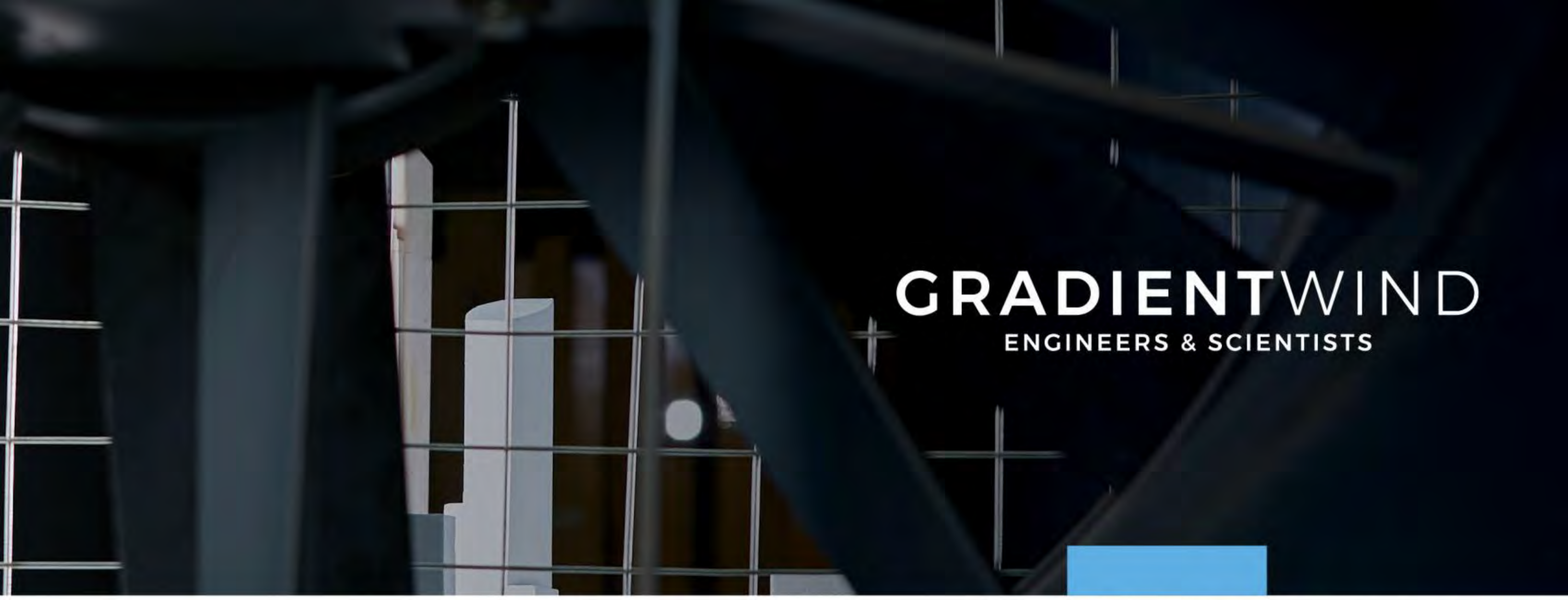
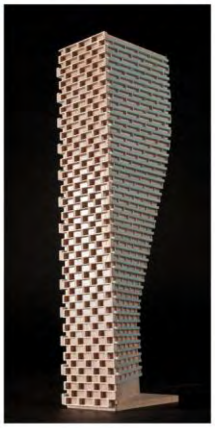


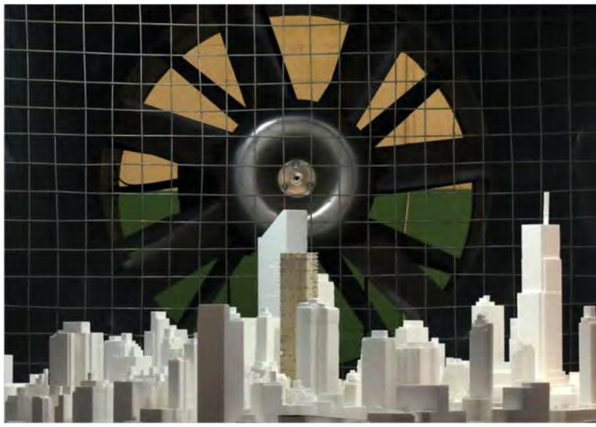
GRADIENTWIND
ENGINEERS & SCIENTISTS

PEDESTRIAN LEVEL WIND STUDY

117 Jackson Street
Hamilton, Ontario

REPORT: GW21-430-WTPLW





December 9, 2022

PREPARED FOR
DiCenzo Construction Company Limited
1070 Stone Church Rd E Unit 39
Hamilton, Ontario
L8W 3K8

PREPARED BY
Patrick Shorey, B.A.Sc., EIT, Junior Wind Scientist
Andrew Sliasas, M.A.Sc., P.Eng., Principal

EXECUTIVE SUMMARY

This report describes a pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 117 Jackson Street East in Hamilton, Ontario. The study involves wind tunnel measurements of pedestrian wind speeds using a physical scale model, combined with meteorological data integration, to assess pedestrian comfort at key areas within and surrounding the study site. Grade-level areas investigated include sidewalks, laneways, parking areas, transit stops, existing patios, and building access points. Wind comfort is also evaluated over the Levels 4 and 5 outdoor amenity terraces. To evaluate the influence of the proposed development on the existing wind conditions surrounding the site, two massing configurations were studied: (i) existing conditions without the proposed development, and (ii) conditions with the proposed development, comprising all phases, in place. 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 wind tunnel testing and data analysis procedures, City of Hamilton wind criteria, architectural drawings provided by Graziani + Corazza Architects in December 2021 and updated in December 2022, surrounding street layouts, as well as existing and approved future building massing information and recent site imagery.

A complete summary of the predicted wind conditions is provided in Section 5.2 of this report, and is also illustrated in Figures 2A-3B, as well as Tables A1-A3 and B1-B4 in the appendices. Based on wind tunnel test results, meteorological data analysis, and experience with similar developments in the area, we conclude that conditions over all pedestrian-sensitive areas within and surrounding the development site will be acceptable for the intended pedestrian uses on an annual and seasonal basis. Over amenity terraces at Levels 4 and 5, to ensure conditions comfortable for sitting or more sedentary activities throughout the terraces during the summer months, mitigation is recommended, as described in Section 5.2.

A comparison of the existing versus future wind comfort surrounding the study site indicates that the proposed development will have a mixed impact on grade-level wind comfort. Reductions in comfort occur to the southeast, along the west end of the north elevation, to the south of Jackson Street east, and over sidewalks along the west side of Catherine Street South, while improvements occur along the east end of the north elevation and west end of the south elevation, with conditions generally unchanged elsewhere. Where wind speeds increase, conditions nevertheless remain acceptable for the intended uses.

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 could be considered unsafe.

TABLE OF CONTENTS

1. INTRODUCTION

This report describes a pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 117 Jackson Street East in Hamilton, Ontario. Two conditions were studied: (i) existing conditions, including all approved, surrounding developments and without the proposed development, and (ii) conditions with the proposed development in place. The study was performed in accordance with industry standard wind tunnel testing techniques, City of Hamilton wind criteria, architectural drawings provided by Graziani + Corazza Architects in December 2021 and updated in December 2022, surrounding street layouts and existing and approved future building massing information, as well as recent site imagery.

2. TERMS OF REFERENCE

The focus of this pedestrian wind study is the proposed mixed-use development located at 117 Jackson Street East in Hamilton, Ontario. The study site is situated over the southwest portion of a lot bounded by Catherine Street South to the west, a laneway to the north, Walnut Street South to the east, and Jackson Street East to the south.

The study building comprises two residential towers, Tower A (30-storey) and Tower B (39-storey), rising from the west and east ends, respectively, of a stepped, four-storey, mixed-use podium. The podium has an approximately rectangular planform at grade, longitudinally aligned with Jackson Street East. At grade, parking and loading entrances are accessible via the laneway along the north elevation. The residential lobby is centrally located along the south elevation, with retail space along the south and west elevations, and parking and building support services elsewhere. At Level 2, the floorplate sets back partially over the residential lobby, and at the southwest corner accommodating private terraces. At Levels 2 and 3 the podium contains residential use along the south and west elevations, and parking along the north elevation, with the floors above comprising primarily residential use. At Level 3, the floorplate sets back from the southwest, accommodating private terraces, while extending to the south, cantilevering over the residential lobby roof, below. At Level 4, setbacks from all elevations meet the typical tower floorplates, which are joined by a single-storey-height indoor amenity space. Outdoor amenity terraces are located to the north and south of the indoor amenity, and to the north and east of Tower B, over the podium rooftop. At Level 5, an additional outdoor amenity is located on the indoor amenity rooftop, between the towers. Towers A and B rise with uniform floorplates to Levels 30 and 39, respectively, where the floorplates set back from the east, before being completed by a mechanical penthouse, above.

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 a sparse mixture of low- and mid-rise buildings with surface parking in most directions, combined with the taller Landmark Place (43-storeys) to the north, and 154 Main Street East (25-storeys) to the east. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer radius) comprise predominantly suburban exposure in all directions, transitioning to hybrid suburban-urban exposure to the west. Approximately 900 metres to the south is the Niagara Escarpment.

Grade-level areas investigated include sidewalks, laneways, parking areas, transit stops, existing patios, and building access points. Wind comfort is also evaluated over the Levels 4 and 5 outdoor amenity terraces. Figures 1A and 1B illustrate the study site and surrounding context for the existing and future test scenarios, respectively, and Photographs 1 through 6 depict the wind tunnel model used to conduct the study.

