summer, becoming suitable for walking, or better, during the three colder seasons. The noted conditions are considered acceptable.

Booth Street, **Building Entrances, and Bus Stops (Tags E-I, Figures 3A/4A/5A/6A):** The sidewalk along Booth Street (Tag E) will be comfortable for sitting during the summer season, becoming suitable for standing, or better, during the remaining colder seasons. Wind conditions near the east corner of Building

2 (Tag F) and Building 5 (Tag G) will be somewhat windier, becoming comfortable for standing throughout the year. Wind conditions at the entrances along the east elevations (Tag H) will be comfortable for sitting during the summer season, becoming suitable for standing during the remaining colder seasons. The bus stops along Booth Street (Tag I) will be somewhat windier, becoming comfortable for standing throughout the year. The noted conditions are considered acceptable according to the comfort criteria in Section 4.4.

Norman Street, **Building Entrances, and Park (Tags J-L, Figures 3A/4A/5A/6A):** The sidewalk along Norman Street (Tag J) will be comfortable for standing, or better, during the summer season, becoming suitable for strolling, or better, during the remaining colder seasons. Wind conditions at the entrances along the east elevations (Tag K) will be comfortable for sitting throughout the year. The park (Tag L) will be comfortable for sitting during the summer season, becoming suitable for standing, or better, during the remaining colder seasons. The noted conditions are considered acceptable.

Rochester Street, **Building Entrances, and Pedestrian Throughway (Tags M-L, Figures 3A/4A/5A/6A):** The sidewalk along the north portion of Rochester Street (Tag M) will be comfortable for standing, or better, during the summer season, becoming suitable for strolling, or better, during the remaining colder seasons. The south portion of Rochester Street (Tag N) will be comfortable for sitting during the summer season, becoming suitable for standing, or better, during the remaining colder seasons. Wind conditions adjacent to the entrances along the east elevations (Tag O) will be comfortable for strolling, or better, throughout the year. The noted conditions are considered acceptable. The pedestrian throughway (Tag P) will be somewhat windier, becoming comfortable for standing during the summer season and for a mix of standing, strolling, and walking during the three colder seasons. The noted conditions are considered acceptable.

Internal Courtyards and Pedestrian Walkways (Tags Q-S, Figures 3A/4A/5A/6A): The internal courtyards (Tag Q) will be comfortable for standing, or better, during the summer season, becoming suitable for strolling, or better, during the remaining colder seasons. The pedestrian walkways (Tag R) will be comfortable for standing, or better, during the summer season, becoming suitable for strolling, or better, during the remaining colder seasons. Wind conditions near the north corner of Building 14 (Tag S) will be somewhat windier, becoming comfortable for standing during the summer season and for walking, or better, during the three colder seasons. The noted conditions are considered acceptable.

Building 1 and 2 Rooftop Amenity Terraces (Tags T & U, Figures 3B/4B/5B/6B): To ensure that conditions over the 3rd and 6th floor rooftop terraces of Building 1, and the 3rd floor rooftop terrace of Building 2 (Tag T) are suitable for a mix of sitting and standing during the typical use period of late spring to early autumn, designated seating areas will require mitigation in the form of wind barriers along the perimeter rising 1.6 m above the walking surface to shield the area from prominent winds. A taller barrier extending to 1.8 m above the local walking surface will also be required to protect the 6th floor rooftop terrace serving Building 2 (Tag U), combined with localized 1.6-m tall high-solidity wind barriers immediately upwind of designated seating areas. Wind barriers may take the form of high-solidity architectural wind screens and may be supplemented with dense coniferous plantings.

Building 5 and 12 Rooftop Amenity Terraces (Tags V & W, Figures 3B/4B/5B/6B): To ensure that conditions over the 3th floor rooftop terrace of Building 5 and Building 12 (Tag V) are suitable for a mix of sitting and standing during the typical use period, designated seating areas will require mitigation in the form of wind barrier along the perimeter rising 1.6 m above the walking surface. The 7th floor terrace serving Building 12 will require a taller barrier extending to 1.8 m above the local walking surface with localized 1.6-m tall high-solidity wind barriers immediately upwind of designated seating areas. Wind barriers may take the form of high-solidity architectural wind screens and may be supplemented with dense coniferous plantings.

Building 8 and 9 Rooftop Amenity Terraces (Tag X, Figures 3B/4B/5B/6B): To ensure that conditions over the rooftop terraces located within the west corner of the buildings (Tag X) are suitable for a mix of sitting and standing during the typical use period, it is recommended to install a wind barrier along the perimeter barriers rising 1.6 m above the walking surface to shield the areas from prominent winds.

Influence of the Proposed Development on Existing Wind Conditions near the Study Site: Wind conditions over surrounding sidewalks beyond the development site, as well as at nearby building entrances, will be comfortable for their intended pedestrian uses during each seasonal period upon the introduction of the planned development.

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

5.2 Existing Wind Conditions

Orangeville Street & Building Entrances (Tags A & C, Figures 7-10): The sidewalk along Orangeville Street (Tag A) will be comfortable for sitting during the summer season, becoming suitable for standing, or better, during the remaining colder seasons, which is acceptable. Wind conditions at the entrances along the north elevation (Tag C) will be comfortable for sitting during the summer seasons, becoming suitable for standing during the remaining colder seasons. The noted conditions are considered acceptable.

Booth Street & Building Entrances (Tags E-I, Figures 7-10): The sidewalk along Booth Street (Tag E) will be comfortable for sitting during the summer season, becoming suitable for standing, or better, during the remaining colder seasons. Wind conditions at the entrances along the east elevations (Tag H) will be comfortable for sitting during the summer seasons, becoming suitable for standing during the remaining colder seasons. The bus stops along booth (Tag I) will be somewhat windier, and comfortable for standing throughout the year. The noted conditions are considered acceptable.

Norman Street & Building Entrances (Tags J & K, Figures 7-10): The sidewalk along Norman Street (Tag J) will be comfortable for standing, or better summer season, becoming suitable for strolling, or better, during the remaining colder seasons. Wind conditions at the entrances along the east elevations (Tag K) will be comfortable for sitting throughout the year. The noted conditions are considered acceptable.

Rochester Street, **Building Entrances, and Pedestrian Throughway (Tags M-O, Figures 7-10):** The sidewalk along the north portion of Rochester Street (Tag M) will be comfortable for standing, or better summer season, becoming suitable for strolling, or better, during the remaining colder seasons. The south portion of Rochester Street (Tag N) will be comfortable for sitting during the summer season, becoming suitable for standing, or better, during the remaining colder seasons for the south portion. Wind conditions at the entrances along the east elevations (Tag O) will be comfortable for strolling or better throughout the year. The noted conditions are considered acceptable. The noted conditions are considered acceptable.

Internal Courtyards and Pedestrian Walkways (Tags Q-S, Figures 7-10): The internal courtyards (Tag Q) will be comfortable for standing, or better summer season, becoming suitable for strolling, or better, during the remaining colder seasons. The pedestrian walkways (Tag R) will be comfortable for standing, or better summer season, becoming suitable for standing, or better, during the remaining colder seasons. The noted conditions are considered acceptable.

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

6. SUMMARY AND RECOMMENDATIONS

The results of the PLW study for the subject site located at 550-568 Booth Street in Ottawa are based on CFD test results, interpretation, and experience with similar developments, and summarized as follows:

1) All grade-level areas within and surrounding the fully-developed future site massing will be acceptable for the intended pedestrian uses on a seasonal basis in accordance with City of Ottawa wind criteria. Surrounding sidewalks, bus stops, park space, and building access points will experience acceptable wind conditions throughout the year.

2) Further to item (1), and as illustrated in wind comfort contour Figures 3A/4A/5A/6A, wind conditions within the fully-developed future site massing will be suitable for a mix of standing and strolling during the spring season, with pockets of sitting conditions immediately adjacent to most of the buildings. Conditions during the summer season will be suitable for a mix of sitting and standing across the site. Wind conditions during the autumn season will be similar to those predicted for the spring season but with more areas suitable for sitting and standing. Conversely, wind conditions during the winter season will be similar to those predicted for the spring season but with more areas suitable for strolling. Additionally, conditions suitable for walking are predicted to impact the area between Buildings 1 and 14 within the north end of the site during the winter season.

3) Regarding the various rooftop areas serving the fully-developed future site massing, mitigation measures will be required to provide sitting conditions during the typical use period of late spring to early autumn. Mitigation strategies will be explored and confirmed for the Site Plan Control (SPA) application.

4) Further to item (3), the unmitigated wind comfort contours are illustrated in Figures 3B/4B/5B/6B. For the 3rd and 6th floor terraces serving Building 1, the 3rd floor terrace serving Building 2, and the 3rd floor terraces serving Buildings 5 and 12, we recommend that 1.6 m tall high-solidity wind barriers be installed along the full perimeter of each terrace to protect the areas from prominent southwesterly winds. For the 6th floor rooftop terrace serving Building 2, and the 7th floor rooftop

terrace serving Building 12, similar barriers are also recommended but at a height of 1.8 m above the walking surface combined with 1.6 m tall high-solidity wind barriers inboard of the perimeter to protect designated seating areas from multiple prominent wind directions. Additionally, for the rooftop terraces situated within the west corner of Buildings 8 and 9, we recommend that 1.6 m tall high-solidity wind barriers also be installed along the perimeters.

5) Grade-level wind conditions for the existing site massing were also quantified and were determined to be suitable for a mix of sitting and standing during the spring season, with pockets of strolling conditions along Rochester Street and Booth Street. Conditions during the summer season will be mostly suitable for sitting, with some smaller areas suitable for standing. Wind conditions during the autumn season will be similar to those predicted for the spring season but with more areas suitable for sitting. Conversely, wind conditions during the winter season will be similar to those predicted for the spring season but with more areas suitable for standing. Additionally, conditions during the winter season along Rochester Street and Booth Street will be suitable for a mix of standing and strolling. The corresponding wind comfort contours are illustrated in Figures 7-10 (following the main text).

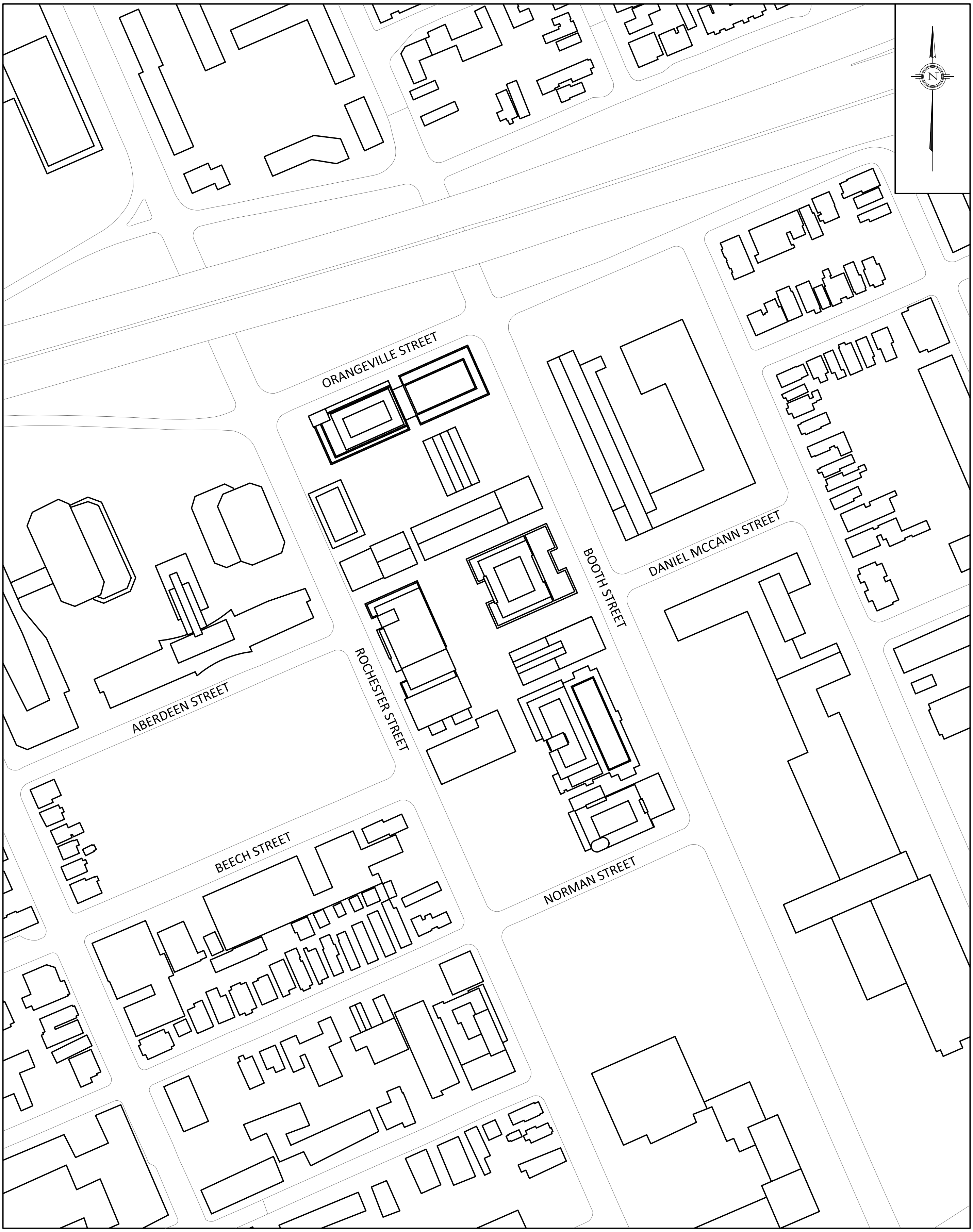
6) Wind conditions over surrounding sidewalks beyond the development site, as well as at nearby building entrances, will be comfortable for their intended pedestrian uses during each seasonal period upon the introduction of the planned development. Of particular importance, excluding anomalous localized storm events such as tornadoes and downbursts, no areas over the study site are considered uncomfortable or unsafe.

