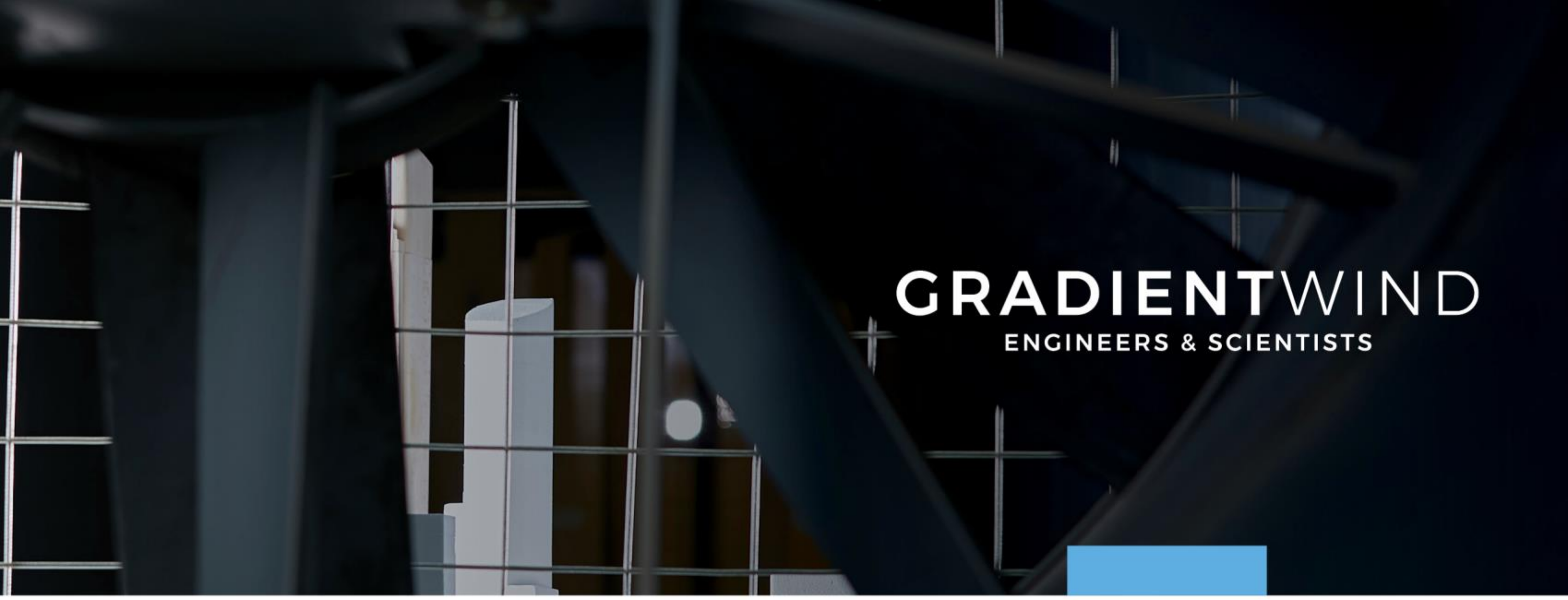
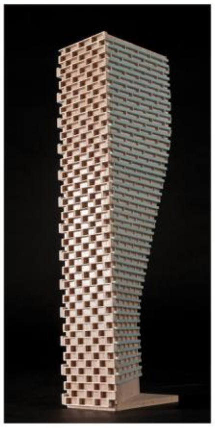
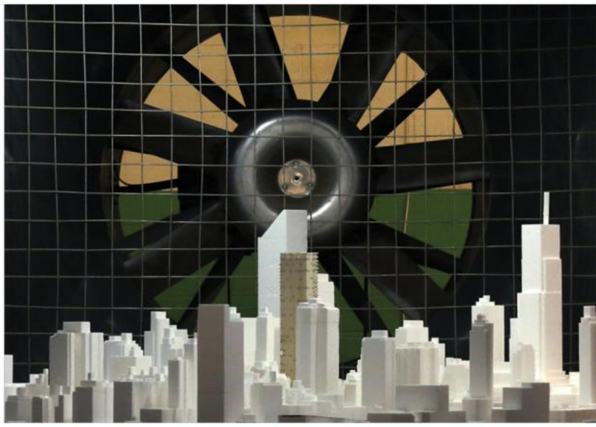


PEDESTRIAN LEVEL WIND STUDY

2900 King Street East
Hamilton, Ontario

REPORT: GW21-232-WTPLW





August 23, 2021

PREPARED FOR
Camarro Developments
c/o Urban Solutions
3 Studebaker Place, Unit 1
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PREPARED BY
Angelina Gomes, B.Eng., EIT, Junior Wind Scientist
Andrew Sliasas, M.A.Sc., P.Eng., Principal

EXECUTIVE SUMMARY

This report describes a comparative pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 2900 King Street East in Hamilton, Ontario. Two configurations were studied: (i) existing conditions, including all approved, surrounding developments and without the proposed development, and (ii) future conditions with the proposed development in place. 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, green spaces, nearby transit stops, Stoney Creek Cemetery, and building access points. Wind comfort is also evaluated over the Level 4 and Level 7 outdoor amenity terraces. 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, architectural drawings provided by RAW Design in July 2021, surrounding street layouts, as well as existing and approved future building massing information obtained from the City of Hamilton, 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 through 5B, as well as Tables A1-A2 and B1-B4 in the appendices. Based on the wind tunnel test results, meteorological data analysis, and experience with similar developments in the Hamilton area, we conclude that the future wind conditions over all grade-level pedestrian wind-sensitive areas within and surrounding the study site will be acceptable for the intended uses on a seasonal basis.

To ensure the Level 4 and Level 7 outdoor amenity terraces are comfortable for sitting or more sedentary activities during the summer, 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 neutral influence on grade-level wind conditions, with improvements occurring along portions of the King Street West, King Street East, and Centennial Parkway South sidewalks, as well as areas across Stoney Creek Cemetery to the west of the site. Although

somewhat windier conditions will be experienced over other portions of sidewalk along Centennial Parkway South and King Street East, wind comfort nevertheless remains 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 that could be considered unsafe.

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1. INTRODUCTION

This report describes a comparative pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 2900 King Street East in Hamilton, Ontario. Two configurations were studied: (i) existing conditions, including all approved, surrounding developments and without the proposed development, and (ii) future conditions with the proposed development in place. The study was performed in accordance with industry standard wind tunnel testing techniques, architectural drawings provided by RAW Design 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 comparative pedestrian wind study is the proposed mixed-use development located at 2900 King Street East in Hamilton, Ontario. The study site is situated at the southwest corner of the intersection of King Street and Centennial Parkway South.

The study building comprises two residential towers, Phase 1 (20 storeys) and Phase 2 (18 storeys), oriented north-south, respectively, on a shared six storey podium. Above two levels of below-grade parking, the ground floor is predominately covered parking, accessed from laneways at the northwest corner and along the south elevation, with residential lobbies in the northeast and southeast corners, retail space along the north elevation fronting King Street East, and residential units along the east and south elevations. Levels 2 and 3 consist of above-grade parking and residential units along the north, east, and south perimeters. At Level 4, the centre of the west elevation sets back to accommodate a courtyard outdoor amenity open to the west, with private terraces along the internal north and south elevations. Levels 5 and 6 continue the ‘C’-shaped planform. At Level 7, the west and east elevations setback to the base of the towers, featuring an outdoor amenity terrace on the east side of the podium roof. The towers rise with uniform rectangular planforms to their respective full heights, above which 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) consist of sparsely distributed low-rise buildings in all directions, a mid-rise to the northwest across King Street East, and largely open-exposure from the east clockwise to the west. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer radius) are characterized by primarily low-rise buildings in all directions, with sparse clusters of mid-rise buildings to the northeast along Centennial Parkway and to the east along King Street West, as well as to the northwest and southwest. The more open exposure of parks and farmland permeates the far-field southeast clockwise to the west.

Grade-level areas investigated include sidewalks, laneways, parking areas, green spaces, nearby transit stops, Stoney Creek Cemetery, and building access points. Wind comfort is also evaluated over the Level 4 and Level 7 outdoor amenity terraces. 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 and of surrounding approved future developments, on the existing wind conditions.

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[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] Terms of Reference: Pedestrian Level Wind Study for Downtown Hamilton

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 67 sensor locations on the scale model in Gradient Wind's wind tunnel. Of these 67 sensors, 57 were located at grade and the remaining ten sensors were located over the Level 4 and Level 7 amenity terraces. Wind speed measurements were performed for each of the 67 sensors for 36 wind directions at 10° intervals. Figures 1A and 1B illustrate a plan of the existing and proposed site and relevant surrounding context, respectively, while sensor locations used to investigate wind conditions are illustrated in Figures 2A through 5B.

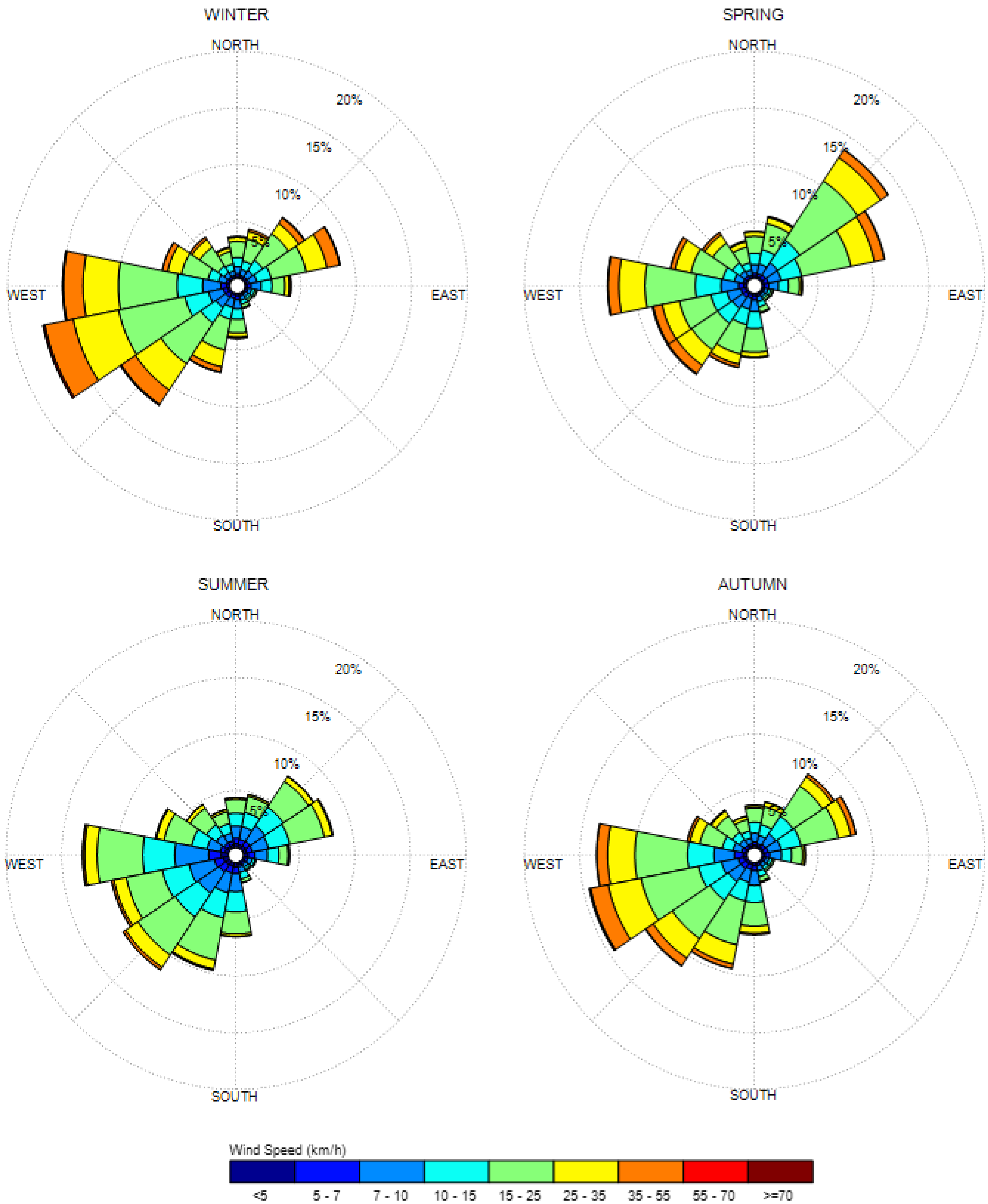
Mean and peak wind speed values for each location and wind direction were calculated from real-time pressure measurements, recorded at a sample rate of 500 samples per second, and taken over a 60-second time period. This period at model-scale corresponds approximately to one hour in full-scale, which 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 Hamilton was developed from approximately 40-years of hourly meteorological wind data recorded at 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. 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 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 and west, as well as 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 the calmest winds relative to the remaining seasonal periods.

SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES
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. Four pedestrian comfort classes are based on 80% non-exceedance gust wind speed ranges, which include (i) Sitting; (ii) Standing; (iii) Walking; and (iv) Uncomfortable. More specifically, the comfort classes and associated gust wind speed ranges are summarized as follows:

(i) **Sitting** – A wind speed below 16 km/h (i.e. 0 – 16 km/h) would be considered acceptable for sedentary activities, including sitting.

(ii) **Standing** – A wind speed below 22 km/h (i.e. 16 km/h – 22 km/h) is acceptable for activities such as standing or leisurely strolling.

(iii) **Walking** – A wind speed below 30 km/h (i.e. 22 km/h – 30 km/h) is acceptable for walking or more vigorous activities.

(iv) **Uncomfortable** – A wind speed over 30 km/h is classified as uncomfortable from a pedestrian comfort standpoint. Brisk walking and exercise, such as jogging, would be acceptable for moderate excesses of this criterion.

The pedestrian safety wind speed guideline is based on the approximate threshold that would cause a vulnerable member of the population to fall. A 0.1% exceedance gust wind speed of greater than 90 km/h is classified as dangerous.

The wind speeds associated with the above categories are gust wind speeds. Corresponding mean wind speeds are approximately calculated as gust wind speed minus 1.5 times the root-mean-square (rms) of the wind speed measurements. Gust speeds are used in the guidelines because people tend to be more sensitive to wind gusts than to steady winds for lower wind speed ranges. For strong winds approaching dangerous levels, this effect is less important, because the mean wind can also cause problems for pedestrians. The gust 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.

THE BEAUFORT SCALE

NUMBER	DESCRIPTION	WIND SPEED (KM/H)	DESCRIPTION
2	Light Breeze	4-8	Wind felt on faces
3	Gentle Breeze	8-15	Leaves and small twigs in constant motion; Wind extends light flags
4	Moderate Breeze	15-22	Wind raises dust and loose paper; Small branches are moved
5	Fresh Breeze	22-30	Small trees in leaf begin to sway
6	Strong Breeze	30-40	Large branches in motion; Whistling heard in electrical wires; Umbrellas used with difficulty
7	Moderate Gale	40-50	Whole trees in motion; Inconvenient walking against wind
8	Gale	50-60	Breaks twigs off trees; Generally impedes progress

Experience and research on people's perception of mechanical wind effects has shown that if the wind speed levels are exceeded for more than 20% of the time, the activity level would be judged to be uncomfortable by most people. For instance, if wind speeds of 16 km/h were exceeded for more than 20% of the time most pedestrians would judge that location to be too windy for sitting or more sedentary activities. Similarly, if 30 km/h at a location were exceeded for more than 20% of the time, walking or less vigorous activities would be considered uncomfortable. As most of these criteria are based on subjective reactions of a population to wind forces, their application is partly based on experience and judgment.

Once the pedestrian wind speed predictions have been established at tested locations, 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 represented by the sensor (i.e. a sidewalk, building entrance, amenity space, or other). 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 19.1 for the summer season indicates that 80% of the measured data falls at or below 19.1 km/h during the summer months and conditions are therefore suitable for standing, as the 80% threshold value falls within the exceedance range of 16-22 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, walking by blue, and 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-A2 in Appendix A, this section summarizes the most significant findings of the PLW study with respect to future conditions, as follows:

1. Most public sidewalks, parking lots, laneways, and green space within and surrounding the study site will be suitable for walking or better throughout the year. Exceptions include areas along Centennial Parkway South to the southeast of the study site (Sensors 13 & 17), and laneway entrances from King Street East (Sensor 28) and Centennial Parkway South (Sensor 45) which will transition to conditions uncomfortable for walking during the colder seasons. However, it is noteworthy that wind speeds will be considered safe (refer to Tables A1-A2 under “Pedestrian Safety”) at these areas. As well, the noted areas along Centennial Parkway South do not presently

consist of sidewalks, and all noted areas are not expected to be subject to frequent pedestrian traffic. Overall, the noted conditions are considered acceptable.

2. All entrances throughout the development, including retail entrances, lobby entrances, secondary building access points, and the private entrances along the east and south elevations, will be comfortable for standing or better throughout the year, which is appropriate.

3. The covered grade-level parking and loading area (Sensors 50-56) will be suitable for sitting or standing throughout the year, which is acceptable.

4. Most nearby transit stops (Sensors 7 & 31) will be comfortable for standing or better throughout the year. One exception is the transit stop east of the site along Centennial Parkway South (Sensor 11), which will experience walking conditions during the three colder seasons. However, the noted conditions are pre-existing and will not be exacerbated by the proposed development.

5. The tested areas of Stoney Creek Cemetery (Sensors 21-25) will be suitable for standing or better during the summer and walking or better throughout the remaining seasonal periods, which is appropriate.

6. The Level 4 outdoor amenity terrace (Sensors 58-60) will be comfortable for standing or better during the summer and walking or better during the spring and autumn. To ensure conditions across the entire terrace to be suitable for sitting or more sedentary activities throughout the warmer months, it is recommended to raise the west perimeter guard to 2.4 metres above the walking surface. It may also be necessary to install localized wind barriers internal to the space directly west of seating areas. The exact placement and configuration of internal barriers, if required, can be coordinated with the design team as the landscaping plan progresses.

7. The majority of the Level 7 outdoor amenity terrace (Sensors 61-67) will be comfortable for sitting during the summer and standing or better during the spring and autumn. Exceptions include areas along the east perimeter (Sensors 63 & 67) where conditions will transition to standing during the summer and walking or better into the shoulder seasons. If seating areas will be provided over the noted windier areas, it will be beneficial to locate vertical wind screening upwind of such spaces to locally improve conditions. The exact placement and configuration of such wind screens, if required, can be coordinated with the design team as the landscaping plan progresses.

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 summer and winter 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 wind speeds at many grade-level areas will remain unchanged upon the introduction of the proposed study building, with improvements on portions of sidewalk along King Street West (Sensors 8 & 9), King Street East (Sensors 31 & 34), and Centennial Parkway South (Sensors 37, 39, 41, 42, & 44), as well as across Stoney Creek Cemetery (Sensors 21-24). Although wind speeds marginally increase along portions of the Centennial Parkway South sidewalk (Sensors 13, 17, & 45) and King Street East sidewalk (Sensor 28), 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 2900 King 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 through 5B, as well as Tables A1-A2 and B1-B4 in the appendices. Based on the wind tunnel test results, meteorological data analysis, and experience with similar developments in the Hamilton area, we conclude that the future wind conditions over all grade-level pedestrian wind-sensitive areas within and surrounding the study site will be acceptable for the intended uses on a seasonal basis.

To ensure the Level 4 and Level 7 outdoor amenity terraces are comfortable for sitting or more sedentary activities during the summer, 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 neutral influence on grade-level wind conditions, with improvements occurring along portions of the King Street West, King Street East, and Centennial Parkway South sidewalks, as well as areas across Stoney Creek Cemetery to the west of the site. Although somewhat windier conditions will be experienced over other portions of sidewalk along Centennial Parkway South and King Street East, wind comfort nevertheless remains 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 that could be considered unsafe.

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

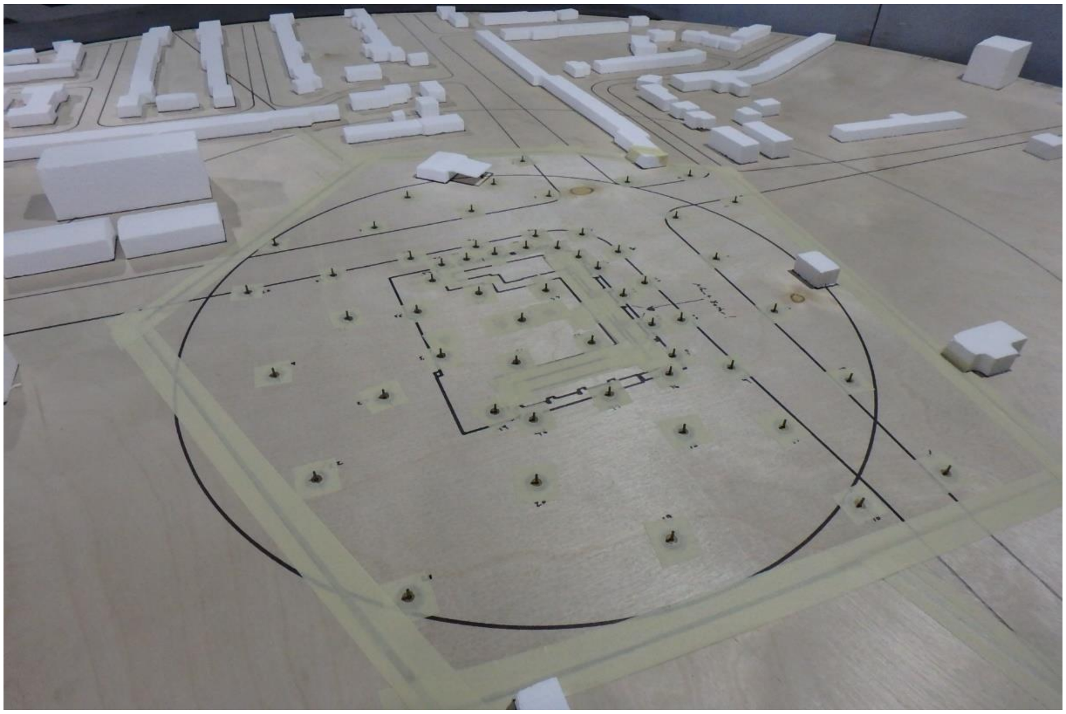
Sincerely,

Gradient Wind Engineering Inc.

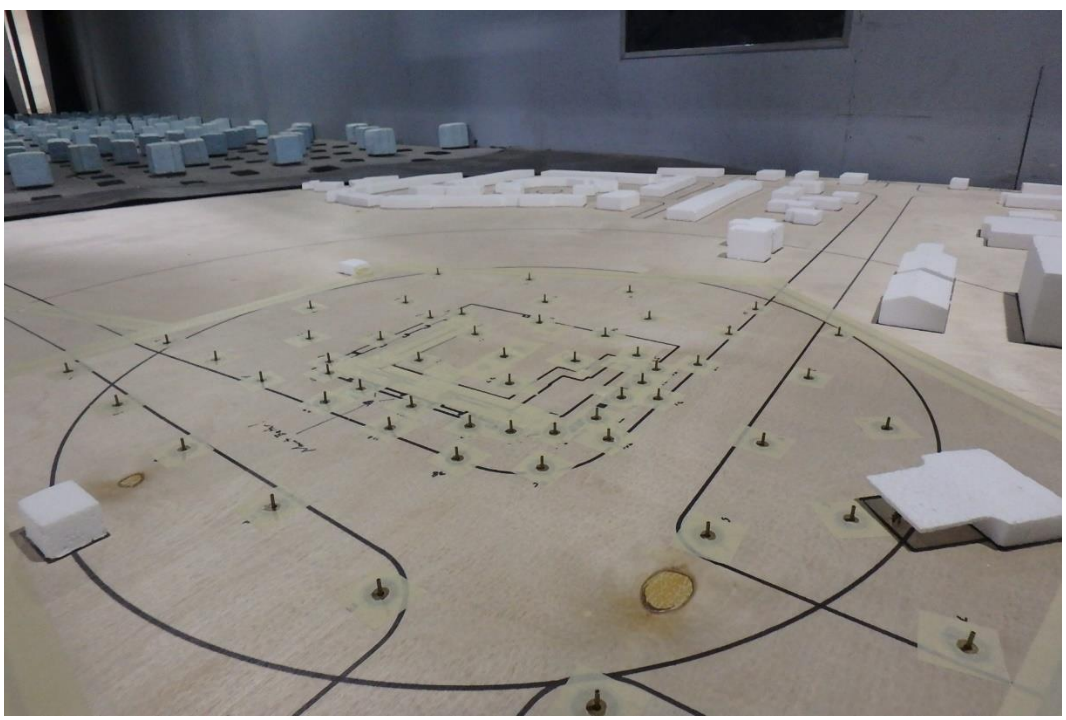
Angelina Gomes, B.Eng., EIT
Junior Wind Scientist

