GRADIENT WIND
ENGINEERING INC

Pedestrian Level Wind Study

Petrie's Landing I – Towers 3, 4, & 5

Ottawa, Ontario

REPORT: GWE18-091-CFDPLW

Prepared For:

Jean-Luc Rivard
Brigil
98 Lois Street
Gatineau, QC J8Y 3R7

Prepared By:

Andrew Sliasas, M.A.Sc., Project Manager
Megan Prescott, MESc., Assistant Project Manager
Vincent Ferraro, M.Eng., P.Eng., Managing Principal

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EXECUTIVE SUMMARY

This report describes a computer-based pedestrian level wind study for Towers 3, 4 and 5 of the proposed Petrie's Landing I development 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.

Our work is based on industry standard CFD simulation and data analysis procedures, a site plan concept provided by NEUF architect(e)s in June 2018, surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa, as well as recent site imagery.

A complete summary of the predicted wind conditions across the study site is presented in Section 5 of this report. Based on CFD test results, interpretation, experience with similar developments, and reference to City of Ottawa pedestrian wind speed criteria, we conclude that wind conditions over many grade-level locations within the study site will be acceptable for the intended pedestrian uses. However, several pedestrian sensitive locations will require mitigation to achieve acceptable wind conditions. These areas include various walkways, the amenity area east of the Tower 5 podium across Inlet Private, amenity spaces between the towers, and the easternmost parking lot. Mitigations for these areas have been recommended in the form of strategically placed wind barriers, as described in Section 5.

Further, rooftop amenity areas for all three towers, including the potential amenity area over the podium rooftop of Tower 5 (if desired as an outdoor amenity area), will require mitigation in the form of wind barriers/canopies to ensure conditions are suitable for sitting or more sedentary activities.

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience conditions that could be considered unsafe.

It is noteworthy that, since the wind analysis was performed, the roof configurations of the various buildings have undergone massing changes that are not reflected in the renderings. The results summarized in this report apply to the current mechanical penthouse configuration provided by NEUF architect(e)s in July 2018, based on simulations performed for the original configuration combined with

professional knowledge of how the current massing will alter the results to influence pedestrian comfort at rooftop amenity areas.

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1. INTRODUCTION

Gradient Wind Engineering Inc. (GWE) was retained by Brigil to undertake a computer-based pedestrian level wind (PLW) study in support of simultaneous Zoning By-Law Amendment (ZBA) and Site Plan Approval (SPA) for Towers 3, 4 and 5 of the proposed Petrie's Landing I development in Ottawa, Ontario. Our mandate within this study, as outlined in GWE proposal #16-131P Towers 3-5, dated April 26, 2018, is to investigate pedestrian wind comfort 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 CFD simulation and data analysis procedures, a site plan concept provided by NEUF architect(e)s in June 2018, surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa, as well as recent site imagery.

It is noteworthy that, since the wind analysis was performed, the roof configurations of the various buildings have undergone massing changes that are not reflected in the renderings. The results summarized in this report apply to the current mechanical penthouse configuration provided by NEUF architect(e)s in July 2018, based on simulations performed for the original configuration combined with professional knowledge of how the current massing will alter the results to influence pedestrian comfort at rooftop amenity areas.

2. TERMS OF REFERENCE

The focus of this PLW study is Towers 3, 4 and 5 of the proposed Petrie's Landing I development in Ottawa, Ontario. The development site occupies a triangular parcel of land located north of Highway 174, approximately 375 m east of Trim Road and bound by green space in all directions. The Ottawa River is located approximately 300 m north of the study site.

Towers 3 and 4 are located to the east of the existing Towers 1 and 2, while Tower 5 is located to the southwest. Tower 3, to the immediate east of Tower 2, is a 22-storey building that features a nearly rectangular planform with rectangular/triangular protrusions. To the east of Tower 3, Tower 4 is an 18-storey building that features an irregular planform with a curved north wall. Tower 5 occupies the southwest corner of the site and is formed by two components: 22-storey Tower 5B on the north and 32-storey Tower 5A on the south, connected by a two-storey podium to create an 'L'-shape building planform. Towers 5A and 5B feature square and rectangular planforms, respectively. An extension of

Inlet Private begins at the northwest corner of the site and curves south to extend along the southeast perimeter of the property. Outdoor amenity areas and pedestrian pathways are located throughout the overall development site at grade, including an amenity area directly east of Tower 5B across the Inlet Private extension, and various spaces between Towers 1, 2, 3 and 4. Further, the rooftops of Towers 3, 4, 5A, and 5B will feature outdoor amenity areas. This study has also considered the podium rooftop of Tower 5 as a potential rooftop amenity area.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-metre radius of the site) are characterized by green space followed by transitional wetland to the north, and green space with intermittent low-rise buildings and surface parking for the remaining directions. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer radius), are characterized by the Ottawa River and Petrie Island Park to the north, and a mixture of green space and low-rise buildings in remaining directions, transitioning to agricultural areas to the southeast and low-rise residential subdivisions to the southwest.

Key areas under consideration for pedestrian wind comfort include surrounding walkways, building access points, and grade-level amenity areas. Figure 1 illustrates the study site and surrounding context. 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 within and surrounding the development site; (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 industry-accepted guidelines[1]. The following sections describe the analysis procedures, including a discussion of the pedestrian comfort guidelines.

[1] City of Ottawa Terms of References: Wind Analysis

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 Ottawa's 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 wind tunnel 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 822 metres.

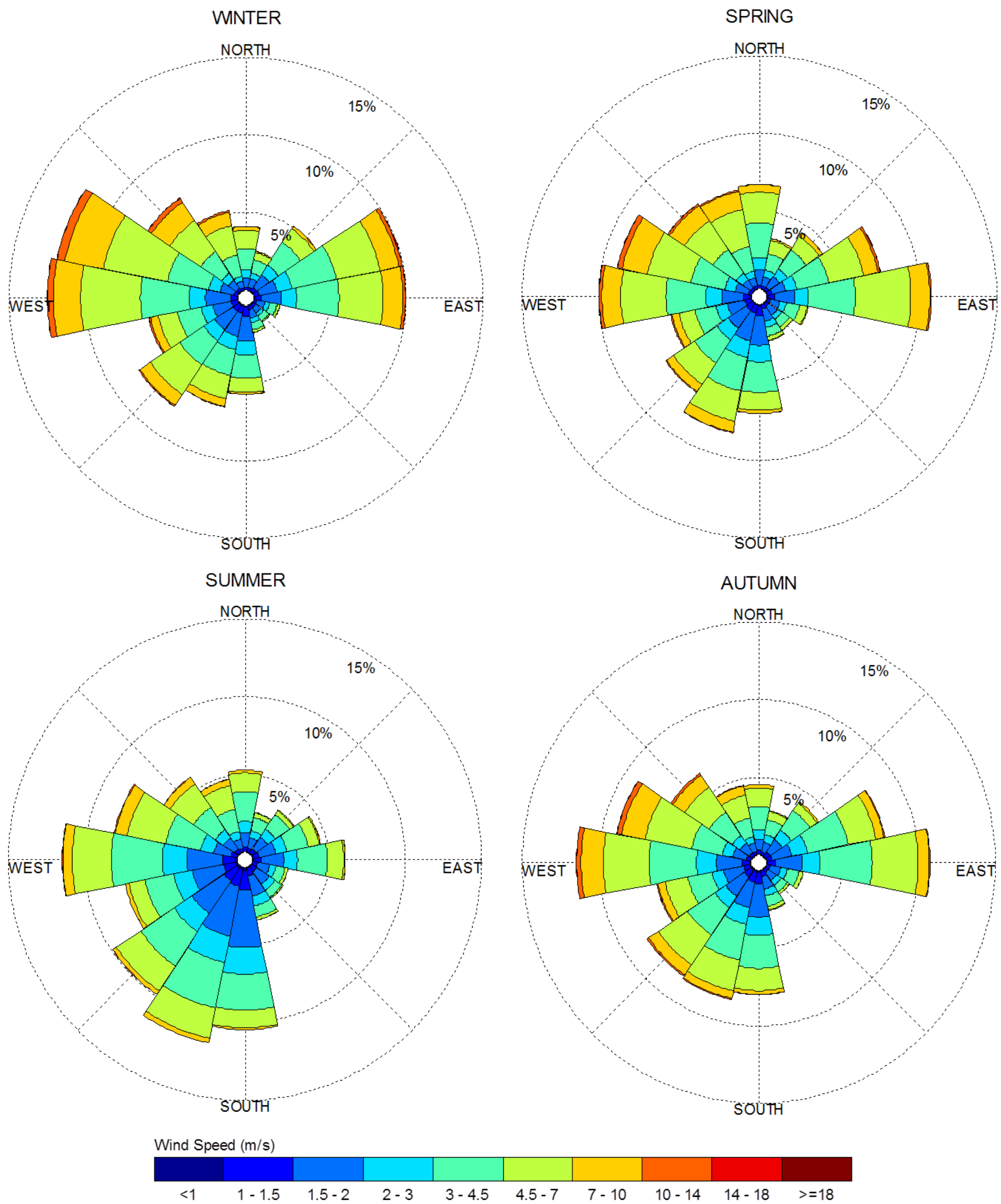
Mean and peak wind speed data obtained over the study site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 metres above local grade were referenced to the wind speed at gradient height to generate mean and peak velocity ratios, which were used to calculate full-scale values. 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.