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

Sincerely,

Gradient Wind Engineering Inc.

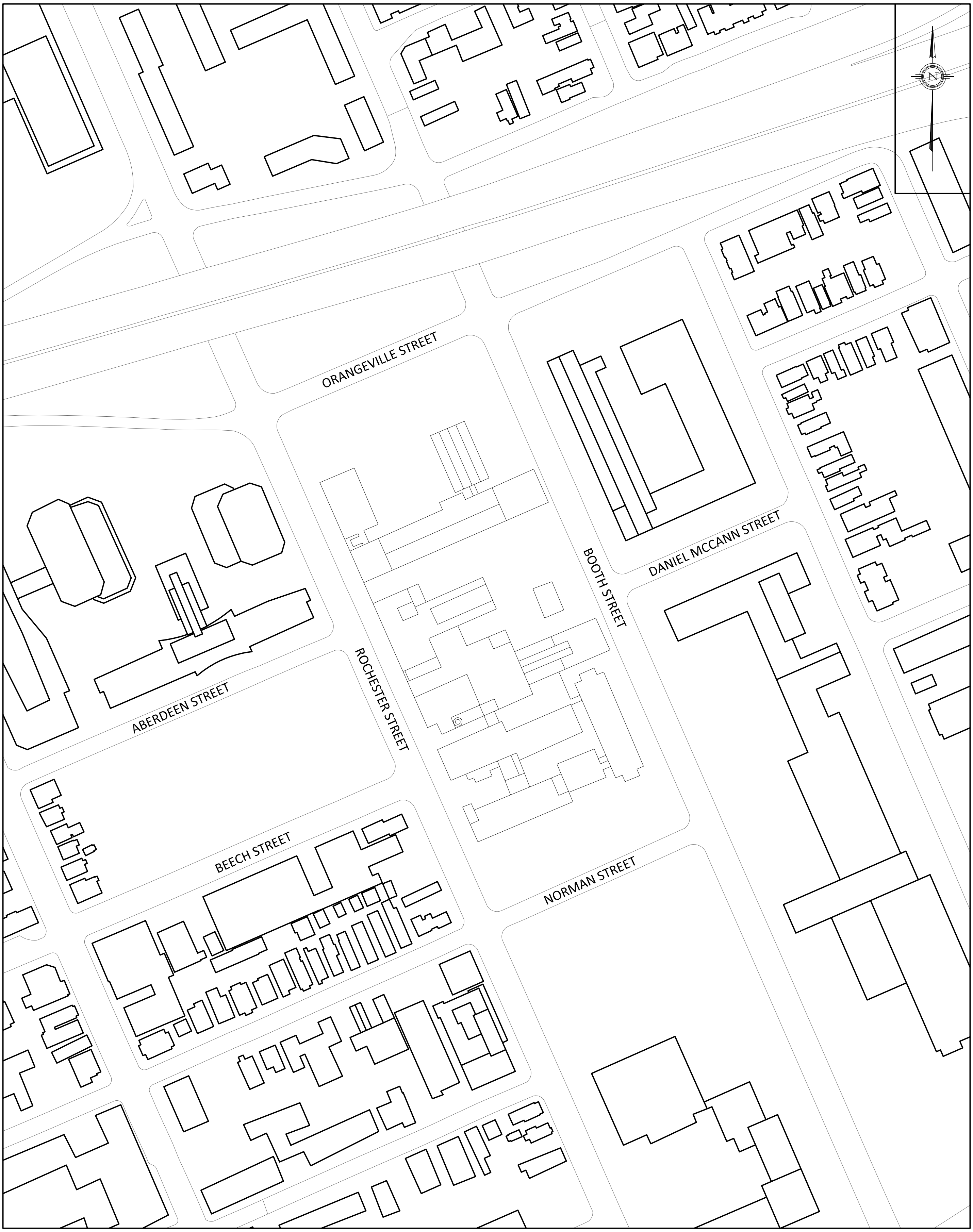
Justin Ferraro	Edward Urbanski, M.Eng.	Vincent Ferraro, M.Eng., P.Eng.
Principal	Junior Wind Scientist	Managing Principal



GRADIENT WIND ENGINEERING INC

127 Walgreen Road
Ottawa, Ontario
(613) 836 0934

PROJECT: 550 BOOTH STREET, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1A: FUTURE SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:2500 (APPROX.)	DRAWING NO.: GWE18-148-CFDPLW-1A	
DATE: OCTOBER 10, 2018	DRAWN BY: B.J.	



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PROJECT	550 BOOTH STREET, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION
SCALE	1:2500 (APPROX.)	DRAWING NO. GWE18-148-CFDPLW-1B	FIGURE 1B: EXISTING SITE PLAN AND SURROUNDING CONTEXT
DATE	OCTOBER 10, 2018	DRAWN BY B.J.	

