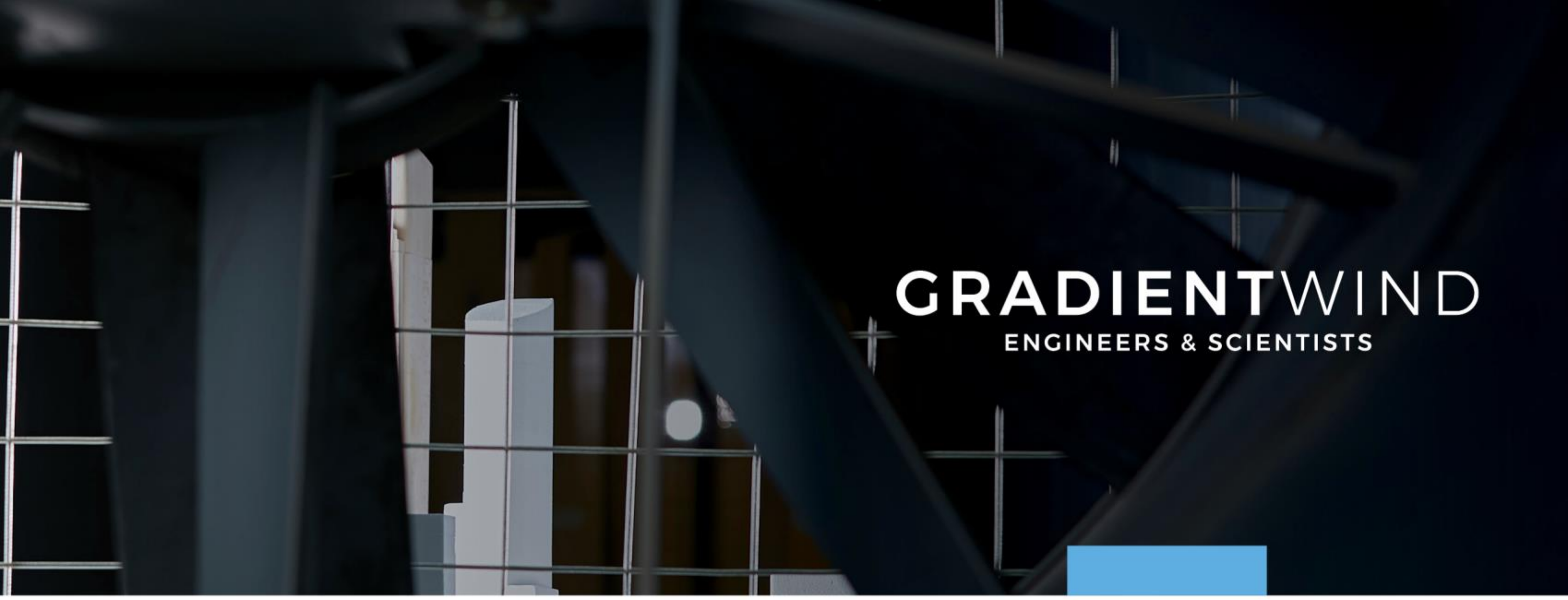
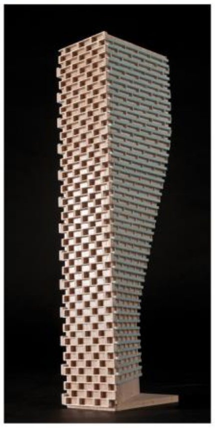
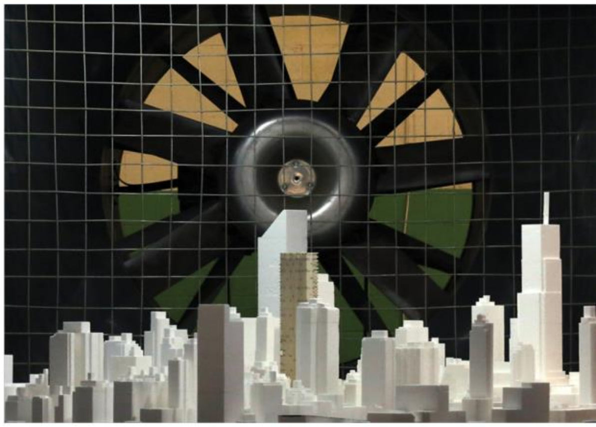


PEDESTRIAN LEVEL WIND STUDY

1047 Richmond Road
Ottawa, Ontario

REPORT: GW21-416-WTPLW-2023-R2





October 3, 2023

PREPARED FOR
1047 Richmond Nominee Inc.
77 King Street W, Suite 3410
Toronto, ON
M5K 2A1

PREPARED BY
Sam Woolsey, M.E.Sc., Junior Wind Scientist
Nick Petersen, P.Eng., Wind Engineer

EXECUTIVE SUMMARY

This report describes a wind tunnel pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 1047 Richmond Road in Ottawa, Ontario. Two configurations were studied: (i) *existing scenario*, including all approved, surrounding developments and without the proposed development, and (ii) *proposed scenario* 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, walkways, laneways, drop-off areas, parks, parking areas, landscaped spaces, nearby transit stops, outdoor amenity areas, P.O.P.S., and building access points. Wind comfort is also evaluated over the various 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 IBI Group Architects (Canada) Inc. in September 2023, surrounding street layouts, as well as existing and approved future building massing information obtained from the City of Ottawa, and recent site imagery.

A complete summary of the predicted wind conditions is provided in Section 5 of this report and is also illustrated in Figures 2A through 3D, as well as Tables A1-A2 and B1-B3 in the appendices. Based on wind tunnel test results, meteorological data analysis, and experience with similar developments in Ottawa, we conclude that the future wind conditions over most grade-level pedestrian wind-sensitive areas within and surrounding the study site will be acceptable for the intended uses on a seasonal basis. Exceptions include various grade level amenity areas and the Tower B main lobby entrance, for which mitigation is recommended as described in Section 5.2. Most elevated amenity spaces will be comfortable for sitting or more sedentary activities throughout the summer months, which is acceptable. To ensure similarly calm conditions over the Tower A Level 7 amenity terrace, mitigation is recommended as described in Section 5.2. It is notable that the development team intends to introduce the recommended mitigation during the SPA stage.

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

GRADIENTWIND
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TABLE OF CONTENTS

1. INTRODUCTION

This report describes a wind tunnel pedestrian level wind (PLW) study undertaken to assess wind conditions for a proposed mixed-use development located at 1047 Richmond Road in Ottawa, Ontario. Two configurations were studied: (i) *existing scenario*, including all approved, surrounding developments and without the proposed development, and (ii) *proposed scenario* with the proposed development in place. The study was performed in accordance with industry standard wind tunnel testing techniques, architectural drawings provided by IBI Group Architects (Canada) Inc. in September 2023, 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 wind tunnel pedestrian wind study is the proposed mixed-use development located at 1047 Richmond Road in Ottawa, Ontario. The study site is situated to the northeast of the intersection of Richmond Road and New Orchard Avenue North. Throughout this report, Richmond Road is referred to as project south.

The proposed development comprises two buildings identified as “Tower A” and “Tower B”. Tower A, to the west, rises 40-storeys from a 6-storey podium. At grade, the building features a residential lobby in the center of the building fronting the east elevation, retail and amenity spaces to the south, with residential units and building support services elsewhere. At Level 2, the floorplate sets back accommodating a central outdoor amenity terrace and also steps out to the east, cantilevering over grade. At Level 7, the podium sets back to the typical tower floorplate, accommodate a large outdoor amenity space, before rising to full height.

Tower B, to the east, rises 38-storeys from a 6-storey podium. At grade, the building features a central residential lobby fronting the west elevation, retail and indoor amenity space to the south, and loading access along the north elevation of the subject site, with residential units elsewhere. At Level 2, the floorplate sets back accommodating outdoor amenity and private terrace spaces. At Level 7, the podium sets back to the typical tower floorplate, accommodate a large outdoor amenity space, before rising to full height.

A park is provided at the south corner of the subject site. Both towers are topped with a mechanical penthouse and share three below-grade parking levels, which are accessed via a ramp located to the northwest of Tower A from a loading / service laneway extending along the north elevation of the subject site from New Orchard Avenue North. An outdoor amenity and a privately-owned publicly accessible space (P.O.P.S.) are in the middle of the site, between Towers A and B.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-metre radius of the site) include the Sir John A. Macdonald Parkway and the Trans-Canada Trail from the west-southwest clockwise to the northeast, high-rise residential buildings to the east-northeast and to the west-southwest, and mostly low-rise residential buildings for the remaining compass directions. Notably, there is a 28-storey apartment building to the immediate east of the subject site at 1025 Richmond Road and a 30-storey residential building has been approved (OPA and ZBLA) at 1071 Ambleside Drive, approximately 90 m to the west. Additionally, the Stage 2 Ottawa Light Rail Transit West Extension and the future New Orchard Station are currently under construction approximately 20 m to the south of the subject site. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer radius), are characterized by the open exposure of the Ottawa River from the west-southwest clockwise to the northeast, and by mostly low-rise buildings with some isolated taller buildings for the remaining compass directions. The Britannia Conservation Area is situated approximately 1 km to the west, and Highway 417 runs southwest-northeast approximately 1.6 km to the southeast.

Grade-level areas investigated include sidewalks, walkways, laneways, drop-off areas, parks, parking areas, landscaped spaces, nearby transit stops, outdoor amenity areas, P.O.P.S., and building access points. Wind comfort is also evaluated over the various outdoor amenity terraces. Figures 1A and 1B illustrate 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.

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 Ottawa 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, 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 an accurate seasonal

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

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 83 sensor locations on the scale model in Gradient Wind's wind tunnel. Of these 83 sensors, 71 were located at grade and the remaining 12 sensors were located over the various outdoor amenity terraces. Wind speed measurements were performed for each of the 83 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 3D.