3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind comfort and safety conditions at key areas within and surrounding the development site; (ii) identify areas where wind conditions may interfere with the intended uses of outdoor spaces; (iii) recommend suitable mitigation measures, where required; and (iv) evaluate the influence of the proposed development on the existing wind conditions surrounding the site.

4. METHODOLOGY

The approach followed to quantify pedestrian wind conditions over the site is based on wind tunnel measurements of wind speeds at selected locations on a reduced-scale physical model, meteorological analysis of the Hamilton area wind climate and synthesis of wind tunnel data with industry-accepted guidelines. The following sections describe the analysis procedures, including a discussion of the pedestrian comfort and safety guidelines.

4.1 Wind Tunnel Context Modelling

A detailed PLW study is performed to determine the influence of local winds at the pedestrian level for a proposed development. The physical model of the proposed development and relevant surroundings, illustrated in Photographs 1 through 6 following the main text, was constructed at a scale of 1:400. The wind tunnel model includes all existing buildings and approved future developments within a full-scale diameter of approximately 840 metres. The general concept and approach to wind tunnel modelling is to provide building and topographic detail in the immediate vicinity of the study site on the surrounding model, and to rely on a length of wind tunnel upwind of the model to develop wind properties consistent with known turbulent intensity profiles that represent the surrounding terrain.

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 study was performed by testing a total of 73 sensor locations on the scale model in Gradient Wind's wind tunnel. Of these 73 sensors, 60 were located at grade and the remaining 13 sensors were located over the elevated amenity terraces. Wind speed measurements were performed for each of the 73 sensors for 36 wind directions at 10° intervals. Figures 1A and 1B illustrate a plan of the site and relevant surrounding context for the existing and future test scenarios, respectively, while sensor locations used to investigate wind conditions are illustrated in Figures 2A through 3B.

Mean and peak wind speed values for each location and wind direction were calculated from real-time pressure measurements, recorded at a sample rate of 500 samples per second, and taken over a 60-second time period. This period at model-scale corresponds approximately to one hour in full-scale, which matches the time frame of full-scale meteorological observations. Measured mean and gust wind speeds at grade were referenced to the wind speed measured near the ceiling of the wind tunnel to generate mean and peak wind speed ratios. Ceiling height in the wind tunnel represents the depth of the boundary layer of wind flowing over the earth's surface, referred to as the gradient height. Within this boundary layer, mean wind speed increases up to the gradient height and remains constant thereafter. Appendices

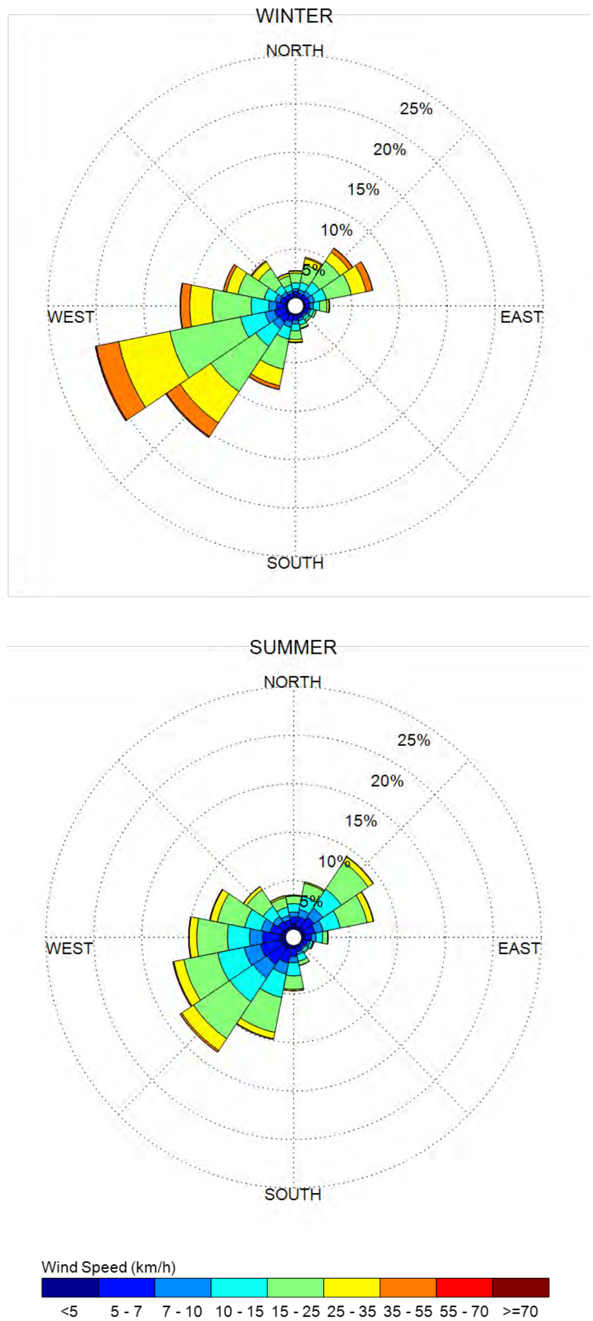
C and D provide greater detail of the theory behind wind speed measurements. Wind tunnel measurements for this project, conducted in Gradient Wind's wind tunnel facility, meet or exceed guidelines found in the National Building Code of Canada 2015 and of 'Wind Tunnel Studies of Buildings and Structures', ASCE Manual 7 Reports on Engineering Practice No 67.

4.3 Meteorological Data Analysis

A statistical model for winds in Hamilton was developed from approximately 40-years of hourly meteorological wind data recorded at John C. Munro Hamilton 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. Following the Terms of Reference: Pedestrian Level Wind Study for Downtown Hamilton, the year is represented by a two-season model, and not according to the traditional calendar method.

The statistical model of the Hamilton 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 Hamilton, the most common winds concerning pedestrian comfort occur from the southwest, followed by those from the northeast. The directional preference and relative magnitude of the wind speed varies somewhat from season to season, with the summer months displaying calmer winds relative to the winter.

SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES
JOHN C. MUNRO HAMILTON INTERNATIONAL AIRPORT, HAMILTON, ONTARIO



Notes:

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

4.4 Pedestrian Comfort and Safety Guidelines

Pedestrian comfort and safety guidelines are based on the mechanical effects of wind without consideration of other meteorological conditions (i.e. temperature, relative humidity). The comfort guidelines assume that pedestrians are appropriately dressed for a specified outdoor activity during any given season. Since both mean and gust wind speeds affect pedestrian comfort, their combined effect is defined in the Terms of Reference: Pedestrian Level Wind Study for Downtown Hamilton. More specifically, the criteria are defined as a Gust Equivalent Mean (GEM) wind speed, which is the greater of the mean wind speed or the gust wind speed divided by 1.85. The wind speed ranges are selected based on 'The Beaufort Scale' (presented on the following page), which describes the effects of forces produced by varying wind speed levels on objects.

Five pedestrian comfort classes and corresponding GEM wind speed ranges are used to assess pedestrian comfort, which include: (i) Sitting; (ii) Standing; (iii) Strolling; (iii) Walking; and (iv) Uncomfortable. More specifically, the comfort classes, wind speed ranges, and limiting criteria are summarized as follows:

(i) **Sitting** – GEM wind speeds below 10 km/h occurring more than 80% of the time would be considered acceptable for sedentary activities, including sitting.

(ii) **Standing** – GEM wind speeds below 14 km/h (i.e. 10-14 km/h) occurring more than 80% of the time are acceptable for standing.

(iii) **Strolling** – GEM wind speeds below 17 km/h (i.e. 14-17 km/h) occurring more than 80% of the time are acceptable for strolling.

(iv) **Walking** – GEM wind speeds below 20 km/h (i.e. 17-20 km/h) occurring more than 80% of the time are acceptable for walking or more vigorous activities.

(v) **Uncomfortable** – Uncomfortable conditions are characterized by predicted values that fall below the 80% criterion for walking. Brisk walking and exercise, such as jogging, would be acceptable for moderate excesses of this criterion.

Gust wind speeds greater than 90 km/h, occurring more than 0.1% of the time on an annual basis, 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 a vulnerable member of the population to fall.

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 GEM wind speeds of 10 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 GEM wind speeds of 20 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
Primary Building Entrance	Standing
Secondary Building Access Point	Walking
Public Sidewalks / Pedestrian Walkways	Strolling / Walking
Outdoor Amenity Spaces	Sitting / Standing
Cafés / Patios / Benches / Gardens	Sitting / Standing
Plazas	Strolling
Transit Stops	Standing
Public Parks	Strolling
Garage / Service Entrances	Walking
Vehicular Drop-Off Zones	Walking
Laneways / Loading Zones	Walking

Following the comparison, the location is assigned a descriptor that indicates the suitability of the location for its intended use. The suitability descriptors are summarized as follows:

- **Acceptable**: The predicted wind conditions are suitable for the intended uses of the associated outdoor spaces without the need for mitigation.
- **Acceptable with Mitigation**: The predicted wind conditions are not acceptable for the intended use of a space; however, following the implementation of typical mitigation measures, the wind conditions are expected to satisfy the required comfort guidelines.
- **Mitigation Testing Recommended**: The effectiveness of typical mitigation measures is uncertain, and additional wind tunnel testing is recommended to explore other options and to ensure compliance with the comfort guidelines.
- **Incompatible**: The predicted wind conditions will interfere with the comfortable and/or safe use of a space and cannot be feasibly mitigated to acceptable levels.