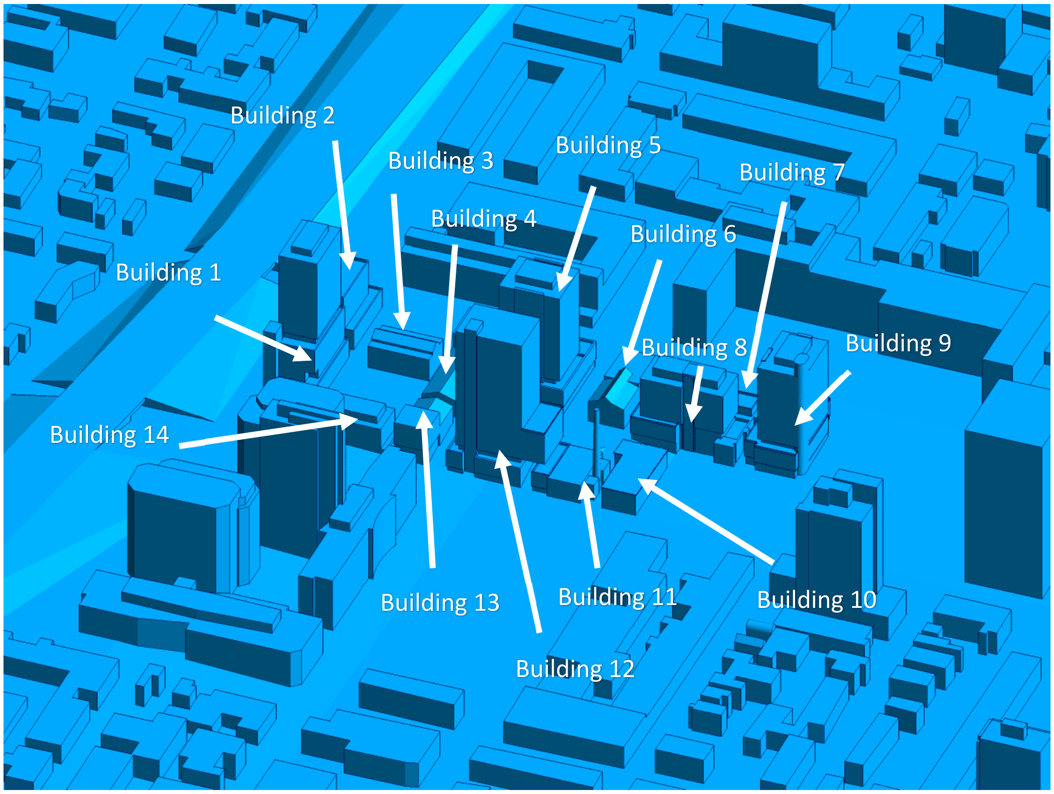


FIGURE 2A: COMPUTATIONAL MODEL – FUTURE CONFIGURATION, SOUTHWEST PERSPECTIVE

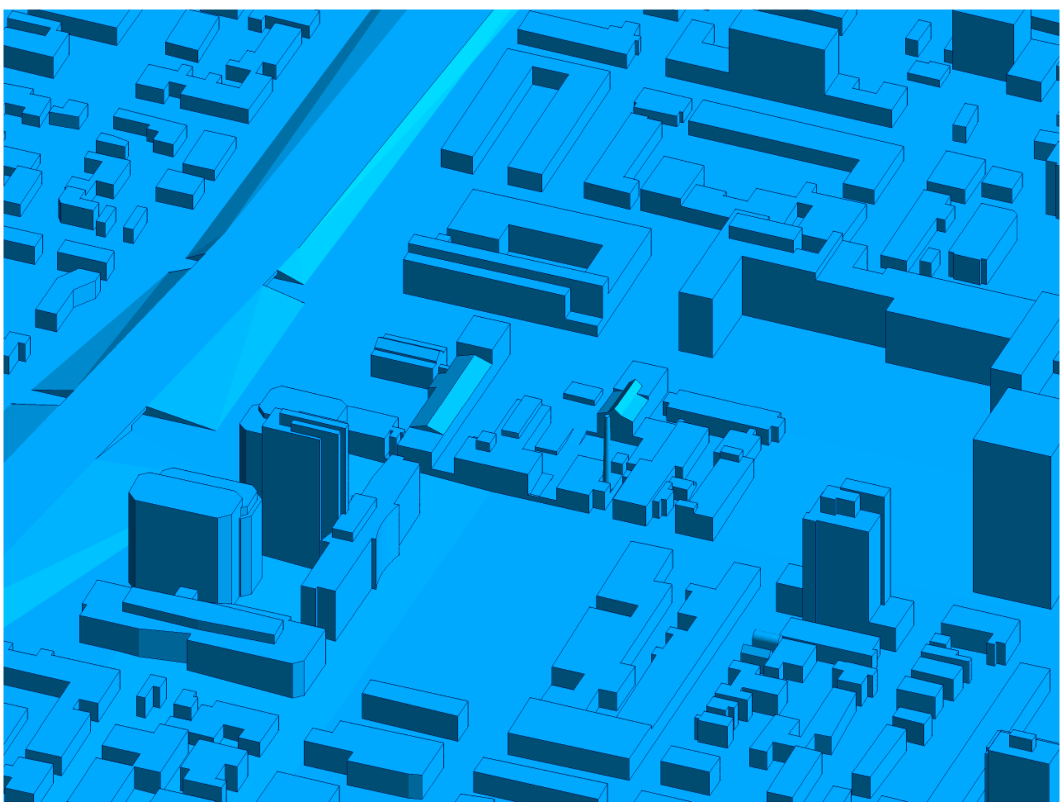


FIGURE 2B: COMPUTATIONAL MODEL – EXISTING CONFIGURATION, SOUTHWEST PERSPECTIVE

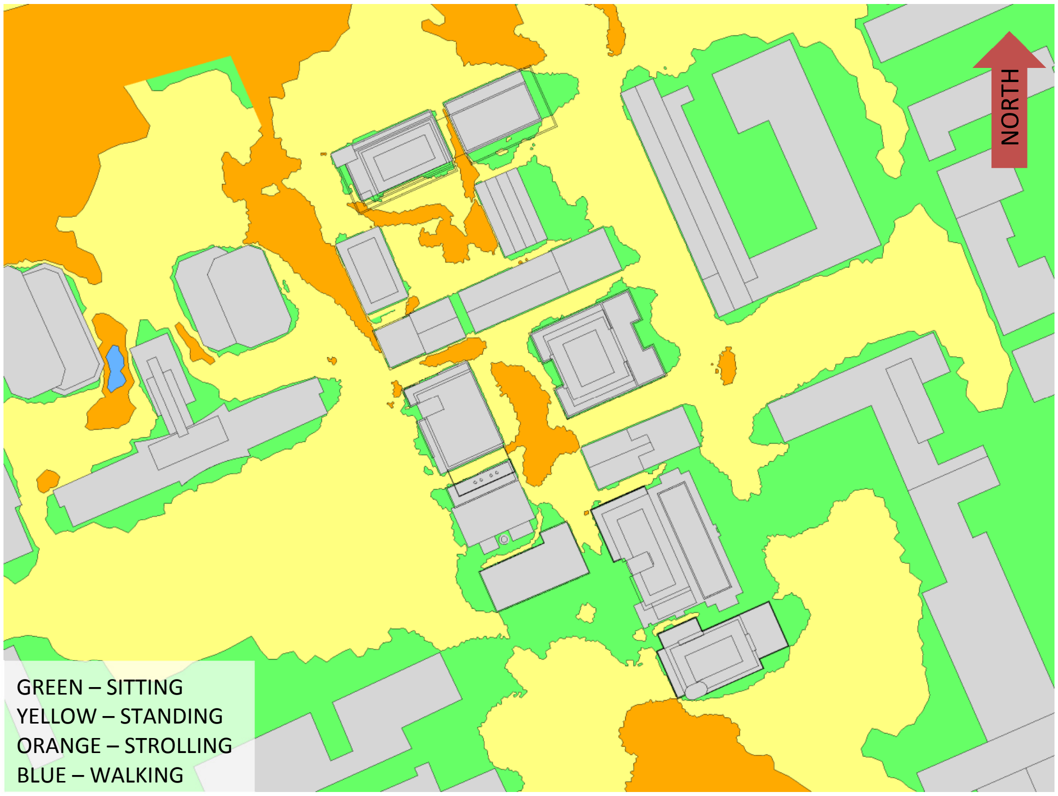
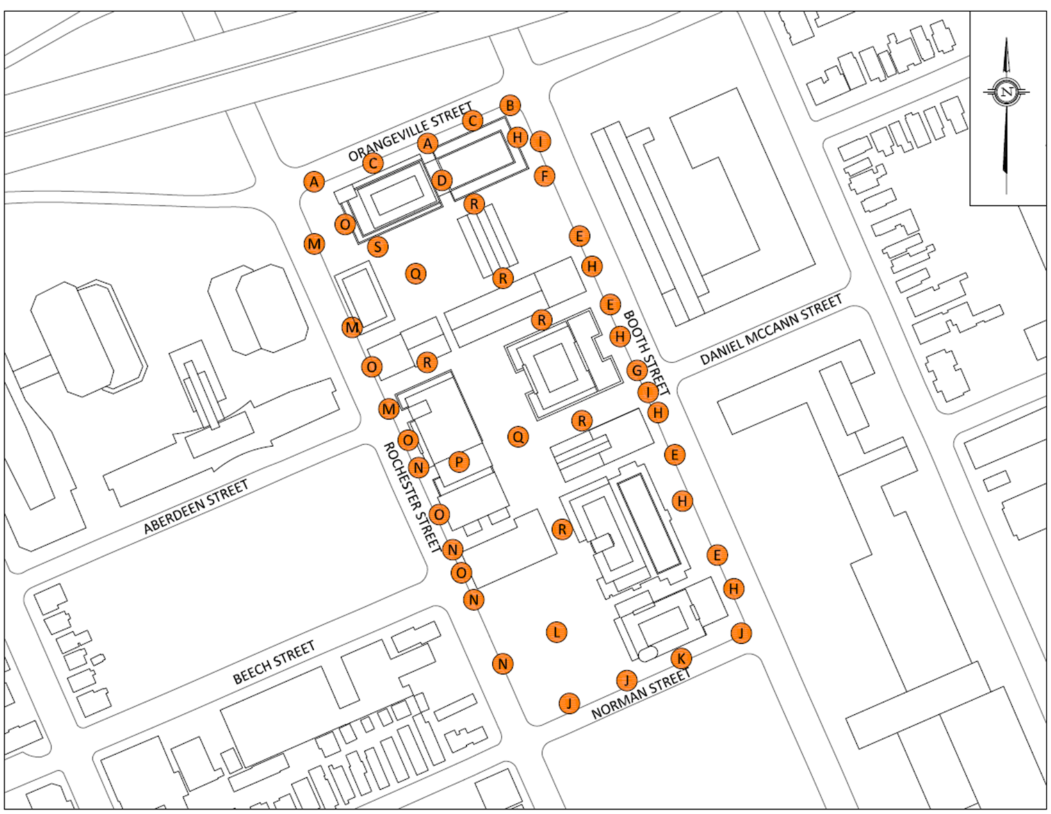


FIGURE 3A: FUTURE CONFIGURATION – SPRING, GRADE-LEVEL PEDESTRIAN WIND CONDITIONS



FUTURE GRADE LEVEL REFERENCE MARKER LOCATIONS

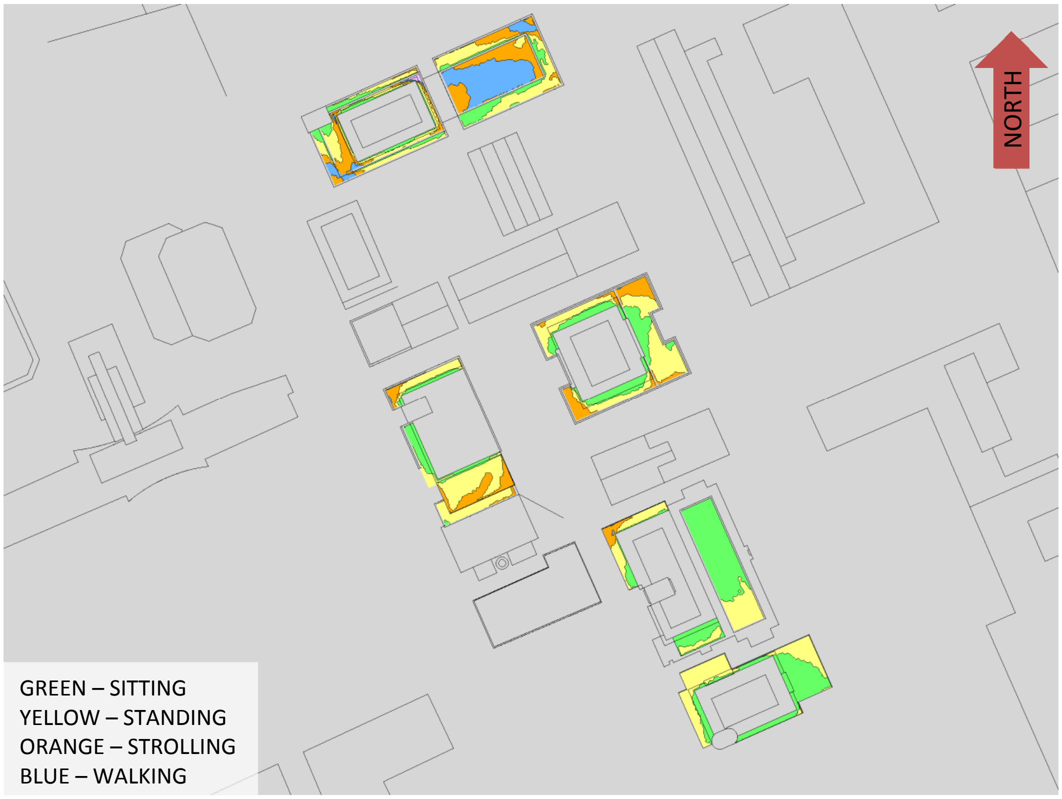
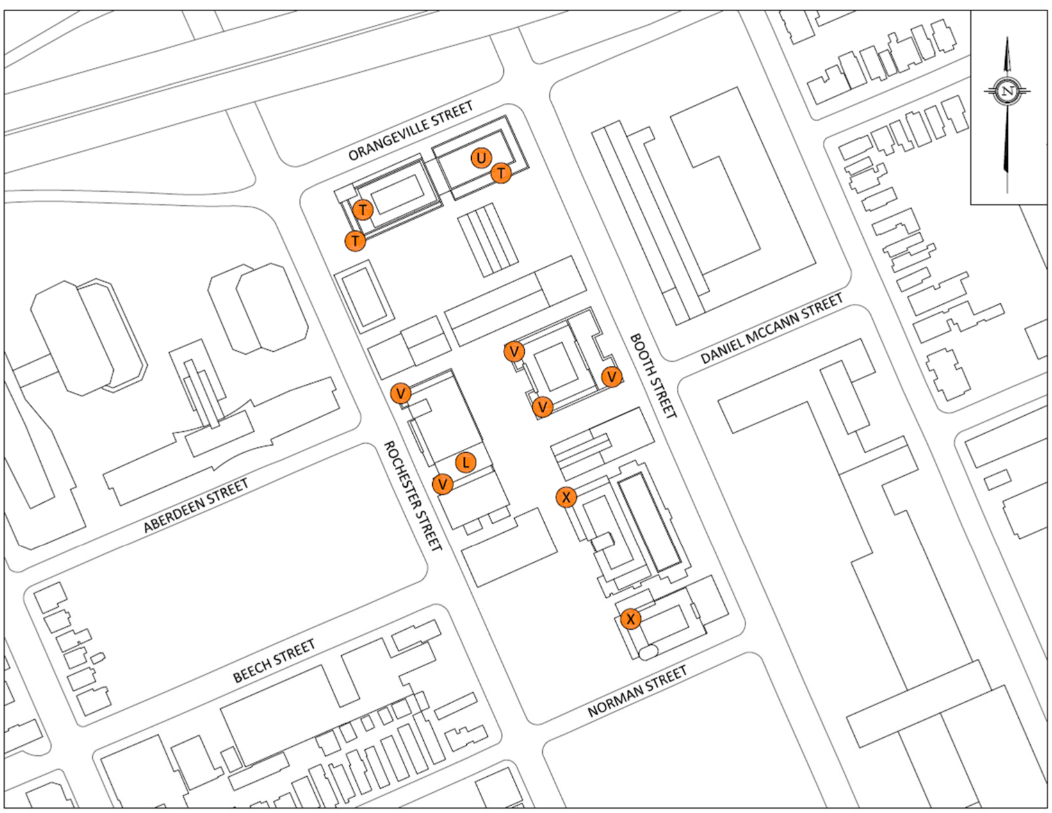