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

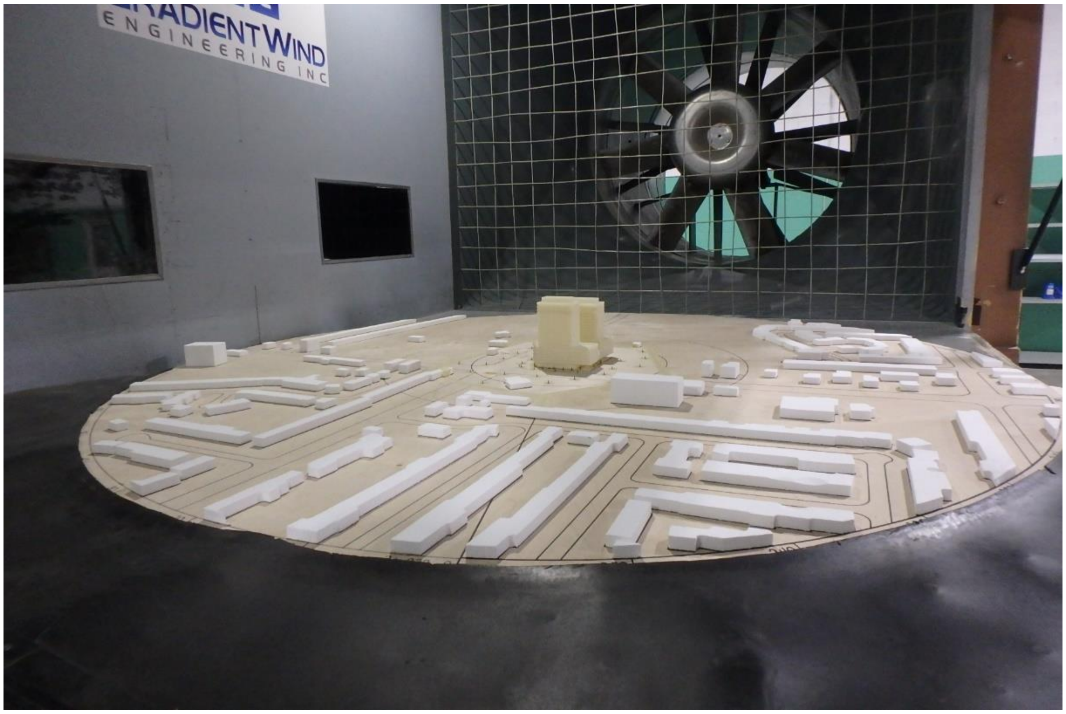
GW21-232-WTPLW



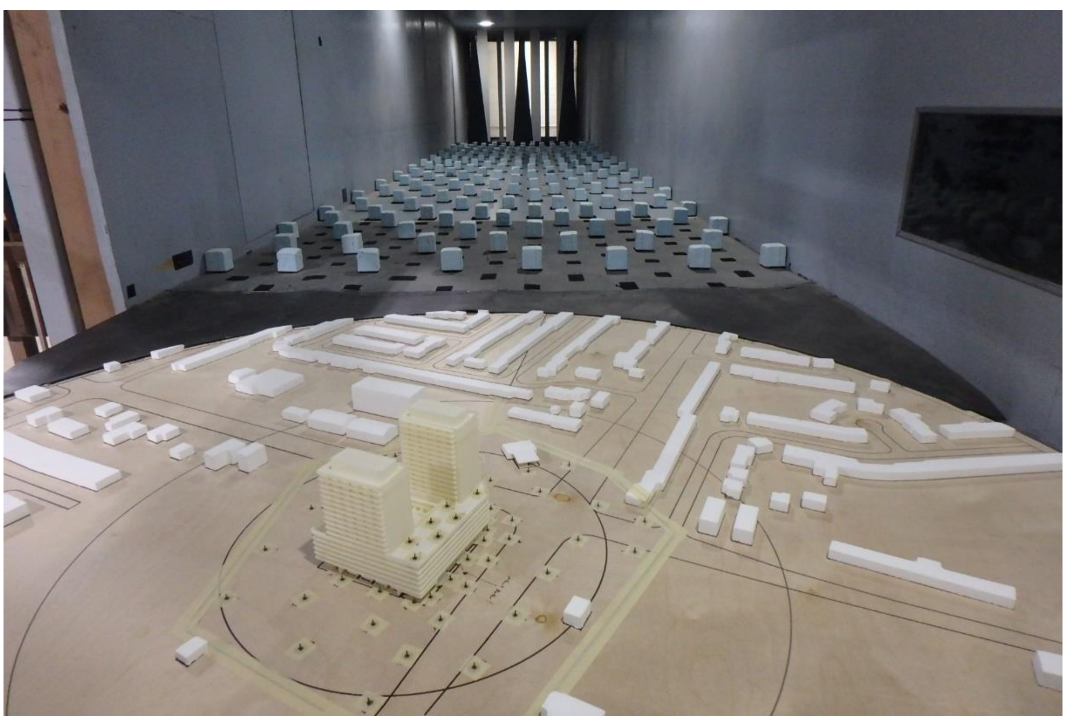
PHOTOGRAPH 1: CLOSE-UP VIEW OF EXISTING CONTEXT MODEL LOOKING NORTHEAST



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

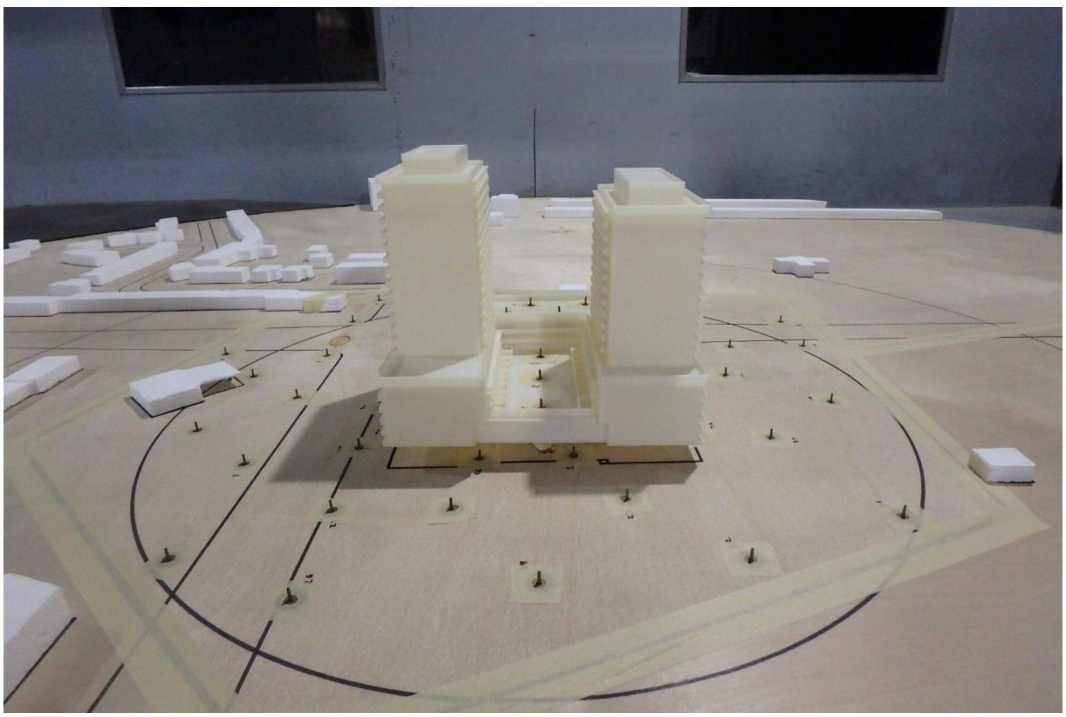


PHOTOGRAPH 3: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING DOWNWIND

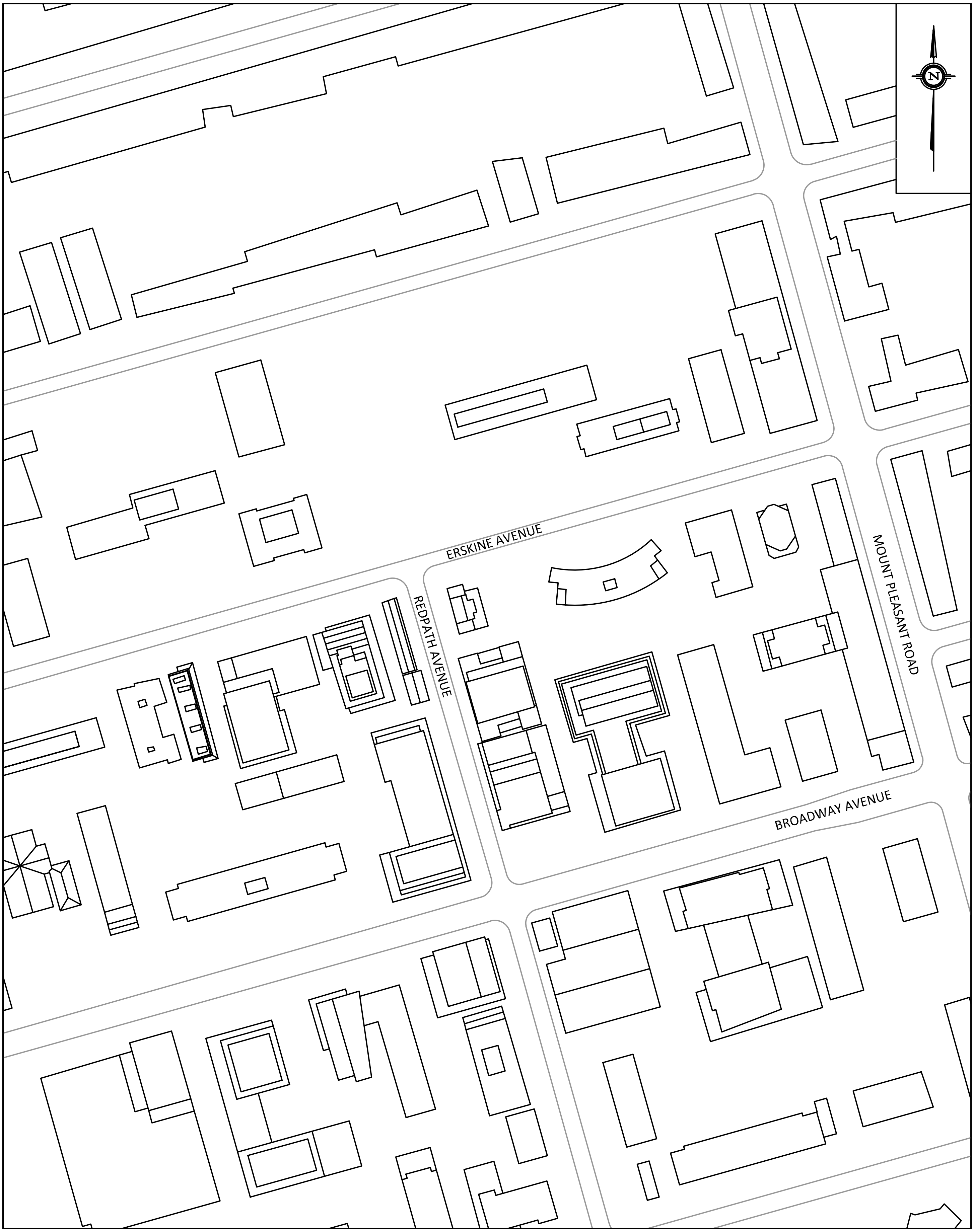


PHOTOGRAPH 4: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING UPWIND

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



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



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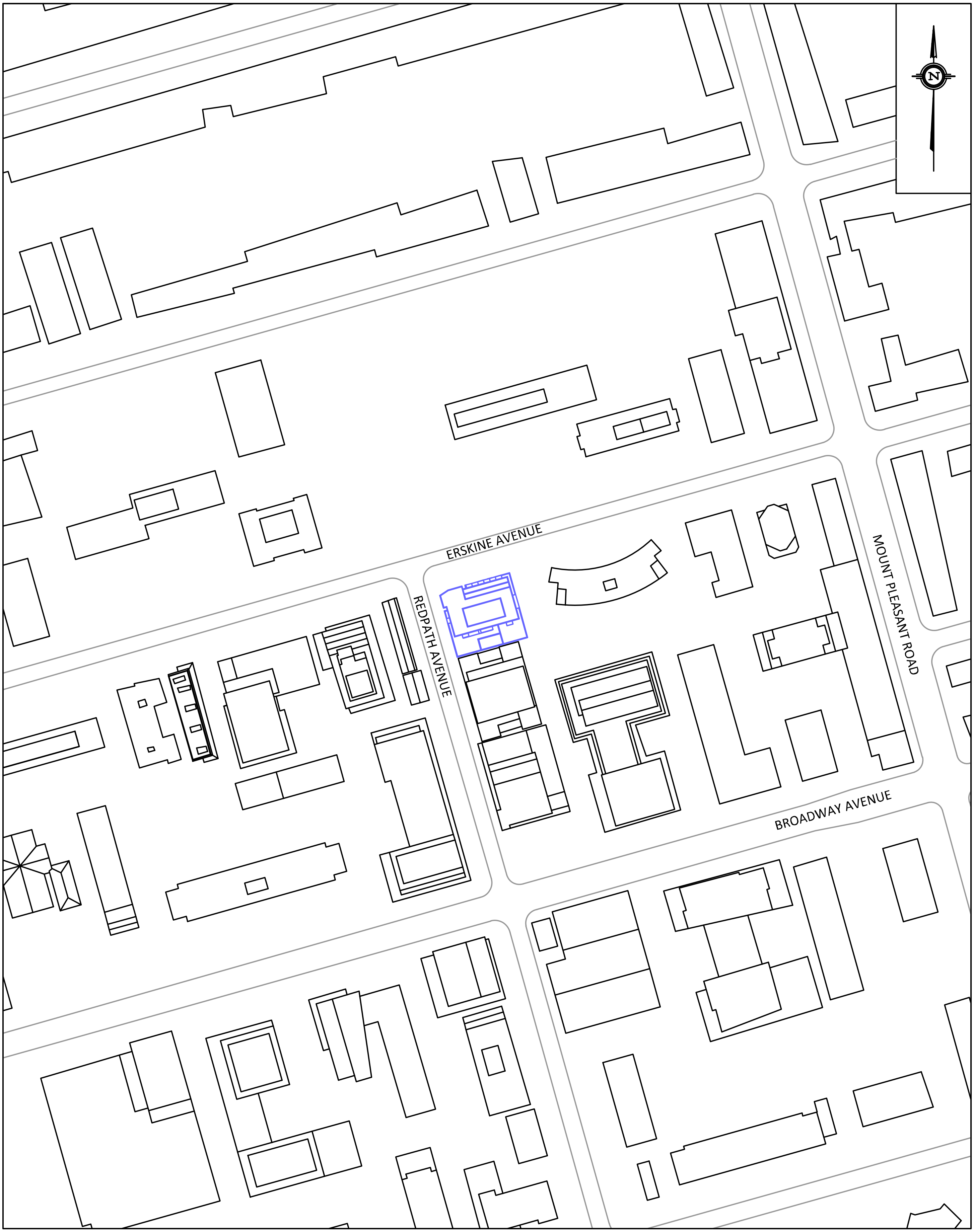
PROJECT	133 ERSKINE AVENUE, TORONTO PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:2500 (APPROX.)	DRAWING NO.	GW21-142-PLW-1A
DATE	OCTOBER 22, 2021	DRAWN BY	C.E.

DESCRIPTION

FIGURE 1A:
EXISTING CONDITIONS
SITE PLAN AND SURROUNDING CONTEXT



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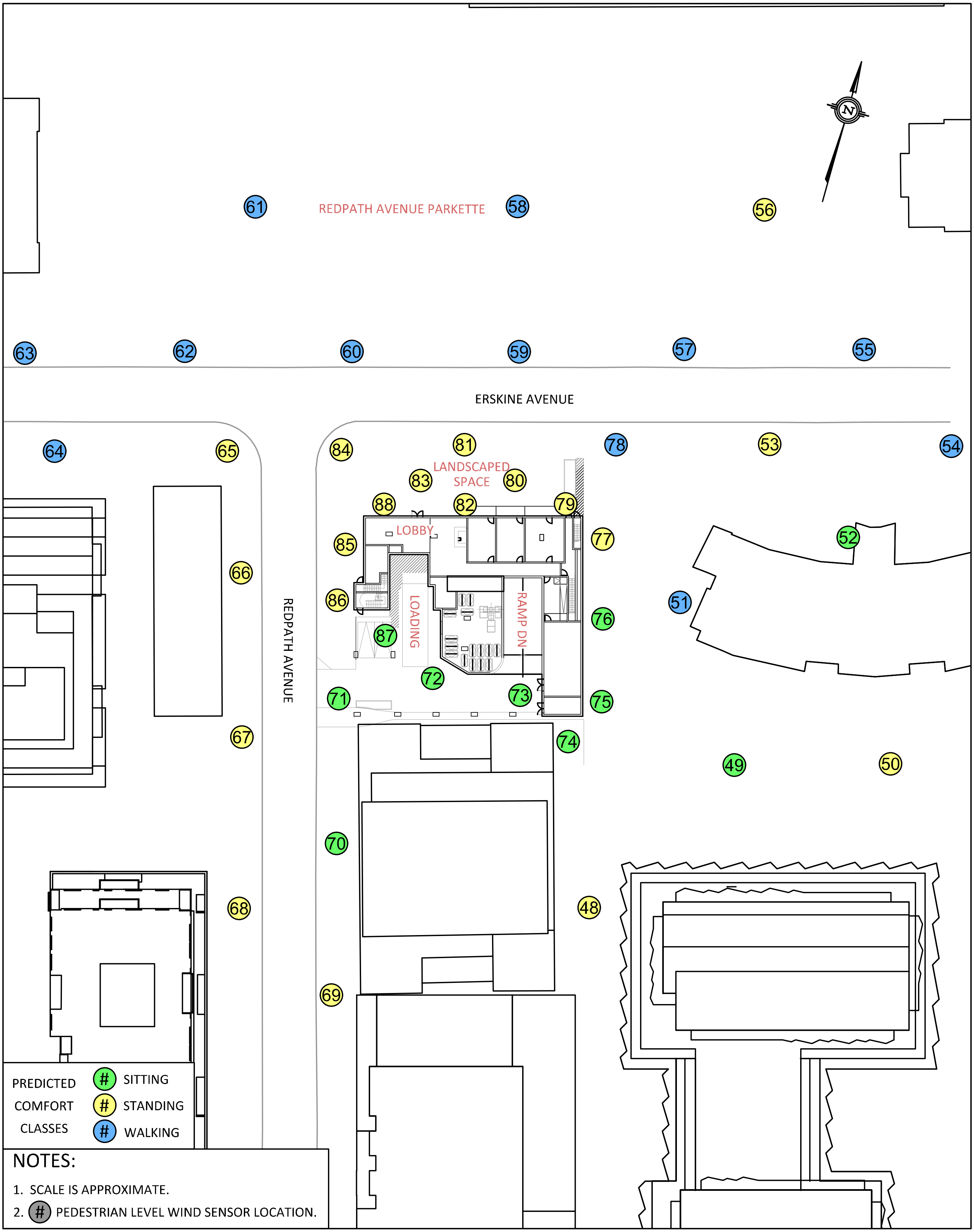