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 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 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 10 metres per second (m/s). 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. Wind speeds represent mean hourly wind speeds measured at 10 m above the ground.

4.4 Pedestrian Comfort Guidelines

Pedestrian comfort guidelines are based on mechanical wind effects without consideration of other meteorological conditions (i.e. temperature, relative humidity). The guidelines provide an assessment of comfort, assuming that 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) Walking; (iv) Uncomfortable; and (v) Dangerous. More 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 kilometers per hour (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 guideline.

(vi) **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 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
Major Building Entrances	Standing
Secondary Building Access Points	Walking
Primary Public Sidewalks	Strolling
Secondary Public Sidewalks / Bicycle Paths	Walking
Outdoor Amenity Spaces	Sitting
Cafés / Patios / Benches / Gardens	Sitting
Transit Shelters	Standing
Public Parks / Plazas	Strolling
Garage / Service Entrances	Walking
Parking Lots, Laneways	Walking
Vehicular Drop-Off Zones	Walking

5. RESULTS AND DISCUSSION

The foregoing discussion of predicted pedestrian wind conditions for the study site is accompanied by Figures 3A through 6B (following the main text) illustrating the seasonal wind conditions at grade level and over rooftop amenity spaces. The colour contours indicate predicted regions of the various comfort classes. Wind conditions comfortable for sitting or more sedentary activities are represented by the colour green, standing are represented by yellow, strolling by orange, and conditions suitable for walking are represented by blue. Conditions uncomfortable for walking are represented by pink.

Extension of Inlet Private, Including Tower 4 Underground Parking Access (Tags A and B): The extension of Inlet Private serving the development begins at the northwest corner of the site and curves south at Tower 5B to extend along the southeast perimeter of the property. Overall, conditions along much of the laneway (Tag A) will be suitable for walking or better throughout the year, with the exception of a portion Inlet Private between the corners of Towers 1 and 5B (Tag B). This area will be somewhat windier due to corner acceleration of westerly winds and wind channelling between the two buildings, resulting in periods of uncomfortable conditions during the winter and spring seasons. This windy region also encompasses the loading area serving Tower 1. To improve wind conditions towards the desired comfort class of walking throughout the year, it is recommended that a series of wind barriers be clustered within the space between the buildings. The wind barriers may comprise high-solidity vertical wind screens and/or dense coniferous plantings, and should measure at least 2.0 metres tall. Furthermore, a setback of at least 3 metres for Tower 5B from the northeast corner of the podium, or a canopy of similar dimensions at this location, would reduce downwash of higher-level winds against the building façade, contributing to calmer conditions at the base of the building. The ramp to underground parking serving Tower 4, which is located where the Inlet Private expansion terminates on-site, will experience conditions suitable for standing or better throughout the year, which is acceptable.

Northeast Parking Lot (Tag C): The northeast parking lot, situated adjacent to Towers 3 and 4 and surrounded on all sides by a laneway, will mostly experience conditions suitable for walking or better throughout the year. Sections of this area may experience conditions uncomfortable for walking during the spring and winter. To improve wind conditions towards the desired comfort class of walking or better throughout the year, it is recommended that a series of wind barriers be clustered near the southwest corner of Tower 4. The wind barriers may comprise high-solidity vertical wind screens or dense coniferous plantings, and should measure at least 2.0 metres tall. This mitigation will simultaneously improve conditions over the adjacent walkways (Tag K) west of Tower 4 at no additional effort.

Central Parking Lots, Including Ramps to Underground Parking (Tag D): Overall, the central-most parking lots and adjacent ramps to underground parking will experience conditions suitable for walking or better throughout the year, which is acceptable.

Southeast Corner of Tower 5, Including Surface Parking and Walkway (Tag E): Overall, conditions at the southeast corner of Tower 5, inclusive of the walkway and all surface parking, are suitable for strolling or better throughout the year, which is acceptable for the intended pedestrian uses of the spaces.

West Side of Tower 5, Including Primary Building Access, Surface Parking and Round-About (Tag F): The primary building access points for Towers 5A and 5B will be suitable for standing or better throughout the year, which is acceptable. Overall, wind conditions over the adjacent surface parking and round-about will be suitable for standing during the summer, strolling or better during the autumn, and walking or better for the remainder of the year, which is acceptable.

Walkways East and North of Tower 5, Including Amenity Area (Tags G & H): The walkways along the east and north façades of Tower 5 (Tag G) will mostly experience conditions suitable for sitting during the summer, and standing or better for the remainder of the year, which is acceptable. The exception is the northeast corner of Tower 5B, which will experience windier conditions becoming uncomfortable for walking during the spring and winter. The wind mitigation previously referenced for Tag B would simultaneously serve to improve conditions in this area at no additional effort. If outdoor seating is desired for these areas during the summer, it is recommended to avoid placement of seating near the northeast corner of Tower 5B. The amenity area east of Tower 5 (Tag H) across the Inlet Private extension will experience conditions suitable for standing during the summer and autumn, and strolling or better for the remainder of the year. Mitigation will be required if seating areas will be provided for this space, for which we recommend a 1.8-metre-tall high solidity wind barrier be installed to shield the space from prominent winds from the west and north quadrants. Furthermore, the planned waterfall installation could be leveraged for mitigation as a wind barrier by relocating it to align with the curve of the amenity space, thereby shielding seating areas from prominent westerly winds – provided the waterfall concept meets or exceeds the recommended barrier height of 1.8 metres.

Walkways and Side Yard Between Towers 1 and 2 (Tag I): The noted areas between Towers 1 and 2, including the paved lookout, will experience conditions suitable for strolling or better during the summer and walking or better during the spring and autumn, transitioning to periods where conditions will be uncomfortable for walking during the winter. If upkeep and use of these walkways are anticipated during the winter season, it is recommended to provide additional clusters of dense coniferous plantings, measuring at least 2.0 metres tall, within the space between Towers 1 and 2 to reduce the strong winds travelling off of the Ottawa River. If winter uses are not anticipated, the noted conditions are acceptable without mitigation.

Walkways and Gazebo Lookout / Amenity Spaces Between Towers 2 and 3 (Tag J): The noted areas between Towers 2 and 3 will experience conditions suitable for strolling or better during the summer and walking or better during the spring and autumn, transitioning to periods where conditions will be uncomfortable for walking during the winter. If upkeep and use of these walkways are anticipated during the winter season, it is recommended ensure to install clusters of dense coniferous plantings, measuring at least 2.0 metres tall, along the walkways. If winter uses are not anticipated, the noted conditions are acceptable without mitigation. For the gazebo area, if seating areas will be provided, it is recommended to provide localized wind barriers to shield the space from northerly and westerly winds channelling between Towers 2 and 3. Such wind barriers should measure at least 1.8 metres tall and be located immediately upwind of the designated seating areas.

Walkway Running West-East Through Site, Including All Adjacent Amenity Areas and Primary Building Access Points (Tag K): The noted walkway extends west to east across the site, south of Towers 1-3 and north/west of Tower 4. Overall, conditions over the walkway will be suitable for strolling or better during the summer, and walking or better during the spring and autumn, which are acceptable conditions. Although sections of the walkway will experience conditions uncomfortable for walking during the winter, the above recommended mitigations described for other uncomfortable areas on-site will simultaneously improve conditions over the walkway to acceptable wind speed levels. If the landscaped space directly east of Tower 3 (surrounded on all sides by a walkway) is intended to provide seating areas, it is recommended to incorporate dense coniferous plantings rising 1.6 metres above the walking surface along the perimeter of the space to improve wind conditions for sitting use during the summer. Primary building access points for Towers 1, 2, and 3 (denoted in Figure 2 by the pathways leading to the south façades) will experience conditions suitable for sitting during the summer and standing for the remainder of the year, which is acceptable. The primary building access for Tower 4, along the building's west façade, will experience conditions suitable for sitting throughout the year. Further, the direct path leading to the Tower 4 entrance will experience calm conditions suitable for standing or better. These conditions are acceptable for the intended uses of the spaces.