FIGURE 3B: FUTURE CONFIGURATION – SPRING, TERRACE-LEVEL PEDESTRIAN WIND CONDITIONS



FUTURE ELEVATED OUTDOOR AMENITY AREA REFERENCE MARKER LOCATIONS

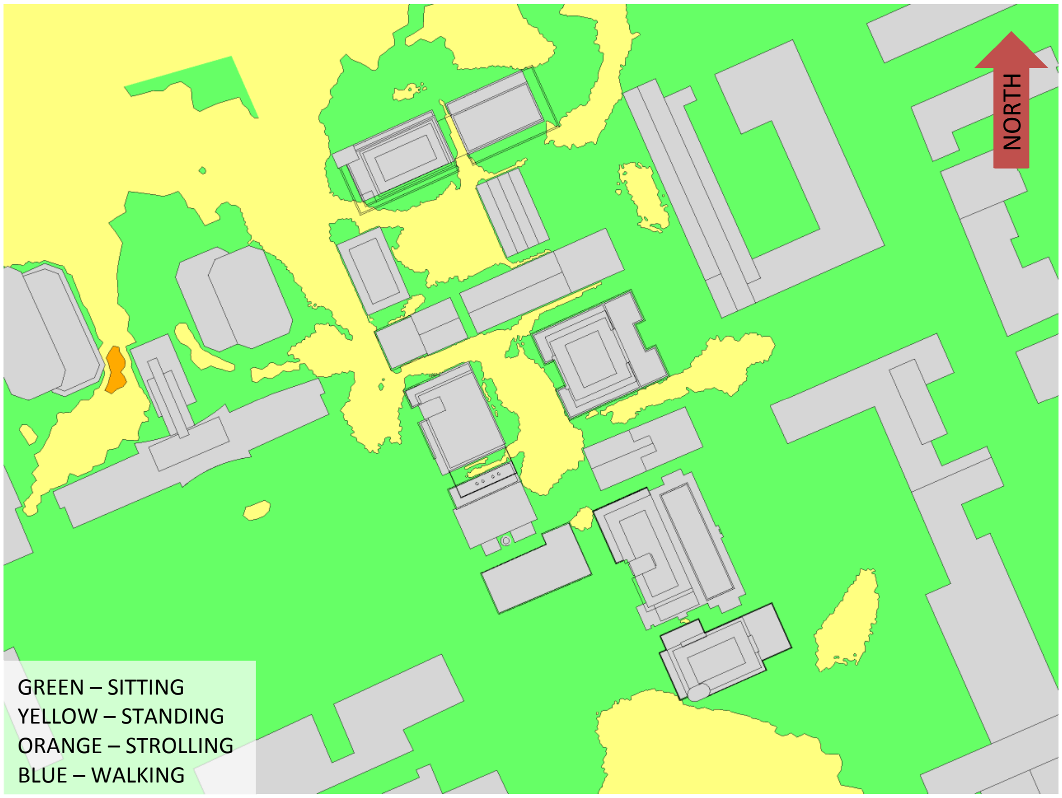
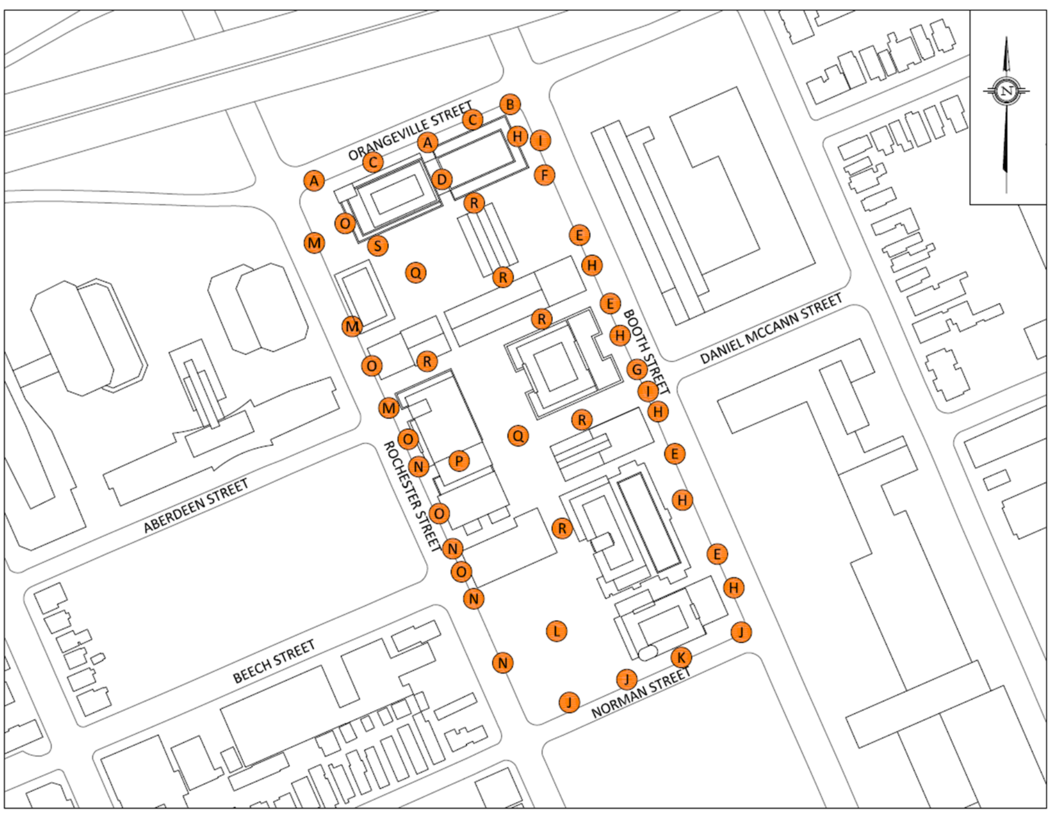


FIGURE 4A: FUTURE CONFIGURATION – SUMMER, GRADE-LEVEL PEDESTRIAN WIND CONDITIONS



FUTURE GRADE LEVEL REFERENCE MARKER LOCATIONS

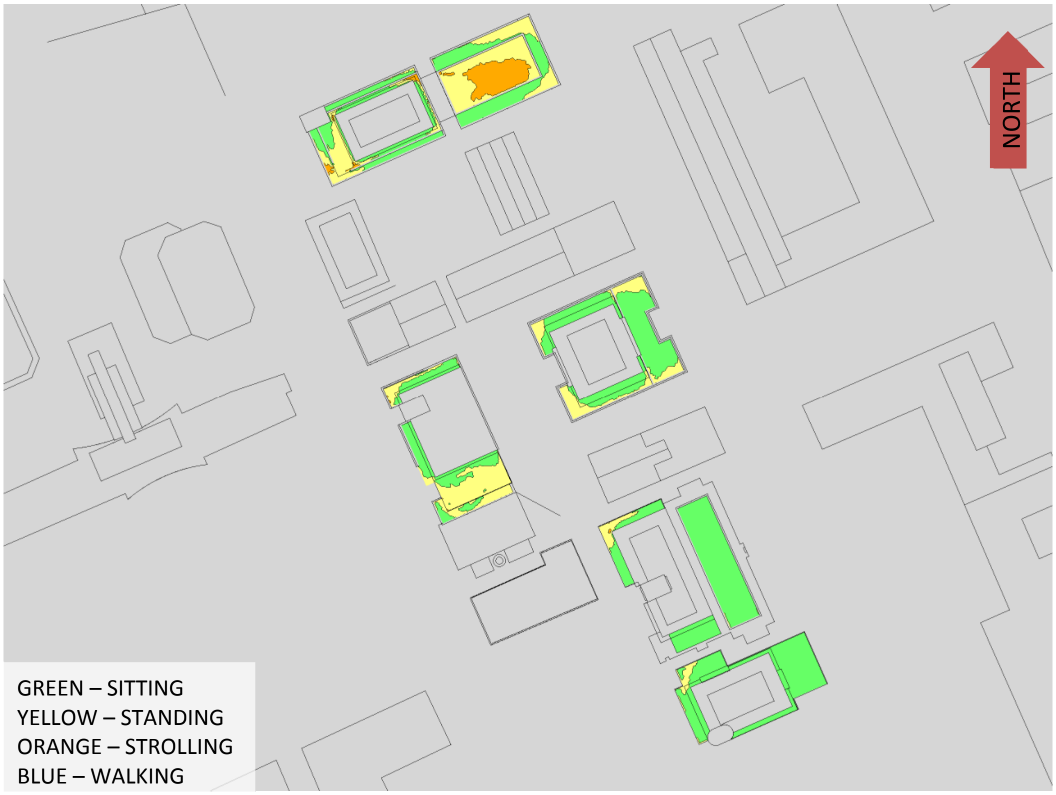
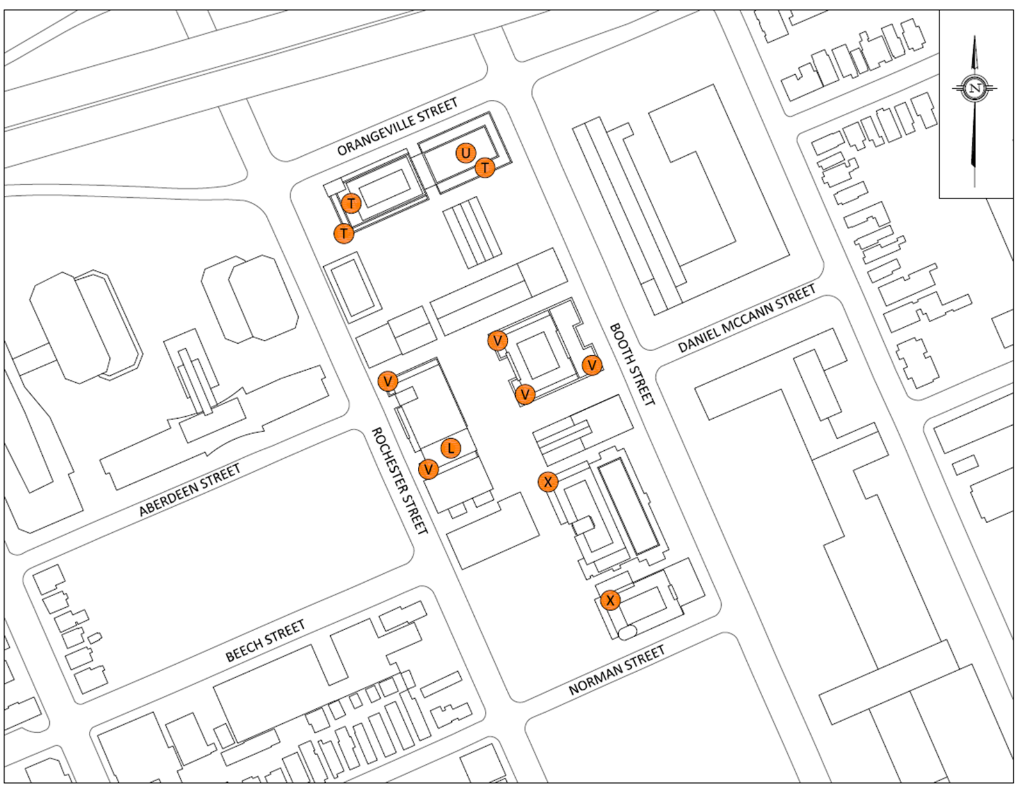


