Pedestrian Level Wind Study

159 Parkdale Avenue

Ottawa, Ontario

REPORT: *GmE* 12-086-PLW

Prepared For:

Phil Castro, MCIP, RPP
Planning and Land Development
Richcraft Group of Companies
2280 St. Laurent Boulevard
Ottawa, Ontario
K1G 4K1

Prepared By:

Justin Ferraro, EIT, Project Manager
Haiye Lou, Ph.D., M.Eng., Senior Engineer
Vincent Ferraro, M.Eng., P.Eng., Principal

September 6, 2012

EXECUTIVE SUMMARY

This report describes a pedestrian level wind study undertaken to assess wind conditions for 159 Parkdale Avenue in Ottawa, Ontario. The study involves simulation of wind speeds for selected key wind directions in a three-dimensional (3D) computer model using the Computational Fluid Dynamics (CFD) technique. The results are combined with meteorological data to assess pedestrian comfort at key pedestrian areas, including building access points and public pathways around the building at grade level. The results and recommendations derived from these considerations are summarized in the following paragraphs and detailed in the subsequent report. Our work was performed in accordance with the terms of *GmE* proposal # 12-129P dated August 10, 2012, and is based on architectural drawings provided by Roderick Lahey Architect Inc. in August of 2012, surrounding context data obtained from in-house archives, and aerial images to obtain site exposure information.

Based on CFD test results, interpretation, and experience with similar developments in Ottawa, we conclude that the wind conditions at grade will be suitable for the intended uses over virtually all areas of the site. Due to localized pockets of wind conditions that exceed the comfort criteria for standing and walking, mitigation is recommended for the following locations:

- The retail entrances along the building's south façade (sensors 9 and 11); and
- A section of public sidewalk at the intersection of Parkdale Avenue and Lyndale Avenue (sensor 12).

Section 5.2 of this report presents recommended mitigation options to reduce wind flow at grade. Adoption of the recommended measures will improve conditions to levels fully acceptable for the intended use of the affected areas. The recommended mitigation options can be explored in cooperation with the design team to ensure their conformance with municipal and architectural design objectives. Notably, within the context of typical weather patterns, excluding severe local storm events, (such as tornadoes and downbursts), no areas over the study site were found to experience conditions that could be considered dangerous or unsafe.

TABLE OF CONTENTS

1. INTRODUCTION 1

2. TERMS OF REFERENCE 1

3. OBJECTIVES 2

4. STUDY METHODOLOGY 2

4.1 Pedestrian Level Winds 3
4.2 Wind Speed Measurements 3
4.3 Meteorological Data Analysis 4
4.4 Pedestrian Comfort Assessment 6

5. RESULTS 9

5.1 Pedestrian Comfort Suitability 9
5.2 Summary of Significant Findings 16

6. CONCLUSIONS 18

RENDERINGS 19
FIGURES 21
APPENDICES:

Appendix A: Raw Data from CFD Simulations
Appendix B: CFD and Wind Tunnel Simulation of the Natural Wind
Appendix C: Pedestrian Level Wind Measurement Methodology

1. INTRODUCTION

Gradient Microclimate Engineering Inc. (*GmE*) was retained by Richcraft Group of Companies to undertake a pedestrian level wind study for 159 Parkdale Avenue in Ottawa, Ontario. This report summarizes the methodology, results and recommendations related to the pedestrian level wind study. The study involves simulation of wind speeds for selected key wind directions in a three-dimensional (3D) computer model using the Computational Fluid Dynamics (CFD) technique. When combined with meteorological statistics for the site, the raw data obtained from the CFD simulations are used to predict pedestrian comfort at grade. 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 architectural drawings of the study building prepared by Roderick Lahey Architect Inc. in August 2012, as well as context data obtained from in-house archives, and aerial images to obtain site exposure information.

2. TERMS OF REFERENCE

The development will be located on the northeast quadrant of the intersection of Parkdale Avenue and Lyndale Avenue, north of Scott Street and approximately half a kilometre south of the Ottawa River shoreline. The planned twenty-eight (28) storey development includes a four (4) storey podium and a setback tower served with balconies at all levels. The building is aligned approximately north-south, with the long axis of its rectangular floor plate parallel to Parkdale Avenue. The main residential entrances are located along the west elevation, which front onto Parkdale Avenue, while vehicle parking will be accommodated within a below-grade multi-level parking garage with egress/ingress provided via ramp access at the building's southeast corner. At the 5th level, the tower steps back over the podium to create a large terrace/green roof area on the north side, while penthouse setbacks are present for the top three levels.

Regarding wind exposure, the study building is surrounded in close proximity by low and mid-height Government of Canada buildings to the west, low and mid-height commercial and residential buildings to the south and north, and a cluster of low-height residential dwellings to the east. At greater distances, the site is situated approximately 2 kilometers (km) west-southwest from the downtown fringe, and is surrounded by the Ottawa River to the north and low-rise residential properties for most other directions. As such, the existing massing creates generally suburban wind exposures for the northeast, clockwise through to the west quadrants, and open exposures resulting from the open fetches of the Ottawa River for the remaining cardinal directions.

With respect to pedestrian winds, key grade-level areas under investigation include surrounding City of Ottawa sidewalks, main building entrances, exit doors along the south and east elevations, the area in the vicinity of the parking ramp, as well as the bicycle storage and maintenance access doors along the east elevation. A site plan is provided in Figure 1, while Renderings 1 and 2 respectively present isometric renderings of the development and study site complete with surrounding context supplied to the CFD environment.

3. OBJECTIVES

The principal objectives of this study are to determine pedestrian level comfort conditions at grade, to identify areas where future wind conditions may interfere with the intended uses of outdoor spaces, and to recommend appropriate mitigation options.

4. STUDY METHODOLOGY

The approach followed to quantify pedestrian wind conditions over the site is based on CFD simulations of wind speeds at selected locations on a reduced scale physical model within a virtual environment. The model includes the study building and all relevant surrounding massing and topography. The raw data for all simulated wind directions are synthesized with a statistical model of the Ottawa wind climate, which is used to develop predictions of pedestrian wind comfort over the study site. The following section describes the analysis process, including a background discussion of pedestrian comfort.

4.1 Pedestrian Level Winds

A PLW assessment was performed to determine the influence of the wind environment over the proposed development site. Pedestrian comfort predictions, based on the mechanical effects of wind, were determined by combining measured wind speed data from CFD simulations with statistical weather data obtained from MacDonald-Cartier International Airport, Ottawa.

The general concept and approach to CFD modelling is to represent building and topographic details in the immediate vicinity of the study site on the surrounding model, and to create suitable atmospheric wind profiles at the model boundary. The wind profiles are designed to have similar mean and turbulent wind properties consistent with actual site exposures. An industry standard practice is to omit trees and other landscape elements from the wind tunnel and CFD models, due to the difficulty of providing accurate representation and because the approach produces slightly conservative results.

4.2 Wind Speed Measurements

The PLW assessment was performed by testing a total of twenty-two (22) representative wind sensor locations covering key areas at grade level. This was achieved by simulating wind flows and gathering velocity data over a CFD model of the site for eight (8) wind directions. The CFD simulation model was centered on the study building, complete with surrounding massing within a diameter of approximately 640 m. Eight wind directions were selected for the simulations based on topographic complexity and for their alignment with statistically prominent directions. Specifically, the simulated wind directions include: 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°. By convention in wind engineering, wind direction refers to the wind origin (e.g., a north wind blows from north to south).

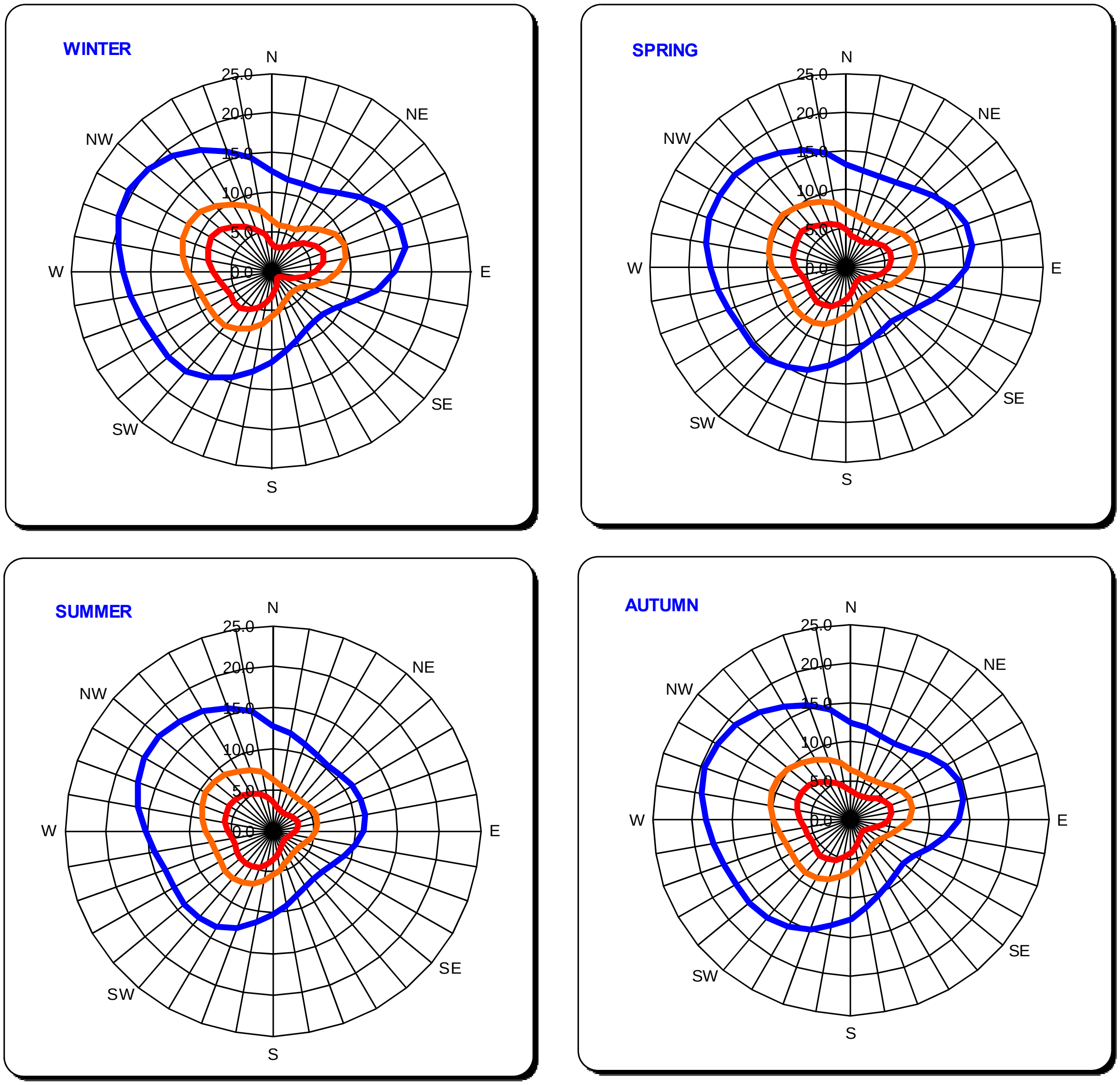
Mean and peak wind speed data obtained from each location and wind direction for all eight simulations were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade were referenced to the wind speed at gradient height to generate mean and peak velocity ratios, which were used to calculate full-scale values. The gradient height represents the theoretical depth of the boundary layer of the Earth's atmosphere, above which the mean wind speed remains constant. Appendix A contains polar plots of velocity ratio data for each sensor location as a function of wind direction, while Appendices B and C provide greater detail of the theory behind wind speed measurements. Sensor locations used to investigate wind conditions are illustrated in Figures 2 through 6, and are also provided in Section 5.

4.3 Meteorological Data Analysis

A statistical model for winds in Ottawa was developed from approximately 40-years of hourly meteorological wind data recorded at MacDonald-Cartier 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: (i) determine the statistically prominent wind directions and corresponding speeds; and (ii) 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, not according to the traditional calendar method.

The statistical model of the Ottawa area wind climate, which indicates the directional character of local winds on a seasonal basis, is illustrated on the following page. The plots illustrate three contours representing three probability levels superimposed on a polar grid of wind speed at gradient height in meters/second (m/s). The three contours represent the mean hourly wind speed occurring once per month (innermost contour), once per year, and once every ten years (outermost contour). The preferred wind directions can be identified as the angular position where the given contour has the largest radial distance from the centre. For Ottawa, the most common winds occur for westerly wind directions, followed by those from the east. The directional preference and relative magnitude of wind speed changes somewhat from season to season.

SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES
MACDONALD-CARTIER INTERNATIONAL AIRPORT, OTTAWA



Notes:

1. Radial distances indicate wind speed in metres/second at a height of 10 m above grade.
2. A point along the innermost contour represents the wind speed exceeded on average 0.1% of the time within a 10° sector centered on that direction.
3. The middle and outermost contours represent probability levels of 0.01% and 0.001%, respectively.

4.4 Pedestrian Comfort Assessment

Pedestrian comfort criteria are based on mechanical wind effects without consideration of other meteorological conditions (i.e. temperature, relative humidity). The criteria 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), occurring more than 70% of the time, are acceptable for sedentary activities, including sitting.

ii) **Standing** – Wind speeds below 22 km/h (i.e. 0 - 22 km/h), occurring 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 target for walking (described in the previous statement). 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 0.01% 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, which is classified as the ‘dangerous’ level.

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 criteria because people tend to be more sensitive to wind gusts than to steady winds for lower wind speed ranges. For strong winds approaching dangerous levels, this effect is less important, because the mean wind can also cause problems for pedestrians. The gust speed ranges are selected based on “The Beaufort Scale” (presented on the following page), which describes the effects of forces produced by varying wind speed levels on objects.

THE BEAUFORT SCALE

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

Experience and research on people's perception of mechanical wind effects has shown that if the wind speed levels are exceeded for more than 20% to 30% 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 recommended comfort class (as dictated by the location type). An overview of common pedestrian location types and their recommended comfort classes are summarized on the following page.

DESIRED PEDESTRIAN COMFORT CLASSES FOR VARIOUS LOCATION TYPES

Location Types	Desired Comfort Classes
Entrance With A Vestibule / Revolving Door	Walking
Entrance Without A Vestibule / Revolving Door	Standing
Building Exits	Walking
Public Sidewalks	Walking
Pedestrian Walkways	Walking
Private Outdoor Amenity Spaces	Sitting
Cafés / Patios / Benches / Gardens	Sitting
Public Monuments	Standing
Children's Play Areas	Standing
Outdoor Exercise Areas	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 criteria.
- **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 criteria.
- **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

5.1 Pedestrian Comfort Suitability

Tables 1 through 6, 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 criteria-defined ranges. Pedestrian comfort is determined by the percentage of time that wind speeds at each sensor location will fall within the stated ranges. A higher numerical value equates to a greater percentage of time that wind speeds will be lower; and correspondingly more comfortable wind conditions.

The predicted values within each Table are accompanied by a suitability assessment that includes the predicted comfort class, the location type, the desired comfort class, and a suitability descriptor. The predicted comfort class is determined by the predicted wind speed range percentages, while the location type and the desired comfort class are determined from 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 6, 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. The colour codes indicate the predicted comfort class at each tested sensor location, as dictated by the noted Tables. Conditions suitable for sitting are represented by the colour green, standing by yellow, walking by blue and uncomfortable by magenta. Figures 7 through 14 illustrate sample CFD simulations of velocity distributions at grade over the study site for the statistically prominent wind directions. Measured mean and gust velocity ratios, which constitute the raw data upon which the results are based, are illustrated in Appendix A in the form of polar plots.