PROJECT	133 ERSKINE AVENUE, TORONTO PEDESTRIAN LEVEL WIND STUDY
SCALE	1:2500 (APPROX.)
DRAWING NO.	GW21-142-PLW-1B
DATE	OCTOBER 22, 2021
DRAWN BY	C.E.
DESCRIPTION	FIGURE 1B: FUTURE PROPOSED CONDITIONS SITE PLAN AND SURROUNDING CONTEXT



NOTES:

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

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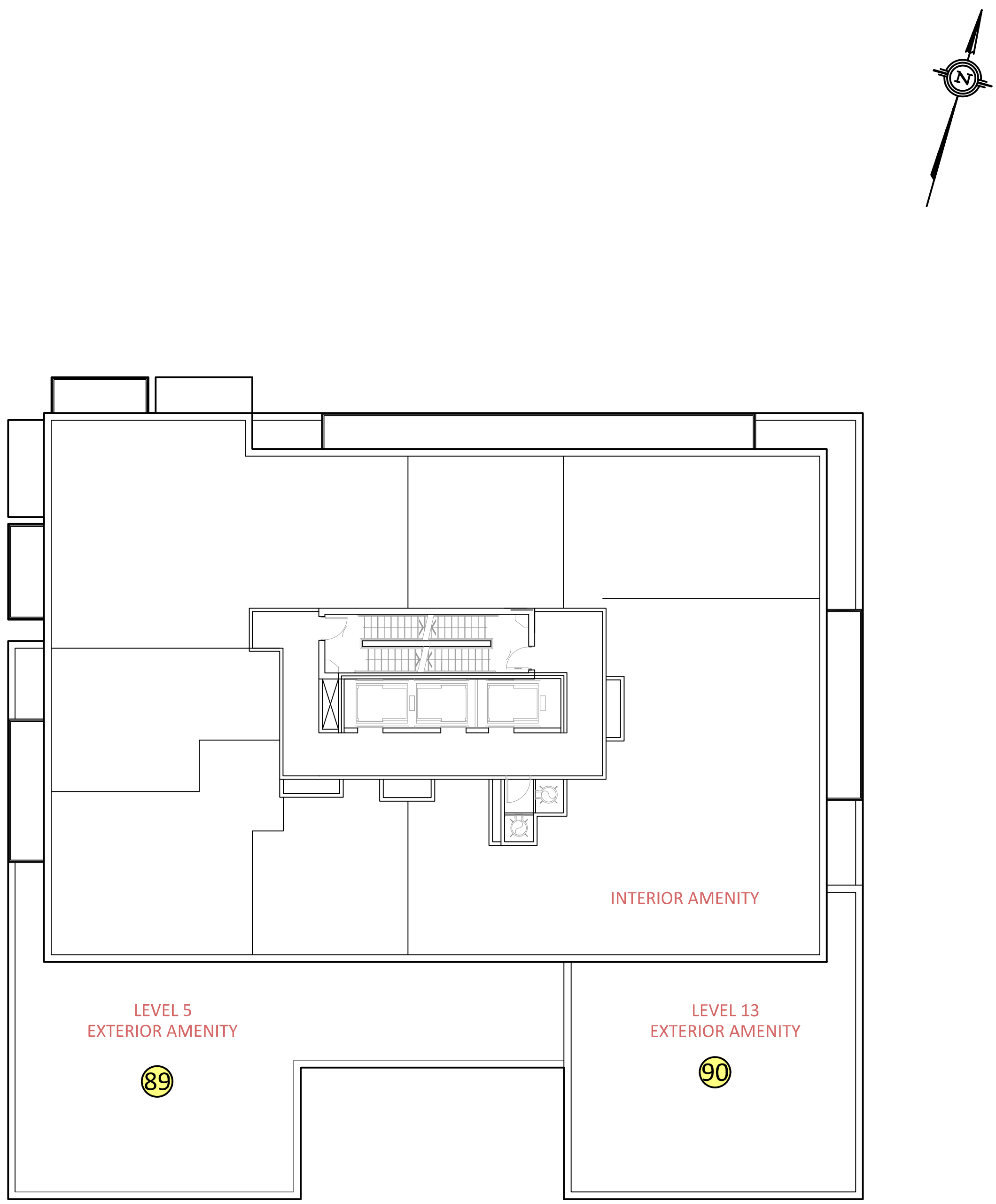
PROJECT: 133 ERSKINE AVENUE, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 2A: SPRING GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS
SCALE: 1:800 (APPROX.)	DRAWING NO.: GW21-142-PLW-2A	
DATE: OCTOBER 22, 2021	DRAWN BY: C.E.	



PREDICTED COMFORT CLASSES
- # SITTING
- # STANDING
- # WALKING

NOTES:

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

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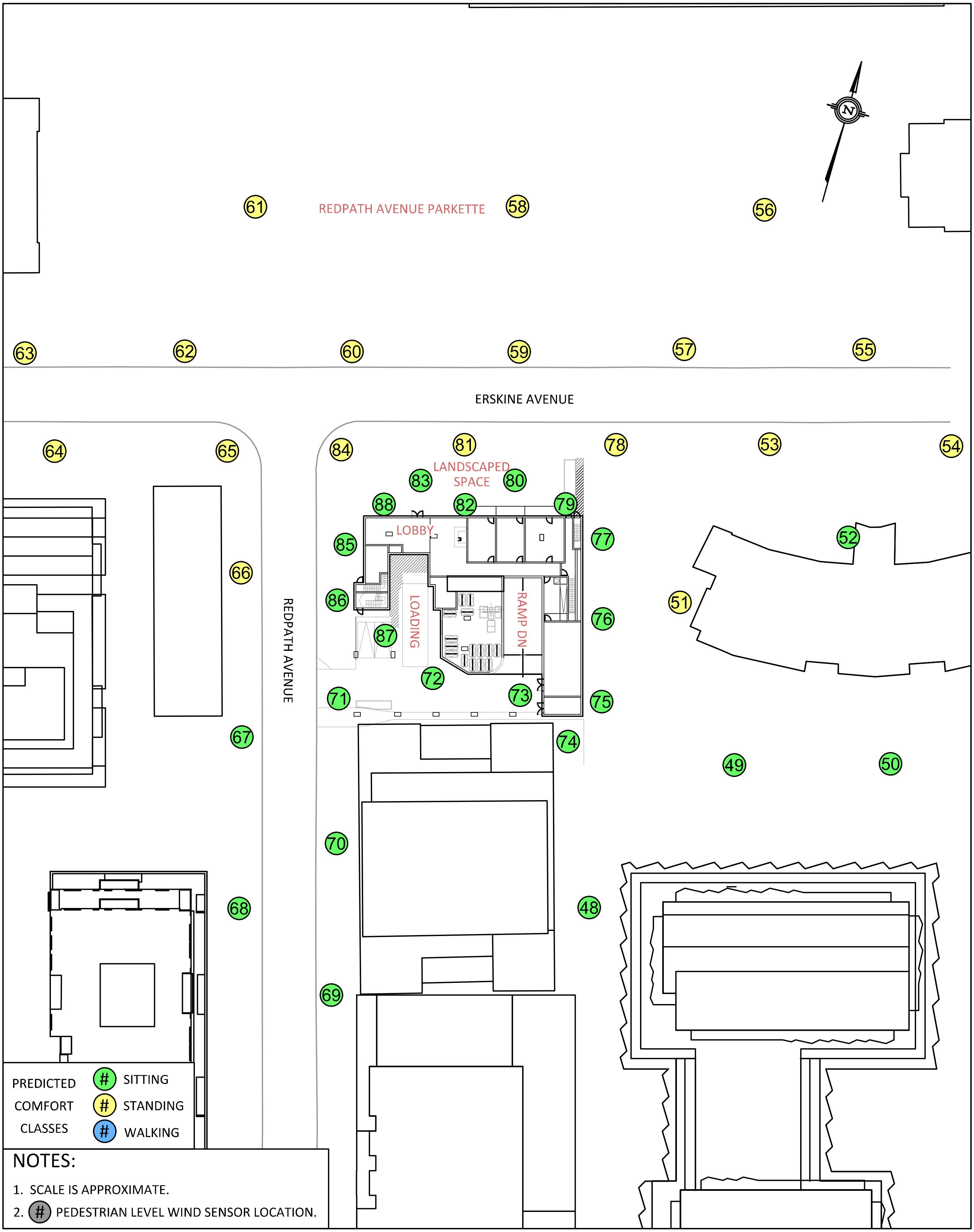
PROJECT	133 ERSKINE AVENUE, TORONTO PEDESTRIAN LEVEL WIND STUDY
SCALE	1:300 (APPROX.)
DRAWING NO.	GW21-142-PLW-2B
DATE	OCTOBER 22, 2021
DRAWN BY	C.E.
DESCRIPTION	FIGURE 2B: SPRING AMENITY FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS



NOTES:

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

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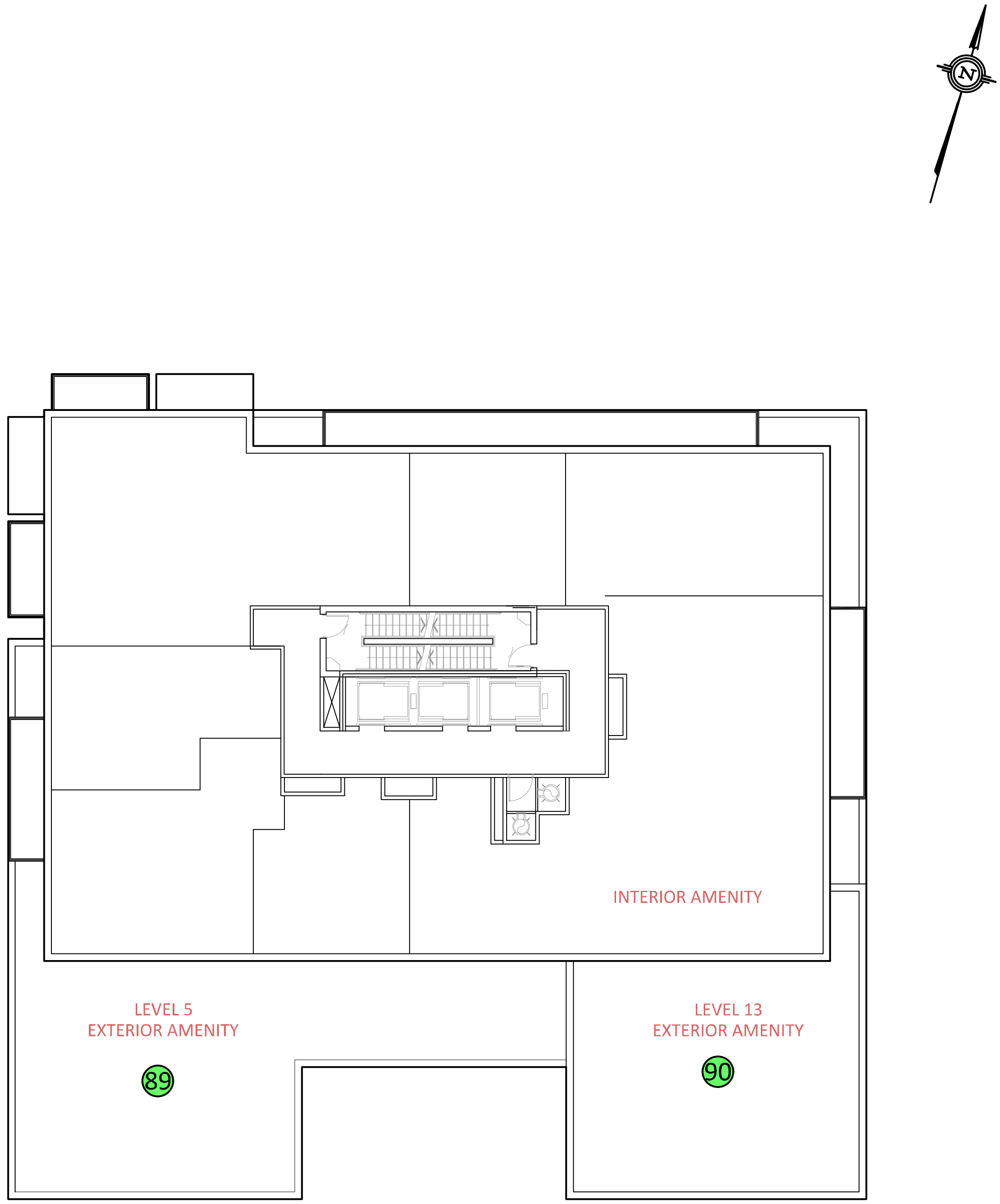
PROJECT	133 ERSKINE AVENUE, TORONTO PEDESTRIAN LEVEL WIND STUDY
SCALE	1:800 (APPROX.)
DRAWING NO.	GW21-142-PLW-3A
DATE	OCTOBER 22, 2021
DRAWN BY	C.E.
DESCRIPTION	FIGURE 3A: SUMMER GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS



PREDICTED COMFORT CLASSES
- # SITTING
- # STANDING
- # WALKING

NOTES:

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

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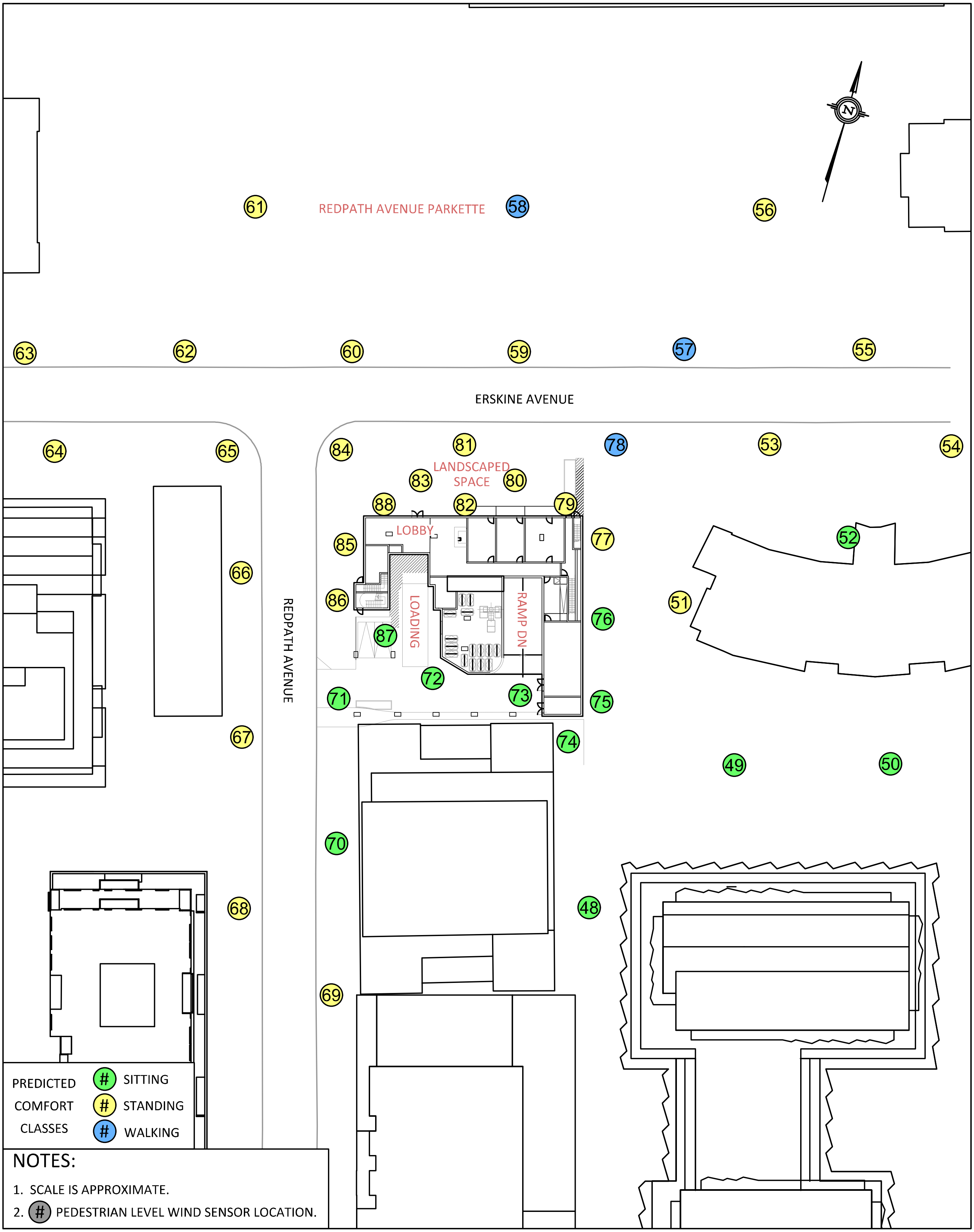
PROJECT: 133 ERSKINE AVENUE, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 3B: SUMMER AMENITY FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS
SCALE: 1:300 (APPROX.)	DRAWING NO.: GW21-142-PLW-3B	
DATE: OCTOBER 22, 2021	DRAWN BY: C.E.	



NOTES:

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

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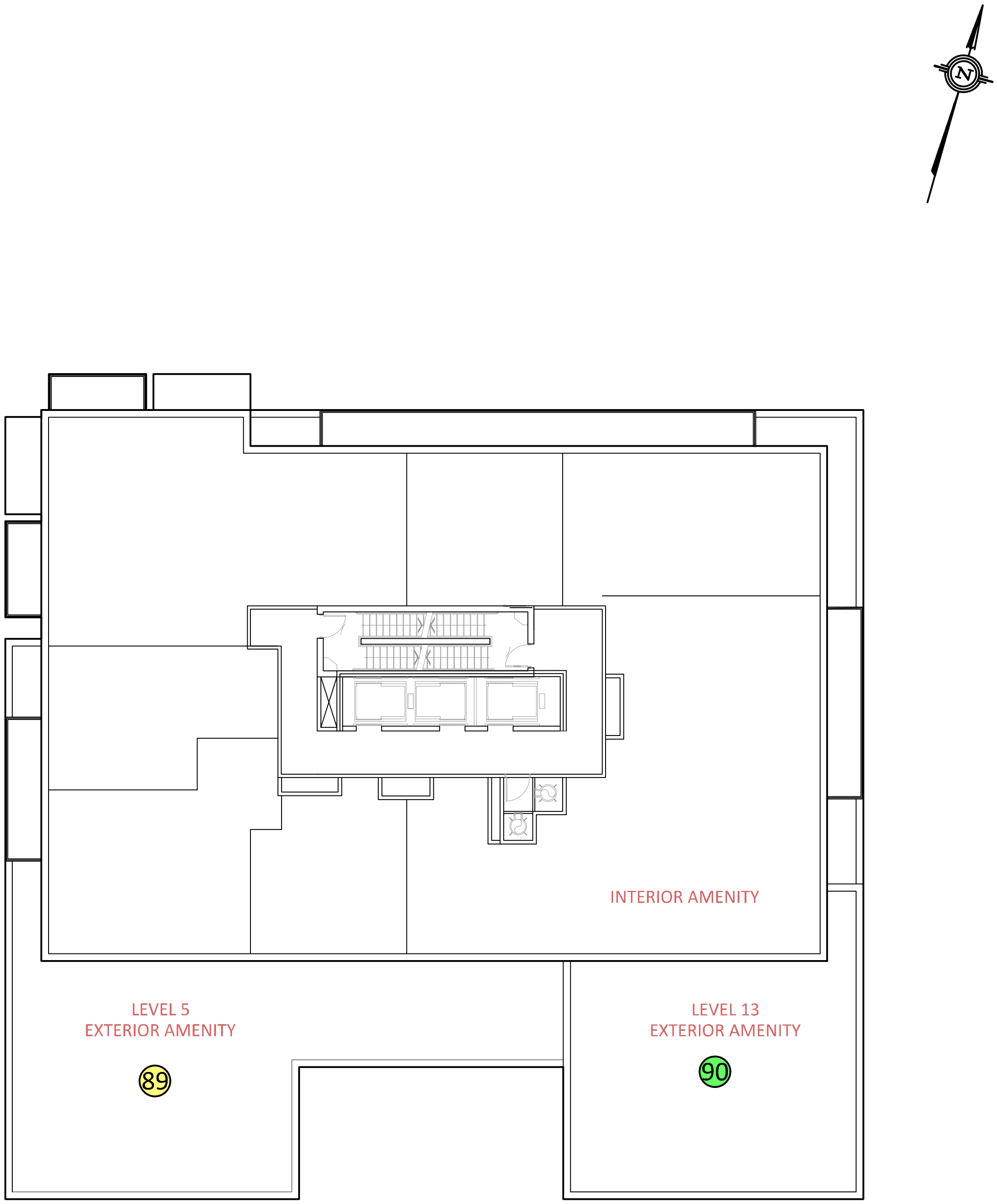
PROJECT: 133 ERSKINE AVENUE, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 4A: AUTUMN GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS
SCALE: 1:800 (APPROX.)	DRAWING NO.: GW21-142-PLW-4A	
DATE: OCTOBER 22, 2021	DRAWN BY: C.E.	