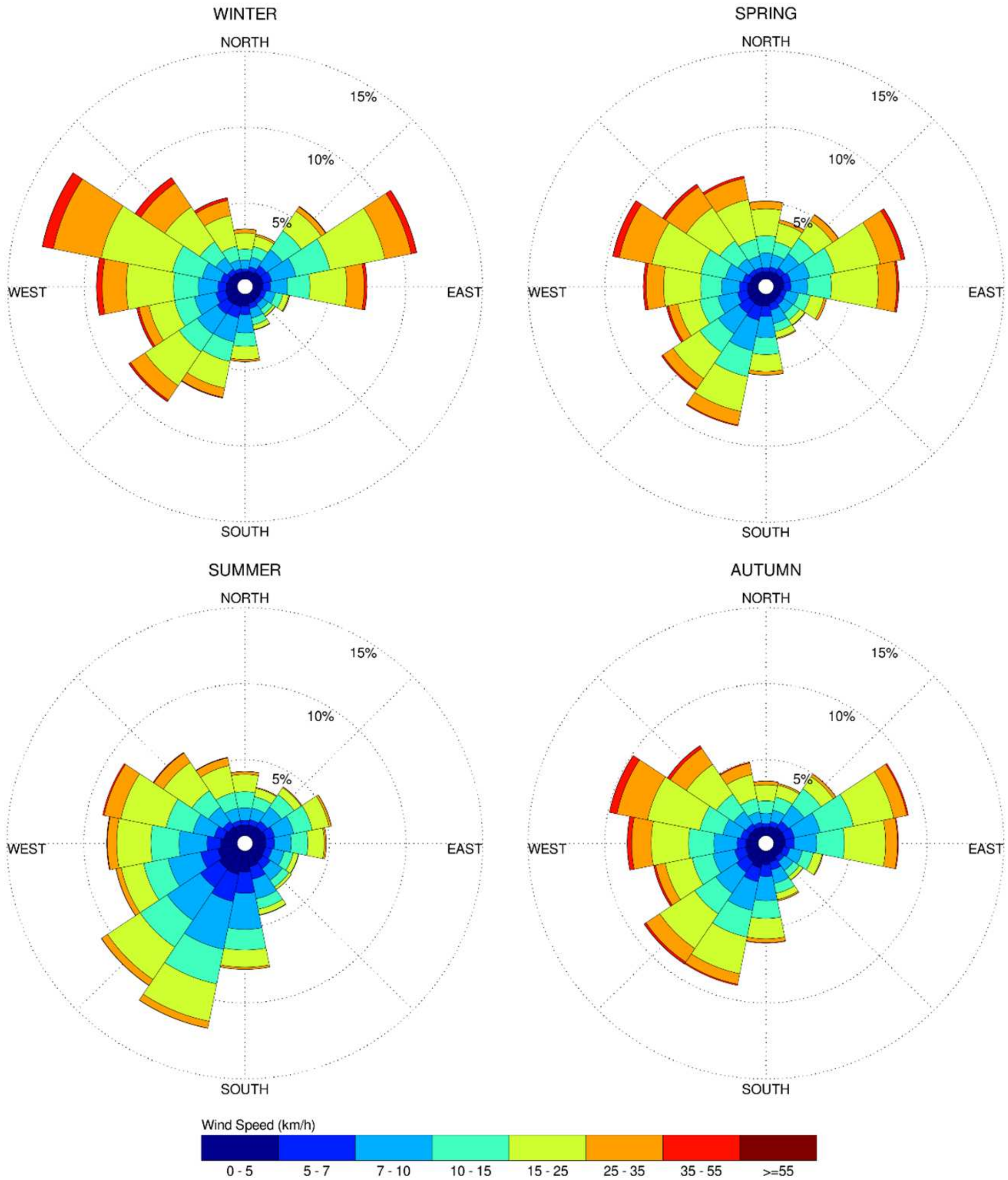
Mean and peak wind speed values for each location and wind direction were calculated from real-time pressure measurements, recorded at a sample rate of 500 samples per second, and taken over a 60-second time period. This period at model-scale corresponds approximately to one hour in full-scale, which 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 Ottawa was developed from approximately 40 years of hourly meteorological wind data recorded at Ottawa Macdonald-Cartier International Airport and obtained from Environment and Climate Change Canada. Wind speed and direction data were analyzed for each month of the year to determine the statistically prominent wind directions and corresponding speeds, and to characterize similarities between monthly weather patterns. Based on this portion of the analysis, the four seasons are represented by grouping data from consecutive months based on similarity of weather patterns, and not according to the traditional calendar method.

The statistical model of the Ottawa area wind climate, which indicates the directional character of local winds on a seasonal basis, is illustrated on the following page. The plots illustrate seasonal distribution of measured wind speeds and directions in kilometers per hour (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 prominent wind speeds and directions can be identified by the longer length of the bars. For Ottawa, the most common winds occur for westerly wind directions, followed by those from the east, while the most common wind speeds are below 36 km/h. The directional prominence and relative magnitude of wind speed changes somewhat from season to season.

SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES
OTTAWA MACDONALD-CARTIER INTERNATIONAL AIRPORT, OTTAWA, 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 Guest Equivalent Mean (GEM) wind speed ranges, which include (i) Sitting; (ii) Standing; (iii) Walking; and (iv) Uncomfortable. More specifically, the comfort classes and associated GEM wind speed ranges are summarized as follows:

(i) **Sitting** – A wind speed below 10 km/h (i.e. 0 – 10 km/h) would be considered acceptable for sedentary activities, including sitting.

(ii) **Standing** – A wind speed below 14 km/h (i.e. 10 km/h – 14 km/h) is acceptable for activities such as standing or leisurely strolling.

(iii) **Strolling** – A wind speed below 17 km/h (i.e. 14 km/h – 17 km/h) is acceptable for activities such as standing or leisurely strolling.

(iv) **Walking** – A wind speed below 20 km/h (i.e. 17 km/h – 20 km/h) is acceptable for walking or more vigorous activities.

(v) **Uncomfortable** – A wind speed over 20 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.

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 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 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 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 below.

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

5. RESULTS AND DISCUSSION

Tables A1 and A2 in Appendix A provide a summary of seasonal comfort predictions for each sensor location under the *existing* massing scenario. Similarly, Tables B1-B3 in Appendix B provide the seasonal comfort predictions for under the *proposed* massing scenario. The tables indicate the 80% non-exceedance GEM wind speeds and corresponding comfort classifications as defined in Section 4.4. In other words, a 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 walking, as the 80% threshold value falls within the exceedance range of 17-20 km/h for walking. The tables include the predicted threshold values for each sensor location during each season, accompanied by the corresponding predicted comfort class (i.e. sitting, standing, strolling, etc.).

The most significant findings of the PLW study are summarized in Sections 5.1 and 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 3D. Conditions suitable for sitting are represented by the colour blue, while standing is represented by green, strolling by magenta, and walking by yellow. Uncomfortable conditions are represented by orange, and locations where the wind safety criterion is exceeded, the sensor is highlighted in red.

5.1 Pedestrian Comfort Suitability – *Existing Scenario*

Based on the analysis of the measured data, consideration of local climate data, and the suitability descriptors provided in Tables A1 and A2 in Appendix A and illustrated in Figures 2A through 2D, this section summarizes the significant findings of the PLW study with respect to the *existing scenario*, as follows:

1. Most public sidewalks, walkways, laneways, landscaped spaces, and parking areas within and surrounding the proposed development currently experience wind conditions suitable for walking or better during each seasonal period. Exceptions include the existing driveway to the east of the site (Sensor 11) and the adjacent northeast corner of the study site (Sensors 44-46), which intermittently becomes uncomfortable for walking during the colder months.

2. The nearby transit stops along Richmond Road (Sensors 18 & 19) currently experience wind conditions suitable for standing or better throughout the year. It is noteworthy that, within the construction scope of the Light Rail Transit New Orchard Station, they will be relocated to the locations represented by Sensors 17 and 20, which are also currently suitable for standing or better throughout the year.

3. 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.

5.2 Pedestrian Comfort Suitability – *Proposed Scenario*

Based on the analysis of the measured data, consideration of local climate data, and the suitability descriptors provided in Tables B1-B3 in Appendix B and illustrated in Figures 3A through 3D, this section summarizes the significant findings of the PLW study with respect to the *proposed scenario*, as follows:

1. Most public sidewalks, walkways, laneways, drop-off areas, landscaped spaces, and parking areas within and surrounding the proposed development will experience wind conditions suitable for walking or better throughout the year, which is acceptable for the intended uses of the spaces. Exceptions include an isolated portion of the sidewalk along Richmond Road (Sensors 13), New Orchard Avenue North (Sensors 3, 4, 22 & 24), the northeast corner of the study site (Sensors 11 & 46), some walkways internal to the site (Sensors 56-59 & 65), where wind conditions transition to uncomfortable for walking during the colder months. It is noteworthy that the exceedance of the walking threshold in most instances is marginal, limited, to the colder months, and all areas remain safe, as defined in Section 4.4.

   Considering the marginality of the exceedances along the noted public sidewalks (Sensors 3, 4, 13, 22, & 24) and that the existing and proposed landscaping is expected to somewhat further reduce local windspeeds, the noted conditions are considered acceptable. The wind conditions at the northeast corner of the study site (Sensors 11 & 46) are comparable to the existing conditions and not significantly exacerbated by the proposed development, with improvements at Sensors 44 and 45. For the uncomfortable walkway segments internal to the site (Sensors 56-59 & 65), it is recommended to extend canopies overhead to buffer accelerated winds.

2. Most primary residential and all retail entrances will be suitable for standing or better throughout the year, which is acceptable. One exception is the Tower B residential entrance (Sensor 56), which exceeds the standing criteria during all seasons. To ensure suitable conditions, it is

recommended to either recess the entrance within the building façade or flank the doorway with vertical wind barriers and provide an overhead canopy.

Most secondary building access points (including building exits, loading areas, vehicle entrances, etc.) will be suitable for walking or better throughout the year, which is acceptable. One exception is the eastern corner exit of Tower B (Sensor 46) which exceeds the walking criterion during the colder months. It is notable that the exceedance is marginal and very little pedestrian traffic is anticipated, therefore, mitigation is not considered necessary.

3. The proposed park at the southwest corner of the study site (Sensors 23-26) will generally be suitable for standing during the summer, strolling in autumn, and walking or better throughout the rest of the year, with marginally uncomfortable conditions during the winter. The noted conditions are acceptable depending on the intended use of the space. If calmer conditions are desired at designated seating areas, then installing vertical wind barriers such as plantings or windscreens to the immediate west of such spaces is recommended.

4. The internal P.O.P.S. (Sensors 50-52, 66 & 67) and the outdoor amenity between Towers A and B (Sensors 53-55 & 62-65) will experience a mix of strolling, standing, and sitting conditions throughout the summer and autumn. Where sitting conditions are desired during the warmer months within these spaces, an arrangement of westerly upwind barriers and/or overhead pergola structures is recommended. Such barriers should measure at least 1.6-metres-tall and may comprise raised planters, high-solidity windscreens, or a combination thereof, the exact composition and configuration of which can be coordinated with the design team as the landscaping plans develop.

5. The future relocated nearby transit stops (Sensors 17 & 20) along Richmond Road and the future New Orchard Station (LRT) (Sensors 15-17) will experience wind conditions generally suitable for standing or better throughout the year, with the stop at Sensor 20 suitable for walking and strolling during the winter and spring, respectively. Assuming the existing shelter along the north side of Richmond Road migrates with the transit stop, additional mitigation will not be required.

6. The internal Level 2 outdoor amenity terraces servicing Towers A and B are well sheltered from most salient wind directions and are expected to be comfortable for sitting or more sedentary activities throughout the summer months, which is acceptable.
7. The Tower B Level 7 outdoor amenities (Sensors 79-83) will generally be suitable for sitting or more sedentary activities throughout the summer months without the need for mitigation. Considering the marginality of the exceedance of the sitting criterion at Sensor 81, mitigation is not considered necessary. To ensure similarly calm conditions over the Tower A Level 7 outdoor amenity spaces (Sensors 72-78), it is recommended to raise the west elevation terrace perimeter guards to at least 2.0 metres above the walking surface, to provide overhead canopy or pergola structures at designated seating areas, and/or to install targeted wind barriers, measuring at least 1.6-metre-tall, to the immediate northwest and southwest of such spaces. The exact composition and configuration of such mitigation can be coordinated with the design team as the terrace design progresses.
8. Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience wind conditions that are considered unsafe.