FIGURE 4B: FUTURE CONFIGURATION – SUMMER, TERRACE-LEVEL PEDESTRIAN WIND CONDITIONS



FUTURE ELEVATED OUTDOOR AMENITY AREA REFERENCE MARKER LOCATIONS

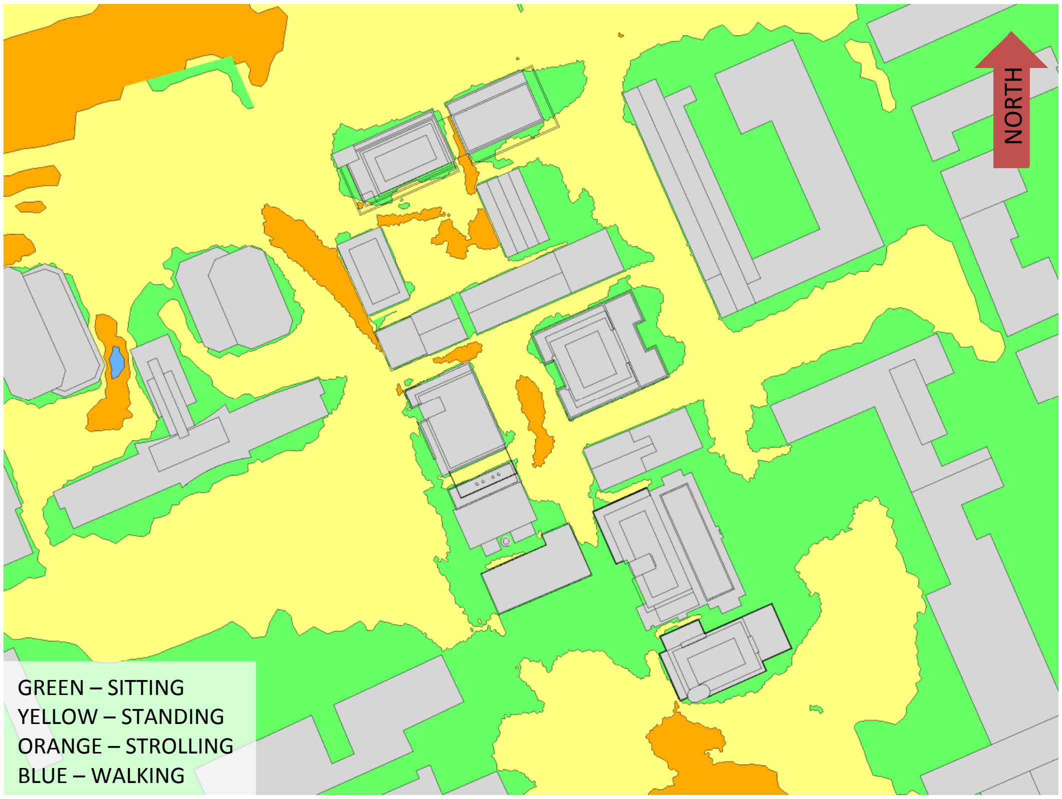
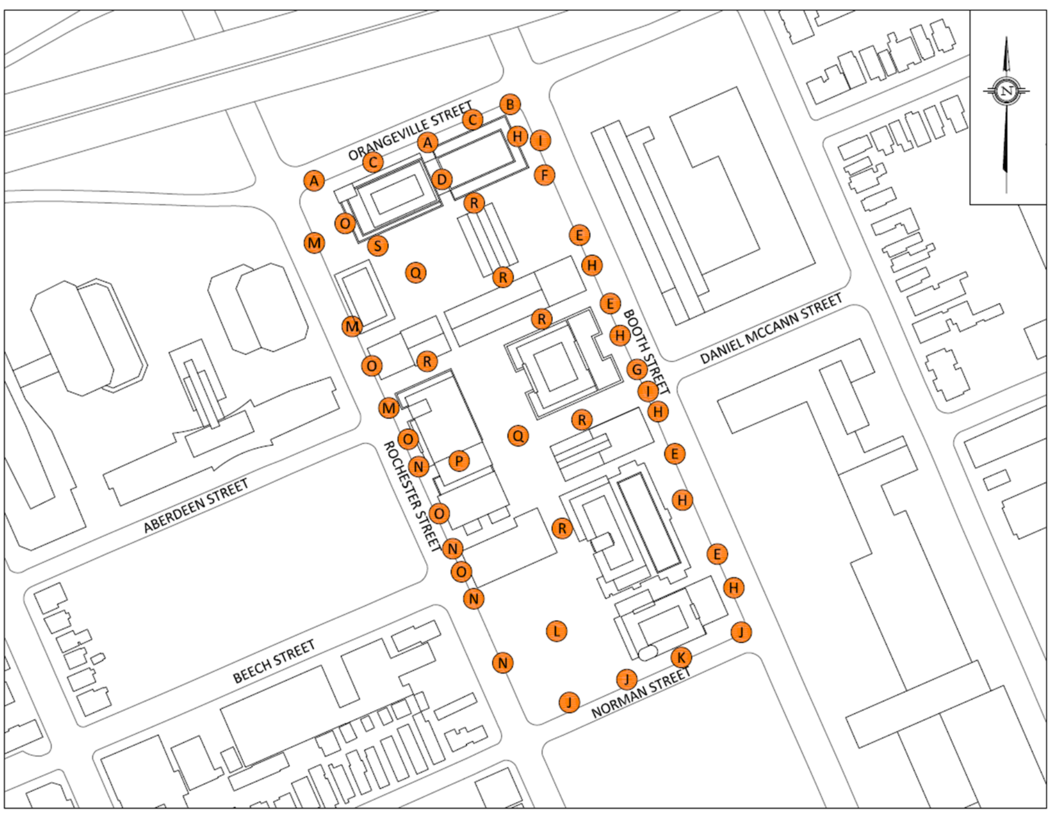


FIGURE 5A: FUTURE CONFIGURATION – AUTUMN, GRADE-LEVEL PEDESTRIAN WIND CONDITIONS



FUTURE GRADE LEVEL REFERENCE MARKER LOCATIONS

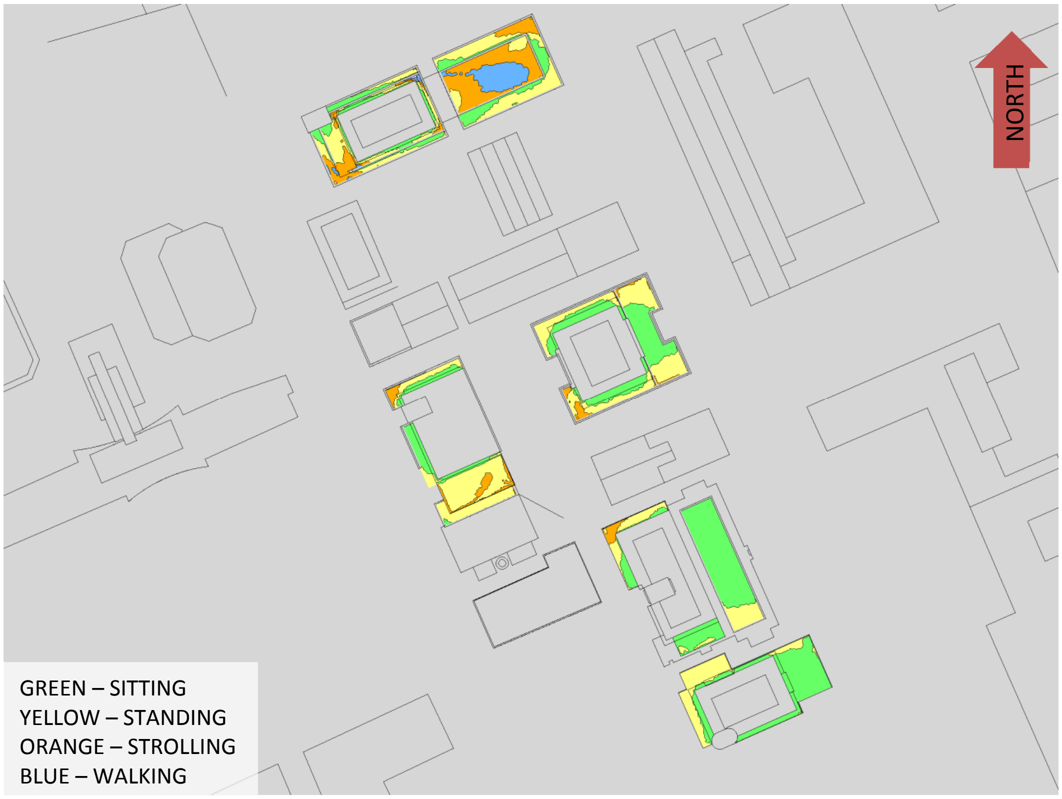
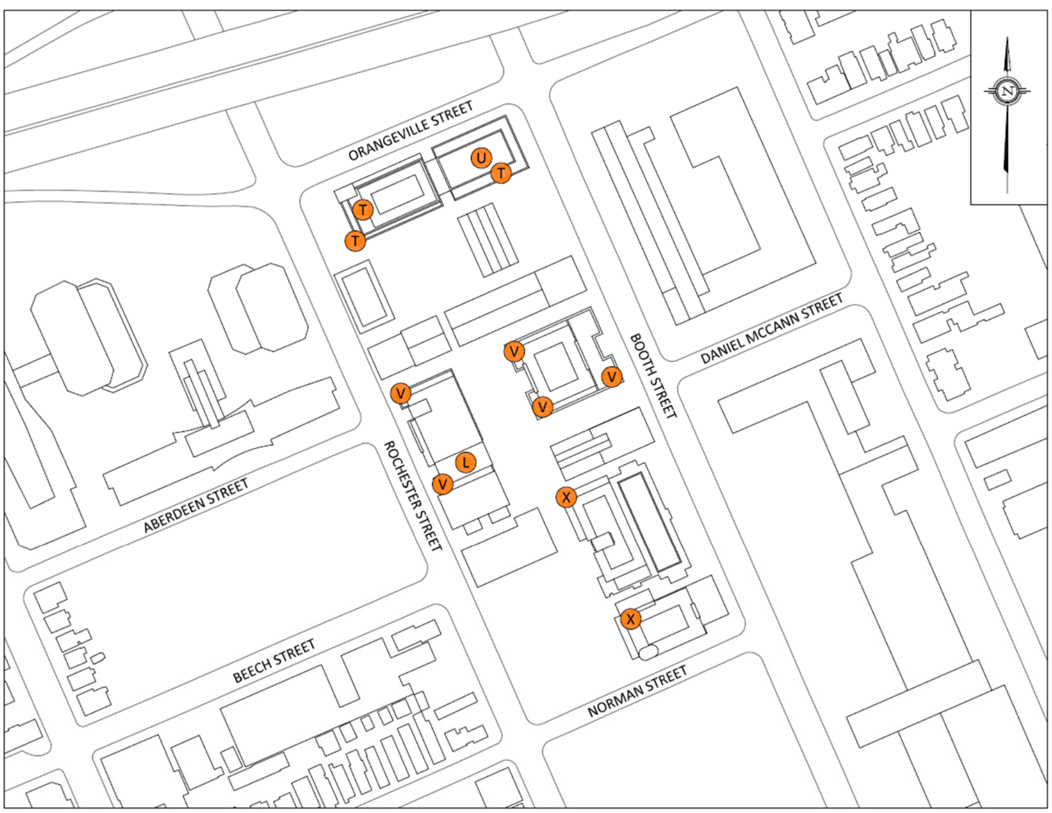