TABLE 1: SUMMARY OF PEDESTRIAN COMFORT SUITABILITY

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		0-14	0-22	0-30				
Limiting Criteria (% of Time)		≥70%	≥80%	≥80%				
Sensor #1	**Spring**	42	61	81	Walking	Pedestrian Walkway	Walking	Acceptable
	Summer	63	83	93	Standing			
	Autumn	52	75	88	Walking			
	Winter	40	65	81	Walking			
Sensor #2	**Spring**	57	75	91	Walking	Pedestrian Walkway	Walking	Acceptable
	Summer	70	88	96	Sitting			
	Autumn	64	85	94	Standing			
	Winter	54	78	90	Walking			
Sensor #3	**Spring**	50	70	89	Walking	Parkdale Avenue Sidewalk	Walking	Acceptable
	Summer	65	86	95	Standing			
	Autumn	58	81	93	Standing			
	Winter	48	74	89	Walking			
Sensor #4	**Spring**	58	75	91	Walking	Pedestrian Walkway	Walking	Acceptable
	Summer	72	89	96	Sitting			
	Autumn	66	85	94	Standing			
	Winter	57	80	90	Standing			

159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS

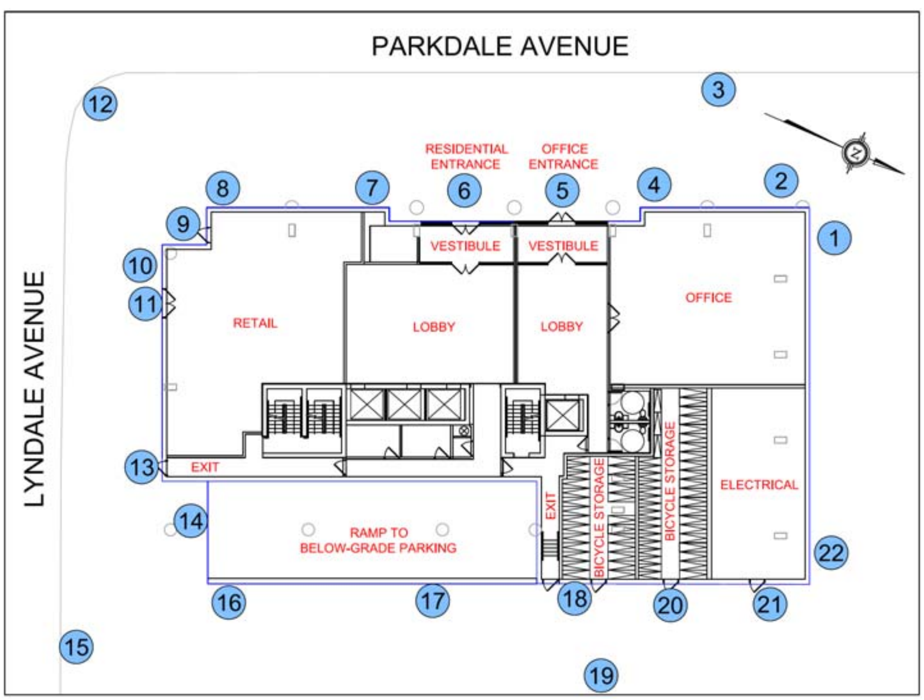


TABLE 2: SUMMARY OF PEDESTRIAN COMFORT SUITABILITY

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		0-14	0-22	0-30				
Limiting Criteria (% of Time)		≥70%	≥80%	≥80%				
Sensor #5	Spring	58	77	92	Walking	Main Office Entrance	Walking	Acceptable
	Summer	73	91	97	Sitting			
	Autumn	67	87	96	Standing			
	Winter	56	80	92	Standing			
Sensor #6	Spring	57	75	91	Walking	Main Residential Entrance	Walking	Acceptable
	Summer	70	89	96	Sitting			
	Autumn	64	85	94	Standing			
	Winter	53	77	90	Walking			
Sensor #7	Spring	55	72	88	Walking	Pedestrian Walkway	Walking	Acceptable
	Summer	70	87	95	Sitting			
	Autumn	63	83	92	Standing			
	Winter	52	74	87	Walking			
Sensor #8	Spring	53	68	85	Walking	Pedestrian Walkway	Walking	Acceptable
	Summer	64	82	92	Standing			
	Autumn	58	80	88	Standing			
	Winter	48	68	82	Walking			

159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS

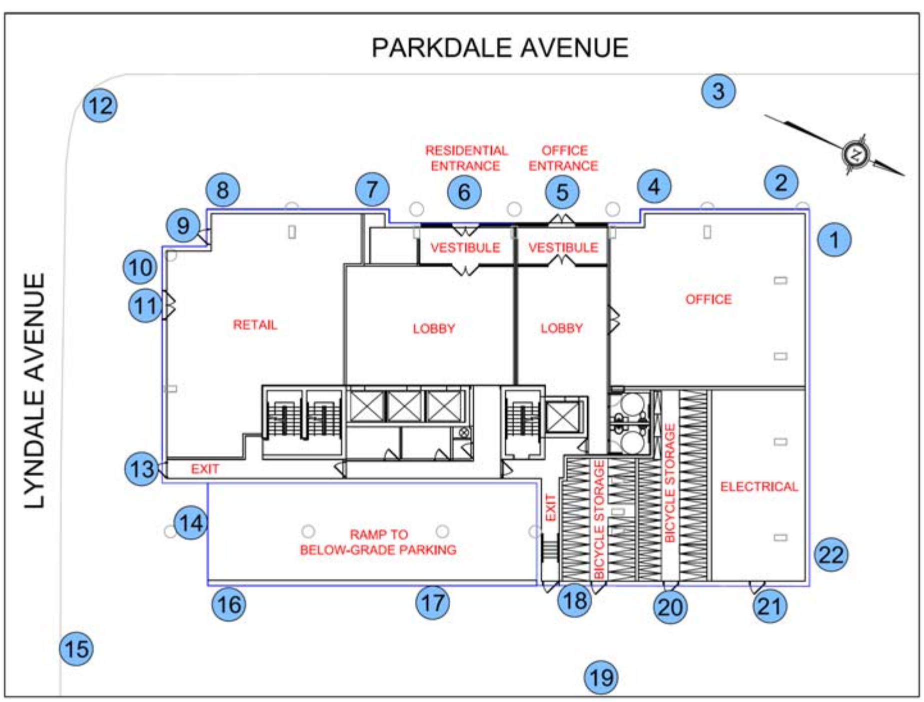


TABLE 3: SUMMARY OF PEDESTRIAN COMFORT SUITABILITY

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		0-14	0-22	0-30				
Limiting Criteria (% of Time)		≥70%	≥80%	≥80%				
Sensor #9	Spring	54	73	89	Walking	Retail Entrance	Standing	Acceptable with Mitigation (Refer to Section 5.2)
	Summer	68	86	94	Standing			
	Autumn	61	81	91	Standing			
	Winter	50	74	86	Walking			
Sensor #10	Spring	47	64	81	Walking	Pedestrian Walkway	Walking	Acceptable
	Summer	62	81	90	Standing			
	Autumn	53	74	85	Walking			
	Winter	44	66	80	Walking			
Sensor #11	Spring	47	65	84	Walking	Retail Entrance	Standing	Acceptable with Mitigation (Refer to Section 5.2)
	Summer	62	83	93	Standing			
	Autumn	53	76	88	Walking			
	Winter	45	69	84	Walking			
Sensor #12	Spring	38	56	77	Uncomfortable	Parkdale Avenue Sidewalk	Walking	Acceptable with Mitigation (Refer to Section 5.2)
	Summer	57	78	89	Walking			
	Autumn	47	69	83	Walking			
	Winter	36	59	75	Uncomfortable			

159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS

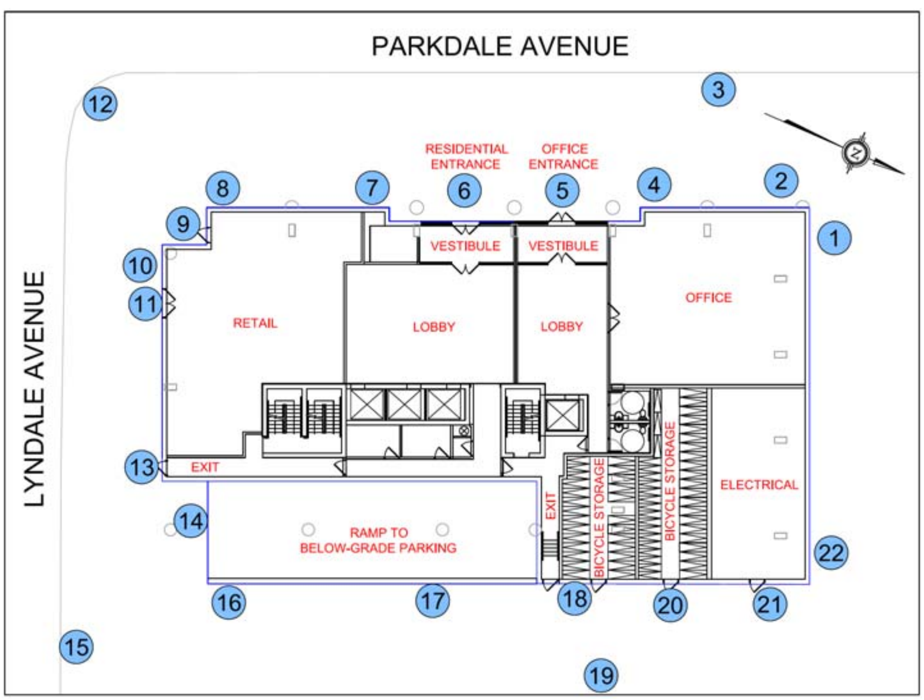


TABLE 4: SUMMARY OF PEDESTRIAN COMFORT SUITABILITY

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		0-14	0-22	0-30				
Limiting Criteria (% of Time)		≥70%	≥80%	≥80%				
Sensor #13	**Spring**	39	58	80	Walking	Exit Door	Walking	Acceptable
	Summer	56	78	90	Walking			
	Autumn	47	71	85	Walking			
	Winter	37	63	80	Walking			
Sensor #14	**Spring**	50	71	90	Walking	Ramp to Below-Grade Parking	Walking	Acceptable
	Summer	68	88	96	Standing			
	Autumn	59	82	93	Standing			
	Winter	48	75	90	Walking			
Sensor #15	**Spring**	42	61	82	Walking	Lyndale Avenue Sidewalk	Walking	Acceptable
	Summer	70	80	91	Sitting			
	Autumn	50	73	87	Walking			
	Winter	39	64	80	Walking			
Sensor #16	**Spring**	53	71	89	Walking	Laneway	Walking	Acceptable
	Summer	74	90	97	Sitting			
	Autumn	64	85	94	Standing			
	Winter	53	77	90	Walking			

159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS

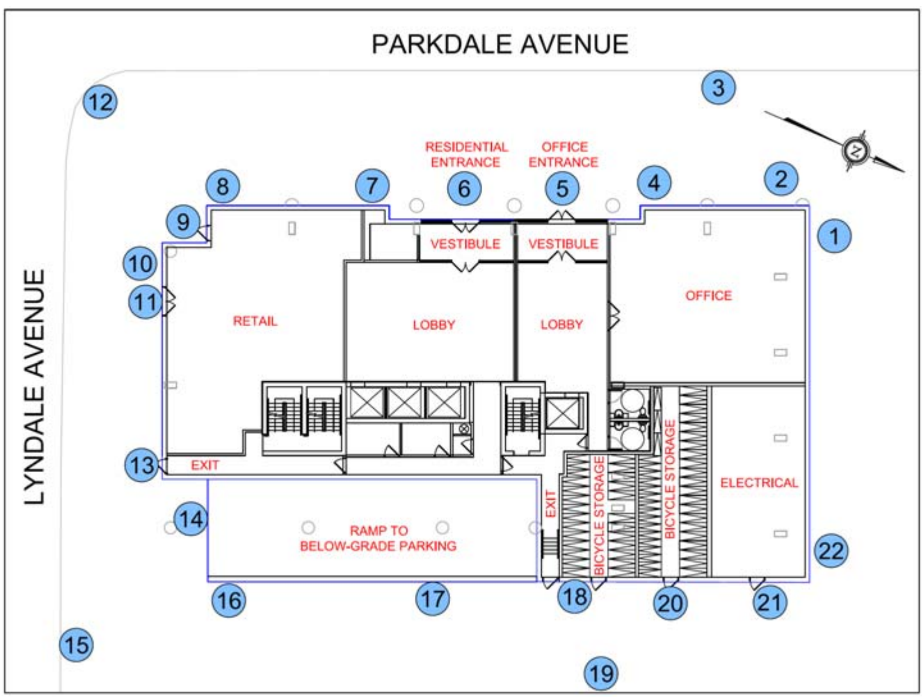


TABLE 5: SUMMARY OF PEDESTRIAN COMFORT SUITABILITY

Activity Type		Sitting	Standing	Walking	Predicted Comfort Class	Location Type	Desired Comfort Class	Suitability
Wind Speed Range (km/h)		0-14	0-22	0-30				
Limiting Criteria (% of Time)		≥70%	≥80%	≥80%				
Sensor #17	Spring	60	80	95	Standing	Laneway	Walking	Acceptable
	Summer	78	94	99	Sitting			
	Autumn	70	91	98	Sitting			
	Winter	59	85	95	Standing			
Sensor #18	Spring	57	77	93	Walking	Bicycle Storage Entrance; Exit Door	Walking	Acceptable
	Summer	75	93	98	Sitting			
	Autumn	66	88	96	Standing			
	Winter	56	81	93	Standing			
Sensor #19	Spring	42	61	82	Walking	Laneway	Walking	Acceptable
	Summer	59	81	92	Standing			
	Autumn	50	74	87	Walking			
	Winter	38	64	81	Walking			
Sensor #20	Spring	53	72	90	Walking	Bicycle Storage Entrance	Walking	Acceptable
	Summer	72	90	97	Sitting			
	Autumn	62	84	94	Standing			
	Winter	51	76	90	Walking			

159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS

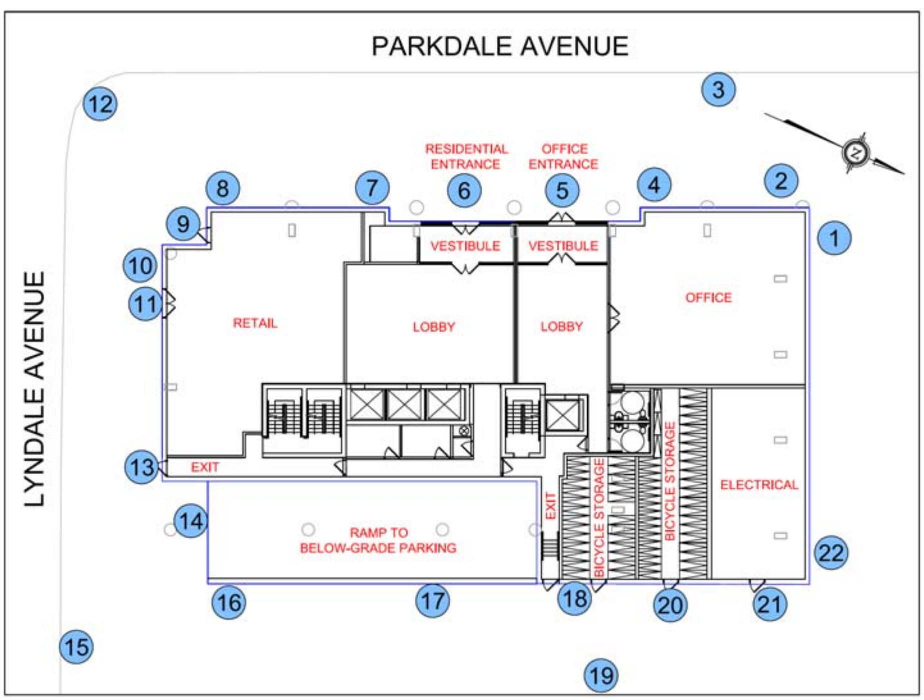
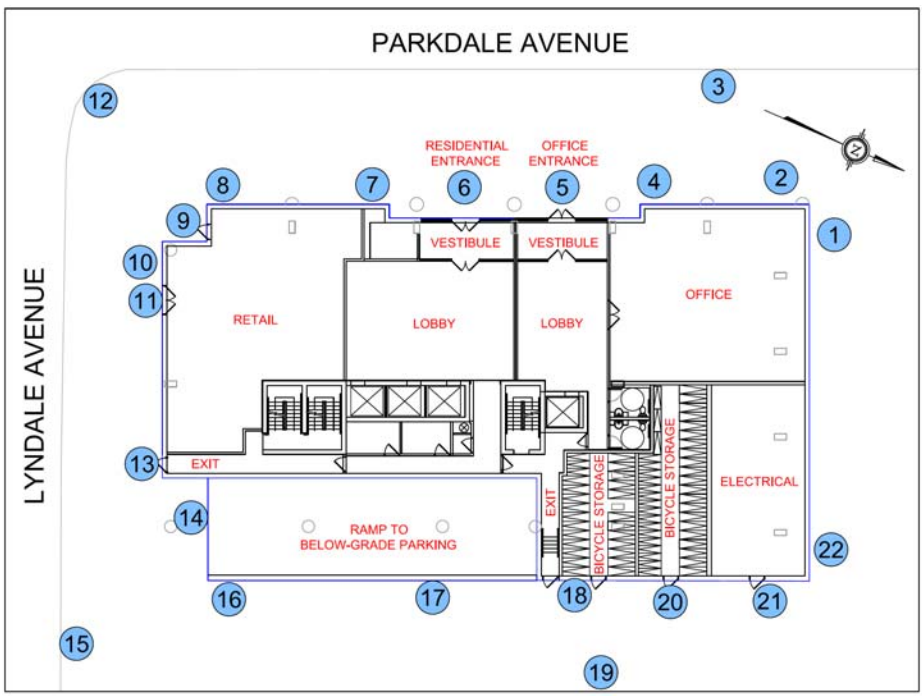


TABLE 6: SUMMARY OF PEDESTRIAN COMFORT SUITABILITY

Activity Type		**Sitting**	**Standing**	**Walking**	**Predicted Comfort Class**	**Location Type**	**Desired Comfort Class**	**Suitability**
Wind Speed Range (km/h)		**0-14**	**0-22**	**0-30**				
Limiting Criteria (% of Time)		**≥70%**	**≥80%**	**≥80%**				
Sensor #21	**Spring**	47	66	85	Walking	Electrical Room Entrance	Walking	Acceptable
	Summer	68	87	95	Standing			
	Autumn	57	80	91	Standing			
	Winter	45	70	85	Walking			
Sensor #22	**Spring**	48	66	84	Walking	Pedestrian Walkway	Walking	Acceptable
	Summer	64	84	93	Standing			
	Autumn	56	77	89	Walking			
	Winter	44	68	80	Walking			

159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS



5.2 Summary of Significant Findings

Through the analysis of the measured data, consideration of local climate data and the suitability comparisons provided in Tables 1 through 6, this section summarizes the most significant findings of the PLW assessment.

