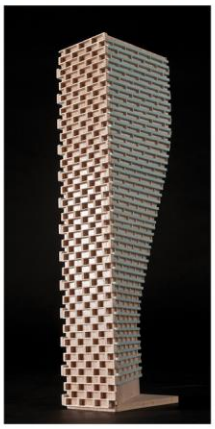
GRADIENTWIND
ENGINEERS & SCIENTISTS

PEDESTRIAN LEVEL WIND STUDY

21-51 Queen Street North
Mississauga, Ontario

REPORT: GWE21-164-WTPLW



August 17, 2021

PREPARED FOR

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EXECUTIVE SUMMARY

This report describes a pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 21-51 Queen Street North in Mississauga, 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 pedestrian areas investigated include nearby sidewalks, laneways, parking areas, patios, green spaces, and building access points. Wind conditions are also measured over the Level 3 and Level 5 rooftop areas. 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 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, the City of Mississauga Terms of Reference for Pedestrian Wind Comfort and Safety Studies, architectural drawings prepared by A&Architects Inc. in July 2021, 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-5B, as well as Tables A1-A2 and B1-B4 in the appendices. Based on wind tunnel test results, meteorological data analysis, and experience with similar developments in Mississauga, we conclude that conditions over all pedestrian-sensitive areas within and surrounding the development site will be acceptable for the intended pedestrian uses on a seasonal basis.

To ensure conditions across the entire Level 3 outdoor amenity terrace are suitable for sitting or more sedentary activities, mitigation is recommended as described in Section 5.2. If the Level 5 podium roof should be utilized as an outdoor amenity, 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 generally calming effect on existing grade-level wind conditions, with improvements occurring along portions of the Queen Street North sidewalk, surrounding parking areas,

and green space northeast of the site. Although somewhat windier conditions will be experienced over parking areas southeast of the site, a portion of the Queen Street North sidewalk west of the site, and green space directly northeast, 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 conditions too windy for walking, or that could be considered unsafe.

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1. INTRODUCTION

This report describes a pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 21-51 Queen Street North in Mississauga, Ontario. The study was performed in accordance with industry standard wind tunnel testing techniques, the City of Mississauga Terms of Reference for Pedestrian Wind Comfort and Safety Studies, architectural drawings prepared by A&Architects Inc. in July 2021, 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 two-tower mixed-use development located at 21-51 Queen Street North in Mississauga, Ontario. The study site is situated centrally on parcel of land bound by Matlock Avenue to the northwest, Queen Street North to the southwest, Britannia Road West to the southeast, and existing developments to the northeast.

The study building comprises two nine-storey buildings aligned longitudinally with Matlock Avenue and oriented north-south (referring to project north) on a shared rectangular two-storey lower podium with a four-storey upper podium segment on the west side. The ground floor consists of a residential lobby and lounge in the southwest corner, and retail spaces along the west elevation, all accessible from Queen Street North, residential units with adjacent private patios along the east and south elevations, and amenity space located centrally. A driveway along the north elevation provides access to a loading area and ramp to three levels of below-grade parking. Level 2 is largely open to areas below on the west side, with residential units on the east and south sides. At Level 3, the centre of the east elevation sets back to form a 'C'-shaped planform open to the east, with a central outdoor amenity terrace, an indoor amenity in the southeast end, and surrounding residential units. Levels 4 and above comprise exclusively of residential units, and at Level 5 the west elevations set back to form two separate rectangular buildings, creating possible additional terrace space on the roof of the connection. Above Level 5, the buildings rise to full height with stepped terraces on the east elevations. Mechanical penthouses complete the development.

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 low-rise buildings in all directions. A railway runs northwest to southeast approximately 75 metres southwest of the site. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer radius) are dominated by low-rise suburban buildings to the north clockwise to the west, and low-rise industrial buildings in the northwest quadrant. The Credit River runs north-south approximately 500 metres to the east.

Grade-level pedestrian areas investigated include nearby sidewalks, laneways, parking areas, patios, green spaces, and building access points. Wind conditions are also measured over the Level 3 and Level 5 roof areas. Figures 1A and 1B illustrates the existing and proposed study sites and surrounding context, 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 Mississauga area wind climate and synthesis of wind tunnel data with industry-accepted guidelines[1]. 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,

[1] City of Mississauga Urban Design Terms of Reference, Wind Comfort and Safety Studies, June 2014

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 68 sensor locations on the scale model in Gradient Wind's wind tunnel. Of these 68 sensors, 54 were located at grade and the remaining 14 sensors were located over the Level 3 and Level 5 outdoor terraces. Wind speed measurements were performed for each of the 68 sensors for 36 wind directions at 10° intervals. Figures 1A and 1B illustrate the existing and proposed study sites and surrounding context, respectively, while sensor locations used to investigate wind conditions are illustrated in Figures 2A through 5B.

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

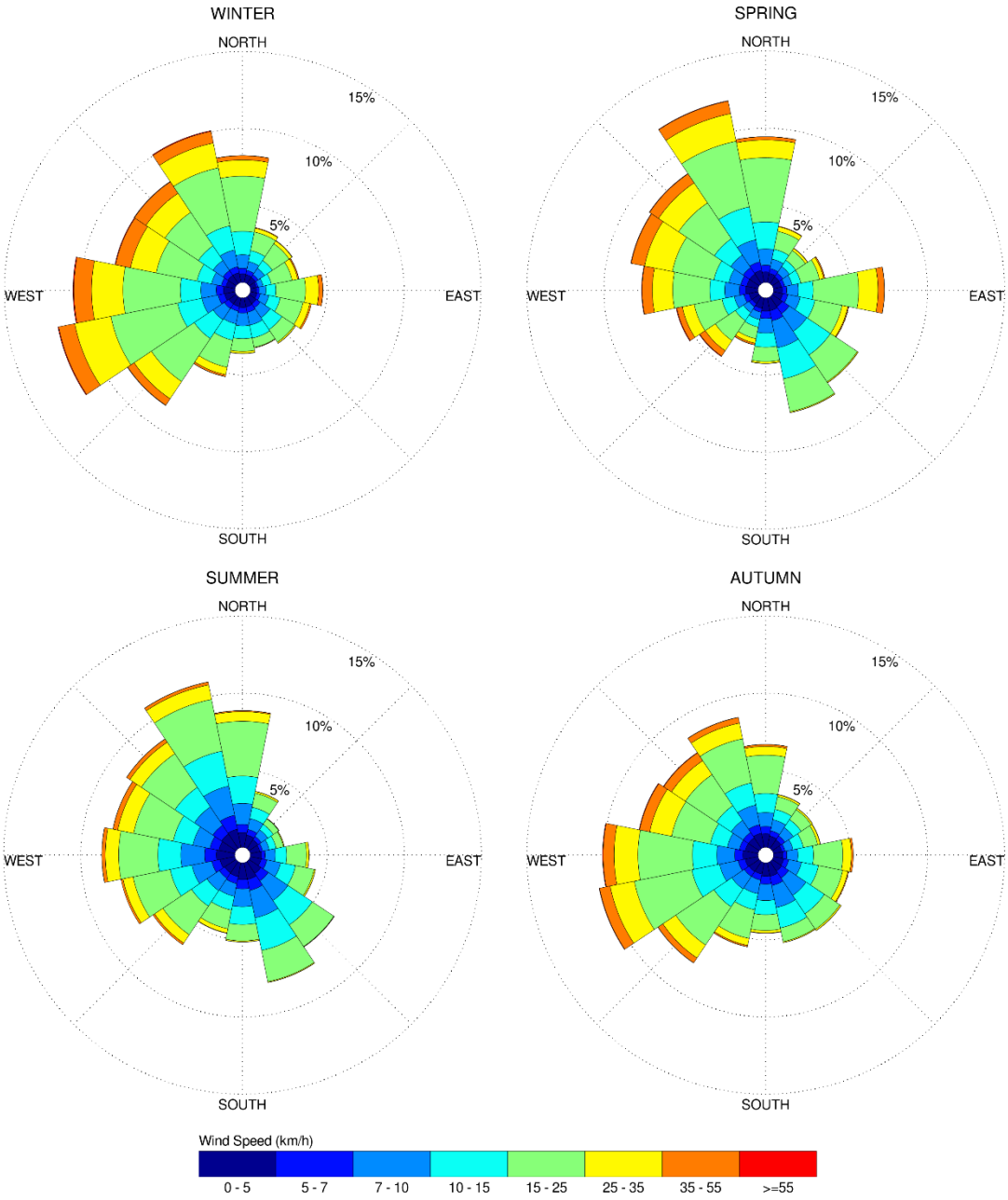
guidelines found in the National Building Code of Canada 2015 and of 'Wind Tunnel Studies of Buildings and Structures', ASCE Manual 7 Reports on Engineering Practice No 67.

4.3 Meteorological Data Analysis

A statistical model for winds in Toronto, representative of the Mississauga area, was developed from approximately 40-years of hourly meteorological wind data recorded at Pearson 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 Mississauga 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 Mississauga, the most common winds concerning pedestrian comfort occur from the southwest clockwise to the north, as well as those from the east. The directional preference and relative magnitude of the wind speed varies somewhat from season to season, with the summer months displaying the calmest winds relative to the remaining seasonal periods.

SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES
PEARSON INTERNATIONAL AIRPORT, MISSISSAUGA , 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 City of Mississauga Urban Design Terms of Reference[1]. 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.

Four pedestrian comfort classes and corresponding GEM wind speed ranges are used to assess pedestrian comfort, which include: (i) Sitting; (ii) Standing; (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 15 km/h (i.e. 10-15 km/h) occurring more than 80% of the time are acceptable for activities such as standing, strolling or more vigorous activities.

(iii) **Walking** – GEM wind speeds below 20 km/h (i.e. 15-20 km/h) occurring more than 80% of the time are acceptable for walking or more vigorous activities.

(iv) **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	Walking
Outdoor Amenity Spaces	Sitting / Standing
Cafés / Patios / Benches / Gardens	Sitting / Standing
Plazas	Standing / Walking
Transit Stops	Standing
Public Parks	Sitting / Walking
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 A2 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 10-15 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, walking, 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 5B. Conditions suitable for sitting are represented by the colour green, while standing is represented by yellow, and walking by blue. 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-A2 in Appendix A, this section summarizes the most significant findings of the PLW study with respect to future conditions, as follows:

1. Public sidewalks, laneways, and parking areas within and surrounding the development will experience wind conditions comfortable for a mix of sitting or standing during the summer and autumn, transitioning to include walking conditions at various locations for the remainder of the year, which is acceptable.
2. The residential and retail entrances fronting Queen Street North will largely be suitable for sitting throughout the year, with the lobby entrance (Sensor 41) experiencing standing conditions in the winter. All secondary building access points (including stairwell exits and vehicle entrances) will

be comfortable for standing or better throughout the year. The noted conditions are considered appropriate.

3. The private patios along the east and south elevations of the ground floor (Sensors 45-54) will be suitable for sitting during the summer and a mix of sitting or standing during the spring and autumn, which is acceptable.