6. CONCLUSIONS AND RECOMMENDATIONS

This report summarizes the methodology, results, and recommendations related to a pedestrian level wind study for a proposed residential development located at 1047 Richmond Road in Ottawa, 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 of this report and is also illustrated in Figures 2A through 3D, as well as Tables A1-A2 and B1-B3 in the appendices. Based on wind tunnel test results, meteorological data analysis, and experience with similar developments in Ottawa, we conclude that the future wind conditions over most grade-level pedestrian wind-sensitive areas within and surrounding the study site will be acceptable for the intended uses on a seasonal basis. Exceptions include various grade level amenity areas and the Tower B main lobby entrance, for which mitigation is recommended as described in Section 5.2. Most elevated amenity spaces will be comfortable for sitting or more sedentary activities throughout the summer months, which is acceptable. To ensure similarly calm conditions over the Tower A Level 7 amenity terrace, mitigation is recommended as described in Section 5.2. It is notable that the development team intends to introduce the recommended mitigation during the SPA stage.

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

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

Sincerely,

Gradient Wind Engineering Inc.

LICENSED PROFESSIONAL ENGINEER
2023-10-05
N. PETERSEN
100506222
PROVINCE OF ONTARIO

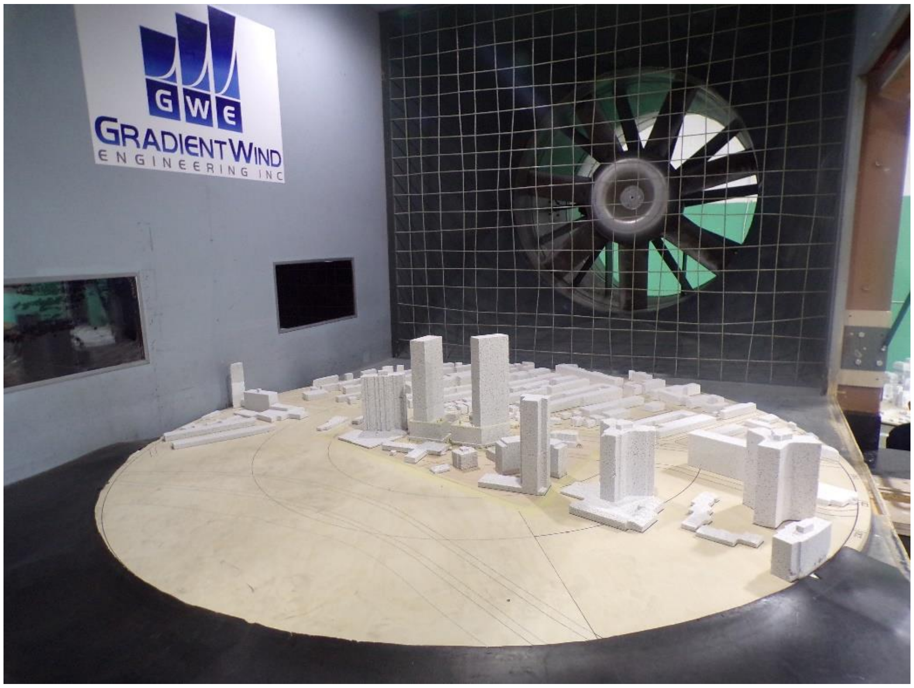
Sam Woolsey, M.E.Sc.
Junior Wind Scientist

Nick Peterson, P.Eng.,
Wind Engineer

GW21-416-WTPLW-R2

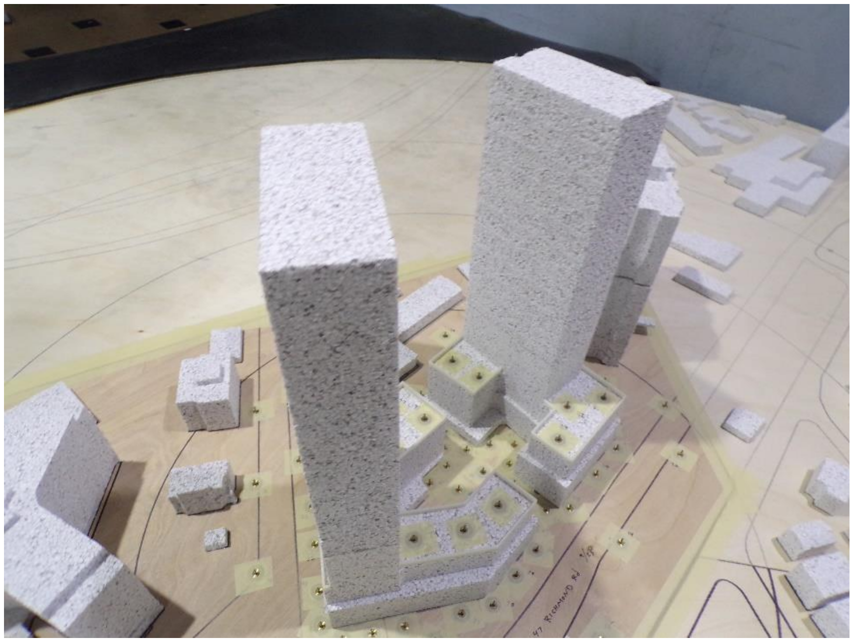
PHOTOGRAPH 1: CLOSE-UP VIEW OF EXISTING CONTEXT MODEL LOOKING NORTHEAST

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



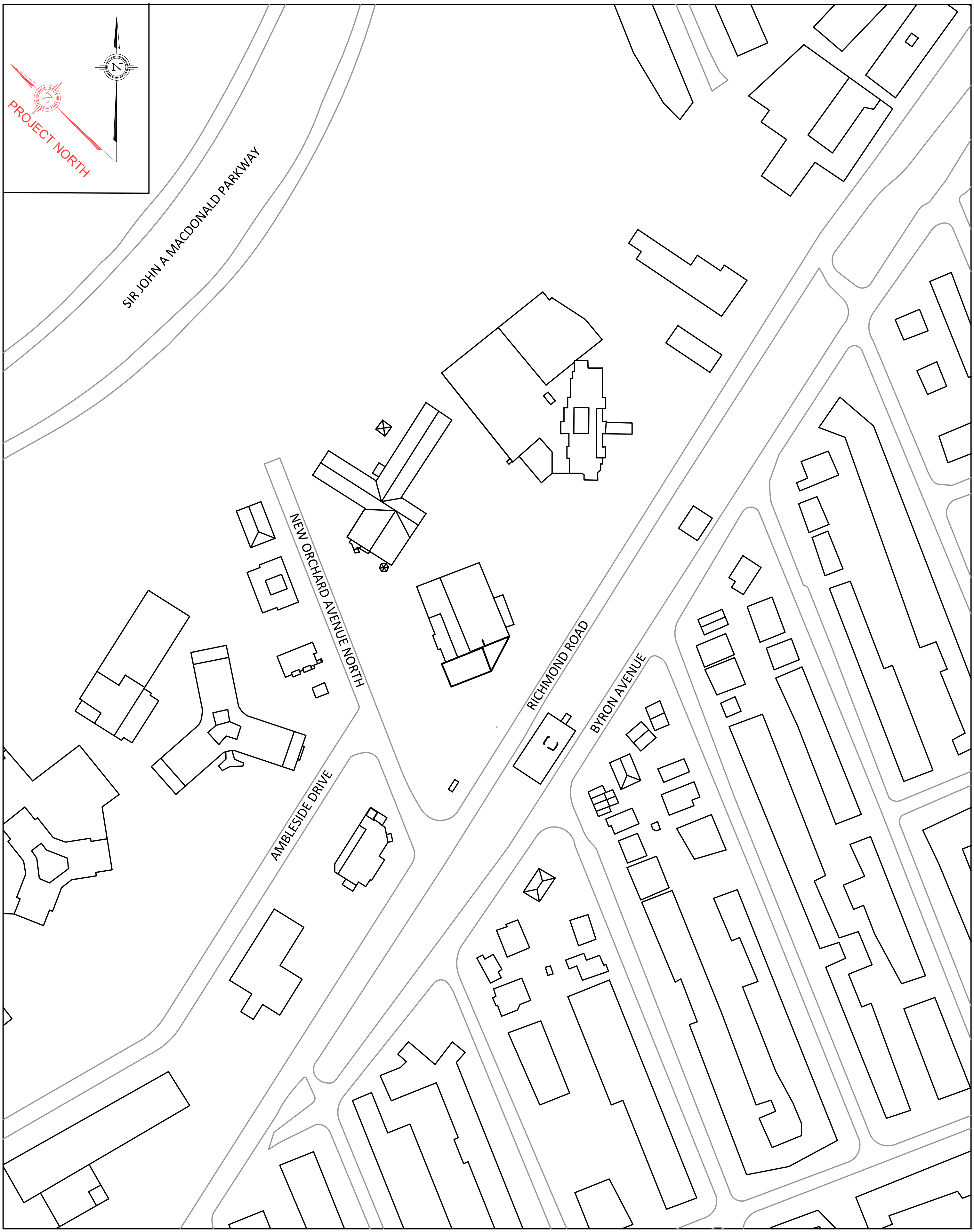
PHOTOGRAPH 3: PROPOSED STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING DOWNWIND

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



PHOTOGRAPH 5: CLOSE-UP VIEW OF PROPOSED STUDY MODEL LOOKING NORTH

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



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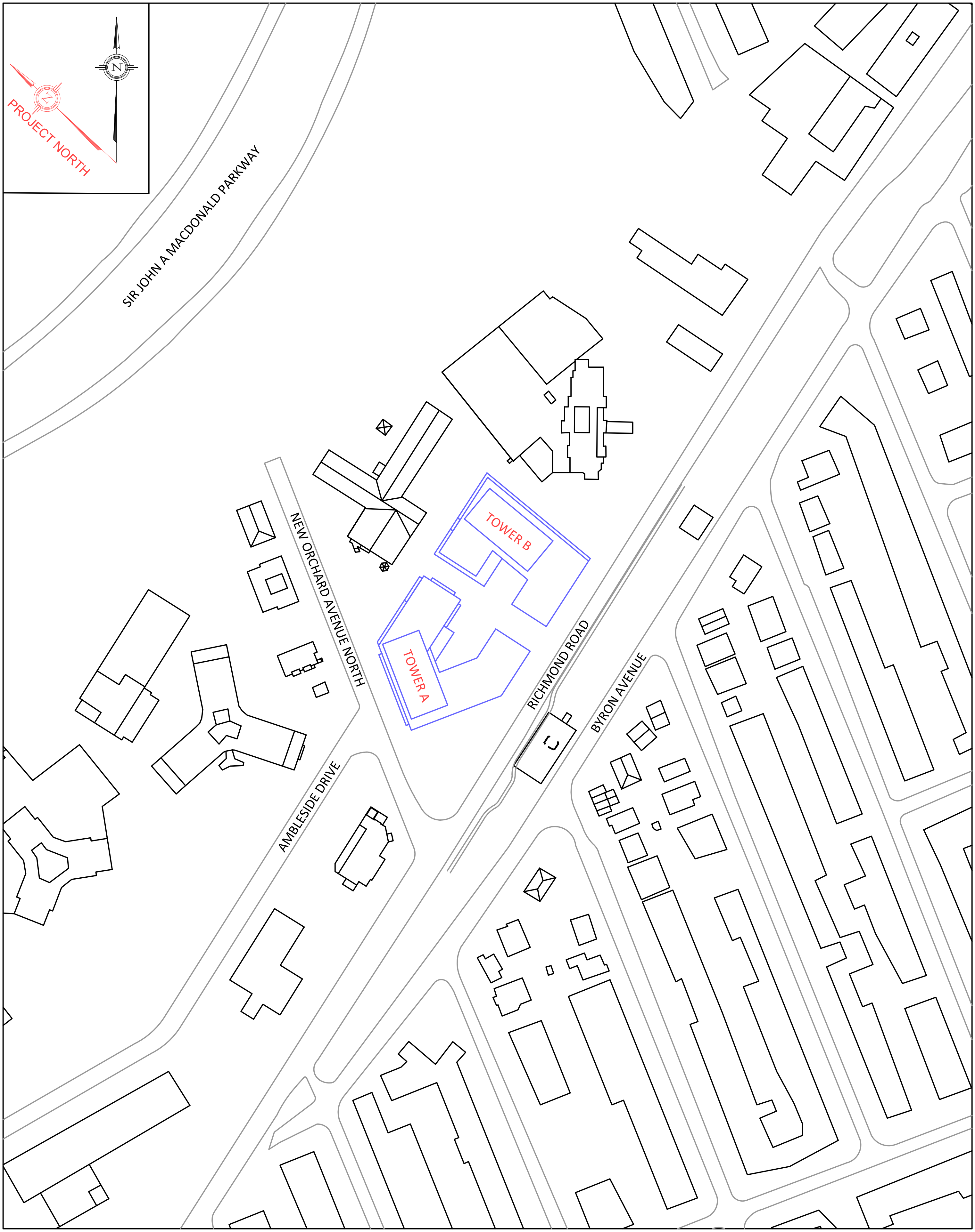
PROJECT	1047 RICHMOND ROAD, OTTAWA PEDESTRIAN LEVEL WIND STUDY
SCALE	1:2500 (APPROX.)
DRAWING NO.	GW21-416-PLW-2023-1A
DATE	OCTOBER 3, 2023
DRAWN BY	K.A.
DESCRIPTION	FIGURE 1A: EXISTING SCENARIO AND SURROUNDING CONTEXT