5. RESULTS AND DISCUSSION

5.1 Pedestrian Comfort Suitability – Future Conditions

Tables A1 through A3 in Appendix A provide a summary of seasonal comfort predictions for each sensor location under the future massing scenario considering the study building and all approved surrounding developments. The tables indicate the 80% non-exceedance gust wind speeds and corresponding comfort classifications as defined in Section 4.4. In other words, a gust wind speed threshold of 12.1 for the summer season indicates that 80% of the measured data falls at or below 12.1 km/h during the summer months and conditions are therefore suitable for standing, as the 80% threshold value falls within the exceedance range of 10-14 km/h for standing. The tables include the predicted threshold values for each sensor location during each season, accompanied by the corresponding predicted comfort class (i.e. sitting, standing, strolling, etc.).

The most significant findings of the PLW are summarized in the Section 5.2. To assist with understanding and interpretation, predicted conditions for the proposed development are also illustrated in colour-coded format in Figures 2A through 3B. Conditions suitable for sitting are represented by the colour green, while standing is represented by yellow, strolling by orange, walking by blue, and conditions uncomfortable for walking by magenta. Measured mean and gust velocity ratios, which constitutes the raw data upon which the results are based, will be made available upon request.

5.2 Summary of Findings – Future Conditions

Based on the analysis of the measured data, consideration of local climate data, and the suitability descriptors provided in Tables A1-A3 in Appendix A, this section summarizes the most significant findings of the PLW study with respect to future conditions, as follows:

1. All public sidewalks within and surrounding the development will be comfortable for walking or better on a seasonal basis, which is acceptable.
2. Most laneways and surface parking within and surrounding the development will be comfortable for walking or better throughout the year, which is acceptable. Exceptions are a portion of laneway along the north elevation of the study building (Sensor 39), as well as a portion of surface parking to the east (Sensor 6), which become uncomfortable for walking on a limited basis during

the winter months. As these locations are not expected to see frequent pedestrian traffic, are isolated, and wind speeds are considered safe (See "Pedestrian Safety" under Tables A1-A3 in the appendices), these conditions are considered acceptable, without the need for mitigation.

3. All primary and secondary building access points are expected to be comfortable for standing or better and walking or better, respectively, throughout the year, which is appropriate for the intended uses of the spaces. Although wind speeds over sidewalks along the south elevation exceed the standing criterion during the winter months, nearby retail entrances (Sensors 48 & 55) are recessed within the building façade, affording locally-calmer conditions.

4. The existing patios fronting Walnut Street South (Sensor 7) and Catherine Street South (Sensor 30) will continue to be comfortable for sitting during the summer months, which is acceptable.

5. The transit stop at the southwest corner of the intersection of Main Street East and Catherine Street South (Sensor 32) will be comfortable for standing or better throughout the year, which is acceptable.

6. The Level 4 outdoor amenity terrace along the south elevation, between the towers (Sensors 61 & 62), will be comfortable for a mix of sitting and standing during the summer months, with the calmer conditions over the east side of the terrace (Sensor 62). To ensure conditions comfortable for sitting or more sedentary activities throughout the summer months, it is recommended to raise the perimeter guards along the south elevation to 1.8 metres above the walking surface.

7. The Level 4 outdoor amenity along the north and east ends of the podium rooftop (Sensors 63-68) will generally not achieve the sitting criterion during the summer months. To ensure conditions over the entire terrace are comfortable for sitting or more sedentary activities throughout the summer months, a combination of perimeter wind barriers and canopies are recommended. Wind barriers are recommended to a height of 2.0 metres along the entire perimeter of the amenity, and canopy or pergola structures should extend 2.0 metres from the east and north Tower B facades, over the space.

8. The Level 5 amenity terrace (Sensors 69-73) will be comfortable for a mix of sitting, standing, and walking during the summer months, with the windier conditions occurring near the northwest corner of Tower B (Sensor 69). To ensure conditions throughout the terrace are comfortable for sitting or more sedentary activities during the summer months, it is recommended to provide a

2.0-metre-height wind barrier along the full perimeter of the terrace, as well as canopy or pergola structures extending 2.0 metres from the adjacent tower facades, wrapping around the northeast and northwest corners of Tower A and Tower B, respectively.

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.

5.3 Pedestrian Comfort Suitability – Existing Versus Future Conditions

To evaluate the influence of the study building on existing wind conditions at and near the study site, an additional pedestrian level wind test was performed for the existing site massing without the study building present. A comparison of wind comfort results for the existing and future configurations is provided in Tables B1 to B4 in Appendix B, which provide a summary of the comparative wind comfort predictions based on annually-averaged wind statistics. The future and existing massing scenarios are shown in Photographs 1 through 6 following the main text.

Pedestrian wind comfort resulting from the construction of the study building and future surrounding developments may be described as being *unchanged*, *improved*, or *reduced* as compared to the existing conditions. These designations are not strictly determined by the predicted percentage values, rather by the change to the predicted comfort class.

A review of Tables B1 to B4 indicates that the introduction of the proposed development will have a mixed impact on wind comfort over the surrounding grade-level areas. Reductions in wind comfort are concentrated around the southeast corner of the study building (Sensors 44-49), extending east to Walnut Street South (Sensors 4-7 & 10-13), along the west end of the north elevation (Sensors 36-37 & 39-41), to the south of Jackson Street East (Sensors 16 & 20), and over sidewalks on the west side of Catherine Street South (Sensors 29 & 30). Improvements in wind comfort are concentrated over sidewalks near the west end of the south elevation (Sensors 18, 21, 51, 54, 57, & 58), and along the east end of the north elevation (Sensors 42 & 43), while elsewhere conditions remain generally unchanged. Where wind speeds increase, conditions nevertheless remain acceptable for the intended uses.

6. CONCLUSIONS AND RECOMMENDATIONS

This report summarizes the methodology, results, and recommendations related to a pedestrian level wind study for a proposed mixed-use development located at 117 Jackson Street East in Hamilton, Ontario. The study was performed in accordance with industry standard wind tunnel testing and data analysis procedures.

A complete summary of the predicted wind conditions is provided in Section 5.2 of this report, and is also illustrated in Figures 2A-3B, as well as Tables A1-A3 and B1-B4 in the appendices. Based on wind tunnel test results, meteorological data analysis, and experience with similar developments in the area, we conclude that conditions over all pedestrian-sensitive areas within and surrounding the development site will be acceptable for the intended pedestrian uses on an annual and seasonal basis. Over amenity terraces at Levels 4 and 5, to ensure conditions comfortable for sitting or more sedentary activities throughout the terraces during the summer months, mitigation is recommended, as described in Section 5.2.

A comparison of the existing versus future wind comfort surrounding the study site indicates that the proposed development will have a mixed impact on grade-level wind comfort. Reductions in comfort occur to the southeast, along the west end of the north elevation, to the south of Jackson Street east, and over sidewalks along the west side of Catherine Street South, while improvements occur along the east end of the north elevation and west end of the south elevation, with conditions generally unchanged elsewhere. Where wind speeds increase, conditions nevertheless remain acceptable for the intended uses.

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 could be considered unsafe.

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

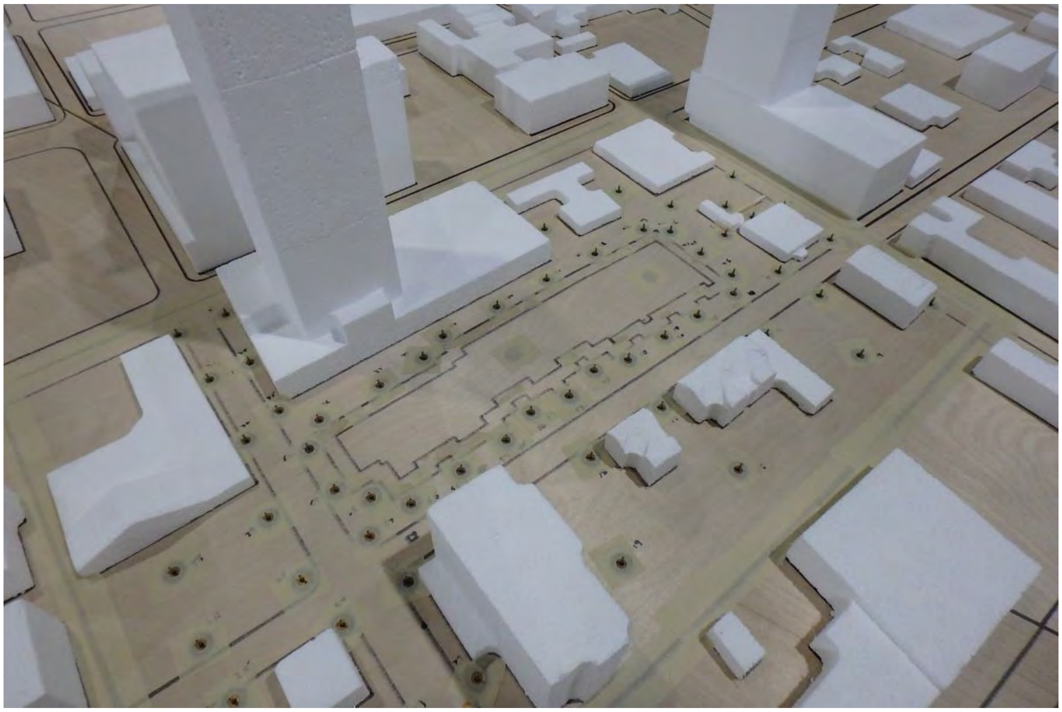
Sincerely,

Gradient Wind Engineering Inc.

