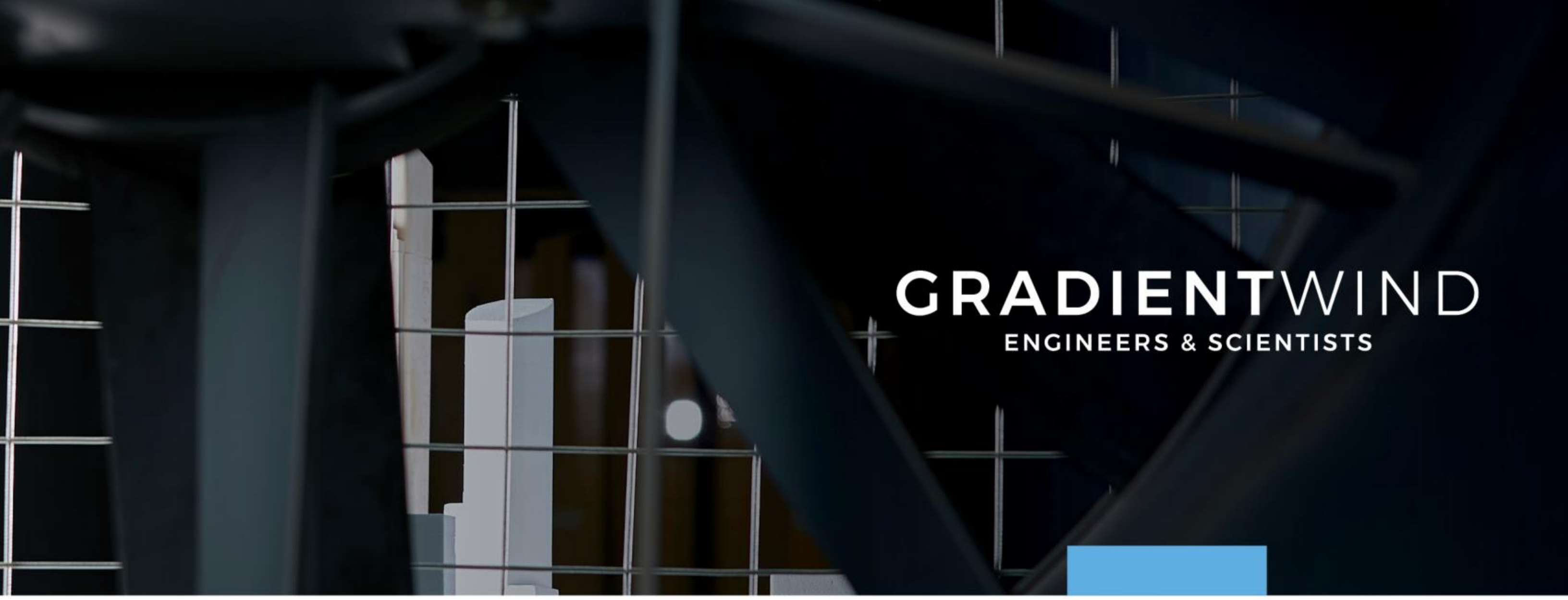
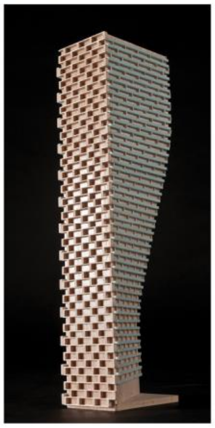
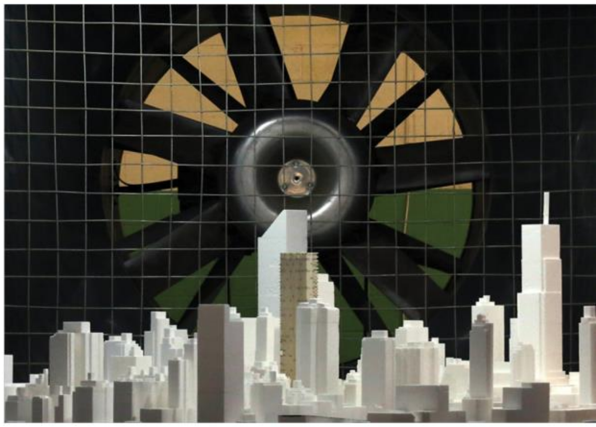



# PEDESTRIAN LEVEL WIND STUDY

36-48 Steeles Avenue East
Markham, Ontario

REPORT: GW18-170-WTPLW





January 14, 2021

PREPARED FOR
**Zonix Homes Inc. (Zonix Group)**
44 Steeles Avenue East
Markham, Ontario
L3T 1A2

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

# EXECUTIVE SUMMARY

This report describes a comparative pedestrian level wind study undertaken to assess wind conditions for a proposed residential development located at 36-48 Steeles Avenue East in Markham, 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, transit stops, driveways, parking areas, landscaped spaces, and building access points. Wind comfort is also evaluated over the Building A Level 9 outdoor amenity terrace. 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 Kirkor Architects and Planners in November 2020 and updated in January 2021, surrounding street layouts, as well as existing and approved future building massing information, and recent site imagery.

A complete summary of the predicted wind conditions is provided in Section 5.2 of this report, and is also illustrated in Figures 2A-5B, and Tables A1-A3 and B1-B5 in the appendices. Based on wind tunnel test results, meteorological data analysis, and experience with similar developments in Markham, 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. An exception is the transit stop at the northeast corner of Dudley Avenue and Steeles Avenue East. To ensure conditions suitable for sitting or more sedentary activities across the full Building A Level 9 amenity terrace throughout the warmer months, mitigation is recommended as described in Section 5.2.

A comparison of the existing versus future wind comfort surrounding the study site indicates that wind comfort will generally be reduced with the introduction of the proposed development. However, aside from the transit stop location discussed in Section 5.2, conditions nevertheless remain acceptable for the intended pedestrian uses, without the need for mitigation.

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

# TABLE OF CONTENTS

## 1. INTRODUCTION

This report describes a comparative pedestrian level wind study undertaken to assess wind conditions for a proposed residential development located at 36-48 Steeles Avenue East in Markham, 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 Kirkor Architects and Planners in November 2020 and updated in January 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 residential development located at 36-48 Steeles Avenue East in Markham, Ontario. The study site is located at the west side of a rectangular parcel of land bound by Steeles Avenue East to the south, Dudley Avenue to the west, Highland Park Boulevard to the north, and Willowdale Boulevard to the east.

The development comprises two buildings: Building A, 33-storeys with an eight-storey podium, to the south, and Building B, six-storeys, to the north. A driveway between the buildings gives access from Dudley Avenue to the drop-off areas, parking garage ramps, and loading zones. Both buildings have a rectangular planform, aligned longitudinally with Steeles Avenue East. Considering Building A, the primary residential lobby entrance fronts Steeles Avenue East, with secondary building access points located along the north elevation. Indoor amenity space is allocated along the west side of the building, with residential units and building support services occupying the remaining space. Setbacks from all directions at Levels 2 and 7 accommodate private terraces. At Level 9, the floorplate sets back from the east and west to meet the typical tower floorplate, with an outdoor amenity terrace located over the east podium rooftop. The tower rises with uniform floorplates to Level 32. At Levels 32, 33 and the MPH Level, setbacks from the north create a stepped profile. Considering Building B, primary and secondary building access points are located on the east end of the south façade, including a ramp to two levels of shared below-grade parking. Indoor amenity space is provided in the northeast corner. Private, recessed entrances serve ground floor residential units along the north and south elevations. Setbacks from the west and north at Level 2, and from the south, west and north at Level 5, accommodate private terraces. At Level 7 the building is completed by a mechanical penthouse.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-metre radius of the site) comprise low-rise residential buildings in all directions, except for a medium-rise apartment building to the west across Dudley Avenue. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer radius) are a continuation of the near-field, transitioning to include low-rise commercial buildings in the west and north directions. Two clusters of high-rise buildings are located between 500 and 900 metres northwest of the study site along Yonge Street.

Grade-level areas investigated include sidewalks, transit stops, driveways, parking areas, landscaped spaces, and building access points. Wind comfort is also evaluated over the Building A Level 9 outdoor amenity. Figure 1A and 1B illustrate the study site and surrounding context for the future and existing scenarios, respectively, and Photographs 1 through 6 depict the wind tunnel model used to conduct the study.

## 3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind comfort and safety conditions at key areas within and surrounding the development site; (ii) identify areas where wind conditions may interfere with the intended uses of outdoor spaces; (iii) recommend suitable mitigation measures, where required; and (iv) evaluate the influence of the proposed development 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 Markham 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 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 82 sensor locations on the scale model in Gradient Wind's wind tunnel. Of these 82 sensors, 75 were located at grade and the remaining seven sensors were located over the Building A Level 9 amenity terrace. Wind speed measurements were performed for each of the 82 sensors for 36 wind directions at 10° intervals. Figures 1A and 1B illustrate a plan of the future and existing site, respectively, and relevant surrounding context, 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

[1] Markham, Pedestrian Level Wind Study Terms of Reference, December 2018

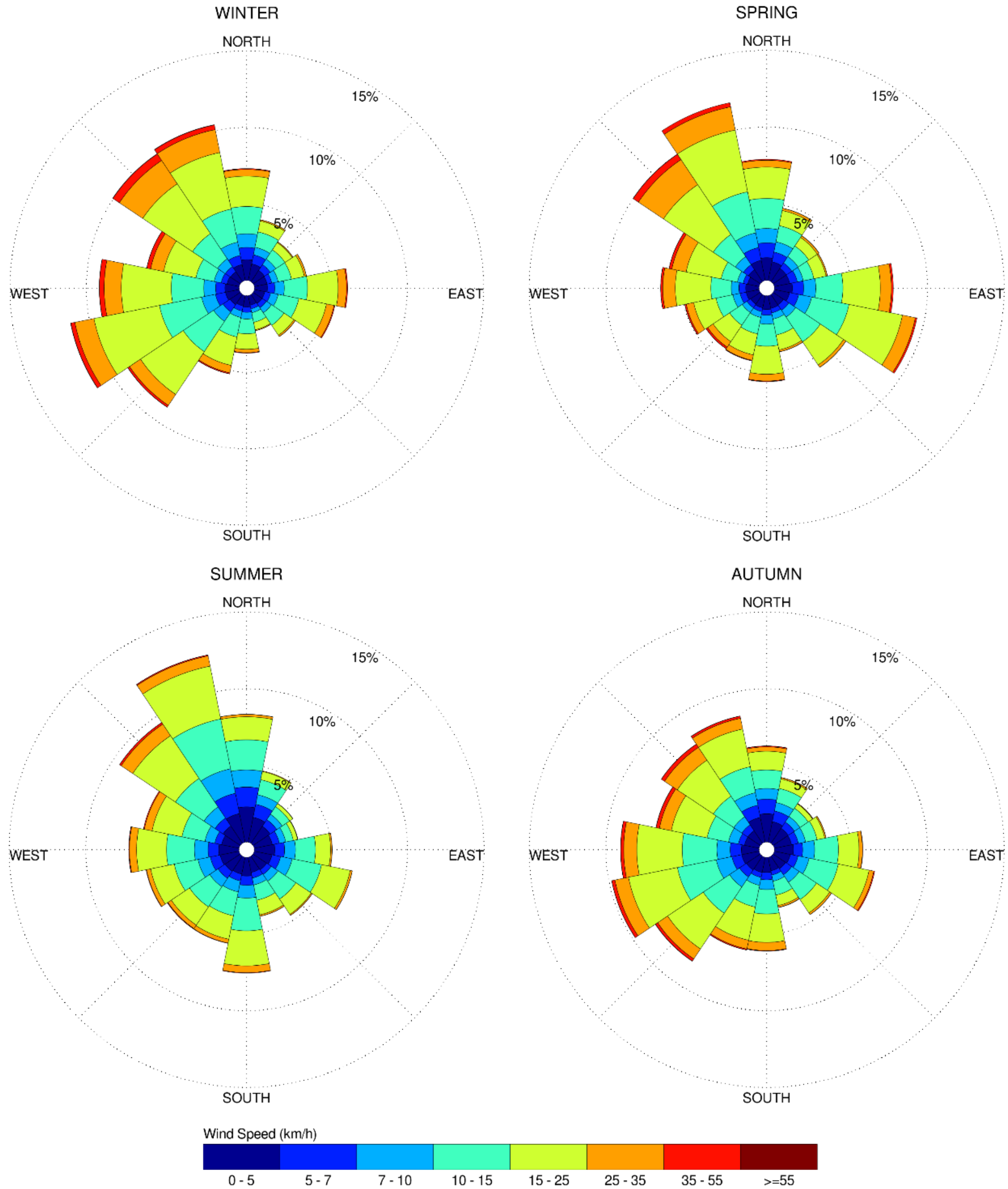
at grade were referenced to the wind speed measured near the ceiling of the wind tunnel to generate mean and peak wind speed ratios. Ceiling height in the wind tunnel represents the depth of the boundary layer of wind flowing over the earth's surface, referred to as the gradient height. Within this boundary 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 Markham was developed from approximately 40-years of hourly meteorological wind data recorded at Buttonville Municipal 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 Markham 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 Markham, the most common winds concerning pedestrian comfort occur from the southwest clockwise to the north, as well as those from the east. The directional preference and relative magnitude of the wind speed varies somewhat from season to season, with the summer months displaying the calmest winds relative to the remaining seasonal periods.

# SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES
# BUTTONVILLE MUNICIPAL AIRPORT, MARKHAM, ONTARIO




**Notes:**

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

## 4.4 Pedestrian Comfort and Safety Guidelines

Pedestrian comfort and safety guidelines are based on the mechanical effects of wind without consideration of other meteorological conditions (i.e. temperature, relative humidity). The comfort guidelines assume that pedestrians are appropriately dressed for a specified outdoor activity during any given season. Since both mean and gust wind speeds affect pedestrian comfort, their combined effect is defined in the City of Markham Terms of Reference[1]. More specifically, the criteria are defined as a Gust Equivalent Mean (GEM) wind speed, which is the greater of the mean wind speed or the gust wind speed divided by 1.85. The wind speed ranges are selected based on 'The Beaufort Scale' (presented on the following page), which describes the effects of forces produced by varying wind speed levels on objects.

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

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

(ii) **Standing** – GEM wind speeds below 15 km/h (i.e. 10-15 km/h) occurring more than 80% of the time are acceptable for activities such as standing, strolling or more vigorous activities.

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

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

Gust wind speeds greater than 90 km/h, occurring more than 0.1% of the time on an annual basis, are classified as dangerous. From calculations of stability, it can be shown that gust wind speeds of 90 km/h would be the approximate threshold wind speed that would cause a vulnerable member of the population to fall.

## THE BEAUFORT SCALE

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

Experience and research on people's perception of mechanical wind effects has shown that if the wind speed levels are exceeded for more than 20% of the time, the activity level would be judged to be uncomfortable by most people. For instance, if GEM wind speeds of 10 km/h were exceeded for more than 20% of the time most pedestrians would judge that location to be too windy for sitting or more sedentary activities. Similarly, if GEM wind speeds of 20 km/h at a location were exceeded for more than 20% of the time, walking or less vigorous activities would be considered uncomfortable. As most of these criteria are based on subjective reactions of a population to wind forces, their application is partly based on experience and judgment.

Once the pedestrian wind speed predictions have been established 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 A3 in Appendix A provide a summary of seasonal comfort predictions for each sensor location under the future massing scenario considering the study building and all approved surrounding developments. The tables indicate the 80% non-exceedance gust wind speeds and corresponding comfort classifications as defined in Section 4.4. In other words, a gust wind speed threshold of 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, and walking by blue. Measured mean and gust velocity ratios, which constitutes the raw data upon which the results are based, will be made available upon request.

## 5.2 Summary of Findings – Future Conditions

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

1. All public sidewalks, parking areas, and landscaped spaces within and surrounding the proposed development will experience wind conditions suitable for walking or better throughout each seasonal period, which is acceptable for the intended uses of the spaces.
2. Under the tested configuration, all secondary building access points will be suitable for walking or better, and the primary Building A entrance will be suitable for standing or better, throughout the year, which is acceptable. Although wind speeds near the primary Building B entrance (Sensor

42) will exceed the standing criterion during the colder months, the doorway is recessed behind the main building façade which will provide local relief from windy conditions.

3. Most private residential entrances will be comfortable for standing or better, while those entrances located along the south elevation of Building B (Sensors 40, 41 and 74) will be comfortable for walking or better, on a seasonal basis. The noted conditions are acceptable provided the current recessed design of the private entrances is retained.

4. The public transit stop at the southwest corner of the intersection of Dudley Avenue and Steeles Avenue East (Sensor 8) will be comfortable for standing or better throughout the year, which is appropriate. The stop at the northeast corner of the intersection (Sensor 61) will exceed the standing criterion during the spring and winter months. To ensure standing conditions throughout the year, a three-walled transit shelter is recommended for this location.

5. The Building A Level 9 outdoor amenity terrace (Sensors 76-82) will be comfortable for sitting or standing during the summer months. To ensure conditions comfortable for sitting or more sedentary activities over the entire terrace throughout the warmer months, it is recommended to install 2.0-metre-high wind barriers along the full perimeter of the terrace. As well, targeted wind screening placed directly northwest of designated seating areas to may also be utilized to provide localized wind mitigation. The exact configuration of such mitigation can be coordinated with the design team as the terrace landscape 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 too windy for walking or 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 B5 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 B5 indicates that wind comfort at many grade-level areas will generally be reduced upon the introduction of the proposed development. Increases in wind speeds are strongest along east-west corridors, specifically along the inward facing elevations of the study buildings, the north side of Highland Park Boulevard, and along Steeles Avenue East. Although wind comfort is generally reduced, aside from the transit stop location discussed in Section 5.2, conditions will nevertheless remain acceptable for the intended pedestrian uses.

## 6. CONCLUSIONS AND RECOMMENDATIONS

This report summarizes the methodology, results, and recommendations related to a pedestrian level wind study for the proposed residential development located at 36-48 Steeles Avenue East in Markham, 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-A3 and B1-B5 in the appendices. Based on the wind tunnel test results, meteorological data analysis, and experience with similar developments in Markham, 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. An exception is the transit stop at the northeast corner of Dudley Avenue and Steeles Avenue East. To ensure conditions suitable for sitting or more sedentary activities across the full Building A Level 9 amenity terrace throughout the warmer months, mitigation is recommended as described in Section 5.2.

A comparison of the existing versus future wind comfort surrounding the study site indicates that wind comfort will generally be reduced with the introduction of the proposed development. However, aside from the transit stop location discussed in Section 5.2, conditions nevertheless remain acceptable for the intended pedestrian uses, without the need for mitigation.

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

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

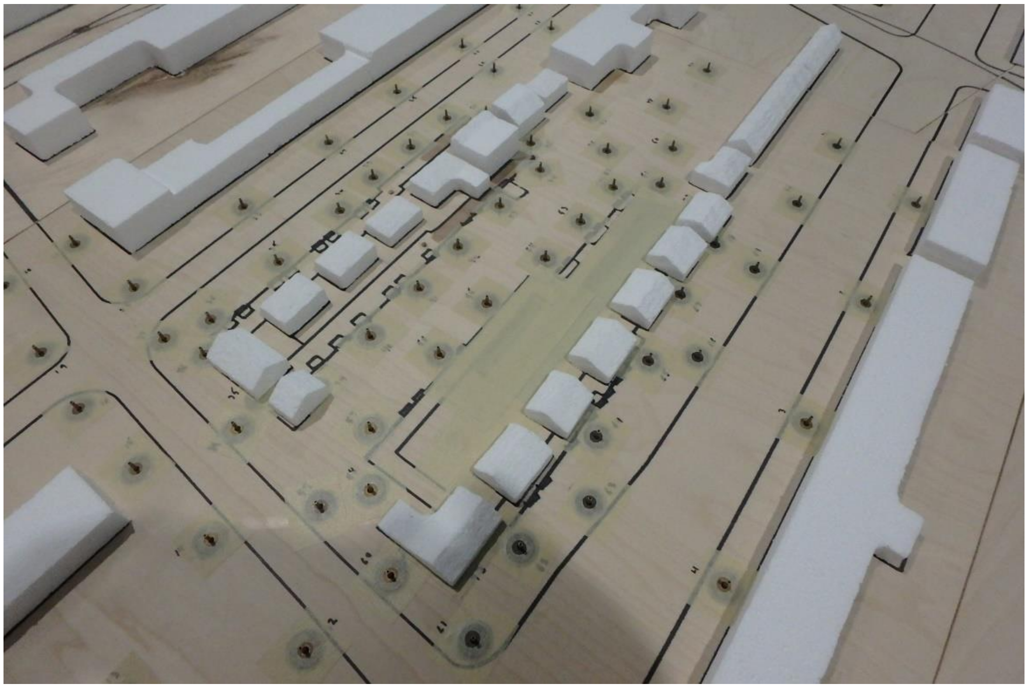
Sincerely,

***Gradient Wind Engineering Inc.***

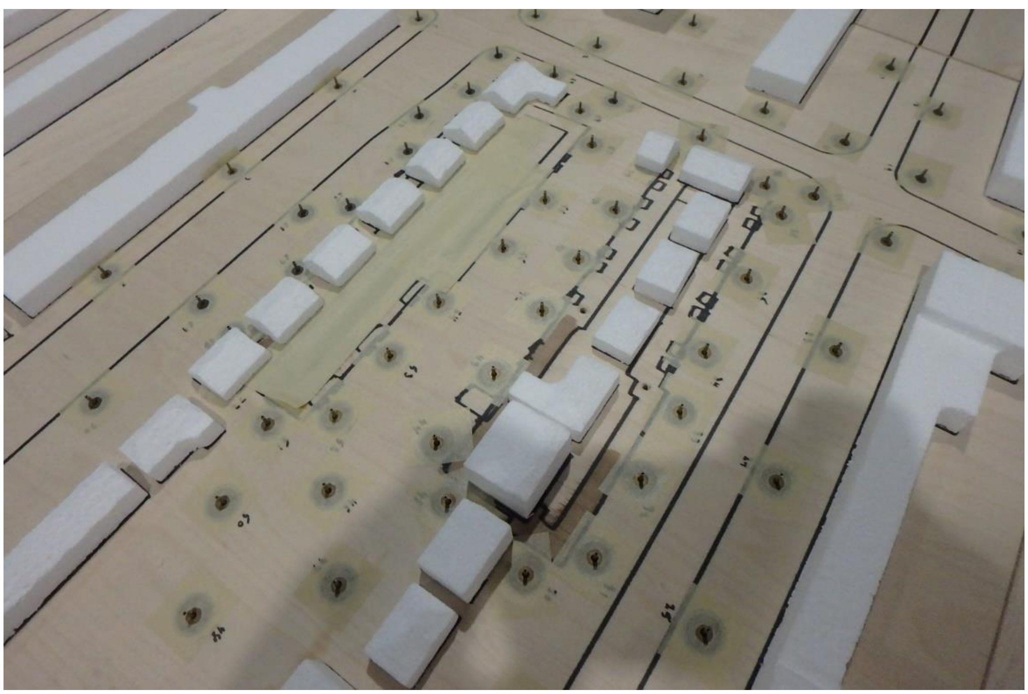
Patrick Shorey, B.A.Sc., EIT
Junior Wind Scientist