Based on wind tunnel test results, interpretation and experience with similar developments in Ottawa, we conclude that the fully developed site will experience a mixture of wind conditions that fall into two (2) general categories that include:

1. **Acceptable**: This designation applies where the predicted wind conditions for a location will be acceptable for the intended pedestrian use of a space on an annual basis (see Tables 1 through 6). These locations will be comfortable and acceptable for common pedestrian activities classified as sitting, standing or walking – as dictated by the location type and associated comfort class. Consequently, no mitigation of winds is required or recommended for these locations.

2. **Acceptable with Mitigation**: Where the predicted wind comfort levels fall short of the criteria-defined targets by small percentages, our experience indicates that the implementation of typical mitigation measures will achieve the target values. These locations include:

   - The retail entrances along the building's south façade (sensors 9 and 11); and
   - A section of public sidewalk in proximity to the intersection of Parkdale Avenue and Lyndale Avenue (sensor 12).

The degree of mitigation required depends on the intended use of an area, the anticipated volume of pedestrian traffic, and the sensitivity of pedestrians within the affected area. Based on the analysis of test data, and drawing from our experience in the field of bluff body aerodynamics, a mitigation strategy is offered on the following page to reduce wind flow at grade that incorporates typical mitigation measures for the areas noted in category (2) above. Adoption of the mitigating strategy will improve wind conditions to acceptable levels according to the pedestrian comfort guidelines in Section 4.4.

Mitigation Strategy: Canopy + Plantings + Vestibule

(i) Introduce a canopy spanning the southwest and south façades of the study building, positioned above locations defined by sensors 8, 9, 10, 11 and 13. The canopy should extend from the noted building façades by no less than 3 m, with a fillet or other defining feature at its southwest intersection (see Rendering 3). The height of the canopy can coincide with the existing canopies positioned over the office and residential entrances on the building's west façade. It should be noted that the introduction of the canopy will effectively replace the two smaller canopies positioned over the retail entrances that were part of the original architectural design.

(ii) Introduce two (2) dense clusters of coniferous plantings, or deciduous trees that keep their leaves during the colder seasons, along the building's west and south façades to provide shelter along walkways. The first cluster of plantings should be parallel to Parkdale Avenue, beginning between sensor locations 7 and 8 and terminating near the building's southwest corner adjacent to sensor location 8. The second cluster of plantings should be parallel to Lyndale Avenue, beginning between sensor locations 8 and 9 and terminating near the building's southeast corner, adjacent to sensor location 13. Both noted clusters must allow for adequate pedestrian movement (i.e., located at least 3 m from the building's west and south façades) and require a minimum height of 2 m to be effective. The recommended extensive plantings are illustrated in Figure 6.

(iii) Recess the entrances into building façades in locations where stronger winds are caused by chanelling and / or downwash wind effects. Specifically, the retail entrance on the building's south façade (sensor 11) is recommended to either be recessed or equipped with a vestibule. In general terms, vestibules serving entrances reduce wind forces on swing doors, thereby making pedestrian access easier and minimizing wear on mechanical components.

Based on experience, we recommend the complete implementation of the mitigation strategy in order to satisfy the intent of mitigation and control wind conditions fully at grade level.

6. CONCLUSIONS

This document summarizes the results of a pedestrian level wind study for 159 Parkdale Avenue in Ottawa, Ontario. This work was performed in accordance with the terms of *GmE* proposal # 12-129P dated August 10th, 2012, as well as industry standard Computational Fluid Dynamics (CFD) testing and data analysis techniques.

Based on CFD test results, interpretation, and experience with similar developments in Ottawa, we conclude that with targeted mitigation, the wind conditions at all ground level areas of the development site can be made acceptable for their intended pedestrian uses year round. Section 5.2 of this report presents a recommended strategy to reduce wind flow at grade that incorporates typical mitigation measures. Adoption of the recommended measures will improve conditions to levels fully acceptable for the intended uses of the affected areas. The recommended mitigation options can be explored in cooperation with the design team to ensure their conformance with municipal and architectural design objectives.

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

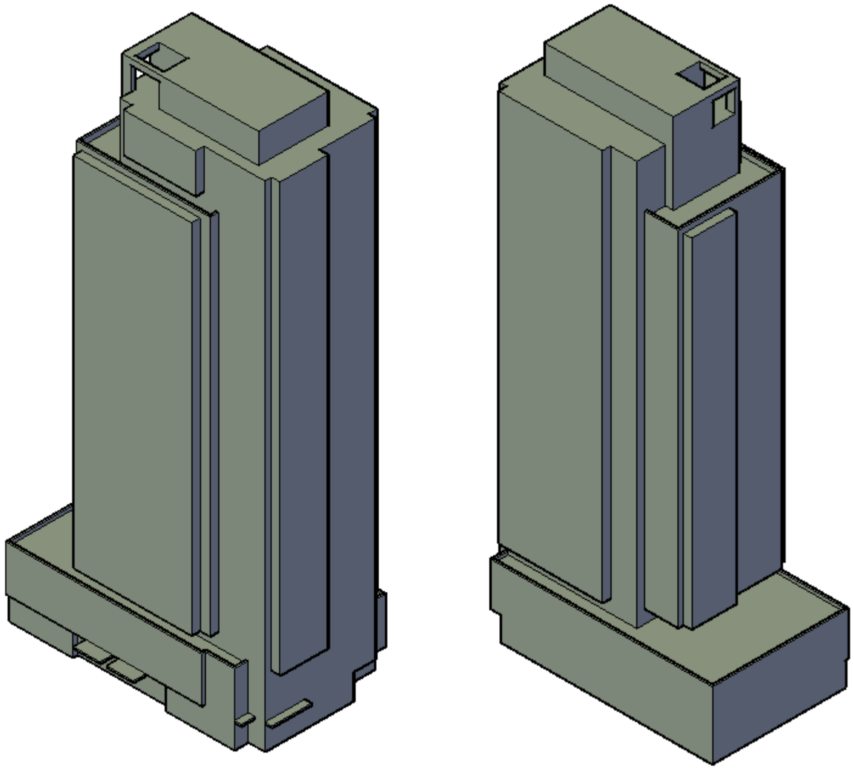
Sincerely,

Gradient Microclimate Engineering Inc.

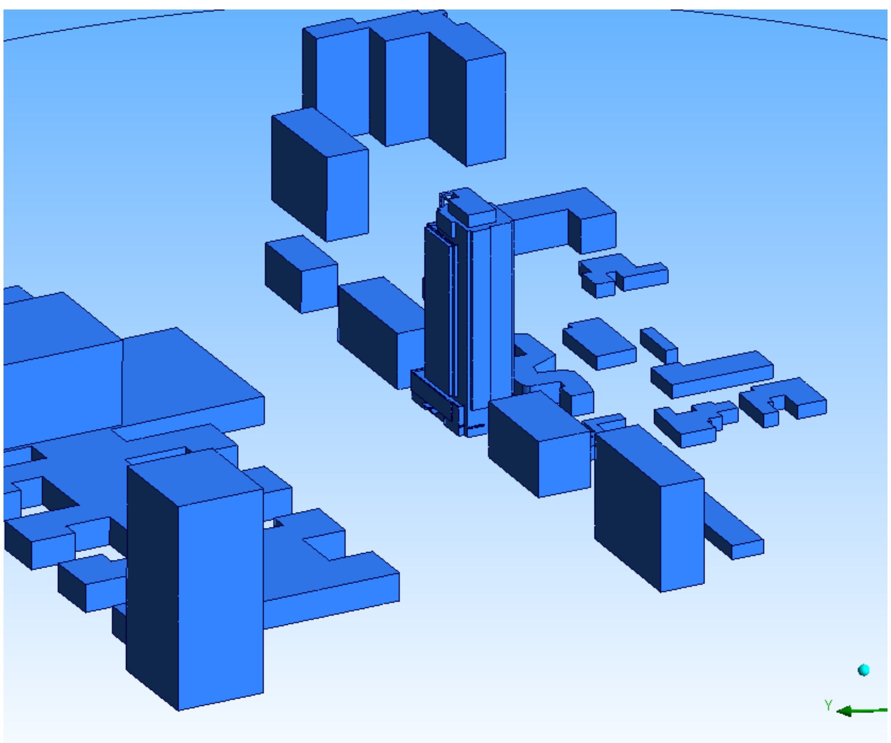
Justin Ferraro, EIT
Project Manager

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

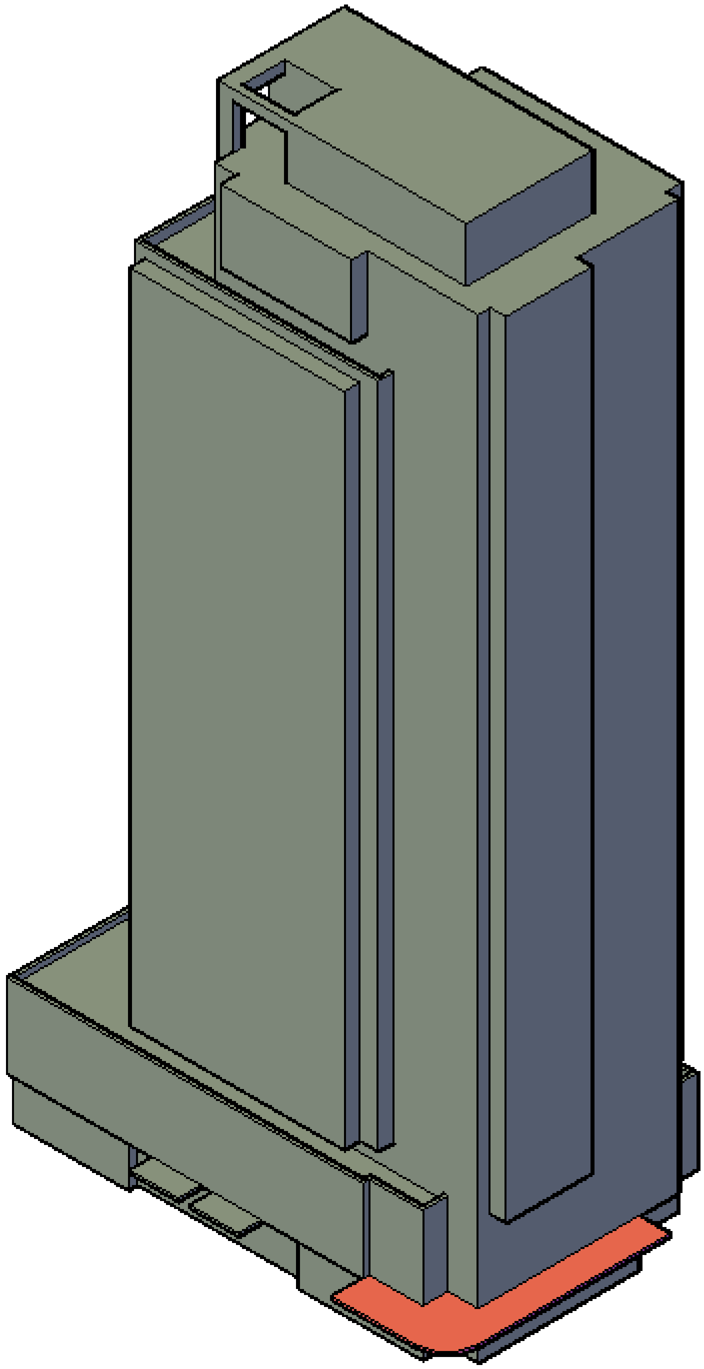
Haiye Lou, Ph.D., M.Eng.
Senior Engineer
GmE 12-086-PLW



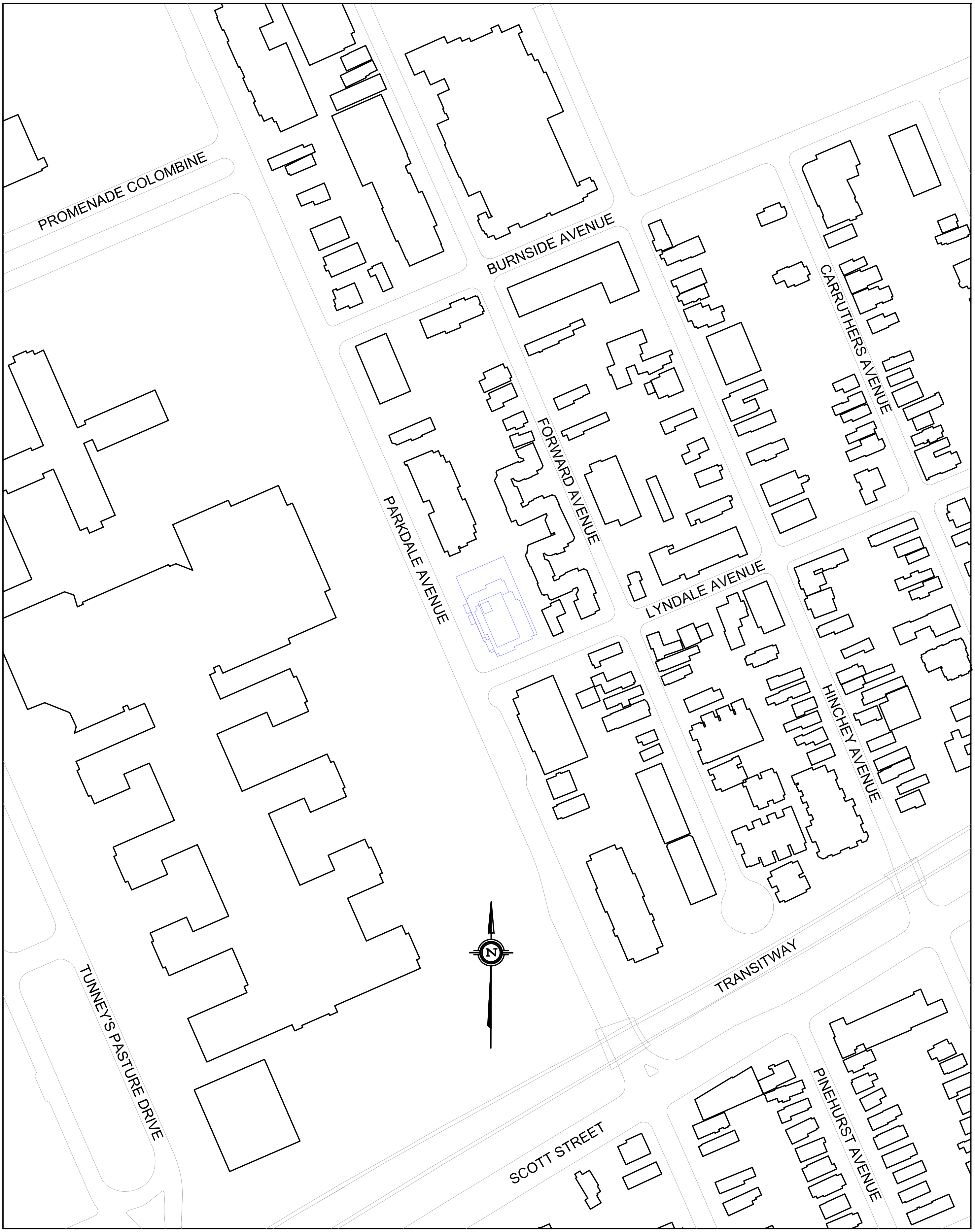
RENDERING 1: CFD MODEL OF 159 PARKDALE AVENUE, ISOMETRICS FROM THE SOUTHWEST (LEFT) AND NORTHEAST (RIGHT)