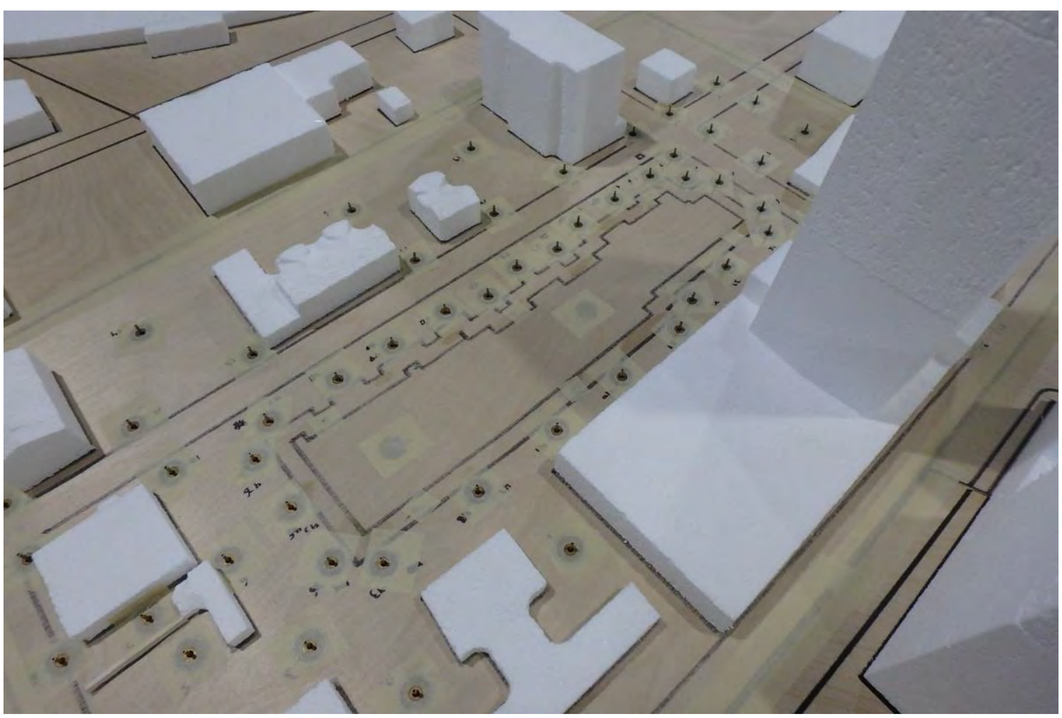
Patrick Shorey, B.A.Sc., EIT
Junior Wind Scientist