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

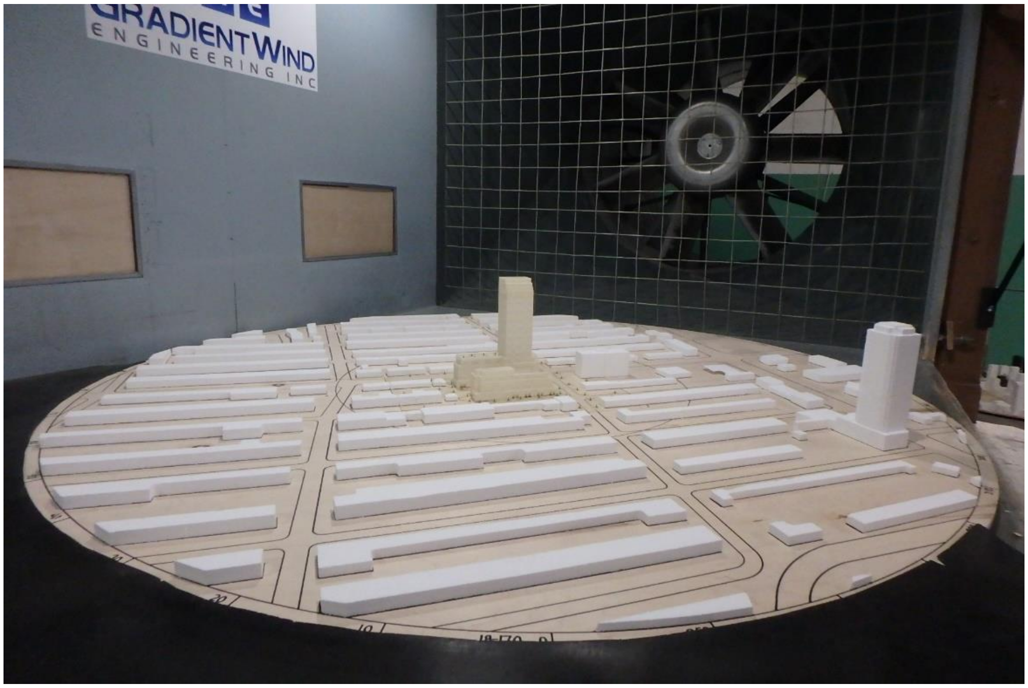
*GW18-170-WTPLW*



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



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

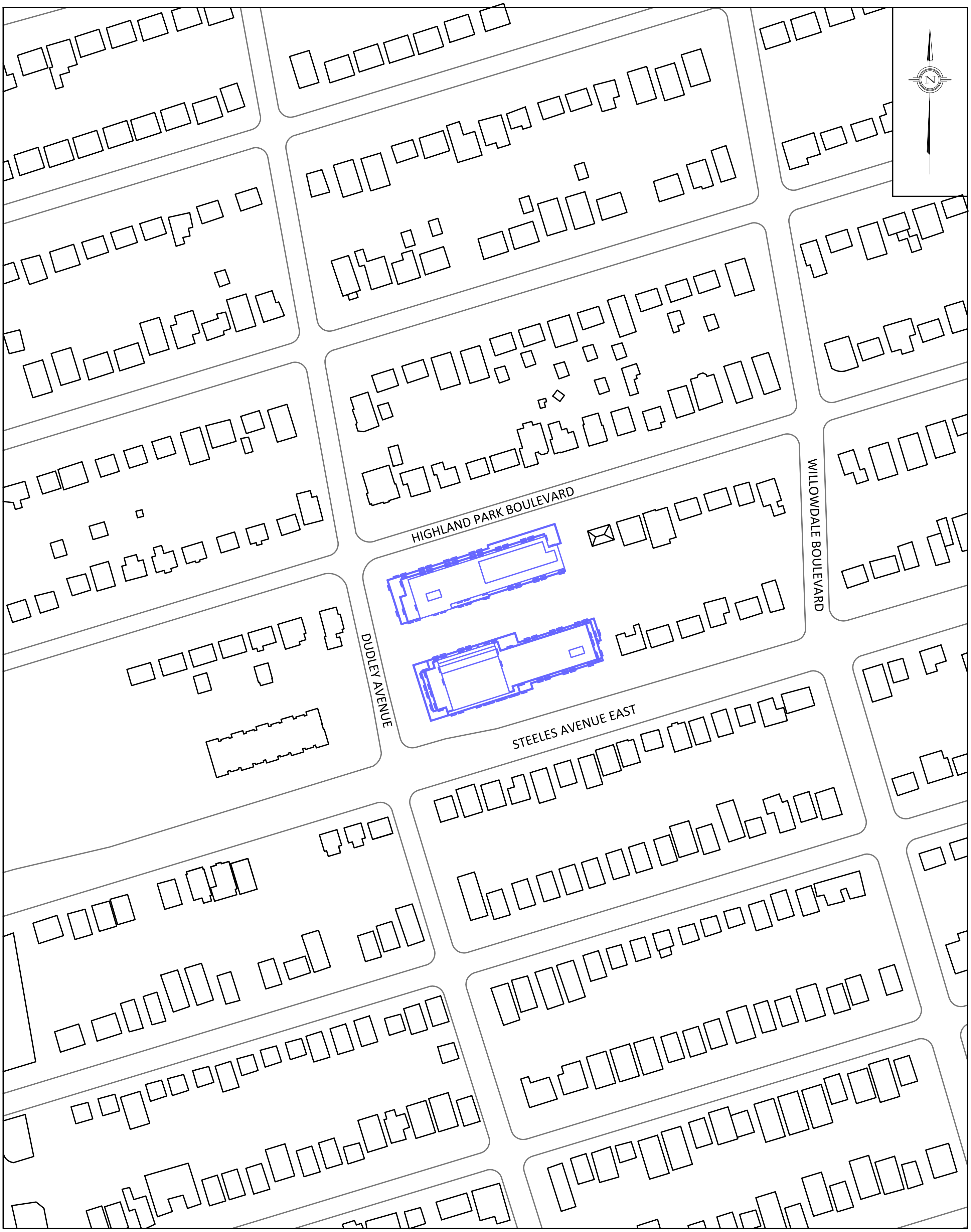



**PHOTOGRAPH 3: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING DOWNWIND**

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

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

**PHOTOGRAPH 6: CLOSE-UP VIEW OF STUDY MODEL LOOKING NORTHWEST**

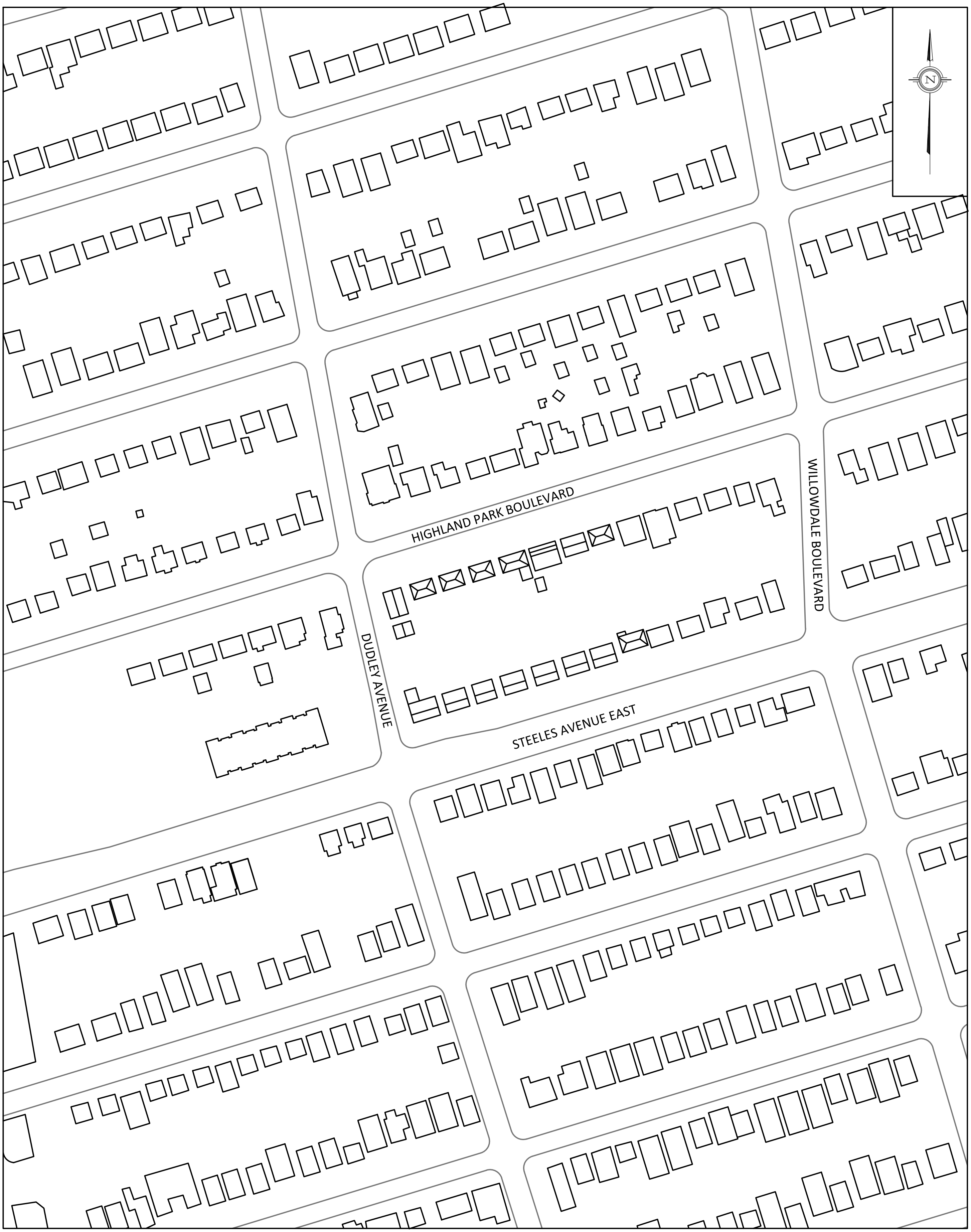



GRADIENTWIND
ENGINEERS & SCIENTISTS
127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM

| | | | |
|---|---|---|---|
| PROJECT | 38-48 STEELES AVENUE EAST, THORNHILL<br>PEDESTRIAN LEVEL WIND STUDY | | |
| SCALE | 1:2500 (APPROX.) | DRAWING NO. | GWE18-170-PLW-2020-1A |
| DATE | DECEMBER 11, 2020 | DRAWN BY | K.A. |

DESCRIPTION

FIGURE 1A:
SITE PLAN AND SURROUNDING CONTEXT
FUTURE SCENARIO





GRADIENTWIND
ENGINEERS & SCIENTISTS
127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM


| PROJECT | 38-48 STEELES AVENUE EAST, THORNHILL PEDESTRIAN LEVEL WIND STUDY | | DESCRIPTION |
|---|---|---|---|
| SCALE | 1:2500 (APPROX.) | DRAWING NO. GWE18-170-PLW-2020-1B | FIGURE 1B: SITE PLAN AND SURROUNDING CONTEXT EXISTING SCENARIO |
| DATE | DECEMBER 11, 2020 | DRAWN BY K.A. | |

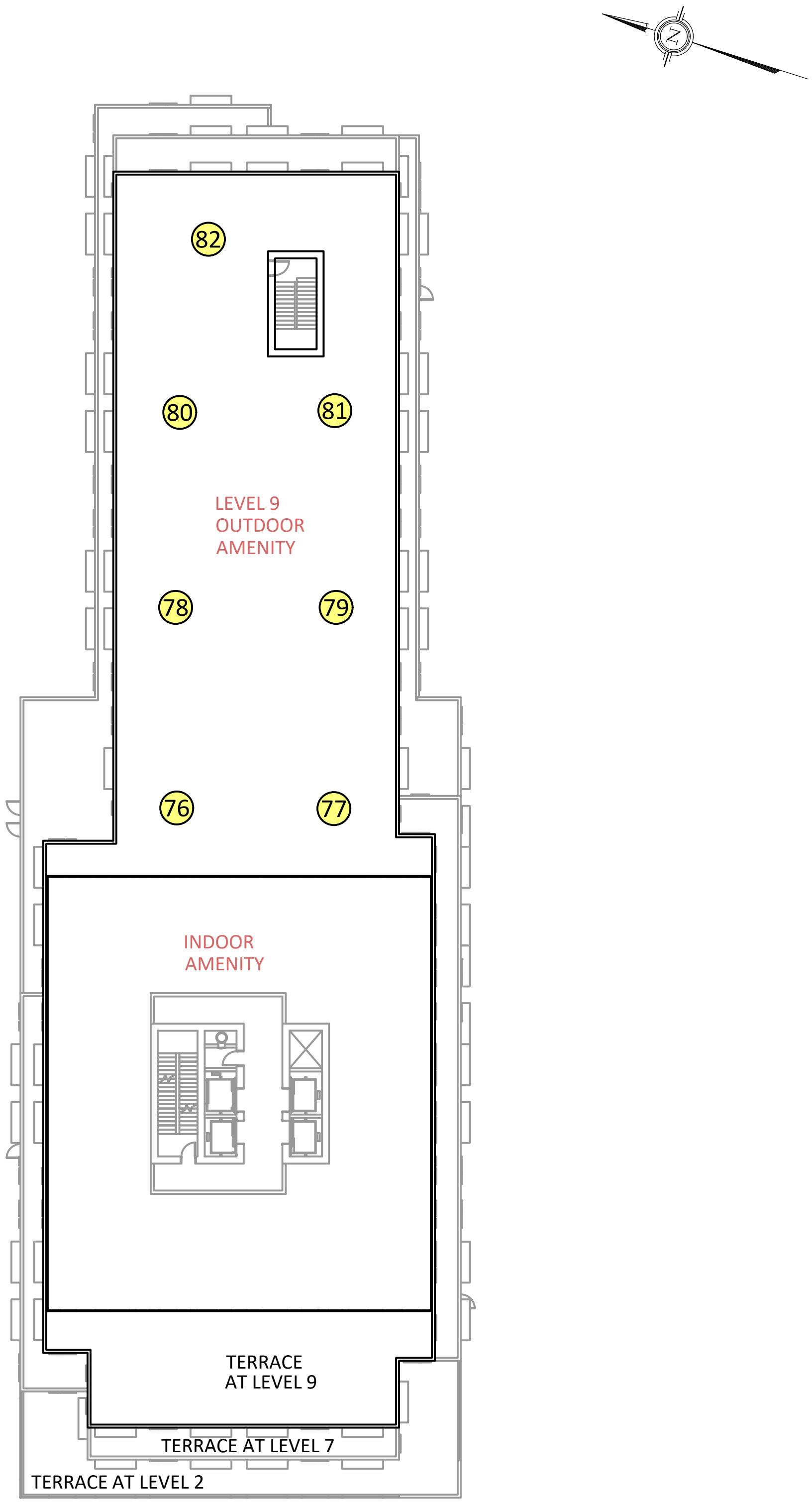

| PREDICTED COMFORT CLASSES | |
|---|---|
| # | SITTING |
| # | STANDING |
| # | WALKING |

NOTES:

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

GRADIENTWIND
ENGINEERS & SCIENTISTS
127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM

| | |
|---|---|
| PROJECT | 38-48 STEELES AVENUE EAST, THORNHILL PEDESTRIAN LEVEL WIND STUDY |
| SCALE | 1:1200 (APPROX.) |
| DRAWING NO. | GWE18-170-PLW-2020-2A |
| DATE | DECEMBER 11, 2020 |
| DRAWN BY | K.A. |
| DESCRIPTION | FIGURE 2A: SPRING GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS |



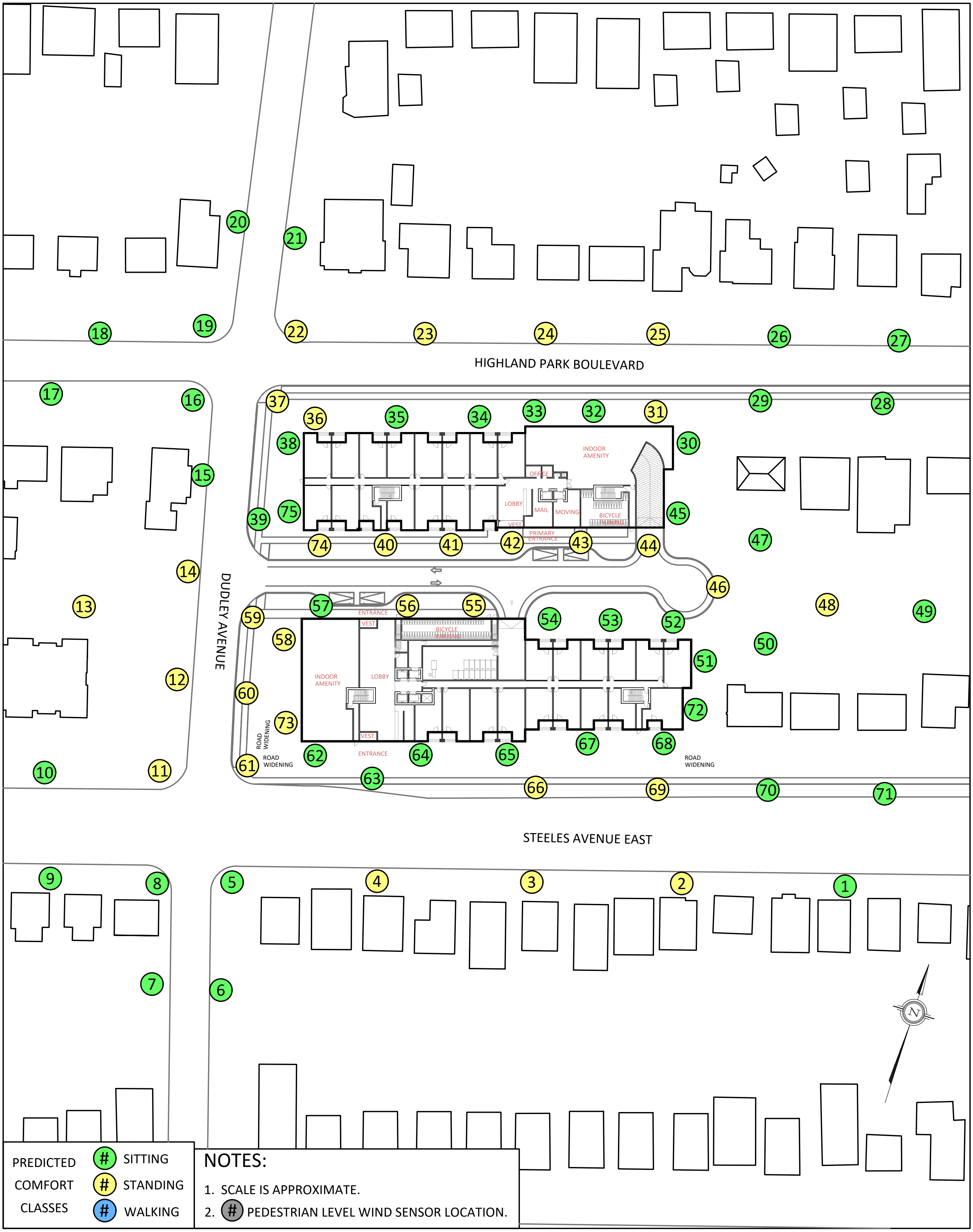

PREDICTED COMFORT CLASSES
- # SITTING
- # STANDING
- # WALKING

NOTES:

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

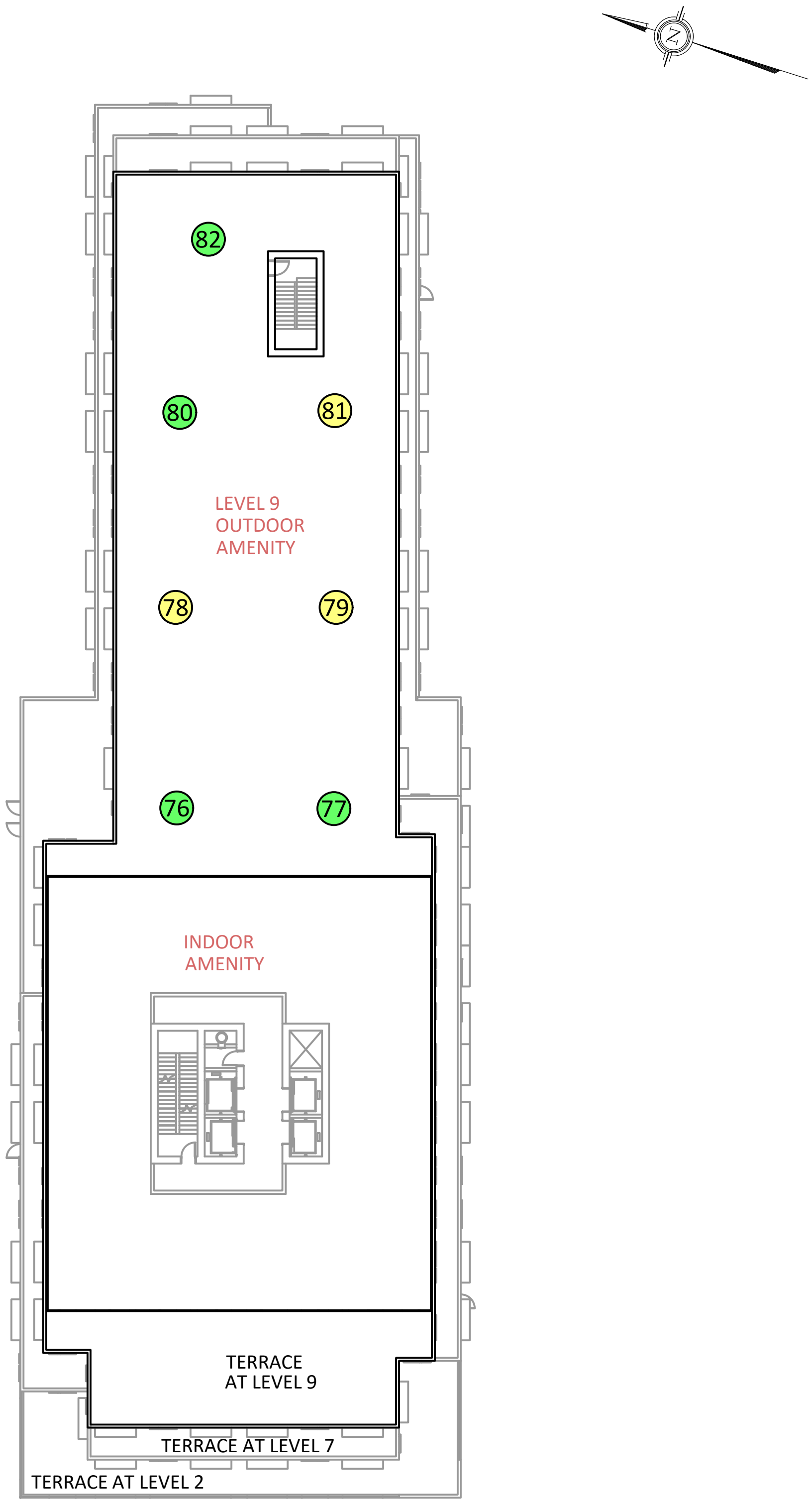

GRADIENTWIND
ENGINEERS & SCIENTISTS
127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM


| PROJECT | 38-48 STEELES AVENUE EAST, THORNHILL PEDESTRIAN LEVEL WIND STUDY | | DESCRIPTION |
|---|---|---|---|
| SCALE | 1:500 (APPROX.) | DRAWING NO. GWE18-170-PLW-2020-2B | FIGURE 2B: SPRING LEVEL 9 OUTDOOR AMENITY TERRACE PEDESTRIAN COMFORT PREDICTIONS |
| DATE | DECEMBER 11, 2020 | DRAWN BY K.A. | |




**GRADIENTWIND**
ENGINEERS & SCIENTISTS
127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM

| | | |
|---|---|---|
| PROJECT: 38-48 STEELES AVENUE EAST, THORNHILL PEDESTRIAN LEVEL WIND STUDY | | DESCRIPTION: FIGURE 3A: SUMMER GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS |
| SCALE: 1:1200 (APPROX.) | DRAWING NO.: GWE18-170-PLW-2020-3A | |
| DATE: DECEMBER 11, 2020 | DRAWN BY: K.A. | |



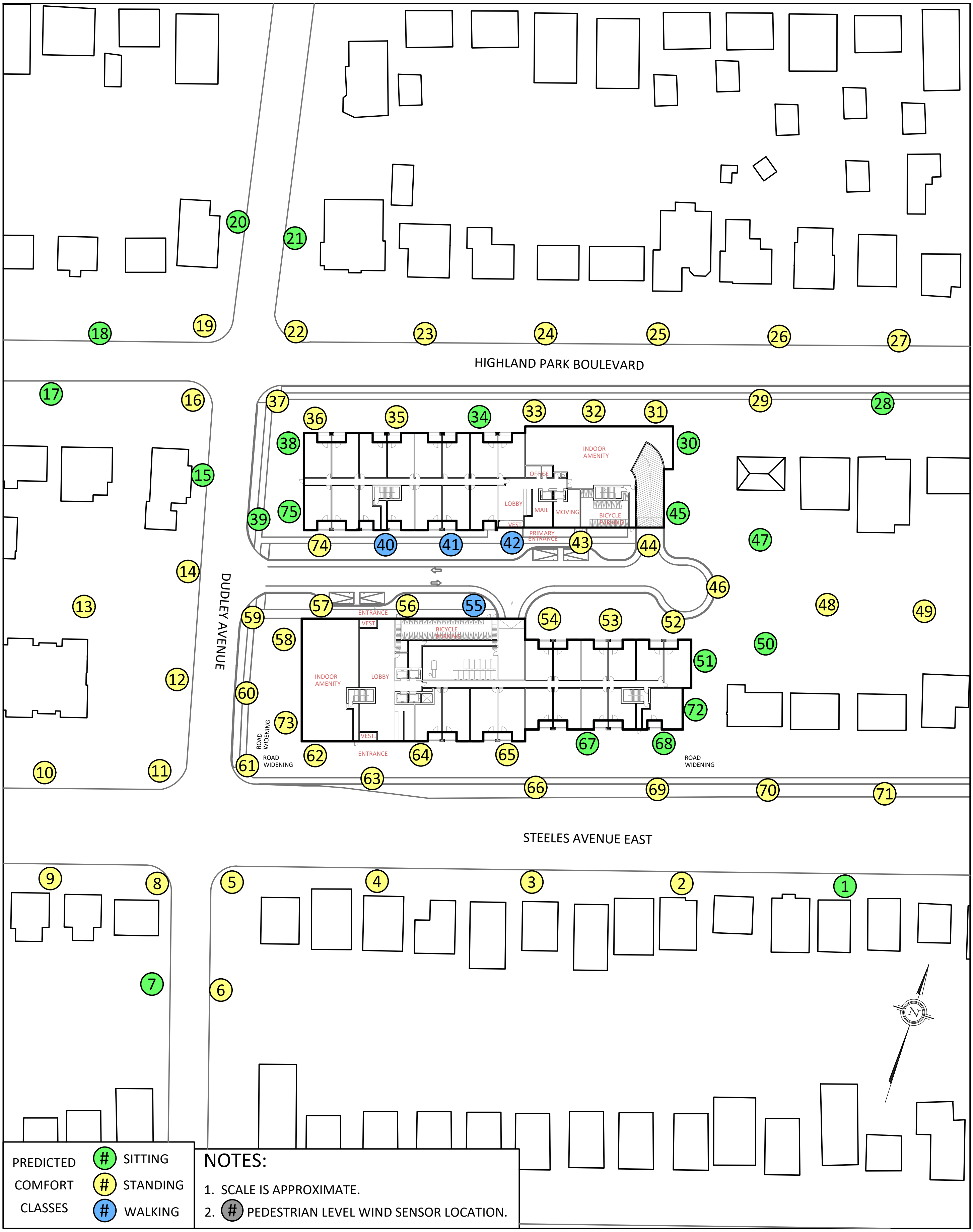

| PREDICTED COMFORT CLASSES | |
|---|---|
| # | SITTING |
| # | STANDING |
| # | WALKING |

NOTES:

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

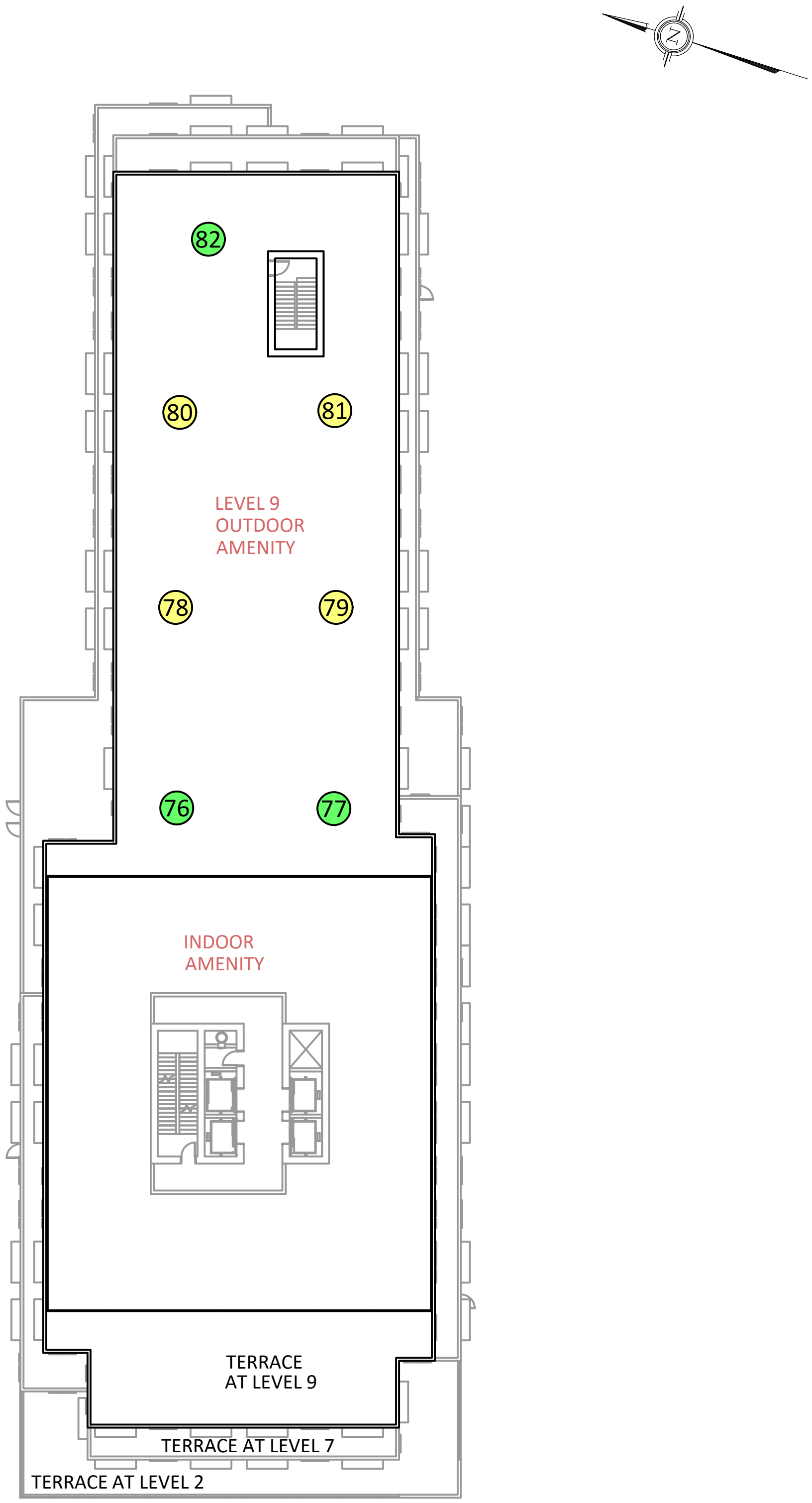

GRADIENTWIND
ENGINEERS & SCIENTISTS
127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM


| | |
|---|---|
| PROJECT | 38-48 STEELES AVENUE EAST, THORNHILL PEDESTRIAN LEVEL WIND STUDY |
| SCALE | 1:500 (APPROX.) |
| DRAWING NO. | GWE18-170-PLW-2020-3B |
| DATE | DECEMBER 11, 2020 |
| DRAWN BY | K.A. |
| DESCRIPTION | FIGURE 3B: SUMMER LEVEL 9 OUTDOOR AMENITY TERRACE PEDESTRIAN COMFORT PREDICTIONS |




GRADIENTWIND
ENGINEERS & SCIENTISTS
127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM

| | | |
|---|---|---|
| PROJECT: 38-48 STEELES AVENUE EAST, THORNHILL PEDESTRIAN LEVEL WIND STUDY | | DESCRIPTION: FIGURE 4A: AUTUMN GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS |
| SCALE: 1:1200 (APPROX.) | DRAWING NO.: GWE18-170-PLW-2020-4A | |
| DATE: DECEMBER 11, 2020 | DRAWN BY: K.A. | |

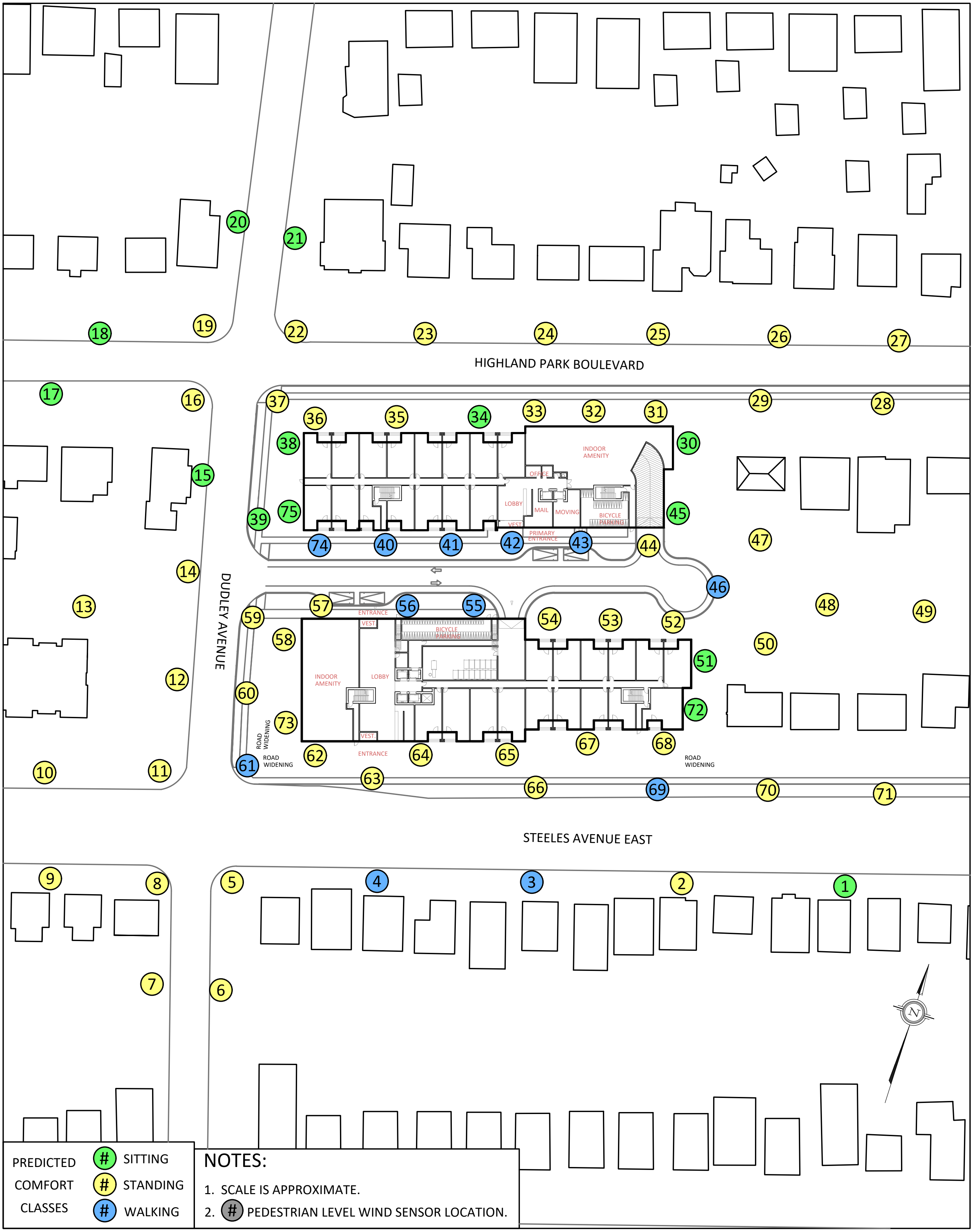



PREDICTED COMFORT CLASSES
- # SITTING
- # STANDING
- # WALKING

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


GRADIENTWIND
ENGINEERS & SCIENTISTS
127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM

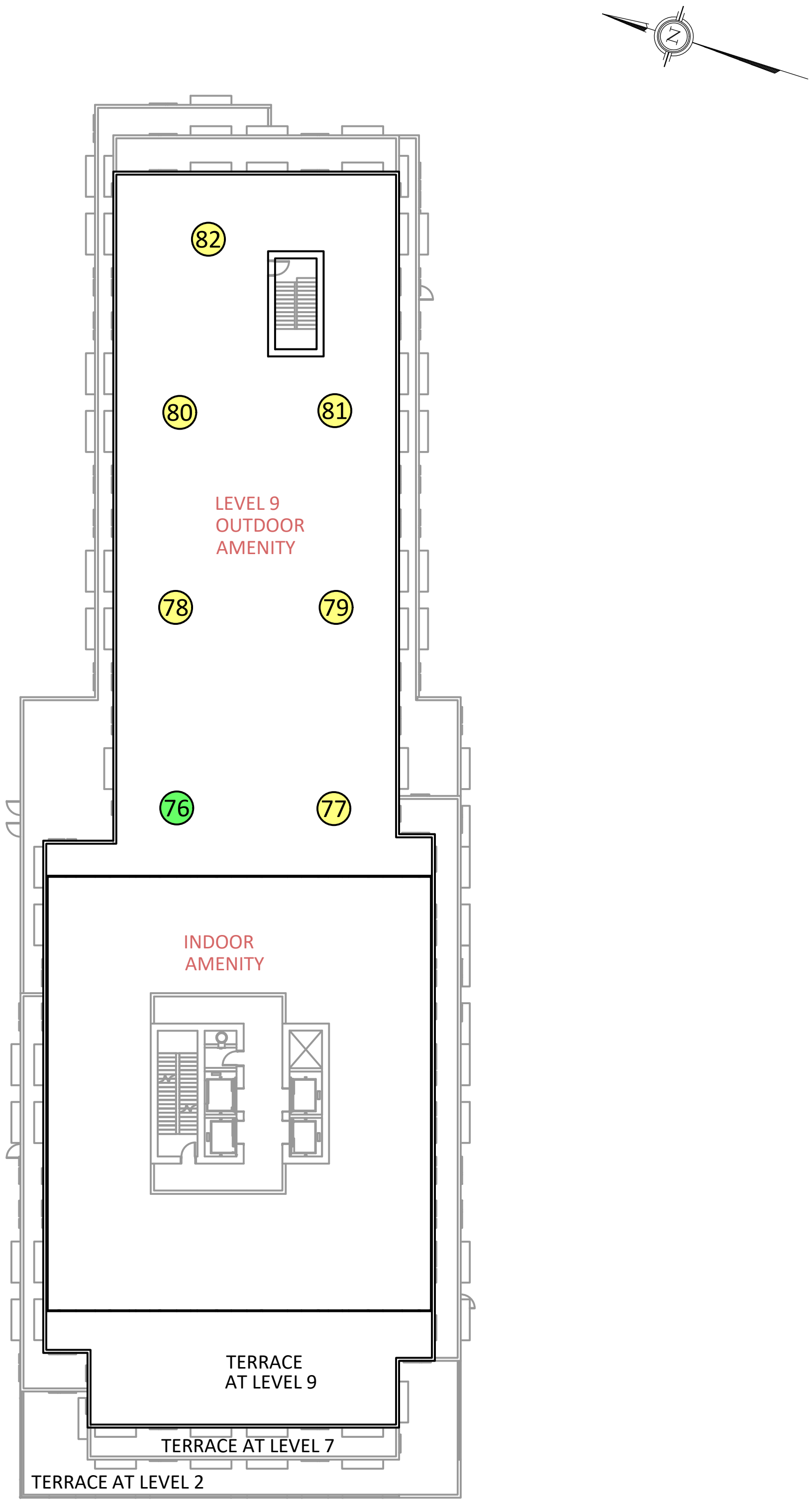

| | |
|---|---|
| PROJECT | 38-48 STEELES AVENUE EAST, THORNHILL PEDESTRIAN LEVEL WIND STUDY |
| SCALE | 1:500 (APPROX.) |
| DRAWING NO. | GWE18-170-PLW-2020-4B |
| DATE | DECEMBER 11, 2020 |
| DRAWN BY | K.A. |
| DESCRIPTION | FIGURE 4B: AUTUMN LEVEL 9 OUTDOOR AMENITY TERRACE PEDESTRIAN COMFORT PREDICTIONS |




**GRADIENTWIND**
ENGINEERS & SCIENTISTS

127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM

| | | |
|---|---|---|
| PROJECT: 38-48 STEELES AVENUE EAST, THORNHILL<br>PEDESTRIAN LEVEL WIND STUDY | | DESCRIPTION: FIGURE 5A: WINTER<br>GROUND FLOOR PLAN<br>PEDESTRIAN COMFORT PREDICTIONS |
| SCALE: 1:1200 (APPROX.) | DRAWING NO.: GWE18-170-PLW-2020-5A | |
| DATE: DECEMBER 11, 2020 | DRAWN BY: K.A. | |




| PREDICTED COMFORT CLASSES | |
|---|---|
| # (green) | SITTING |
| # (yellow) | STANDING |
| # (blue) | WALKING |

NOTES:

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


GRADIENTWIND
ENGINEERS & SCIENTISTS
127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM


| | |
|---|---|
| PROJECT | 38-48 STEELES AVENUE EAST, THORNHILL PEDESTRIAN LEVEL WIND STUDY |
| SCALE | 1:500 (APPROX.) |
| DRAWING NO. | GWE18-170-PLW-2020-5B |
| DATE | DECEMBER 11, 2020 |
| DRAWN BY | K.A. |
| DESCRIPTION | FIGURE 5B: WINTER LEVEL 9 OUTDOOR AMENITY TERRACE PEDESTRIAN COMFORT PREDICTIONS |