Lastly, the paved areas encircled by the walkway north and west of Tower 4 will mostly experience conditions suitable for strolling or better throughout the year without consideration of potential waterfall installations, which is acceptable provided seating is not intended for these areas. If seating is desired within these areas, the circular space encircled by two waterfall installations west of Tower 4 is expected to be suitable for sitting during the summer season provided the noted waterfall features are installed and rise at least 1.6 metres from the walking surface. For the circular space north of Tower 4, a wind barrier rising at least 1.6 metres from the walking surface will also be required along the west and north sections of the space to ensure conditions within are suitable for sitting during the summer.

Tower 5A Rooftop Amenity Area (Tag L): The Tower 5A rooftop amenity area north of the mechanical penthouse will experience conditions suitable for strolling during the summer and walking during the autumn, transitioning to conditions uncomfortable for walking during the spring and winter. If seating or other sedentary use areas are planned for this space, a 1.8-metre-tall high-solidity wind barrier should be installed along the entire perimeter of the terrace.

Tower 5B Rooftop Amenity Area (Tag M): The Tower 5B rooftop, which is located primarily to the north of the mechanical penthouse, will likely experience conditions suitable for strolling during the summer and walking or better during the autumn, transitioning to conditions uncomfortable for walking during the spring and winter. To permit sitting during the summer season as well as mitigate uncomfortable and windier edge conditions for all seasons, it is recommended to install 1.8-metre-tall high-solidity wind barrier along the entire perimeter of the terrace.

Potential Tower 5 Podium Rooftop Amenity Area (Tag N): Overall, the Tower 5 podium rooftop will mostly experience conditions suitable for standing or better during the summer and autumn and strolling or better for the remainder of the year, with windier conditions towards the east side of the podium (strolling during the summer and autumn, and walking during the winter). If the area is desired as an outdoor amenity area, mitigation is recommended to ensure acceptable wind comfort. If seating areas will be provided along the west portion of the terrace, it is recommended to increase the height of the terrace guard on the west perimeter of the roof to 1.8 metres above the walking surface. If seating areas will be located over the east side of the terrace, the east perimeter guard should be increased to 1.6 metres, while simultaneously providing localized 1.6-metre-tall wind barriers to the immediate west of designated seating areas. Seating areas located near the south elevation of Tower 5B will also benefit from a canopy installed along the south elevation of the tower to deflect downwash winds.

Tower 3 Rooftop Amenity Area (Tag O): Overall, conditions over the Tower 3 rooftop amenity area, which is primarily to the north of the mechanical penthouse, will likely be suitable for strolling or better during the summer and walking or better for the remainder of the year, with windier conditions towards the east and south edges of the rooftop and occasionally uncomfortable conditions during the colder seasons. If sitting or more sedentary activities are required over the space during the summer, as well as to mitigate uncomfortable and windier edge conditions, it is recommended to install a 1.8-metre-tall high-solidity wind barrier along the entire perimeter of the terrace.

Tower 4 Rooftop Amenity Areas (Tag P): Overall, conditions over the majority of the Tower 4 rooftop will be suitable for standing or better during the summer and strolling or better for the remainder of the year, with windier conditions experienced towards the west edge of rooftop. Conditions at these windier sections may transition to become uncomfortable for walking during the colder seasons. To ensure that the east portion of the terrace is comfortable for sitting during the warmer months, it is recommended to provide a 1.6-metre-tall wind barrier around the terrace space. If the north and west sides of the rooftop will contain seating areas, it is recommended to install a 1.8-metre-tall high-solidity wind barrier along the north and west perimeters.

Influence of the Proposed Development on Existing Wind Conditions near the Study Site: Wind conditions over surrounding laneways and other areas beyond the development site will be comfortable for their intended pedestrian uses during each seasonal period upon the introduction of the proposed development at Petrie's Landing I.

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 unsafe.

6. SUMMARY AND RECOMMENDATIONS

This report summarizes the methodology, results, and recommendations related to a pedestrian level wind study for Towers 3, 4 and 5 of the proposed Petrie's Landing I development in Ottawa, Ontario. The study was performed in accordance with the scope of work described in GWE proposal #16-131P Towers 3-5, dated April 26, 2018, as well as industry standard CFD simulation and data analysis procedures.

A complete summary of the predicted wind conditions is provided in Section 5 of this report and illustrated in Figures 3A-6B following the main text. Based on CFD test results, meteorological data analysis of the Ottawa wind climate, and experience with similar developments in Ottawa, we conclude that wind conditions over many grade-level locations within the study site will be acceptable for the intended pedestrian uses. However, several pedestrian sensitive locations will require mitigation to achieve acceptable wind conditions. These areas include various walkways, the amenity area east of the Tower 5 podium across Inlet Private, amenity spaces between the towers, and the easternmost parking lot. Mitigations for these areas have been recommended in the form of strategically placed wind barriers, as described in Section 5.

Further, potential rooftop amenity areas for all three towers, including the podium rooftop of Tower 5, will require mitigation in the form of wind barriers/canopies to ensure conditions are suitable for sitting or more sedentary activities, if these spaces are intended for use as outdoor amenity areas.

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience conditions that could be considered unsafe.

It is noteworthy that, since the wind analysis was performed, the roof configurations of the various buildings have undergone massing changes that are not reflected in the renderings. The results summarized in this report apply to the current mechanical penthouse configuration provided by NEUF architect(e)s in July 2018, based on simulations performed for the original configuration combined with professional knowledge of how the current massing will alter the results to influence pedestrian comfort at rooftop amenity areas.

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

Sincerely,

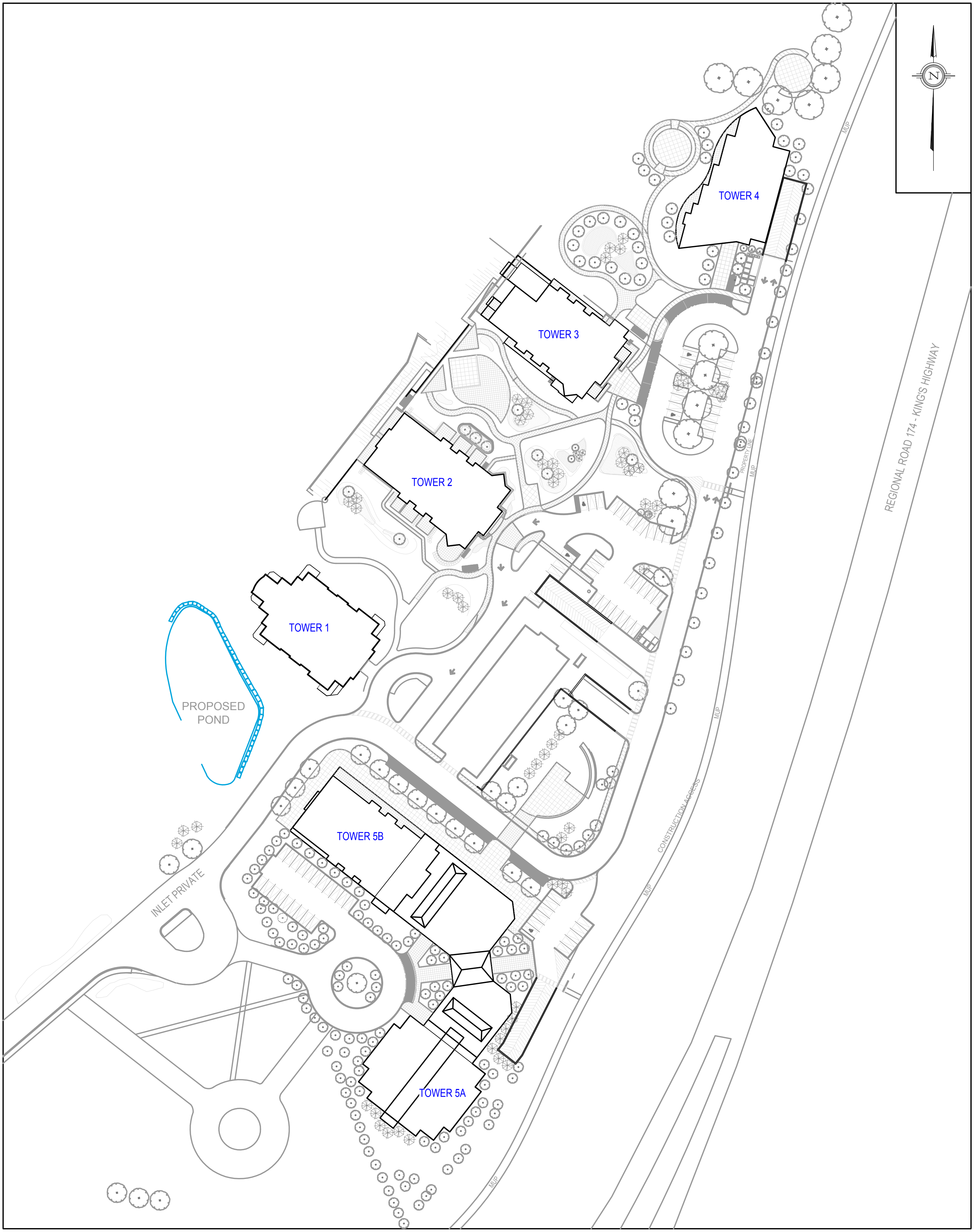
Gradient Wind Engineering Inc.