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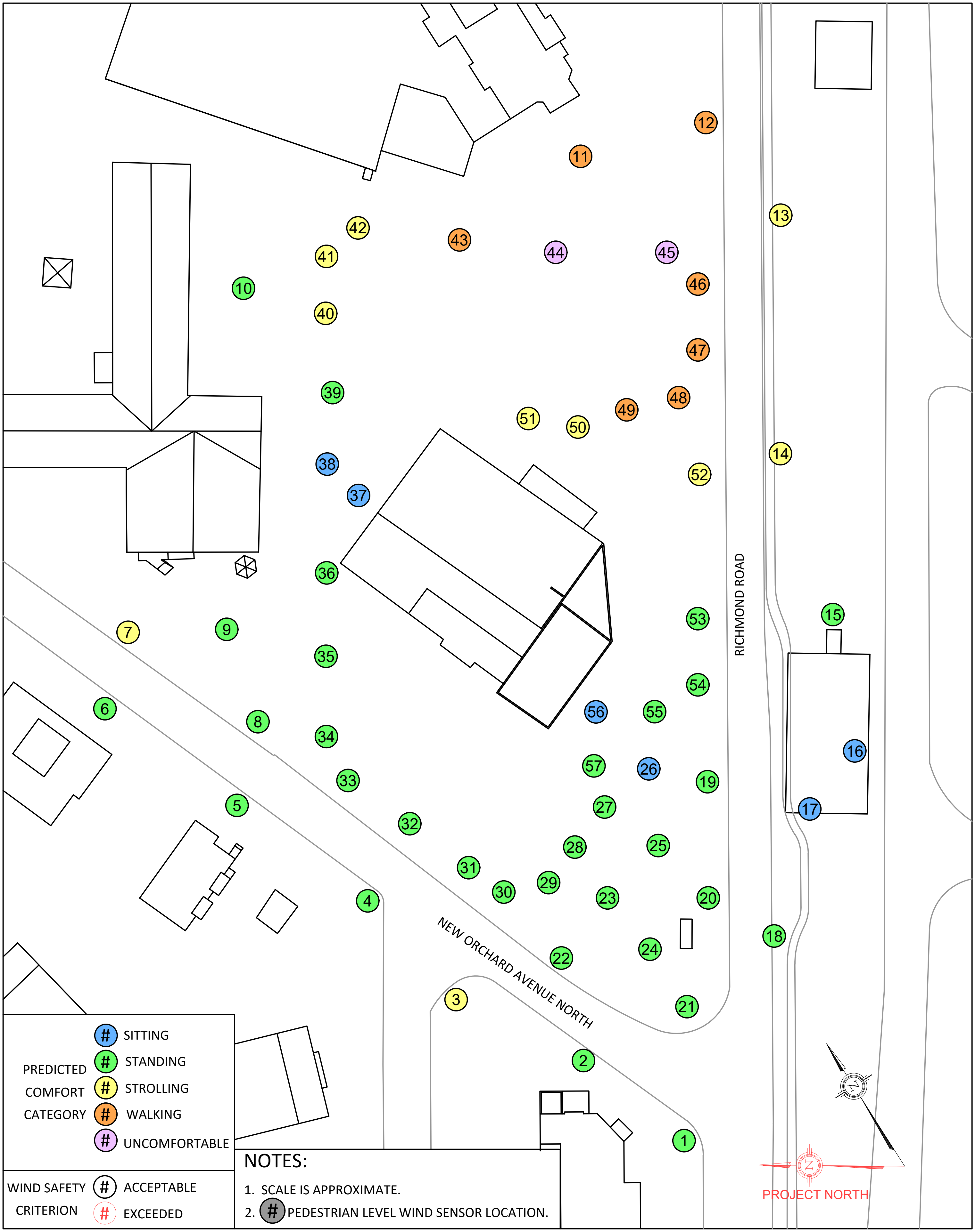
PROJECT: 1047 RICHMOND ROAD, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1B: FUTURE SCENARIO AND SURROUNDING CONTEXT
SCALE: 1:2500 (APPROX.)	DRAWING NO. GW21-416-PLW-2023-1B	
DATE: OCTOBER 3, 2023	DRAWN BY: K.A.	



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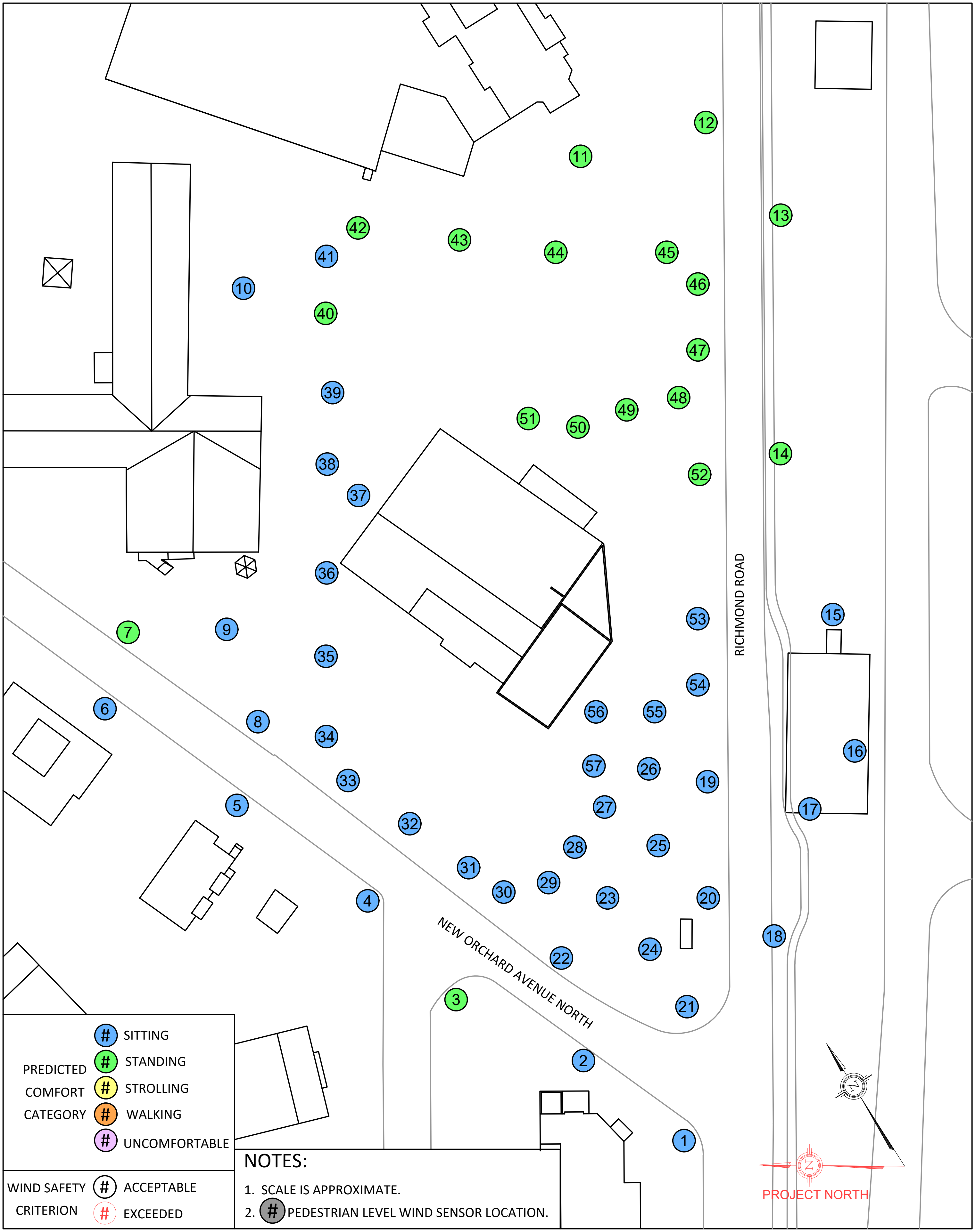
PROJECT: 1047 RICHMOND ROAD, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 2A: SPRING EXISTING GRADE LEVEL PLW SENSOR LAYOUT PEDESTRIAN COMFORT PREDICTIONS
SCALE: 1:1000 (APPROX.)	DRAWING NO.: GW21-416-PLW-2023-2A	
DATE: OCTOBER 3, 2023	DRAWN BY: K.A.	