# APPENDIX A

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

127 WALGREEN ROAD, OTTAWA, ON, CANADA K0A 1L0 | 613 836 0934
GRADIENTWIND.COM

| Guidelines | |
|---|---|
| Pedestrian Comfort | **20% exceedance GEM wind speed**<br>0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 km/h = Walking, >20 km/h = Uncomfortable |
| Pedestrian Safety | **0.1% exceedance gust wind speed**<br>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** | 8.6 | Sitting | 7.4 | Sitting | 7.8 | Sitting | 8.6 | Sitting | 36.0 | Safe |
| **2** | 11.5 | Standing | 10.1 | Standing | 11.6 | Standing | 12.9 | Standing | 46.3 | Safe |
| **3** | 13.5 | Standing | 11.4 | Standing | 14.0 | Standing | 15.5 | Walking | 58.6 | Safe |
| **4** | 15.5 | Walking | 12.1 | Standing | 14.2 | Standing | 16.3 | Walking | 55.9 | Safe |
| **5** | 12.6 | Standing | 9.9 | Sitting | 11.3 | Standing | 12.8 | Standing | 43.8 | Safe |
| **6** | 11.2 | Standing | 8.8 | Sitting | 10.3 | Standing | 11.5 | Standing | 41.9 | Safe |
| **7** | 10.6 | Standing | 8.5 | Sitting | 10.0 | Sitting | 10.8 | Standing | 38.5 | Safe |
| **8** | 11.6 | Standing | 9.4 | Sitting | 10.6 | Standing | 11.8 | Standing | 41.7 | Safe |
| **9** | 10.7 | Standing | 8.6 | Sitting | 10.0 | Standing | 11.4 | Standing | 41.5 | Safe |
| **10** | 10.6 | Standing | 8.7 | Sitting | 10.1 | Standing | 10.7 | Standing | 41.0 | Safe |
| **11** | 13.7 | Standing | 11.0 | Standing | 11.5 | Standing | 12.9 | Standing | 48.9 | Safe |
| **12** | 16.3 | Walking | 13.3 | Standing | 13.8 | Standing | 15.0 | Standing | 52.9 | Safe |
| **13** | 14.6 | Standing | 11.2 | Standing | 12.3 | Standing | 13.5 | Standing | 55.5 | Safe |
| **14** | 12.4 | Standing | 10.1 | Standing | 10.7 | Standing | 11.3 | Standing | 47.8 | Safe |
| **15** | 10.6 | Standing | 8.4 | Sitting | 8.7 | Sitting | 9.4 | Sitting | 40.5 | Safe |
| **16** | 11.9 | Standing | 9.6 | Sitting | 10.9 | Standing | 11.6 | Standing | 43.4 | Safe |
| **17** | 9.1 | Sitting | 7.4 | Sitting | 8.7 | Sitting | 9.7 | Sitting | 36.7 | Safe |
| **18** | 9.2 | Sitting | 7.6 | Sitting | 9.1 | Sitting | 9.8 | Sitting | 40.3 | Safe |
| **19** | 11.1 | Standing | 9.4 | Sitting | 10.8 | Standing | 11.8 | Standing | 42.7 | Safe |
| **20** | 8.1 | Sitting | 6.6 | Sitting | 6.8 | Sitting | 7.6 | Sitting | 30.7 | Safe |
| **21** | 8.2 | Sitting | 6.9 | Sitting | 7.7 | Sitting | 8.2 | Sitting | 34.2 | Safe |
| **22** | 12.3 | Standing | 10.1 | Standing | 11.9 | Standing | 12.6 | Standing | 45.0 | Safe |
| **23** | 13.1 | Standing | 11.2 | Standing | 13.0 | Standing | 14.0 | Standing | 47.6 | Safe |
| **24** | 13.5 | Standing | 11.0 | Standing | 13.0 | Standing | 13.7 | Standing | 45.9 | Safe |
| **25** | 14.6 | Standing | 11.8 | Standing | 13.7 | Standing | 14.6 | Standing | 47.7 | Safe |
| **26** | 11.9 | Standing | 9.6 | Sitting | 11.3 | Standing | 12.3 | Standing | 42.6 | Safe |
| **27** | 10.6 | Standing | 8.7 | Sitting | 10.5 | Standing | 11.6 | Standing | 41.9 | Safe |
| **28** | 10.4 | Standing | 8.1 | Sitting | 9.8 | Sitting | 10.8 | Standing | 39.0 | Safe |
| **29** | 11.7 | Standing | 9.8 | Sitting | 11.7 | Standing | 13.1 | Standing | 49.0 | Safe |
| **30** | 9.3 | Sitting | 7.1 | Sitting | 7.8 | Sitting | 8.4 | Sitting | 37.5 | Safe |
| **31** | 12.9 | Standing | 10.1 | Standing | 12.1 | Standing | 13.4 | Standing | 47.3 | Safe |
| **32** | 11.1 | Standing | 8.8 | Sitting | 10.9 | Standing | 12.0 | Standing | 43.5 | Safe |
| **33** | 10.5 | Standing | 8.4 | Sitting | 10.4 | Standing | 11.5 | Standing | 41.1 | Safe |
| **34** | 9.5 | Sitting | 7.8 | Sitting | 9.1 | Sitting | 9.9 | Sitting | 35.4 | Safe |
| **35** | 10.5 | Standing | 8.6 | Sitting | 10.5 | Standing | 11.7 | Standing | 46.1 | Safe |

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

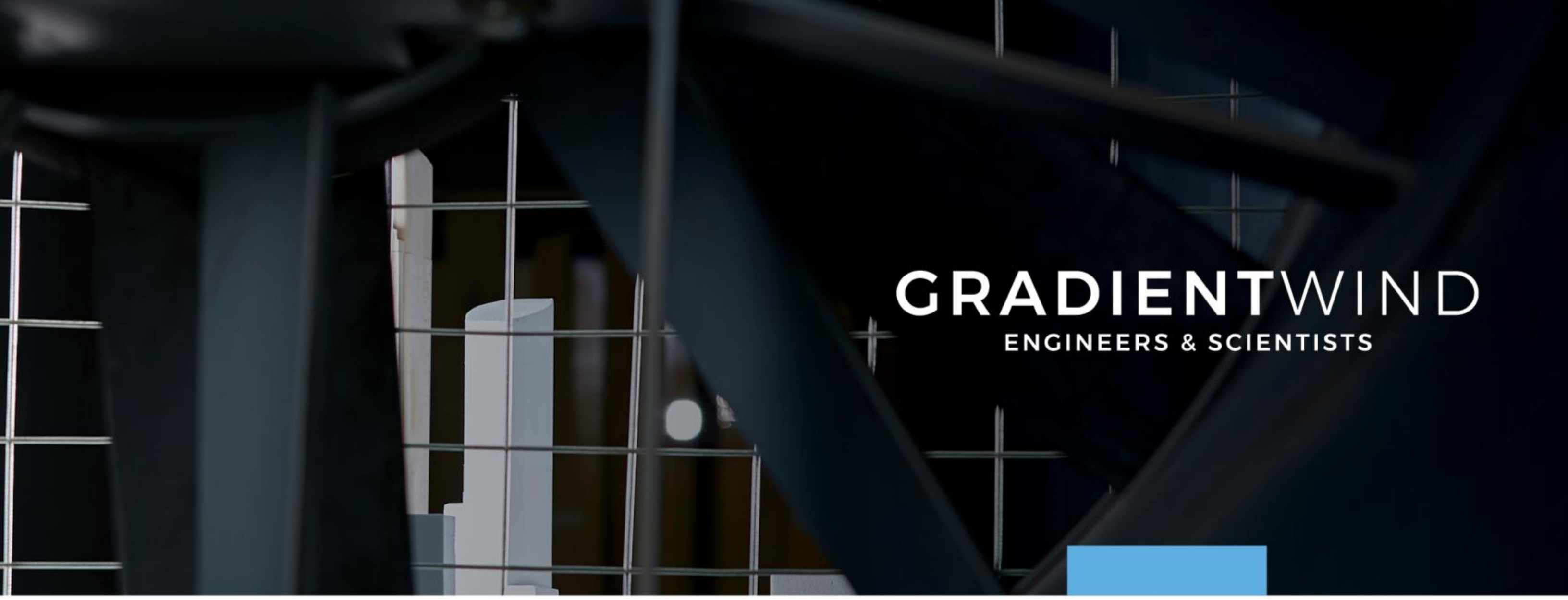
## TABLE A2: SUMMARY OF PEDESTRIAN COMFORT (FUTURE CONDITONS)

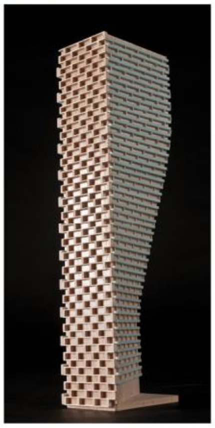
| Sensor | Pedestrian Comfort | | | | | | | | Pedestrian Safety | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Spring | | Summer | | Autumn | | Winter | | Annual | |
| | Wind Speed | Comfort Class | Wind Speed | Comfort Class | Wind Speed | Comfort Class | Wind Speed | Comfort Class | Wind Speed | Safety Class |
| **36** | 12.3 | Standing | 10.1 | Standing | 12.5 | Standing | 14.0 | Standing | 58.3 | Safe |
| **37** | 14.3 | Standing | 11.7 | Standing | 13.2 | Standing | 14.3 | Standing | 49.5 | Safe |
| **38** | 9.3 | Sitting | 8.3 | Sitting | 9.8 | Sitting | 9.9 | Sitting | 47.5 | Safe |
| **39** | 10.2 | Standing | 8.2 | Sitting | 9.1 | Sitting | 9.1 | Sitting | 41.9 | Safe |
| **40** | 17.4 | Walking | 14.3 | Standing | 16.6 | Walking | 17.5 | Walking | 57.7 | Safe |
| **41** | 17.5 | Walking | 14.5 | Standing | 17.2 | Walking | 18.1 | Walking | 61.8 | Safe |
| **42** | 16.0 | Walking | 13.7 | Standing | 15.4 | Walking | 16.7 | Walking | 53.1 | Safe |
| **43** | 15.9 | Walking | 13.1 | Standing | 14.7 | Standing | 16.0 | Walking | 51.3 | Safe |
| **44** | 14.3 | Standing | 11.4 | Standing | 12.8 | Standing | 14.1 | Standing | 47.2 | Safe |
| **45** | 7.4 | Sitting | 5.8 | Sitting | 6.2 | Sitting | 7.0 | Sitting | 29.7 | Safe |
| **46** | 15.0 | Standing | 12.2 | Standing | 13.7 | Standing | 15.6 | Walking | 60.1 | Safe |
| **47** | 10.7 | Standing | 8.5 | Sitting | 9.5 | Sitting | 10.3 | Standing | 38.1 | Safe |
| **48** | 12.7 | Standing | 10.3 | Standing | 11.4 | Standing | 12.8 | Standing | 55.0 | Safe |
| **49** | 11.9 | Standing | 9.8 | Sitting | 11.1 | Standing | 11.8 | Standing | 47.6 | Safe |
| **50** | 11.7 | Standing | 9.5 | Sitting | 9.9 | Sitting | 11.7 | Standing | 51.8 | Safe |
| **51** | 9.7 | Sitting | 7.5 | Sitting | 8.0 | Sitting | 8.2 | Sitting | 42.6 | Safe |
| **52** | 13.1 | Standing | 10.0 | Sitting | 11.3 | Standing | 13.3 | Standing | 49.6 | Safe |
| **53** | 11.1 | Standing | 8.9 | Sitting | 10.2 | Standing | 11.4 | Standing | 40.8 | Safe |
| **54** | 11.1 | Standing | 9.4 | Sitting | 10.7 | Standing | 12.0 | Standing | 47.5 | Safe |
| **55** | 14.6 | Standing | 12.0 | Standing | 15.2 | Walking | 16.5 | Walking | 56.4 | Safe |
| **56** | 14.4 | Standing | 11.4 | Standing | 14.6 | Standing | 16.1 | Walking | 54.4 | Safe |
| **57** | 11.5 | Standing | 9.0 | Sitting | 11.2 | Standing | 12.6 | Standing | 48.0 | Safe |
| **58** | 12.1 | Standing | 10.2 | Standing | 11.0 | Standing | 11.4 | Standing | 46.5 | Safe |
| **59** | 15.4 | Walking | 12.8 | Standing | 13.3 | Standing | 14.0 | Standing | 52.6 | Safe |
| **60** | 14.4 | Standing | 12.0 | Standing | 12.8 | Standing | 13.3 | Standing | 46.6 | Safe |
| **61** | 17.7 | Walking | 13.8 | Standing | 14.8 | Standing | 16.5 | Walking | 55.9 | Safe |
| **62** | 12.9 | Standing | 9.6 | Sitting | 11.7 | Standing | 12.5 | Standing | 54.7 | Safe |
| **63** | 12.3 | Standing | 9.7 | Sitting | 11.9 | Standing | 13.3 | Standing | 49.6 | Safe |
| **64** | 10.4 | Standing | 8.4 | Sitting | 11.1 | Standing | 13.0 | Standing | 52.2 | Safe |
| **65** | 10.6 | Standing | 9.4 | Sitting | 12.0 | Standing | 13.3 | Standing | 54.6 | Safe |
| **66** | 13.0 | Standing | 11.1 | Standing | 14.0 | Standing | 15.0 | Standing | 57.8 | Safe |
| **67** | 9.1 | Sitting | 7.8 | Sitting | 9.4 | Sitting | 10.1 | Standing | 38.9 | Safe |
| **68** | 10.0 | Standing | 8.8 | Sitting | 9.9 | Sitting | 10.7 | Standing | 44.7 | Safe |
| **69** | 14.1 | Standing | 12.4 | Standing | 14.4 | Standing | 15.2 | Walking | 54.7 | Safe |
| **70** | 10.7 | Standing | 9.8 | Sitting | 11.8 | Standing | 11.9 | Standing | 51.9 | Safe |

