Pedestrian Level Wind Study

11-21 Yorkville Avenue &
16-18 Cumberland Street

Toronto, Ontario

REPORT: GWE17-092-PLW

Prepared For:

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EXECUTIVE SUMMARY

This report describes a detailed pedestrian level wind study undertaken to assess wind comfort for 11-21 Yorkville Avenue & 16-18 Cumberland Street, a planned mixed-use development located in Toronto, Ontario. The study involves wind tunnel measurements of pedestrian wind speeds using a physical scale model, combined with meteorological data integration, to assess pedestrian comfort and safety at key areas within and surrounding the development site. Grade-level pedestrian areas considered in this study include surrounding sidewalks, laneways, walkways, building access points, transit stops, privately owned public space (POPS), and parks. Wind conditions are also measured on the level three amenity terrace. The results and recommendations derived from these considerations are summarized in the following paragraphs and detailed in the subsequent report.

This study was performed in accordance with the scope of work described in GWE proposal #17-139P dated June 7, 2017. The work is based on industry standard wind tunnel testing and data analysis procedures, architectural drawings provided by Sweeny&Co Architects in January 2018 and updated in March 2018, surrounding street layouts, as well as existing and approved future building massing information obtained from the City of Toronto, and recent site imagery.

A complete summary of the predicted wind conditions is provided in Sections 5.1 and 5.2 of this report and illustrated in Figures 2 through 5. Based on the wind tunnel test results, meteorological data analysis, and experience with similar developments in Toronto, we conclude that the wind conditions within and surrounding the full study site will be acceptable for the intended pedestrian uses on a seasonal basis. Regarding the pedestrian walkway along the west side of the development, wind conditions will be comfortable for sitting during the summer months, and for standing or better throughout the rest of the year. If specific seating areas will be used throughout the shoulder seasons of spring and autumn, then 1.6-metre-tall high-solidity wind screens or raised planters with coniferous plantings are recommended to be installed to the immediate north of any such areas.

Regarding the level three outdoor amenity terrace, the majority of the space will be comfortable for sitting or more sedentary activities during the warmer months. If seating areas will be provided near the southeast corner of the terrace, it is recommended to increase the height of the terrace perimeter guard and introduce a wraparound canopy, as detailed in Section 5.2.

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

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1. INTRODUCTION

Gradient Wind Engineering Inc. (GWE) was retained by 17 Yorkville Limited Partnership c/o RioCan Realty Investments Partnership Thirteen LP to undertake a pedestrian level wind study for 11-21 Yorkville Avenue & 16-18 Cumberland Street, a planned mixed-use development located in Toronto, Ontario. Our mandate within this study, as outlined in GWE proposal #17-139P dated June 7, 2017, is to investigate pedestrian wind comfort within and surrounding the development site, and to identify any areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, where necessary.

Our work is based on industry standard wind tunnel testing techniques, architectural drawings provided by Sweeny&Co Architects in January 2018 and updated in March 2018, surrounding street layouts and existing and approved future building massing information obtained from the City of Toronto, as well as recent site imagery.

2. TERMS OF REFERENCE

The focus of this pedestrian level wind study is 11-21 Yorkville Avenue & 16-18 Cumberland Street, a planned mixed-use development located towards the west side of a city block bounded by Yorkville Avenue to the north, Yonge Street to the east, Cumberland Street to the south, and Bay Street to the west. The study site resides on the fringe of an urban area, surrounded in the near field by a dense concentration of existing and approved medium- and high-rise buildings in all directions. Specifically:

- To the northeast of the site is 18 Yorkville (36 storeys);
- To the east of the site is 1 Yorkville (58 Storeys);
- To the southeast of the site is the approved Eight Cumberland (51 Storeys); and
- To the west of the site is the approved 33 Yorkville Avenue (64 & 42 storeys).

Beyond the near field, the upwind exposure is classified as urban from the east, rotating clockwise to the southwest, and suburban for the remaining compass azimuth directions.

The proposed development comprises a 62-storey tower on a rectangular two-storey podium, reaching a maximum height of approximately 211 metres above local grade to the mechanical penthouse roof. Above four levels of below-grade parking, a concourse level provides a PATH connection to neighboring buildings west of the development, as well as retail space and bicycle storage. At grade, a residential lobby, loading space, and underground parking are accessible from a laneway along the east elevation. The remaining floorplan comprises retail space fronting Yorkville Avenue along the north elevation, and fronting POPS space along the west elevation. A mezzanine level provides bicycle parking, and Level 2 comprises additional retail space. At Level 3 the podium steps back on the east, south, and west sides to the base of the tower, accommodating indoor and outdoor amenity space. Level 4 also contains indoor amenity space, above which the remaining floors comprise residential occupancy. Multiple tower setbacks accommodate private terraces at Level 10 on the north elevation, at Level 18 on the west elevation, at Level 24 on the east elevation, and at Level 30 on the north and south elevations. The proposed development also includes a two-storey retail building to the south of the tower, across the lane.

Grade-level pedestrian areas considered in this study include surrounding sidewalks, laneways, walkways, building access points, transit stops, privately owned public space (POPS), and parks. Wind comfort is also evaluated on the level three amenity terrace. Figure 1 illustrates the study site and surrounding context. Photographs 1 through 4 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; and (iii) recommend suitable mitigation measures, where required.

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 Toronto 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 4 following the main text, was constructed at a scale of 1:400. The

[1] Toronto Development Guide, Pedestrian Level Wind Study Terms of Reference, November 2010

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. For this study, the wind tunnel was configured to simulate atmospheric velocity profiles consistent with urban and suburban upwind 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 66 sensor locations on the scale model in GWE's wind tunnel. Of the 66 sensors, 60 were placed at grade level, with the remaining six on the Level 3 amenity terrace. Wind speed measurements were performed for each of the sensors for 36 wind directions at 10° intervals. Figure 1 illustrates a plan of the site and relevant surrounding context, while sensor locations used to investigate wind conditions are illustrated in Figures 2 through 5, and in reference images provided throughout the report.

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

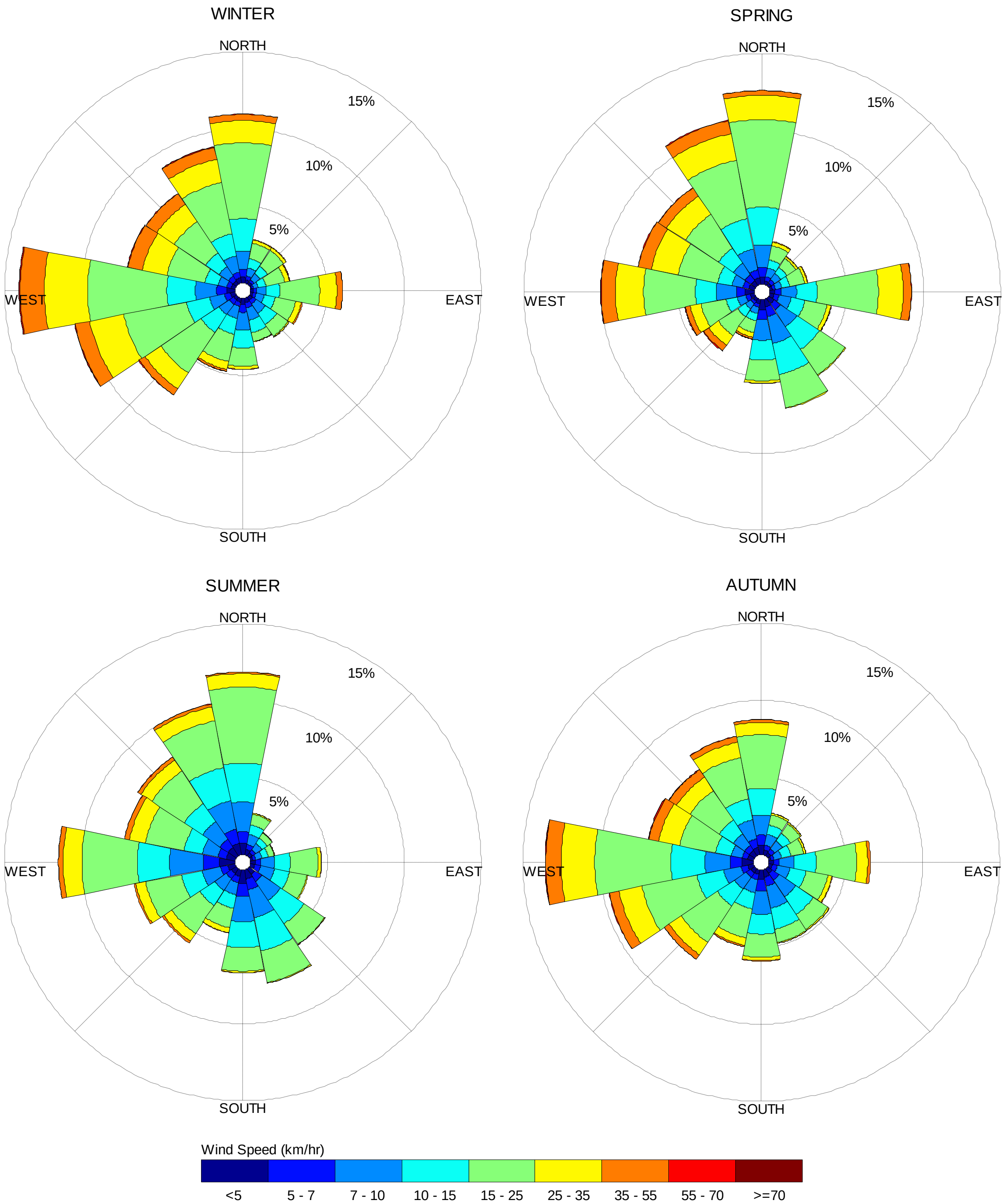
4.3 Meteorological Data Analysis

A statistical model for winds in Toronto was developed from approximately 40-years of hourly meteorological wind data recorded at Pearson International Airport, and obtained from the local branch of Atmospheric Environment Services of Environment Canada. Wind speed and direction data were analyzed for each month of the year in order to determine the statistically prominent wind directions and corresponding speeds, and to characterize similarities between monthly weather patterns. Based on this portion of the analysis, the four seasons are represented by grouping data from consecutive months based on similarity of weather patterns, and not according to the traditional calendar method.

The statistical model of the Toronto 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 Toronto, the most common winds concerning pedestrian comfort occur from the southwest clockwise to the north, as well as those from the east. The directional preference and relative magnitude of the wind speed varies somewhat from season to season, with the summer months displaying the calmest winds relative to the remaining seasonal periods.

SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES

PEARSON INTERNATIONAL AIRPORT, TORONTO, ONTARIO



Notes:

1. Radial distances indicate percentage of time of wind events.
2. Wind speeds represent mean hourly wind speeds measured at 10 m above the ground.

4.4 Pedestrian Comfort Guidelines

Pedestrian comfort guidelines are based on mechanical wind effects without consideration of other meteorological conditions (i.e. temperature, relative humidity). The guidelines provide an assessment of comfort, assuming that pedestrians are appropriately dressed for a specified outdoor activity during any given season. Five pedestrian comfort classes and corresponding gust wind speed ranges are used to assess pedestrian comfort, which include: (i) Sitting; (ii) Standing; (iii) Walking; (iv) Uncomfortable; and (v) Dangerous. More specifically, the comfort classes, associated wind speed ranges, and limiting criteria are summarized as follows:

(i) **Sitting** – Wind speeds below 14 km/h (i.e. 0 – 14 km/h) that occur more than 70% of the time would be considered acceptable for sedentary activities, including sitting.

(ii) **Standing** – Wind speeds below 22 km/h (i.e. 0 – 22 km/h) that occur more than 80% of the time are acceptable for activities such as standing, strolling or more vigorous activities.

(iii) **Walking** – Wind speeds below 30 km/h (i.e. 0 – 30 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.

(v) **Dangerous** – Wind speeds greater than 90 km/h, occurring more than 0.1% of the time, 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 an average elderly person in good health to fall.

The wind speeds associated with the above categories are gust wind speeds. Corresponding mean wind speeds are approximately calculated as gust wind speed divided by 1.5. Gust speeds are used in the guidelines because people tend to be more sensitive to wind gusts than to steady winds for lower wind speed ranges. For strong winds approaching dangerous levels, this effect is less important, because the mean wind can also cause problems for pedestrians. The gust speed ranges are selected based on 'The Beaufort Scale', presented on the following page, which describes the effects of forces produced by varying wind speed levels on objects.

THE BEAUFORT SCALE

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

Experience and research on people's perception of mechanical wind effects has shown that if the wind speed levels are exceeded for more than 70% or 80% of the time, the activity level would be judged to be uncomfortable by most people. For instance, if wind speeds of 14 km/h were exceeded for more than 30% of the time most pedestrians would judge that location to be too windy for sitting or more sedentary activities. Similarly, if 30 km/h at a location were exceeded for more than 20% of the time, walking or less vigorous activities would be considered uncomfortable. As most of these criteria are based on subjective reactions of a population to wind forces, their application is partly based on experience and judgment.

Once the pedestrian wind speed predictions have been established at tested locations, the assessment of pedestrian comfort involves determining the suitability of the predicted wind conditions for their associated spaces. This step involves comparing the predicted comfort class to the desired comfort class, which is dictated by the location type. 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 / Plazas	Sitting / Standing
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

Tables 1 through 16 beginning on the following page, provide a summary of seasonal comfort predictions for each sensor location. The Tables indicate the predicted percentages of time that wind speeds will fall into the ranges defined in the guidelines. A higher numerical value equates to a greater percentage of time that wind speeds will be lower, and therefore more comfortable. Pedestrian comfort is determined by the percentage of time that wind speeds will fall within the stated ranges.