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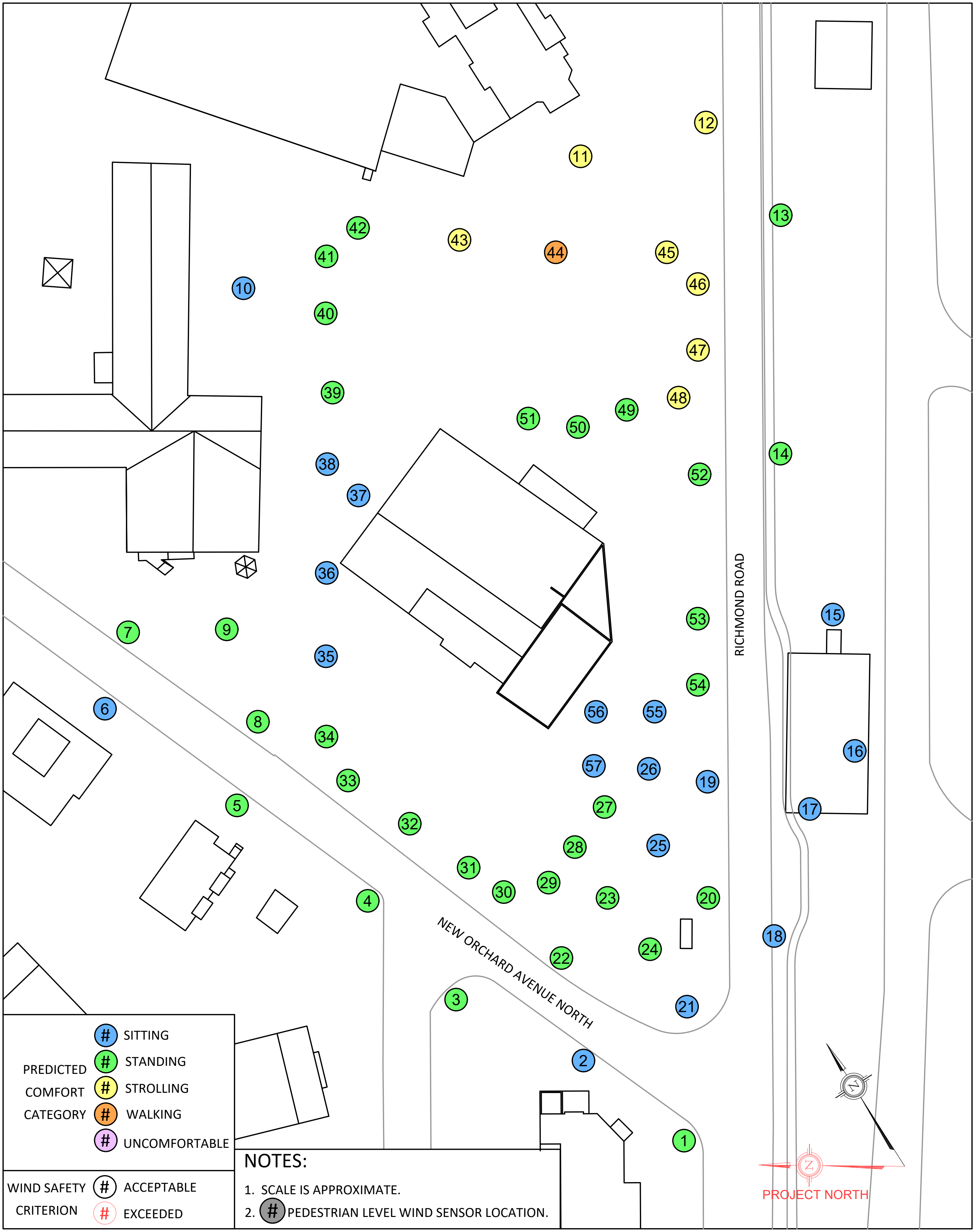
1047 RICHMOND ROAD, OTTAWA PEDESTRIAN LEVEL WIND STUDY		FIGURE 2B: SUMMER EXISTING GRADE LEVEL PLW SENSOR LAYOUT PEDESTRIAN COMFORT PREDICTIONS
SCALE: 1:1000 (APPROX.)	DRAWING NO.: GW21-416-PLW-2023-2B	
DATE: OCTOBER 3, 2023	DRAWN BY: K.A.	



NOTES:

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

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PROJECT	1047 RICHMOND ROAD, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION FIGURE 2C: AUTUMN EXISTING GRADE LEVEL PLW SENSOR LAYOUT PEDESTRIAN COMFORT PREDICTIONS
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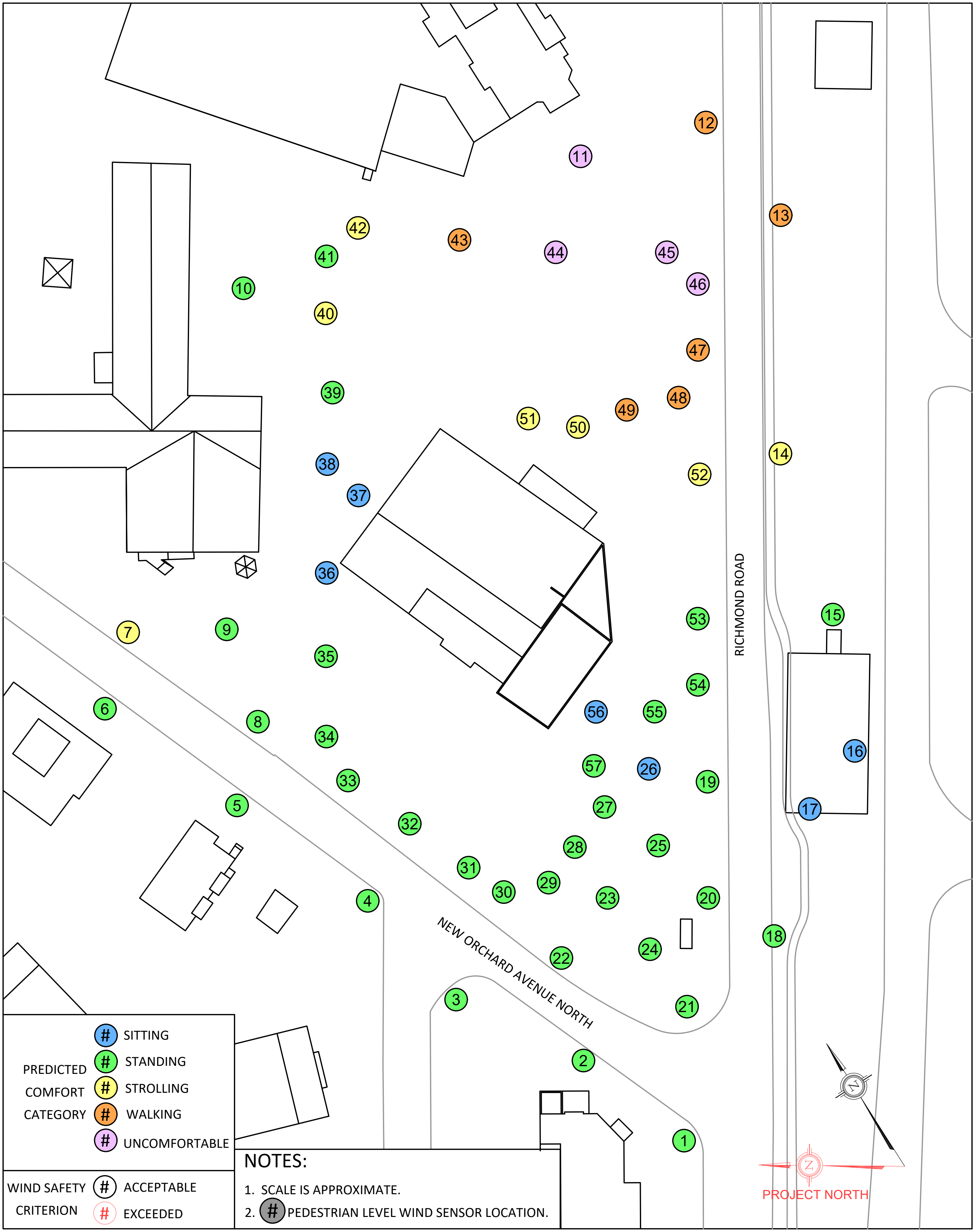
DATE	OCTOBER 3, 2023	DRAWN BY K.A.	



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PROJECT	1047 RICHMOND ROAD, OTTAWA PEDESTRIAN LEVEL WIND STUDY
SCALE	1:1000 (APPROX.)
DRAWING NO.	GW21-416-PLW-2023-2D
DATE	OCTOBER 3, 2023
DRAWN BY	K.A.
DESCRIPTION	FIGURE 2D: WINTER EXISTING GRADE LEVEL PLW SENSOR LAYOUT PEDESTRIAN COMFORT PREDICTIONS

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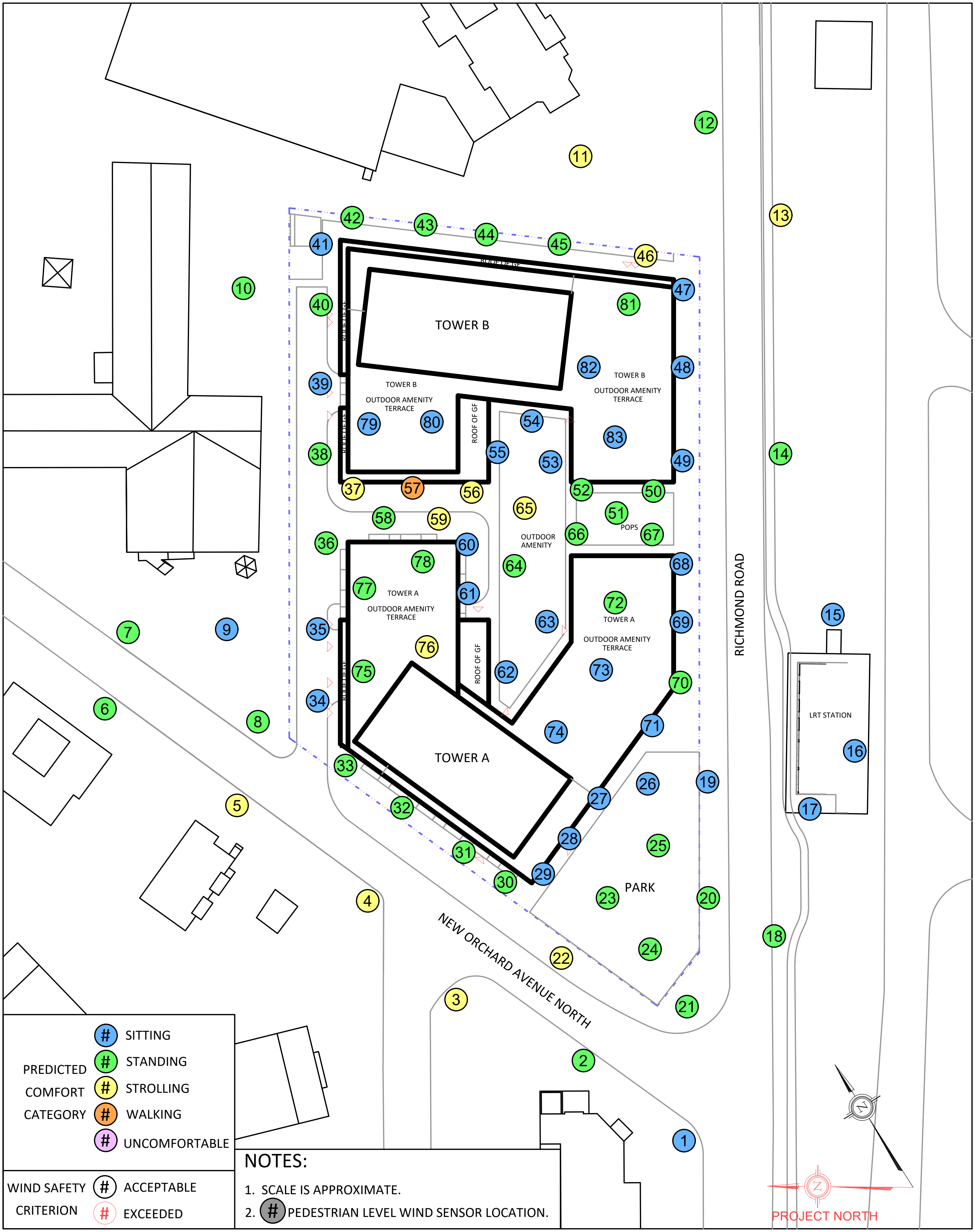
PROJECT	1047 RICHMOND ROAD, OTTAWA PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:1000 (APPROX.)	DRAWING NO.	GW21-416-PLW-2023-3A
DATE	OCTOBER 3, 2023	DRAWN BY	K.A.