RENDERING 2: CFD MODEL OF THE STUDY SITE

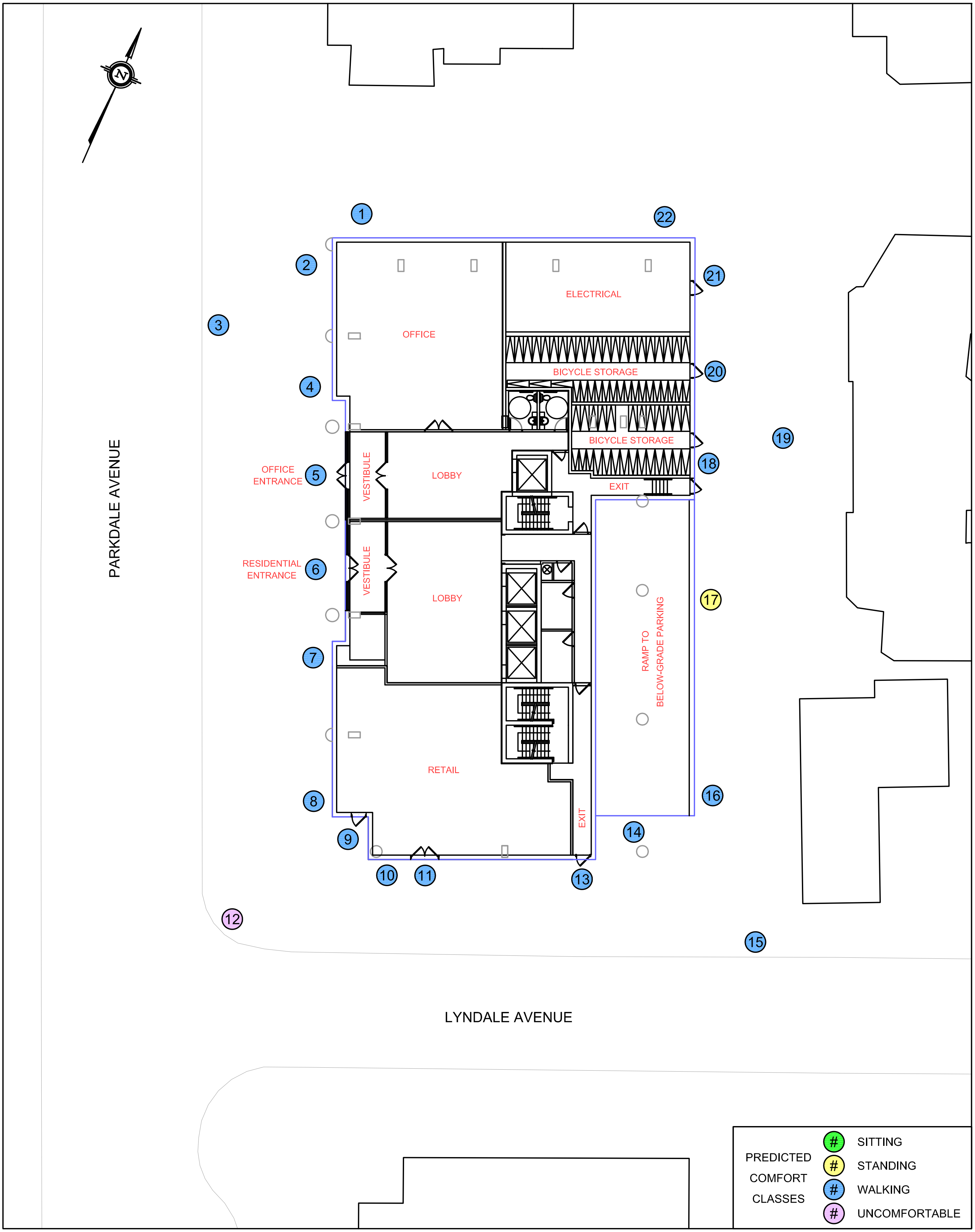


**RENDERING 3: MITIGATION FOR 159 PARKDALE AVENUE,
ISOMETRIC SHOWING RECOMMENDED CANOPY AT BUILDING'S SOUTHWEST CORNER**



GmE Gradient Microclimate Engineering Inc
127 Walgreen Road
Ottawa, Ontario
K0A 1L0
(613) 836-0934

PROJECT		DESCRIPTION
159 PARKDALE AVENUE, OTTAWA - PEDESTRIAN LEVEL WIND STUDY		FIGURE 1: SITE PLAN AND SURROUNDING CONTEXT
SCALE 1:2500 (APPROX.)	DRAWING NO. GmE12-086-PLW-1	
DATE SEPTEMBER 6, 2012	DRAWN BY J.F.	



PREDICTED COMFORT CLASSES	
#	SITTING
#	STANDING
#	WALKING
#	UNCOMFORTABLE

GmE Gradient Microclimate Engineering Inc
127 Walgreen Road
Ottawa, Ontario
K0A 1L0
(613) 836-0934

PROJECT: 159 PARKDALE AVENUE, OTTAWA - PEDESTRIAN LEVEL WIND STUDY

SCALE: 1:350 (APPROX.)

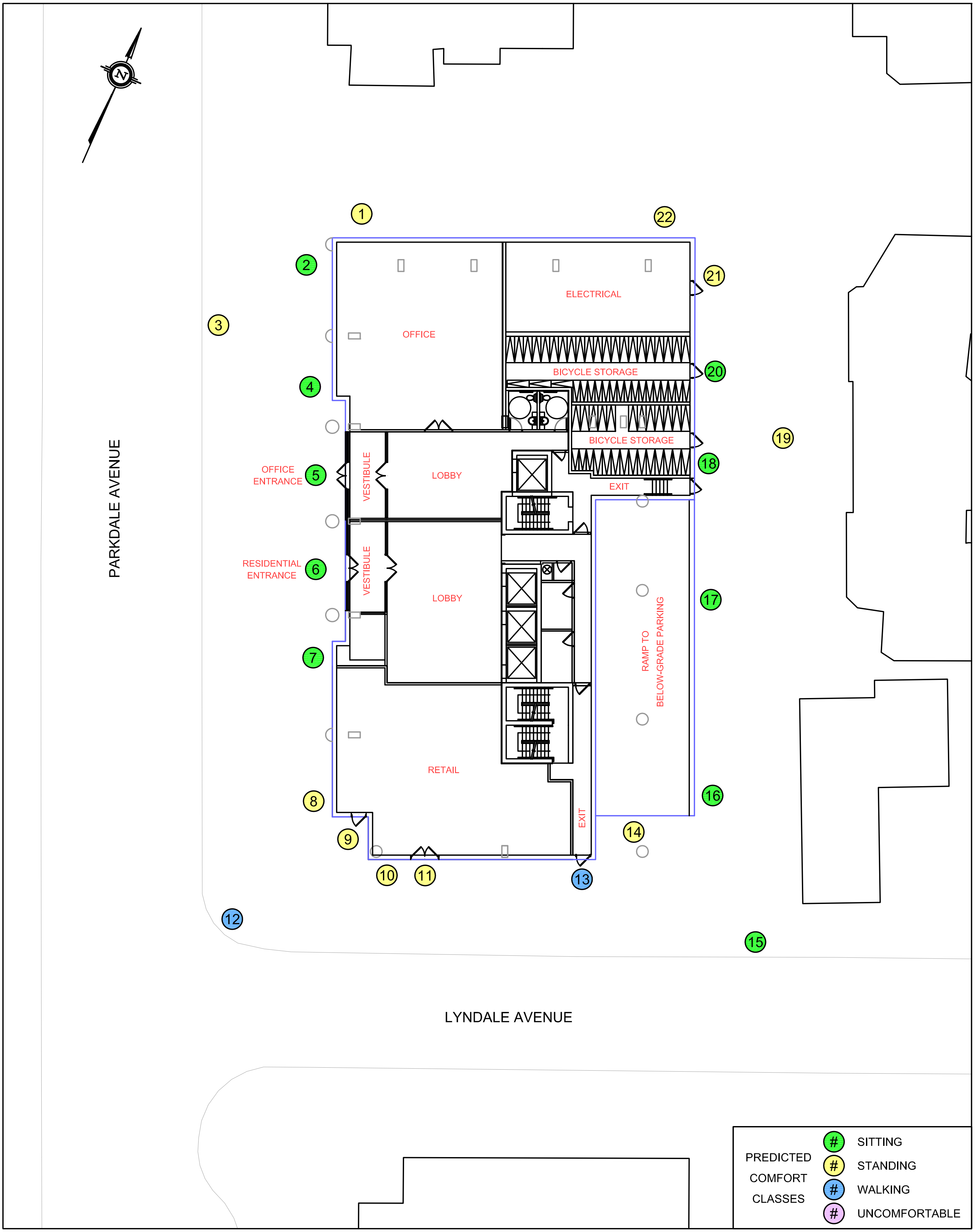
DRAWING NO.: GmE12-086-PLW-2

DATE: SEPTEMBER 6, 2012

DRAWN BY: J.F.

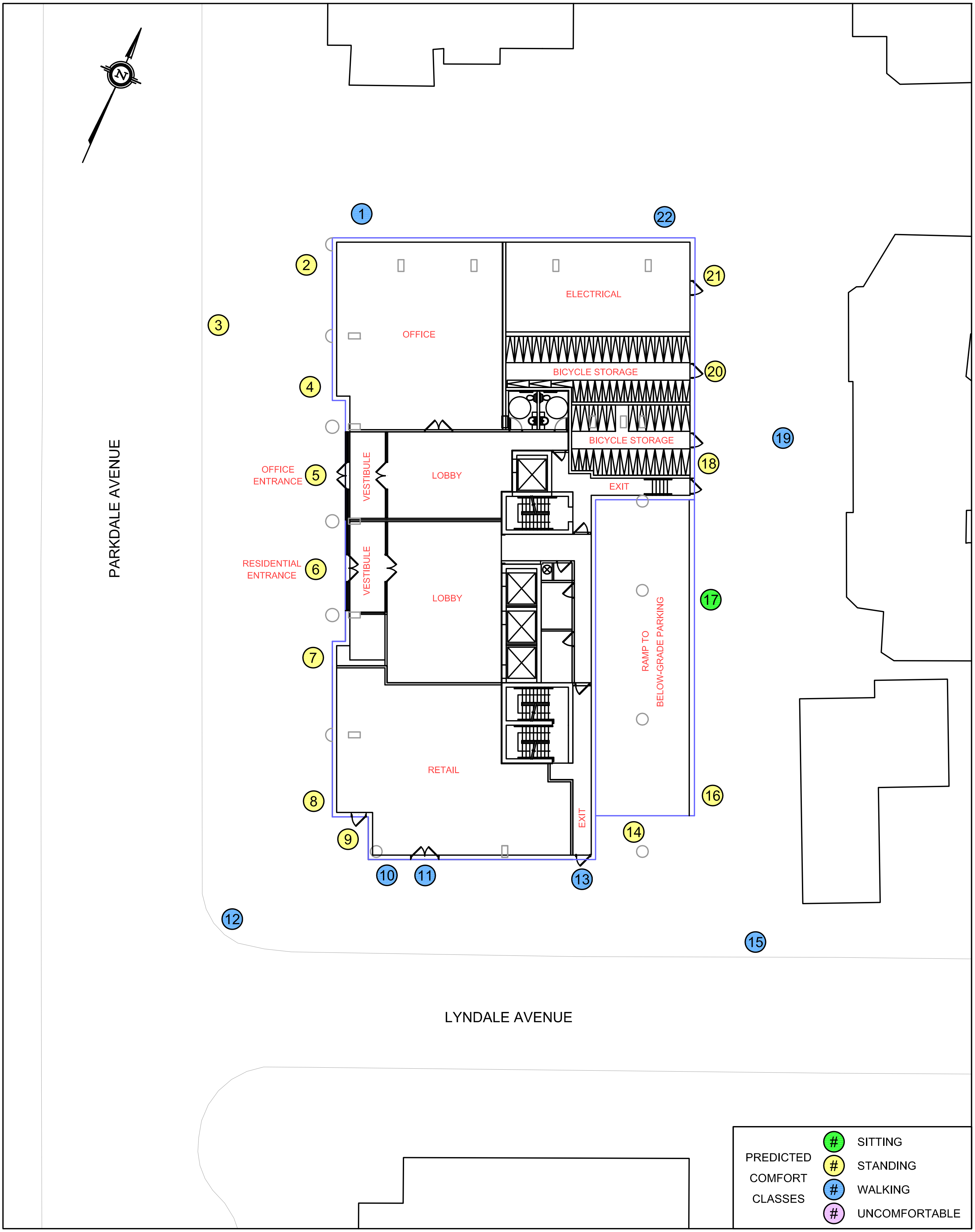
DESCRIPTION

FIGURE 2: SPRING
PEDESTRIAN COMFORT PREDICTIONS AT GRADE



GmE Gradient Microclimate Engineering Inc
127 Walgreen Road
Ottawa, Ontario
K0A 1L0
(613) 836-0934