Andrew Sliasas, M.A.Sc.
Project Manager

Vincent Ferraro, M.Eng., P.Eng.,
Managing Principal

Megan Prescott, MESc
Assistant Project Manager

GWE18-091-CFD



127 Walgreen Road
Ottawa, Ontario
(613) 836 0934

GRADIENT WIND ENGINEERING INC

PROJECT	PETRIE'S LANDING I, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION
SCALE	1:1600 (APPROX.)	DRAWING NO. GWE18-091-CFDPLW-1	FIGURE 1: SITE PLAN
DATE	JULY 6, 2018	DRAWN BY B.J.	

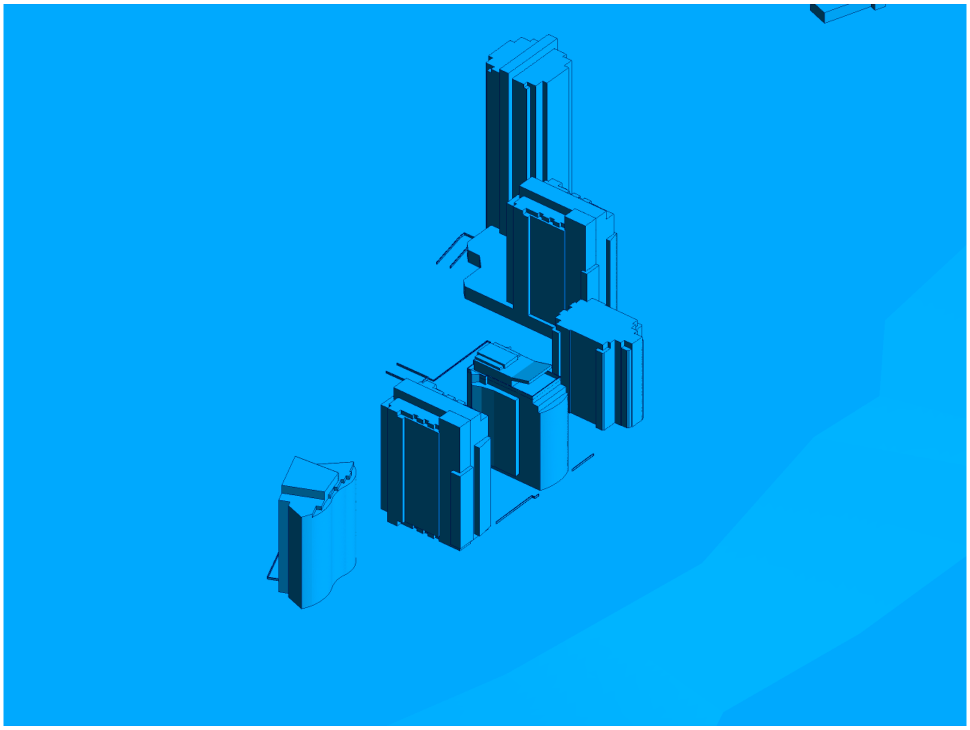


FIGURE 2A: COMPUTATIONAL MODEL, NORTHEAST PERSPECTIVE

FIGURE 2B: STUDY BUILDING, SOUTHWEST PERSPECTIVE

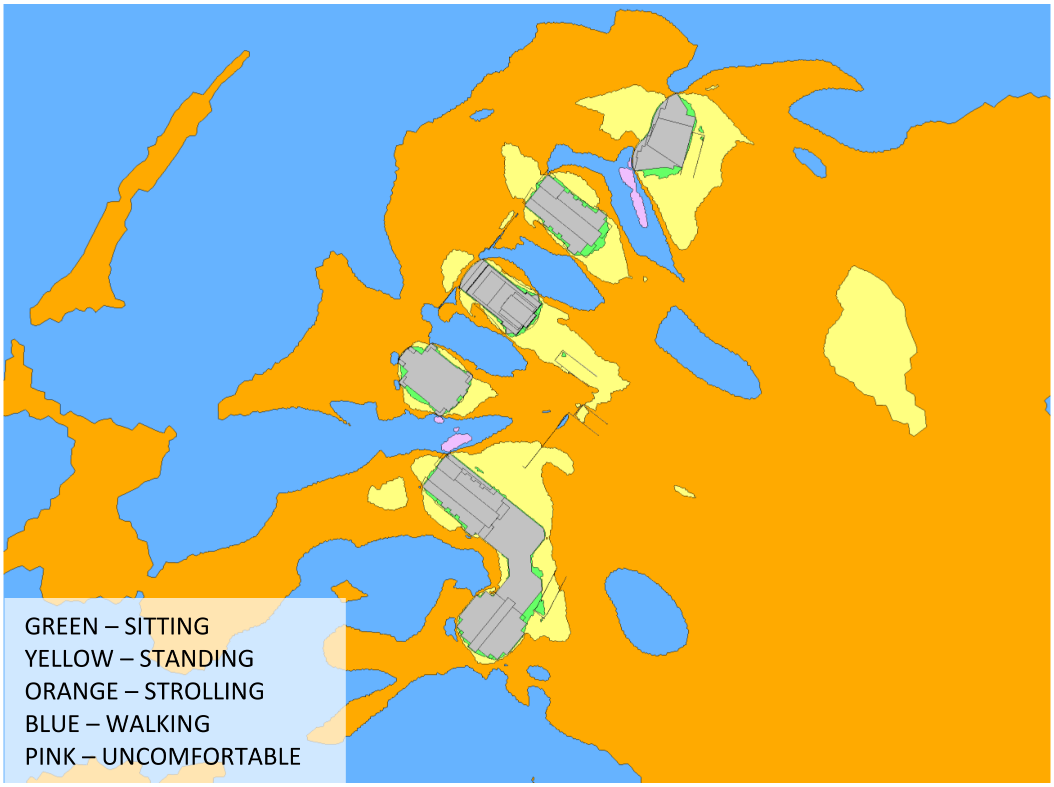


FIGURE 3A: SPRING – GRADE-LEVEL PEDESTRIAN WIND CONDITIONS

PETRIE'S LANDING I – GRADE REFERENCE MARKER LOCATIONS

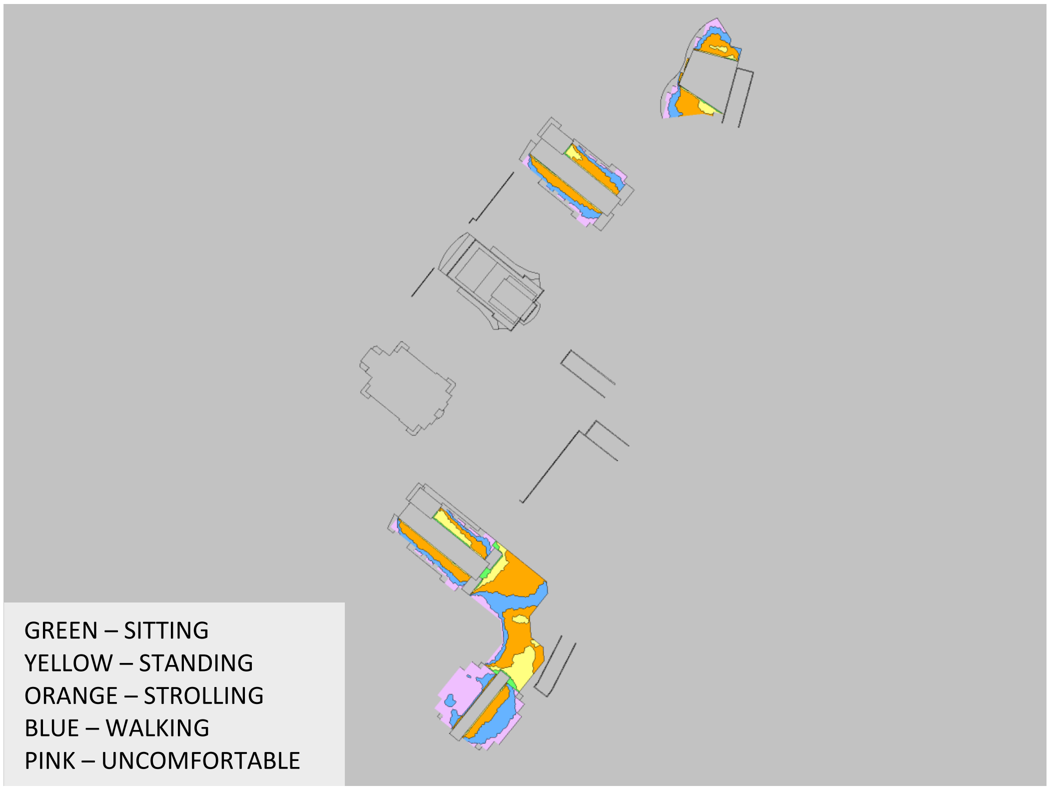
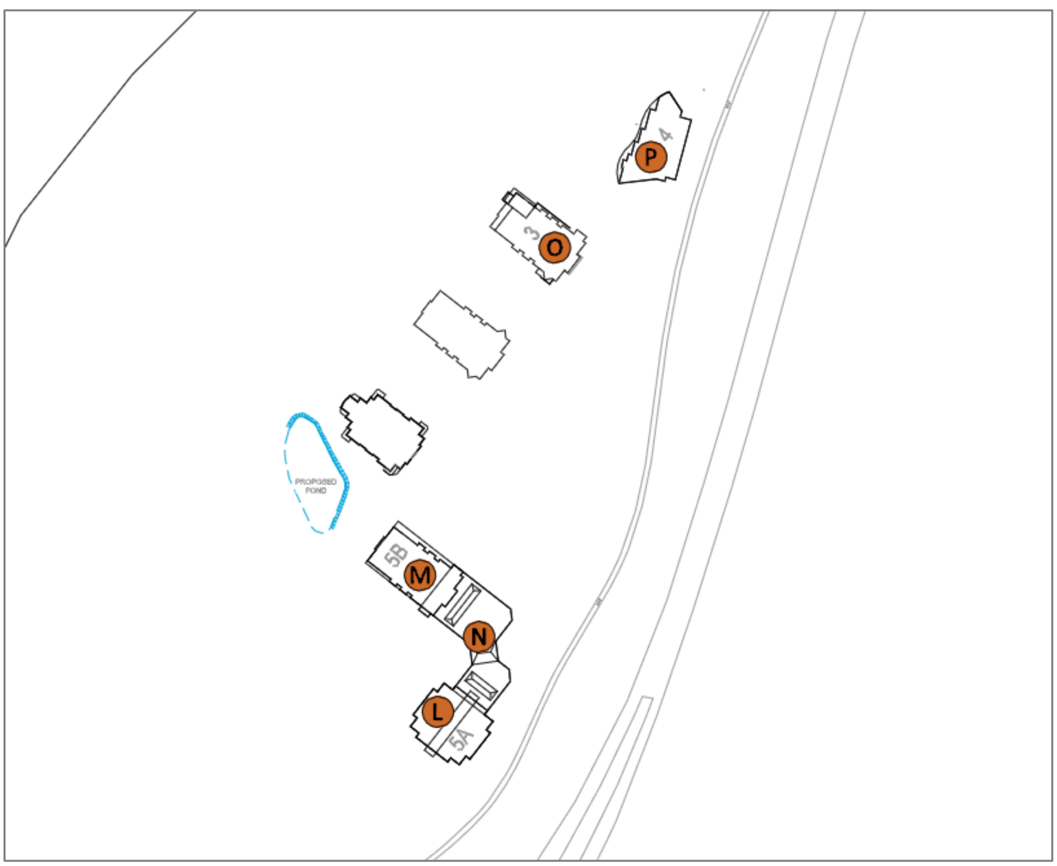


