APPENDIX D

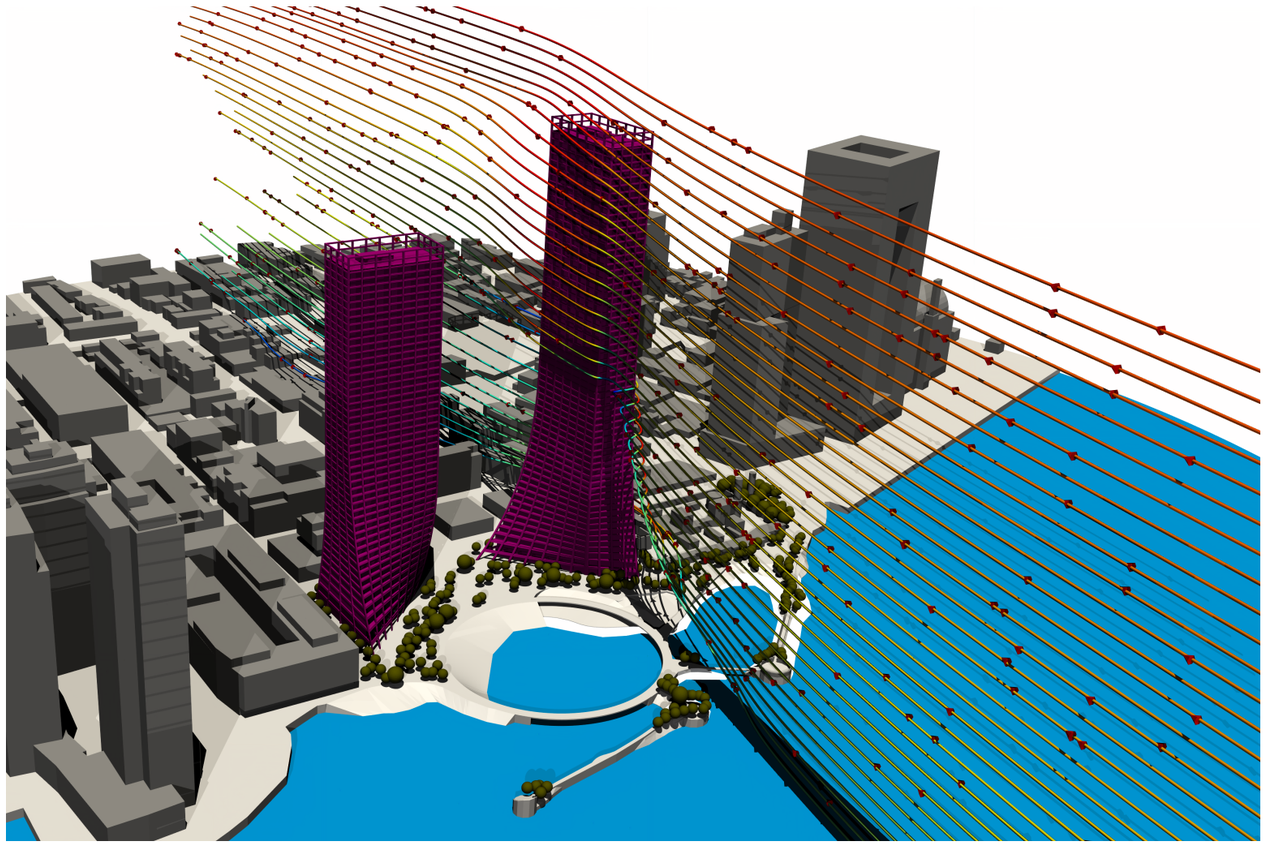
URBAN DESIGN AND VISUAL RESOURCES

- *Pedestrian Microclimate CFD Study*

WINDTECH

PEDESTRIAN MICROCLIMATE CFD STUDY

RIVER STREET, BROOKLYN



WF446-03F02(REV2) - WE CFD REPORT
APRIL 16, 2021

Prepared for:
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Date	Revision History	Non-Issued Revision	Issued Revision	Prepared By (Initials)	Instructed By (Initials)	Reviewed & Authorised By (Initials)
12/04/2021	-	-	0	AF	NO	NT & NO
15/04/2021	1- UK to US english minor changes	-	1	AF	NO	NO
16/04/2021	2 - Updates to text as per client	-	2	AF	NO	NO

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Executive Summary

Measurements were made in the conducted simulations at selected critical trafficable outdoor locations within and around the Proposed Development from 16 wind directions using a 1:1 scale detailed model. The effect of nearby buildings and land topography has been accounted for through the use of a proximity model, which represents an area within a radius of 500m. The model was based on the architectural model received on the 10th of March 2021.