The predicted values within each table are accompanied by a suitability assessment that includes the predicted comfort class (i.e. sitting, standing, walking, etc.), the location type, the desired comfort class, and a suitability descriptor. The predicted comfort class is defined by the predicted wind speed range percentages, while the location type and the desired comfort class relate to the sensor placement on the wind tunnel model. The suitability descriptor is assigned based on the relationship between the predicted comfort class (for each seasonal period) and the desired comfort class.

Following Tables 1 through 16, the most significant findings of the PLW are summarized. To assist with understanding and interpretation, predicted conditions for the proposed development are also illustrated in colour-coded format in Figures 2 through 5. 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.

TABLE 1: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #1	**Spring**	72	92	98	Sitting	Public Sidewalk	Walking	Acceptable
	Summer	82	96	99	Sitting			
	Autumn	73	92	98	Sitting			
	Winter	66	88	97	Standing			
Sensor #2	**Spring**	57	80	91	Standing	Public Sidewalk	Walking	Acceptable
	Summer	68	88	96	Standing			
	Autumn	58	80	91	Standing			
	Winter	50	74	88	Walking			
Sensor #3	**Spring**	64	86	95	Standing	Transit Stop/ Public Sidewalk	Standing/ Walking	Acceptable
	Summer	76	93	98	Sitting			
	Autumn	67	88	96	Standing			
	Winter	59	83	94	Standing			
Sensor #4	**Spring**	75	92	97	Sitting	Town Hall Square Park	Sitting/ Standing	Acceptable
	Summer	85	96	99	Sitting			
	Autumn	78	93	98	Sitting			
	Winter	71	90	97	Sitting			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

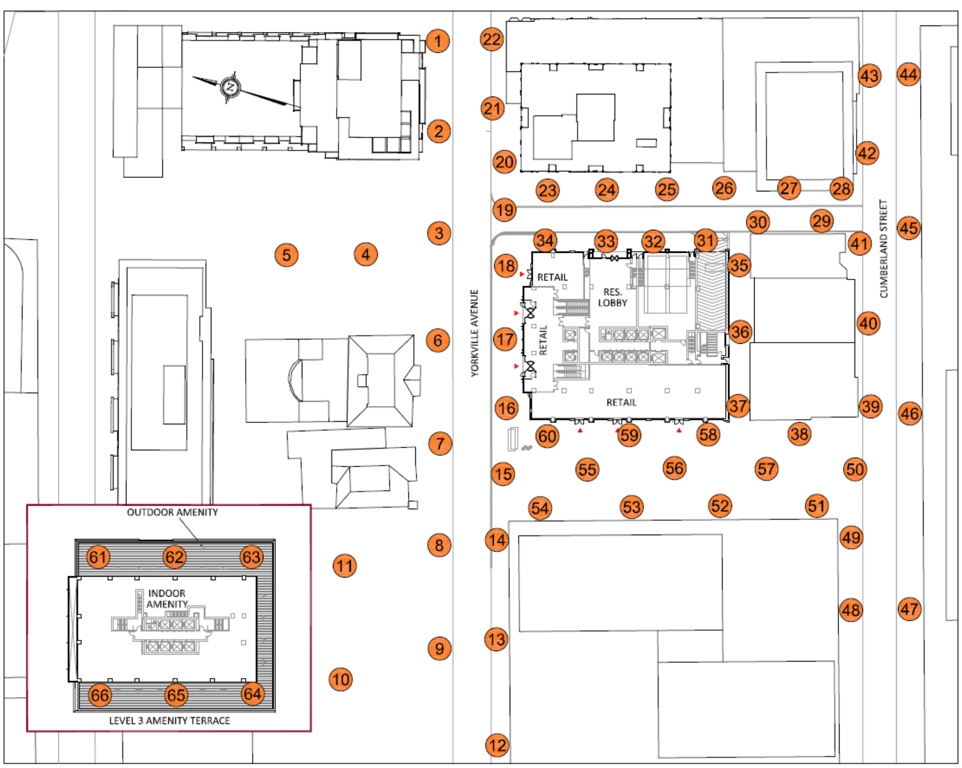


TABLE 2: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #5	Spring	73	90	97	Sitting	Town Hall Square Park	Sitting/ Standing	Acceptable
	Summer	83	95	99	Sitting			
	Autumn	74	91	97	Sitting			
	Winter	67	88	96	Standing			
Sensor #6	Spring	64	86	95	Standing	Public Sidewalk	Walking	Acceptable
	Summer	74	92	98	Sitting			
	Autumn	65	86	95	Standing			
	Winter	57	82	93	Standing			
Sensor #7	Spring	67	87	95	Standing	Public Sidewalk	Walking	Acceptable
	Summer	76	92	98	Sitting			
	Autumn	68	87	95	Standing			
	Winter	59	82	93	Standing			
Sensor #8	Spring	68	87	95	Standing	Public Sidewalk	Walking	Acceptable
	Summer	76	92	97	Sitting			
	Autumn	67	86	94	Standing			
	Winter	59	82	92	Standing			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

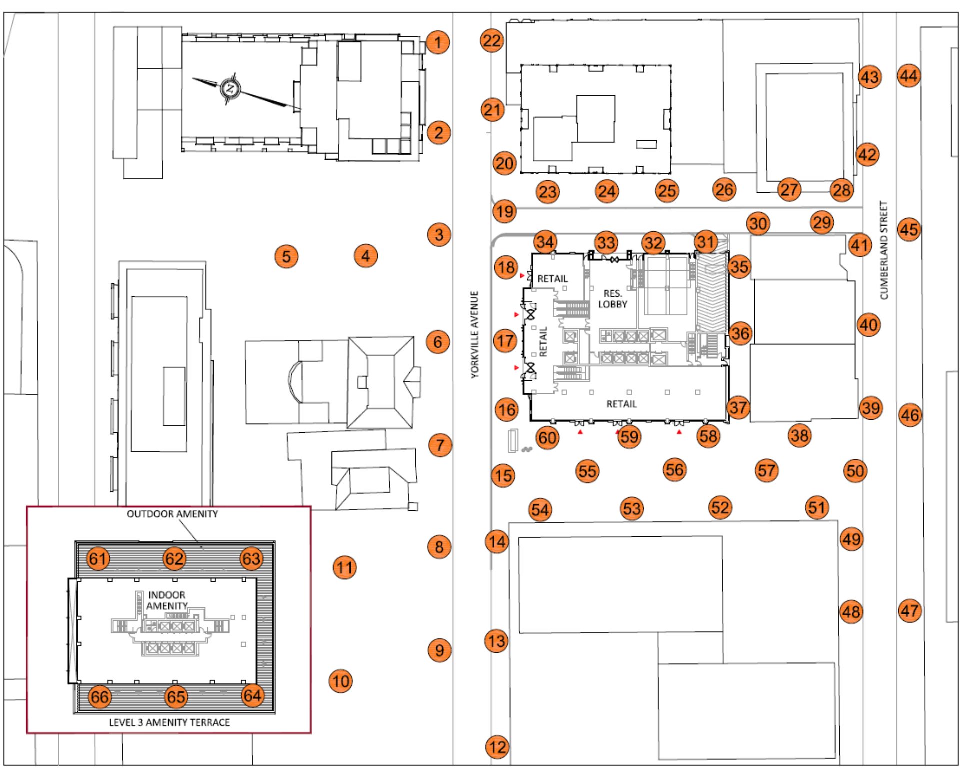


TABLE 3: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #9	**Spring**	60	82	92	Standing	Public Sidewalk	Walking	Acceptable
	Summer	69	88	96	Standing			
	Autumn	61	82	92	Standing			
	Winter	51	76	89	Walking			
Sensor #10	**Spring**	59	77	87	Walking	Drop-off Area	Walking	Acceptable
	Summer	67	84	93	Standing			
	Autumn	60	78	89	Walking			
	Winter	50	72	85	Walking			
Sensor #11	**Spring**	74	90	96	Sitting	Landscaped Area	Sitting/ Standing	Acceptable
	Summer	81	94	98	Sitting			
	Autumn	72	89	96	Sitting			
	Winter	65	85	94	Standing			
Sensor #12	**Spring**	51	73	86	Walking	Public Sidewalk	Walking	Acceptable
	Summer	61	82	92	Standing			
	Autumn	54	76	88	Walking			
	Winter	44	68	83	Walking			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

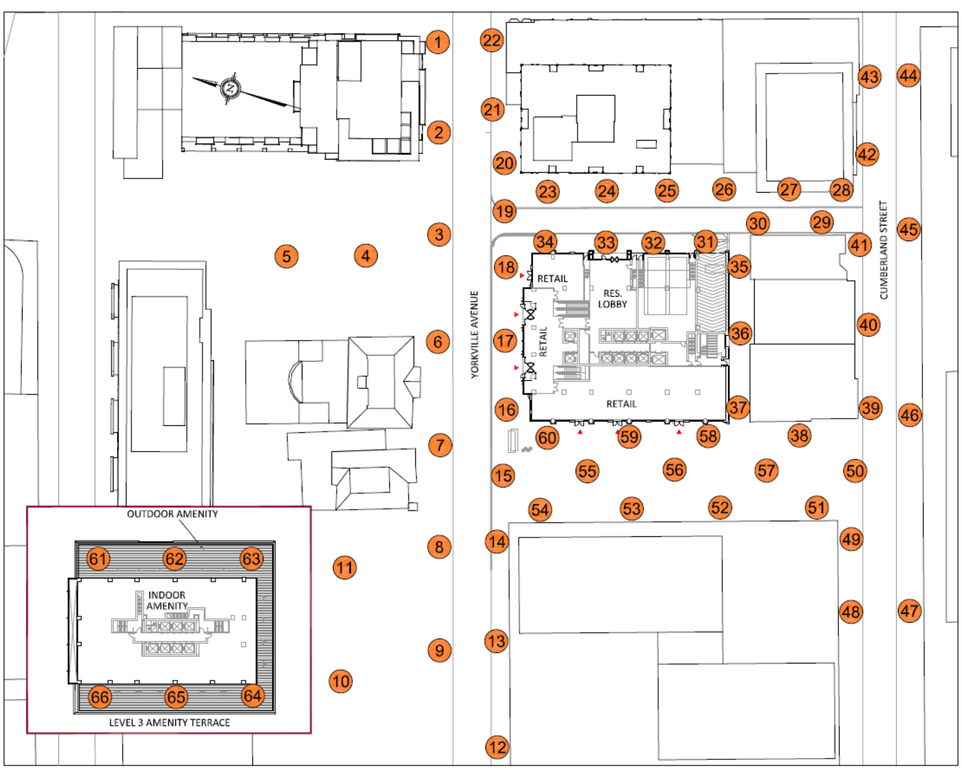


TABLE 4: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #13	Spring	63	81	89	Standing	Public Sidewalk	Walking	Acceptable
	Summer	70	86	94	Sitting			
	Autumn	62	80	89	Standing			
	Winter	54	75	86	Walking			
Sensor #14	Spring	66	82	90	Standing	Public Sidewalk	Walking	Acceptable
	Summer	73	87	94	Sitting			
	Autumn	65	81	90	Standing			
	Winter	57	76	87	Walking			
Sensor #15	Spring	59	80	92	Standing	Public Sidewalk	Walking	Acceptable
	Summer	71	89	96	Sitting			
	Autumn	63	84	93	Standing			
	Winter	54	78	90	Walking			
Sensor #16	Spring	60	84	94	Standing	Public Sidewalk	Walking	Acceptable
	Summer	72	91	97	Sitting			
	Autumn	63	85	94	Standing			
	Winter	54	79	92	Walking			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