FIGURE 3B: SPRING – ROOFTOP AMENITY PEDESTRIAN WIND CONDITIONS



PETRIE'S LANDING I – ROOFTOP REFERENCE MARKER LOCATIONS

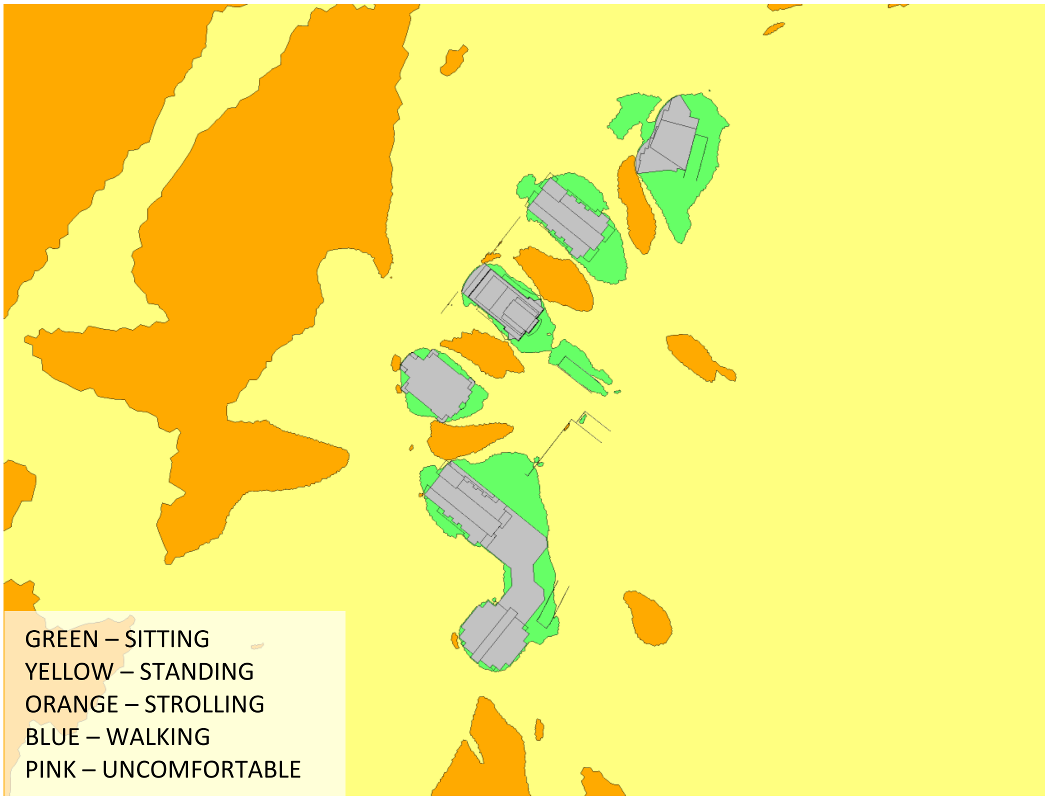


FIGURE 4A: SUMMER – GRADE-LEVEL PEDESTRIAN WIND CONDITIONS

PETRIE'S LANDING I – GRADE REFERENCE MARKER LOCATIONS

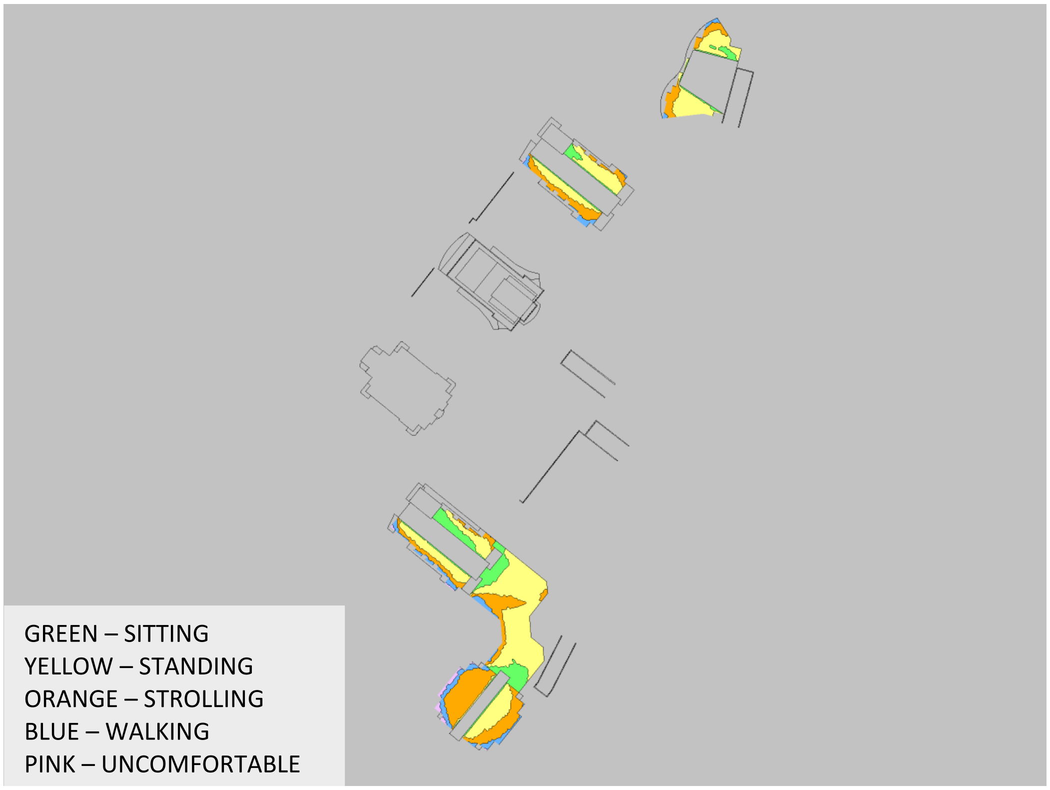
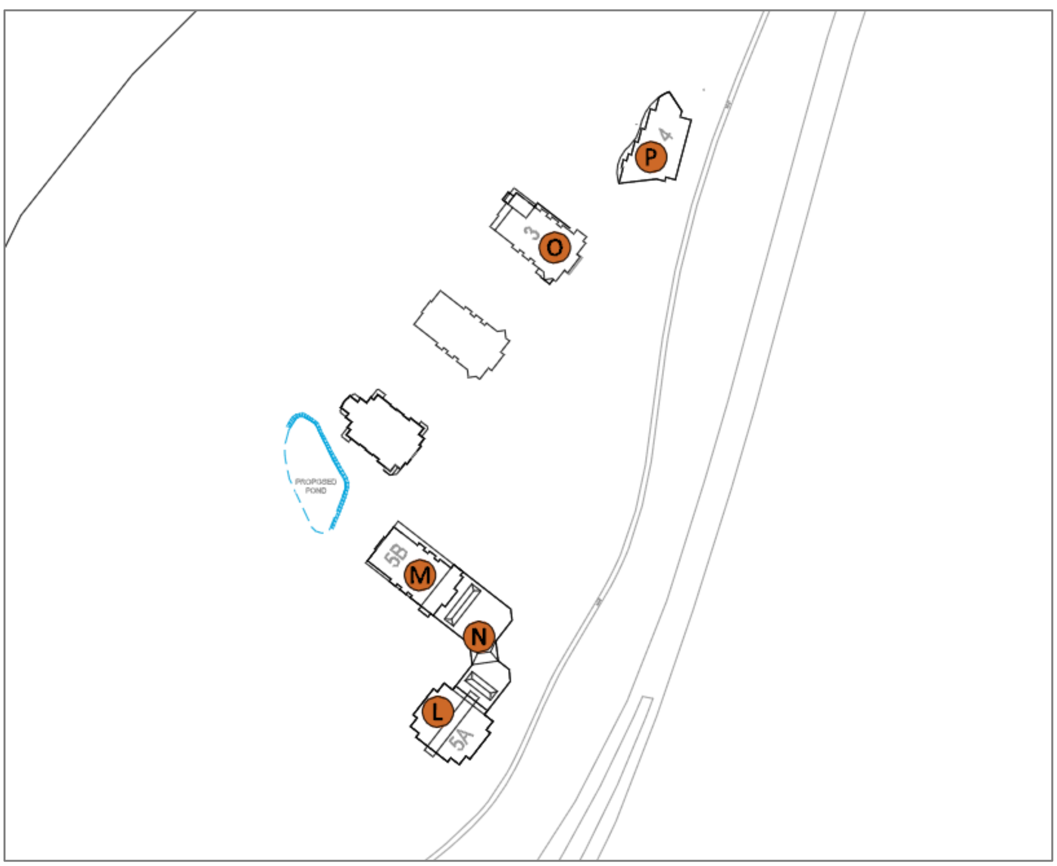