PREDICTED COMFORT CLASSES
- # SITTING
- # STANDING
- # WALKING

NOTES:

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

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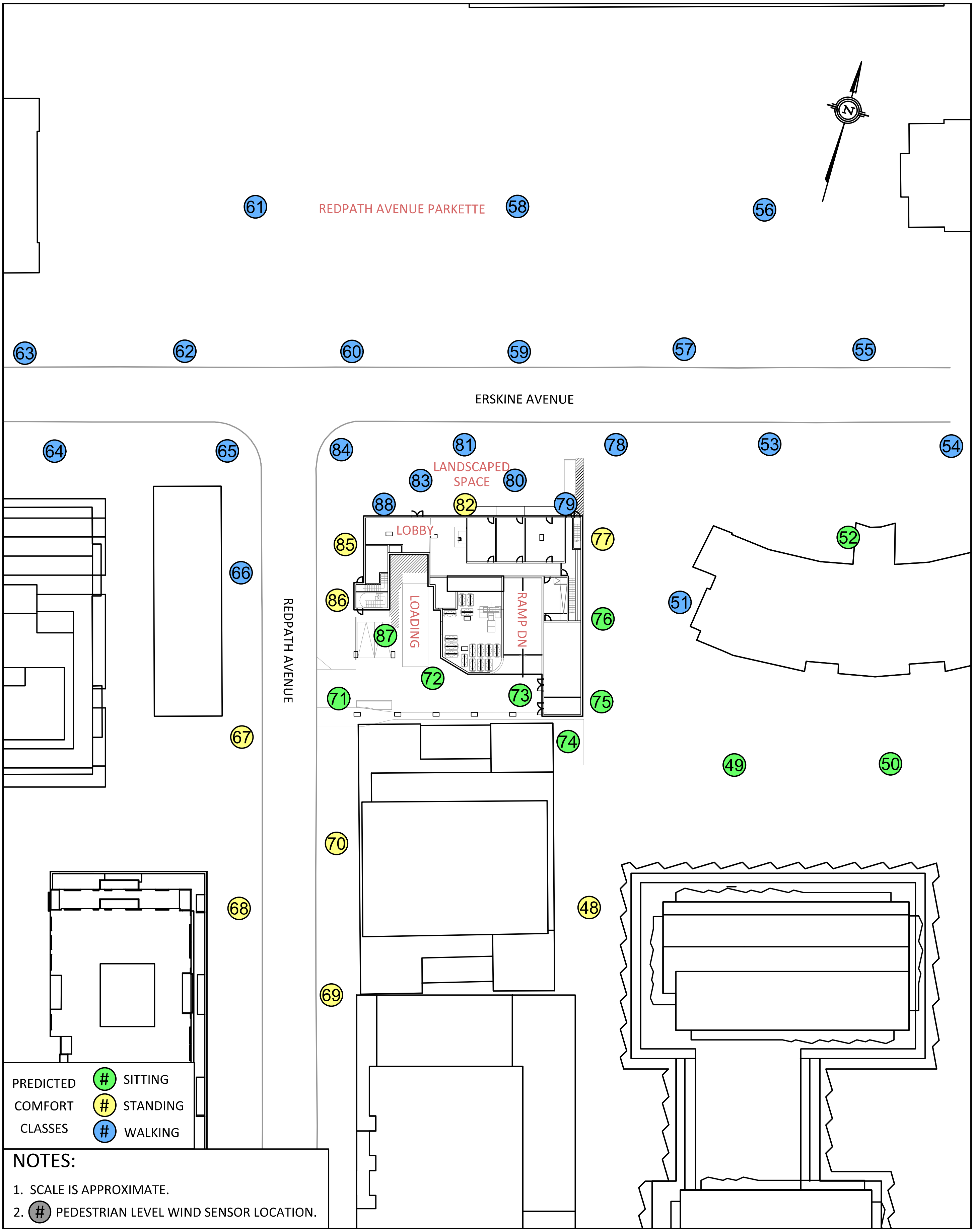
PROJECT: 133 ERSKINE AVENUE, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 4B: AUTUMN AMENITY FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS
SCALE: 1:300 (APPROX.)	DRAWING NO. GW21-142-PLW-4B	
DATE: OCTOBER 22, 2021	DRAWN BY: C.E.	



NOTES:

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

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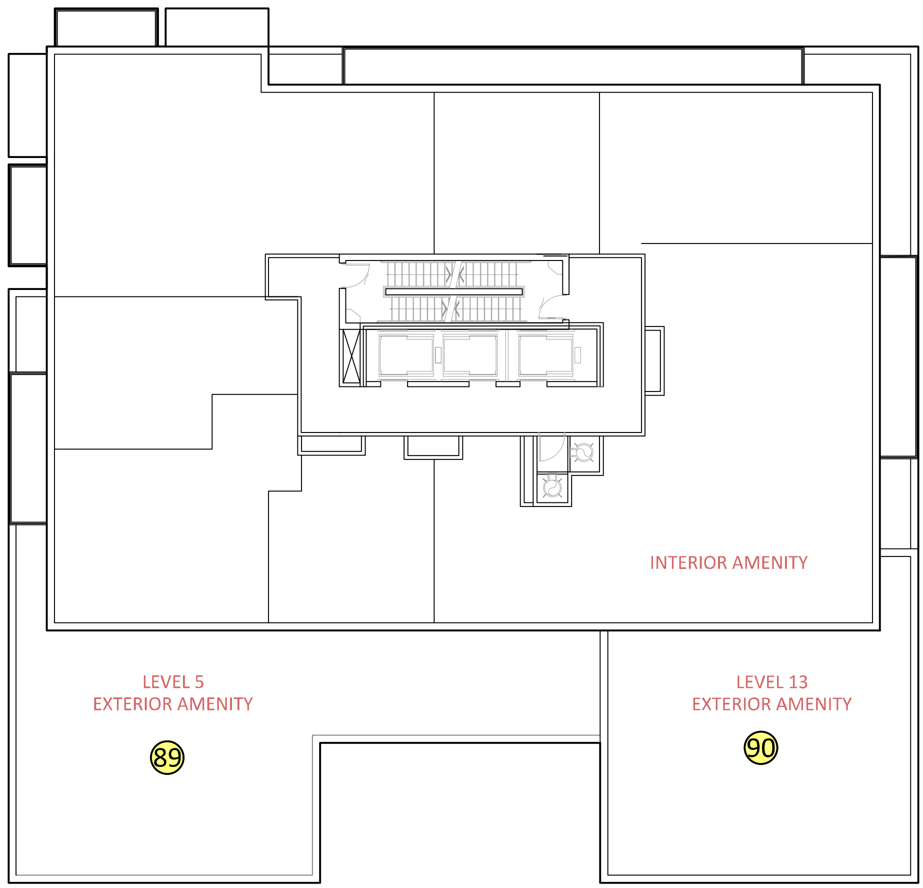
PROJECT	133 ERSKINE AVENUE, TORONTO PEDESTRIAN LEVEL WIND STUDY	
SCALE 1:800 (APPROX.)	DRAWING NO. GW21-142-PLW-5A	
DATE OCTOBER 22, 2021	DRAWN BY C.E.	

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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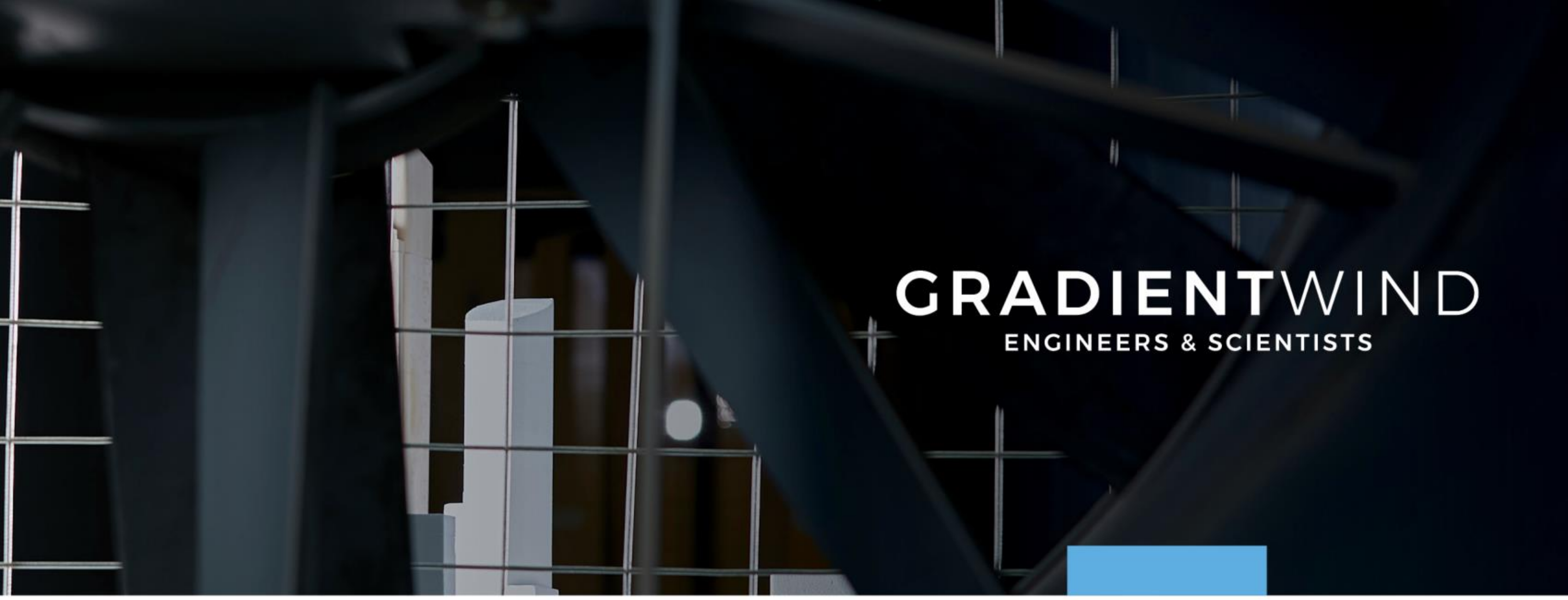
PROJECT	133 ERSKINE AVENUE, TORONTO PEDESTRIAN LEVEL WIND STUDY
SCALE	1:300 (APPROX.)
DRAWING NO.	GW21-142-PLW-5B
DATE	OCTOBER 22, 2021
DRAWN BY	C.E.
DESCRIPTION	FIGURE 5B: WINTER AMENITY FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS



APPENDIX A

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

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Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-16 km/h = Sitting, 16-22 km/h = Standing, 22-30 km/h = Walking, >30 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