DESCRIPTION

FIGURE 3A: SPRING
FUTURE GRADE LEVEL PLW SENSOR LAYOUT
PEDESTRIAN COMFORT PREDICTIONS



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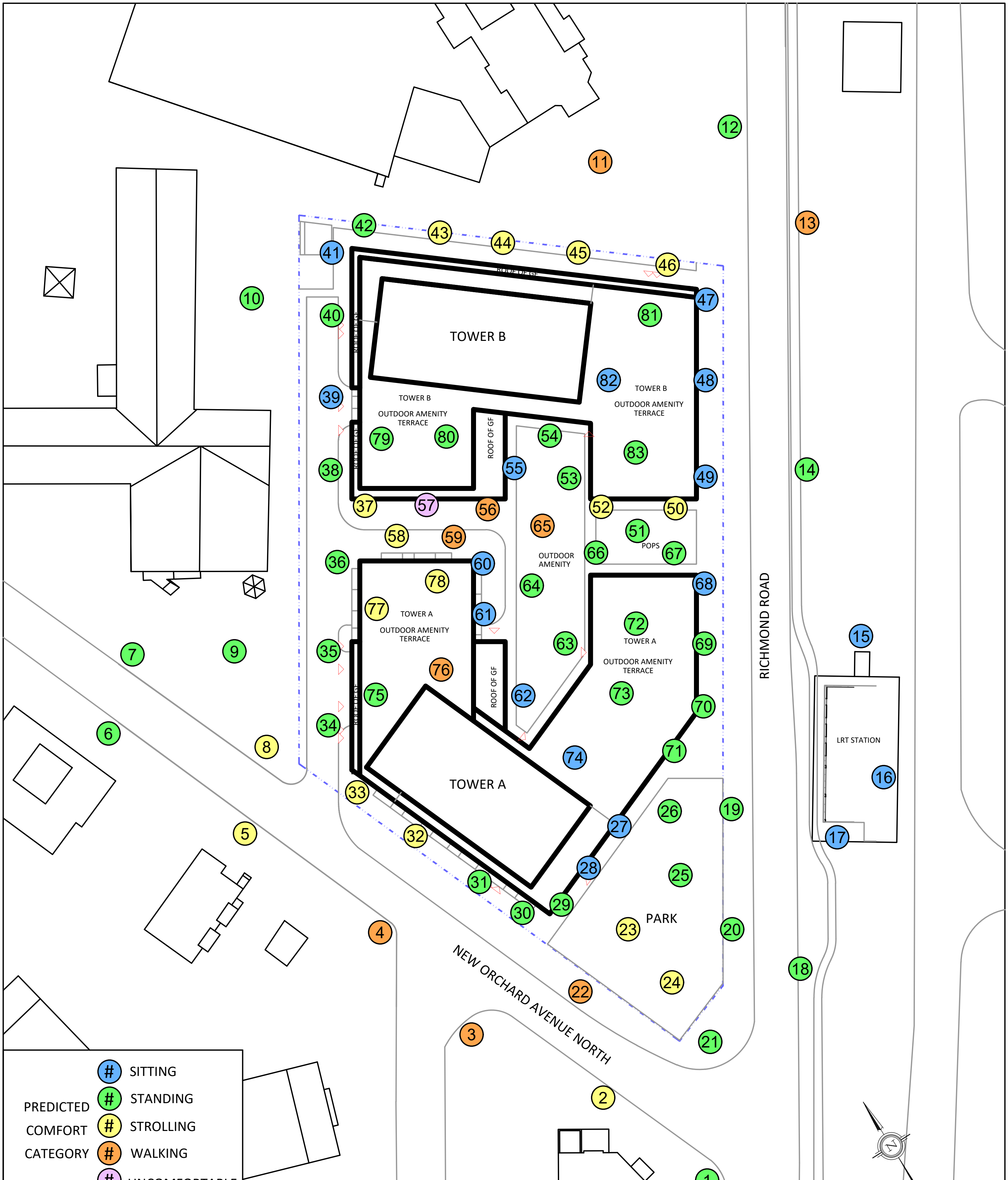
PROJECT	1047 RICHMOND ROAD, OTTAWA PEDESTRIAN LEVEL WIND STUDY	
SCALE	1:1000 (APPROX.)	DRAWING NO. GW21-416-PLW-2023-3B
DATE	OCTOBER 3, 2023	DRAWN BY K.A.

DESCRIPTION

FIGURE 3B: SUMMER
FUTURE GRADE LEVEL PLW SENSOR LAYOUT
PEDESTRIAN COMFORT PREDICTIONS



NOTES:

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

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PROJECT	1047 RICHMOND ROAD, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION FIGURE 3C: AUTUMN FUTURE GRADE LEVEL PLW SENSOR LAYOUT PEDESTRIAN COMFORT PREDICTIONS
SCALE	1:1000 (APPROX.)	DRAWING NO. GW21-416-PLW-2023-3C	
DATE	OCTOBER 3, 2023	DRAWN BY K.A.	

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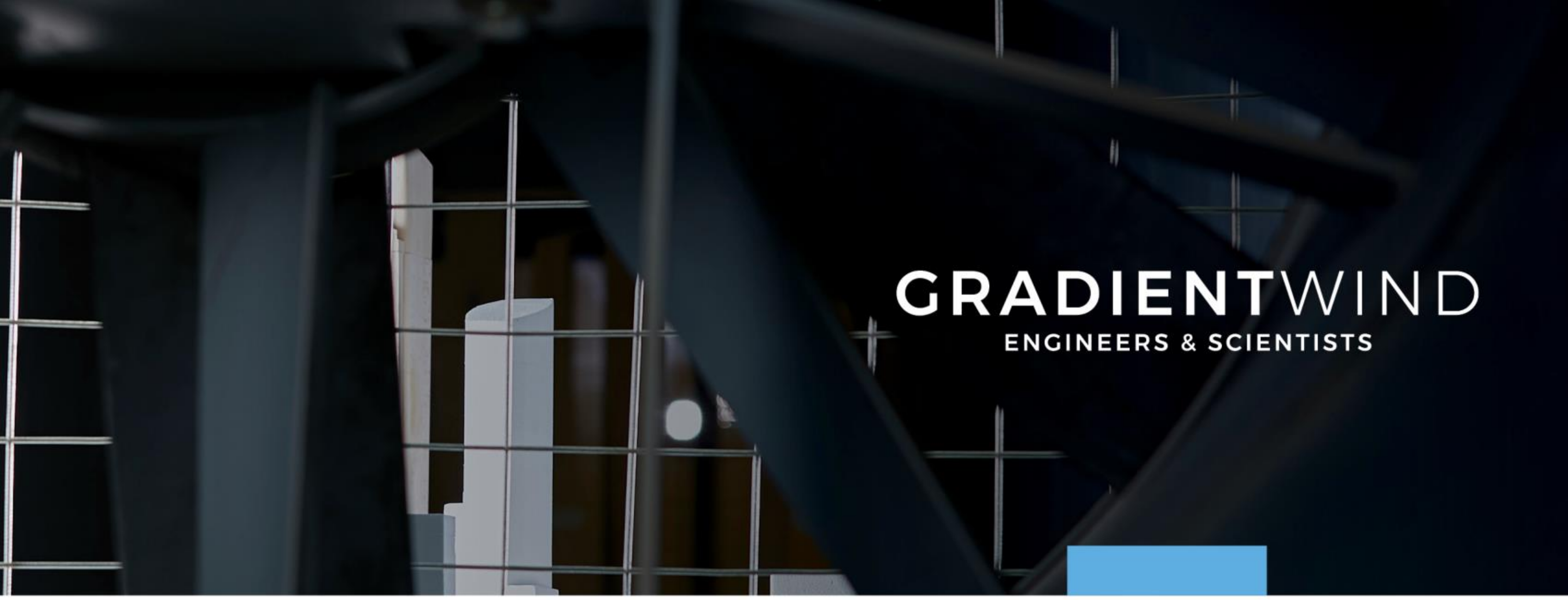
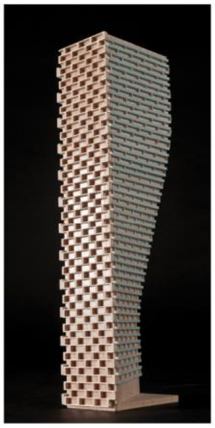
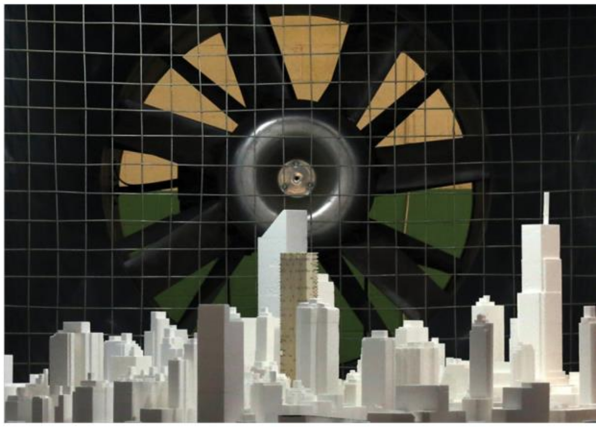
PROJECT	1047 RICHMOND ROAD, OTTAWA PEDESTRIAN LEVEL WIND STUDY	
SCALE 1:1000 (APPROX.)	DRAWING NO. GW21-416-PLW-2023-3D	
DATE OCTOBER 3, 2023	DRAWN BY K.A.	