FIGURE 4B: SUMMER – ROOFTOP AMENITY PEDESTRIAN WIND CONDITIONS



PETRIE'S LANDING I – ROOFTOP REFERENCE MARKER LOCATIONS

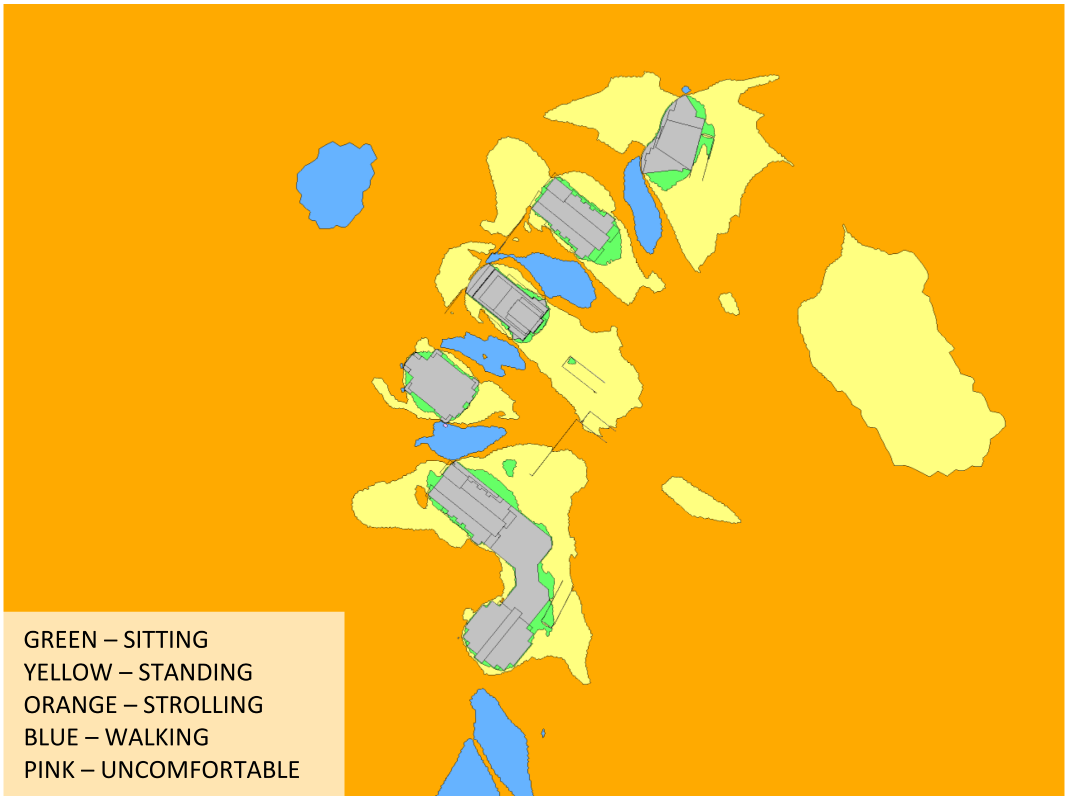


FIGURE 5A: AUTUMN – GRADE-LEVEL PEDESTRIAN WIND CONDITIONS

PETRIE'S LANDING I – GRADE REFERENCE MARKER LOCATIONS

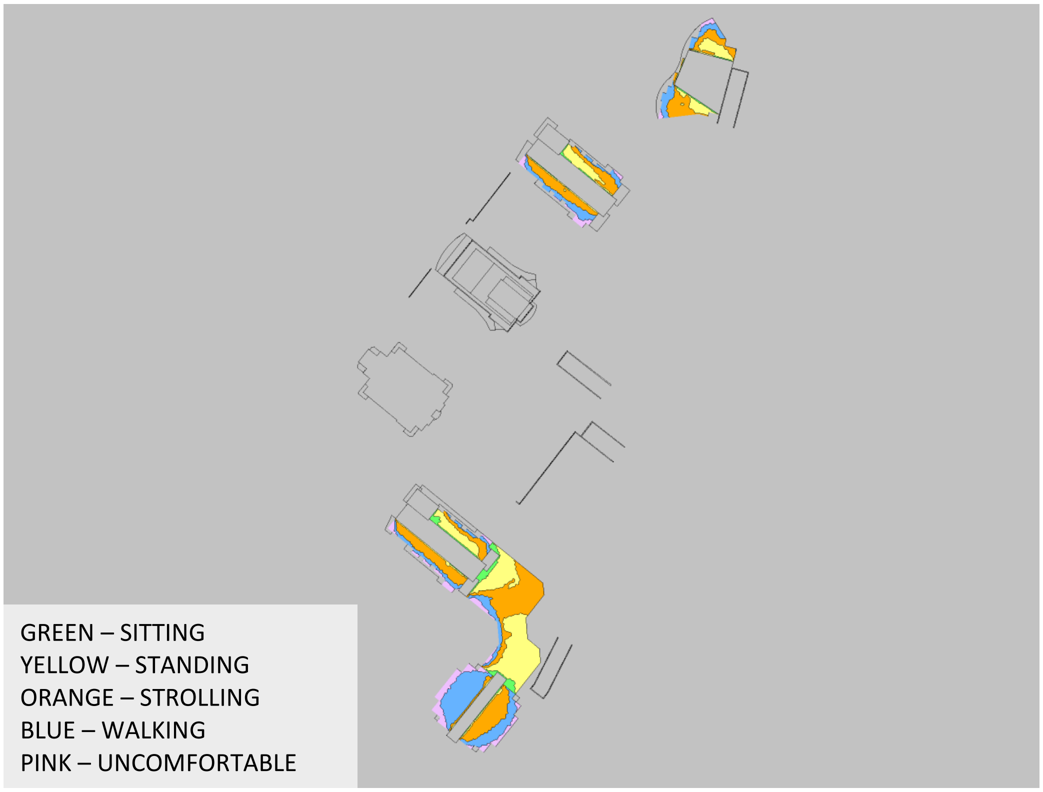