FIGURE 5B: FUTURE CONFIGURATION – AUTUMN, TERRACE-LEVEL PEDESTRIAN WIND CONDITIONS



FUTURE ELEVATED OUTDOOR AMENITY AREA REFERENCE MARKER LOCATIONS

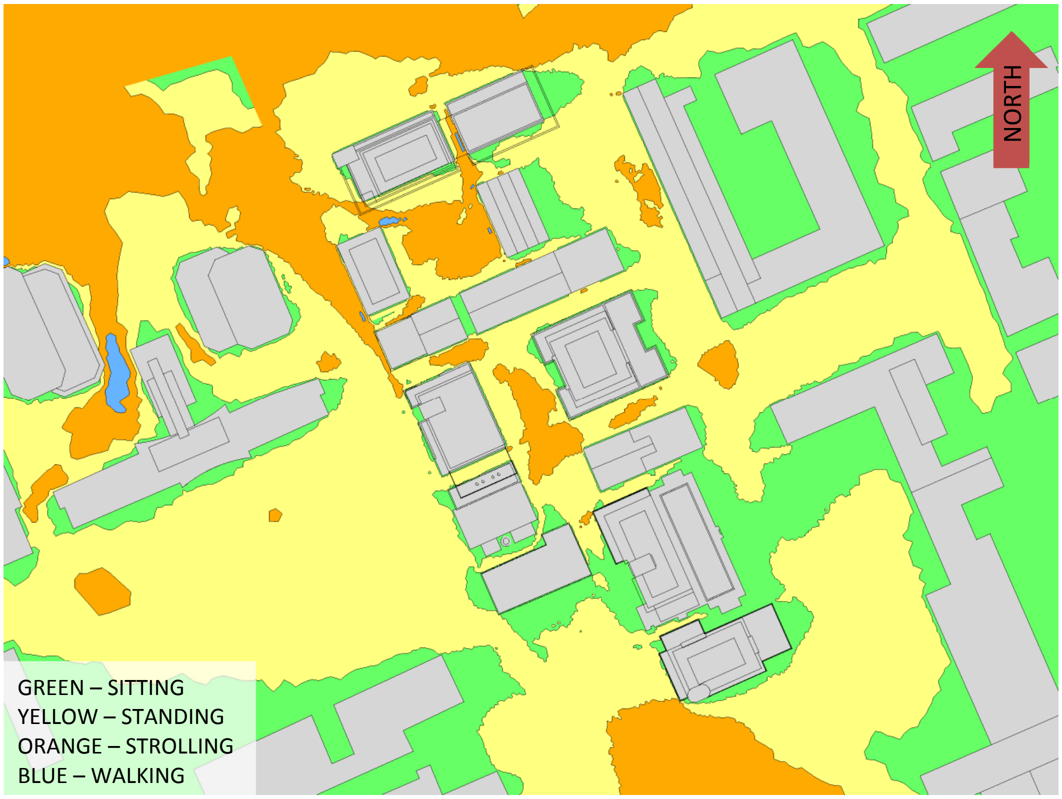
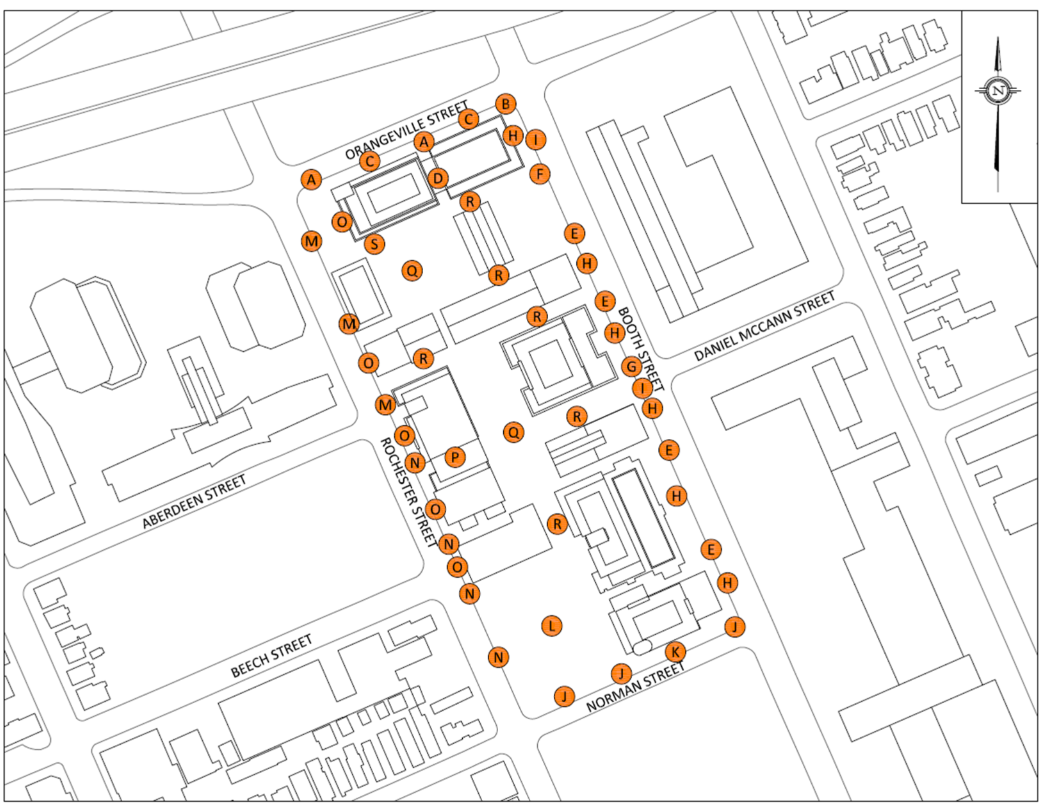


FIGURE 6A: FUTURE CONFIGURATION – WINTER, GRADE-LEVEL PEDESTRIAN WIND CONDITIONS



FUTURE GRADE LEVEL REFERENCE MARKER LOCATIONS

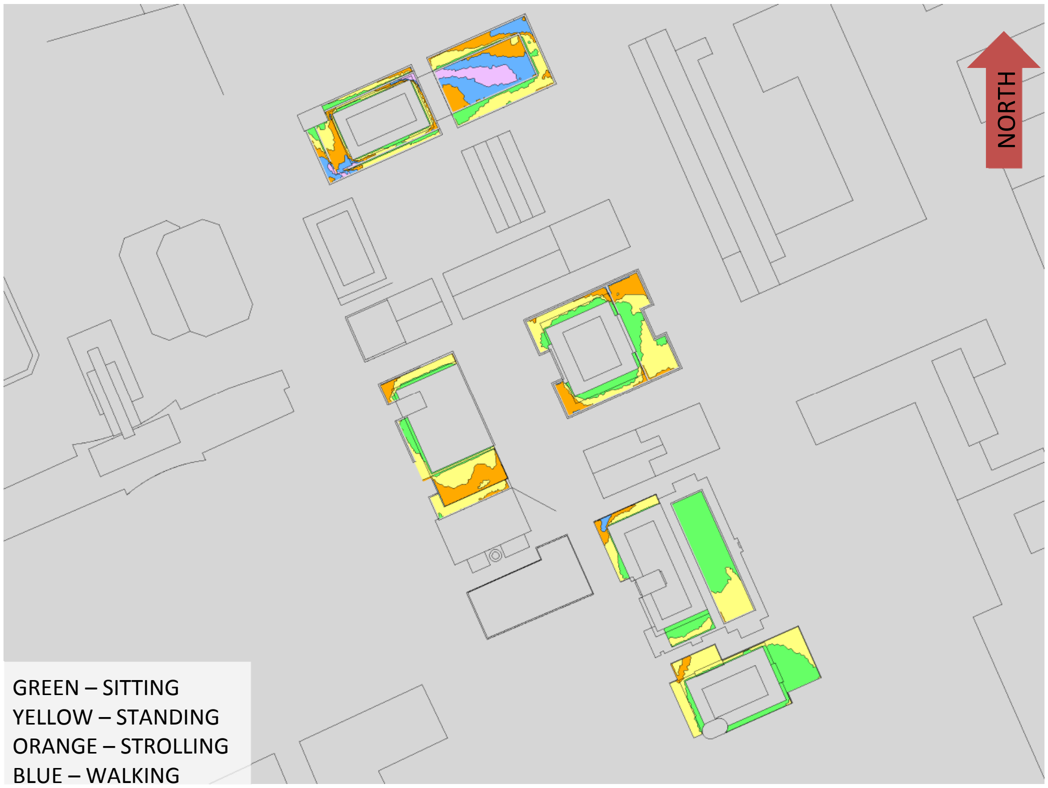
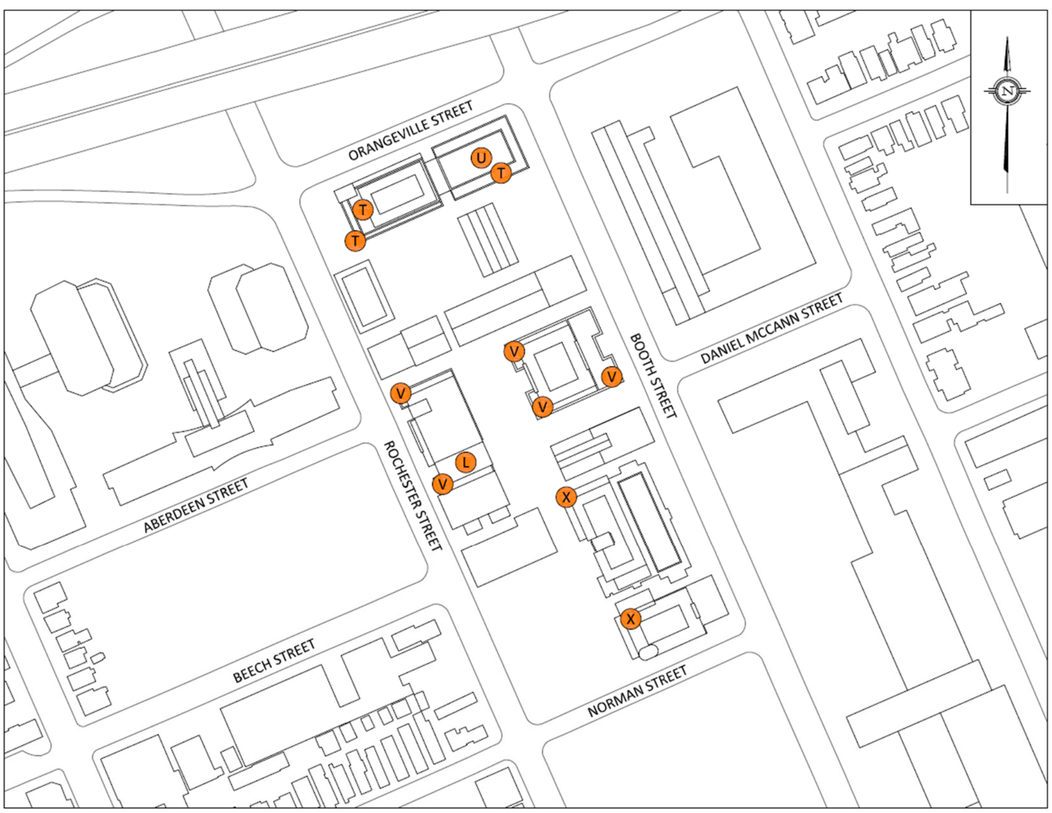
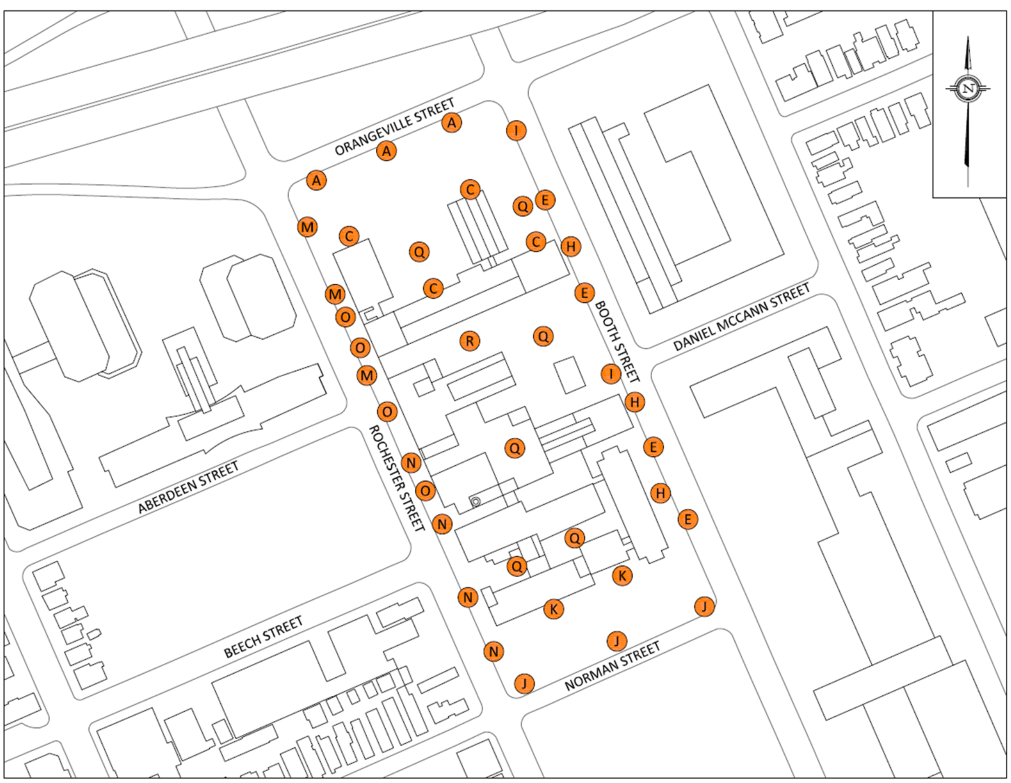