Andrew Sliasas, M.A.Sc., P.Eng.
Principal

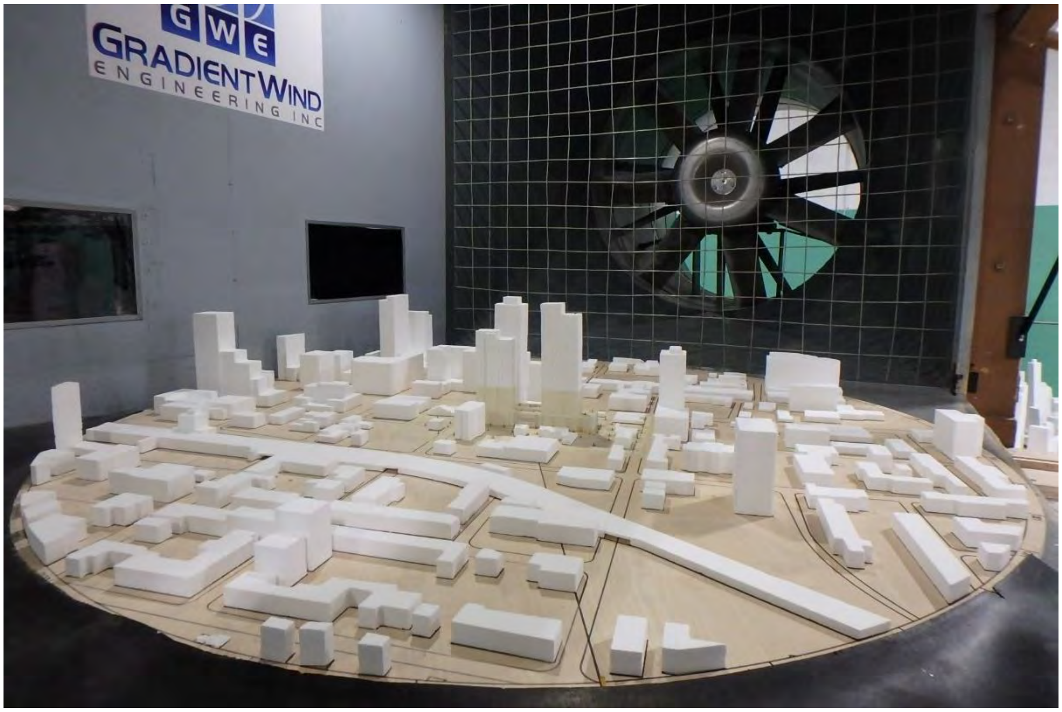
GWE21-430-WTPLW



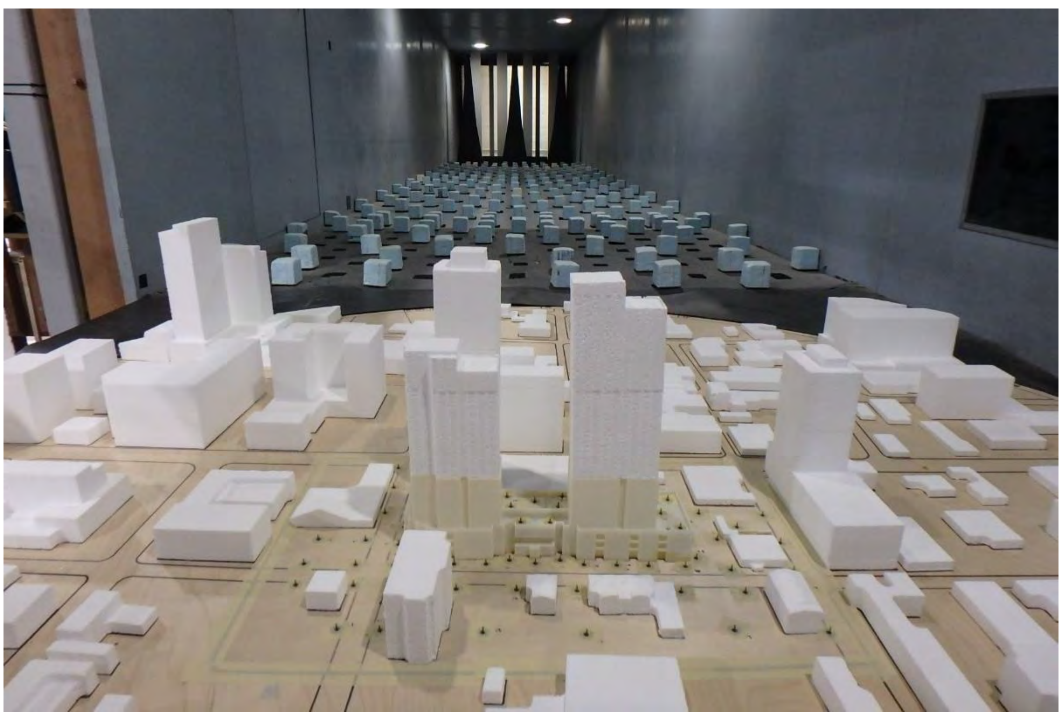
PHOTOGRAPH 1: CLOSE-UP VIEW OF EXISTING CONTEXT MODEL LOOKING NORTHEAST



PHOTOGRAPH 2: CLOSE-UP VIEW OF EXISTING CONTEXT MODEL LOOKING SOUTHWEST

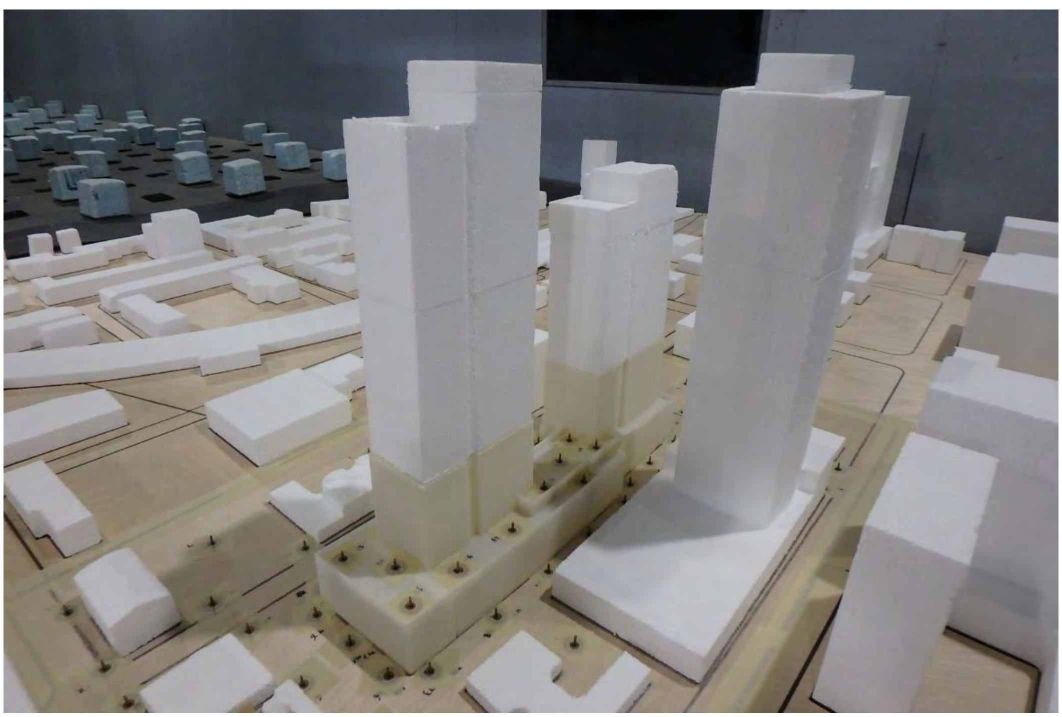


PHOTOGRAPH 3: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING DOWNWIND



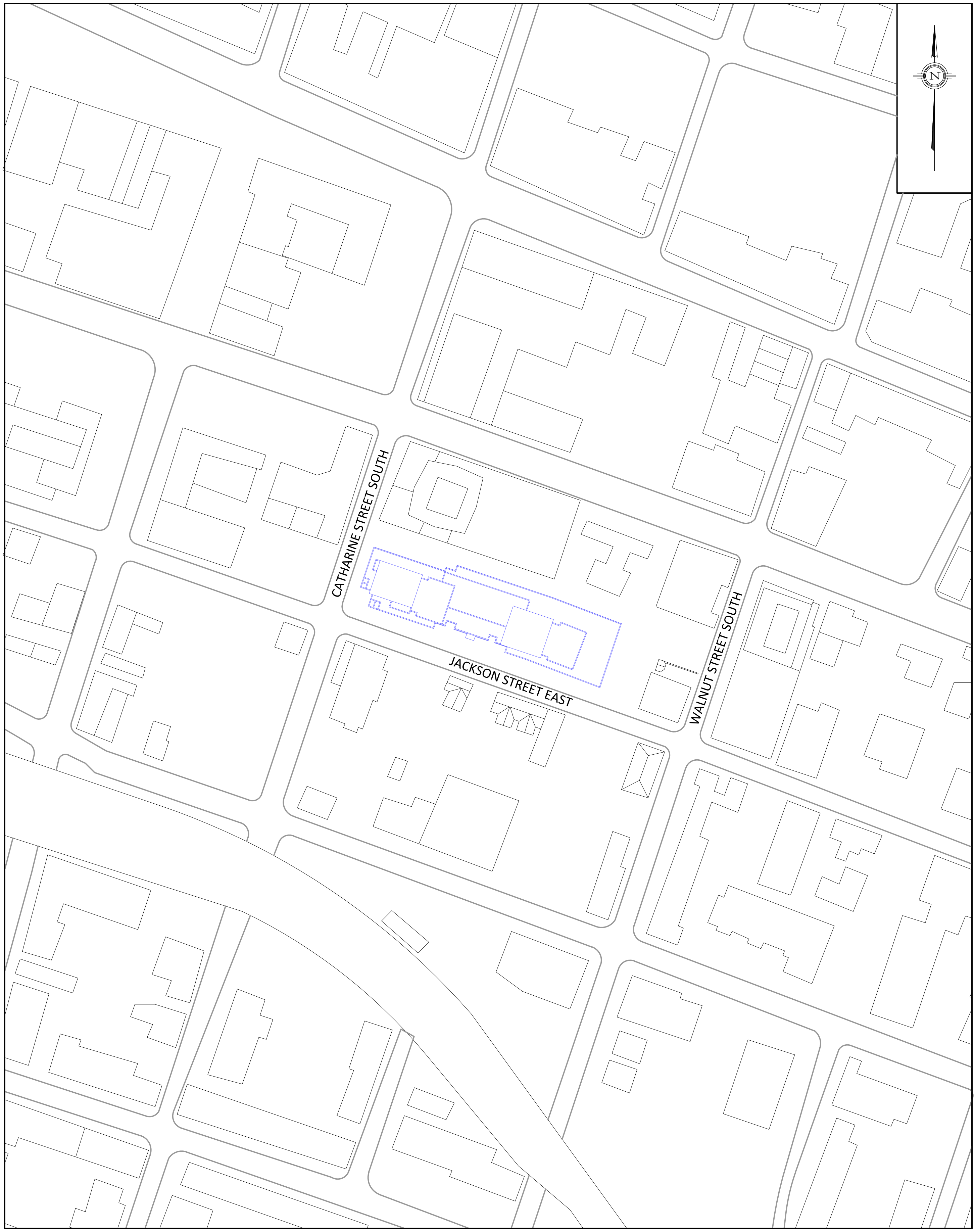
PHOTOGRAPH 4: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING UPWIND

PHOTOGRAPH 5: CLOSE-UP VIEW OF STUDY MODEL LOOKING NORTHEAST



PHOTOGRAPH 6: CLOSE-UP VIEW OF STUDY MODEL LOOKING SOUTHWEST

GRADIENTWIND ENGINEERS & SCIENTISTS 127 WALGREEN ROAD, OTTAWA, ON 613 836 0934 • GRADIENTWIND.COM	PROJECT: 117 JACKSON STREET EAST, HAMILTON PEDESTRIAN LEVEL WIND STUDY	DESCRIPTION: FIGURE 1A: SITE PLAN AND SURROUNDING CONTEXT EXISTING TEST SCENARIO
	SCALE: 1:2500 (APPROX.)	DRAWING NO. GW21-430-PLW-1A
	DATE: JANUARY 21, 2022	DRAWN BY: C.E.



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PROJECT	117 JACKSON STREET EAST, HAMILTON PEDESTRIAN LEVEL WIND STUDY
SCALE	1:2500 (APPROX.)
DRAWING NO.	GW21-430-PLW-1B
DATE	JANUARY 21, 2022
DRAWN BY	C.E.
DESCRIPTION	FIGURE 1B: SITE PLAN AND SURROUNDING CONTEXT FUTURE TEST SCENARIO

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PROJECT	117 JACKSON STREET EAST, HAMILTON PEDESTRIAN LEVEL WIND STUDY
SCALE	1:1200 (APPROX.)
DRAWING NO.	GW21-430-PLW-2A
DATE	JANUARY 21, 2022
DRAWN BY	C.E.
DESCRIPTION	FIGURE 2A: SUMMER GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS

PREDICTED COMFORT CLASSES	# (green)	SITTING
	# (yellow)	STANDING
	# (orange)	STROLLING
	# (blue)	WALKING
	# (pink)	UNCOMFORTABLE

NOTES:

1. SCALE IS APPROXIMATE.
2. # PEDESTRIAN LEVEL WIND SENSOR LOCATION.

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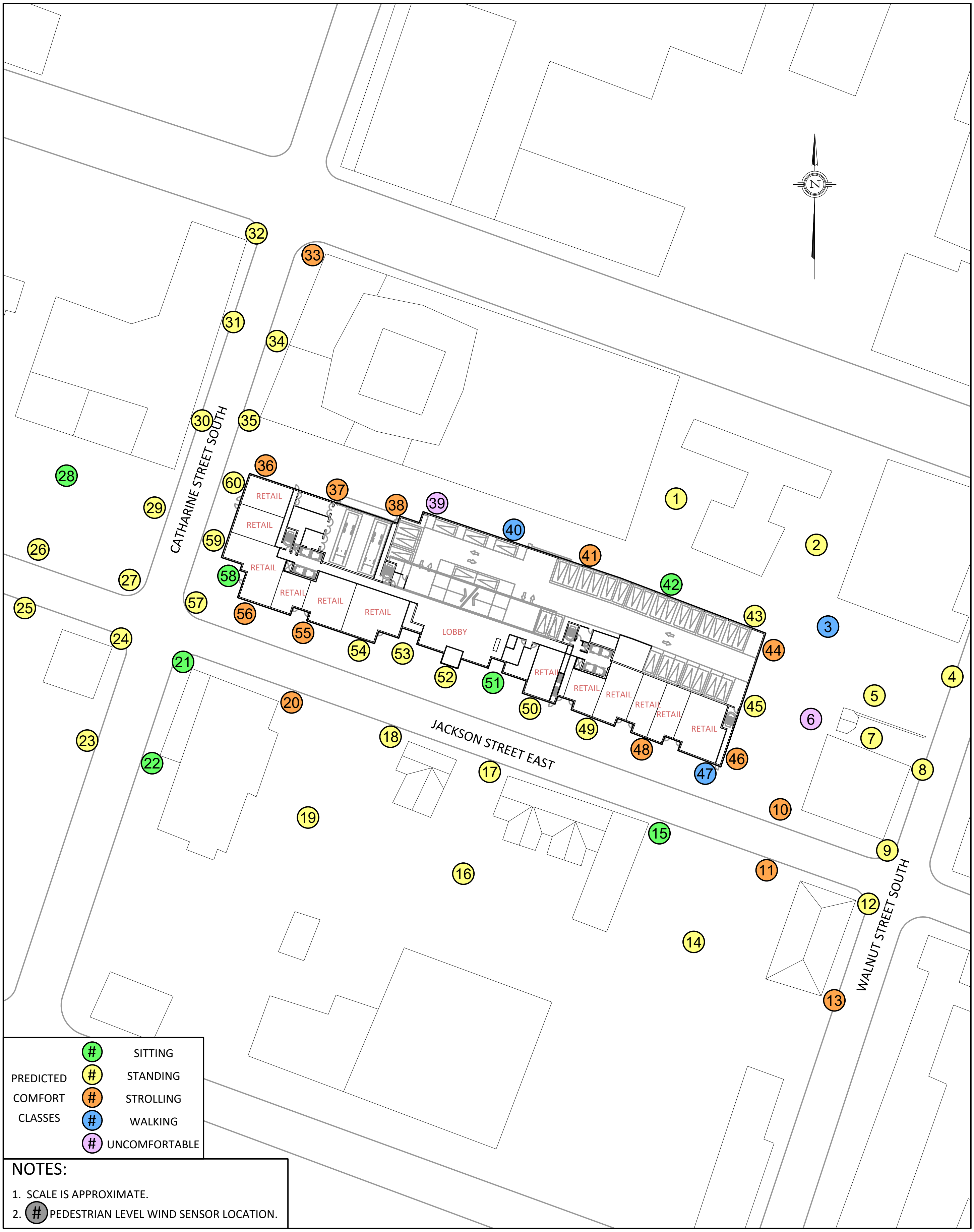
PROJECT	117 JACKSON STREET EAST, HAMILTON PEDESTRIAN LEVEL WIND STUDY
SCALE	1:700 (APPROX.)
DRAWING NO.	GW21-430-PLW-2B
DATE	JANUARY 21, 2022
DRAWN BY	C.E.
DESCRIPTION	FIGURE 2B: SUMMER LEVEL 4 & 5 AMENITY TERRACES PEDESTRIAN COMFORT PREDICTIONS