** Note the model of the development has been tested without the effect of additional forms of wind ameliorating devices such as screens, balustrades, etc. (Except those already incorporated in the approximate study model).

- No regions exceeding wind safety criteria to the general or frail members of the public are found within the vicinity of the proposed development. A region exceeding the frail safety criterion was found, outside of the proposed development area, to be a result of existing buildings and not due to the proposed development.
- It should be noted that the majority of the surrounding area, in the streets around the Proposed Development adheres to conditions suitable for strolling or better and are deemed suitable for their intended use.
- The proposed development shows some quantifiable effects where airflow will be accelerated and funneled. These effects are most noticeable between the two towers and the outer corners. The planned vegetation is able to mitigate the majority of wind speeds across the site.
- Optional mitigation measures have been suggested in some areas should further reductions of wind speeds be desired. This includes the introduction of vegetation, moveable planters and trellises close to the site and balustrades for the waterfront areas.
- The proposed development is expected to satisfy its respective comfort criteria and as such outdoor trafficable areas within and around the proposed development are expected to be suitable for their intended use. Areas have been highlighted for which wind conditions can be improved further to make conditions suitable for stationary activities, and suitable mitigation measures suggested.

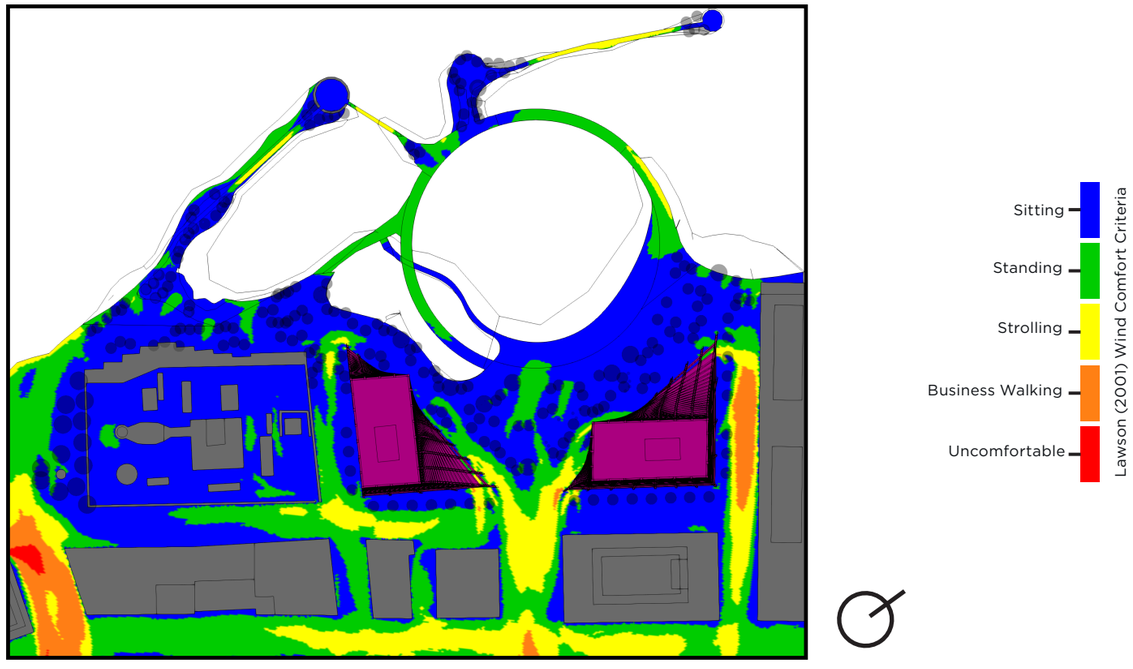


Figure i. Lawsons (2001) Comfort Contours for Proposed Site

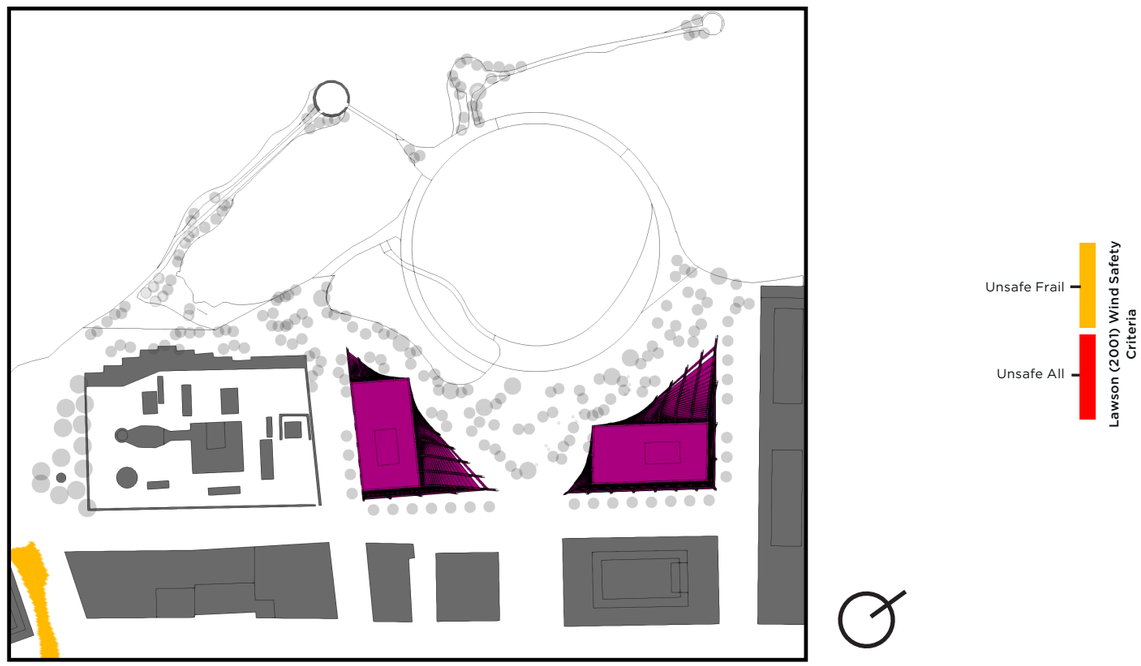


Figure ii. Lawsons (2001) Safety Contours for Proposed Site

CONTENTS

1. Introduction

This assessment has been prepared by WINDTECH Consultants to assess wind microclimate issues around the Proposed Development located in River Street, Brooklyn, New York State.

Description of the Proposed Development

The Site itself is a rectangular plot running alongside the East River. The site is bounded by North 3rd Street to the North and River Street to the East, the East River to the West and the NYPA plant and Grand Ferry park to the South. The urban expanse of Williamsburg lies to the east of the site. High rise buildings can be found along the waterfront to the North and South of the site, such as 1 South 1st Street at Domino and 2 Northside Piers. Figure 1 shows a close-up of the site location. The Proposed Development consists of the development of two mixed use buildings upon the currently existing site and redevelopment of the waterfront into a public park.