FIGURE 6B: FUTURE CONFIGURATION – WINTER, TERRACE-LEVEL PEDESTRIAN WIND CONDITIONS



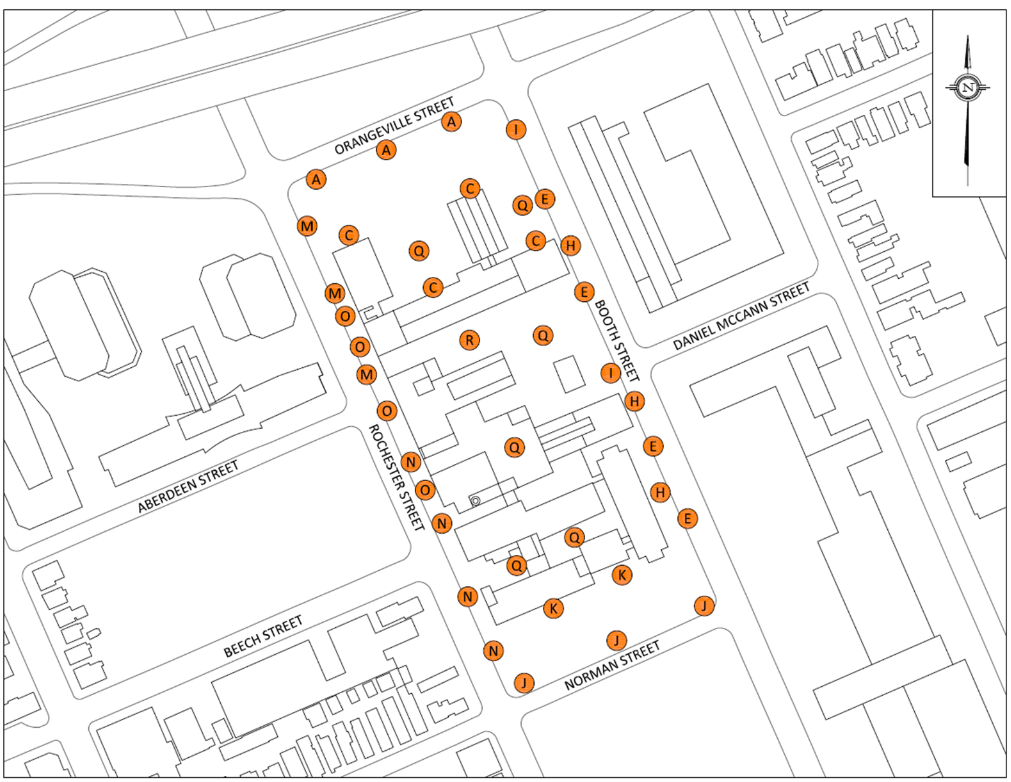
FUTURE ELEVATED OUTDOOR AMENITY AREA REFERENCE MARKER LOCATIONS

FIGURE 7: EXISTING CONFIGURATION – SPRING, GRADE-LEVEL PEDESTRIAN WIND CONDITIONS



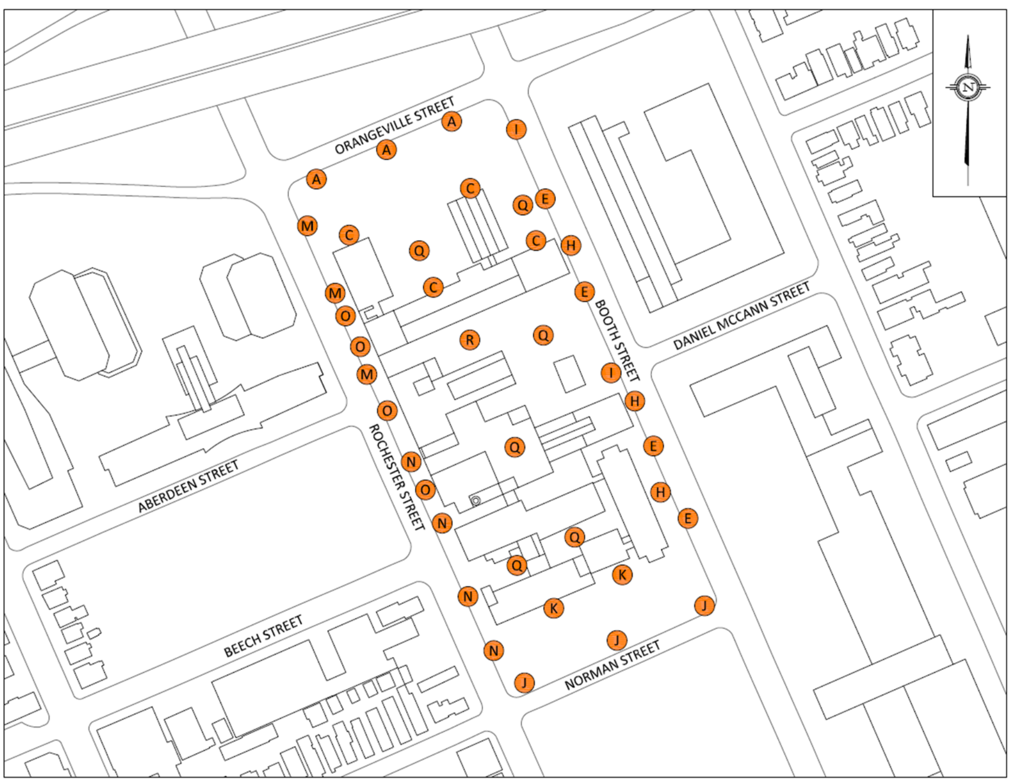
EXISTING GRADE LEVEL REFERENCE MARKER LOCATIONS

FIGURE 8: FUTURE CONFIGURATION – SUMMER, GRADE-LEVEL PEDESTRIAN WIND CONDITIONS



EXISTING GRADE LEVEL REFERENCE MARKER LOCATIONS

FIGURE 9: FUTURE CONFIGURATION – AUTUMN, GRADE-LEVEL PEDESTRIAN WIND CONDITIONS



EXISTING GRADE LEVEL REFERENCE MARKER LOCATIONS

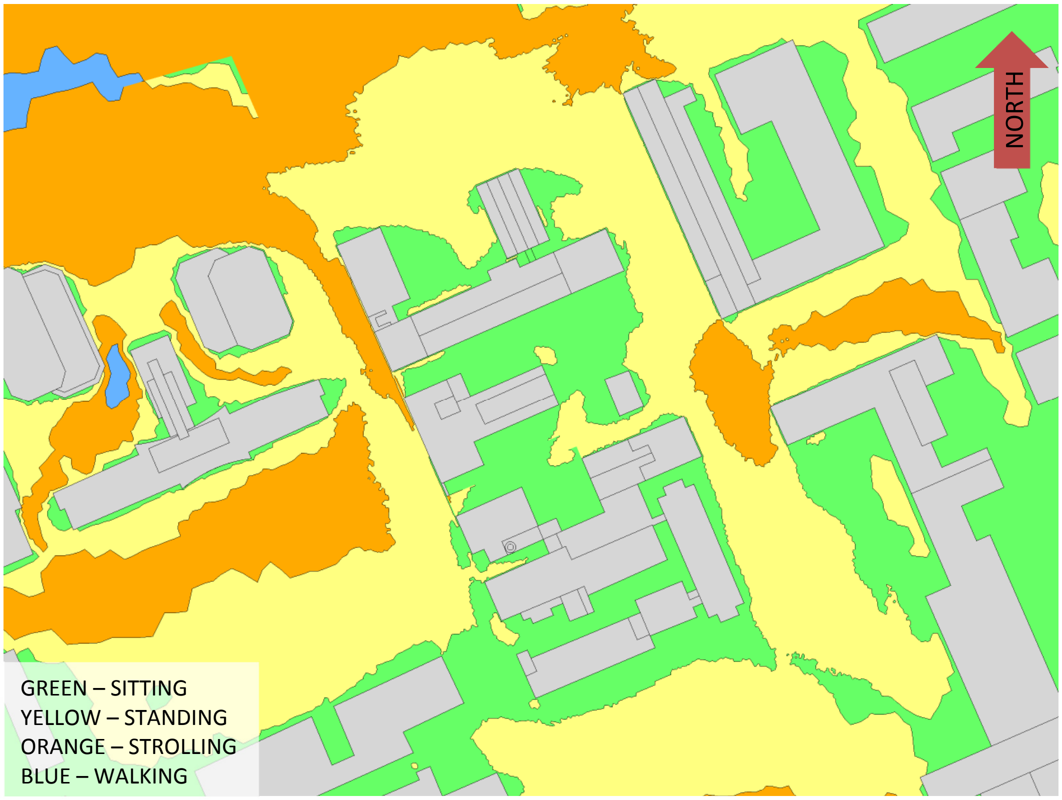
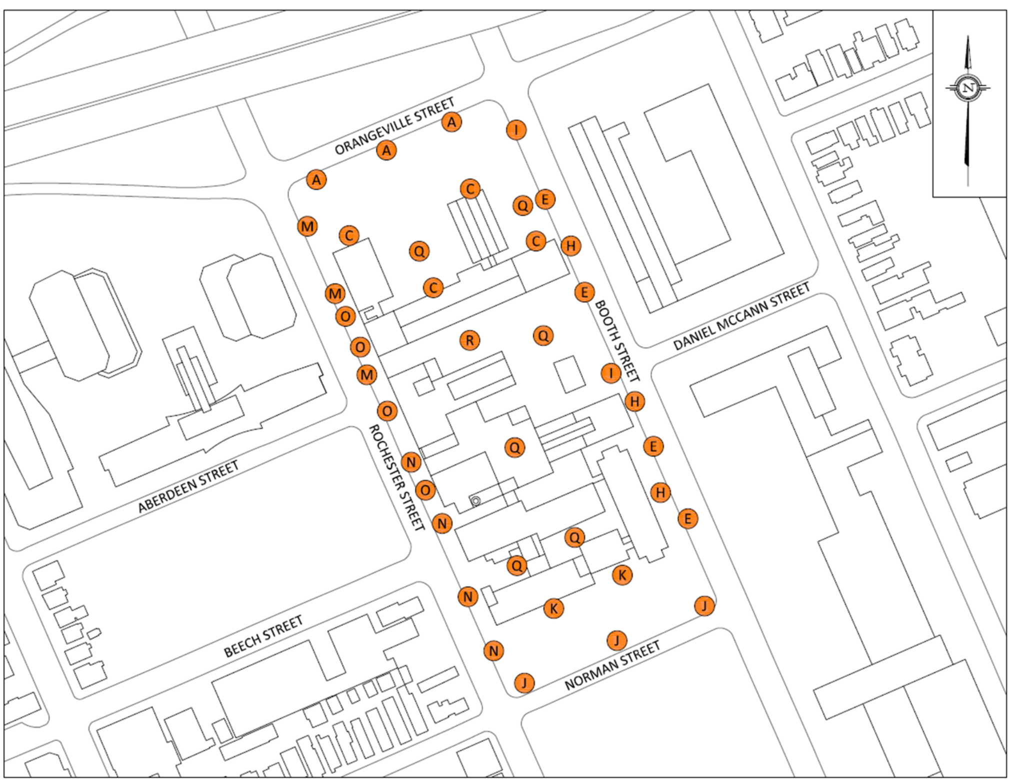


FIGURE 10: FUTURE CONFIGURATION – WINTER, GRADE-LEVEL PEDESTRIAN WIND CONDITIONS



EXISTING GRADE LEVEL REFERENCE MARKER LOCATIONS

APPENDIX A

SIMULATION OF THE NATURAL WIND

The information contained within this appendix is offered to provide a greater understanding of the relationship between the physical wind tunnel testing method and virtual computer-based simulations

WIND TUNNEL AND CFD SIMULATION OF THE NATURAL WIND

Wind flowing over the surface of the earth develops a boundary layer due to the drag produced by surface features such as vegetation and man-made structures. Within this boundary layer, the mean wind speed varies from zero at the surface to the gradient wind speed at the top of the layer. The height of the top of the boundary layer is referred to as the gradient height, above which the velocity remains more-or-less constant for a given synoptic weather system. The mean wind speed is taken to be the average value over one hour. Superimposed on the mean wind speed are fluctuating (or turbulent) components in the longitudinal (i.e. along wind), vertical and lateral directions. Although turbulence varies according to the roughness of the surface, the turbulence level generally increases from nearly zero (smooth flow) at gradient height to maximum values near the ground. While for a calm ocean the maximum could be 20%, the maximum for a very rough surface such as the center of a city could be 100%, or equal to the local mean wind speed. The height of the boundary layer varies in time and over different terrain roughness within the range of 400 metres (m) to 600 m.