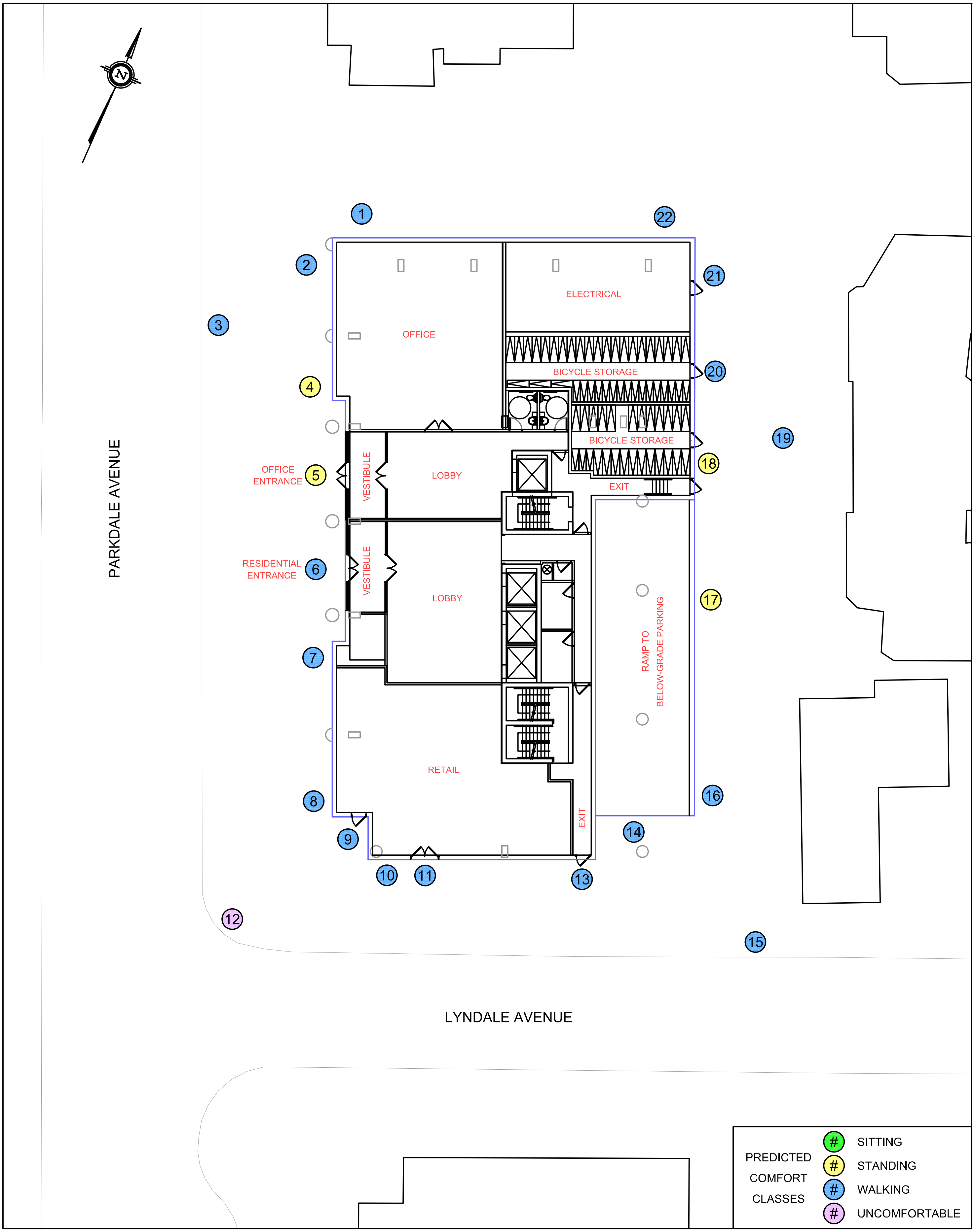
PROJECT: 159 PARKDALE AVENUE, OTTAWA - PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION
SCALE: 1:350 (APPROX.)	DRAWING NO.: GmE12-086-PLW-3	FIGURE 3: SUMMER PEDESTRIAN COMFORT PREDICTIONS AT GRADE
DATE: SEPTEMBER 6, 2012	DRAWN BY: J.F.	



GmE Gradient Microclimate Engineering Inc

127 Walgreen Road
Ottawa, Ontario
K0A 1L0
(613) 836-0934

PROJECT	159 PARKDALE AVENUE, OTTAWA - PEDESTRIAN LEVEL WIND STUDY
SCALE	1:350 (APPROX.)
DRAWING NO.	GmE12-086-PLW-4
DATE	SEPTEMBER 6, 2012
DRAWN BY	J.F.
DESCRIPTION	FIGURE 4: AUTUMN PEDESTRIAN COMFORT PREDICTIONS AT GRADE

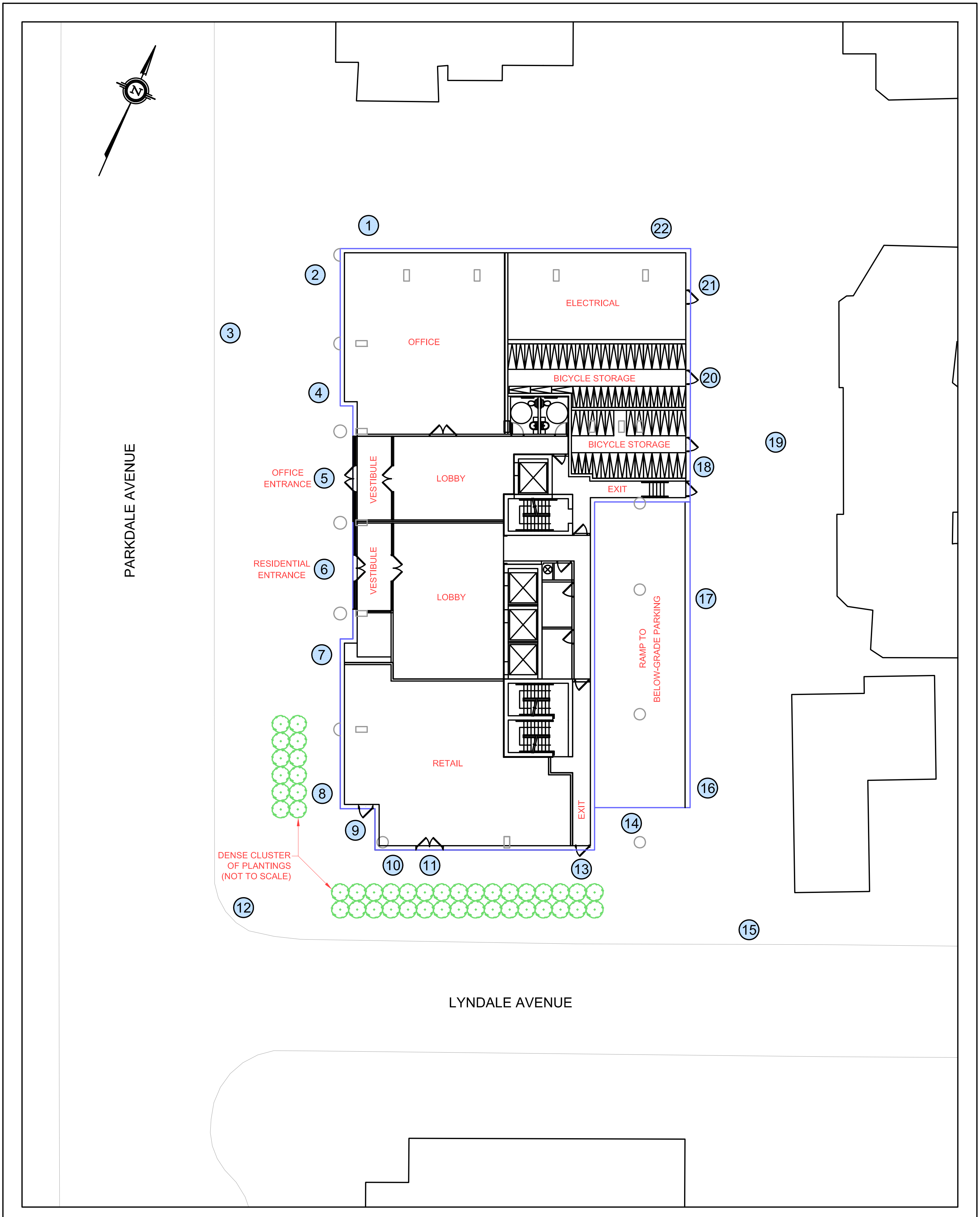


Gradient Microclimate Engineering Inc
127 Walgreen Road
Ottawa, Ontario
K0A 1L0
(613) 836-0934

PROJECT	159 PARKDALE AVENUE, OTTAWA - PEDESTRIAN LEVEL WIND STUDY
SCALE	1:350 (APPROX.)
DRAWING NO.	GmE12-086-PLW-5
DATE	SEPTEMBER 6, 2012
DRAWN BY	J.F.

DESCRIPTION

FIGURE 5: WINTER
PEDESTRIAN COMFORT PREDICTIONS AT GRADE



GmE Gradient Microclimate Engineering Inc
127 Walgreen Road
Ottawa, Ontario
K0A 1L0
(613) 836-0934

PROJECT: 159 PARKDALE AVENUE, OTTAWA - PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION
SCALE: 1:350 (APPROX.)	DRAWING NO.: GmE12-086-PLW-6	FIGURE 6: MITIGATION STRATEGY EXTENSIVE TREE PLANTINGS AT GRADE
DATE: SEPTEMBER 6, 2012	DRAWN BY: J.F.	

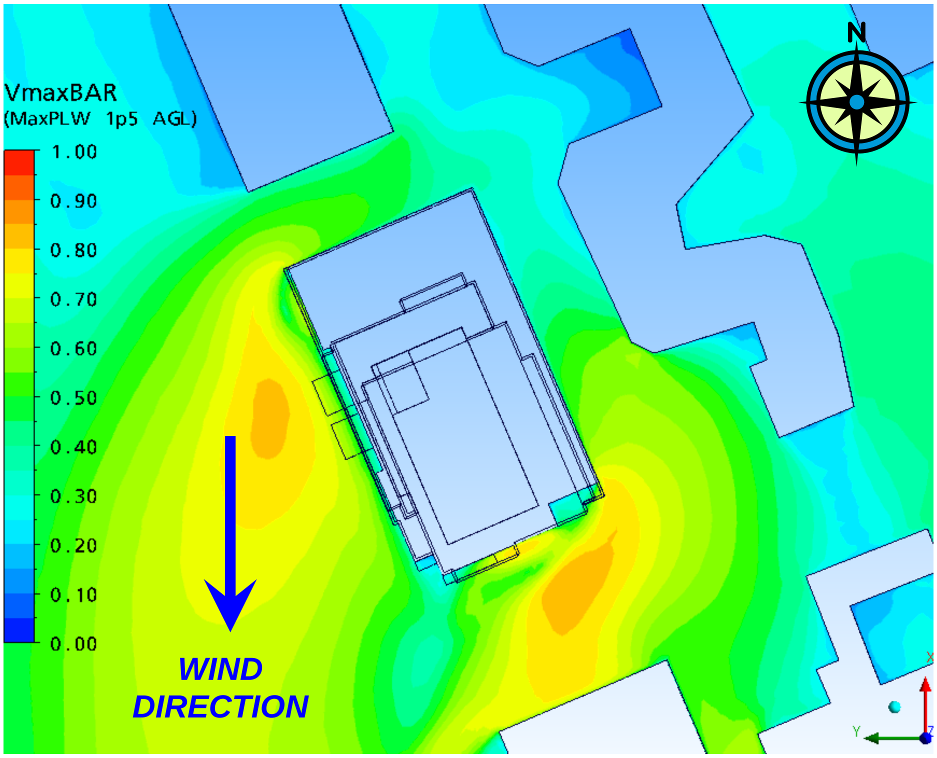


FIGURE 7: PLAN VIEW OF RELATIVE WIND SPEEDS OVER THE STUDY SITE (WIND DIRECTION: 0°)

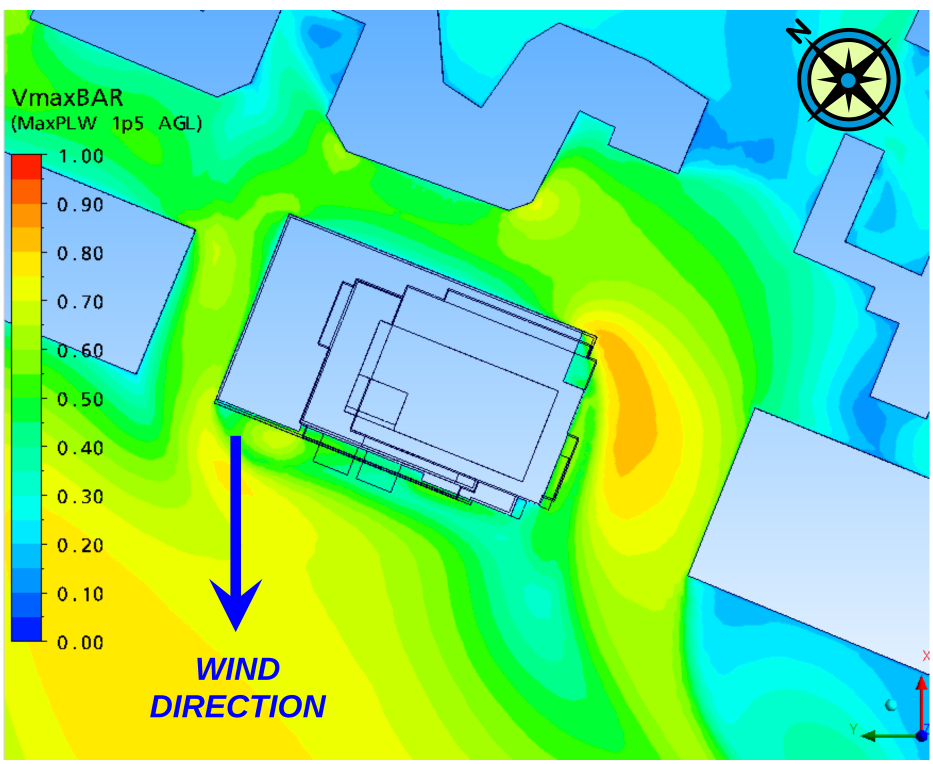


FIGURE 8: PLAN VIEW OF RELATIVE WIND SPEEDS OVER THE STUDY SITE (WIND DIRECTION: 45° CLOCKWISE FROM NORTH)

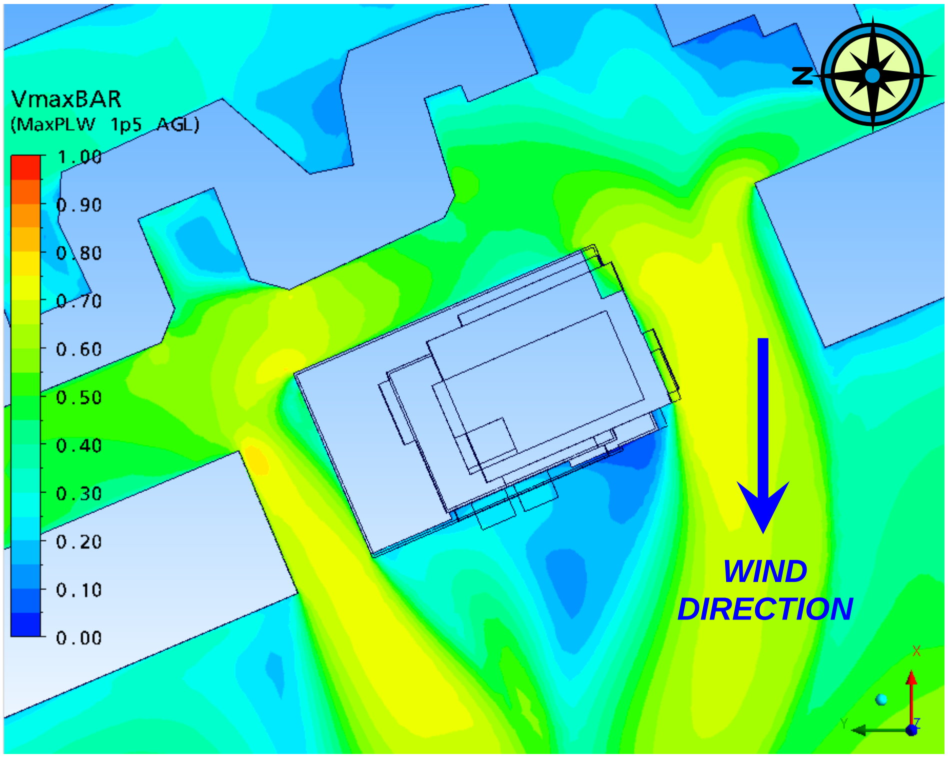


FIGURE 9: PLAN VIEW OF RELATIVE WIND SPEEDS OVER THE STUDY SITE (WIND DIRECTION: 90° CLOCKWISE FROM NORTH)