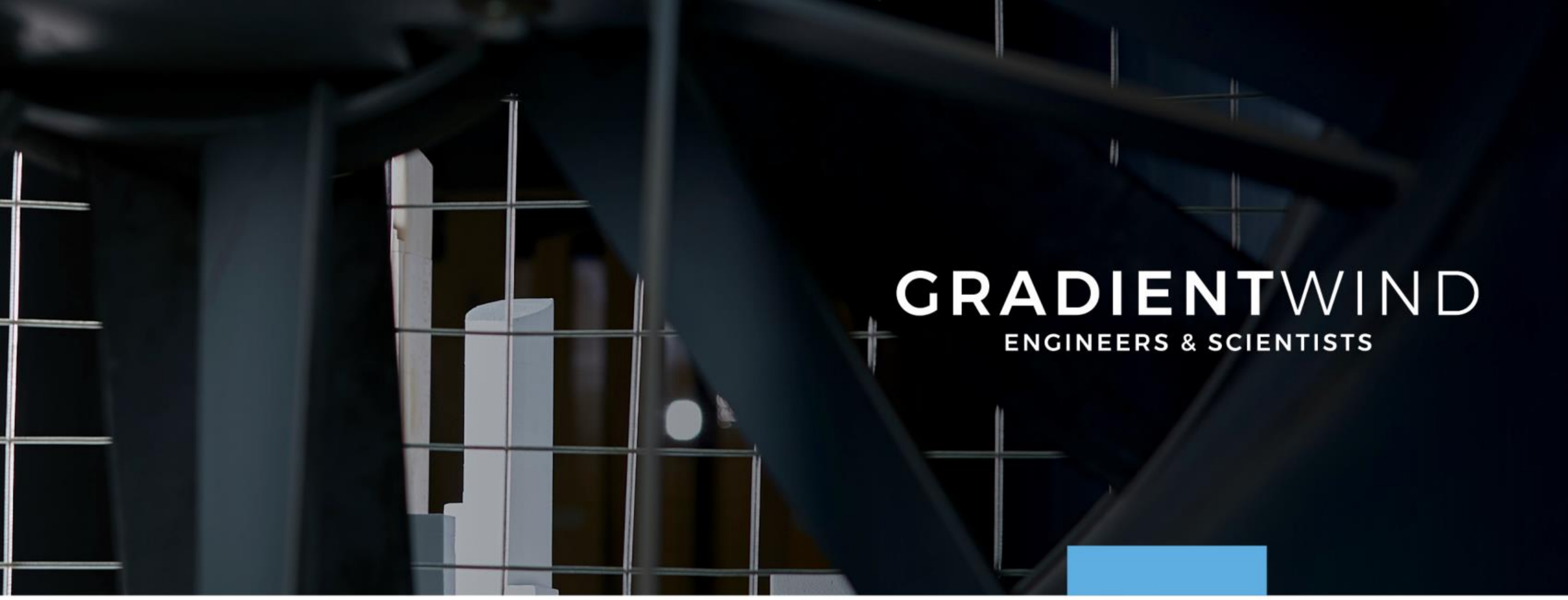
TABLE A1: SUMMARY OF PEDESTRIAN COMFORT (FUTURE CONDITIONS)

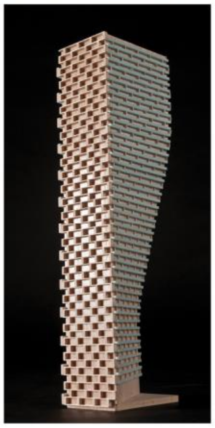
Sensor	Pedestrian Comfort								Pedestrian Safety	
	Spring		Summer		Autumn		Winter		Annual	
	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Safety Class
1	23.0	Walking	17.8	Standing	22.7	Walking	25.7	Walking	55.8	Safe
2	23.7	Walking	18.4	Standing	24.5	Walking	28.0	Walking	64.6	Safe
3	20.1	Standing	17.0	Standing	22.9	Walking	25.8	Walking	63.6	Safe
4	22.4	Walking	17.0	Standing	22.8	Walking	26.5	Walking	65.4	Safe
5	21.2	Standing	16.5	Standing	22.0	Standing	24.6	Walking	60.4	Safe
6	21.8	Standing	16.6	Standing	22.6	Walking	26.3	Walking	64.6	Safe
7	18.6	Standing	14.4	Sitting	18.9	Standing	21.0	Standing	50.0	Safe
8	19.5	Standing	15.6	Sitting	20.2	Standing	21.8	Standing	48.9	Safe
9	20.2	Standing	15.9	Sitting	20.3	Standing	22.6	Walking	51.0	Safe
10	22.6	Walking	18.2	Standing	23.5	Walking	26.1	Walking	62.4	Safe
11	23.0	Walking	19.0	Standing	23.9	Walking	26.4	Walking	61.9	Safe
12	24.1	Walking	19.5	Standing	25.0	Walking	26.9	Walking	64.3	Safe
13	26.3	Walking	21.2	Standing	28.1	Walking	31.4	Uncomfortable	75.4	Safe
14	25.1	Walking	19.8	Standing	25.5	Walking	29.2	Walking	64.0	Safe
15	23.9	Walking	18.0	Standing	23.4	Walking	26.4	Walking	56.6	Safe
16	25.0	Walking	18.5	Standing	23.7	Walking	27.3	Walking	59.0	Safe
17	27.0	Walking	20.5	Standing	26.5	Walking	30.1	Uncomfortable	65.7	Safe
18	26.5	Walking	19.8	Standing	25.7	Walking	29.3	Walking	69.8	Safe
19	25.7	Walking	18.0	Standing	22.8	Walking	26.4	Walking	64.2	Safe
20	23.3	Walking	17.5	Standing	22.1	Walking	25.1	Walking	60.8	Safe
21	21.0	Standing	16.0	Sitting	20.2	Standing	22.8	Walking	49.9	Safe
22	20.2	Standing	15.6	Sitting	19.2	Standing	20.8	Standing	45.9	Safe
23	20.8	Standing	16.4	Standing	20.2	Standing	21.6	Standing	53.0	Safe
24	21.2	Standing	16.1	Standing	20.2	Standing	21.9	Standing	53.5	Safe
25	23.1	Walking	17.0	Standing	21.3	Standing	23.0	Walking	60.9	Safe
26	22.9	Walking	17.3	Standing	21.8	Standing	24.0	Walking	56.6	Safe
27	27.2	Walking	20.3	Standing	25.9	Walking	28.6	Walking	69.3	Safe
28	28.5	Walking	21.3	Standing	28.2	Walking	32.8	Uncomfortable	73.0	Safe
29	18.3	Standing	12.1	Sitting	14.3	Sitting	16.4	Standing	54.9	Safe
30	16.2	Standing	11.4	Sitting	14.2	Sitting	16.1	Standing	46.7	Safe
31	17.7	Standing	12.6	Sitting	15.4	Sitting	17.7	Standing	46.0	Safe
32	15.7	Sitting	11.3	Sitting	14.1	Sitting	16.2	Standing	41.6	Safe
33	17.4	Standing	12.7	Sitting	15.3	Sitting	17.9	Standing	51.5	Safe
34	21.1	Standing	15.6	Sitting	19.0	Standing	21.8	Standing	54.3	Safe
35	18.4	Standing	13.4	Sitting	16.0	Sitting	18.0	Standing	60.5	Safe

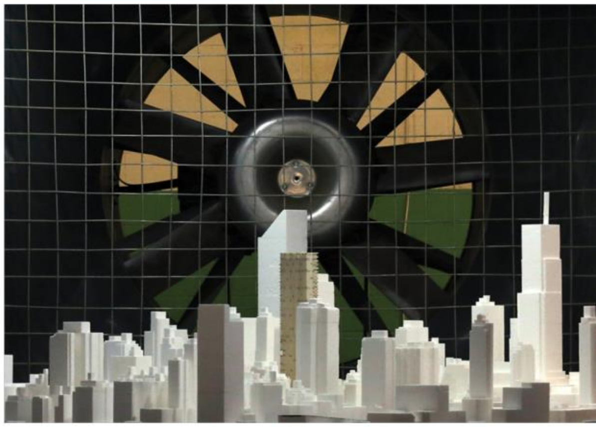
Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-16 km/h = Sitting, 16-22 km/h = Standing, 22-30 km/h = Walking, >30 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

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	22.1	Walking	17.2	Standing	20.9	Standing	23.2	Walking	57.8	Safe
37	17.7	Standing	12.9	Sitting	16.0	Sitting	17.3	Standing	49.1	Safe
38	22.4	Walking	17.7	Standing	21.5	Standing	23.3	Walking	58.2	Safe
39	18.0	Standing	13.6	Sitting	16.4	Standing	17.8	Standing	50.7	Safe
40	22.4	Walking	16.8	Standing	20.8	Standing	22.9	Walking	55.4	Safe
41	18.5	Standing	14.1	Sitting	17.4	Standing	19.3	Standing	45.5	Safe
42	17.6	Standing	12.8	Sitting	15.7	Sitting	17.3	Standing	45.8	Safe
43	24.3	Walking	18.1	Standing	22.3	Walking	24.2	Walking	60.2	Safe
44	18.8	Standing	12.6	Sitting	15.3	Sitting	16.6	Standing	57.6	Safe
45	30.8	Uncomfortable	24.4	Walking	32.4	Uncomfortable	36.3	Uncomfortable	85.1	Safe
46	21.2	Standing	18.6	Standing	25.9	Walking	29.0	Walking	76.8	Safe
47	13.7	Sitting	11.3	Sitting	15.5	Sitting	18.2	Standing	50.8	Safe
48	14.9	Sitting	11.6	Sitting	15.6	Sitting	18.5	Standing	50.0	Safe
49	27.2	Walking	22.4	Walking	28.4	Walking	29.9	Walking	76.7	Safe
50	16.8	Standing	13.5	Sitting	17.7	Standing	19.9	Standing	44.3	Safe
51	9.4	Sitting	7.1	Sitting	9.2	Sitting	10.2	Sitting	21.4	Safe
52	9.5	Sitting	7.2	Sitting	9.1	Sitting	10.4	Sitting	21.8	Safe
53	9.0	Sitting	7.0	Sitting	9.0	Sitting	10.2	Sitting	21.9	Safe
54	8.4	Sitting	6.3	Sitting	7.9	Sitting	9.1	Sitting	19.0	Safe
55	10.0	Sitting	7.6	Sitting	10.1	Sitting	11.5	Sitting	25.8	Safe
56	15.6	Sitting	12.7	Sitting	16.9	Standing	19.3	Standing	45.6	Safe
57	20.9	Standing	16.9	Standing	24.1	Walking	28.0	Walking	71.2	Safe
58	21.8	Standing	16.8	Standing	21.0	Standing	23.7	Walking	57.9	Safe
59	23.9	Walking	20.1	Standing	26.4	Walking	30.1	Uncomfortable	77.2	Safe
60	14.4	Sitting	11.6	Sitting	15.1	Sitting	16.5	Standing	38.7	Safe
61	17.1	Standing	12.2	Sitting	15.1	Sitting	16.1	Standing	47.7	Safe
62	17.4	Standing	12.4	Sitting	15.6	Sitting	16.8	Standing	72.0	Safe
63	24.0	Walking	16.8	Standing	21.1	Standing	22.6	Walking	73.2	Safe
64	21.9	Standing	15.7	Sitting	19.1	Standing	20.5	Standing	60.5	Safe
65	19.8	Standing	15.5	Sitting	19.3	Standing	21.0	Standing	49.1	Safe
66	16.9	Standing	11.8	Sitting	14.5	Sitting	15.6	Sitting	49.0	Safe
67	22.7	Walking	17.9	Standing	23.3	Walking	26.4	Walking	69.7	Safe







APPENDIX B

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

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Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-16 km/h = Sitting, 16-22 km/h = Standing, 22-30 km/h = Walking, >30 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	17.5	Standing	-	24.9	Walking	-
	Future	17.8	Standing	Unchanged	25.7	Walking	Unchanged
2	Existing	17.0	Standing	-	24.1	Walking	-
	Future	18.4	Standing	Unchanged	28.0	Walking	Unchanged
3	Existing	16.2	Standing	-	23.3	Walking	-
	Future	17.0	Standing	Unchanged	25.8	Walking	Unchanged
4	Existing	17.1	Standing	-	25.0	Walking	-
	Future	17.0	Standing	Unchanged	26.5	Walking	Unchanged
5	Existing	18.0	Standing	-	25.7	Walking	-
	Future	16.5	Standing	Unchanged	24.6	Walking	Unchanged
6	Existing	16.7	Standing	-	24.5	Walking	-
	Future	16.6	Standing	Unchanged	26.3	Walking	Unchanged
7	Existing	15.6	Sitting	-	21.9	Standing	-
	Future	14.4	Sitting	Unchanged	21.0	Standing	Unchanged
8	Existing	16.4	Standing	-	23.4	Walking	-
	Future	15.6	Sitting	Improved	21.8	Standing	Improved
9	Existing	17.0	Standing	-	25.6	Walking	-
	Future	15.9	Sitting	Improved	22.6	Walking	Unchanged
10	Existing	17.7	Standing	-	26.0	Walking	-
	Future	18.2	Standing	Unchanged	26.1	Walking	Unchanged
11	Existing	18.5	Standing	-	26.7	Walking	-
	Future	19.0	Standing	Unchanged	26.4	Walking	Unchanged
12	Existing	19.3	Standing	-	27.9	Walking	-
	Future	19.5	Standing	Unchanged	26.9	Walking	Unchanged
13	Existing	18.5	Standing	-	26.6	Walking	-
	Future	21.2	Standing	Unchanged	31.4	Uncomfortable	Reduced
14	Existing	18.7	Standing	-	27.0	Walking	-
	Future	19.8	Standing	Unchanged	29.2	Walking	Unchanged
15	Existing	18.3	Standing	-	26.5	Walking	-
	Future	18.0	Standing	Unchanged	26.4	Walking	Unchanged