4. The Level 3 outdoor amenity terrace (Sensors 55-63) will generally be comfortable for standing during the spring, summer, and autumn, with sitting conditions occurring towards the south end and centre (Sensors 59 and 63) and walking conditions centrally (Sensor 58). To ensure designated seating areas are comfortable for the intended uses, it is recommended to provide localized wind barriers to the immediate west and north of such spaces. It may also be beneficial to install a pergola and canopy structure overhead of seating areas. The exact placement and configuration of mitigation can be confirmed at a later date as the landscape plan progresses.

5. The Level 5 podium roof (Sensors 64-68) will be suitable for a mix of sitting or standing during the spring and summer, and a mix of standing and walking during the autumn. Should this area be utilized as an outdoor amenity, it is recommended to raise the full perimeter guard to 2.4 metres above the walking surface, and extend canopy or pergola structures from the tower facades over the terrace.

6. 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. 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 wind comfort at many grade-level areas will remain unchanged upon the introduction of the proposed study building, with improvements occurring over portions of sidewalk along Queen Street North (Sensors 3, 7, 9, 27-29, & 31), surrounding parking areas (Sensors 1, 12, 13, 18, 32, & 33) and green space northeast of the site (Sensors 15 & 17). Although somewhat windier conditions occur over parking areas southeast of the site (Sensors 24 & 26), a portion of the Queen Street North sidewalk west of the site (Sensor 30), and green space directly northeast (Sensors 16, 19, & 20), 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 the proposed mixed-use development located at 21-51 Queen Street North in Mississauga, 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-5B, as well as Tables A1-A2 and B1-B4 in the appendices. Based on wind tunnel test results, meteorological data analysis, and experience with similar developments in Mississauga, we conclude that conditions over all pedestrian-sensitive areas within and surrounding the development site will be acceptable for the intended pedestrian uses on a seasonal basis.

To ensure conditions across the entire Level 3 outdoor amenity terrace are suitable for sitting or more sedentary activities, mitigation is recommended as described in Section 5.2. If the Level 5 podium roof should be utilized as an outdoor amenity, 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 generally calming effect on existing grade-level wind conditions, with improvements occurring along portions of the Queen Street North sidewalk, surrounding parking areas,

and green space northeast of the site. Although somewhat windier conditions will be experienced over parking areas southeast of the site, a portion of the Queen Street North sidewalk west of the site, and green space directly northeast, 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 conditions too windy for walking, or 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.

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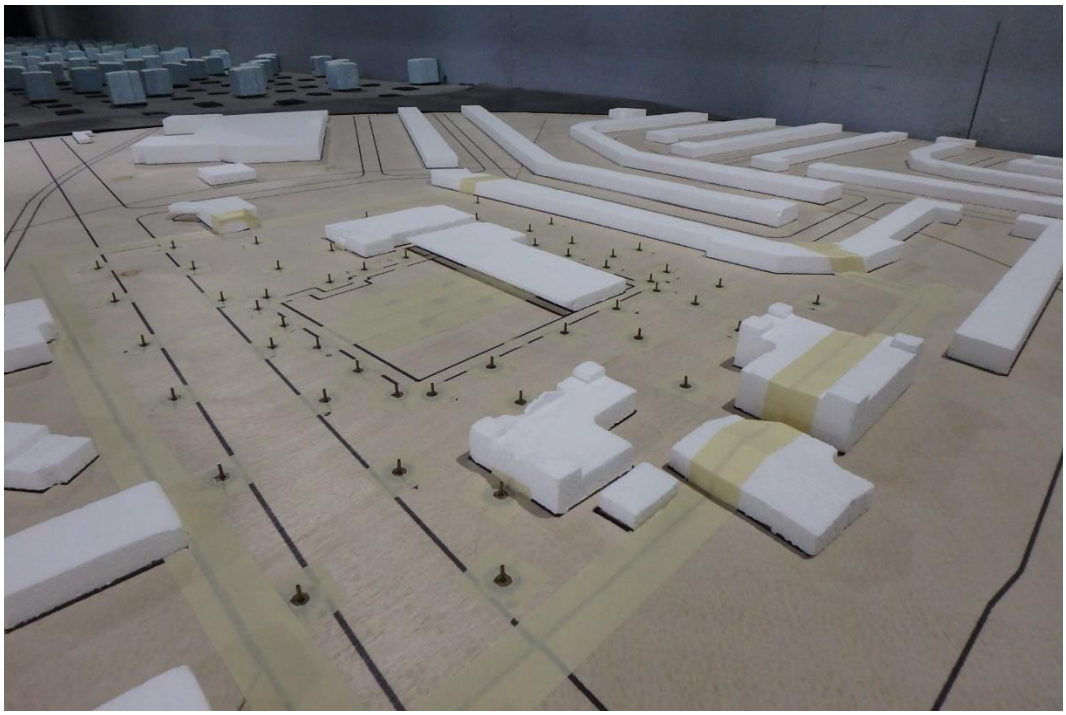
Junior Wind Scientist

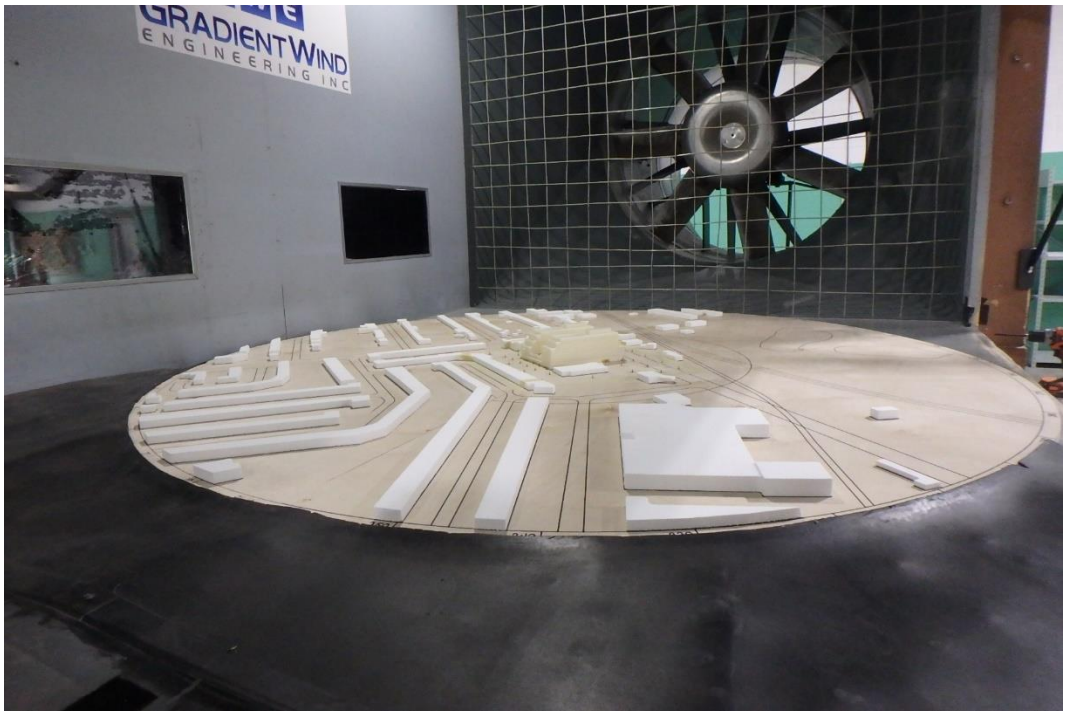
Andrew Sliasas, M.A.Sc., P.Eng.,
Principal