Simulating real wind behavior in a wind tunnel, or by computer models (CFD), requires simulating the variation of mean wind speed with height, simulating the turbulence intensity, and matching the typical length scales of turbulence. It is the ratio between wind tunnel turbulence length scales and turbulence scales in the atmosphere that determines the geometric scales that models can assume in a wind tunnel. Hence, when a 1:200 scale model is quoted, this implies that the turbulence scales in the wind tunnel and the atmosphere have the same ratios. Some flexibility in this requirement has been shown to produce reasonable wind tunnel predictions compared to full-scale. In model scale the mean and turbulence characteristics of the wind are obtained with the use of spires at one end of the tunnel and roughness elements along the floor of the tunnel. The fan is located at the model end and wind is pulled over the spires, roughness elements and model. It has been found that, to a good approximation, the mean wind profile can be represented by a power law relation, shown below, giving height above ground versus wind speed.

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

Where; ***U*** = mean wind speed, ***Ug*** = gradient wind speed, ***Z*** = height above ground, ***Zg*** = depth of the boundary layer (gradient height) and α is the power law exponent.

Figure A1 plots three such profiles for the open country, suburban and urban exposures. The exponent α varies according to the type of terrain; α = 0.14, 0.25 and 0.33 for open country, suburban and urban exposures respectively. Figure A2 illustrates the theoretical variation of turbulence in full scale and some wind tunnel measurement for comparison.

The integral length scale of turbulence can be thought of as an average size of gust in the atmosphere. Although it varies with height and ground roughness, it has been found to generally be in the range of 100 m to 200 m in the upper half of the boundary layer. For a 1:300 scale, for example, the model value should be between 1/3 and 2/3 of a meter. Integral length scales are derived from power spectra, which describe the energy content of wind as a function of frequency. There are several ways of determining integral length scales of turbulence. One way is by comparison of a measured power spectrum in model scale to a non-dimensional theoretical spectrum such as the Davenport spectrum of longitudinal turbulence. Using the Davenport spectrum, which agrees well with full-scale spectra, one can estimate the integral scale by plotting the theoretical spectrum with varying L until it matches as closely as possible the measured spectrum:

$$f \times S(f) = \frac{\dfrac{4(Lf)^2}{U_{10}{}^2}}{\left[1 + \dfrac{4(Lf)^2}{U_{10}{}^2}\right]^{\frac{4}{3}}}$$

Where, $\boldsymbol{f}$ is frequency, $\boldsymbol{S(f)}$ is the spectrum value at frequency $\boldsymbol{f}$, $\boldsymbol{U_{10}}$ is the wind speed 10 m above ground level, and $\boldsymbol{L}$ is the characteristic length of turbulence.

Once the wind simulation is correct, the model, constructed to a suitable scale, is installed at the center of the working section of the wind tunnel. Different wind directions are represented by rotating the model to align with the wind tunnel centre-line axis.

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3. ESDU, '*Characteristics of Atmospheric Turbulence Near the Ground*', 74030

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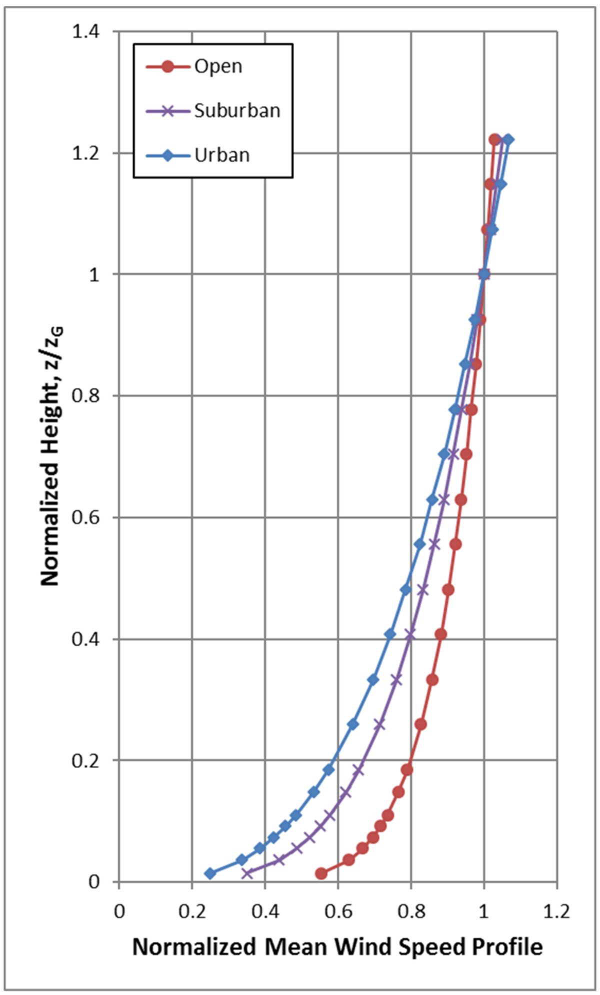


Figure A1: Mean Wind Speed Profiles

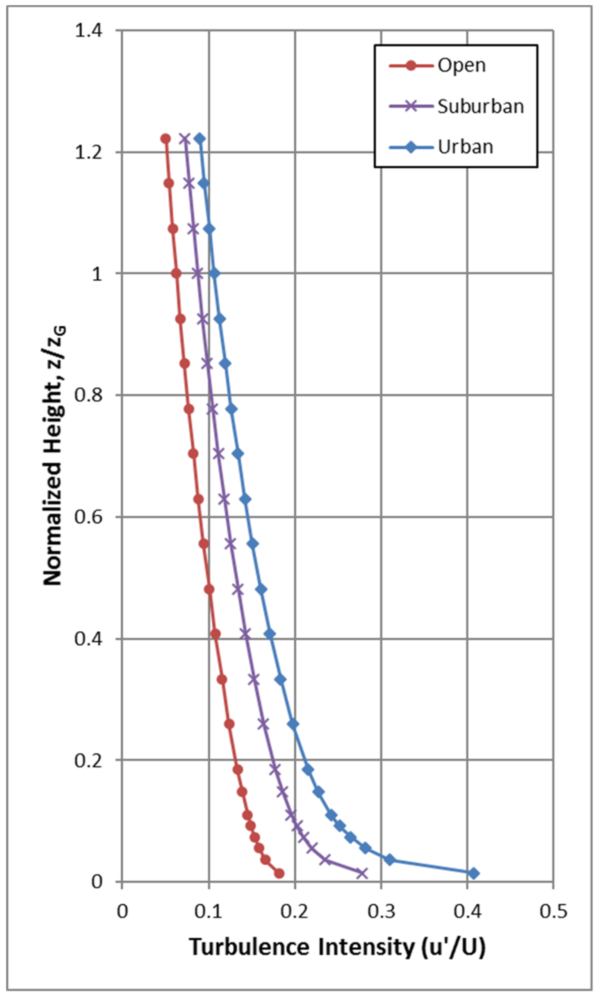


Figure A2: Turbulence Intensity Profiles

APPENDIX B

PEDESTRIAN LEVEL WIND MEASUREMENT METHODOLOGY

The information contained within this appendix is offered to provide a greater understanding of the relationship between the physical wind tunnel testing method and virtual computer-based simulations

PEDESTRIAN LEVEL WIND MEASUREMENT METHODOLOGY

Pedestrian level wind studies are performed in a wind tunnel on a physical model of the study buildings at a suitable scale. Instantaneous wind speed measurements are recorded at a model height corresponding to 1.5 metres (m) full scale using either a hot wire anemometer or a pressure-based transducer. Measurements are performed at any number of locations on the model and usually for 36 wind directions. For each wind direction, the roughness of the upwind terrain is matched in the wind tunnel to generate the correct mean and turbulent wind profiles approaching the model.

The hot wire anemometer is an instrument consisting of a thin metallic wire conducting an electric current. It is an omni-directional device equally sensitive to wind approaching from any direction in the horizontal plane. By compensating for the cooling effect of wind flowing over the wire, the associated electronics produce an analog voltage signal that can be calibrated against velocity of the air stream. For all measurements, the wire is oriented vertically so as to be sensitive to wind approaching from all directions in a horizontal plane.

The pressure sensor is a small cylindrical device that measures instantaneous pressure differences over a small area. The sensor is connected via tubing to a transducer that translates the pressure to a voltage signal that is recorded by computer. With appropriately designed tubing, the sensor is sensitive to a suitable range of fluctuating velocities.

For a given wind direction and location on the model, a time history of the wind speed is recorded for a period of time equal to one hour in full-scale. The analog signal produced by the hot wire or pressure sensor is digitized at a rate of 400 samples per second. A sample recording for several seconds is illustrated in Figure B. This data is analyzed to extract the mean, root-mean-square (rms) and the peak of the signal. The peak value, or gust wind speed, is formed by averaging a number of peaks obtained from sub-intervals of the sampling period. The mean and gust speeds are then normalized by the wind tunnel gradient wind speed, which is the speed at the top of the model boundary layer, to obtain mean and gust ratios. At each location, the measurements are repeated for 36 wind directions to produce normalized polar plots, which will be provided upon request.

In order to determine the duration of various wind speeds at full-scale for a given measurement location the gust ratios are combined with a statistical (mathematical) model of the wind climate for the project site. This mathematical model is based on hourly wind data obtained from one or more meteorological stations (usually airports) close to the project location. The probability model used to represent the data is the Weibull distribution expressed as:

$$P\left(> U_g\right) = A_\theta \bullet \exp\left[\left(-\frac{U_g}{C_\theta}\right)^{K_\theta}\right]$$

Where,

P (> Ug) is the probability, fraction of time, that the gradient wind speed ***Ug*** is exceeded; $\boldsymbol{\theta}$ is the wind direction measured clockwise from true north, ***A***, ***C***, ***K*** are the Weibull coefficients, (Units: A - dimensionless, C - wind speed units [km/h] for instance, K - dimensionless). $\boldsymbol{A_\theta}$ is the fraction of time wind blows from a 10° sector centered on $\boldsymbol{\theta}$.

Analysis of the hourly wind data recorded for a length of time, on the order of 10 to 30 years, yields the $\boldsymbol{A_\theta}$, $\boldsymbol{C_\theta}$ and $\boldsymbol{K_\theta}$ values. The probability of exceeding a chosen wind speed level, say 20 km/h, at sensor *N* is given by the following expression:

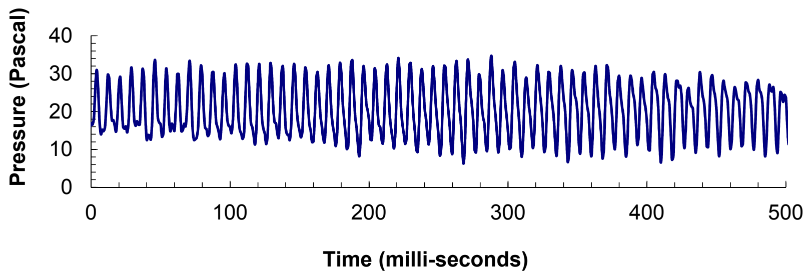
$$P_N(> 20) = \Sigma_\theta P\left[\frac{(> 20)}{\left(\frac{U_N}{U_g}\right)}\right]$$

$\boldsymbol{P_N (> 20) \;=\; \Sigma_\theta P \{ > 20/(U_N/Ug) \}}$

Where, $\boldsymbol{U_N/Ug}$ is the aforementioned normalized gust velocity ratios where the summation is taken over all 36 wind directions at 10° intervals.

If there are significant seasonal variations in the weather data, as determined by inspection of the $\boldsymbol{C_\theta}$ and $\boldsymbol{K_\theta}$ values, then the analysis is performed separately for two or more times corresponding to the groupings of seasonal wind data. Wind speed levels of interest for predicting pedestrian comfort are based on the comfort guidelines chosen to represent various pedestrian activity levels as discussed in the main text.

FIGURE B: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR



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