DESCRIPTION

FIGURE 3D: WINTER
FUTURE GRADE LEVEL PLW SENSOR LAYOUT
PEDESTRIAN COMFORT PREDICTIONS







APPENDIX A

PEDESTRIAN COMFORT SUITABILITY, TABLES A1-A2 (EXISTING SCENARIO)

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

TABLE A1: SUMMARY OF PEDESTRIAN COMFORT (EXISTING SCENARIO)

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	12.1	Standing	8.8	Sitting	10.2	Standing	11.0	Standing	45.8	Safe
2	11.6	Standing	7.7	Sitting	9.4	Sitting	10.8	Standing	46.0	Safe
3	14.7	Strolling	11.2	Standing	12.9	Standing	13.9	Standing	51.6	Safe
4	12.8	Standing	9.3	Sitting	10.7	Standing	12.5	Standing	53.2	Safe
5	12.9	Standing	8.5	Sitting	10.3	Standing	12.2	Standing	58.6	Safe
6	11.4	Standing	7.7	Sitting	9.3	Sitting	11.0	Standing	44.8	Safe
7	15.6	Strolling	10.7	Standing	12.7	Standing	16.4	Strolling	64.3	Safe
8	13.1	Standing	9.3	Sitting	10.9	Standing	13.1	Standing	48.8	Safe
9	12.5	Standing	8.7	Sitting	10.4	Standing	12.8	Standing	48.6	Safe
10	11.7	Standing	7.9	Sitting	9.6	Sitting	12.2	Standing	46.8	Safe
11	19.5	Walking	13.4	Standing	16.4	Strolling	21.3	Uncomfortable	75.2	Safe
12	17.8	Walking	13.6	Standing	15.9	Strolling	18.2	Walking	71.8	Safe
13	15.9	Strolling	11.9	Standing	13.7	Standing	17.6	Walking	77.3	Safe
14	15.0	Strolling	10.2	Standing	12.2	Standing	15.4	Strolling	54.6	Safe
15	10.6	Standing	7.1	Sitting	8.4	Sitting	10.6	Standing	43.2	Safe
16	5.9	Sitting	4.6	Sitting	5.3	Sitting	5.9	Sitting	22.2	Safe
17	5.7	Sitting	4.5	Sitting	5.2	Sitting	6.0	Sitting	28.0	Safe
18	11.0	Standing	8.3	Sitting	9.5	Sitting	10.9	Standing	42.9	Safe
19	10.5	Standing	8.0	Sitting	9.2	Sitting	10.3	Standing	36.4	Safe
20	12.7	Standing	9.4	Sitting	10.8	Standing	12.6	Standing	48.4	Safe
21	11.2	Standing	8.1	Sitting	9.4	Sitting	10.8	Standing	49.3	Safe
22	13.6	Standing	9.8	Sitting	11.5	Standing	12.9	Standing	51.5	Safe
23	13.0	Standing	9.4	Sitting	11.0	Standing	12.8	Standing	50.0	Safe
24	12.1	Standing	9.3	Sitting	10.6	Standing	11.8	Standing	45.2	Safe
25	11.3	Standing	8.4	Sitting	9.7	Sitting	11.4	Standing	45.7	Safe
26	9.6	Sitting	7.2	Sitting	8.5	Sitting	9.7	Sitting	38.8	Safe
27	12.4	Standing	9.2	Sitting	10.7	Standing	12.5	Standing	47.0	Safe
28	13.6	Standing	10.0	Sitting	11.6	Standing	13.6	Standing	49.7	Safe
29	13.1	Standing	9.6	Sitting	11.1	Standing	12.9	Standing	51.0	Safe
30	13.1	Standing	9.7	Sitting	11.2	Standing	12.8	Standing	51.9	Safe
31	13.4	Standing	9.9	Sitting	11.5	Standing	13.3	Standing	51.9	Safe
32	13.5	Standing	9.6	Sitting	11.1	Standing	13.2	Standing	54.6	Safe
33	13.1	Standing	9.4	Sitting	11.0	Standing	13.1	Standing	53.7	Safe
34	13.0	Standing	9.2	Sitting	10.8	Standing	13.2	Standing	50.9	Safe
35	11.6	Standing	8.2	Sitting	9.5	Sitting	11.6	Standing	42.5	Safe

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

TABLE A2: SUMMARY OF PEDESTRIAN COMFORT (EXISTING SCENARIO)

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	10.2	Standing	7.7	Sitting	8.8	Sitting	9.9	Sitting	41.6	Safe
37	9.7	Sitting	6.7	Sitting	7.9	Sitting	9.7	Sitting	38.9	Safe
38	9.3	Sitting	6.2	Sitting	7.6	Sitting	8.9	Sitting	37.4	Safe
39	13.4	Standing	8.7	Sitting	10.8	Standing	13.3	Standing	53.8	Safe
40	15.6	Strolling	10.4	Standing	12.8	Standing	15.6	Strolling	55.4	Safe
41	14.2	Strolling	9.8	Sitting	11.7	Standing	14.0	Standing	51.1	Safe
42	14.7	Strolling	10.1	Standing	12.5	Standing	14.6	Strolling	52.4	Safe
43	18.1	Walking	12.2	Standing	14.6	Strolling	18.7	Walking	60.1	Safe
44	21.7	Uncomfortable	14.0	Standing	17.6	Walking	22.7	Uncomfortable	69.5	Safe
45	20.4	Uncomfortable	13.6	Standing	16.7	Strolling	22.2	Uncomfortable	77.7	Safe
46	18.9	Walking	13.0	Standing	15.7	Strolling	20.8	Uncomfortable	73.1	Safe
47	17.6	Walking	12.1	Standing	14.3	Strolling	18.9	Walking	64.9	Safe
48	17.2	Walking	11.9	Standing	14.1	Strolling	18.3	Walking	61.2	Safe
49	17.1	Walking	11.7	Standing	13.9	Standing	18.0	Walking	61.0	Safe
50	16.0	Strolling	11.0	Standing	12.9	Standing	16.6	Strolling	59.7	Safe
51	15.3	Strolling	10.5	Standing	12.1	Standing	15.7	Strolling	58.2	Safe
52	15.5	Strolling	10.6	Standing	12.7	Standing	15.8	Strolling	55.9	Safe
53	12.5	Standing	9.0	Sitting	10.6	Standing	12.1	Standing	43.7	Safe
54	12.2	Standing	9.0	Sitting	10.6	Standing	12.2	Standing	41.8	Safe
55	11.1	Standing	8.1	Sitting	9.6	Sitting	11.1	Standing	42.0	Safe
56	9.2	Sitting	6.7	Sitting	8.1	Sitting	9.2	Sitting	35.9	Safe
57	11.3	Standing	8.1	Sitting	9.7	Sitting	11.4	Standing	42.2	Safe

APPENDIX B

PEDESTRIAN COMFORT SUITABILITY, TABLES B1-B3
(PROPOSED SCENARIO)

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

TABLE B1: SUMMARY OF PEDESTRIAN COMFORT (PROPOSED SCENARIO)

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	13.1	Standing	9.3	Sitting	10.8	Standing	14.1	Strolling	62.8	Safe
2	17.9	Walking	12.3	Standing	14.2	Strolling	18.3	Walking	65.4	Safe
3	23.8	Uncomfortable	16.1	Strolling	19.5	Walking	24.1	Uncomfortable	76.0	Safe
4	20.5	Uncomfortable	15.1	Strolling	17.5	Walking	21.4	Uncomfortable	73.3	Safe
5	19.0	Walking	14.4	Strolling	16.5	Strolling	19.1	Walking	58.9	Safe
6	14.2	Strolling	10.8	Standing	12.5	Standing	14.2	Strolling	48.8	Safe
7	14.3	Strolling	11.2	Standing	12.9	Standing	14.7	Strolling	50.9	Safe
8	17.1	Walking	13.5	Standing	15.3	Strolling	17.6	Walking	59.2	Safe
9	12.6	Standing	9.8	Sitting	11.5	Standing	13.4	Standing	52.0	Safe
10	13.1	Standing	10.3	Standing	11.8	Standing	14.2	Strolling	52.6	Safe
11	21.9	Uncomfortable	15.1	Strolling	18.2	Walking	22.7	Uncomfortable	71.7	Safe
12	15.0	Strolling	11.6	Standing	13.4	Standing	15.2	Strolling	56.0	Safe
13	20.1	Uncomfortable	14.9	Strolling	17.3	Walking	21.3	Uncomfortable	82.6	Safe
14	13.7	Standing	10.5	Standing	12.0	Standing	13.9	Standing	51.7	Safe
15	10.9	Standing	7.7	Sitting	8.9	Sitting	11.3	Standing	44.7	Safe
16	7.7	Sitting	5.7	Sitting	6.8	Sitting	8.0	Sitting	35.1	Safe
17	7.1	Sitting	5.7	Sitting	6.4	Sitting	7.7	Sitting	37.1	Safe
18	15.1	Strolling	11.0	Standing	12.8	Standing	16.8	Strolling	77.4	Safe
19	12.9	Standing	9.5	Sitting	11.3	Standing	13.1	Standing	51.8	Safe
20	16.7	Strolling	11.8	Standing	14.0	Standing	18.2	Walking	80.8	Safe
21	16.6	Strolling	11.6	Standing	13.7	Standing	18.3	Walking	74.6	Safe
22	23.0	Uncomfortable	15.3	Strolling	18.8	Walking	23.6	Uncomfortable	77.5	Safe
23	18.1	Walking	12.7	Standing	15.5	Strolling	19.6	Walking	75.6	Safe
24	19.3	Walking	13.5	Standing	15.9	Strolling	21.0	Uncomfortable	76.3	Safe
25	14.2	Strolling	10.6	Standing	12.5	Standing	14.8	Strolling	72.0	Safe
26	12.7	Standing	9.6	Sitting	11.4	Standing	12.9	Standing	49.8	Safe
27	9.0	Sitting	6.9	Sitting	8.3	Sitting	9.3	Sitting	39.6	Safe
28	9.7	Sitting	6.5	Sitting	8.3	Sitting	9.6	Sitting	50.1	Safe
29	12.7	Standing	8.8	Sitting	11.2	Standing	12.8	Standing	56.8	Safe
30	15.7	Strolling	11.5	Standing	13.2	Standing	16.1	Strolling	64.3	Safe
31	14.4	Strolling	10.3	Standing	11.8	Standing	14.5	Strolling	62.5	Safe
32	16.9	Strolling	12.3	Standing	14.4	Strolling	16.9	Strolling	63.5	Safe
33	17.2	Walking	13.1	Standing	15.0	Strolling	16.6	Strolling	65.2	Safe
34	12.3	Standing	10.0	Sitting	11.1	Standing	11.7	Standing	55.9	Safe
35	12.3	Standing	9.4	Sitting	10.8	Standing	12.1	Standing	49.2	Safe

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

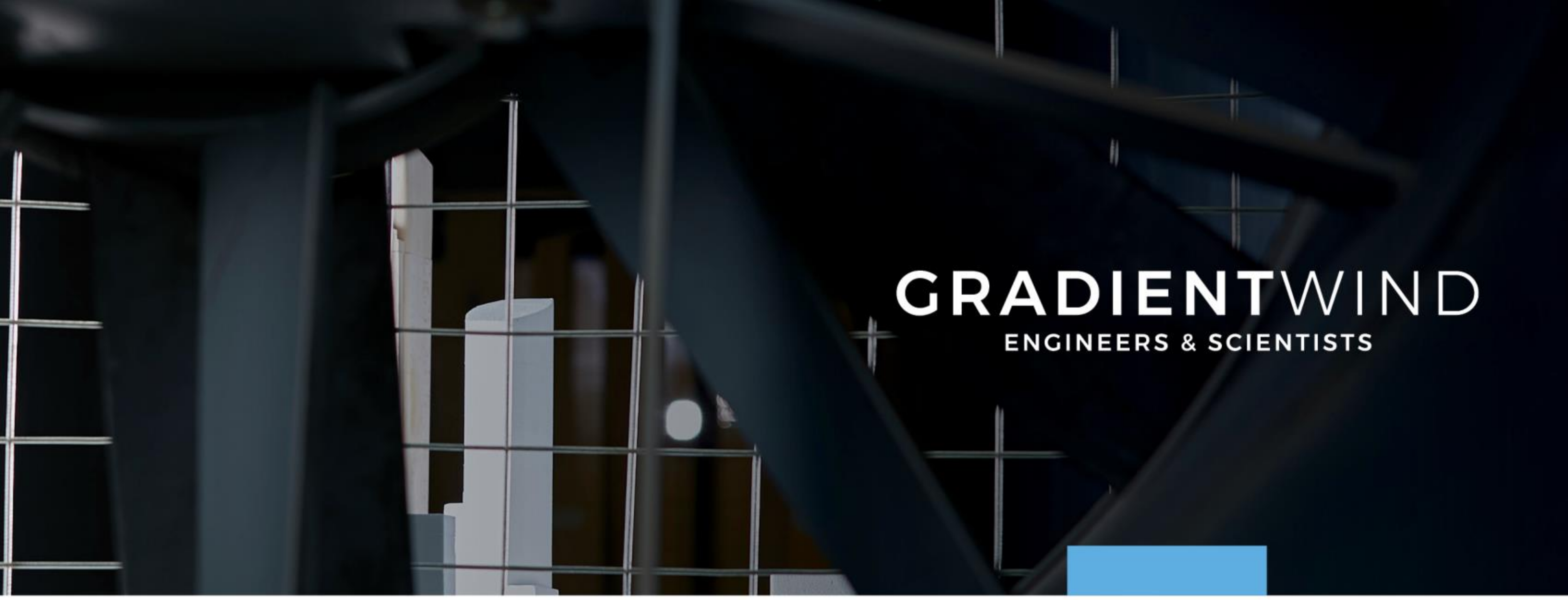
TABLE B2: SUMMARY OF PEDESTRIAN COMFORT (PROPOSED SCENARIO)