GW21-164-WTPLW

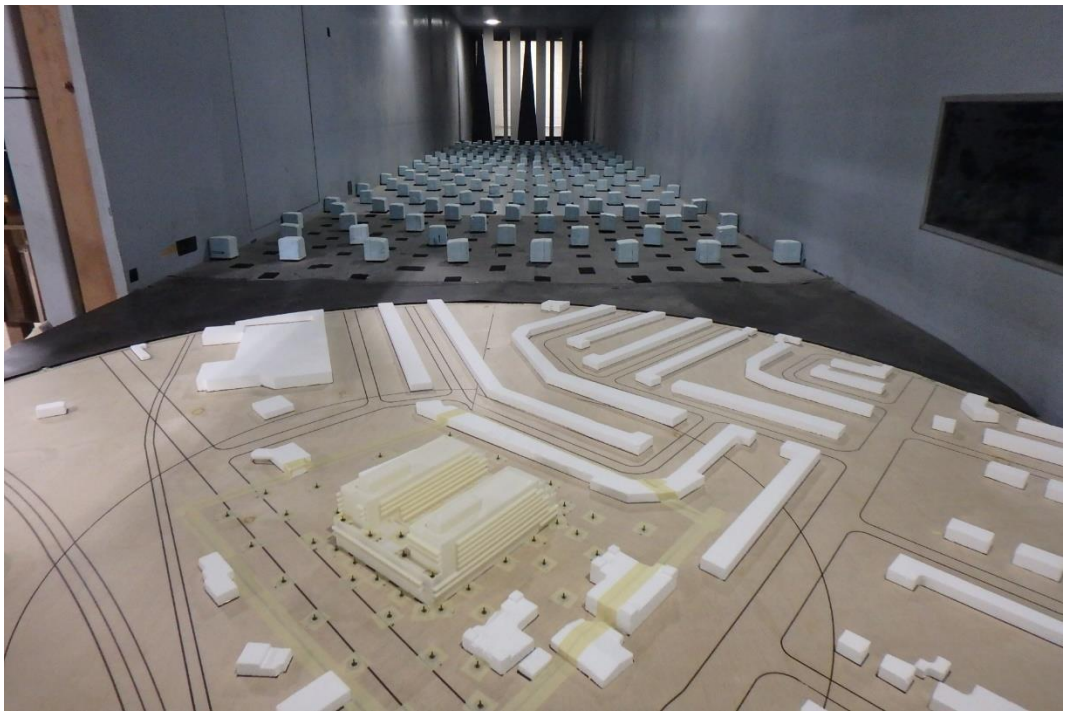


PHOTOGRAPH 1: CLOSE-UP VIEW OF EXISTING CONTEXT MODEL LOOKING NORTH

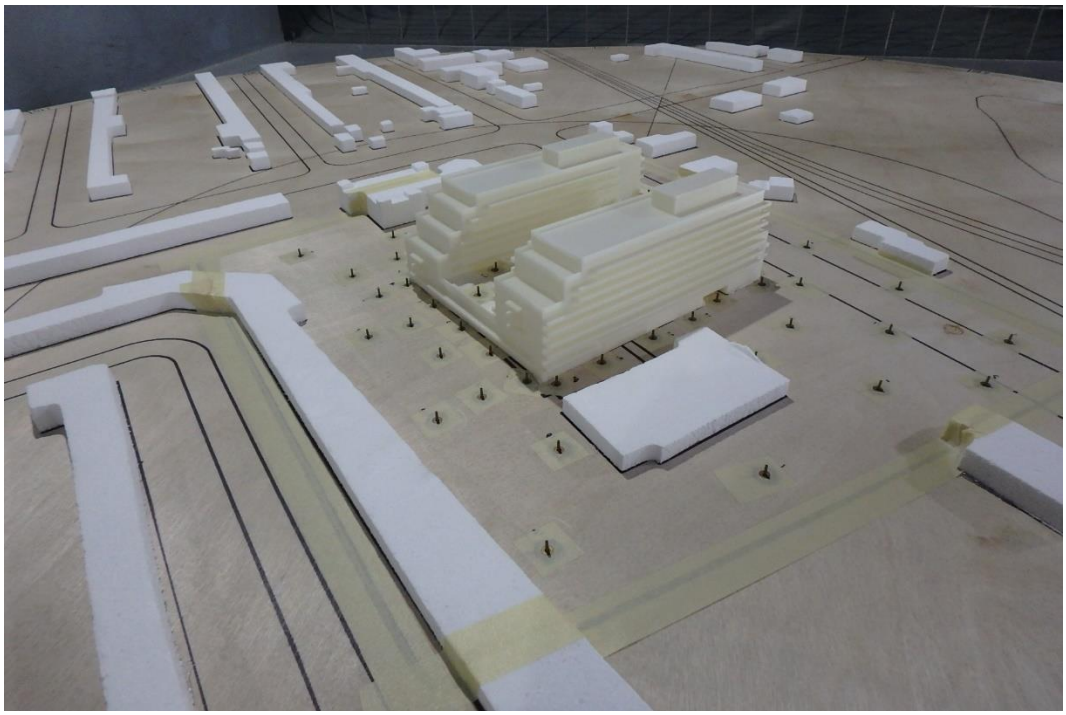
PHOTOGRAPH 2: CLOSE-UP VIEW OF EXISTING CONTEXT MODEL LOOKING SOUTH



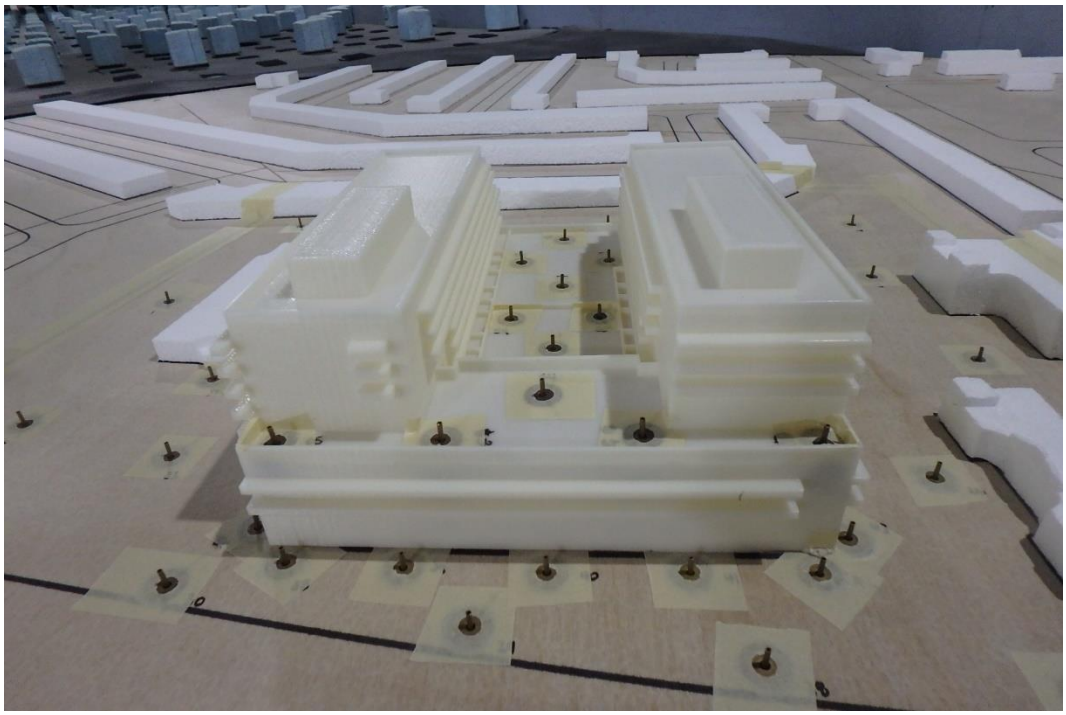
PHOTOGRAPH 3: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING DOWNWIND



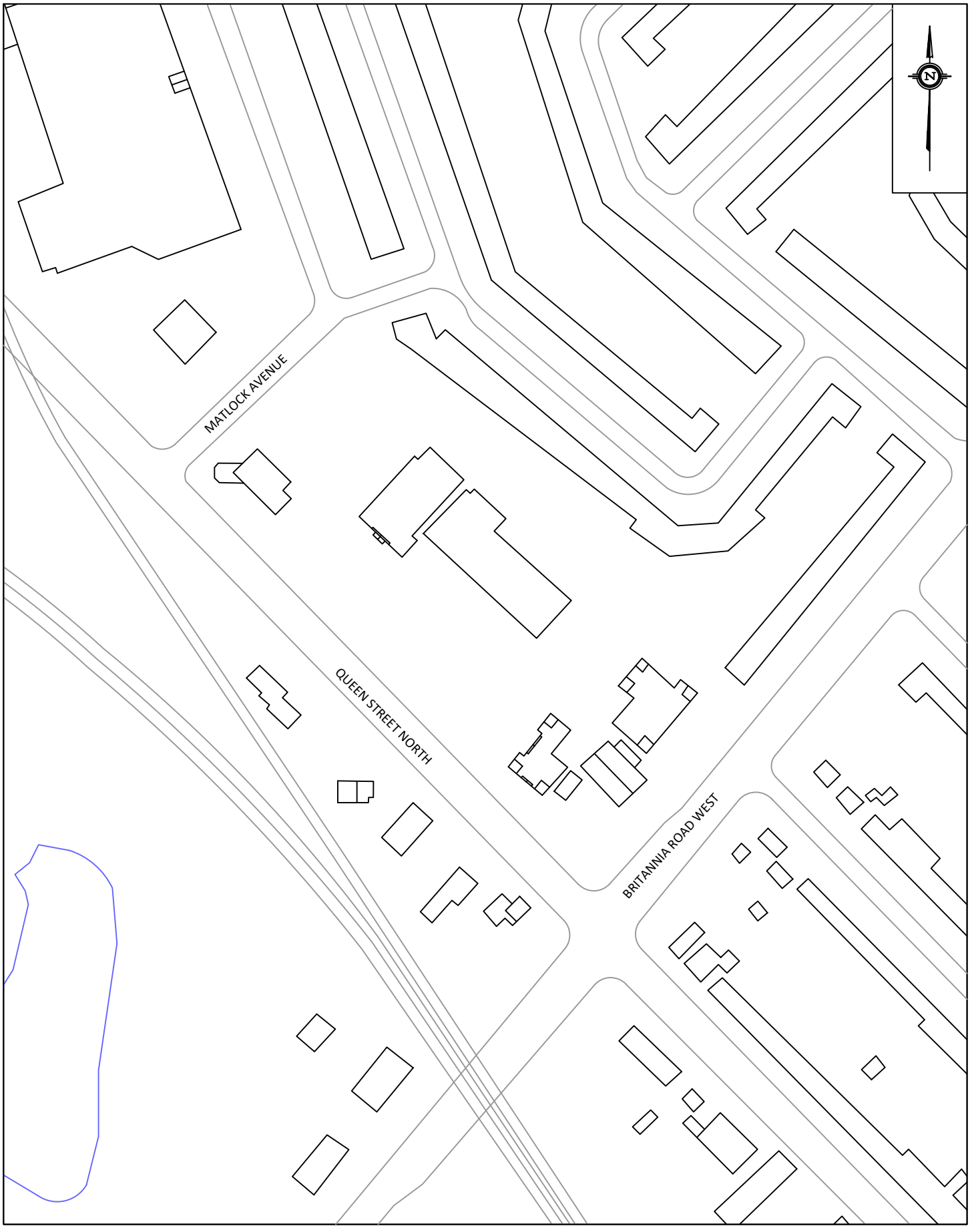
PHOTOGRAPH 4: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING UPWIND



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



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



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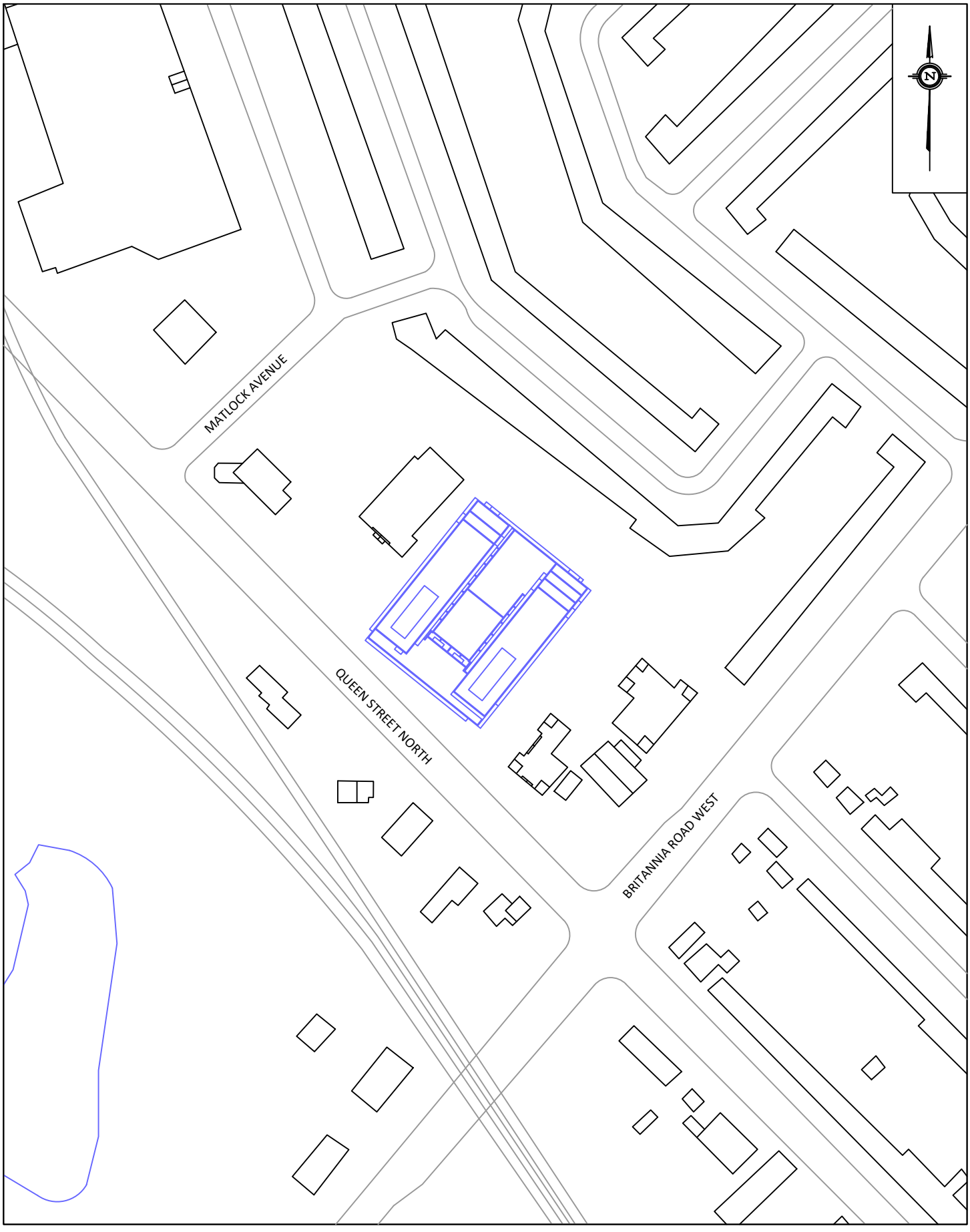
PROJECT	21-51 QUEEN STREET NORTH, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY
SCALE	1:2500 (APPROX.)
DRAWING NO.	GW21-164-PLW-1A
DATE	AUGUST 17, 2021
DRAWN BY	C.E.