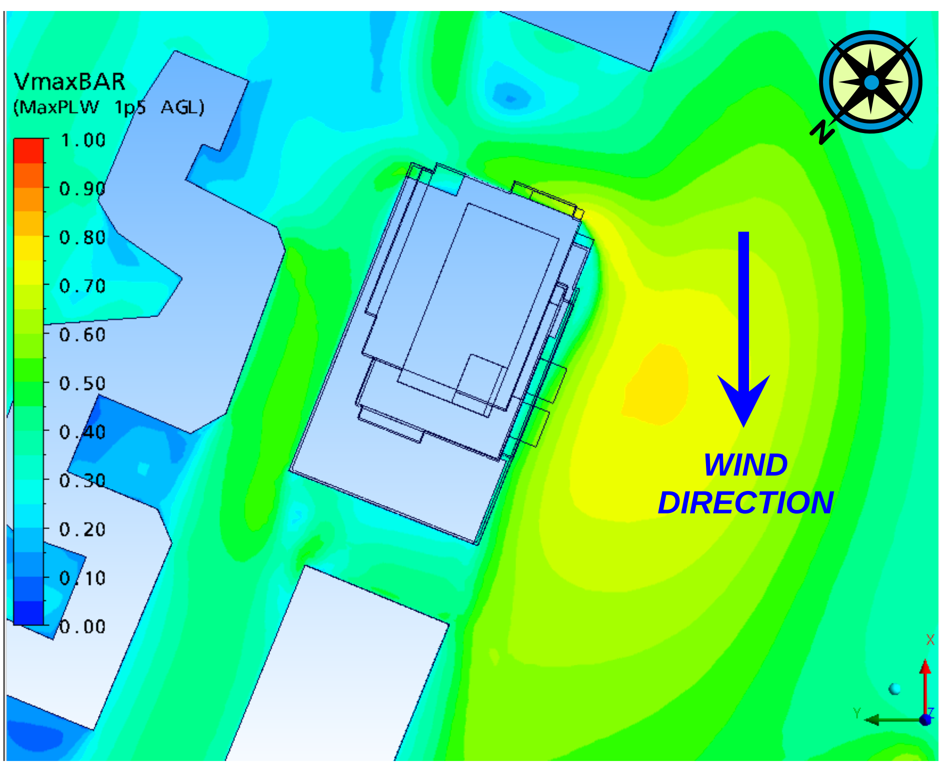


FIGURE 10: PLAN VIEW OF RELATIVE WIND SPEEDS OVER THE STUDY SITE (WIND DIRECTION: 135° CLOCKWISE FROM NORTH)

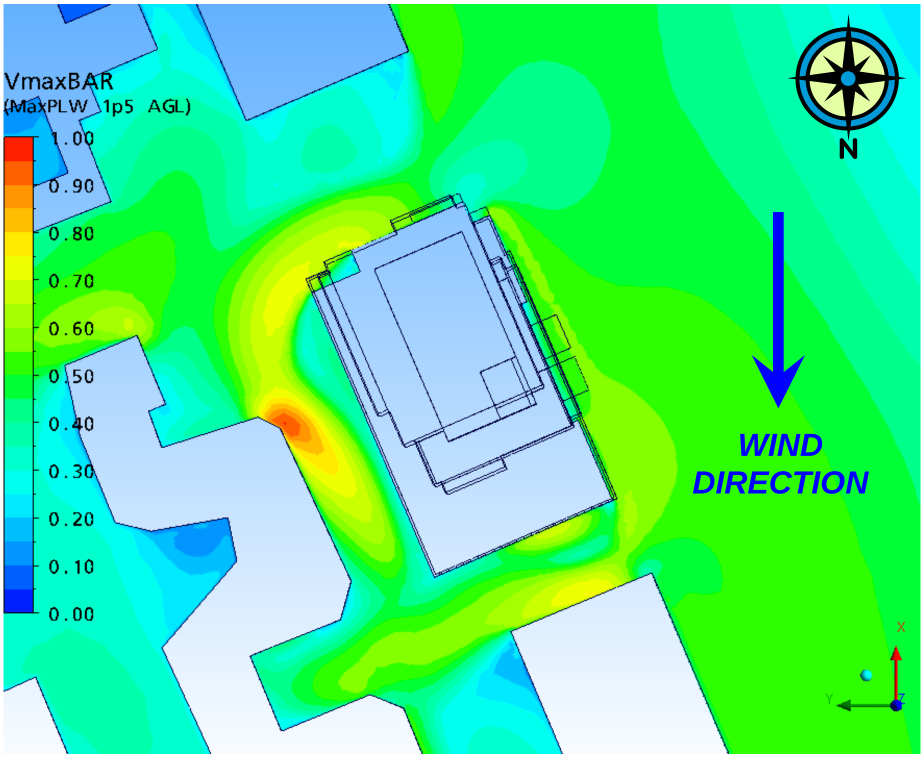


FIGURE 11: PLAN VIEW OF RELATIVE WIND SPEEDS OVER THE STUDY SITE (WIND DIRECTION: 180° CLOCKWISE FROM NORTH)

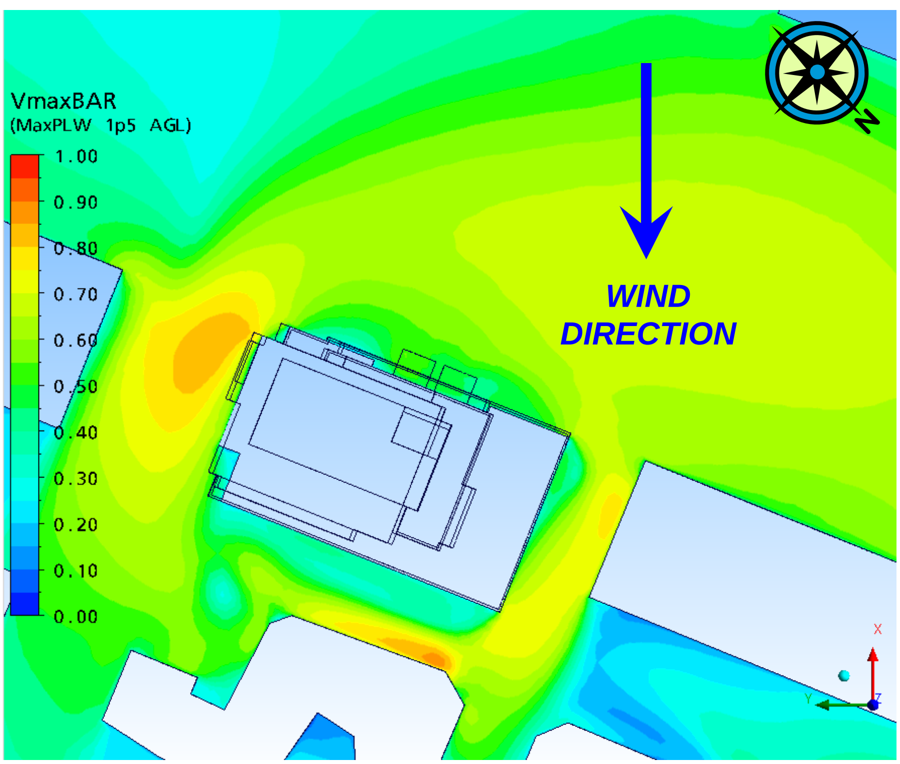


FIGURE 12: PLAN VIEW OF RELATIVE WIND SPEEDS OVER THE STUDY SITE (WIND DIRECTION: 225° CLOCKWISE FROM NORTH)

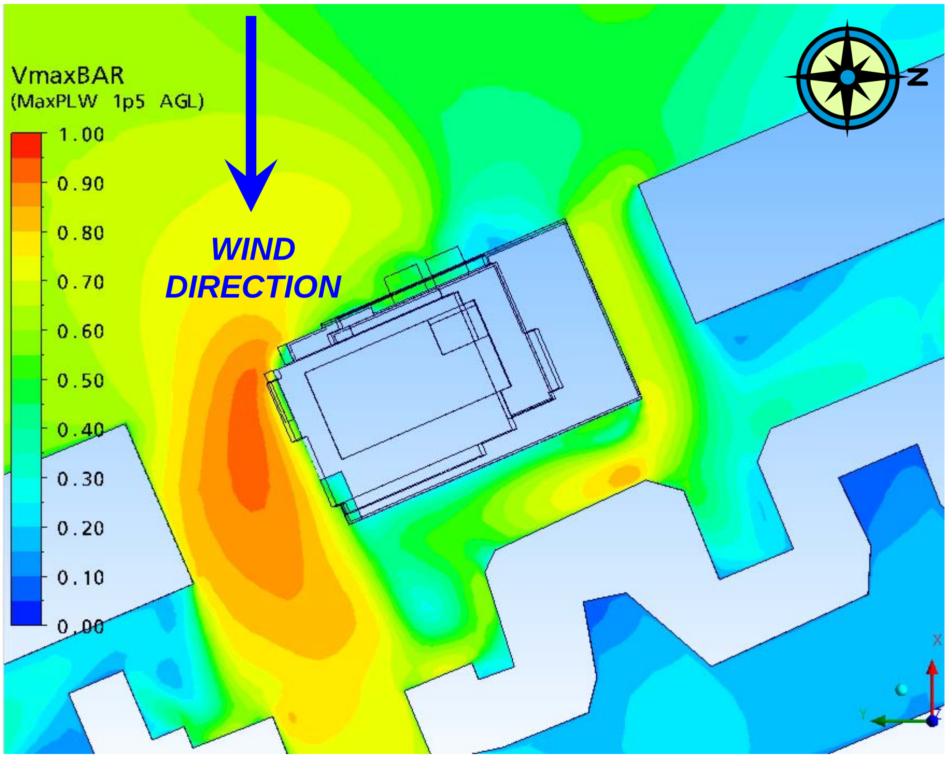


FIGURE 13: PLAN VIEW OF RELATIVE WIND SPEEDS OVER THE STUDY SITE (WIND DIRECTION: 270° CLOCKWISE FROM NORTH)

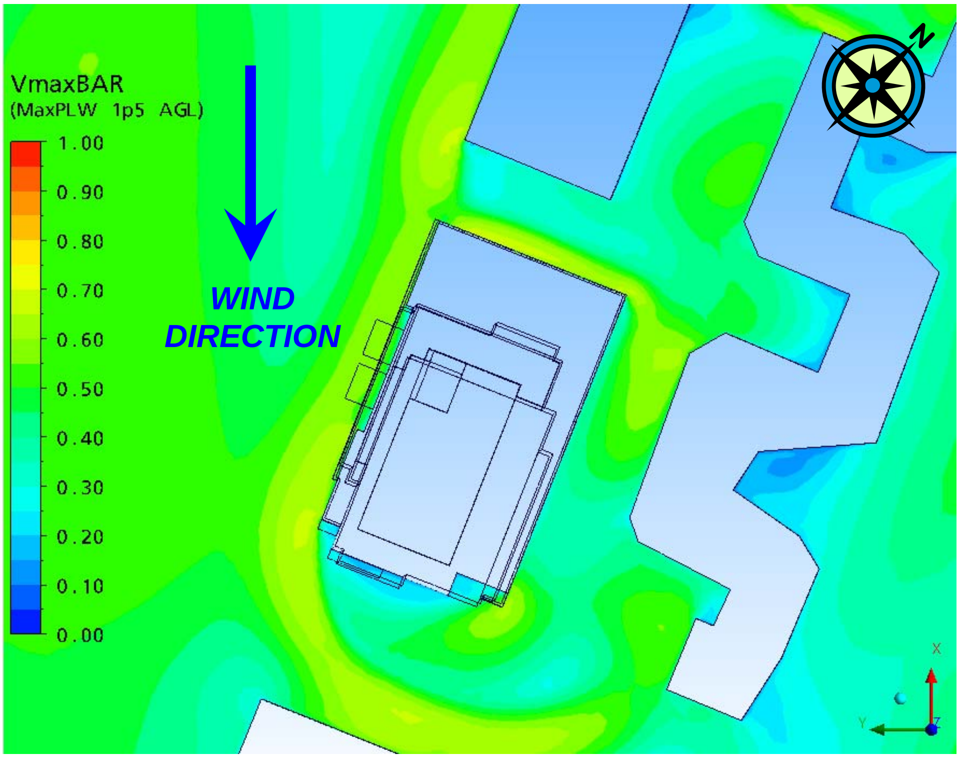
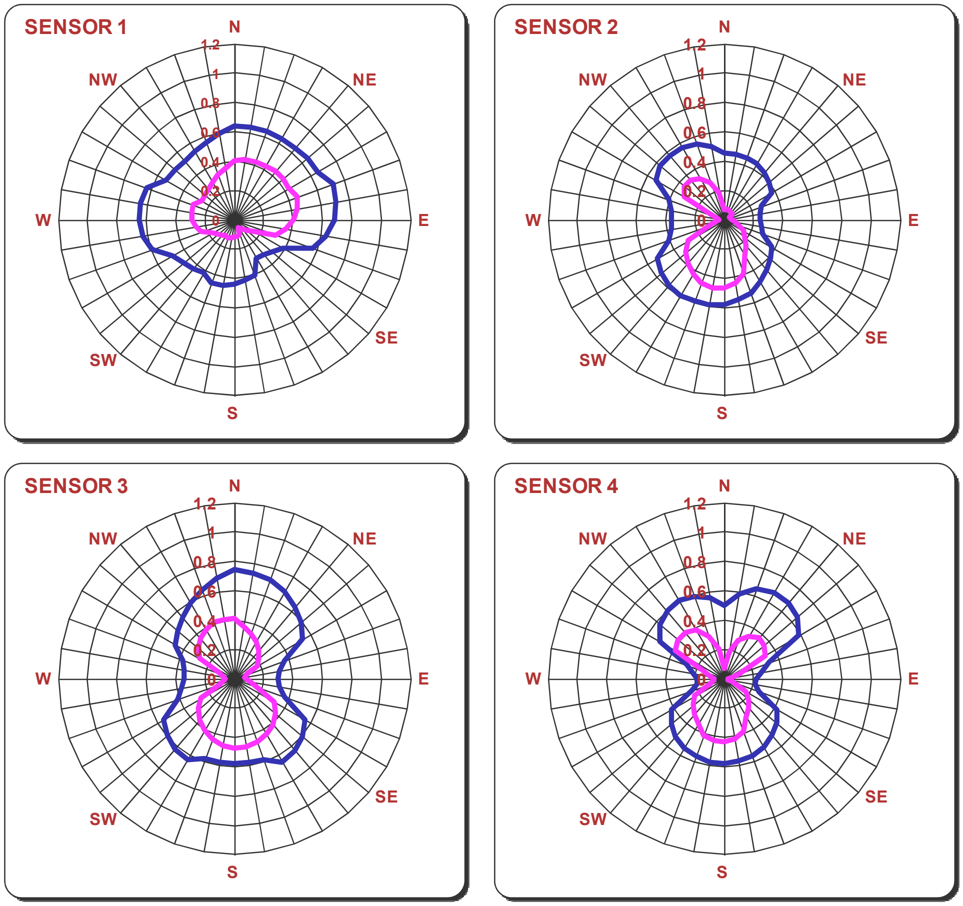


FIGURE 14: PLAN VIEW OF RELATIVE WIND SPEEDS OVER THE STUDY SITE (WIND DIRECTION: 315° CLOCKWISE FROM NORTH)

APPENDIX A

RAW DATA FROM CFD SIMULATIONS

FIGURE A1: VELOCITY RATIO PLOTS AT SENSORS 1 THROUGH 4
[MEAN (INNER CURVE) AND PEAK (OUTER CURVE)]