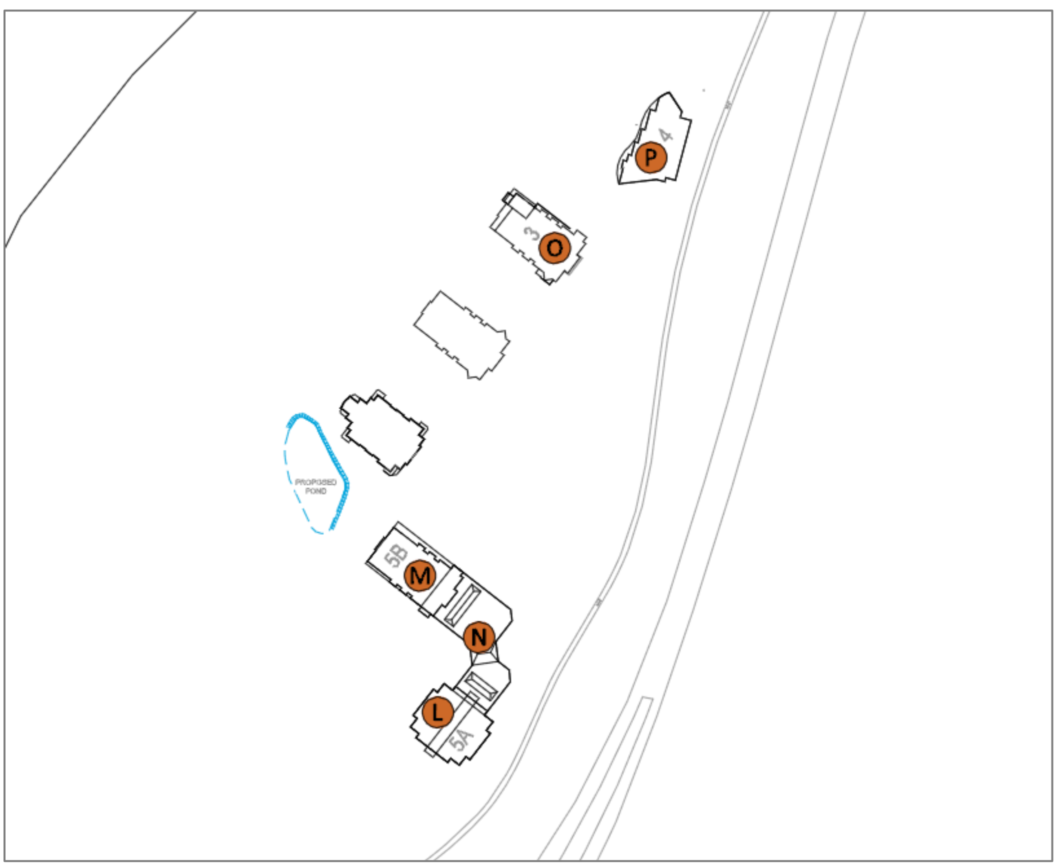


FIGURE 5B: AUTUMN – ROOFTOP AMENITY PEDESTRIAN WIND CONDITIONS



PETRIE'S LANDING I – ROOFTOP REFERENCE MARKER LOCATIONS

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

PETRIE'S LANDING I – GRADE REFERENCE MARKER LOCATIONS

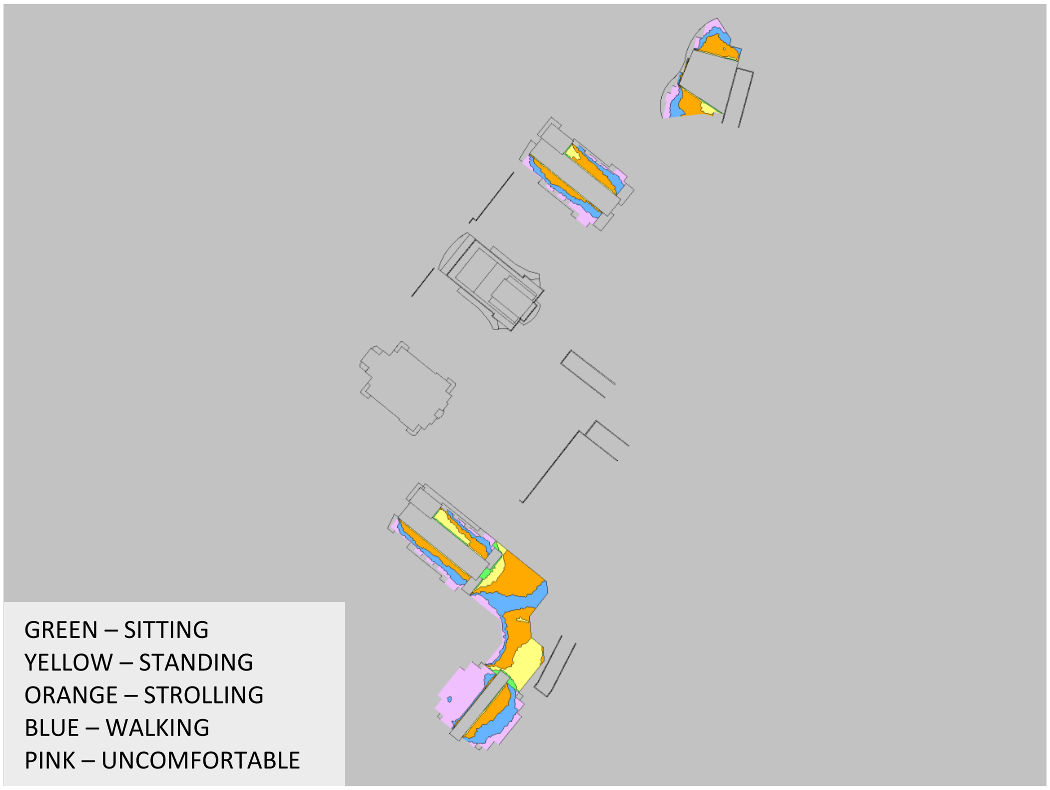
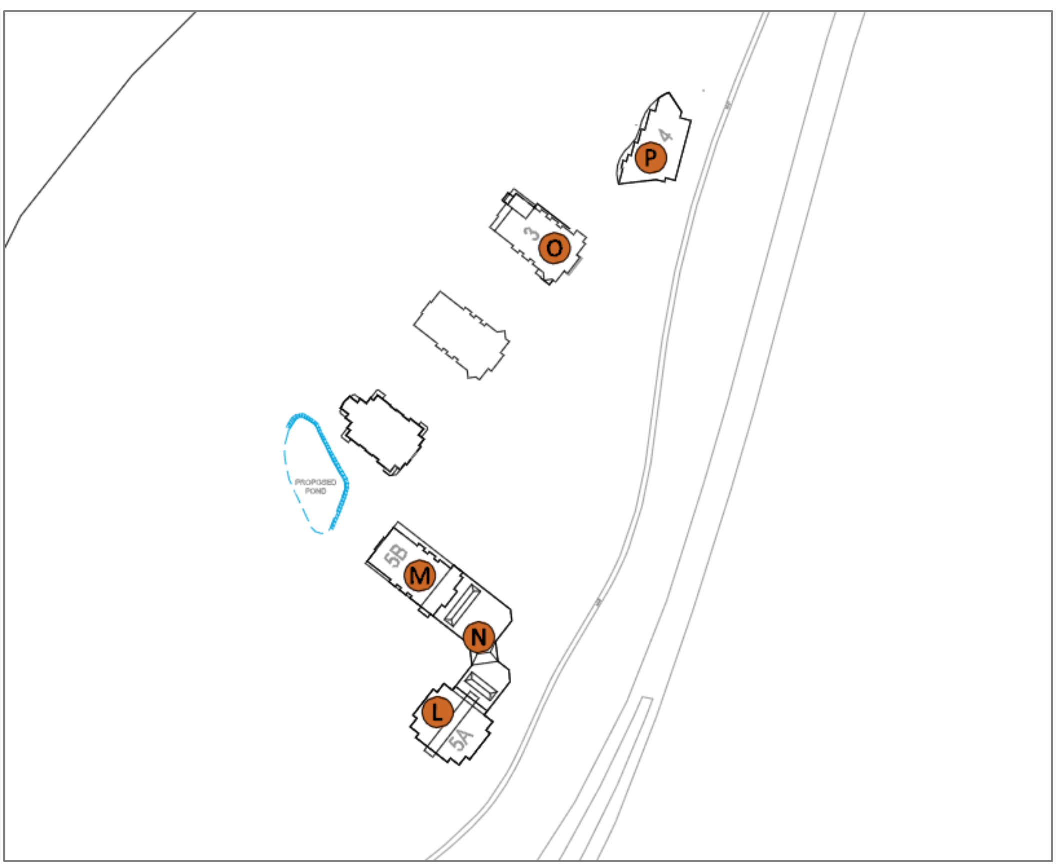