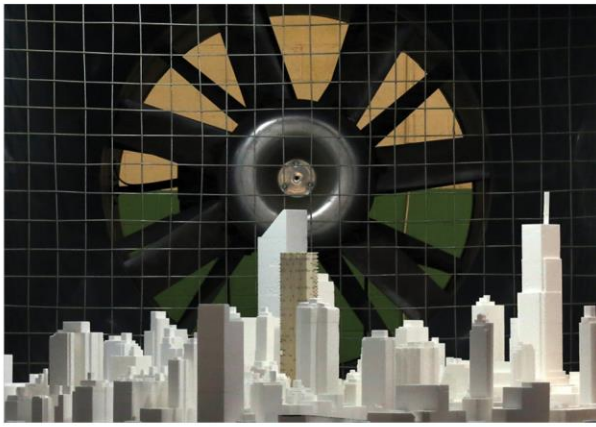
| Guidelines | |
|---|---|
| Pedestrian Comfort | **20% exceedance GEM wind speed**<br>0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 km/h = Walking, >20 km/h = Uncomfortable |
| Pedestrian Safety | **0.1% exceedance gust wind speed**<br>0-90 km/h = Safe |

## TABLE A3: 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 |
| **71** | 10.6 | Standing | 9.2 | Sitting | 10.7 | Standing | 11.5 | Standing | 46.0 | Safe |
| **72** | 8.8 | Sitting | 7.0 | Sitting | 7.2 | Sitting | 8.1 | Sitting | 42.4 | Safe |
| **73** | 13.8 | Standing | 11.1 | Standing | 12.2 | Standing | 14.1 | Standing | 52.6 | Safe |
| **74** | 16.6 | Walking | 13.1 | Standing | 14.7 | Standing | 16.5 | Walking | 54.2 | Safe |
| **75** | 8.1 | Sitting | 6.9 | Sitting | 7.7 | Sitting | 7.7 | Sitting | 40.6 | Safe |
| **76** | 10.4 | Standing | 8.1 | Sitting | 8.4 | Sitting | 9.5 | Sitting | 38.4 | Safe |
| **77** | 11.8 | Standing | 9.6 | Sitting | 9.6 | Sitting | 10.7 | Standing | 44.6 | Safe |
| **78** | 12.6 | Standing | 10.3 | Standing | 11.2 | Standing | 11.7 | Standing | 48.4 | Safe |
| **79** | 13.3 | Standing | 10.6 | Standing | 11.5 | Standing | 13.0 | Standing | 50.7 | Safe |
| **80** | 11.9 | Standing | 9.9 | Sitting | 11.1 | Standing | 11.5 | Standing | 46.1 | Safe |
| **81** | 14.7 | Standing | 11.9 | Standing | 13.3 | Standing | 14.8 | Standing | 52.4 | Safe |
| **82** | 10.9 | Standing | 8.9 | Sitting | 10.0 | Sitting | 10.6 | Standing | 40.6 | Safe |





# APPENDIX B

## PEDESTRIAN COMFORT SUITABILITY, TABLES B1-B5 (EXISTING VS FUTURE CONDITIONS)

127 WALGREEN ROAD, OTTAWA, ON, CANADA K0A 1L0 | 613 836 0934
GRADIENTWIND.COM

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

## TABLE B1: COMPARATIVE SUMMARY OF PEDESTRIAN COMFORT

| Sensor | Massing Scenario | Summer Pedestrian Comfort | | | Winter Pedestrian Comfort | | |
|---|---|---|---|---|---|---|---|
| | | Wind Speed (km/h) 80% data ≤ | Predicted Comfort Class | Future Comfort Class Compared to Existing | Wind Speed (km/h) 80% data ≤ | Predicted Comfort Class | Future Comfort Class Compared to Existing |
| 1 | Existing | 7.2 | Sitting | - | 9.3 | Sitting | - |
| | Future | 7.4 | Sitting | Unchanged | 8.6 | Sitting | Unchanged |
| 2 | Existing | 6.9 | Sitting | - | 9.6 | Sitting | - |
| | Future | 10.1 | Standing | Reduced | 12.9 | Standing | Reduced |
| 3 | Existing | 7.6 | Sitting | - | 10.7 | Standing | - |
| | Future | 11.4 | Standing | Reduced | 15.5 | Walking | Reduced |
| 4 | Existing | 7.1 | Sitting | - | 9.6 | Sitting | - |
| | Future | 12.1 | Standing | Reduced | 16.3 | Walking | Reduced |
| 5 | Existing | 9.0 | Sitting | - | 11.2 | Standing | - |
| | Future | 9.9 | Sitting | Unchanged | 12.8 | Standing | Unchanged |
| 6 | Existing | 7.8 | Sitting | - | 10.1 | Standing | - |
| | Future | 8.8 | Sitting | Unchanged | 11.5 | Standing | Unchanged |
| 7 | Existing | 8.6 | Sitting | - | 10.8 | Standing | - |
| | Future | 8.5 | Sitting | Unchanged | 10.8 | Standing | Unchanged |
| 8 | Existing | 9.0 | Sitting | - | 11.7 | Standing | - |
| | Future | 9.4 | Sitting | Unchanged | 11.8 | Standing | Unchanged |
| 9 | Existing | 8.5 | Sitting | - | 11.5 | Standing | - |
| | Future | 8.6 | Sitting | Unchanged | 11.4 | Standing | Unchanged |
| 10 | Existing | 8.8 | Sitting | - | 11.1 | Standing | - |
| | Future | 8.7 | Sitting | Unchanged | 10.7 | Standing | Unchanged |
| 11 | Existing | 10.0 | Sitting | - | 11.9 | Standing | - |
| | Future | 11.0 | Standing | Reduced | 12.9 | Standing | Unchanged |
| 12 | Existing | 11.1 | Standing | - | 12.4 | Standing | - |
| | Future | 13.3 | Standing | Unchanged | 15.0 | Standing | Unchanged |
| 13 | Existing | 11.4 | Standing | - | 14.4 | Standing | - |
| | Future | 11.2 | Standing | Unchanged | 13.5 | Standing | Unchanged |
| 14 | Existing | 9.6 | Sitting | - | 12.2 | Standing | - |
| | Future | 10.1 | Standing | Reduced | 11.3 | Standing | Unchanged |
| 15 | Existing | 7.2 | Sitting | - | 8.3 | Sitting | - |
| | Future | 8.4 | Sitting | Unchanged | 9.4 | Sitting | Unchanged |

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

## TABLE B2: COMPARATIVE SUMMARY OF PEDESTRIAN COMFORT

| Sensor | Massing Scenario | Summer Pedestrian Comfort | | | Winter Pedestrian Comfort | | |
|---|---|---|---|---|---|---|---|
| | | Wind Speed (km/h) 80% data ≤ | Predicted Comfort Class | Future Comfort Class Compared to Existing | Wind Speed (km/h) 80% data ≤ | Predicted Comfort Class | Future Comfort Class Compared to Existing |
| 16 | Existing | 9.1 | Sitting | - | 11.6 | Standing | - |
| | Future | 9.6 | Sitting | Unchanged | 11.6 | Standing | Unchanged |
| 17 | Existing | 7.0 | Sitting | - | 9.7 | Sitting | - |
| | Future | 7.4 | Sitting | Unchanged | 9.7 | Sitting | Unchanged |
| 18 | Existing | 7.7 | Sitting | - | 10.3 | Standing | - |
| | Future | 7.6 | Sitting | Unchanged | 9.8 | Sitting | Improved |
| 19 | Existing | 8.7 | Sitting | - | 11.2 | Standing | - |
| | Future | 9.4 | Sitting | Unchanged | 11.8 | Standing | Unchanged |
| 20 | Existing | 6.7 | Sitting | - | 7.8 | Sitting | - |
| | Future | 6.6 | Sitting | Unchanged | 7.6 | Sitting | Unchanged |
| 21 | Existing | 7.3 | Sitting | - | 8.6 | Sitting | - |
| | Future | 6.9 | Sitting | Unchanged | 8.2 | Sitting | Unchanged |
| 22 | Existing | 9.6 | Sitting | - | 12.2 | Standing | - |
| | Future | 10.1 | Standing | Reduced | 12.6 | Standing | Unchanged |
| 23 | Existing | 7.3 | Sitting | - | 9.6 | Sitting | - |
| | Future | 11.2 | Standing | Reduced | 14.0 | Standing | Reduced |
| 24 | Existing | 7.0 | Sitting | - | 9.3 | Sitting | - |
| | Future | 11.0 | Standing | Reduced | 13.7 | Standing | Reduced |
| 25 | Existing | 7.4 | Sitting | - | 10.1 | Standing | - |
| | Future | 11.8 | Standing | Reduced | 14.6 | Standing | Unchanged |
| 26 | Existing | 7.9 | Sitting | - | 10.6 | Standing | - |
| | Future | 9.6 | Sitting | Unchanged | 12.3 | Standing | Unchanged |
| 27 | Existing | 8.5 | Sitting | - | 11.3 | Standing | - |
| | Future | 8.7 | Sitting | Unchanged | 11.6 | Standing | Unchanged |
| 28 | Existing | 7.4 | Sitting | - | 9.8 | Sitting | - |
| | Future | 8.1 | Sitting | Unchanged | 10.8 | Standing | Reduced |
| 29 | Existing | 8.0 | Sitting | - | 11.2 | Standing | - |
| | Future | 9.8 | Sitting | Unchanged | 13.1 | Standing | Unchanged |
| 30 | Existing | 7.0 | Sitting | - | 9.3 | Sitting | - |
| | Future | 7.1 | Sitting | Unchanged | 8.4 | Sitting | Unchanged |

| Guidelines | |
|---|---|
| Pedestrian Comfort | **20% exceedance GEM wind speed**<br>0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 km/h = Walking, >20 km/h = Uncomfortable |
| Pedestrian Safety | **0.1% exceedance gust wind speed**<br>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 | 7.7 | Sitting | - | 10.4 | Standing | - |
| | Future | 10.1 | Standing | Reduced | 13.4 | Standing | Unchanged |
| **32** | Existing | 7.4 | Sitting | - | 10.1 | Standing | - |
| | Future | 8.8 | Sitting | Unchanged | 12.0 | Standing | Unchanged |
| **33** | Existing | 7.2 | Sitting | - | 9.8 | Sitting | - |
| | Future | 8.4 | Sitting | Unchanged | 11.5 | Standing | Reduced |
| **34** | Existing | 7.2 | Sitting | - | 9.4 | Sitting | - |
| | Future | 7.8 | Sitting | Unchanged | 9.9 | Sitting | Unchanged |
| **35** | Existing | 7.7 | Sitting | - | 10.2 | Standing | - |
| | Future | 8.6 | Sitting | Unchanged | 11.7 | Standing | Unchanged |
| **36** | Existing | 8.1 | Sitting | - | 11.0 | Standing | - |
| | Future | 10.1 | Standing | Reduced | 14.0 | Standing | Unchanged |
| **37** | Existing | 9.3 | Sitting | - | 12.3 | Standing | - |
| | Future | 11.7 | Standing | Reduced | 14.3 | Standing | Unchanged |
| **38** | Existing | 7.7 | Sitting | - | 10.3 | Standing | - |
| | Future | 8.3 | Sitting | Unchanged | 9.9 | Sitting | Improved |
| **39** | Existing | 7.9 | Sitting | - | 9.2 | Sitting | - |
| | Future | 8.2 | Sitting | Unchanged | 9.1 | Sitting | Unchanged |
| **40** | Existing | 7.1 | Sitting | - | 8.5 | Sitting | - |
| | Future | 14.3 | Standing | Reduced | 17.5 | Walking | Reduced |
| **41** | Existing | 7.8 | Sitting | - | 9.6 | Sitting | - |
| | Future | 14.5 | Standing | Reduced | 18.1 | Walking | Reduced |
| **42** | Existing | 7.8 | Sitting | - | 9.7 | Sitting | - |
| | Future | 13.7 | Standing | Reduced | 16.7 | Walking | Reduced |
| **43** | Existing | 7.8 | Sitting | - | 10.3 | Standing | - |
| | Future | 13.1 | Standing | Reduced | 16.0 | Walking | Reduced |
| **44** | Existing | 6.8 | Sitting | - | 8.9 | Sitting | - |
| | Future | 11.4 | Standing | Reduced | 14.1 | Standing | Reduced |
| **45** | Existing | 5.8 | Sitting | - | 7.0 | Sitting | - |
| | Future | 5.8 | Sitting | Unchanged | 7.0 | Sitting | Unchanged |