159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS

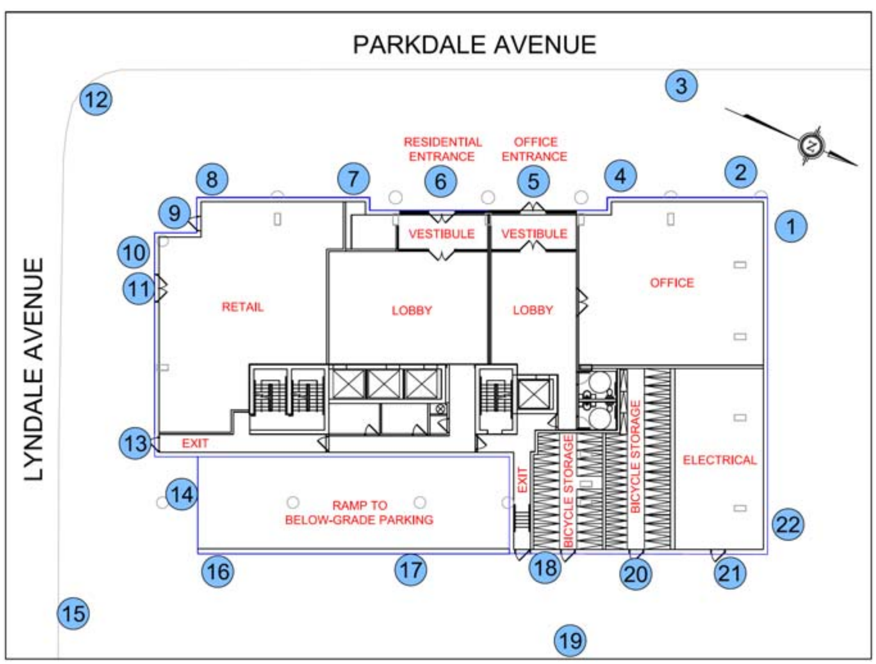
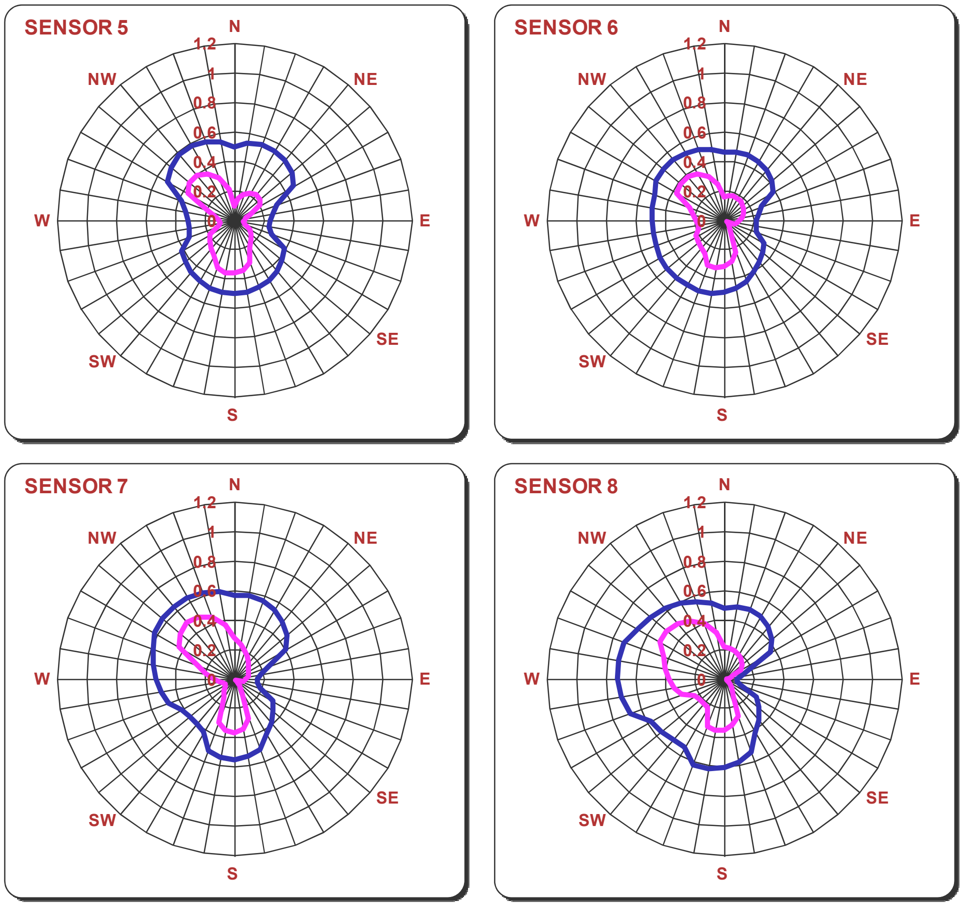


FIGURE A2: VELOCITY RATIO PLOTS AT SENSORS 5 THROUGH 8
[MEAN (INNER CURVE) AND PEAK (OUTER CURVE)]



159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS

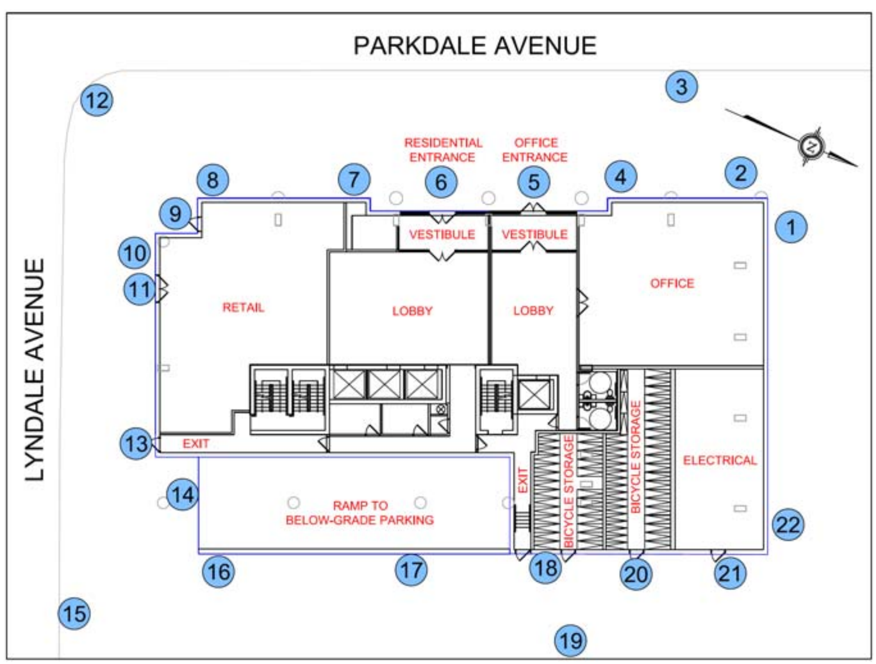
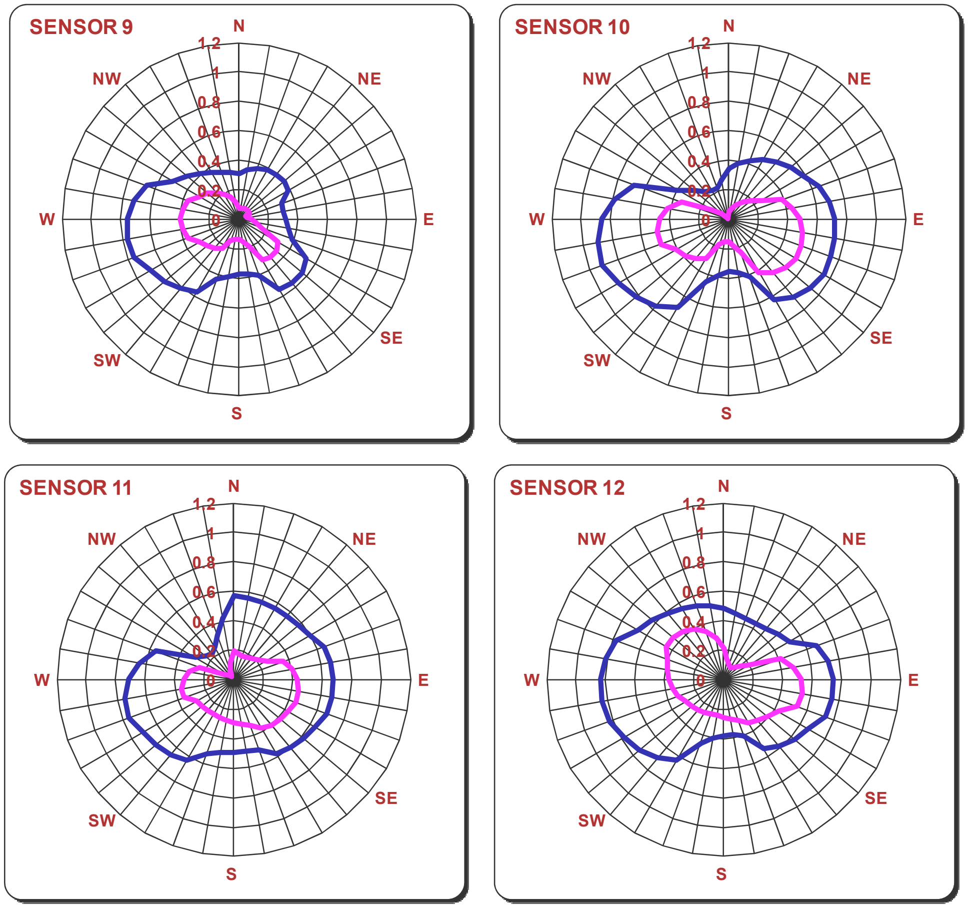


FIGURE A3: VELOCITY RATIO PLOTS AT SENSORS 9 THROUGH 12 [MEAN (INNER CURVE) AND PEAK (OUTER CURVE)]



159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS

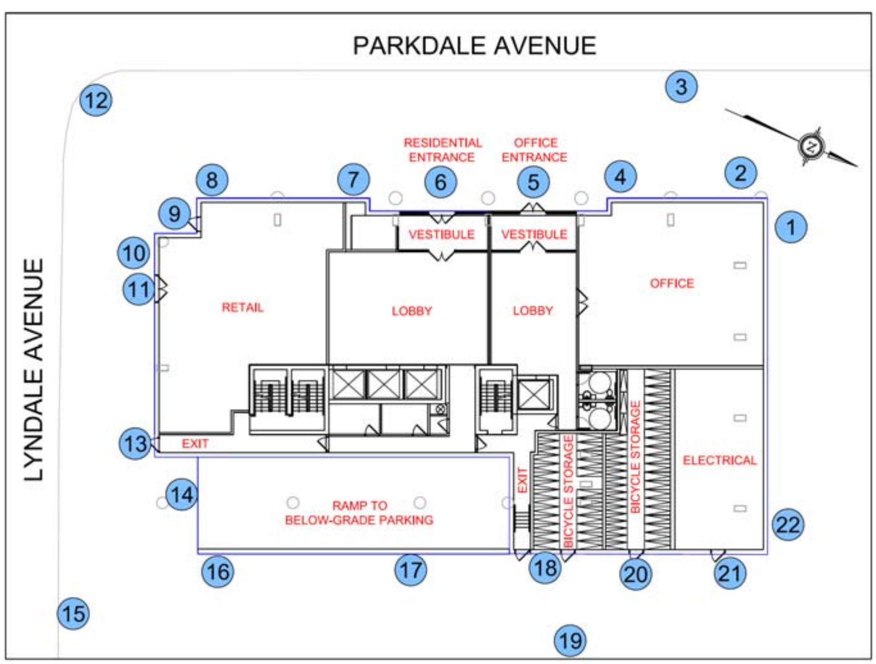
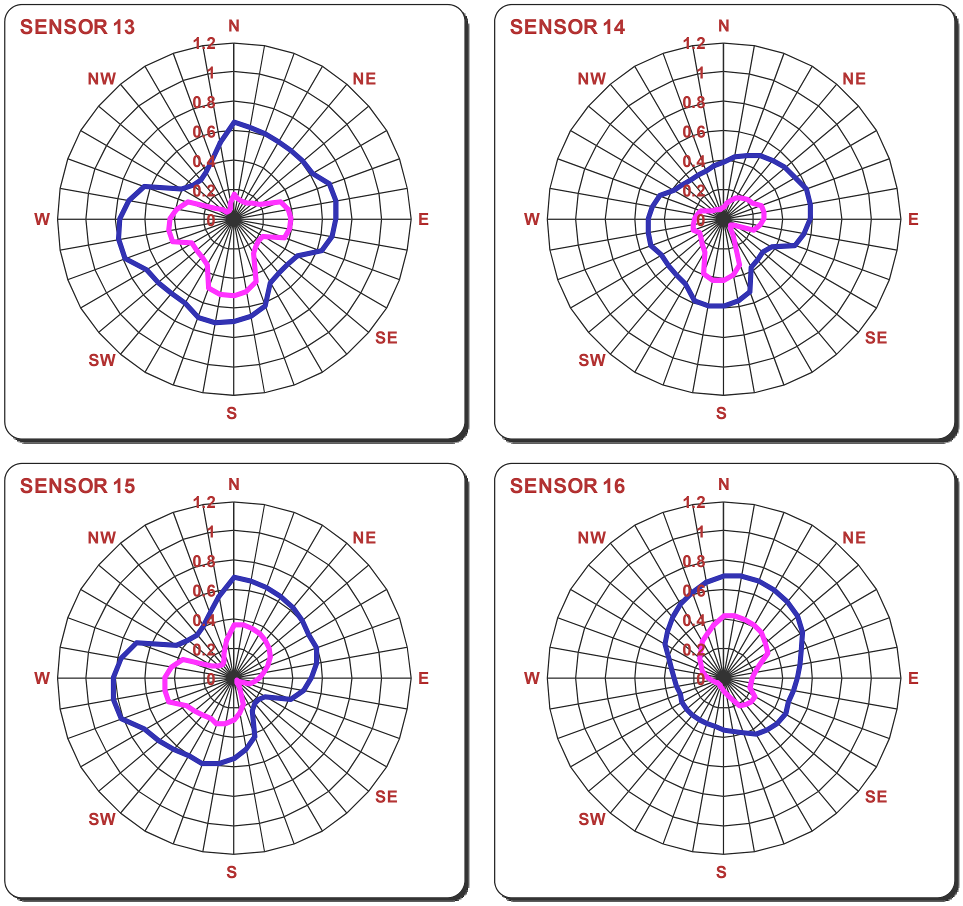


FIGURE A4: VELOCITY RATIO PLOTS AT SENSORS 13 THROUGH 16
[MEAN (INNER CURVE) AND PEAK (OUTER CURVE)]



159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS

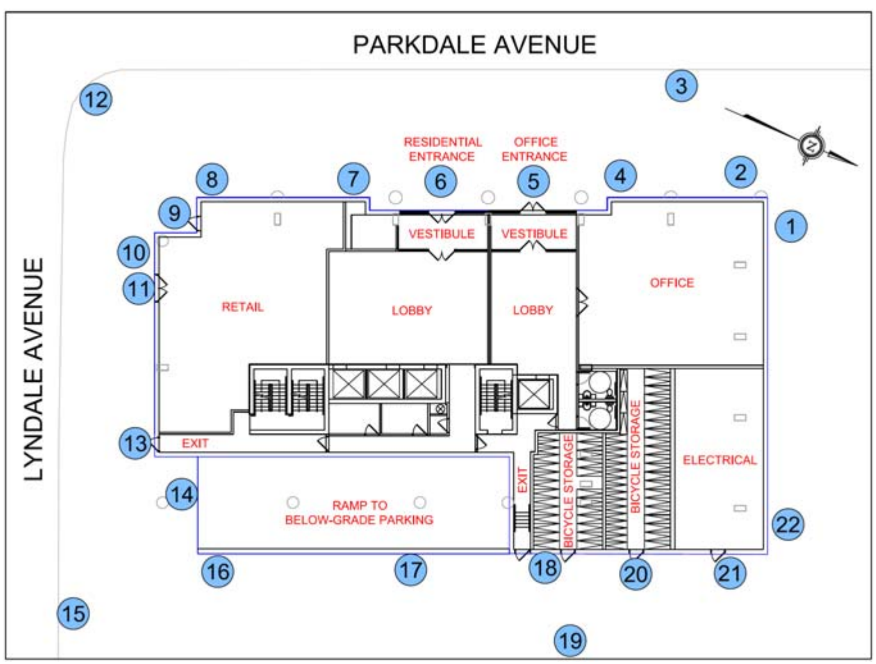
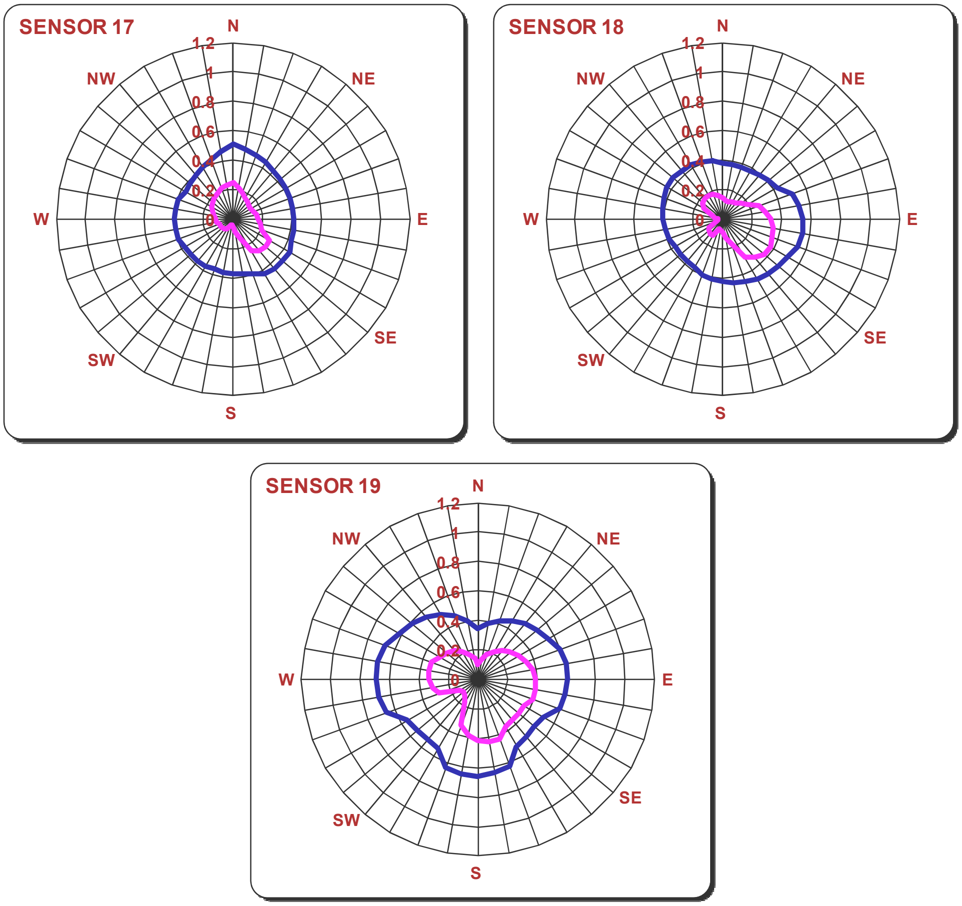