PREDICTED COMFORT CLASSES

- # SITTING
- # STANDING
- # STROLLING
- # WALKING
- # UNCOMFORTABLE

NOTES:

1. SCALE IS APPROXIMATE.
2. # PEDESTRIAN LEVEL WIND SENSOR LOCATION.

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PROJECT	117 JACKSON STREET EAST, HAMILTON PEDESTRIAN LEVEL WIND STUDY
SCALE	1:1200 (APPROX.)
DRAWING NO.	GW21-430-PLW-3A
DATE	JANUARY 21, 2022
DRAWN BY	C.E.
DESCRIPTION	FIGURE 3A: WINTER GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS

PREDICTED COMFORT CLASSES	
# (green)	SITTING
# (yellow)	STANDING
# (orange)	STROLLING
# (blue)	WALKING
# (violet)	UNCOMFORTABLE

NOTES:

1. SCALE IS APPROXIMATE.
2. # PEDESTRIAN LEVEL WIND SENSOR LOCATION.

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PROJECT	117 JACKSON STREET EAST, HAMILTON PEDESTRIAN LEVEL WIND STUDY
SCALE	1:700 (APPROX.)
DRAWING NO.	GW21-430-PLW-3B
DATE	JANUARY 21, 2022
DRAWN BY	C.E.
DESCRIPTION	FIGURE 3B: WINTER LEVEL 4 & 5 AMENITY TERRACES PEDESTRIAN COMFORT PREDICTIONS

APPENDIX A

PEDESTRIAN COMFORT SUITABILITY, TABLES A1-A3
(FUTURE CONDITIONS)

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Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-10 km/h = Sitting, 10-14 km/h = Standing, 14-17 km/h = Strolling, 17-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE A1: SUMMARY OF PEDESTRIAN COMFORT (FUTURE CONDITIONS)

Sensor	Pedestrian Comfort				Pedestrian Safety	
	Summer		Winter		Annual	
	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Safety Class
1	8.6	Sitting	11.3	Standing	45.7	Safe
2	8.6	Sitting	10.8	Standing	50.1	Safe
3	13.1	Standing	17.1	Walking	69.2	Safe
4	10.7	Standing	13.9	Standing	51.9	Safe
5	9.7	Sitting	12.9	Standing	55.4	Safe
6	16.0	Strolling	22.0	Uncomfortable	81.0	Safe
7	8.9	Sitting	11.9	Standing	50.1	Safe
8	9.7	Sitting	13.0	Standing	52.2	Safe
9	9.1	Sitting	12.0	Standing	41.0	Safe
10	12.0	Standing	15.6	Strolling	55.6	Safe
11	11.2	Standing	14.5	Strolling	51.6	Safe
12	10.0	Standing	12.9	Standing	50.0	Safe
13	11.2	Standing	15.4	Strolling	57.4	Safe
14	9.2	Sitting	11.8	Standing	52.2	Safe
15	7.2	Sitting	9.0	Sitting	44.0	Safe
16	9.1	Sitting	12.3	Standing	51.9	Safe
17	8.5	Sitting	11.0	Standing	43.8	Safe
18	9.6	Sitting	12.7	Standing	45.3	Safe
19	9.5	Sitting	12.2	Standing	53.8	Safe
20	11.9	Standing	15.8	Strolling	56.6	Safe
21	7.3	Sitting	9.8	Sitting	35.1	Safe
22	6.7	Sitting	8.8	Sitting	37.4	Safe
23	7.9	Sitting	10.0	Standing	39.0	Safe
24	8.4	Sitting	10.6	Standing	39.0	Safe
25	8.0	Sitting	10.1	Standing	44.8	Safe
26	8.2	Sitting	10.6	Standing	43.4	Safe
27	8.6	Sitting	10.6	Standing	43.1	Safe
28	7.2	Sitting	9.0	Sitting	39.0	Safe
29	10.7	Standing	13.2	Standing	54.1	Safe
30	10.0	Sitting	12.3	Standing	49.6	Safe
31	9.7	Sitting	12.3	Standing	50.2	Safe
32	9.4	Sitting	12.3	Standing	48.2	Safe
33	10.6	Standing	15.2	Strolling	66.7	Safe
34	8.7	Sitting	11.6	Standing	51.0	Safe
35	11.0	Standing	13.9	Standing	55.3	Safe

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-10 km/h = Sitting, 10-14 km/h = Standing, 14-17 km/h = Strolling, 17-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE A2: SUMMARY OF PEDESTRIAN COMFORT (FUTURE CONDITONS)

Sensor	Pedestrian Comfort				Pedestrian Safety	
	Summer		Winter		Annual	
	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Safety Class
36	11.4	Standing	15.7	Strolling	64.1	Safe
37	11.6	Standing	15.8	Strolling	62.7	Safe
38	12.0	Standing	16.5	Strolling	62.6	Safe
39	16.4	Strolling	22.6	Uncomfortable	75.0	Safe
40	11.9	Standing	17.0	Walking	64.4	Safe
41	10.6	Standing	15.1	Strolling	59.3	Safe
42	7.5	Sitting	9.9	Sitting	43.7	Safe
43	8.5	Sitting	11.3	Standing	47.5	Safe
44	11.7	Standing	14.8	Strolling	60.2	Safe
45	10.3	Standing	13.3	Standing	53.4	Safe
46	11.8	Standing	14.5	Strolling	67.1	Safe
47	12.9	Standing	18.4	Walking	74.7	Safe
48	9.9	Sitting	14.2	Strolling	54.7	Safe
49	8.4	Sitting	11.1	Standing	49.0	Safe
50	9.0	Sitting	12.1	Standing	45.5	Safe
51	7.6	Sitting	9.8	Sitting	35.5	Safe
52	8.8	Sitting	11.3	Standing	40.4	Safe
53	7.8	Sitting	10.3	Standing	37.1	Safe
54	9.6	Sitting	13.2	Standing	46.9	Safe
55	10.3	Standing	14.5	Strolling	51.4	Safe
56	10.7	Standing	14.0	Strolling	50.0	Safe
57	10.8	Standing	13.8	Standing	48.4	Safe
58	6.5	Sitting	8.4	Sitting	31.2	Safe
59	8.2	Sitting	10.4	Standing	42.7	Safe
60	9.9	Sitting	12.9	Standing	55.0	Safe
61	10.4	Standing	14.9	Strolling	69.1	Safe
62	8.7	Sitting	11.1	Standing	49.4	Safe
63	18.1	Walking	24.6	Uncomfortable	82.1	Safe
64	12.6	Standing	15.0	Strolling	69.4	Safe
65	14.5	Strolling	17.8	Walking	66.4	Safe
66	10.5	Standing	13.9	Standing	54.1	Safe
67	7.2	Sitting	9.5	Sitting	39.0	Safe
68	15.3	Strolling	21.1	Uncomfortable	87.1	Safe
69	18.8	Walking	25.4	Uncomfortable	81.2	Safe
70	14.0	Standing	17.5	Walking	84.5	Safe

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-10 km/h = Sitting, 10-14 km/h = Standing, 14-17 km/h = Strolling, 17-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE A3: SUMMARY OF PEDESTRIAN COMFORT (FUTURE CONDITONS)

Sensor	Pedestrian Comfort				Pedestrian Safety	
	Summer		Winter		Annual	
	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Safety Class
71	13.3	Standing	16.6	Strolling	63.4	Safe
72	9.4	Sitting	11.7	Standing	48.2	Safe
73	10.1	Standing	12.7	Standing	49.6	Safe

APPENDIX B

PEDESTRIAN COMFORT SUITABILITY, TABLES B1-B4
(EXISTING VS FUTURE CONDITIONS)

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Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-10 km/h = Sitting, 10-14 km/h = Standing, 14-17 km/h = Strolling, 17-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE B1: COMPARATIVE SUMMARY OF PEDESTRIAN COMFORT