DESCRIPTION

FIGURE 1A:
EXISTING CONDITIONS
SITE PLAN AND SURROUNDING CONTEXT



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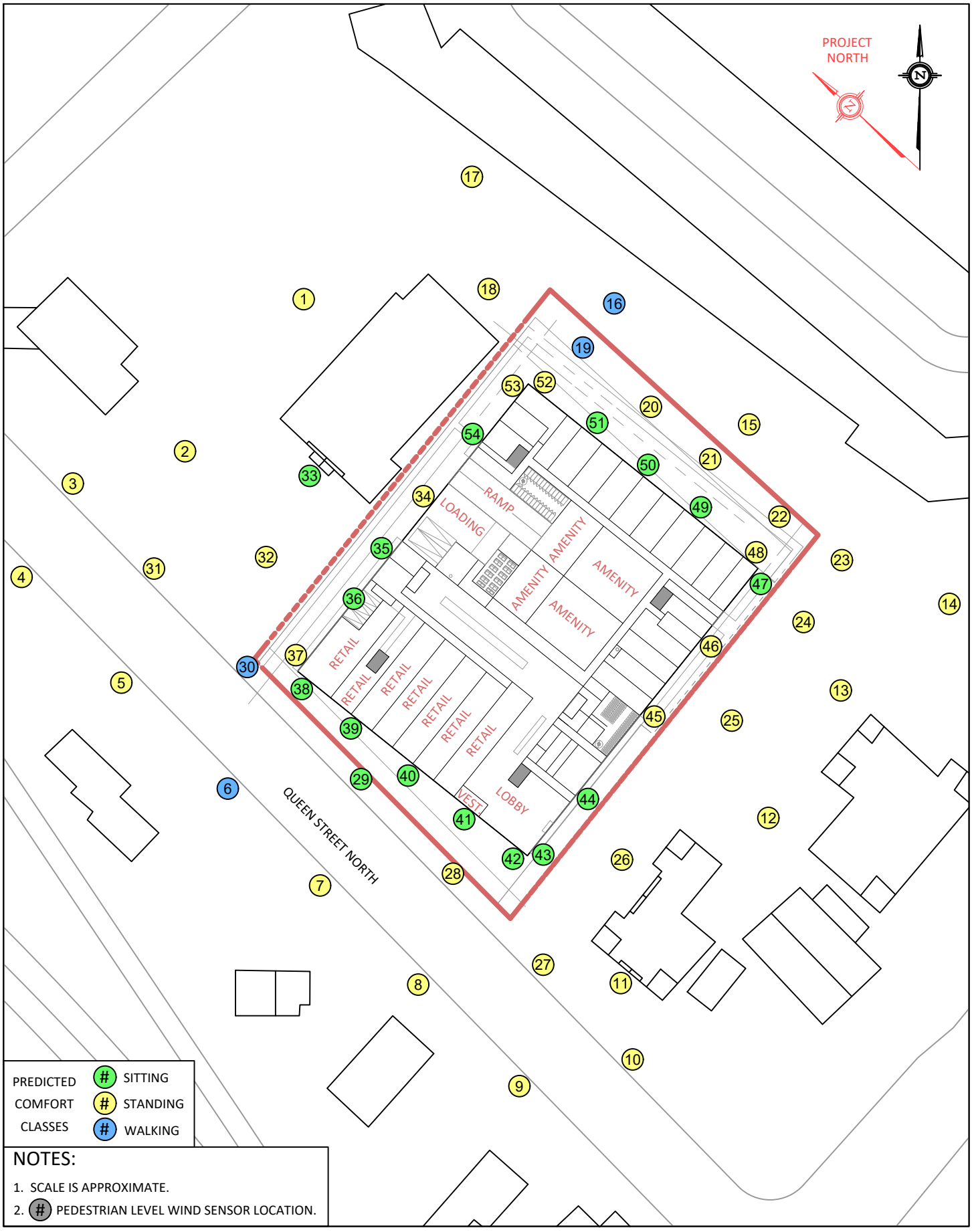
PROJECT	21-51 QUEEN STREET NORTH, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY
SCALE	1:2500 (APPROX.)
DRAWING NO.	GW21-164-PLW-1B
DATE	AUGUST 17, 2021
DRAWN BY	C.E.

DESCRIPTION

FIGURE 1B:
FUTURE PROPOSED CONDITIONS
SITE PLAN AND SURROUNDING CONTEXT



NOTES:

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

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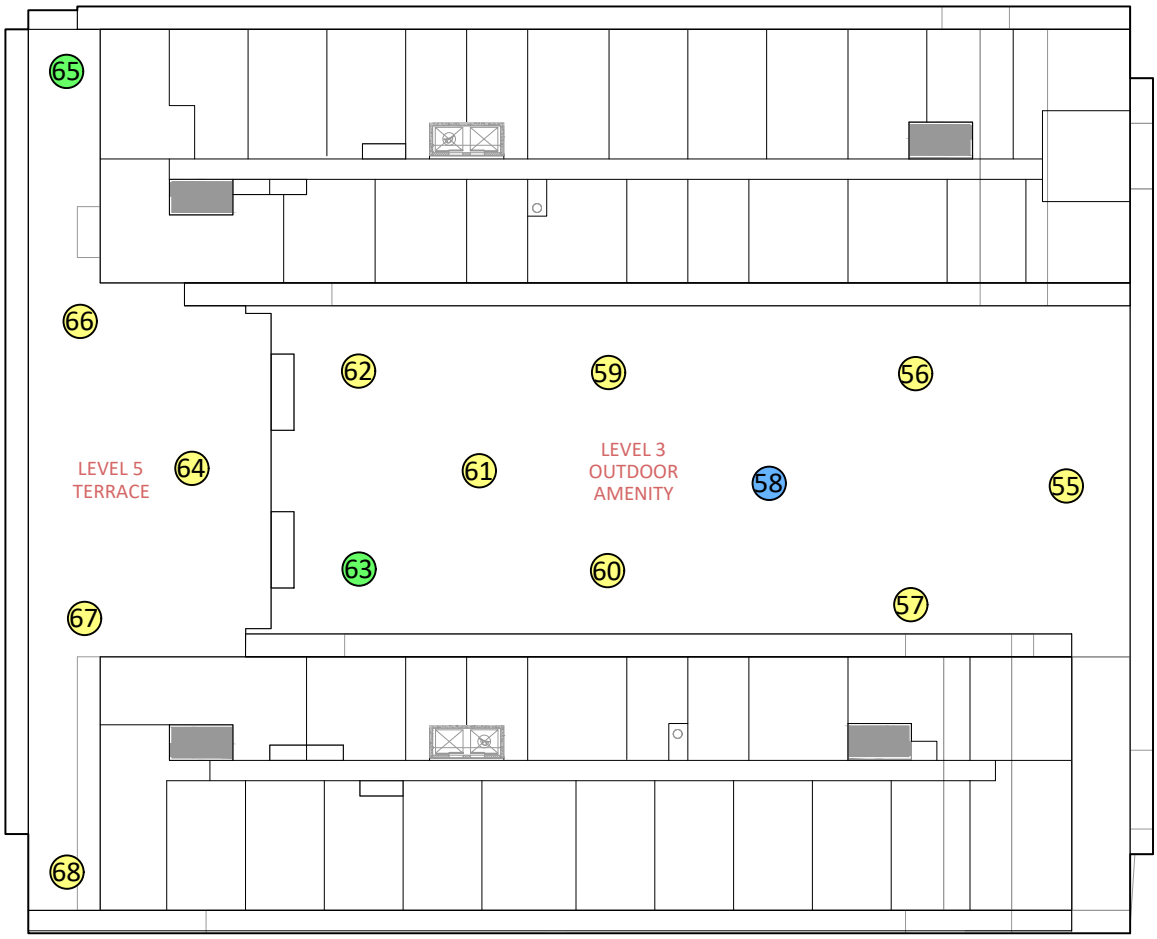
PROJECT	21-51 QUEEN STREET NORTH, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY
SCALE	1:800 (APPROX.)
DRAWING NO.	GW21-164-PLW-2A
DATE	AUGUST 17, 2021
DRAWN BY	C.E.

DESCRIPTION

FIGURE 2A: SPRING
GROUND FLOOR PLAN
PEDESTRIAN COMFORT PREDICTIONS



PREDICTED COMFORT CLASSES	
	# SITTING
	# STANDING
	# WALKING

NOTES:

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

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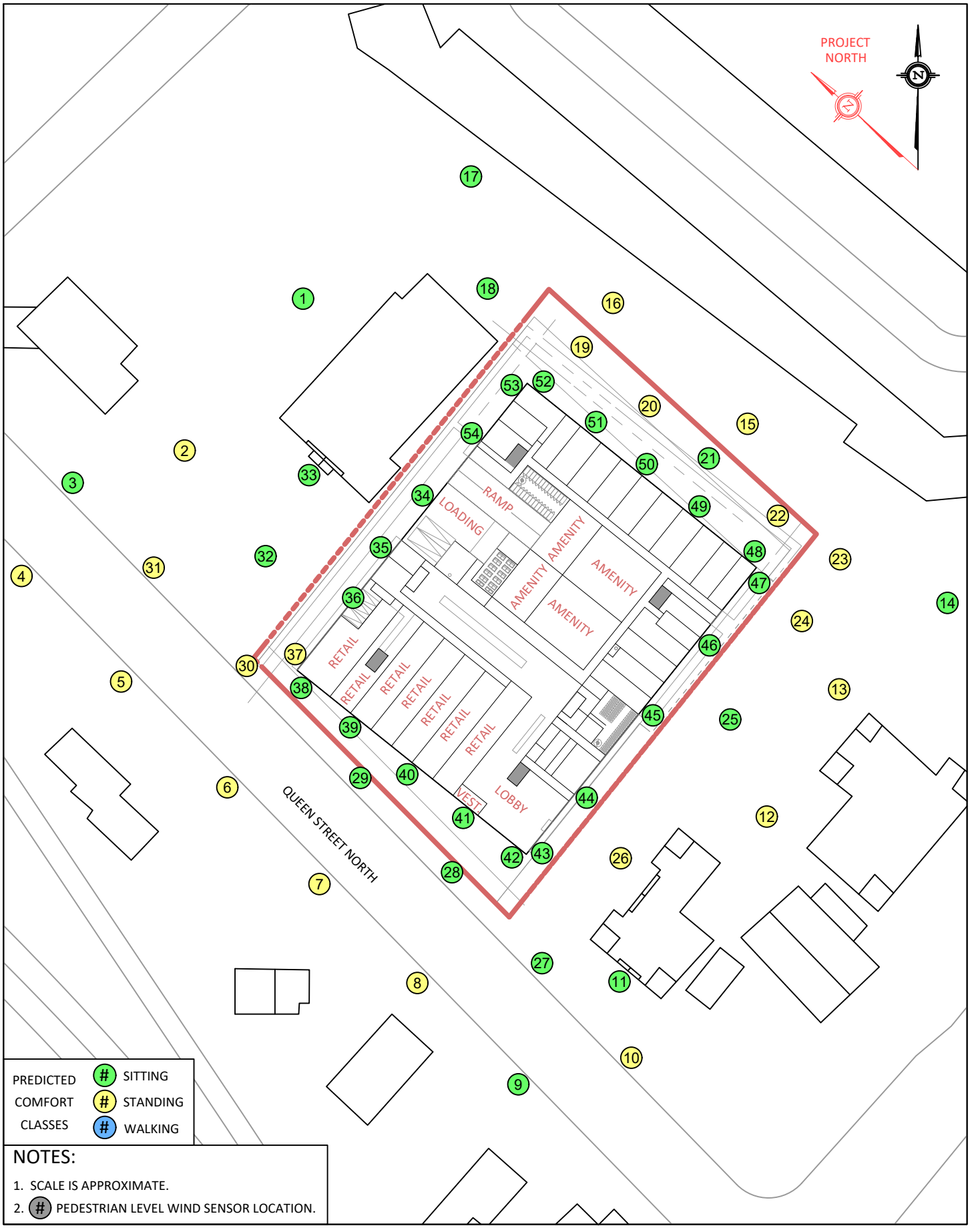
PROJECT	21-51 QUEEN STREET NORTH, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY
SCALE	1:800 (APPROX.)
DRAWING NO.	GW21-164-PLW-2B
DATE	AUGUST 17, 2021
DRAWN BY	C.E.