Initial Wind Tunnel Study

A traditional wind tunnel study was conducted in April 2020 to simulate wind conditions and quantitatively assess the effect of the Proposed Development on the pedestrian comfort levels in and around the Site (Doc Ref: WF446-01F02(REV0)- WE REPORT). A model of the proposed development including the surrounding neighborhood buildings was built in a 3D computer format to a resolution of 0.2m and then physically 3D printed.

The final model was then placed in the wind tunnel and run for a 5% weekly wind speed for 16 individual directions in the wind tunnel. The measurements were then exported for the selected probe locations within the model domain (i.e 500m radius) at 1.5m from the ground. 84 years of historical local weather data was then used to compute the Lawsons comfort criteria for every point. Thereby categorizing the intended use of the space for wind comfort and safety.

The results were then presented in probe point plots (figures) of Lawsons wind comfort and safety at locations across the site. In the cases where a physical wind tunnel model has preceded a computational model (such as this one) the wind tunnel probe measurements that are on the boundary of the site (which are not affected by any change to building massing configurations) are used to calibrate and validate the CFD simulation runs via scaling of input coefficients.

This provides a certainty that the measurements deriving from the CFD simulation have a minimal offset and are consistent with that obtained in the wind tunnel model.

Scope of the CFD Study

Simulations of the wind microclimate were conducted to quantitatively assess the effect of the Proposed Development on the pedestrian comfort levels in and around the Site.

The assessment was undertaken through Computational Wind Engineering (CWE), which uses Computational Fluid Dynamic (CFD) techniques to model a 'virtual wind tunnel' and simulate conditions around the site. This report contains the methodology and results from these simulations.

Wind speed contour plots representing the local wind speed-up ratios are derived from the simulations and are combined with a statistical model of the regional wind climate (which accounts for the directional strength and frequency of occurrence of the prevailing regional winds). These wind speed-up ratios are then used in the calculation of the Lawsons criteria (2001) for pedestrian wind comfort and safety.