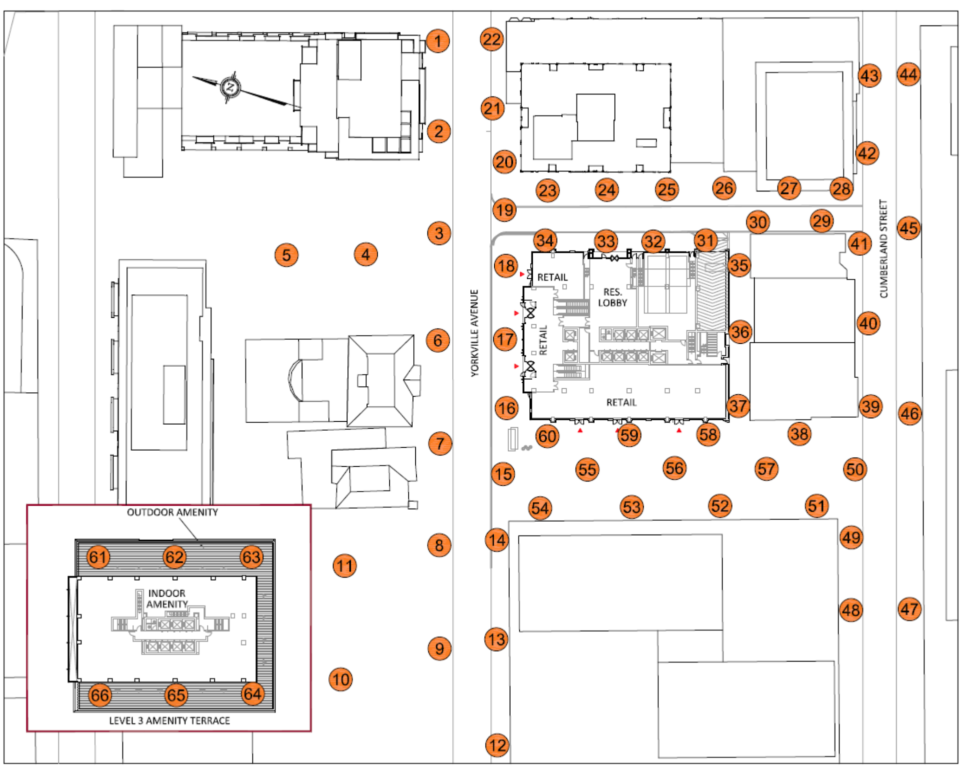


TABLE 5: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #17	Spring	71	90	97	Sitting	Retail Entrance/ Public Sidewalk	Standing/ Walking	Acceptable
	Summer	82	96	99	Sitting			
	Autumn	73	91	98	Sitting			
	Winter	66	88	96	Standing			
Sensor #18	Spring	74	93	99	Sitting	Retail Entrances/ Public Sidewalk	Standing/ Walking	Acceptable
	Summer	86	98	100	Sitting			
	Autumn	79	95	99	Sitting			
	Winter	71	93	99	Sitting			
Sensor #19	Spring	62	85	95	Standing	Public Sidewalk	Walking	Acceptable
	Summer	75	94	99	Sitting			
	Autumn	67	89	97	Standing			
	Winter	58	84	95	Standing			
Sensor #20	Spring	64	85	94	Standing	Public Sidewalk	Walking	Acceptable
	Summer	73	90	96	Sitting			
	Autumn	63	83	92	Standing			
	Winter	55	78	89	Walking			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

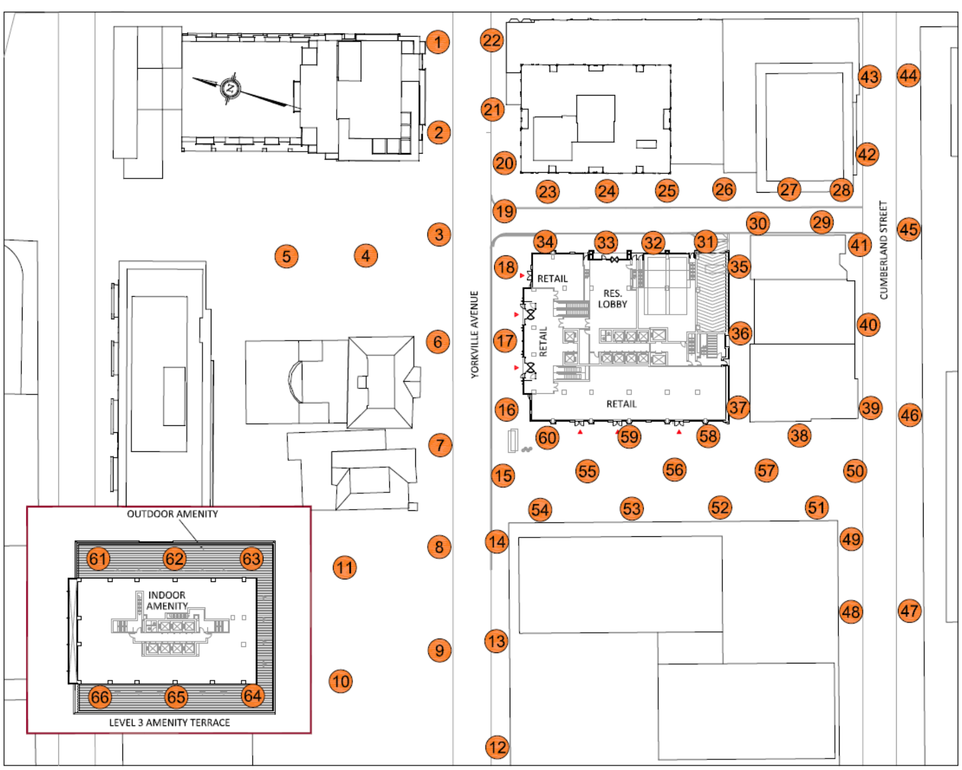


TABLE 6: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #21	Spring	53	75	88	Walking	Public Sidewalk	Walking	Acceptable
	Summer	64	85	95	Standing			
	Autumn	55	77	90	Walking			
	Winter	45	70	85	Walking			
Sensor #22	Spring	64	85	95	Standing	Public Sidewalk	Walking	Acceptable
	Summer	76	93	98	Sitting			
	Autumn	67	87	96	Standing			
	Winter	58	82	93	Standing			
Sensor #23	Spring	71	88	96	Sitting	Future Pedestrian Walkway	Walking	Acceptable
	Summer	79	94	99	Sitting			
	Autumn	74	91	97	Sitting			
	Winter	66	87	96	Standing			
Sensor #24	Spring	65	85	94	Standing	Future Pedestrian Walkway	Walking	Acceptable
	Summer	72	90	96	Sitting			
	Autumn	65	84	93	Standing			
	Winter	56	79	90	Walking			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

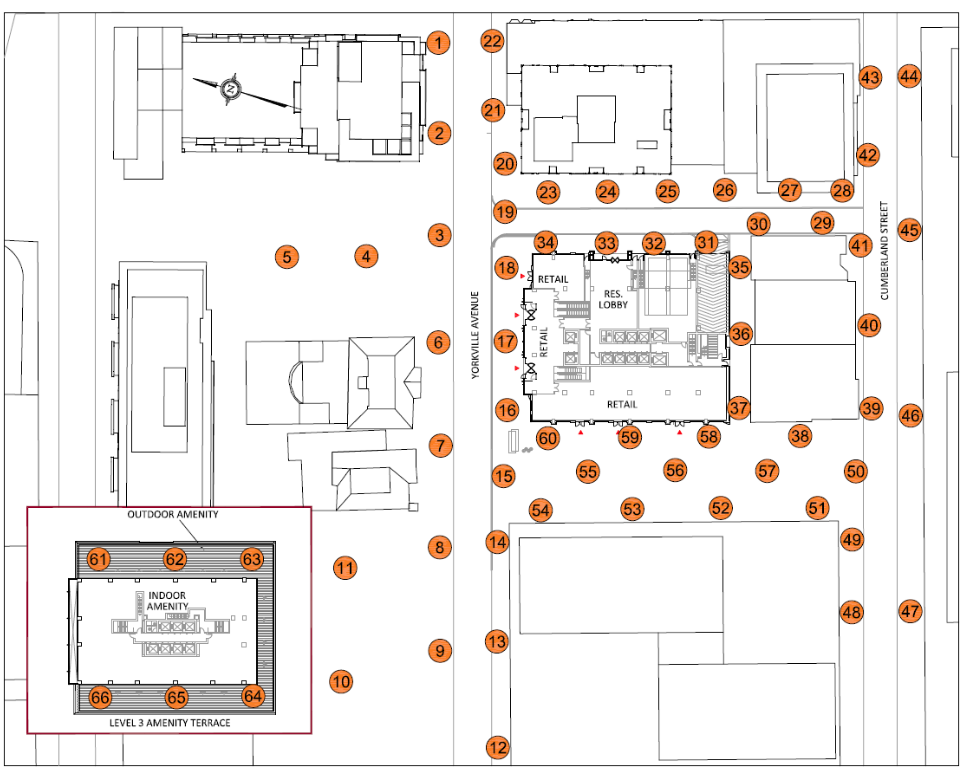


TABLE 7: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #25	**Spring**	51	71	84	Walking	Future Pedestrian Walkway	Walking	Acceptable
	Summer	62	81	91	Standing			
	Autumn	56	77	89	Walking			
	Winter	45	69	84	Walking			
Sensor #26	**Spring**	63	84	95	Standing	Future Pedestrian Walkway	Walking	Acceptable
	Summer	73	92	98	Sitting			
	Autumn	66	87	96	Standing			
	Winter	56	81	94	Standing			
Sensor #27	**Spring**	69	89	97	Standing	Future Pedestrian Walkway	Walking	Acceptable
	Summer	80	95	99	Sitting			
	Autumn	75	93	98	Sitting			
	Winter	66	88	97	Standing			
Sensor #28	**Spring**	73	91	97	Sitting	Future Pedestrian Walkway	Walking	Acceptable
	Summer	82	96	99	Sitting			
	Autumn	75	92	98	Sitting			
	Winter	67	88	97	Standing			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

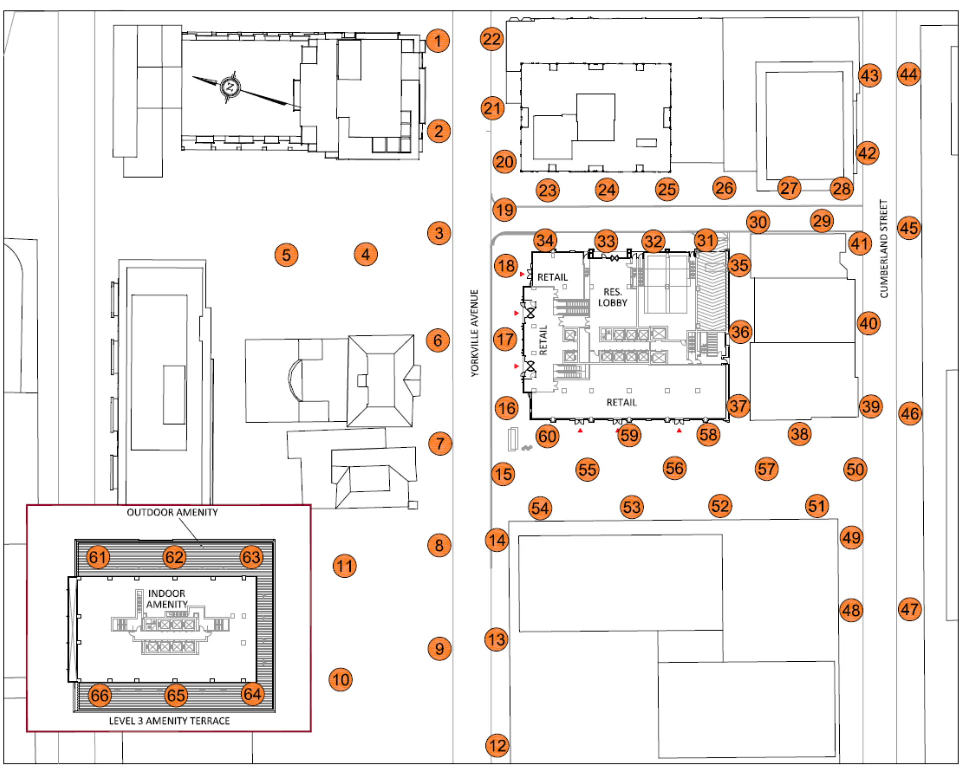


TABLE 8: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #29	Spring	70	90	97	Sitting	Laneway	Walking	Acceptable
	Summer	80	95	99	Sitting			
	Autumn	73	92	98	Sitting			
	Winter	64	87	96	Standing			
Sensor #30	Spring	64	85	95	Standing	Laneway	Walking	Acceptable
	Summer	76	93	98	Sitting			
	Autumn	68	88	97	Standing			
	Winter	59	83	94	Standing			
Sensor #31	Spring	70	90	97	Sitting	Vehicular Entrance/ Walkway	Walking	Acceptable
	Summer	81	96	99	Sitting			
	Autumn	74	92	98	Sitting			
	Winter	65	88	97	Standing			
Sensor #32	Spring	72	91	98	Sitting	Loading Entrance/ Walkway	Walking	Acceptable
	Summer	84	97	100	Sitting			
	Autumn	80	95	99	Sitting			
	Winter	72	91	98	Sitting			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