Sensor	Massing Scenario	Summer Pedestrian Comfort			Winter Pedestrian Comfort		
		Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing	Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing
1	Existing	7.8	Sitting	-	10.1	Standing	-
	Future	8.6	Sitting	Unchanged	11.3	Standing	Unchanged
2	Existing	9.5	Sitting	-	12.2	Standing	-
	Future	8.6	Sitting	Unchanged	10.8	Standing	Unchanged
3	Existing	7.5	Sitting	-	9.6	Sitting	-
	Future	13.1	Standing	Reduced	17.1	Walking	Reduced
4	Existing	9.1	Sitting	-	12.2	Standing	-
	Future	10.7	Standing	Reduced	13.9	Standing	Unchanged
5	Existing	6.4	Sitting	-	8.4	Sitting	-
	Future	9.7	Sitting	Unchanged	12.9	Standing	Reduced
6	Existing	8.1	Sitting	-	10.3	Standing	-
	Future	16.0	Strolling	Reduced	22.0	Uncomfortable	Reduced
7	Existing	6.7	Sitting	-	8.7	Sitting	-
	Future	8.9	Sitting	Unchanged	11.9	Standing	Reduced
8	Existing	8.0	Sitting	-	10.6	Standing	-
	Future	9.7	Sitting	Unchanged	13.0	Standing	Unchanged
9	Existing	8.5	Sitting	-	11.4	Standing	-
	Future	9.1	Sitting	Unchanged	12.0	Standing	Unchanged
10	Existing	8.3	Sitting	-	10.8	Standing	-
	Future	12.0	Standing	Reduced	15.6	Strolling	Reduced
11	Existing	8.6	Sitting	-	11.5	Standing	-
	Future	11.2	Standing	Reduced	14.5	Strolling	Reduced
12	Existing	7.8	Sitting	-	10.1	Standing	-
	Future	10.0	Standing	Reduced	12.9	Standing	Unchanged
13	Existing	8.8	Sitting	-	12.4	Standing	-
	Future	11.2	Standing	Reduced	15.4	Strolling	Reduced
14	Existing	8.2	Sitting	-	10.4	Standing	-
	Future	9.2	Sitting	Unchanged	11.8	Standing	Unchanged
15	Existing	7.6	Sitting	-	9.4	Sitting	-
	Future	7.2	Sitting	Unchanged	9.0	Sitting	Unchanged

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-10 km/h = Sitting, 10-14 km/h = Standing, 14-17 km/h = Strolling, 17-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE B2: COMPARATIVE SUMMARY OF PEDESTRIAN COMFORT

Sensor	Massing Scenario	Summer Pedestrian Comfort			Winter Pedestrian Comfort		
		Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing	Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing
16	Existing	7.1	Sitting	-	9.7	Sitting	-
	Future	9.1	Sitting	Unchanged	12.3	Standing	Reduced
17	Existing	8.4	Sitting	-	10.8	Standing	-
	Future	8.5	Sitting	Unchanged	11.0	Standing	Unchanged
18	Existing	10.5	Standing	-	13.4	Standing	-
	Future	9.6	Sitting	Improved	12.7	Standing	Unchanged
19	Existing	9.5	Sitting	-	12.4	Standing	-
	Future	9.5	Sitting	Unchanged	12.2	Standing	Unchanged
20	Existing	8.7	Sitting	-	11.3	Standing	-
	Future	11.9	Standing	Reduced	15.8	Strolling	Reduced
21	Existing	9.4	Sitting	-	12.4	Standing	-
	Future	7.3	Sitting	Unchanged	9.8	Sitting	Improved
22	Existing	6.4	Sitting	-	8.4	Sitting	-
	Future	6.7	Sitting	Unchanged	8.8	Sitting	Unchanged
23	Existing	8.4	Sitting	-	10.7	Standing	-
	Future	7.9	Sitting	Unchanged	10.0	Standing	Unchanged
24	Existing	8.2	Sitting	-	10.6	Standing	-
	Future	8.4	Sitting	Unchanged	10.6	Standing	Unchanged
25	Existing	8.6	Sitting	-	11.1	Standing	-
	Future	8.0	Sitting	Unchanged	10.1	Standing	Unchanged
26	Existing	8.3	Sitting	-	11.5	Standing	-
	Future	8.2	Sitting	Unchanged	10.6	Standing	Unchanged
27	Existing	7.8	Sitting	-	10.2	Standing	-
	Future	8.6	Sitting	Unchanged	10.6	Standing	Unchanged
28	Existing	6.0	Sitting	-	7.8	Sitting	-
	Future	7.2	Sitting	Unchanged	9.0	Sitting	Unchanged
29	Existing	7.2	Sitting	-	9.2	Sitting	-
	Future	10.7	Standing	Reduced	13.2	Standing	Reduced
30	Existing	7.8	Sitting	-	9.7	Sitting	-
	Future	10.0	Sitting	Unchanged	12.3	Standing	Reduced

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-10 km/h = Sitting, 10-14 km/h = Standing, 14-17 km/h = Strolling, 17-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE B3: COMPARATIVE SUMMARY OF PEDESTRIAN COMFORT

Sensor	Massing Scenario	Summer Pedestrian Comfort			Winter Pedestrian Comfort		
		Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing	Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing
31	Existing	9.0	Sitting	-	11.6	Standing	-
	Future	9.7	Sitting	Unchanged	12.3	Standing	Unchanged
32	Existing	8.8	Sitting	-	11.4	Standing	-
	Future	9.4	Sitting	Unchanged	12.3	Standing	Unchanged
33	Existing	10.8	Standing	-	14.9	Strolling	-
	Future	10.6	Standing	Unchanged	15.2	Strolling	Unchanged
34	Existing	9.0	Sitting	-	11.3	Standing	-
	Future	8.7	Sitting	Unchanged	11.6	Standing	Unchanged
35	Existing	10.6	Standing	-	13.0	Standing	-
	Future	11.0	Standing	Unchanged	13.9	Standing	Unchanged
36	Existing	8.6	Sitting	-	10.8	Standing	-
	Future	11.4	Standing	Reduced	15.7	Strolling	Reduced
37	Existing	10.8	Standing	-	14.0	Standing	-
	Future	11.6	Standing	Unchanged	15.8	Strolling	Reduced
38	Existing	12.3	Standing	-	16.7	Strolling	-
	Future	12.0	Standing	Unchanged	16.5	Strolling	Unchanged
39	Existing	12.2	Standing	-	16.7	Strolling	-
	Future	16.4	Strolling	Reduced	22.6	Uncomfortable	Reduced
40	Existing	12.4	Standing	-	16.6	Strolling	-
	Future	11.9	Standing	Unchanged	17.0	Walking	Reduced
41	Existing	10.0	Sitting	-	13.5	Standing	-
	Future	10.6	Standing	Reduced	15.1	Strolling	Reduced
42	Existing	8.9	Sitting	-	11.7	Standing	-
	Future	7.5	Sitting	Unchanged	9.9	Sitting	Improved
43	Existing	10.1	Standing	-	13.1	Standing	-
	Future	8.5	Sitting	Improved	11.3	Standing	Unchanged
44	Existing	9.9	Sitting	-	12.8	Standing	-
	Future	11.7	Standing	Reduced	14.8	Strolling	Reduced
45	Existing	9.9	Sitting	-	12.5	Standing	-
	Future	10.3	Standing	Reduced	13.3	Standing	Unchanged

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-10 km/h = Sitting, 10-14 km/h = Standing, 14-17 km/h = Strolling, 17-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE B4: COMPARATIVE SUMMARY OF PEDESTRIAN COMFORT

Sensor	Massing Scenario	Summer Pedestrian Comfort			Winter Pedestrian Comfort		
		Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing	Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing
46	Existing	9.3	Sitting	-	11.7	Standing	-
	Future	11.8	Standing	Reduced	14.5	Strolling	Reduced
47	Existing	8.0	Sitting	-	10.0	Standing	-
	Future	12.9	Standing	Reduced	18.4	Walking	Reduced
48	Existing	7.4	Sitting	-	9.9	Sitting	-
	Future	9.9	Sitting	Unchanged	14.2	Strolling	Reduced
49	Existing	6.8	Sitting	-	8.9	Sitting	-
	Future	8.4	Sitting	Unchanged	11.1	Standing	Reduced
50	Existing	8.8	Sitting	-	11.6	Standing	-
	Future	9.0	Sitting	Unchanged	12.1	Standing	Unchanged
51	Existing	9.1	Sitting	-	12.0	Standing	-
	Future	7.6	Sitting	Unchanged	9.8	Sitting	Improved
52	Existing	8.7	Sitting	-	11.2	Standing	-
	Future	8.8	Sitting	Unchanged	11.3	Standing	Unchanged
53	Existing	9.6	Sitting	-	12.9	Standing	-
	Future	7.8	Sitting	Unchanged	10.3	Standing	Unchanged
54	Existing	10.2	Standing	-	13.7	Standing	-
	Future	9.6	Sitting	Improved	13.2	Standing	Unchanged
55	Existing	10.8	Standing	-	15.0	Strolling	-
	Future	10.3	Standing	Unchanged	14.5	Strolling	Unchanged
56	Existing	11.4	Standing	-	16.0	Strolling	-
	Future	10.7	Standing	Unchanged	14.0	Strolling	Unchanged
57	Existing	11.3	Standing	-	15.1	Strolling	-
	Future	10.8	Standing	Unchanged	13.8	Standing	Improved
58	Existing	10.9	Standing	-	14.7	Strolling	-
	Future	6.5	Sitting	Improved	8.4	Sitting	Improved
59	Existing	8.9	Sitting	-	11.9	Standing	-
	Future	8.2	Sitting	Unchanged	10.4	Standing	Unchanged
60	Existing	9.0	Sitting	-	11.3	Standing	-
	Future	9.9	Sitting	Unchanged	12.9	Standing	Unchanged

APPENDIX C

WIND TUNNEL SIMULATION OF THE NATURAL WIND

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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 metres (m) to 600 m.