Figure 1. Existing Site (site boundary is shown in red)

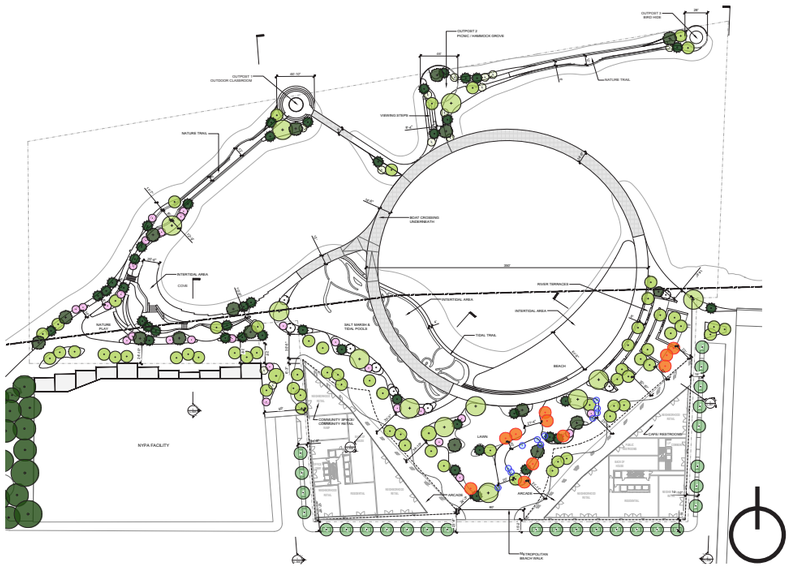


Figure 2. Proposed Site (Based on drawings received 30/03/2021)

2. Environmental Wind Speed Criteria

Wind Effects on People

The acceptability of wind in any area is dependent upon its use. For example, people walking or window-shopping will tolerate higher wind speeds than those seated at an outdoor restaurant. Various other researchers, such as A.G. Davenport, T.V. Lawson, W.H. Melbourne, A.D. Penwarden, etc., Have published criteria for pedestrian comfort for pedestrians in outdoor spaces for various types of activities.

A.D. Penwarden (1975) Criteria for Gust Wind Speeds

The following table developed by A.D. Penwarden (1975) is a modified version of the Beaufort Scale, and describes the effects of various wind intensities on people. Note that the effects column relates to wind conditions that occur frequently (approximately once per week on average). Higher ranges of wind speeds can be tolerated for rarer events.

Type of Winds	Wind	Wind Speed (m/s)	Effect
Calm, light air	1	0-1.5	Calm, no noticeable wind
Light breeze	2	1.6-3.3	Wind felt on face
Gentle breeze	3	3.4-5.4	Hair is disturbed, Clothing flaps
Moderate breeze	4	5.5-7.9	Raises dust, dry soil and loose paper. Hair disarranged
Fresh breeze	5	8.0-10.7	Force of wind felt on body
Strong breeze	6	10.8-13.8	Umbrellas used with difficulty, hair blows straight, difficult to walk steadily. Wind noise on ears unpleasant
Near gale	7	13.9-17.1	Inconvenience felt when walking
Gale	8	17.2-20.7	Generally impedes progress. Great difficulty with balance
Strong gale	9	20.8-24.4	People blown over by gusts

Table 1. Pedwarden Criteria for Gust Wind Speeds

T.V. Lawson Criteria for Mean Wind Speeds

In 1973, T.V. Lawson quotes that A.D. Penwarden's Beaufort 4 (as listed in Table 1) would be acceptable if it is not exceeded for more than 4% of the time; and Beaufort 6 would be unacceptable if it is exceeded more than 2% of the time. Later, in 1975, T.V. Lawson presented a set of criteria very similar to those of A.G. Davenport's. These are presented in Tables 2 and 3.

T.V. Lawson (1980) presented a further set of criteria that has been

Classification	Activities	Annual Maximum Mean
Safety (all weather areas)	Accessible by the general public	15m/s
Safety (fair weather areas)	Private outdoor areas (balconies, terraces etc.)	20m/s

Table 2. Safety Criteria by T.V. Lawson (1975)

Classification	Activities	95th Percentile Maximum Mean (approx once per week)
Business Walking	Objective walking from A to B	8m/s < V < 10m/s
Pedestrian Walking	Slow walking etc.	6m/s < V 8m/s
Short Exposure Activities	Pedestrian standing or sitting for short times	4m/s < V < 6m/s
Long Exposure Activities	Pedestrian sitting for a long duration	V < 4m/s

Table 3. Comfort Criteria by T.V. Lawson (1975)

widely adopted in the UK. These criteria are based on Beaufort scale levels and have a variable probability of exceedance. These criteria are based on mean wind speeds and are outlined in Table 4.

For this study, the measured wind conditions for the various critical outdoor trafficable areas within and around the subject development are compared against the Lawsons Criteria (2001). Note the criteria differ to the Lawson (1975) criteria which was used in the previous wind tunnel study performed by Windtech Consultants (Doc ref: WF446-01F02(REV0)- WE REPORT), as GEM wind speeds are taken for use for the CFD study.