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	13.1	Standing	10.3	Standing	11.8	Standing	13.4	Standing	54.5	Safe
37	19.6	Walking	14.6	Strolling	16.8	Strolling	20.0	Walking	69.0	Safe
38	14.2	Strolling	10.8	Standing	12.2	Standing	13.9	Standing	54.4	Safe
39	10.9	Standing	8.9	Sitting	9.9	Sitting	10.6	Standing	47.8	Safe
40	12.2	Standing	10.1	Standing	11.1	Standing	12.3	Standing	48.6	Safe
41	10.3	Standing	8.7	Sitting	9.6	Sitting	11.1	Standing	51.2	Safe
42	16.0	Strolling	10.7	Standing	13.2	Standing	16.5	Strolling	73.0	Safe
43	17.8	Walking	11.6	Standing	14.7	Strolling	18.2	Walking	66.0	Safe
44	18.2	Walking	11.9	Standing	14.9	Strolling	18.8	Walking	59.9	Safe
45	18.4	Walking	13.3	Standing	15.2	Strolling	19.5	Walking	65.9	Safe
46	20.1	Uncomfortable	14.5	Strolling	16.6	Strolling	21.6	Uncomfortable	70.8	Safe
47	9.9	Sitting	7.8	Sitting	9.1	Sitting	9.8	Sitting	43.4	Safe
48	10.0	Sitting	8.4	Sitting	9.4	Sitting	10.0	Sitting	37.2	Safe
49	9.9	Sitting	7.5	Sitting	8.9	Sitting	10.0	Sitting	42.0	Safe
50	17.2	Walking	12.2	Standing	14.2	Strolling	17.3	Walking	64.0	Safe
51	17.1	Walking	11.8	Standing	14.0	Standing	17.1	Walking	60.2	Safe
52	18.1	Walking	13.9	Standing	16.0	Strolling	18.1	Walking	64.3	Safe
53	12.6	Standing	8.6	Sitting	10.5	Standing	12.4	Standing	51.1	Safe
54	14.6	Strolling	9.6	Sitting	11.8	Standing	14.3	Strolling	50.4	Safe
55	10.8	Standing	7.2	Sitting	9.0	Sitting	10.4	Standing	45.9	Safe
56	22.2	Uncomfortable	15.0	Strolling	17.6	Walking	22.3	Uncomfortable	76.0	Safe
57	25.6	Uncomfortable	18.0	Walking	21.3	Uncomfortable	26.2	Uncomfortable	80.8	Safe
58	21.1	Uncomfortable	14.0	Standing	16.1	Strolling	21.1	Uncomfortable	78.5	Safe
59	22.2	Uncomfortable	15.3	Strolling	17.5	Walking	22.6	Uncomfortable	80.1	Safe
60	9.7	Sitting	6.8	Sitting	8.6	Sitting	10.3	Standing	51.0	Safe
61	8.7	Sitting	6.5	Sitting	7.8	Sitting	8.7	Sitting	32.5	Safe
62	9.5	Sitting	7.0	Sitting	8.2	Sitting	9.6	Sitting	38.0	Safe
63	13.0	Standing	9.3	Sitting	11.1	Standing	13.8	Standing	60.3	Safe
64	15.4	Strolling	10.9	Standing	13.6	Standing	15.7	Strolling	59.6	Safe
65	21.7	Uncomfortable	15.1	Strolling	18.2	Walking	21.6	Uncomfortable	66.9	Safe
66	14.4	Strolling	10.3	Standing	12.0	Standing	15.1	Strolling	56.5	Safe
67	15.5	Strolling	10.7	Standing	12.4	Standing	16.6	Strolling	63.9	Safe
68	8.8	Sitting	7.2	Sitting	8.1	Sitting	8.8	Sitting	41.1	Safe
69	11.5	Standing	8.8	Sitting	10.3	Standing	11.7	Standing	45.3	Safe
70	13.3	Standing	10.2	Standing	12.4	Standing	13.9	Standing	55.8	Safe

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

TABLE B3: SUMMARY OF PEDESTRIAN COMFORT (PROPOSED SCENARIO)

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
71	11.5	Standing	9.0	Sitting	10.7	Standing	12.1	Standing	48.7	Safe
72	13.0	Standing	10.3	Standing	11.7	Standing	13.4	Standing	51.3	Safe
73	12.2	Standing	9.5	Sitting	10.9	Standing	12.1	Standing	48.0	Safe
74	8.6	Sitting	6.6	Sitting	7.7	Sitting	8.5	Sitting	34.3	Safe
75	14.4	Strolling	10.1	Standing	11.9	Standing	14.3	Strolling	56.2	Safe
76	21.6	Uncomfortable	15.1	Strolling	17.4	Walking	21.4	Uncomfortable	84.7	Safe
77	20.3	Uncomfortable	13.3	Standing	16.3	Strolling	21.1	Uncomfortable	72.6	Safe
78	18.7	Walking	12.6	Standing	15.5	Strolling	20.3	Uncomfortable	68.3	Safe
79	12.0	Standing	9.3	Sitting	10.5	Standing	11.6	Standing	51.7	Safe
80	12.4	Standing	10.0	Sitting	11.2	Standing	14.2	Strolling	57.3	Safe
81	13.2	Standing	10.1	Standing	11.5	Standing	12.4	Standing	60.2	Safe
82	10.5	Standing	7.9	Sitting	9.3	Sitting	10.8	Standing	43.5	Safe
83	13.0	Standing	9.1	Sitting	11.1	Standing	13.4	Standing	50.6	Safe



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; $\boldsymbol{U}$ = mean wind speed, $\boldsymbol{U_g}$ = gradient wind speed, $\boldsymbol{Z}$ = height above ground, $\boldsymbol{Z_g}$ = depth of the boundary layer (gradient height) and α is the power law exponent.

Figure 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.

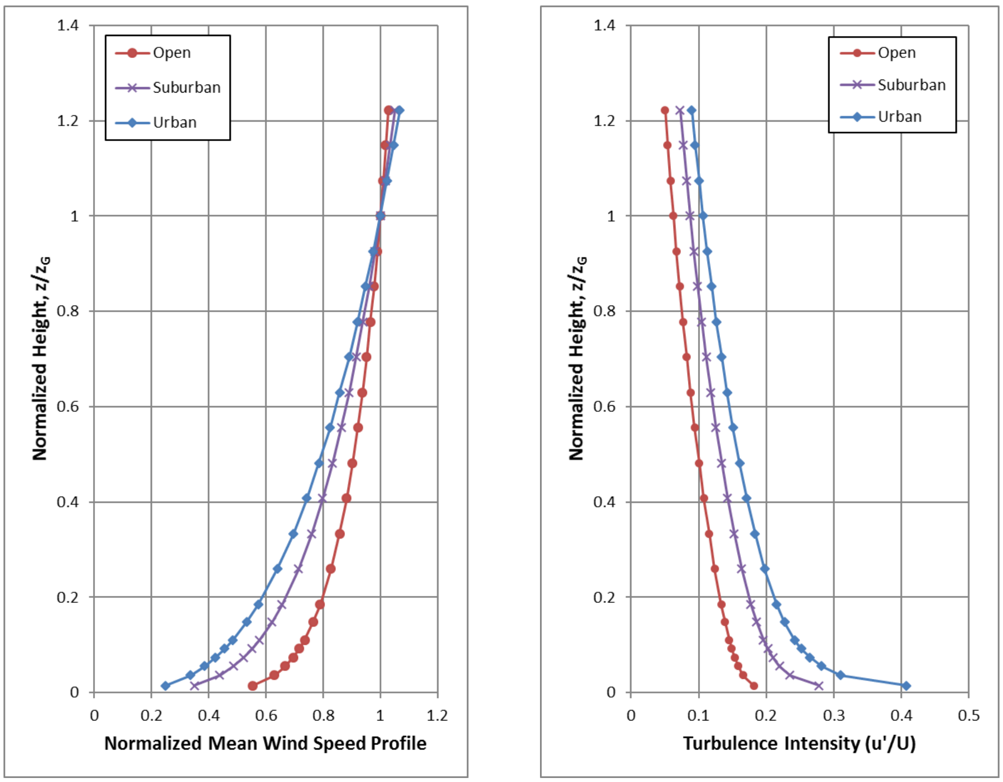

FIGURE C1 (LEFT): MEAN WIND SPEED PROFILES;
FIGURE C2 (RIGHT): TURBULENCE INTENSITY PROFILES

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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 the velocity of the air stream. For all measurements, the wire is oriented vertically so as to be sensitive to wind approaching from all directions in a horizontal plane.

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

For a given wind direction and location on the model, a time history of the wind speed is recorded for a period of time equal to one hour in full-scale. The analog signal produced by the hot wire or pressure sensor is digitized at a rate of 400 samples per second. A sample recording for several seconds is illustrated in Figure D1. This data is analyzed to extract the mean, root-mean-square (rms), and the peak of the signal. The peak value, or gust wind speed, is formed by averaging a number of peaks obtained from sub-intervals of the sampling period. The mean and gust speeds are then normalized by the wind tunnel gradient wind speed, which is the speed at the top of the model boundary layer, to obtain mean and gust ratios. At each location, the measurements are repeated for 36 wind directions to produce normalized polar plots, which will be provided upon request.

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

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

Where,

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

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

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

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

Where, U_N/U_g is the gust velocity ratios, where the summation is taken over all 36 wind directions at 10° intervals.

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

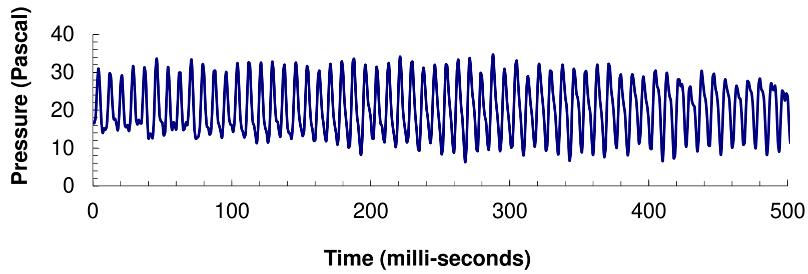

FIGURE D1: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR

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