DESCRIPTION

FIGURE 2B: SPRING
ELEVATED OUTDOOR AMENITY PLAN
PEDESTRIAN COMFORT PREDICTIONS



NOTES:

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

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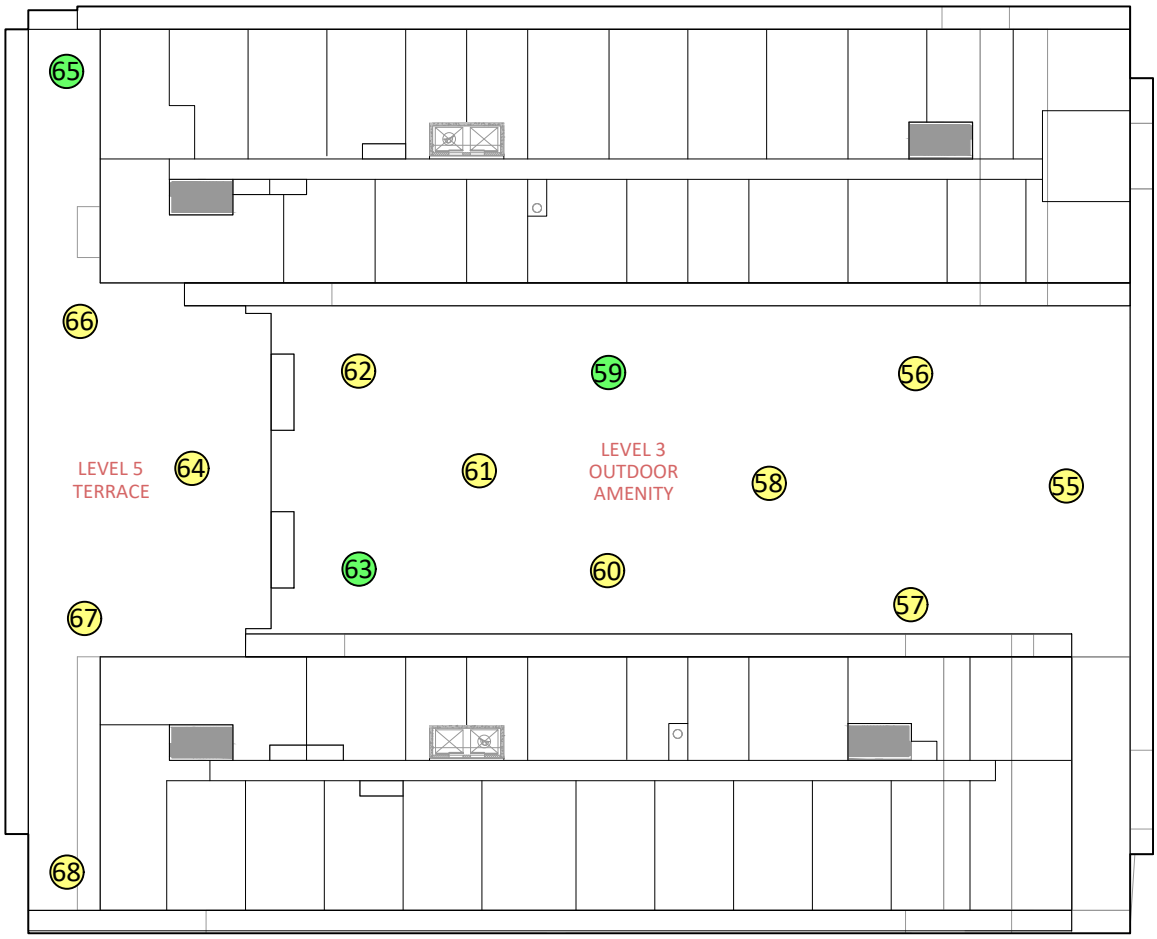
SCALE	1:800 (APPROX.)
DRAWING NO.	GW21-164-PLW-3A
DATE	AUGUST 17, 2021
DRAWN BY	C.E.

DESCRIPTION

FIGURE 3A: SUMMER
GROUND FLOOR PLAN
PEDESTRIAN COMFORT PREDICTIONS



PREDICTED COMFORT CLASSES	
	# SITTING
	# STANDING
	# WALKING

NOTES:

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

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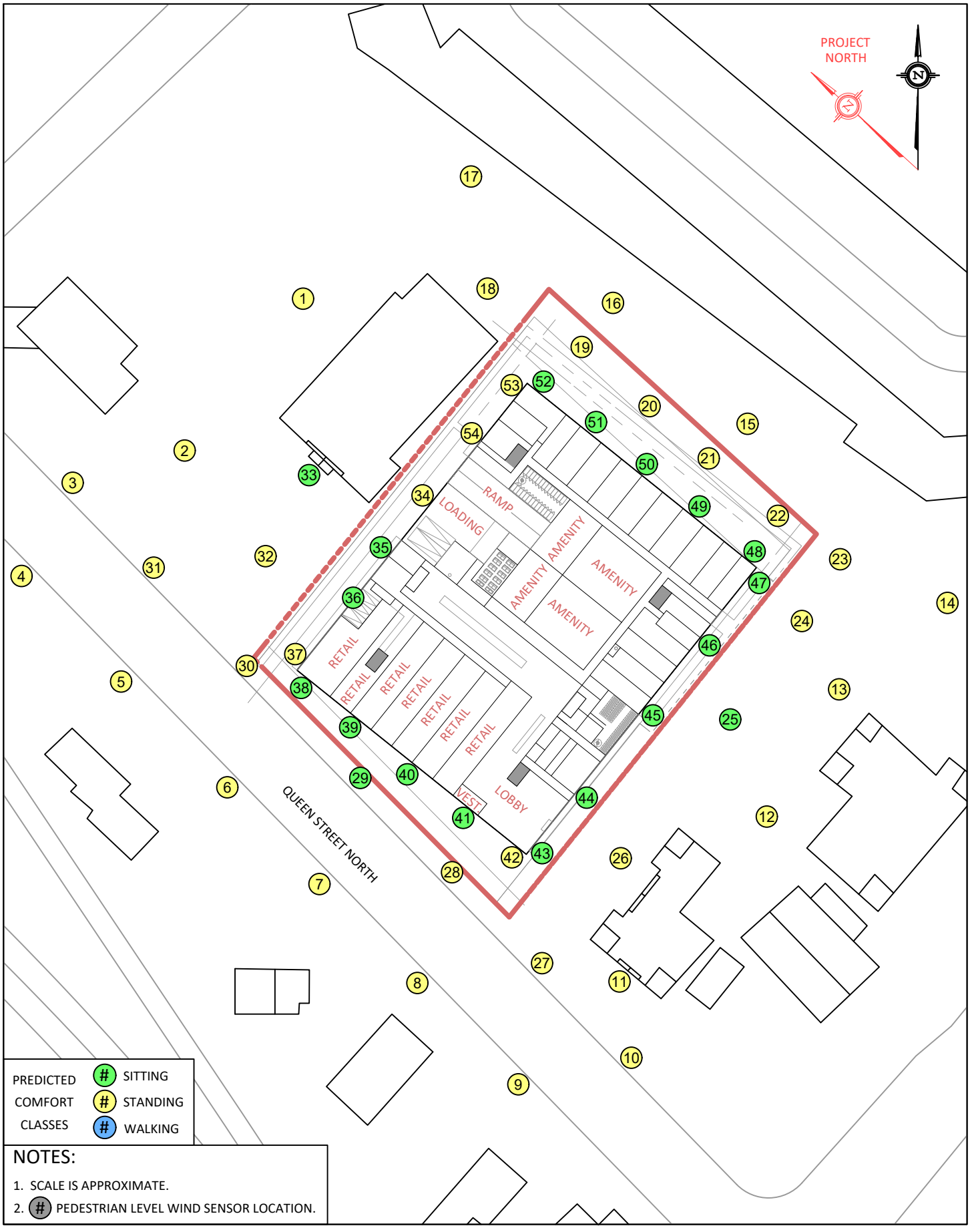
SCALE	1:800 (APPROX.)
DRAWING NO.	GW21-164-PLW-3B
DATE	AUGUST 17, 2021
DRAWN BY	C.E.