These criteria were firstly developed by Tom Lawson who was a Professor of Industrial Aerodynamics at Bristol University and have been widely adopted by planning authorities in the UK. The 2001 Lawson Criteria comprises both comfort and safety criteria. The comfort criteria sets out distinct pedestrian activities, with less active pursuits requiring more benign wind conditions; while the safety criteria relate to the wind speed at which a person is likely to be blown over. For comfort, the criteria are used in conjunction with a maximum Gust Equivalent Mean (GEM) wind speed. For safety, 2001 Lawson criteria unacceptable criteria for is used in conjunction with a maximum GEM wind speed (Table 5). This differs to the Melbourne Safety criteria reported in the previous Wind Tunnel Study as this relates to annual gust wind speeds opposed to GEM wind speeds.

Within the following report the safety and comfort conditions are presented using the color-coded diagrams in Figure 3.

Classification	Activities	95th Percentile Maximum Mean (approx once per week)
Sitting	Acceptable for outdoor sitting use, e.g. restaurant or cafe	< 4.0m/s
Standing	Acceptable for entrances, bus stops, covered walkways or passageways	< 6.0m/s
Strolling	Acceptable for external pavements or walkways for leisure use	< 8.0m/s
Business Walking	Acceptable for external pavements or walkways for locomotion only	< 10.0m/s
Uncomfortable	Not comfortable for regular pedestrian access	> 10.0m/s

Table 4. Lawson 2001 Comfort Criteria (2001)

Classification	Activities	Mean and GEM wind speed (0.002% exceedance)
Unsafe Frail	Presents a safety risk, especially to more vulnerable members of the public	15m/s
Unsafe All	Presents a safety risk to all members of the public	20m/s

Table 5. Lawson 2001 Safety Criteria (2001)

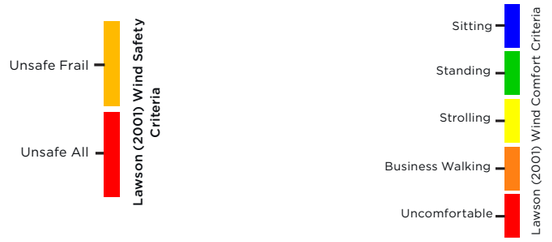


Figure 3. Lawson's contours used in this study

3. CFD Methodology

Wind Tunnel Validation

The CFD model was validated using data from the Wind Tunnel Study previously carried out by Windtech Consultants (Doc Ref: WF446-01F02(REV0)- WE REPORT). Validation was carried out for the prevailing north-westerly wind direction using a CFD model without any porous regions with respect to landscaping, as these were not modeled within the wind tunnel study. Speed up coefficients were found to be within a **5%** demonstrating alignment with wind tunnel data.

Solver	Coupled
Formulation	Implicit
Time	Steady
Operating Conditions	Pressure
Viscous Model	Realizable K-Epsilon (2 Equation) Standard Wall Functions
Pressure-Velocity Coupling	Coupled
Discretization	Pressure (Standard) Momentum (Second Order Upwind)
Boundary Conditions	Velocity Normal Inlet Outlets
Under Relaxation Factors	0.4 for the pressure 0.7 for momentum
Residuals	0.001 for Continuity, Momentum, K, Epsilon Equations

Table 6. CFD Simulation Setup

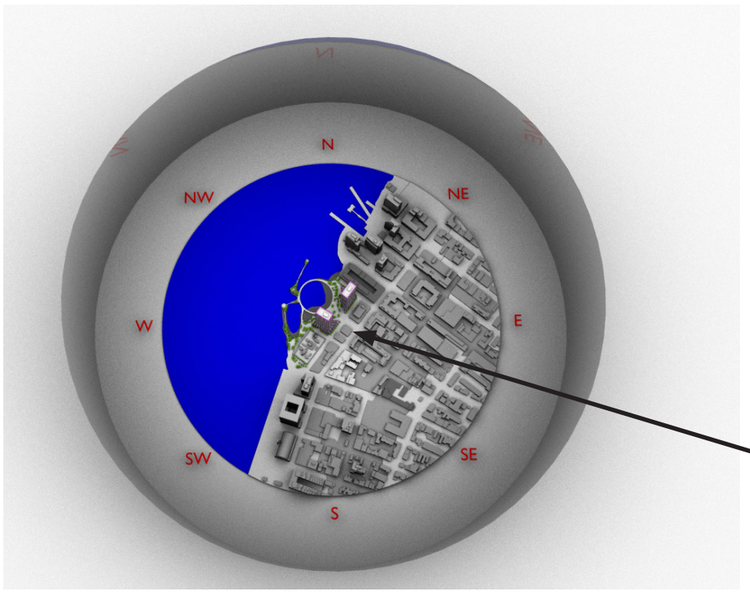


Figure 4. Computational Domain

Numerical Setup

The numerical modeling was conducted using the HELYX 3.2.1 computational package. A detailed wind driven flow simulation was conducted in order to assess the wind speeds throughout the development site. The characteristics of the CFD simulation are detailed in Table 6 below.