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

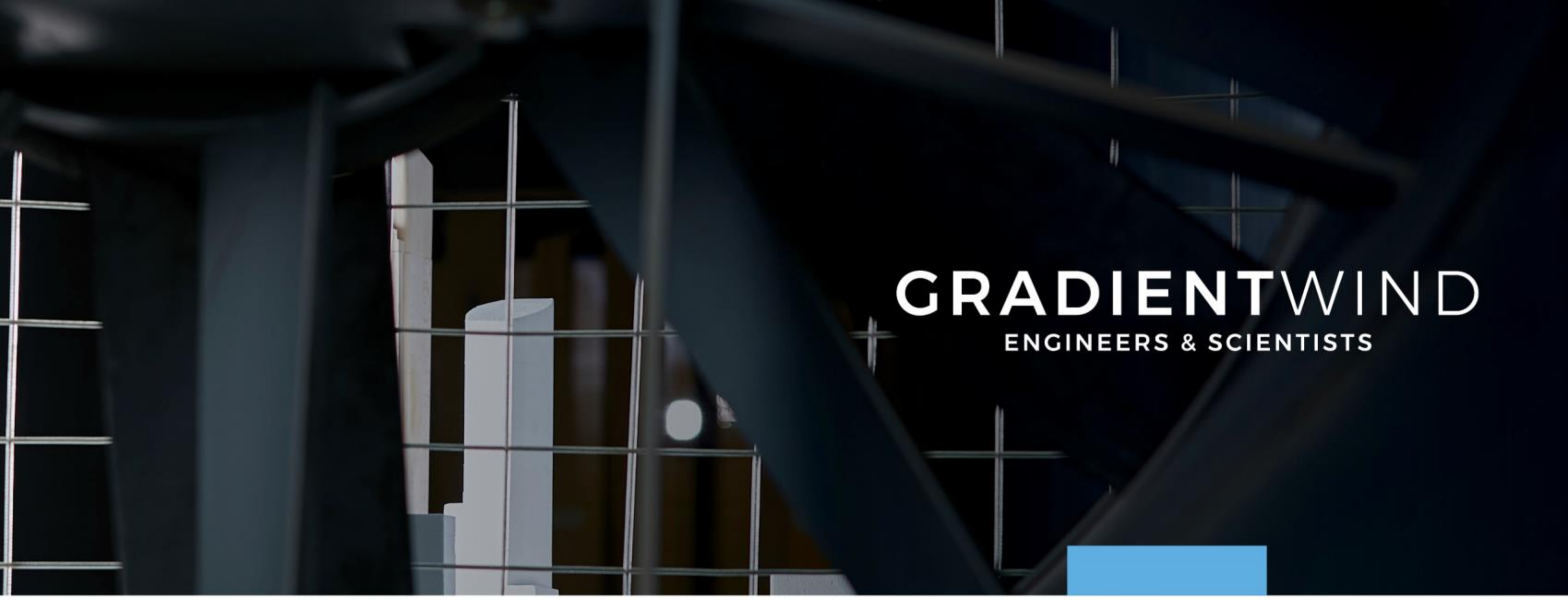
## TABLE B4: COMPARATIVE SUMMARY OF PEDESTRIAN COMFORT

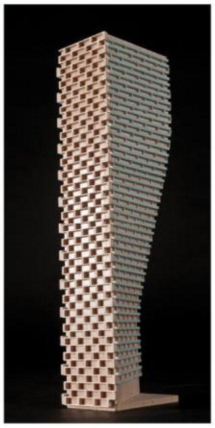
| Sensor | Massing Scenario | Summer Pedestrian Comfort | | | Winter Pedestrian Comfort | | |
|---|---|---|---|---|---|---|---|
| | | Wind Speed (km/h) 80% data ≤ | Predicted Comfort Class | Future Comfort Class Compared to Existing | Wind Speed (km/h) 80% data ≤ | Predicted Comfort Class | Future Comfort Class Compared to Existing |
| 46 | Existing | 7.7 | Sitting | - | 10.4 | Standing | - |
| | Future | 12.2 | Standing | Reduced | 15.6 | Walking | Reduced |
| 47 | Existing | 6.9 | Sitting | - | 8.5 | Sitting | - |
| | Future | 8.5 | Sitting | Unchanged | 10.3 | Standing | Reduced |
| 48 | Existing | 8.0 | Sitting | - | 10.8 | Standing | - |
| | Future | 10.3 | Standing | Reduced | 12.8 | Standing | Unchanged |
| 49 | Existing | 8.6 | Sitting | - | 11.5 | Standing | - |
| | Future | 9.8 | Sitting | Unchanged | 11.8 | Standing | Unchanged |
| 50 | Existing | 7.3 | Sitting | - | 10.0 | Sitting | - |
| | Future | 9.5 | Sitting | Unchanged | 11.7 | Standing | Reduced |
| 51 | Existing | 7.8 | Sitting | - | 10.5 | Standing | - |
| | Future | 7.5 | Sitting | Unchanged | 8.2 | Sitting | Improved |
| 52 | Existing | 8.1 | Sitting | - | 11.0 | Standing | - |
| | Future | 10.0 | Sitting | Unchanged | 13.3 | Standing | Unchanged |
| 53 | Existing | 8.2 | Sitting | - | 10.8 | Standing | - |
| | Future | 8.9 | Sitting | Unchanged | 11.4 | Standing | Unchanged |
| 54 | Existing | 8.2 | Sitting | - | 11.0 | Standing | - |
| | Future | 9.4 | Sitting | Unchanged | 12.0 | Standing | Unchanged |
| 55 | Existing | 8.7 | Sitting | - | 11.3 | Standing | - |
| | Future | 12.0 | Standing | Reduced | 16.5 | Walking | Reduced |
| 56 | Existing | 8.4 | Sitting | - | 10.8 | Standing | - |
| | Future | 11.4 | Standing | Reduced | 16.1 | Walking | Reduced |
| 57 | Existing | 9.2 | Sitting | - | 12.2 | Standing | - |
| | Future | 9.0 | Sitting | Unchanged | 12.6 | Standing | Unchanged |
| 58 | Existing | 9.6 | Sitting | - | 12.4 | Standing | - |
| | Future | 10.2 | Standing | Reduced | 11.4 | Standing | Unchanged |
| 59 | Existing | 9.1 | Sitting | - | 11.2 | Standing | - |
| | Future | 12.8 | Standing | Reduced | 14.0 | Standing | Unchanged |
| 60 | Existing | 9.2 | Sitting | - | 10.5 | Standing | - |
| | Future | 12.0 | Standing | Reduced | 13.3 | Standing | Unchanged |

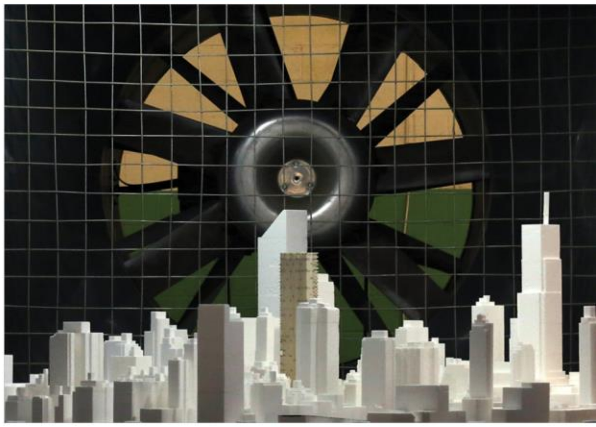
| Guidelines | |
|---|---|
| Pedestrian Comfort | **20% exceedance GEM wind speed**<br>0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 km/h = Walking, >20 km/h = Uncomfortable |
| Pedestrian Safety | **0.1% exceedance gust wind speed**<br>0-90 km/h = Safe |

## TABLE B5: 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 |
| 61 | Existing | 10.4 | Standing | - | 12.9 | Standing | - |
| | Future | 13.8 | Standing | Unchanged | 16.5 | Walking | Reduced |
| 62 | Existing | 7.7 | Sitting | - | 9.8 | Sitting | - |
| | Future | 9.6 | Sitting | Unchanged | 12.5 | Standing | Reduced |
| 63 | Existing | 8.2 | Sitting | - | 10.7 | Standing | - |
| | Future | 9.7 | Sitting | Unchanged | 13.3 | Standing | Unchanged |
| 64 | Existing | 7.6 | Sitting | - | 10.1 | Standing | - |
| | Future | 8.4 | Sitting | Unchanged | 13.0 | Standing | Unchanged |
| 65 | Existing | 8.4 | Sitting | - | 10.8 | Standing | - |
| | Future | 9.4 | Sitting | Unchanged | 13.3 | Standing | Unchanged |
| 66 | Existing | 8.9 | Sitting | - | 11.9 | Standing | - |
| | Future | 11.1 | Standing | Reduced | 15.0 | Standing | Unchanged |
| 67 | Existing | 9.4 | Sitting | - | 11.6 | Standing | - |
| | Future | 7.8 | Sitting | Unchanged | 10.1 | Standing | Unchanged |
| 68 | Existing | 7.1 | Sitting | - | 8.6 | Sitting | - |
| | Future | 8.8 | Sitting | Unchanged | 10.7 | Standing | Reduced |
| 69 | Existing | 8.4 | Sitting | - | 11.6 | Standing | - |
| | Future | 12.4 | Standing | Reduced | 15.2 | Walking | Reduced |
| 70 | Existing | 8.6 | Sitting | - | 12.1 | Standing | - |
| | Future | 9.8 | Sitting | Unchanged | 11.9 | Standing | Unchanged |
| 71 | Existing | 8.2 | Sitting | - | 11.4 | Standing | - |
| | Future | 9.2 | Sitting | Unchanged | 11.5 | Standing | Unchanged |





**APPENDIX C**

**WIND TUNNEL SIMULATION OF THE NATURAL WIND**

127 WALGREEN ROAD, OTTAWA, ON, CANADA K0A 1L0 | 613 836 0934
GRADIENTWIND.COM

# 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 $\alpha$ is the power law exponent.

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

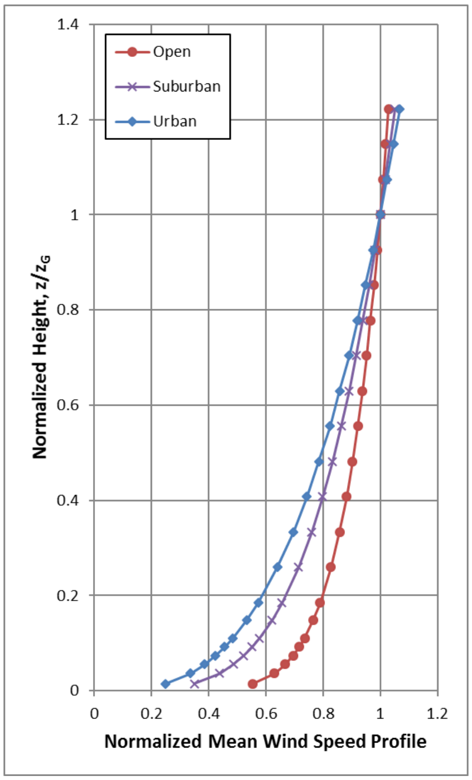
The exponent $\alpha$ varies according to the type of upwind terrain; $\alpha$ ranges from 0.14 for open country to 0.33 for an urban exposure. Figure C2 illustrates the theoretical variation of turbulence for open country, suburban and urban exposures.

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.



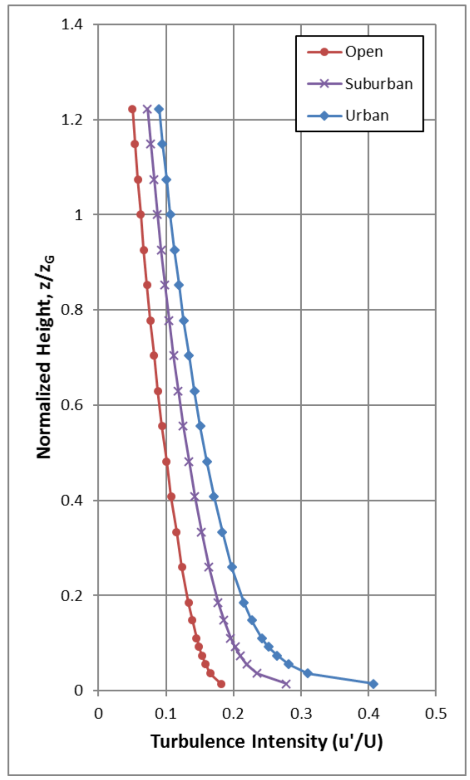




**FIGURE C1 (LEFT): MEAN WIND SPEED PROFILES;**
**FIGURE C2 (RIGHT): TURBULENCE INTENSITY PROFILES**

## REFERENCES

1. Teunissen, H.W., 'Characteristics of The Mean Wind And Turbulence In The Planetary Boundary Layer', Institute For Aerospace Studies, University Of Toronto, UTIAS # 32, Oct. 1970

2. Flay, R.G., Stevenson, D.C., 'Integral Length Scales in an Atmospheric Boundary Layer Near The Ground', 9th Australian Fluid Mechanics Conference, Auckland, Dec. 1966

3. ESDU, 'Characteristics of Atmospheric Turbulence Near the Ground', 74030

4. Bradley, E.F., Coppin, P.A., Katen, P.C., '*Turbulent Wind Structure Above Very Rugged Terrain*', 9th Australian Fluid Mechanics Conference, Auckland, Dec. 1966


**APPENDIX D**

## PEDESTRIAN LEVEL WIND MEASUREMENT METHODOLOGY

127 WALGREEN ROAD, OTTAWA, ON, CANADA K0A 1L0 | 613 836 0934
GRADIENTWIND.COM

# 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; ***$\theta$*** 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). ***$A_\theta$*** is the fraction of time wind blows from a 10° sector centered on ***$\theta$***.

Analysis of the hourly wind data recorded for a length of time, on the order of 10 to 30 years, yields the ***$A_\theta$, $C_\theta$*** and ***$K_\theta$*** 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 $C_\theta$ and $K_\theta$ 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.

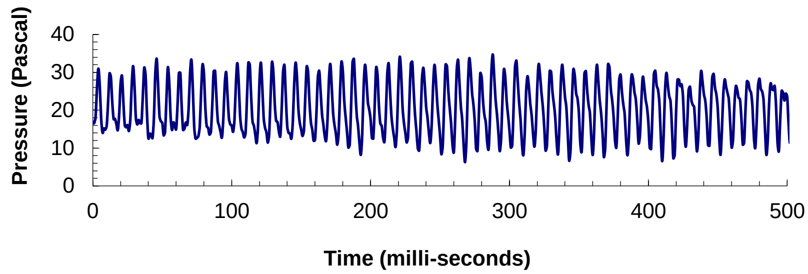



**FIGURE D1: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR**

## REFERENCES

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

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