DESCRIPTION

FIGURE 3B: SUMMER
ELEVATED OUTDOOR AMENITY PLAN
PEDESTRIAN COMFORT PREDICTIONS



NOTES:

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

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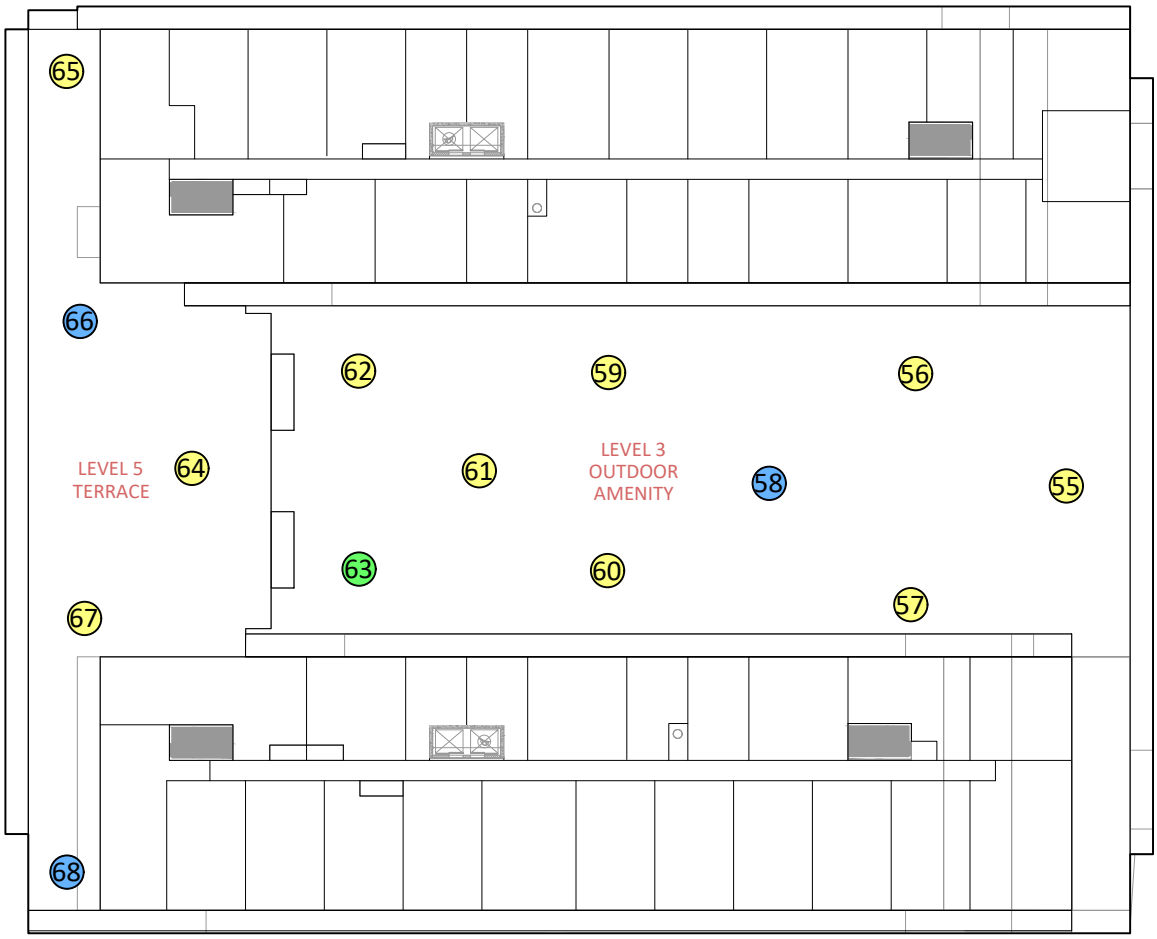
DRAWING NO.	GW21-164-PLW-4A
DATE	AUGUST 17, 2021
DRAWN BY	C.E.

DESCRIPTION

FIGURE 4A: AUTUMN
GROUND FLOOR PLAN
PEDESTRIAN COMFORT PREDICTIONS



PREDICTED COMFORT CLASSES	
	# SITTING
	# STANDING
	# WALKING

NOTES:

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

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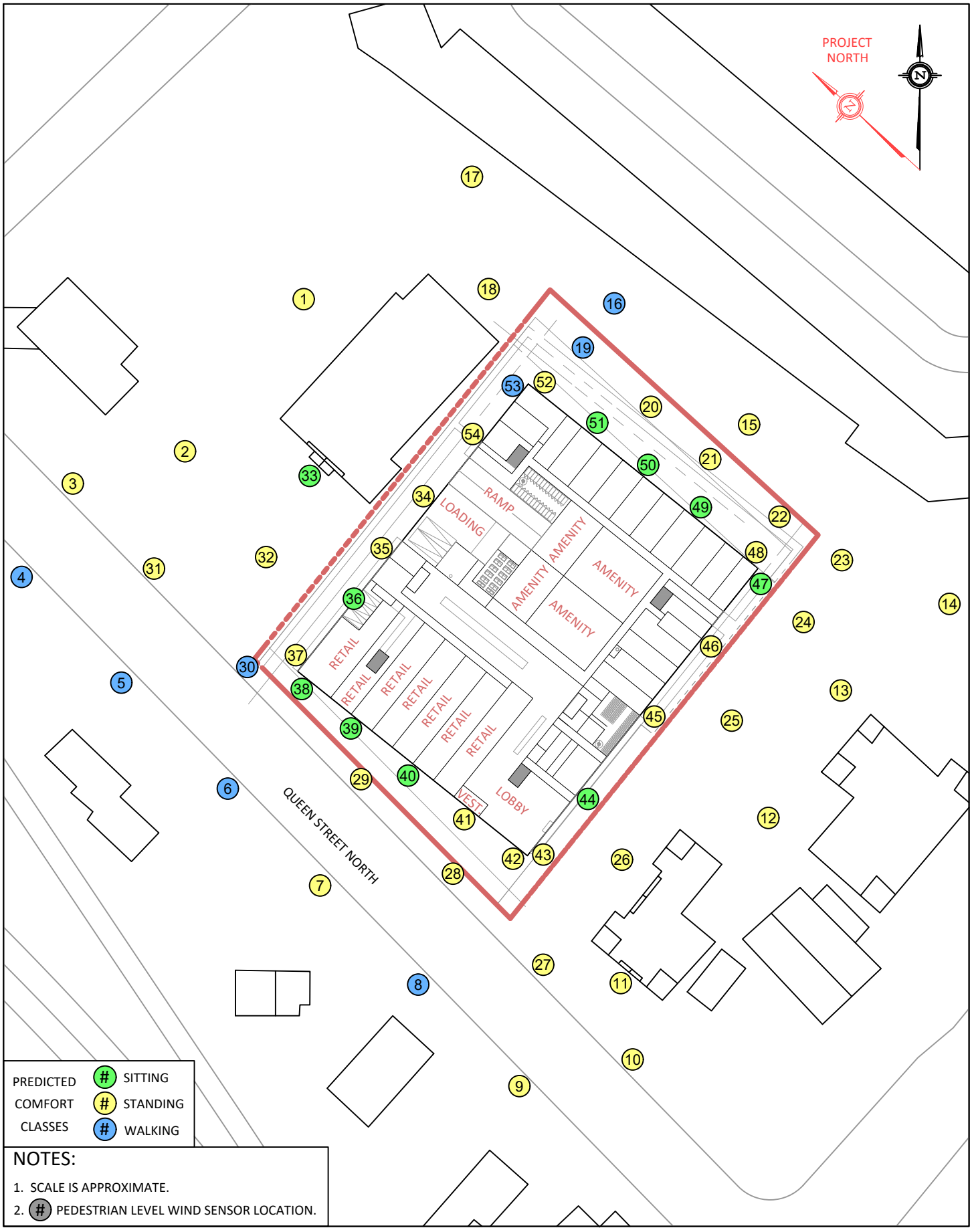
SCALE	1:800 (APPROX.)	DRAWING NO.	GW21-164-PLW-4B
DATE	AUGUST 17, 2021	DRAWN BY	C.E.

DESCRIPTION

FIGURE 4B: AUTUMN
ELEVATED OUTDOOR AMENITY PLAN
PEDESTRIAN COMFORT PREDICTIONS



NOTES:

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

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SCALE	1:800 (APPROX.)
DRAWING NO.	GW21-164-PLW-5A
DATE	AUGUST 17, 2021
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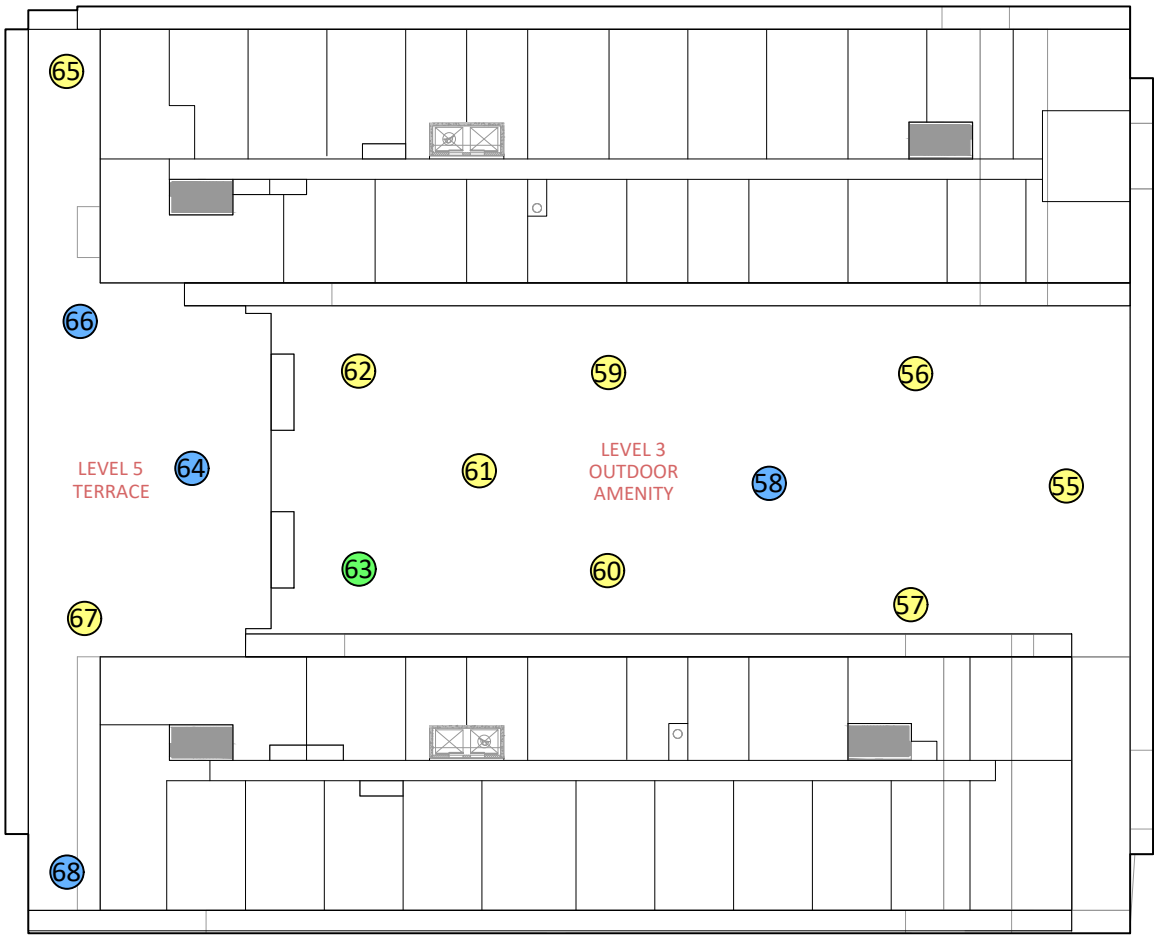
DESCRIPTION

FIGURE 5A: WINTER
GROUND FLOOR PLAN
PEDESTRIAN COMFORT PREDICTIONS



PREDICTED COMFORT CLASSES		
	#	SITTING
	#	STANDING
	#	WALKING

NOTES:

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

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SCALE	1:800 (APPROX.)
DRAWING NO.	GW21-164-PLW-5B
DATE	AUGUST 17, 2021
DRAWN BY	C.E.