Boundary Conditions

The wind velocity in and around the development was evaluated by solving the Reynolds' Averaged Navier Stokes (RANS) equations for the flow. A cylindrical computational domain with a height of 500 meters (accounting for 4 times the height of the tallest building within the domain) and a radius of 500 meters was generated, as shown in Figure 4. The side walls of the computational domain were used as the computed inlet and outlet for the boundary layer input. In total, 16 wind directions were analyzed for the annual case for this study based on the proposed site configuration.

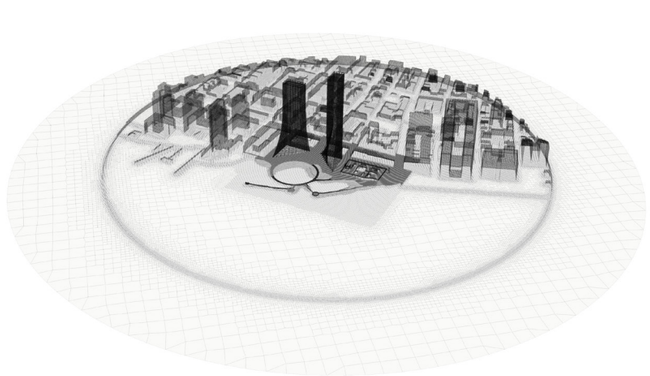
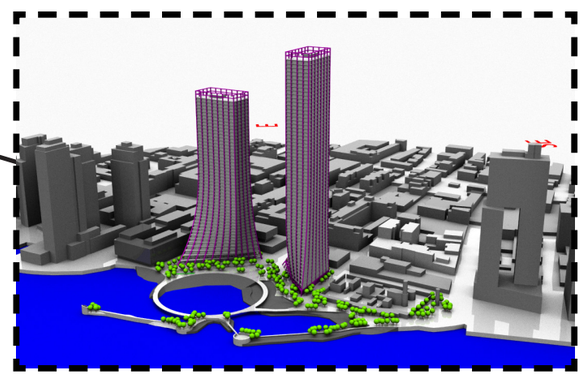


Figure 5. Computational Grid



Porous Regions

Trees from the proposed site landscaping plan were accounted for as porous cell volume zones using the Darcy-Forchheimer method to determine porosity. Zones were representative of solid tree trunks (0% porous) or the more porous foliage. The Darcy-Forchheimer method allows the associated pressure drop as the flow traverses through a porous zone to be modeled.

Computational Mesh and Grid Independence Study

A grid independence study was undertaken for the external wind speeds of the computational model, for the Southerly wind case. Results from the two grids employed (G1 & G2) were measured at chosen located for various heights. These included y = 10m, y = 22.5m as well as y=30m. The results are summarized in Table 7 and Table 8 below. G1 was taken for use to maximize computational efficiency.

Grid	Element	Base Mesh Size (m)	Cell Count (x10E6)
G1	Hexahedral	0.28	47.8
G2	Hexahedral	0.32	43.1

Table 7. Grid Properties for domains tested

Grid	G1 Velocity Magnitude (m/s)	G2 Velocity Magnitude (m/s)	Percentage Difference (%)
G1	5.0	5.1	1.4
G2	8.5	8.6	1.6

Table 8. Grid Independence Results for this Study

4. Meteorological Data for New York

Meteorological Data

Details of the wind climate of the New York region have been determined from a detailed statistical analysis of measured mean wind speed data from La Guaridia and JFK airports, 84 years of wind climate data has been collected from this station, and the data has been corrected so that it represents winds over standard open terrain at a height of 10m above ground. The corrected data is summarized in Table 9 for the estimated weekly and annual return periods in the form of hourly means and the corresponding 3-second gust values. These directional wind speeds are also presented in Figure 6 (referenced as hourly mean wind speeds) for the New York Region. The data indicate that the maximum wind speeds for the region are from the north-west. Additionally, the most frequent winds for the region occur from the north-west.