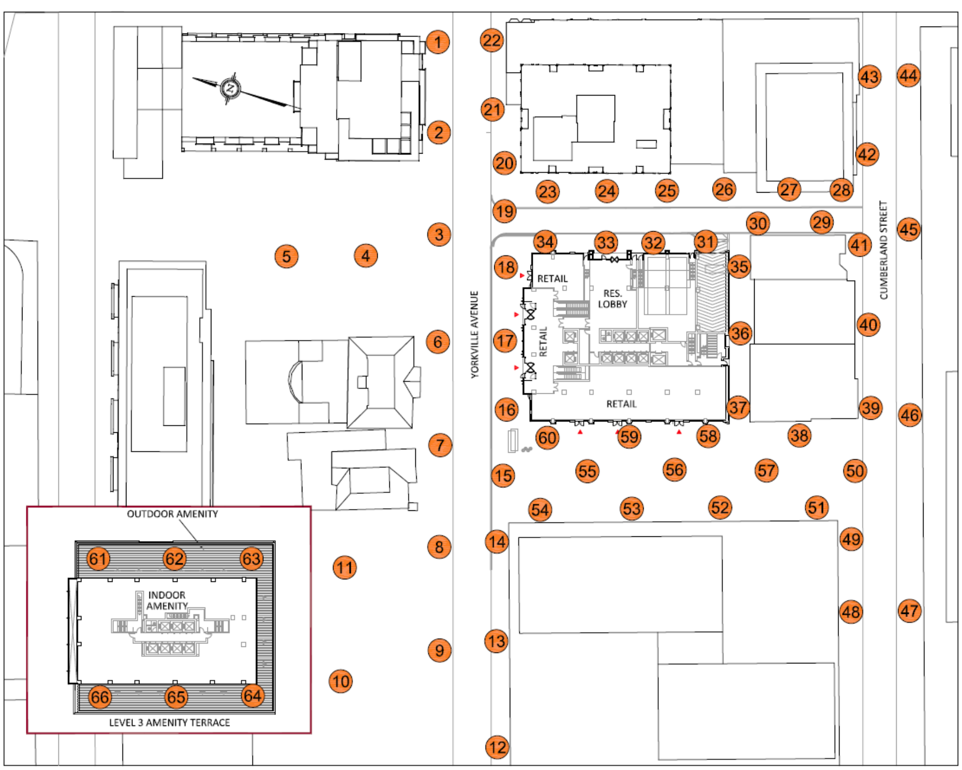


TABLE 9: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #33	**Spring**	73	92	98	Sitting	Residential Lobby Entrance/ Walkway	Standing/ Walking	Acceptable
	Summer	85	98	100	Sitting			
	Autumn	78	95	99	Sitting			
	Winter	71	92	98	Sitting			
Sensor #34	**Spring**	68	88	96	Standing	Walkway	Walking	Acceptable
	Summer	81	95	99	Sitting			
	Autumn	77	92	98	Sitting			
	Winter	69	88	96	Standing			
Sensor #35	**Spring**	58	79	91	Walking	Laneway	Walking	Acceptable
	Summer	68	87	96	Standing			
	Autumn	62	83	94	Standing			
	Winter	51	76	90	Walking			
Sensor #36	**Spring**	68	87	96	Standing	Laneway	Walking	Acceptable
	Summer	78	94	99	Sitting			
	Autumn	73	91	97	Sitting			
	Winter	63	86	95	Standing			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

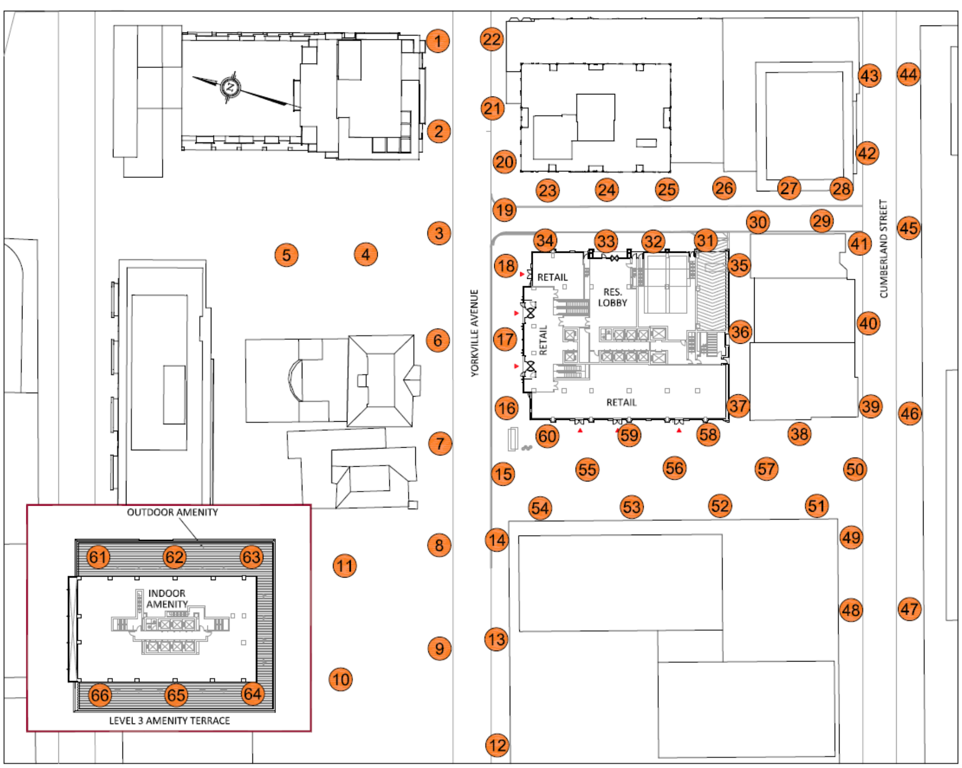


TABLE 10: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #37	**Spring**	87	97	99	Sitting	Laneway	Walking	Acceptable
	Summer	93	99	100	Sitting			
	Autumn	87	97	99	Sitting			
	Winter	82	96	99	Sitting			
Sensor #38	**Spring**	70	86	92	Sitting	Laneway	Walking	Acceptable
	Summer	76	89	95	Sitting			
	Autumn	68	83	91	Standing			
	Winter	61	79	88	Walking			
Sensor #39	**Spring**	72	89	95	Sitting	Public Sidewalk	Walking	Acceptable
	Summer	80	93	98	Sitting			
	Autumn	72	89	95	Sitting			
	Winter	65	85	94	Standing			
Sensor #40	**Spring**	74	92	98	Sitting	Public Sidewalk	Walking	Acceptable
	Summer	84	97	99	Sitting			
	Autumn	77	93	98	Sitting			
	Winter	70	90	97	Sitting			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

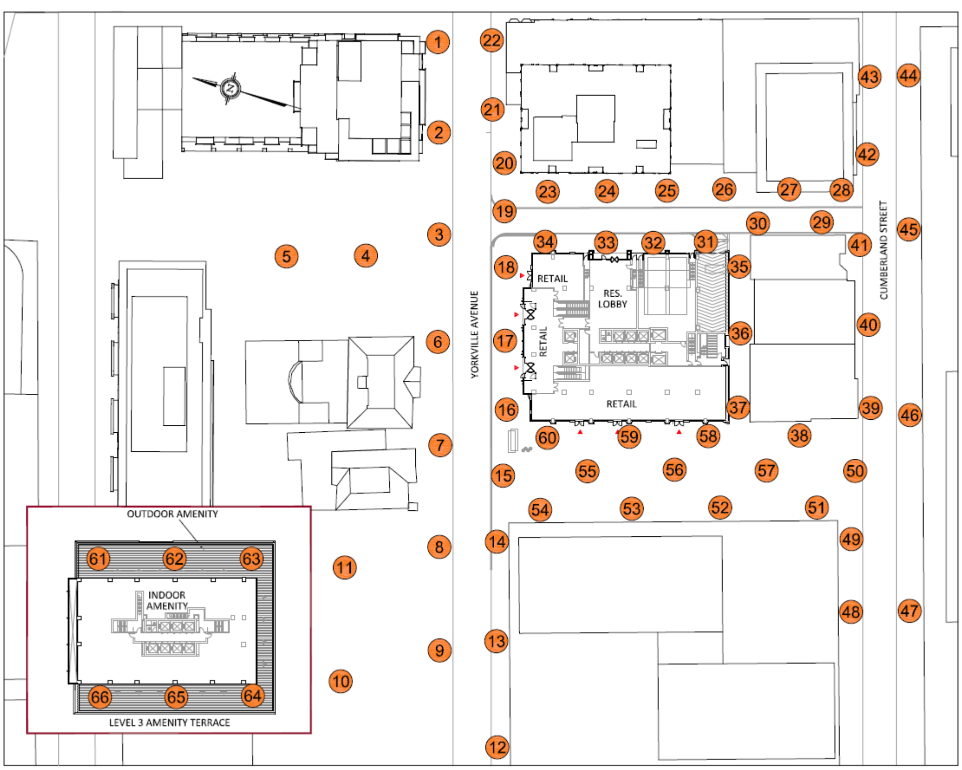


TABLE 11: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #41	Spring	73	91	97	Sitting	Public Sidewalk	Walking	Acceptable
	Summer	83	96	99	Sitting			
	Autumn	76	92	98	Sitting			
	Winter	69	89	97	Standing			
Sensor #42	Spring	60	81	92	Standing	Public Sidewalk	Walking	Acceptable
	Summer	71	90	97	Sitting			
	Autumn	62	84	94	Standing			
	Winter	54	78	91	Walking			
Sensor #43	Spring	59	83	94	Standing	Public Sidewalk	Walking	Acceptable
	Summer	71	91	98	Sitting			
	Autumn	62	84	95	Standing			
	Winter	53	79	92	Walking			
Sensor #44	Spring	57	80	93	Standing	Public Sidewalk	Walking	Acceptable
	Summer	70	90	98	Sitting			
	Autumn	62	85	95	Standing			
	Winter	52	78	92	Walking			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

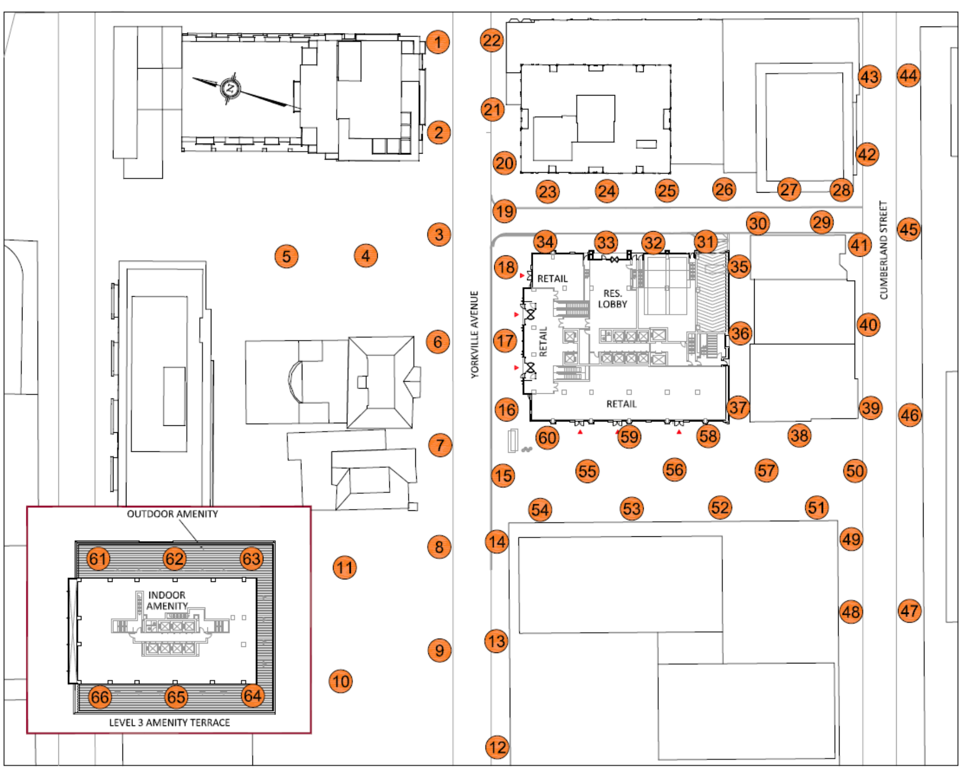


TABLE 12: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #45	Spring	69	90	97	Standing	Public Sidewalk	Walking	Acceptable
	Summer	82	97	100	Sitting			
	Autumn	75	94	99	Sitting			
	Winter	67	90	97	Standing			
Sensor #46	Spring	76	93	98	Sitting	Public Sidewalk	Walking	Acceptable
	Summer	85	97	99	Sitting			
	Autumn	78	94	98	Sitting			
	Winter	71	91	98	Sitting			
Sensor #47	Spring	56	74	85	Walking	Public Sidewalk	Walking	Acceptable
	Summer	65	82	91	Standing			
	Autumn	58	77	88	Walking			
	Winter	48	69	82	Walking			
Sensor #48	Spring	67	85	93	Standing	Public Sidewalk	Walking	Acceptable
	Summer	76	91	97	Sitting			
	Autumn	69	86	94	Standing			
	Winter	61	82	92	Standing			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

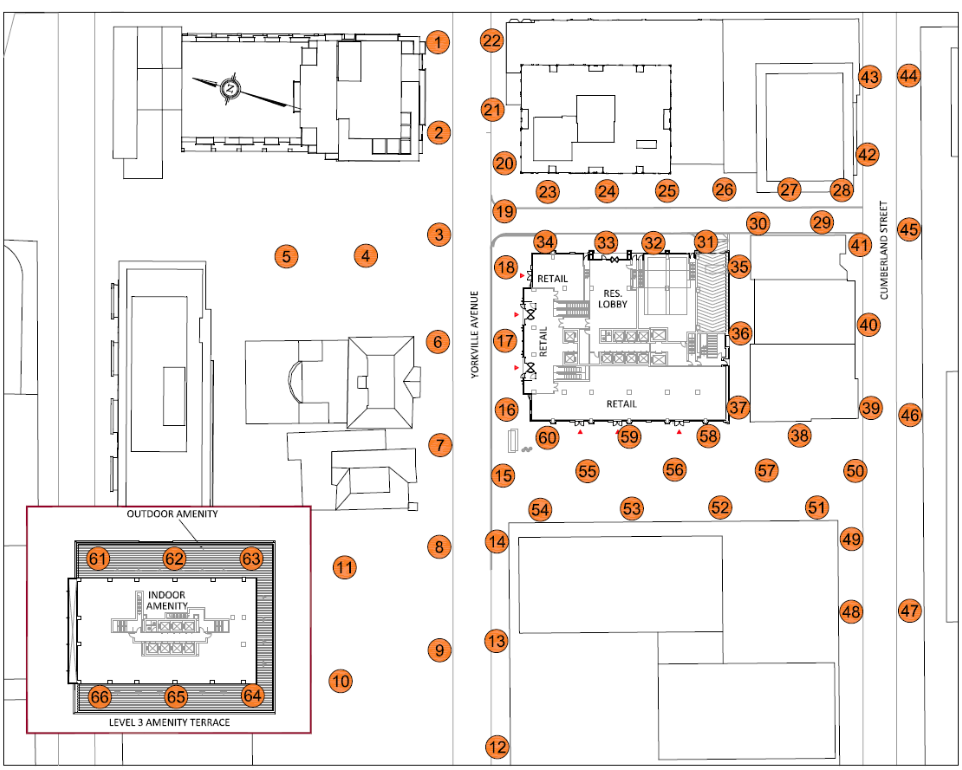


TABLE 13: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #49	**Spring**	73	87	93	Sitting	Public Sidewalk	Walking	Acceptable
	Summer	79	91	96	Sitting			
	Autumn	71	86	93	Sitting			
	Winter	64	82	91	Standing			
Sensor #50	**Spring**	67	85	94	Standing	Public Sidewalk	Walking	Acceptable
	Summer	75	91	97	Sitting			
	Autumn	68	86	94	Standing			
	Winter	59	81	91	Standing			
Sensor #51	**Spring**	76	92	98	Sitting	Future Walkway	Walking	Acceptable
	Summer	86	96	99	Sitting			
	Autumn	82	95	99	Sitting			
	Winter	75	92	98	Sitting			
Sensor #52	**Spring**	68	88	96	Standing	Future Walkway	Sitting/ Standing	Acceptable
	Summer	79	94	99	Sitting			
	Autumn	73	90	97	Sitting			
	Winter	63	86	95	Standing			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