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-16 km/h = Sitting, 16-22 km/h = Standing, 22-30 km/h = Walking, >30 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	18.2	Standing	-	26.2	Walking	-
	Future	18.5	Standing	Unchanged	27.3	Walking	Unchanged
17	Existing	18.9	Standing	-	27.1	Walking	-
	Future	20.5	Standing	Unchanged	30.1	Uncomfortable	Reduced
18	Existing	18.3	Standing	-	26.3	Walking	-
	Future	19.8	Standing	Unchanged	29.3	Walking	Unchanged
19	Existing	17.7	Standing	-	25.0	Walking	-
	Future	18.0	Standing	Unchanged	26.4	Walking	Unchanged
20	Existing	18.2	Standing	-	26.3	Walking	-
	Future	17.5	Standing	Unchanged	25.1	Walking	Unchanged
21	Existing	18.1	Standing	-	26.0	Walking	-
	Future	16.0	Sitting	Improved	22.8	Walking	Unchanged
22	Existing	17.9	Standing	-	25.4	Walking	-
	Future	15.6	Sitting	Improved	20.8	Standing	Improved
23	Existing	17.9	Standing	-	25.1	Walking	-
	Future	16.4	Standing	Unchanged	21.6	Standing	Improved
24	Existing	17.8	Standing	-	25.0	Walking	-
	Future	16.1	Standing	Unchanged	21.9	Standing	Improved
25	Existing	17.0	Standing	-	24.3	Walking	-
	Future	17.0	Standing	Unchanged	23.0	Walking	Unchanged
26	Existing	16.9	Standing	-	24.0	Walking	-
	Future	17.3	Standing	Unchanged	24.0	Walking	Unchanged
27	Existing	17.3	Standing	-	24.6	Walking	-
	Future	20.3	Standing	Unchanged	28.6	Walking	Unchanged
28	Existing	17.9	Standing	-	25.6	Walking	-
	Future	21.3	Standing	Unchanged	32.8	Uncomfortable	Reduced
29	Existing	17.0	Standing	-	24.3	Walking	-
	Future	12.1	Sitting	Improved	16.4	Standing	Improved
30	Existing	17.0	Standing	-	24.2	Walking	-
	Future	11.4	Sitting	Improved	16.1	Standing	Improved

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-16 km/h = Sitting, 16-22 km/h = Standing, 22-30 km/h = Walking, >30 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	17.5	Standing	-	25.0	Walking	-
	Future	12.6	Sitting	Improved	17.7	Standing	Improved
32	Existing	18.0	Standing	-	25.5	Walking	-
	Future	11.3	Sitting	Improved	16.2	Standing	Improved
33	Existing	18.2	Standing	-	26.5	Walking	-
	Future	12.7	Sitting	Improved	17.9	Standing	Improved
34	Existing	17.9	Standing	-	25.2	Walking	-
	Future	15.6	Sitting	Improved	21.8	Standing	Improved
35	Existing	17.8	Standing	-	25.8	Walking	-
	Future	13.4	Sitting	Improved	18.0	Standing	Improved
36	Existing	17.7	Standing	-	25.9	Walking	-
	Future	17.2	Standing	Unchanged	23.2	Walking	Unchanged
37	Existing	18.3	Standing	-	26.5	Walking	-
	Future	12.9	Sitting	Improved	17.3	Standing	Improved
38	Existing	18.4	Standing	-	26.6	Walking	-
	Future	17.7	Standing	Unchanged	23.3	Walking	Unchanged
39	Existing	17.4	Standing	-	25.2	Walking	-
	Future	13.6	Sitting	Improved	17.8	Standing	Improved
40	Existing	18.2	Standing	-	26.2	Walking	-
	Future	16.8	Standing	Unchanged	22.9	Walking	Unchanged
41	Existing	18.8	Standing	-	27.2	Walking	-
	Future	14.1	Sitting	Improved	19.3	Standing	Improved
42	Existing	18.6	Standing	-	26.2	Walking	-
	Future	12.8	Sitting	Improved	17.3	Standing	Improved
43	Existing	19.0	Standing	-	27.3	Walking	-
	Future	18.1	Standing	Unchanged	24.2	Walking	Unchanged
44	Existing	18.6	Standing	-	26.8	Walking	-
	Future	12.6	Sitting	Improved	16.6	Standing	Improved
45	Existing	19.2	Standing	-	27.3	Walking	-
	Future	24.4	Walking	Reduced	36.3	Uncomfortable	Reduced

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-16 km/h = Sitting, 16-22 km/h = Standing, 22-30 km/h = Walking, >30 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	18.6	Standing	-	26.7	Walking	-
	Future	18.6	Standing	Unchanged	29.0	Walking	Unchanged
47	Existing	18.1	Standing	-	26.2	Walking	-
	Future	11.3	Sitting	Improved	18.2	Standing	Improved
48	Existing	17.6	Standing	-	25.2	Walking	-
	Future	11.6	Sitting	Improved	18.5	Standing	Improved
49	Existing	18.3	Standing	-	26.2	Walking	-
	Future	22.4	Walking	Reduced	29.9	Walking	Unchanged
50	Existing	17.9	Standing	-	25.5	Walking	-
	Future	13.5	Sitting	Improved	19.9	Standing	Improved
51	Existing	18.1	Standing	-	26.4	Walking	-
	Future	7.1	Sitting	Improved	10.2	Sitting	Improved
52	Existing	18.3	Standing	-	26.4	Walking	-
	Future	7.2	Sitting	Improved	10.4	Sitting	Improved
53	Existing	18.1	Standing	-	26.2	Walking	-
	Future	7.0	Sitting	Improved	10.2	Sitting	Improved
54	Existing	17.9	Standing	-	25.7	Walking	-
	Future	6.3	Sitting	Improved	9.1	Sitting	Improved
55	Existing	17.7	Standing	-	25.1	Walking	-
	Future	7.6	Sitting	Improved	11.5	Sitting	Improved
56	Existing	16.7	Standing	-	23.9	Walking	-
	Future	12.7	Sitting	Improved	19.3	Standing	Improved
57	Existing	18.1	Standing	-	25.9	Walking	-
	Future	16.9	Standing	Unchanged	28.0	Walking	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.

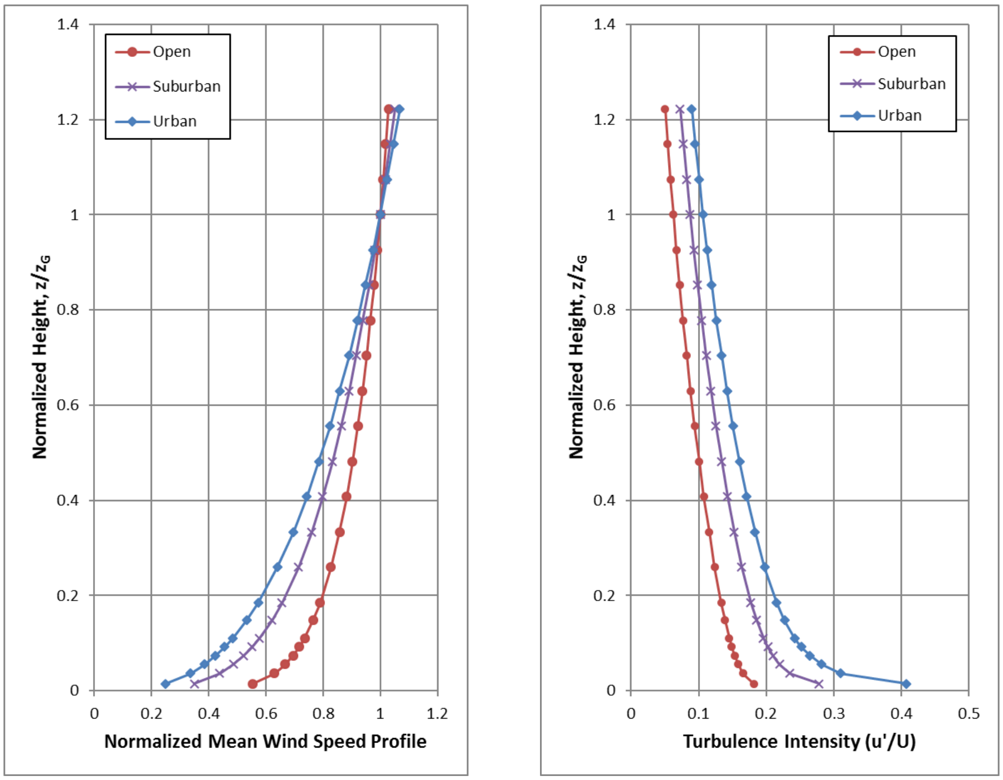

FIGURE C1 (LEFT): MEAN WIND SPEED PROFILES;
FIGURE C2 (RIGHT): TURBULENCE INTENSITY PROFILES

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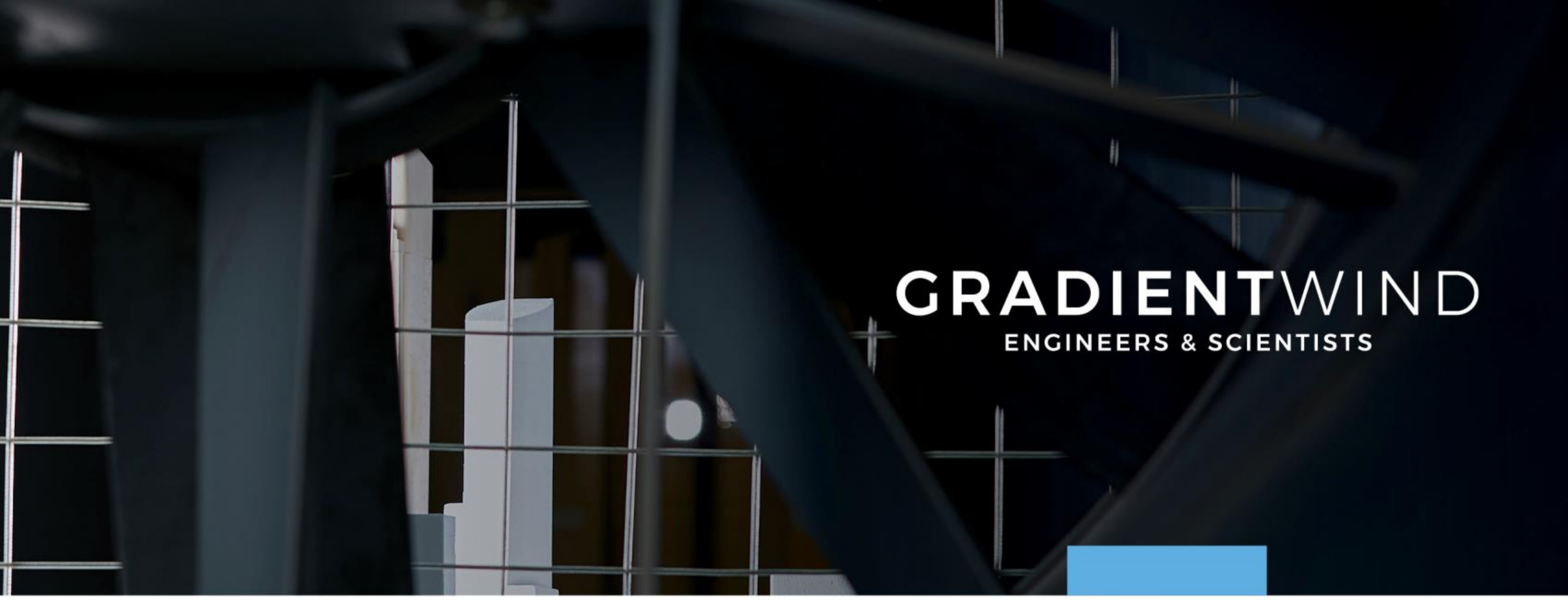

APPENDIX D

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:

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

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

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

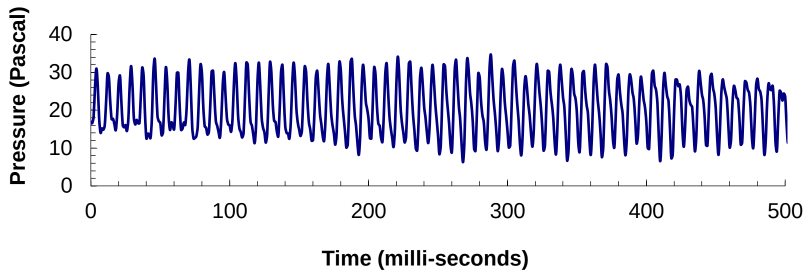

FIGURE D1: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR

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