Simulating real wind behaviour in a wind tunnel 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, U_g = gradient wind speed, Z = height above ground, Z_g = depth of the boundary layer (gradient height) and α is the power law exponent.

Figure B1 on the following page plots three velocity profiles for open country, and suburban and urban exposures.

The exponent α varies according to the type of upwind terrain; α ranges from 0.14 for open country to 0.33 for an urban exposure. Figure C2 illustrates the theoretical variation of turbulence for open country, suburban and urban exposures.

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. Thus, for a 1:300 scale, 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, U10 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.

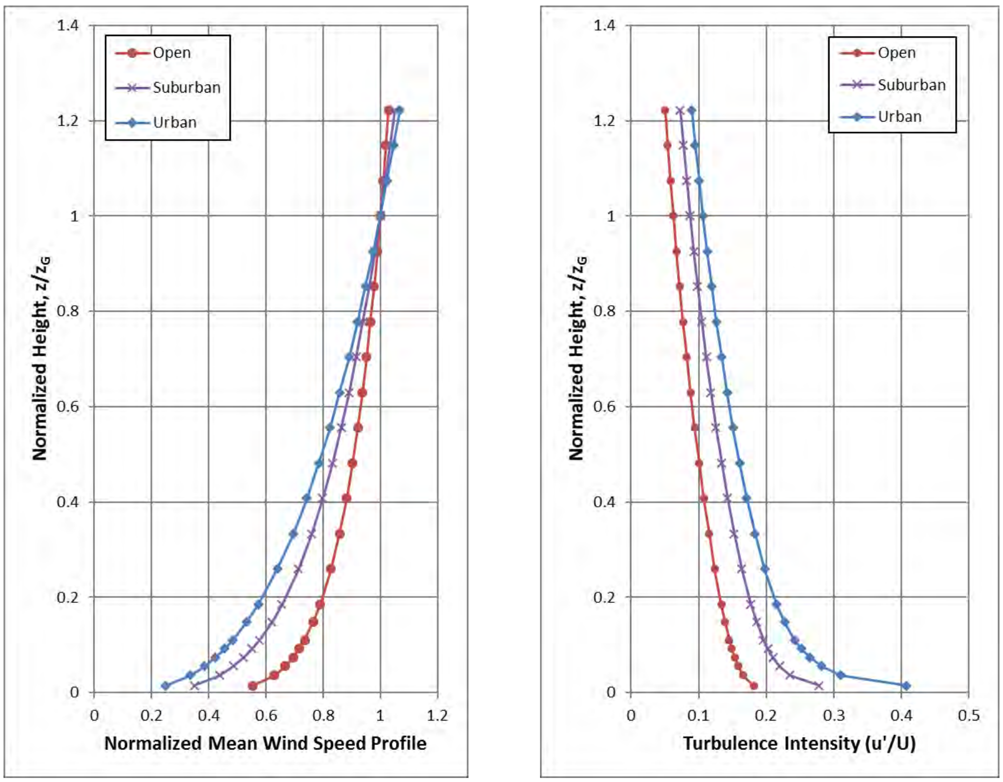

FIGURE C1 (LEFT): MEAN WIND SPEED PROFILES;
FIGURE C2 (RIGHT): TURBULENCE INTENSITY PROFILES

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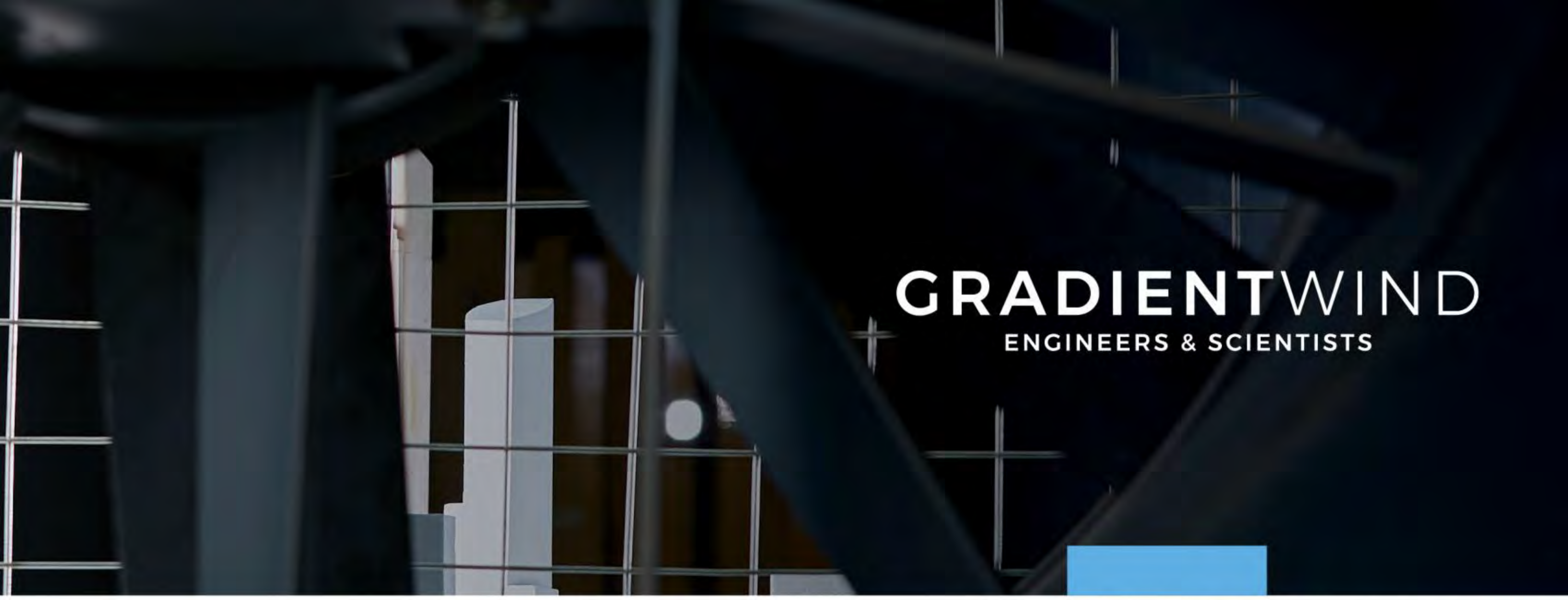

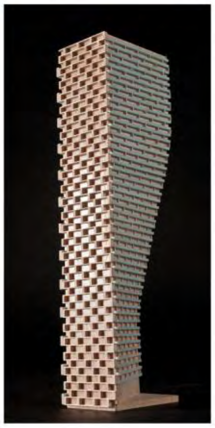

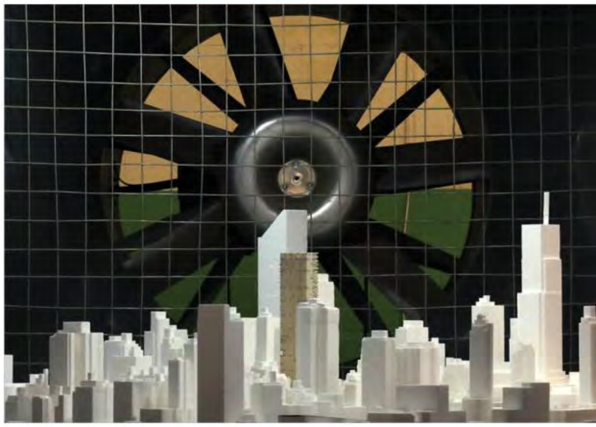

APPENDIX D

PEDESTRIAN LEVEL WIND MEASUREMENT METHODOLOGY

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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 D1. 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 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.

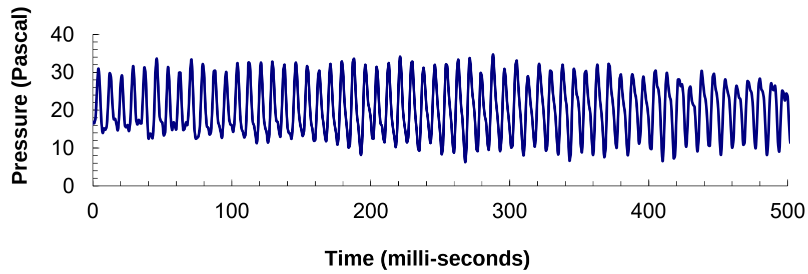

FIGURE D1: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR

REFERENCES

1. Davenport, A.G., '*The Dependence of Wind Loading on Meteorological Parameters*', Proc. of Int. Res. Seminar, Wind Effects on Buildings & Structures, NRC, Ottawa, 1967, University of Toronto Press.

2. Wu, S., Bose, N., 'An *Extended Power Law Model for the Calibration of Hot-wire/Hot-film Constant Temperature Probes*', Int. J. of Heat Mass Transfer, Vol.17, No.3, pp.437-442, Pergamon Press.