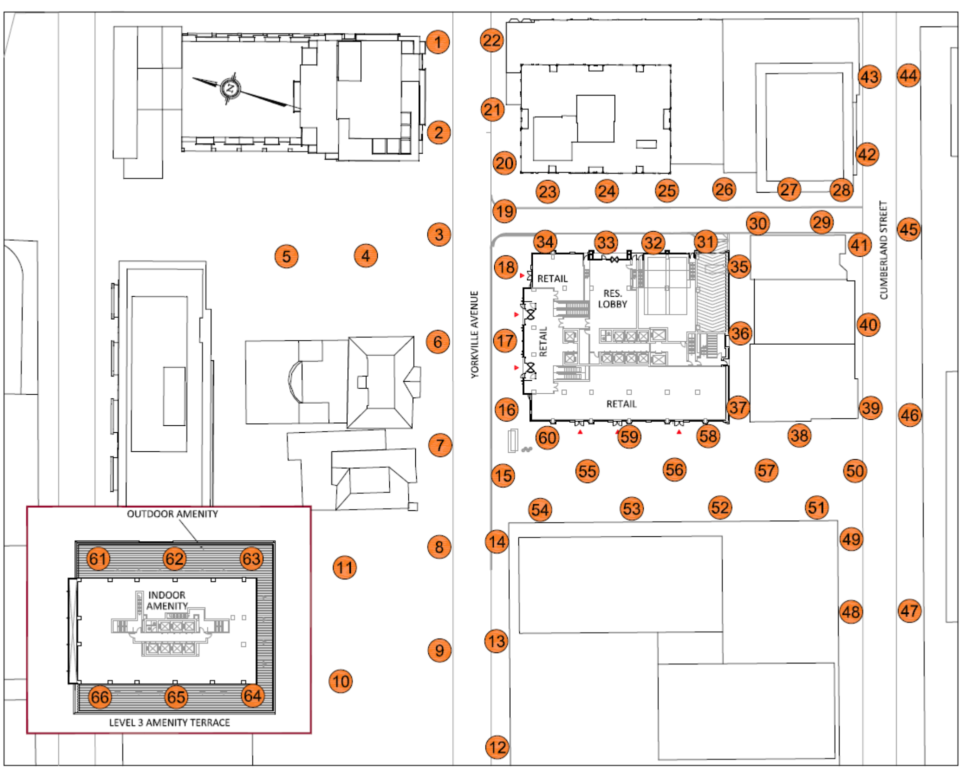


TABLE 14: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #53	Spring	60	82	94	Standing	Future Walkway	Sitting/ Standing	Acceptable
	Summer	74	92	98	Sitting			
	Autumn	67	88	96	Standing			
	Winter	58	82	93	Standing			
Sensor #54	Spring	70	90	97	Sitting	Future Walkway	Sitting/ Standing	Acceptable
	Summer	83	96	99	Sitting			
	Autumn	78	94	99	Sitting			
	Winter	70	91	98	Sitting			
Sensor #55	Spring	64	82	93	Standing	POPS/ Park	Sitting/ Standing	Acceptable (See §5.2)
	Summer	75	90	97	Sitting			
	Autumn	71	88	96	Sitting			
	Winter	62	83	93	Standing			
Sensor #56	Spring	68	88	96	Standing	POPS/ Park	Sitting/ Standing	Acceptable (See §5.2)
	Summer	79	94	99	Sitting			
	Autumn	74	92	98	Sitting			
	Winter	65	88	96	Standing			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

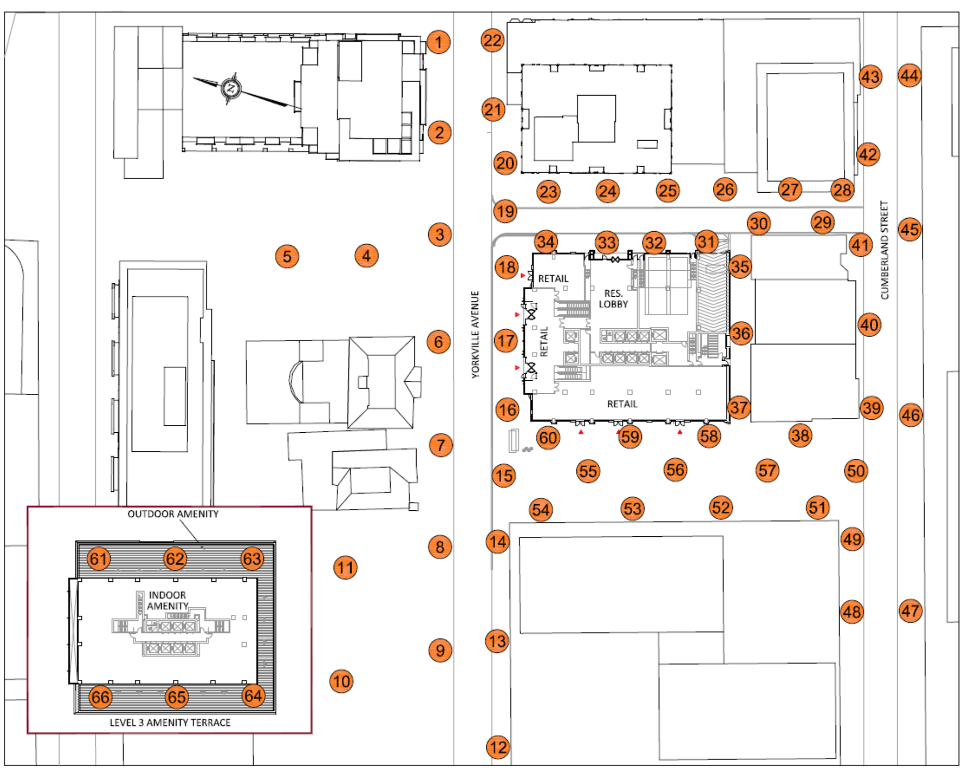


TABLE 14: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #57	Spring	66	85	93	Standing	POPS/ Park	Sitting/ Standing	Acceptable (See §5.2)
	Summer	74	90	96	Sitting			
	Autumn	67	84	92	Standing			
	Winter	58	79	90	Walking			
Sensor #58	Spring	82	96	99	Sitting	POPS/ Retail Entrance	Sitting/ Standing	Acceptable
	Summer	89	98	100	Sitting			
	Autumn	85	97	100	Sitting			
	Winter	79	95	99	Sitting			
Sensor #59	Spring	71	88	95	Sitting	POPS/ Retail Entrance	Sitting/ Standing	Acceptable (See §5.2)
	Summer	80	93	98	Sitting			
	Autumn	75	90	96	Sitting			
	Winter	67	87	95	Standing			
Sensor #60	Spring	66	85	94	Standing	POPS/ Retail Entrance	Sitting/ Standing	Acceptable (See §5.2)
	Summer	74	91	97	Sitting			
	Autumn	69	88	95	Standing			
	Winter	61	83	93	Standing			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

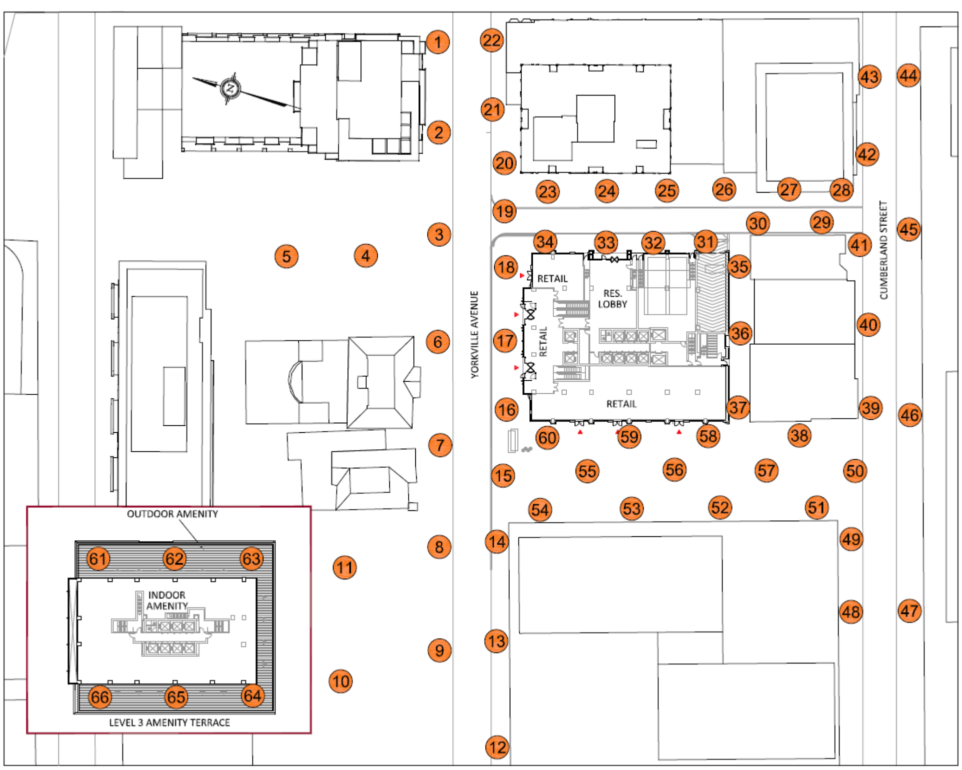


TABLE 15: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #61	Spring	80	95	99	Sitting	Level 3 Amenity Terrace	Sitting	Acceptable
	Summer	90	98	100	Sitting			
	Autumn	86	97	100	Sitting			
	Winter	80	95	99	Sitting			
Sensor #62	Spring	65	86	95	Standing	Level 3 Amenity Terrace	Sitting	Acceptable (See §5.2)
	Summer	75	92	98	Sitting			
	Autumn	68	88	96	Standing			
	Winter	60	83	94	Standing			
Sensor #63	Spring	58	79	91	Walking	Level 3 Amenity Terrace	Sitting	Acceptable with Mitigation (See §5.2)
	Summer	66	86	95	Standing			
	Autumn	59	80	91	Standing			
	Winter	49	73	87	Walking			
Sensor #64	Spring	72	88	95	Sitting	Level 3 Amenity Terrace	Sitting	Acceptable
	Summer	78	93	98	Sitting			
	Autumn	72	88	96	Sitting			
	Winter	64	84	93	Standing			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS

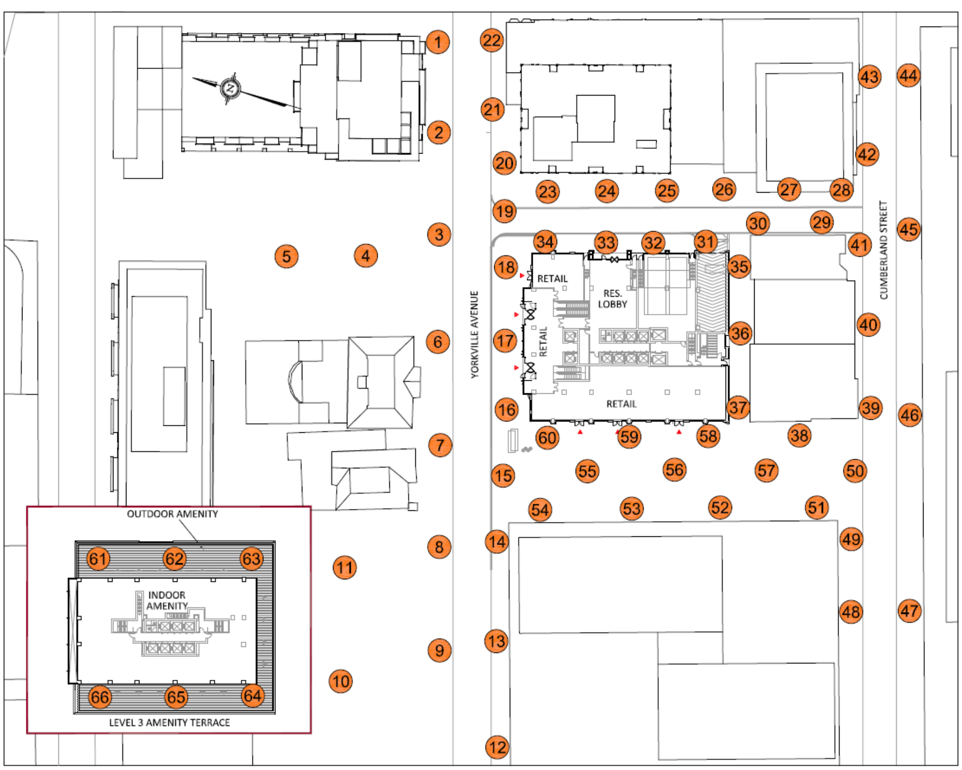
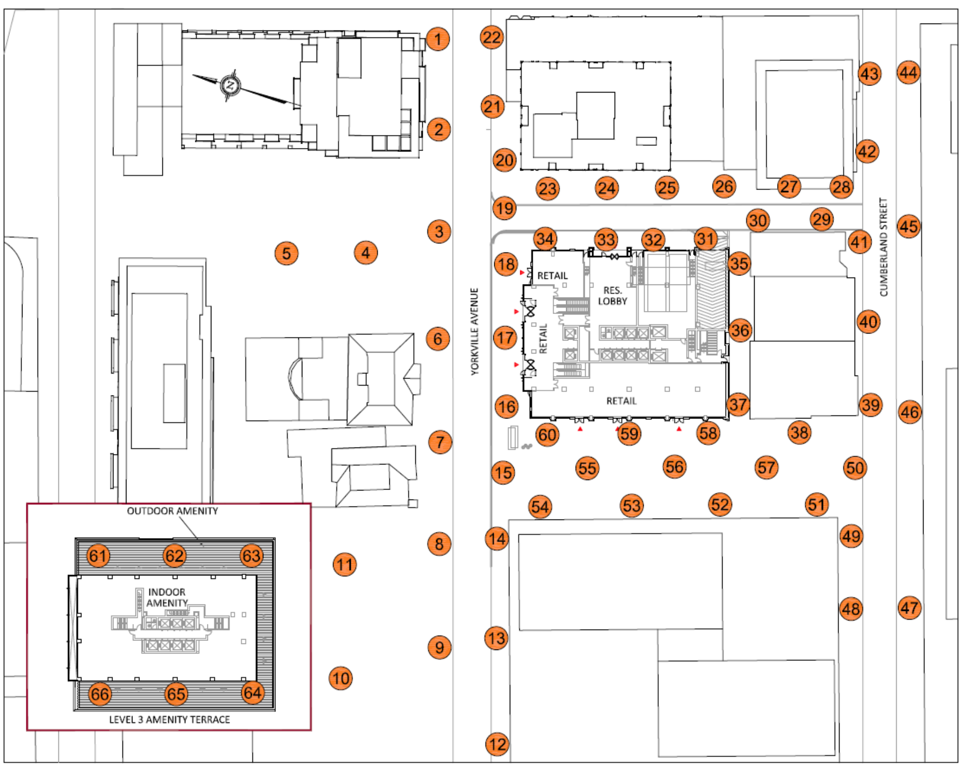


TABLE 16: SUMMARY OF PEDESTRIAN COMFORT

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		≤ 14	≤ 22	≤ 30				
Guideline (% of Time)		≥70%	≥80%	≥80%				
Sensor #65	Spring	67	86	95	Standing	Level 3 Amenity Terrace	Sitting	Acceptable (See §5.2)
	Summer	75	92	98	Sitting			
	Autumn	68	87	96	Standing			
	Winter	59	83	94	Standing			
Sensor #66	Spring	73	90	97	Sitting	Level 3 Amenity Terrace	Sitting	Acceptable
	Summer	80	95	99	Sitting			
	Autumn	75	92	98	Sitting			
	Winter	68	88	97	Standing			

11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET: PLW SENSOR LOCATIONS



5.2 Summary of Findings

Based on the analysis of the measured data, consideration of local climate data, and the suitability descriptors provided in Tables 1 through 16 in Section 5.1, this section summarizes the most significant findings of the PLW study, as follows:

1. All existing and future surrounding sidewalks, laneways, and walkways will experience wind conditions suitable for walking, or better, during each seasonal period, which is considered acceptable for the intended uses of the spaces.

2. The transit stop along Yorkville Avenue (Sensor 3) will be suitable for standing, or better, throughout the year, which is acceptable.

3. Within the Town Hall Square park to the north of the site (Sensors 4 & 5), as well as the landscaped area to the northwest (Sensor 11), wind comfort will be suitable for sitting during the spring, summer, and autumn, and for sitting or standing during the winter, which is apropriate.

4. All building access points for the study building will be acceptable for standing, or better, throughout the year, which is appropriate.

5. For the future park / POPS space to the west of the site (Sensors 55 – 60), wind conditions will be comfortable for sitting during the summer months, for sitting or standing during the spring and autumn, and for walking, or better, during the winter. The noted conditions are generally considered acceptable. If specific seating areas will used during the shoulder seasons of spring and autumn, then the installation of 1.6-metre-tall high-solidity wind screens or raised planters with coniferous plantings are recommended to the north of any such areas.

6. Regarding the level three outdoor amenity terrace (Sensors 61 – 66), wind conditions will generally be comfortable for sitting during the summer months, except for the southeast corner (Sensor 63), which is comfortable for standing. If seating areas will be provided at the southeast corner, it is recommended to increase the height of the terrace perimeter guard to 1.6 metres above the walking surface along the eastern half of the south elevation. As well, it is recommended to install a wraparound canopy at the tower corner. The canopy should extend at least 10 metres in either direction from the building corner, and project at least 2.0 metres from the building façade.

7. 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 11-21 Yorkville Avenue & 16-18 Cumberland Street, a planned mixed-use development located in Toronto, Ontario. This work was performed in accordance with the scope of work described in GWE proposal #17-139P dated June 7, 2017 and is based on industry standard wind tunnel testing and data analysis procedures, architectural drawings prepared by Sweeny&Co Architects in January 2018 and updated in March 2018, surrounding street layouts and existing and approved future building massing information obtained from the City of Toronto, as well as recent site imagery.

A complete summary of the predicted wind conditions is provided in Sections 5.1 and 5.2 of this report and illustrated in Figures 2 through 5. Based on the wind tunnel test results, meteorological data analysis, and experience with similar developments in Toronto, we conclude that the wind conditions within and surrounding the full study site will be acceptable for the intended pedestrian uses on a seasonal basis. Regarding the pedestrian walkway along the west side of the development, wind conditions will be comfortable for sitting during the summer months, and for standing or better throughout the rest of the year. If specific seating areas will be used throughout the shoulder seasons of spring and autumn, then 1.6-metre-tall high-solidity wind screens or raised planters with coniferous plantings are recommended to be installed to the immediate north of any such areas.

Regarding the level three outdoor amenity terrace, the majority of the space will be comfortable for sitting or more sedentary activities during the warmer months. If seating areas will be provided near the southeast corner of the terrace, it is recommended to increase the height of the terrace perimeter guard and introduce a wraparound canopy, as detailed in Section 5.2.

Additionally, 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.

Andrew Sliasas, M.A.Sc.,
Project Manager

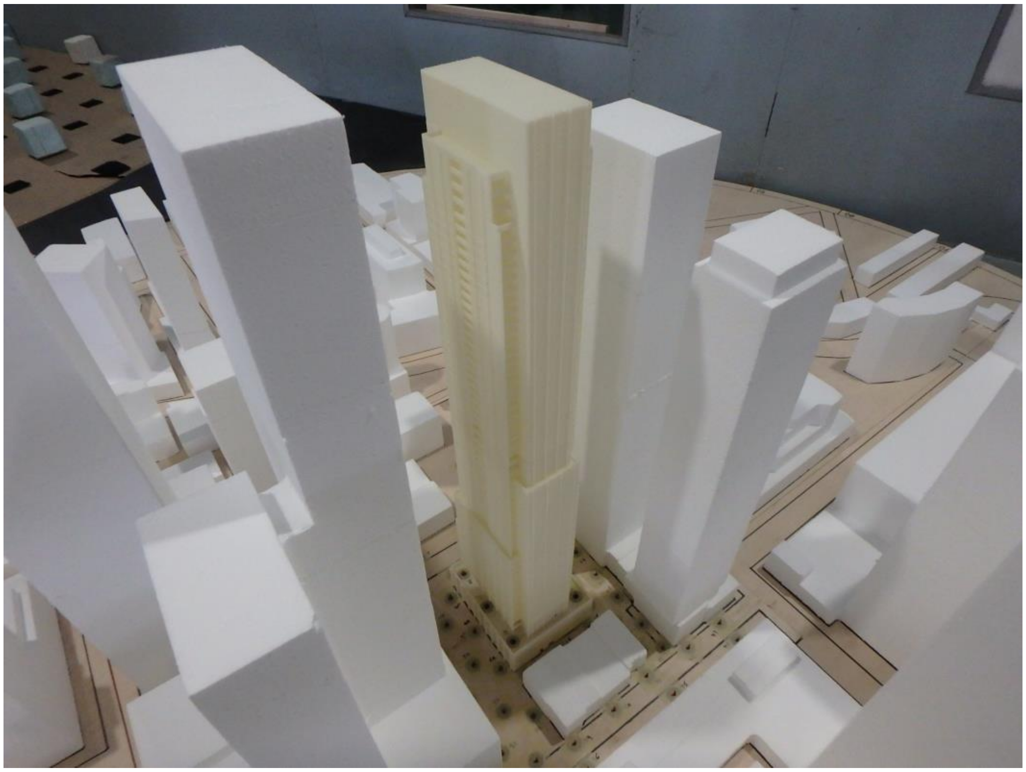
Vincent Ferraro, M.Eng., P.Eng.,
Principal