FIGURE A5: VELOCITY RATIO PLOTS AT SENSORS 17 THROUGH 19 [MEAN (INNER CURVE) AND PEAK (OUTER CURVE)]



159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS

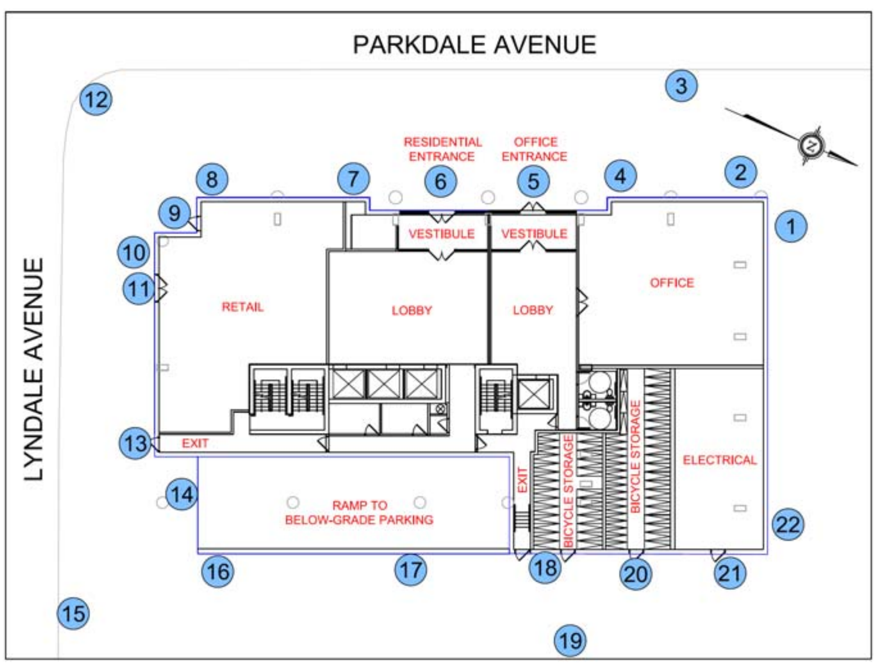
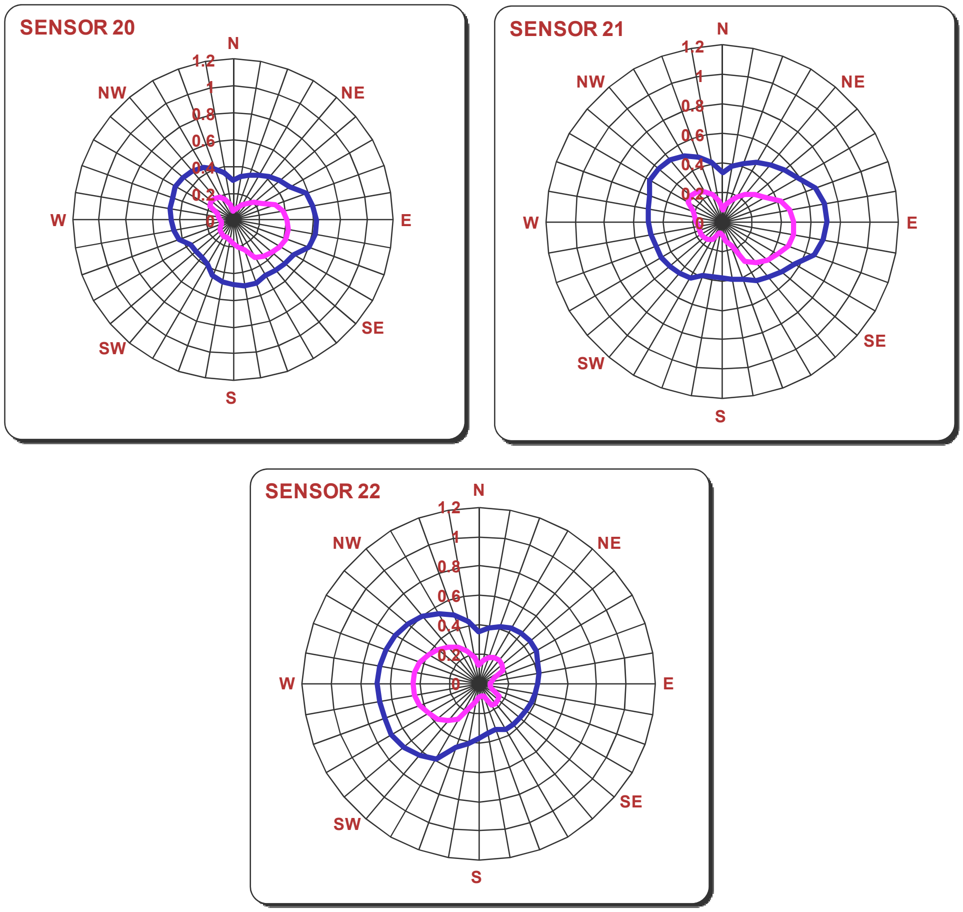
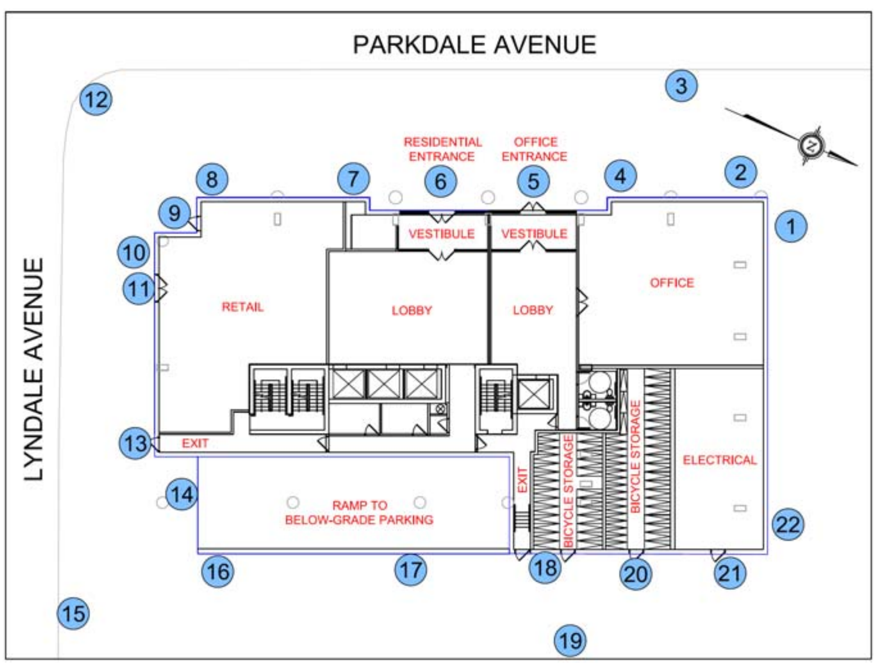


FIGURE A6: VELOCITY RATIO PLOTS AT SENSORS 20 THROUGH 22
[MEAN (INNER CURVE) AND PEAK (OUTER CURVE)]



159 PARKDALE AVENUE, OTTAWA: PLW SENSOR LOCATIONS



APPENDIX B

CFD AND WIND TUNNEL SIMULATION OF THE NATURAL WIND

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 magnitude 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 centre 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 behavior, whether in a wind tunnel or by computer models (CFD), 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 turbulence length scales in the model 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 wind tunnel scales, 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. In computational fluid dynamic models, the mean and turbulence profiles are represented by similar formulas, where α is selected per wind direction according to appropriate terrain roughness such as α = 0.14, 0.25 and 0.33 for open country, suburban and urban exposures respectively.

Figure B1 plots three (3) profiles for typical open country, suburban and urban exposures, whereas Figure B2 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 1:400 scale, the model value should be between 1/4 and 1/2 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, U_{10} is the wind speed 10 m above ground level, and L is the characteristic length of turbulence.

CFD models can be undertaken either at some predetermined model scale or in full scale. Whether by physical model or CFD simulation, the study site, once constructed to a suitable scale, is installed at the centre of the site context model which includes all surrounding building massing within a predetermined radius, usually of 400 m to 500 m in full scale. Different wind directions are represented by rotating the model to align with the wind tunnel centre-line axis.

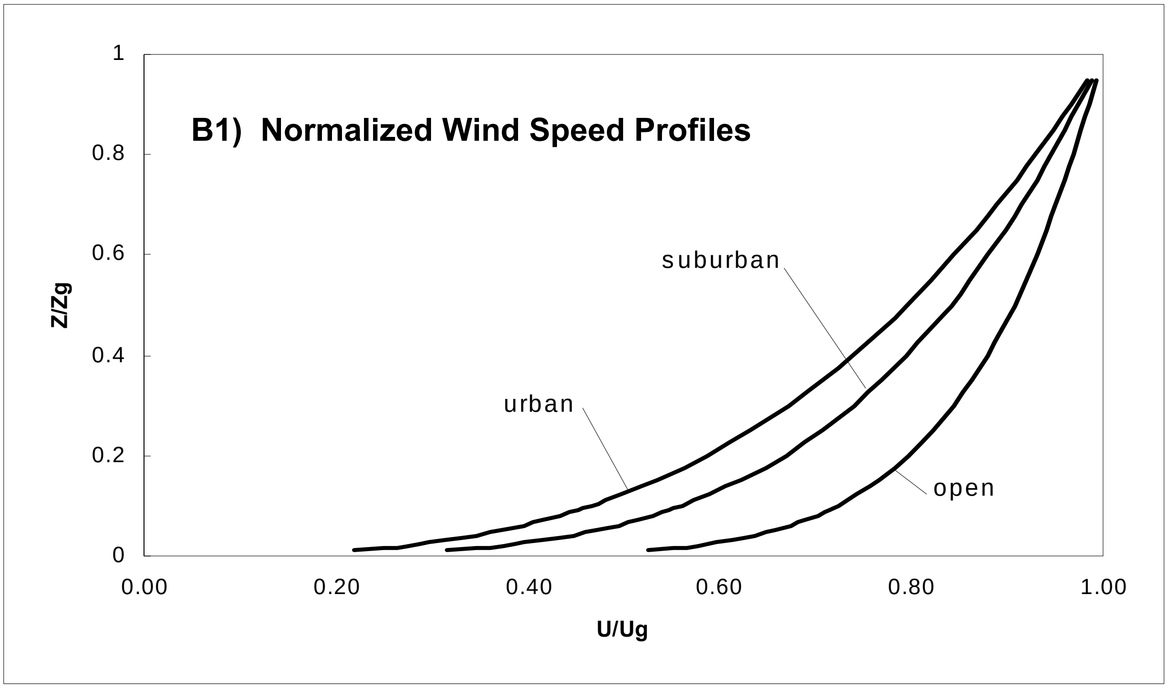
References

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



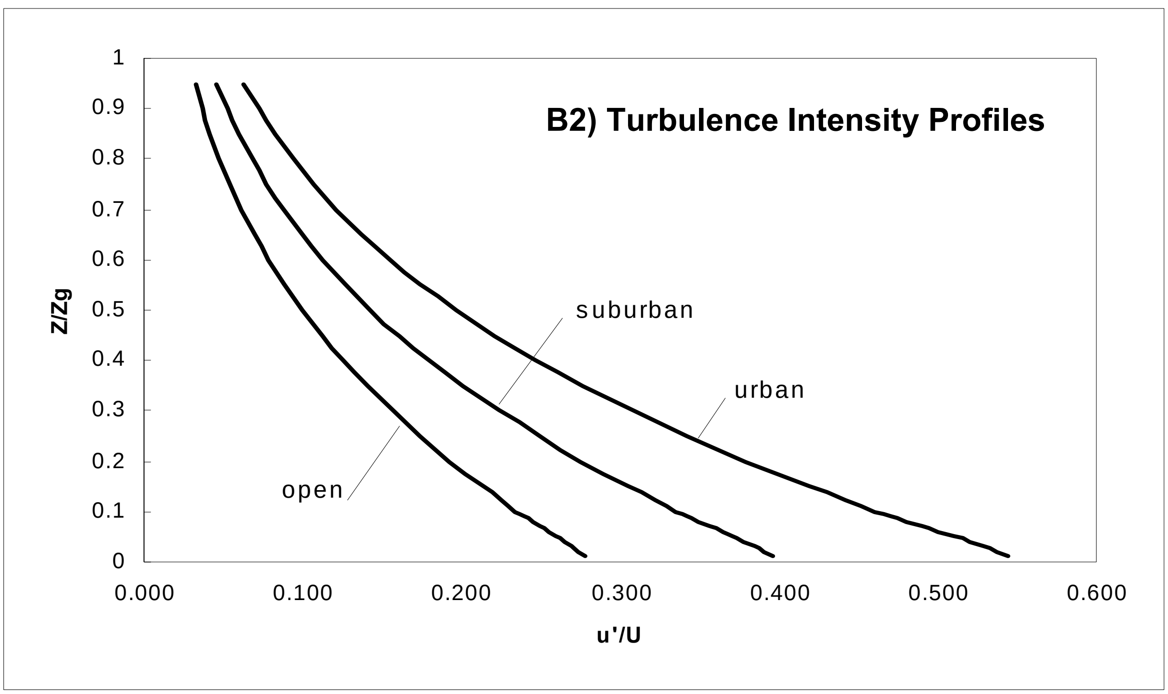


Figure B1 (Top): Mean Wind Speed Profiles

Figure B2 (Bottom): Turbulence Intensity Profiles (u' = fluctuation of mean velocity)

APPENDIX C

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 C1. 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 polar plots as shown in Appendix A.

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:

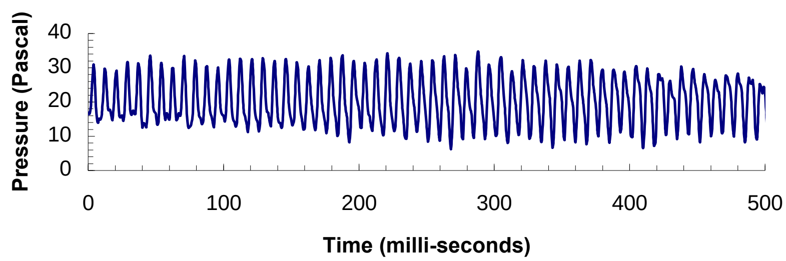
$$P_N(>20) = \Sigma_\theta P\left[\frac{(>20)}{\left(\frac{U_N}{U_g}\right)}\right]$$

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

Where, U_N/U_g is the gust velocity ratios plotted in Figures A1 to A6, where the summation is taken over all 36 wind directions at 10° intervals.

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

FIGURE C1: 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.