DESCRIPTION

FIGURE 5B: WINTER
ELEVATED OUTDOOR AMENITY PLAN
PEDESTRIAN COMFORT PREDICTIONS

APPENDIX A

PEDESTRIAN COMFORT SUITABILITY, TABLES A1-A2 (FUTURE CONDITIONS)

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Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

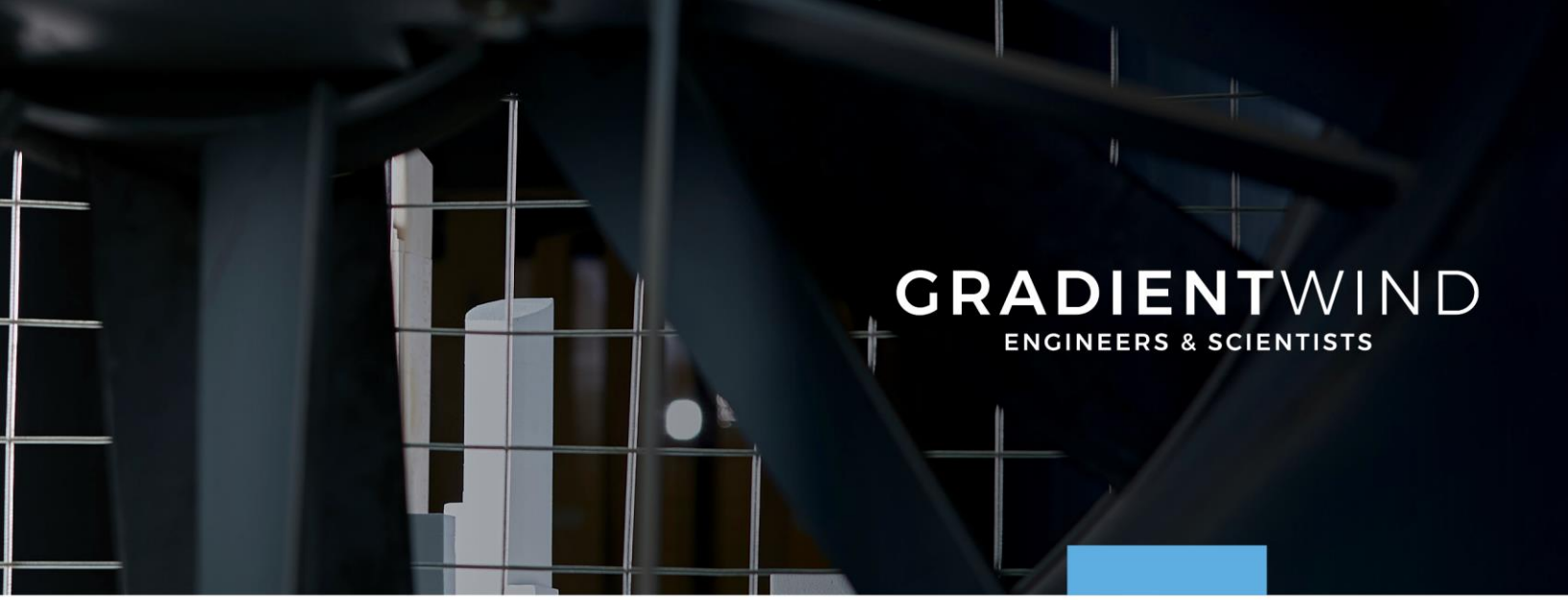
TABLE A1: SUMMARY OF PEDESTRIAN COMFORT (FUTURE CONDITIONS)

Sensor	Pedestrian Comfort								Pedestrian Safety	
	Spring		Summer		Autumn		Winter		Annual	
	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Safety Class
1	11.7	Standing	9.3	Sitting	11.5	Standing	13.3	Standing	45.7	Safe
2	12.7	Standing	10.7	Standing	12.1	Standing	13.9	Standing	45.8	Safe
3	11.5	Standing	9.9	Sitting	11.7	Standing	13.1	Standing	46.3	Safe
4	14.4	Standing	12.4	Standing	14.4	Standing	16.3	Walking	52.3	Safe
5	13.9	Standing	11.6	Standing	13.1	Standing	15.0	Walking	51.2	Safe
6	16.5	Walking	12.9	Standing	14.0	Standing	16.6	Walking	64.7	Safe
7	13.0	Standing	10.2	Standing	12.3	Standing	14.4	Standing	60.3	Safe
8	14.1	Standing	10.4	Standing	13.4	Standing	15.5	Walking	55.1	Safe
9	12.2	Standing	9.8	Sitting	11.8	Standing	13.6	Standing	46.8	Safe
10	12.8	Standing	10.2	Standing	12.8	Standing	14.6	Standing	53.6	Safe
11	10.2	Standing	8.6	Sitting	11.1	Standing	12.9	Standing	56.4	Safe
12	13.1	Standing	10.1	Standing	11.2	Standing	13.3	Standing	62.1	Safe
13	12.4	Standing	10.0	Standing	10.9	Standing	12.7	Standing	47.5	Safe
14	11.5	Standing	9.2	Sitting	10.3	Standing	11.8	Standing	47.2	Safe
15	13.3	Standing	10.5	Standing	12.0	Standing	13.9	Standing	54.9	Safe
16	15.1	Walking	11.6	Standing	14.7	Standing	16.8	Walking	57.8	Safe
17	11.9	Standing	9.0	Sitting	11.0	Standing	12.9	Standing	44.8	Safe
18	11.5	Standing	8.8	Sitting	10.5	Standing	12.3	Standing	42.3	Safe
19	15.5	Walking	11.2	Standing	14.1	Standing	16.9	Walking	65.7	Safe
20	13.6	Standing	10.6	Standing	12.0	Standing	14.0	Standing	55.3	Safe
21	12.7	Standing	10.0	Sitting	11.2	Standing	13.1	Standing	51.0	Safe
22	14.7	Standing	11.7	Standing	12.1	Standing	13.8	Standing	56.4	Safe
23	14.1	Standing	11.8	Standing	12.0	Standing	13.6	Standing	53.9	Safe
24	14.8	Standing	12.5	Standing	12.6	Standing	14.5	Standing	57.7	Safe
25	10.8	Standing	9.0	Sitting	9.6	Sitting	10.8	Standing	43.7	Safe
26	12.2	Standing	10.1	Standing	13.1	Standing	14.8	Standing	59.4	Safe
27	12.3	Standing	9.7	Sitting	12.2	Standing	14.3	Standing	53.3	Safe
28	10.1	Standing	8.6	Sitting	10.8	Standing	12.3	Standing	52.0	Safe
29	8.9	Sitting	7.6	Sitting	9.1	Sitting	10.4	Standing	47.0	Safe
30	16.4	Walking	13.6	Standing	14.2	Standing	16.2	Walking	65.8	Safe
31	12.0	Standing	10.4	Standing	11.7	Standing	12.9	Standing	44.7	Safe
32	11.2	Standing	9.4	Sitting	11.1	Standing	12.5	Standing	48.8	Safe
33	7.5	Sitting	6.2	Sitting	7.4	Sitting	8.5	Sitting	33.8	Safe
34	10.7	Standing	9.1	Sitting	11.0	Standing	12.9	Standing	51.2	Safe
35	9.8	Sitting	8.3	Sitting	9.9	Sitting	11.6	Standing	48.1	Safe

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 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	
	Spring		Summer		Autumn		Winter		Annual	
	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Safety Class
36	7.8	Sitting	6.1	Sitting	7.0	Sitting	8.3	Sitting	33.4	Safe
37	12.7	Standing	10.1	Standing	10.8	Standing	13.0	Standing	58.3	Safe
38	8.2	Sitting	7.0	Sitting	8.1	Sitting	8.8	Sitting	44.3	Safe
39	7.6	Sitting	6.5	Sitting	7.9	Sitting	8.9	Sitting	42.9	Safe
40	8.2	Sitting	6.9	Sitting	8.6	Sitting	9.8	Sitting	45.2	Safe
41	8.6	Sitting	7.3	Sitting	9.1	Sitting	10.4	Standing	47.6	Safe
42	9.5	Sitting	8.5	Sitting	12.0	Standing	13.9	Standing	62.3	Safe
43	9.8	Sitting	7.6	Sitting	9.2	Sitting	10.3	Standing	52.7	Safe
44	9.2	Sitting	7.0	Sitting	8.5	Sitting	9.7	Sitting	40.5	Safe
45	10.3	Standing	8.6	Sitting	9.8	Sitting	11.1	Standing	39.2	Safe
46	10.1	Standing	8.5	Sitting	9.3	Sitting	10.2	Standing	35.5	Safe
47	8.7	Sitting	7.5	Sitting	7.9	Sitting	8.4	Sitting	36.3	Safe
48	12.6	Standing	9.5	Sitting	9.8	Sitting	12.1	Standing	56.9	Safe
49	7.9	Sitting	6.0	Sitting	6.8	Sitting	8.1	Sitting	34.1	Safe
50	9.5	Sitting	7.3	Sitting	8.3	Sitting	9.8	Sitting	38.3	Safe
51	9.1	Sitting	6.9	Sitting	7.8	Sitting	9.2	Sitting	40.4	Safe
52	10.2	Standing	7.3	Sitting	8.5	Sitting	10.1	Standing	50.8	Safe
53	11.5	Standing	9.9	Sitting	13.0	Standing	15.3	Walking	65.6	Safe
54	9.1	Sitting	8.1	Sitting	10.8	Standing	12.8	Standing	56.0	Safe
55	12.9	Standing	10.4	Standing	11.9	Standing	13.8	Standing	55.0	Safe
56	13.4	Standing	10.5	Standing	12.2	Standing	13.9	Standing	51.3	Safe
57	13.8	Standing	10.7	Standing	12.3	Standing	14.6	Standing	63.3	Safe
58	17.6	Walking	13.4	Standing	15.3	Walking	17.7	Walking	63.7	Safe
59	10.9	Standing	8.1	Sitting	10.1	Standing	11.5	Standing	49.9	Safe
60	13.3	Standing	10.6	Standing	11.2	Standing	13.4	Standing	54.9	Safe
61	14.0	Standing	10.5	Standing	12.2	Standing	14.3	Standing	56.1	Safe
62	13.3	Standing	10.5	Standing	12.0	Standing	13.8	Standing	45.1	Safe
63	8.6	Sitting	6.5	Sitting	7.8	Sitting	9.1	Sitting	46.3	Safe
64	12.5	Standing	11.1	Standing	13.5	Standing	15.3	Walking	66.0	Safe
65	9.9	Sitting	9.4	Sitting	11.0	Standing	11.9	Standing	84.8	Safe
66	11.0	Standing	10.3	Standing	15.1	Walking	17.7	Walking	80.1	Safe
67	11.1	Standing	10.0	Standing	11.4	Standing	12.4	Standing	58.8	Safe
68	11.2	Standing	10.8	Standing	16.0	Walking	18.5	Walking	84.5	Safe



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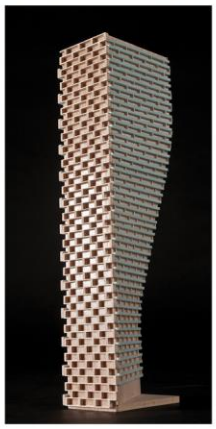