Nick Petersen, B.Eng., EIT.,
Junior Wind Scientist

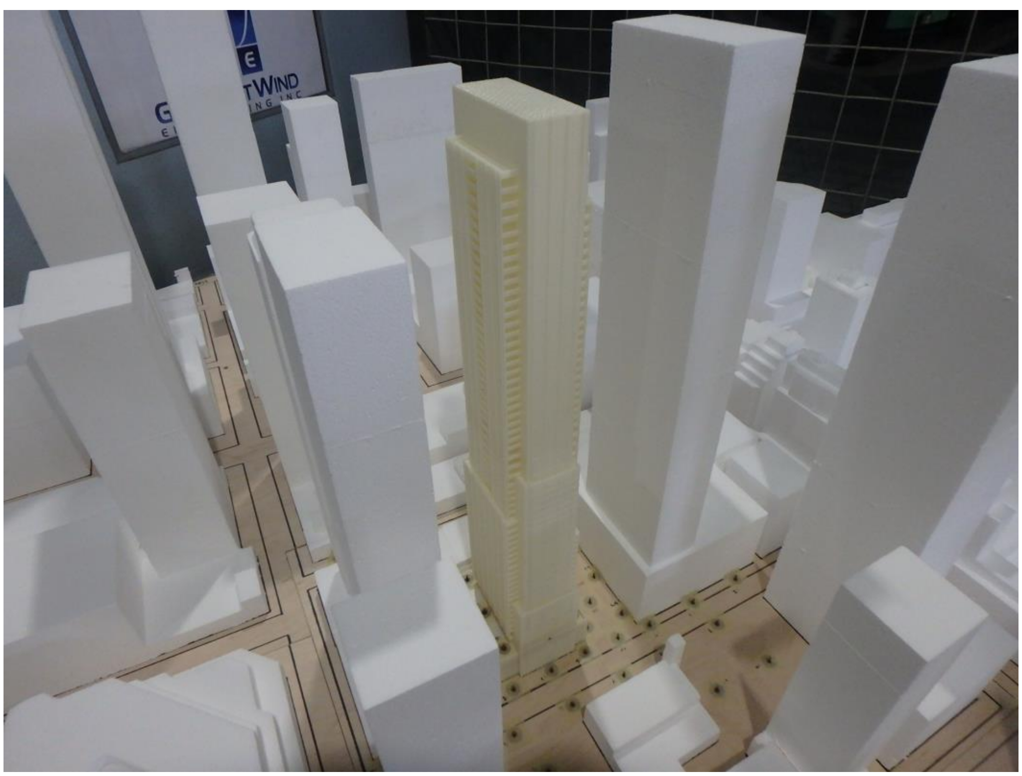
GWE17-092-PLW

PHOTOGRAPH 1: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING DOWNWIND

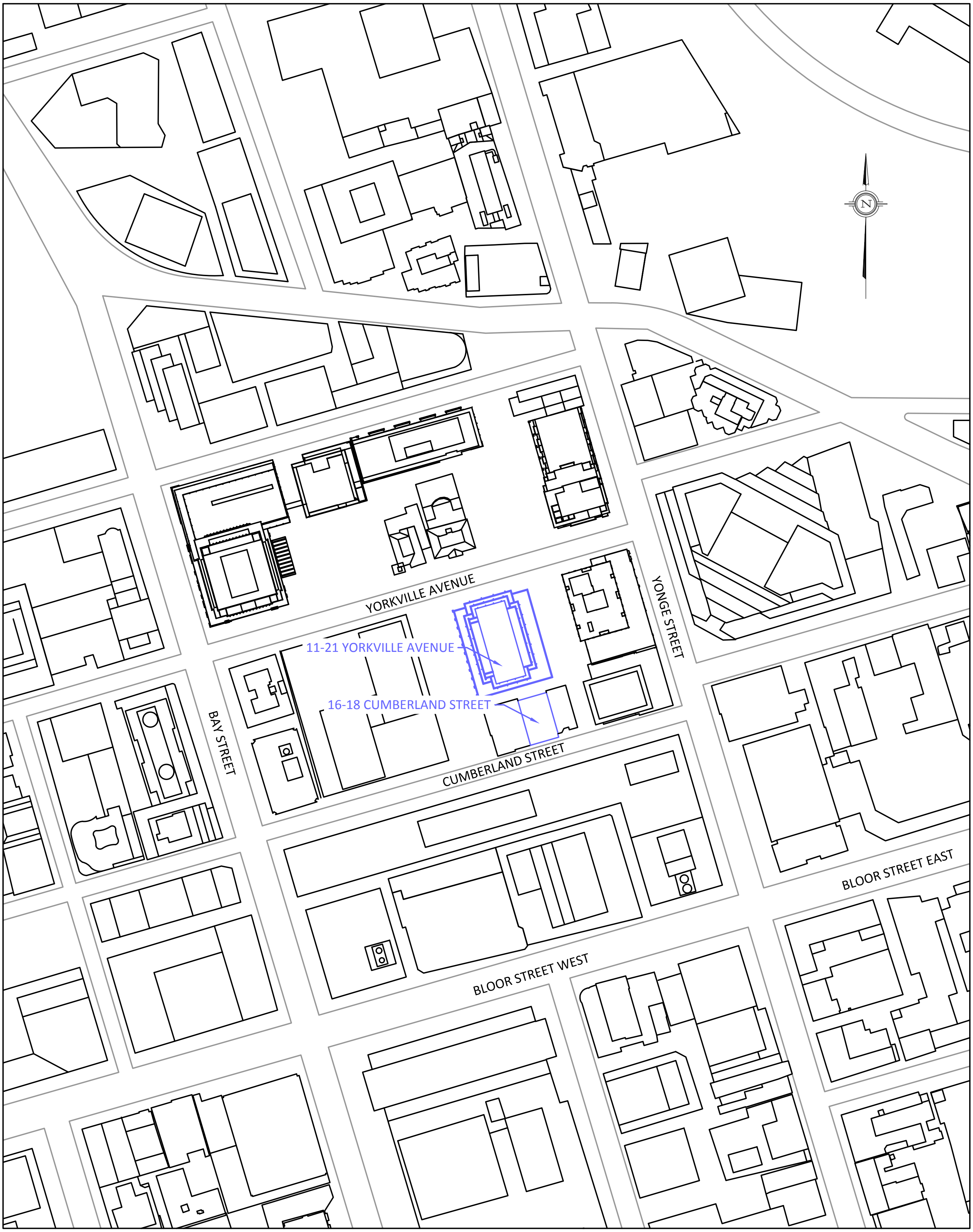
PHOTOGRAPH 2: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING UPWIND



PHOTOGRAPH 3: CLOSE-UP VIEW OF STUDY MODEL LOOKING NORTHEAST



PHOTOGRAPH 4: CLOSE-UP VIEW OF STUDY MODEL LOOKING SOUTHWEST



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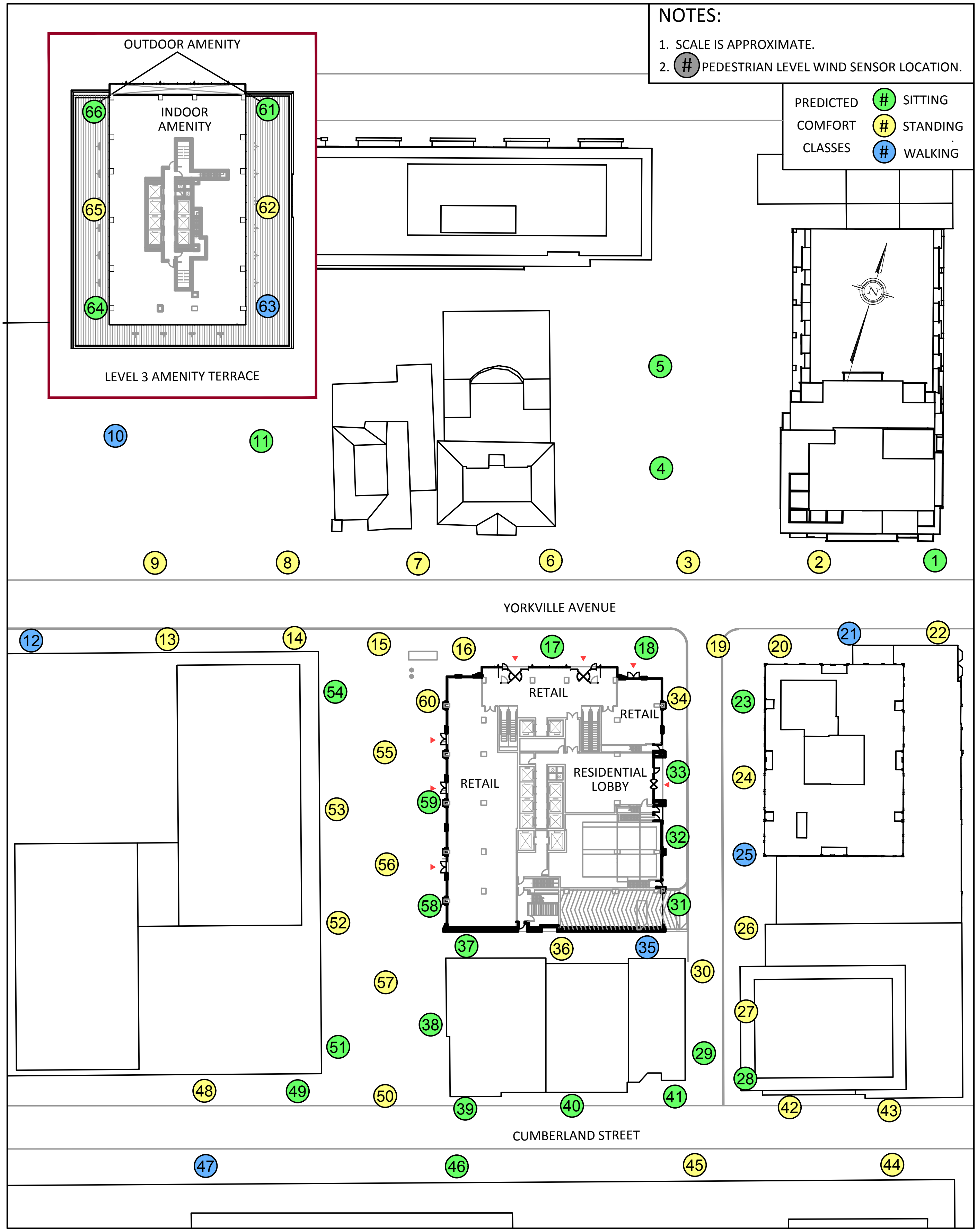
PROJECT	11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:2500 (APPROX.)	DRAWING NO.	GWE17-092-PLW-2
DATE	MARCH 7, 2018	DRAWN BY	B.J.

DESCRIPTION

FIGURE 1:
SITE PLAN AND SURROUNDING CONTEXT



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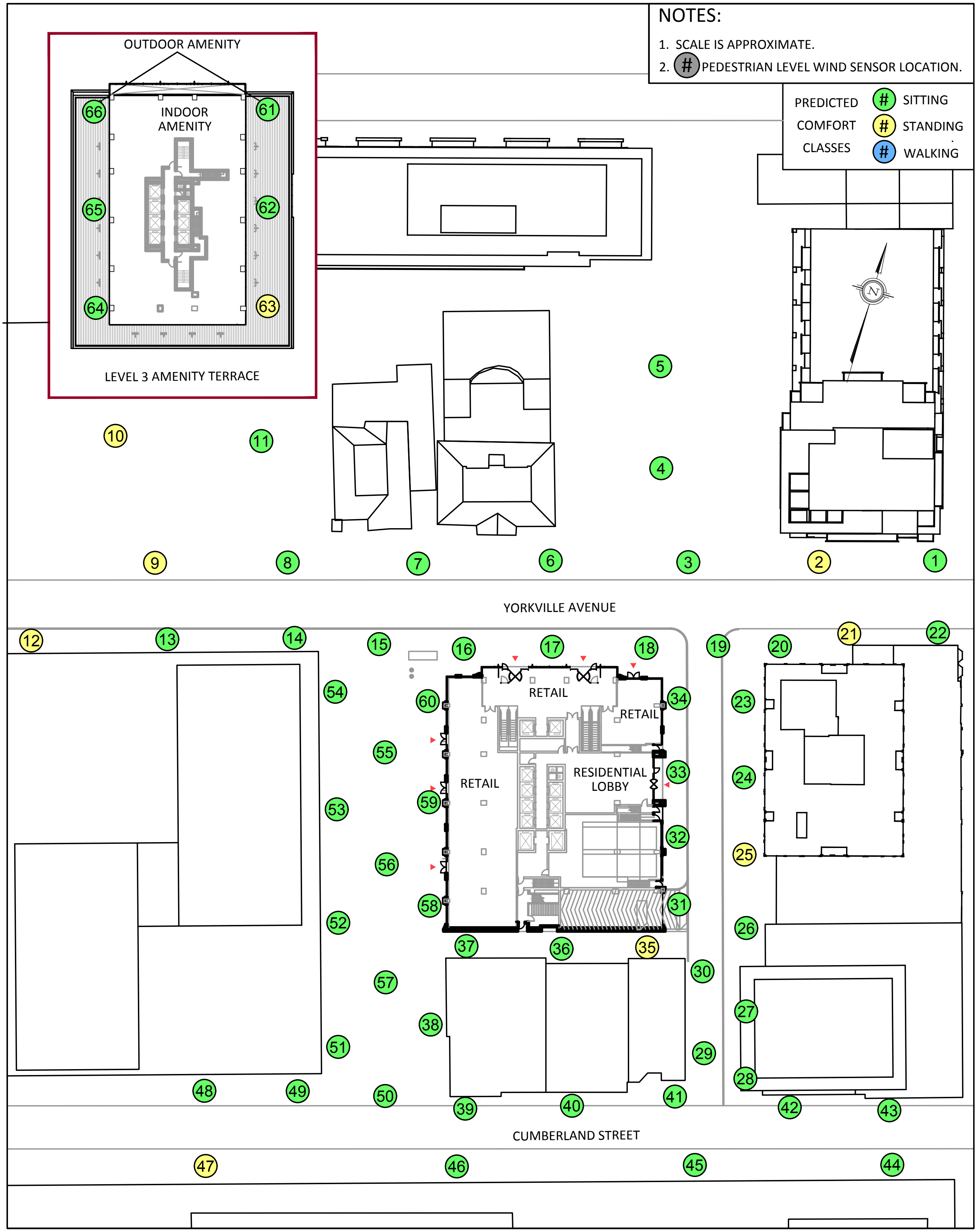
PROJECT: 11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 2: SPRING PEDESTRIAN COMFORT PREDICTIONS
SCALE: 1:900 (APPROX.)	DRAWING NO.: GWE17-092-PLW-2	
DATE: MARCH 7, 2018	DRAWN BY: B.J.	



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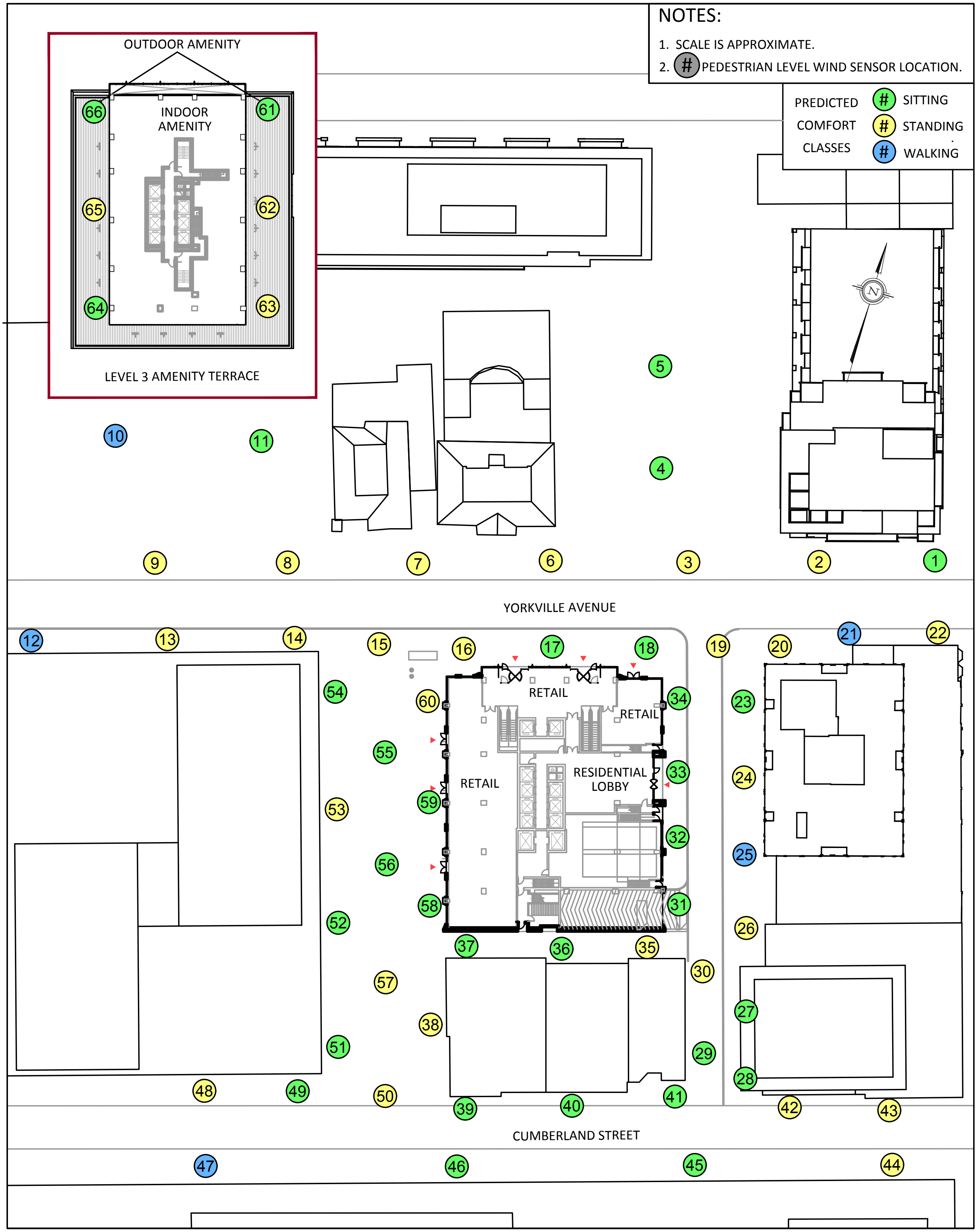
PROJECT	11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET PEDESTRIAN LEVEL WIND STUDY
SCALE	1:900 (APPROX.)
DRAWING NO.	GWE17-092-PLW-3
DATE	MARCH 7, 2018
DRAWN BY	B.J.
DESCRIPTION	FIGURE 3: SUMMER PEDESTRIAN COMFORT PREDICTIONS