Wind Direction	Hourly Mean (Weekly Recurrence)	3 - Second Gust (Weekly Recurrence)	Hourly Mean (Annual Recurrence)	3-Second Gust (Annual Recurrence)
	(m/s)	(m/s)	(m/s)	(m/s)
N	7.8	11.9	11.3	17.3
NNE	7.0	10.6	10.8	16.4
NE	7.9	12.1	12.1	18.4
ENE	7.2	11.1	12.1	18.4
E	5.4	8.2	10.6	16.2
ESE	4.9	7.5	9.6	14.7
SE	5.2	8.0	9.9	15.2
SSE	6.6	10.1	10.9	16.7
S	8.4	12.8	11.7	17.8
SSW	7.0	10.6	10.0	15.3
SW	7.0	10.7	9.6	14.7
WSW	7.4	11.3	11.1	17.0
W	8.9	13.5	13.0	19.8
WNW	9.7	14.8	13.4	20.4
NW	10.5	16.1	13.7	20.9
NNW	8.7	13.3	12.1	18.5

Table 9. Directional Mean and Gust Wind Speeds for the New York Area

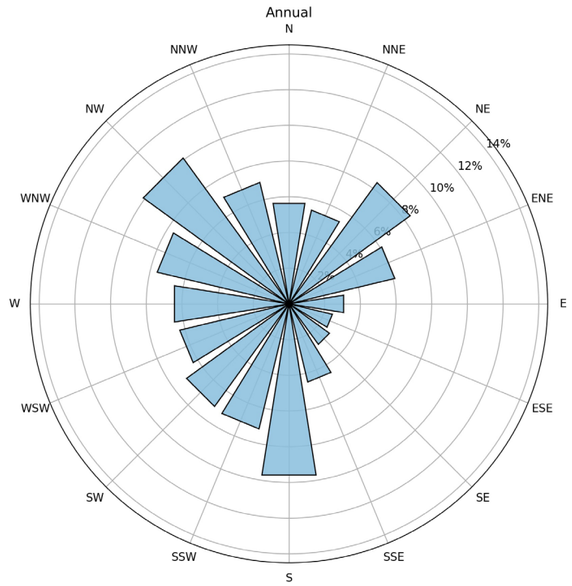


Figure 6. Wind Rose (Frequency of Occurrence) for the New York Area

Approaching Wind Speeds

The approaching wind terrain category was assessed using the terrain descriptions from Eurocode 1: Actions on Structures – Part 1-4: General Actions-Wind Actions (BS EN 1991-1-4:2005) and International Standard Wind Actions on structure (ISO 4354). For winds occurring from all three predominant directions modeled, the terrain was assessed to be a Suburban Terrain (Terrain Category III or Terrain Category 3). The approaching terrain profiles were combined with the local wind climate described to determine the site wind speeds. These are presented in Table 10 and are used to determine the inputs conditions for the CFD simulations The site hourly mean wind speeds are used when determining the speedup ratio for a given wind direction, a speed up ratio of zero implies no speed up compared to the boundary condition whereas a speed up ratio of one predicts the wind speed at a point is double that of the inlet condition; the speed up ratios for this study can be found in Appendix A.

Wind Direction	Terrain Category (EN 1991-1-4, ISO 4354)	Basic Hourly Mean Wind Speed at 10m Height	Site Hourly Mean Wind Speed at 10m Height
		(m/s)	(m/s)
NW	III, 3	10.5	6.4
S	III, 3	8.4	5.7
NE	III, 3	7.9	5.1

Table 10. Hourly Mean Site Wind Speeds

5. Results and Discussion
Annual Lawson's Wind Comfort Criteria Fields

Presented in Figure 7 are Lawson (2001) comfort criteria contours for the annual condition for the proposed site. For the proposed development a variety of wind comfort conditions are predicted at the ground level trafficable areas across the site.

A. Funneling effects occur between the two proposed towers resulting in higher wind speeds between the two towers. This region is predicted to be suitable for strolling and business walking activities for the annual condition. The funneling effect seen here align with the prevailing north-westerly wind from which no shielding is provided by upstream buildings. Corner acceleration is also a dominant effect within this region.
B. High wind speeds are predicted within the south-eastern regions of the arcades. This is primarily due to downdraughts entering through the open arcade double height structure.
C. Funneling is seen in portions along the center of the street bed of North 3rd Street. A region unsuitable for leisurely activities (strolling and stationary activities) is predicted as a result. The funneling did not present concerns along the sidewalks.
D. A region of higher speed flow is predicted to the south-east of the South Tower, this is a result of wind accelerating around the north-eastern corner of the tower. Wind comfort levels in this region are predicted to be unsuitable for stationary activities.
E. Some areas of the paths within the proposed open space see higher wind speeds resulting in areas unsuitable for stationary activities. This is primarily due to the lack of any shielding from nearby buildings.
F. An area exceeding the comfort limit is predicted to the south-west of the site (outside of the proposed development site). This is likely as a result of south-westerly winds accelerating around the corner of existing buildings and not as a result of the proposed development.

Most of the trafficable area of the development is predicted to see wind speeds suitable for sitting and standing activities.