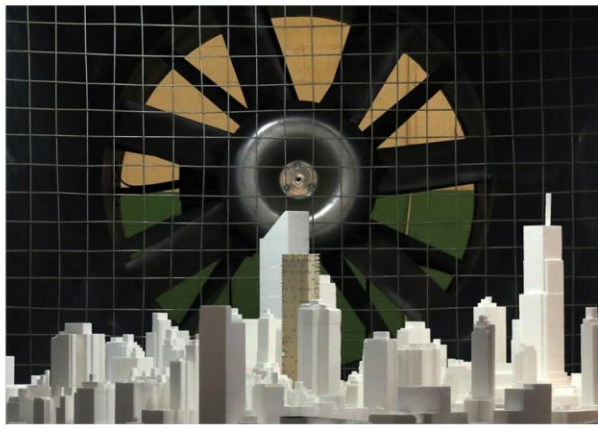

APPENDIX B

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

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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	10.1	Standing	-	14.0	Standing	-
	Future	9.3	Sitting	Improved	13.3	Standing	Unchanged
2	Existing	10.7	Standing	-	13.9	Standing	-
	Future	10.7	Standing	Unchanged	13.9	Standing	Unchanged
3	Existing	11.6	Standing	-	15.6	Walking	-
	Future	9.9	Sitting	Improved	13.1	Standing	Improved
4	Existing	13.2	Standing	-	18.2	Walking	-
	Future	12.4	Standing	Unchanged	16.3	Walking	Unchanged
5	Existing	12.0	Standing	-	17.1	Walking	-
	Future	11.6	Standing	Unchanged	15.0	Walking	Unchanged
6	Existing	12.0	Standing	-	15.5	Walking	-
	Future	12.9	Standing	Unchanged	16.6	Walking	Unchanged
7	Existing	12.4	Standing	-	16.7	Walking	-
	Future	10.2	Standing	Unchanged	14.4	Standing	Improved
8	Existing	11.1	Standing	-	15.3	Walking	-
	Future	10.4	Standing	Unchanged	15.5	Walking	Unchanged
9	Existing	11.4	Standing	-	15.4	Walking	-
	Future	9.8	Sitting	Improved	13.6	Standing	Improved
10	Existing	10.4	Standing	-	14.7	Standing	-
	Future	10.2	Standing	Unchanged	14.6	Standing	Unchanged
11	Existing	8.4	Sitting	-	11.4	Standing	-
	Future	8.6	Sitting	Unchanged	12.9	Standing	Unchanged
12	Existing	9.4	Sitting	-	12.3	Standing	-
	Future	10.1	Standing	Improved	13.3	Standing	Unchanged
13	Existing	9.7	Sitting	-	13.7	Standing	-
	Future	10.0	Standing	Improved	12.7	Standing	Unchanged
14	Existing	9.9	Sitting	-	14.4	Standing	-
	Future	9.2	Sitting	Unchanged	11.8	Standing	Unchanged
15	Existing	9.0	Sitting	-	11.9	Standing	-
	Future	10.5	Standing	Improved	13.9	Standing	Unchanged

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** (0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 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	9.6	Sitting	-	12.6	Standing	-
	Future	11.6	Standing	Reduced	16.8	Walking	Reduced
17	Existing	10.2	Standing	-	14.0	Standing	-
	Future	9.0	Sitting	Improved	12.9	Standing	Unchanged
18	Existing	10.1	Standing	-	13.2	Standing	-
	Future	8.8	Sitting	Improved	12.3	Standing	Unchanged
19	Existing	9.7	Sitting	-	12.7	Standing	-
	Future	11.2	Standing	Reduced	16.9	Walking	Reduced
20	Existing	10.0	Sitting	-	13.2	Standing	-
	Future	10.6	Standing	Reduced	14.0	Standing	Unchanged
21	Existing	8.6	Sitting	-	11.6	Standing	-
	Future	10.0	Sitting	Unchanged	13.1	Standing	Unchanged
22	Existing	10.0	Sitting	-	13.5	Standing	-
	Future	11.7	Standing	Reduced	13.8	Standing	Unchanged
23	Existing	10.5	Standing	-	14.7	Standing	-
	Future	11.8	Standing	Unchanged	13.6	Standing	Unchanged
24	Existing	10.0	Sitting	-	13.6	Standing	-
	Future	12.5	Standing	Reduced	14.5	Standing	Unchanged
25	Existing	8.1	Sitting	-	11.8	Standing	-
	Future	9.0	Sitting	Unchanged	10.8	Standing	Unchanged
26	Existing	7.9	Sitting	-	10.9	Standing	-
	Future	10.1	Standing	Reduced	14.8	Standing	Unchanged
27	Existing	11.5	Standing	-	14.6	Standing	-
	Future	9.7	Sitting	Improved	14.3	Standing	Unchanged
28	Existing	11.5	Standing	-	15.4	Walking	-
	Future	8.6	Sitting	Improved	12.3	Standing	Improved
29	Existing	11.3	Standing	-	15.2	Walking	-
	Future	7.6	Sitting	Improved	10.4	Standing	Improved
30	Existing	11.1	Standing	-	14.8	Standing	-
	Future	13.6	Standing	Unchanged	16.2	Walking	Reduced

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** (0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 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	12.1	Standing	-	16.2	Walking	-
	Future	10.4	Standing	Unchanged	12.9	Standing	Improved
32	Existing	12.0	Standing	-	16.3	Walking	-
	Future	9.4	Sitting	Improved	12.5	Standing	Improved
33	Existing	8.4	Sitting	-	10.5	Standing	-
	Future	6.2	Sitting	Unchanged	8.5	Sitting	Improved
34	Existing	6.6	Sitting	-	8.4	Sitting	-
	Future	9.1	Sitting	Unchanged	12.9	Standing	Reduced
35	Existing	10.6	Standing	-	14.6	Standing	-
	Future	8.3	Sitting	Improved	11.6	Standing	Unchanged
36	Existing	10.0	Standing	-	13.6	Standing	-
	Future	6.1	Sitting	Improved	8.3	Sitting	Improved
37	Existing	11.9	Standing	-	16.2	Walking	-
	Future	10.1	Standing	Unchanged	13.0	Standing	Improved
38	Existing	11.9	Standing	-	16.2	Walking	-
	Future	7.0	Sitting	Improved	8.8	Sitting	Improved
39	Existing	11.9	Standing	-	16.3	Walking	-
	Future	6.5	Sitting	Improved	8.9	Sitting	Improved
40	Existing	12.1	Standing	-	16.4	Walking	-
	Future	6.9	Sitting	Improved	9.8	Sitting	Improved
41	Existing	12.3	Standing	-	16.4	Walking	-
	Future	7.3	Sitting	Improved	10.4	Standing	Improved
42	Existing	12.1	Standing	-	15.9	Walking	-
	Future	8.5	Sitting	Improved	13.9	Standing	Improved
43	Existing	11.7	Standing	-	15.6	Walking	-
	Future	7.6	Sitting	Improved	10.3	Standing	Improved
44	Existing	11.0	Standing	-	15.2	Walking	-
	Future	7.0	Sitting	Improved	9.7	Sitting	Improved
45	Existing	11.0	Standing	-	16.0	Walking	-
	Future	8.6	Sitting	Improved	11.1	Standing	Improved

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** (0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 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	6.9	Sitting	-	9.2	Sitting	-
	Future	8.5	Sitting	Unchanged	10.2	Standing	Reduced
47	Existing	9.7	Sitting	-	12.5	Standing	-
	Future	7.5	Sitting	Unchanged	8.4	Sitting	Improved
48	Existing	9.3	Sitting	-	12.5	Standing	-
	Future	9.5	Sitting	Unchanged	12.1	Standing	Unchanged
49	Existing	8.7	Sitting	-	11.6	Standing	-
	Future	6.0	Sitting	Unchanged	8.1	Sitting	Improved
50	Existing	9.7	Sitting	-	12.5	Standing	-
	Future	7.3	Sitting	Unchanged	9.8	Sitting	Improved
51	Existing	9.3	Sitting	-	12.0	Standing	-
	Future	6.9	Sitting	Unchanged	9.2	Sitting	Improved

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:

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

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.

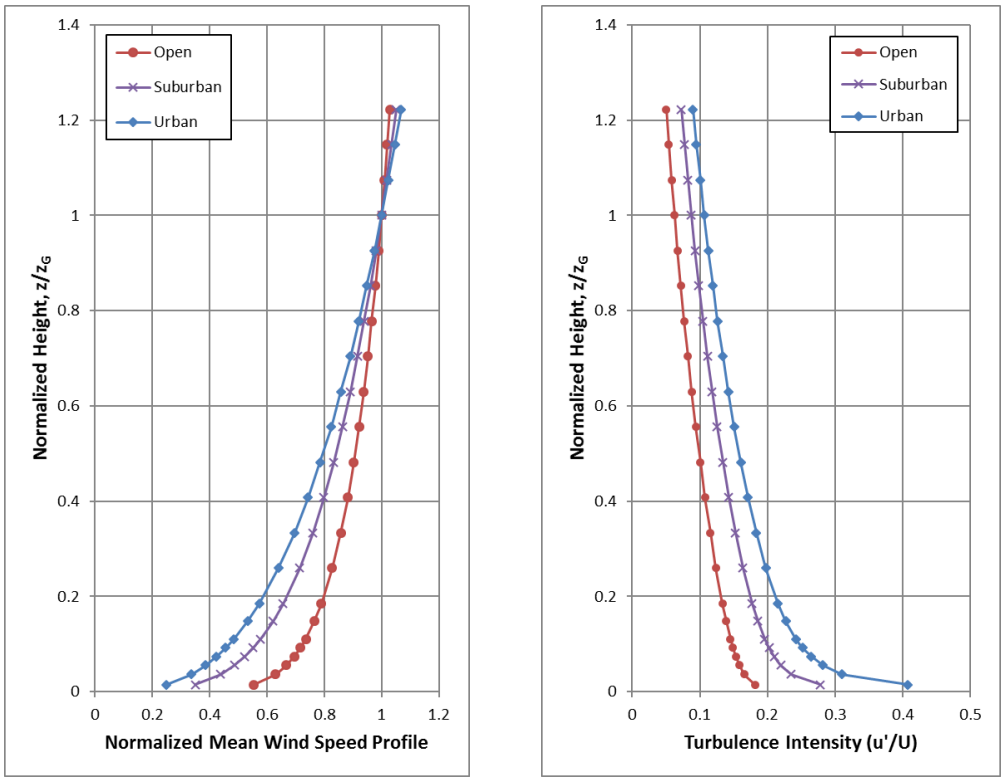

FIGURE C1 (LEFT): MEAN WIND SPEED PROFILES;
FIGURE C2 (RIGHT): TURBULENCE INTENSITY PROFILES

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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) = Σ_θ 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.

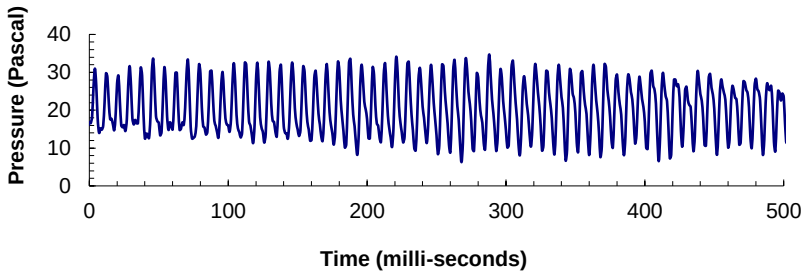

FIGURE D1: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR

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