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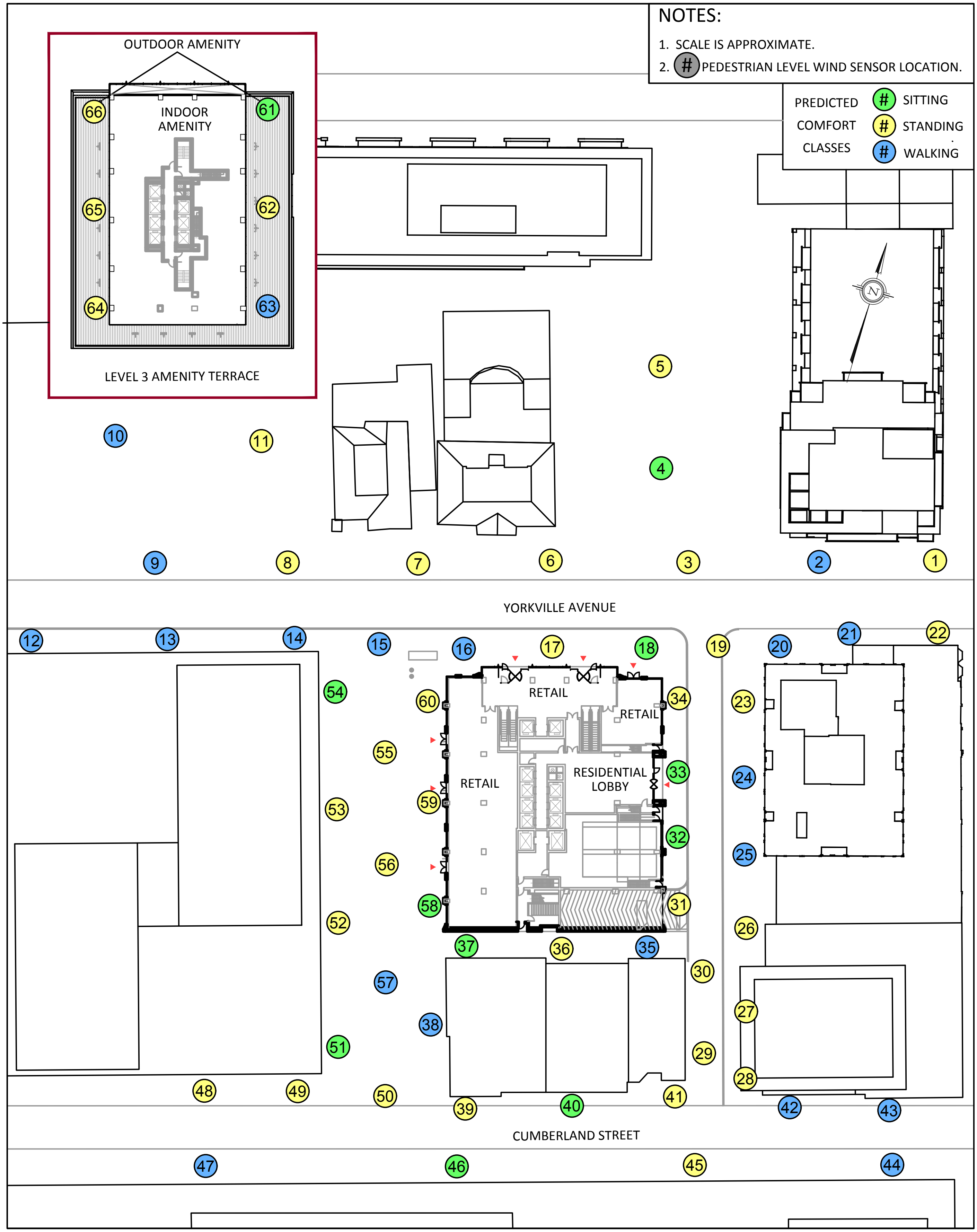
PROJECT: 11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET PEDESTRIAN LEVEL WIND STUDY	DESCRIPTION: FIGURE 4: AUTUMN PEDESTRIAN COMFORT PREDICTIONS
SCALE: 1:900 (APPROX.)	DRAWING NO. GWE17-092-PLW-4
DATE: MARCH 7, 2018	DRAWN BY: B.J.



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PROJECT	11-21 YORKVILLE AVENUE & 16-18 CUMBERLAND STREET PEDESTRIAN LEVEL WIND STUDY
SCALE	1:900 (APPROX.)
DRAWING NO.	GWE17-092-PLW-5
DATE	MARCH 7, 2018
DRAWN BY	B.J.
DESCRIPTION	FIGURE 5: WINTER PEDESTRIAN COMFORT PREDICTIONS

APPENDIX A

WIND TUNNEL SIMULATION OF THE NATURAL WIND

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 m to 600 m.

Simulating real wind behaviour in a wind tunnel requires simulating the variation of mean wind speed with height, simulating the turbulence intensity, and matching the typical length scales of turbulence. It is the ratio between wind tunnel turbulence length scales and turbulence scales in the atmosphere that determines the geometric scales that models can assume in a wind tunnel. Hence, when a 1:200 scale model is quoted, this implies that the turbulence scales in the wind tunnel and the atmosphere have the same ratios. Some flexibility in this requirement has been shown to produce reasonable wind tunnel predictions compared to full scale. In model scale the mean and turbulence characteristics of the wind are obtained with the use of spires at one end of the tunnel and roughness elements along the floor of the tunnel. The fan is located at the model end and wind is pulled over the spires, roughness elements and model. It has been found that, to a good approximation, the mean wind profile can be represented by a power law relation, shown below, giving height above ground versus wind speed.

$$U = U_g \left(\frac{Z}{Z_g} \right)^{\alpha}$$

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

Figure A1 plots three such profiles for the open country, suburban and urban exposures.

The exponent α varies according to the type of terrain; α = 0.14, 0.25 and 0.33 for open country, suburban and urban exposures respectively. Figure A2 illustrates the theoretical variation of turbulence in full scale and some wind tunnel measurement for comparison.

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***, $\boldsymbol{U_{10}}$ 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.

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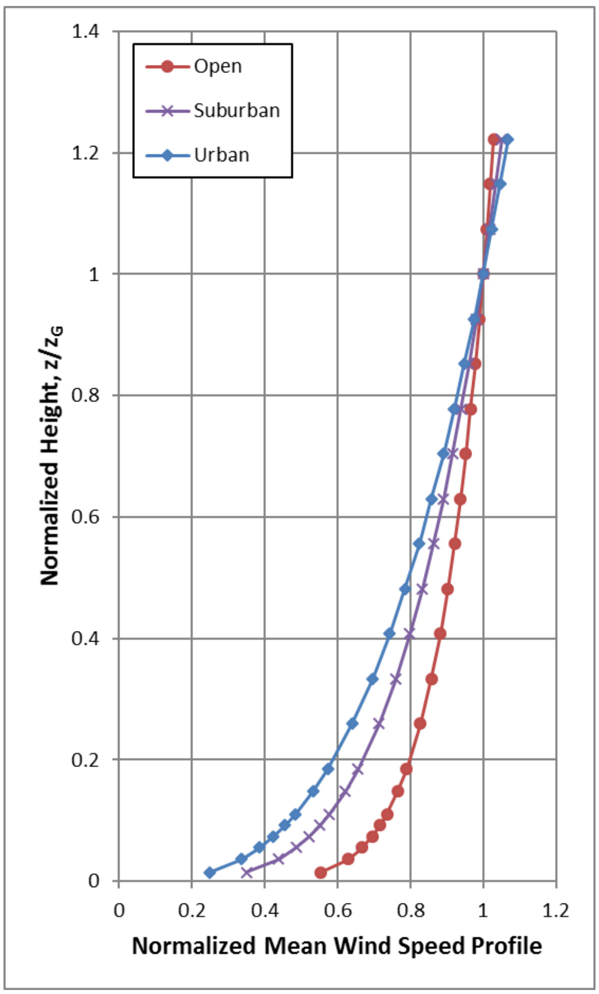


Figure A1: Mean Wind Speed Profiles

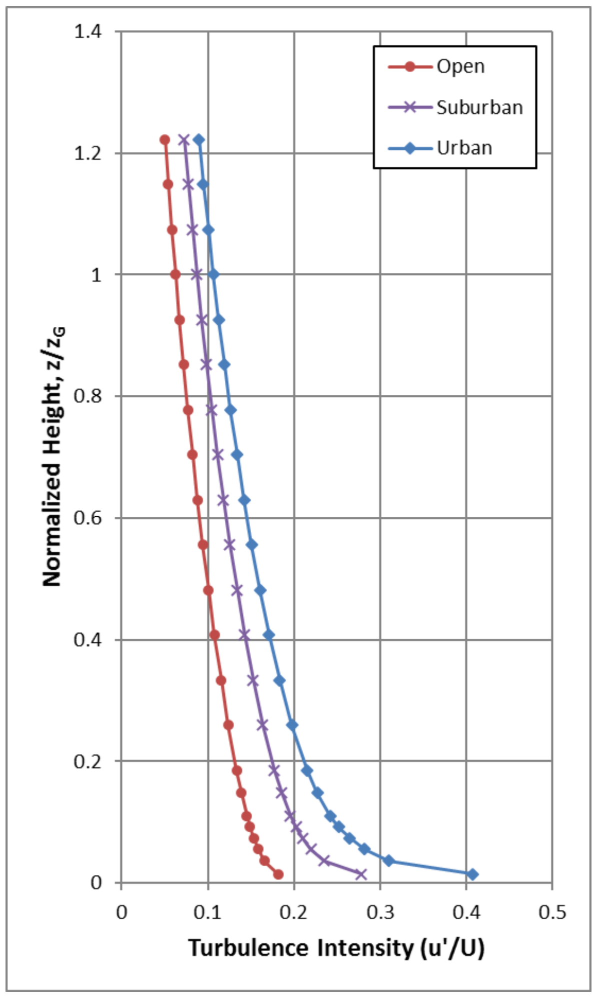


Figure A2: Turbulence Intensity Profiles

APPENDIX B

PEDESTRIAN LEVEL WIND MEASUREMENT METHODOLOGY

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 B1. This data is analyzed to extract the mean, root-mean-square (rms) and the peak of the signal. The peak value, or gust wind speed, is formed by averaging a number of peaks obtained from sub-intervals of the sampling period. The mean and gust speeds are then normalized by the wind tunnel gradient wind speed, which is the speed at the top of the model boundary layer, to obtain mean and gust ratios. At each location, the measurements are repeated for 36 wind directions to produce normalized polar plots, which will be provided upon request.

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

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

Where,

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

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

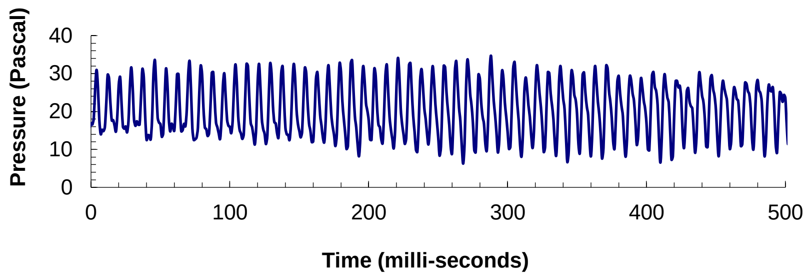
$$P_N(>20) = \Sigma_\theta P\left[\frac{(>20)}{\left(\frac{U_N}{U_g}\right)}\right]$$

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

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 B1: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR



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