FIGURE 6B: WINTER – ROOFTOP AMENITY PEDESTRIAN WIND CONDITIONS



PETRIE'S LANDING I – ROOFTOP 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 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 m to 600 m.

Simulating real wind behaviour 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; $\boldsymbol{U}$ = 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.

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 metre. 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, f is frequency, $S(f)$ is the spectrum value at frequency f, U_{10} is the wind speed 10 m above ground level, and 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 center-line axis.

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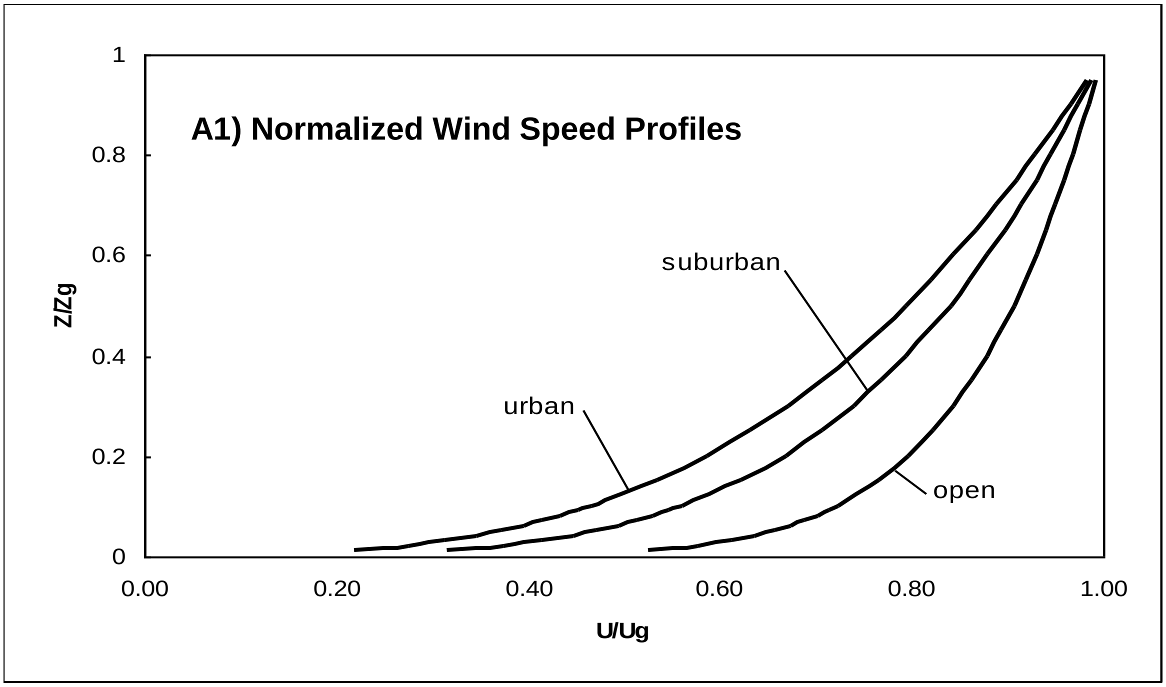


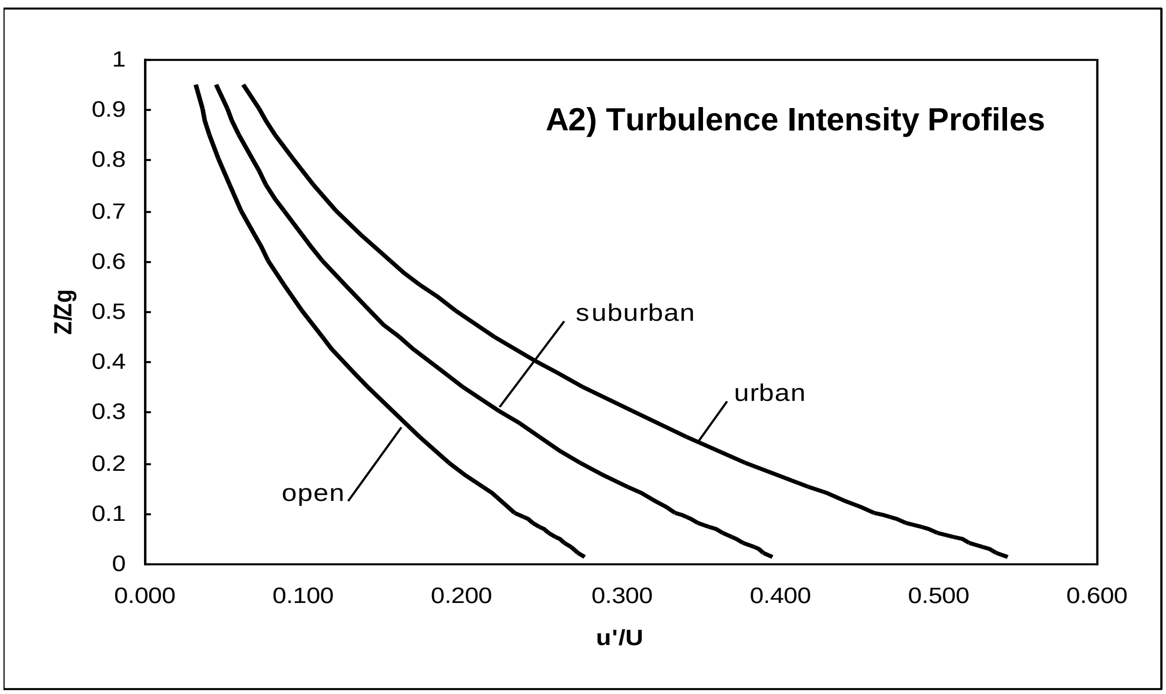


Figure A1 (Top): Mean Wind Speed Profiles

Figure A2 (Bottom): Turbulence Intensity Profiles (u' = fluctuation of mean velocity)

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 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 (> U_g) is the probability, fraction of time, that the gradient wind speed ***U_g*** is exceeded; ***θ*** 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). ***A_θ*** is the fraction of time wind blows from a 10° sector centered on ***θ***.

Analysis of the hourly wind data recorded for a length of time, on the order of 10 to 30 years, yields the ***A_θ, C_θ*** and ***K_θ*** values. The probability of exceeding a chosen wind speed level, say 20 km/h, at sensor *N* is given by the following expression:

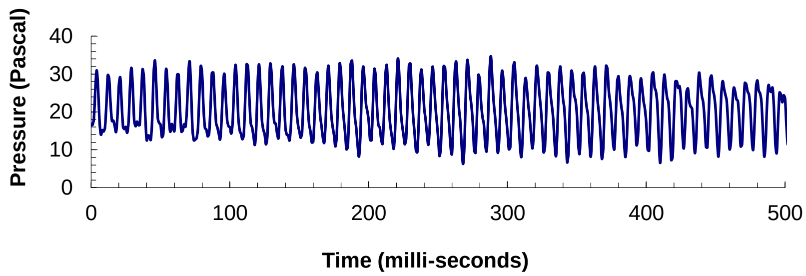
$$P_N(>20) = \Sigma_\theta P\left[\frac{(>20)}{\left(\frac{U_N}{U_g}\right)}\right]$$

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

Where, ***U_N/U_g*** 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 ***C_θ*** and ***K_θ*** 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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