** Note that comfort conditions here are impacted by the inclusion of the modeled vegetation which is reflective of the landscaping plans proposed by the Applicant in their WPAA. The vegetation serves as a natural mitigation measure and will act to slow down airflow. Removing or altering the vegetation may result in comfort levels no longer being reflective of this analysis.

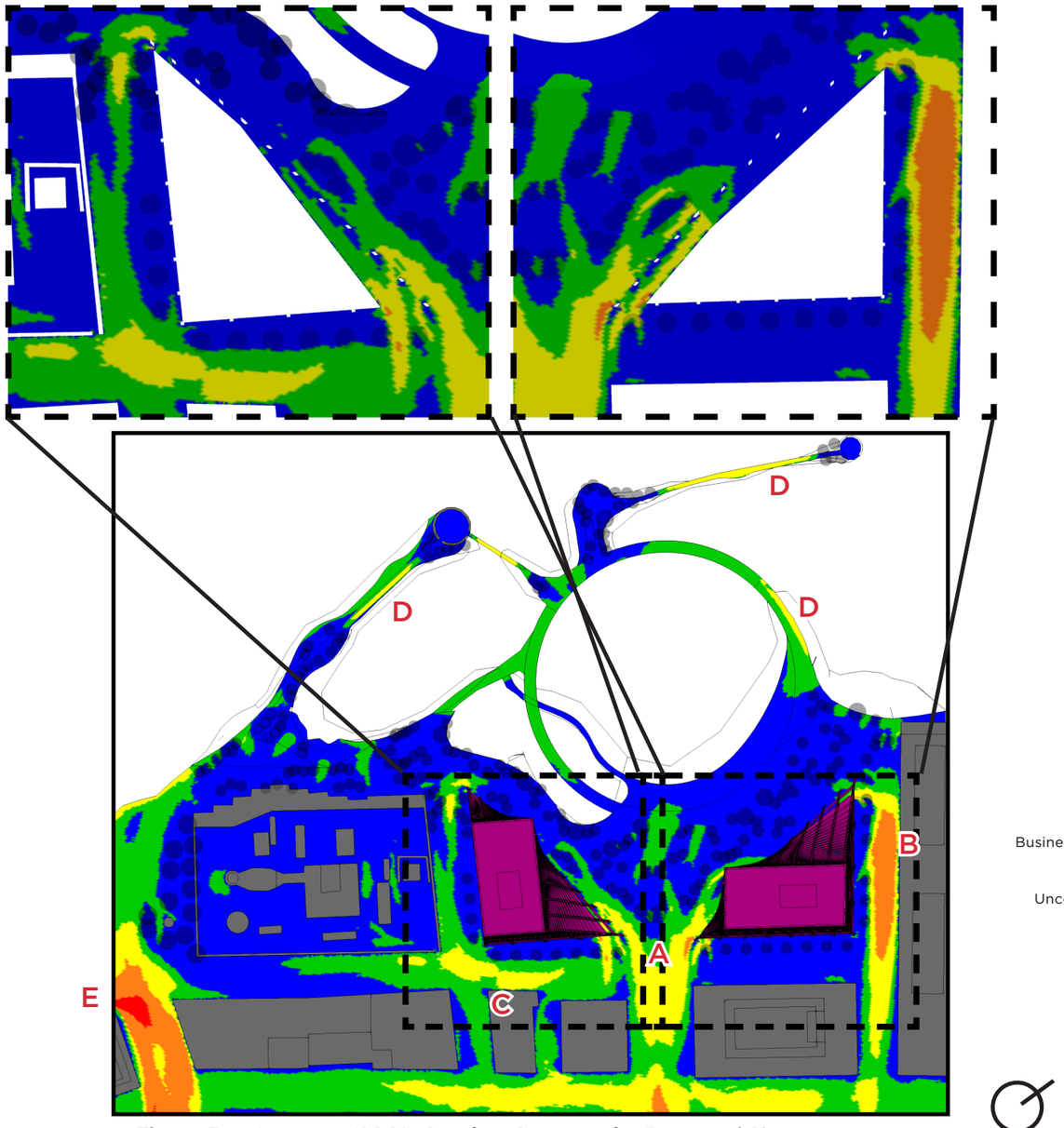


Figure 7. Lawsons (2001) Comfort Contours for Proposed Site

5. Results and Discussion
Annual Lawson's Wind Safety Criteria Fields

Observations

- Presented in Figure 8 are Lawson (2001) safety criteria contours for the annual condition for the site.

- Wind safety conditions at the ground level trafficable areas of the development suggests wind speeds will not pose a danger to members of the public. Note, this is with the inclusion of the modeled vegetation.

- An area exceeding the safety limit with respect to frail safety is predicted to the south-west of the site. This is likely as a result of south-westerly winds accelerating around the corner of the existing building found here and not as a result of the proposed development.

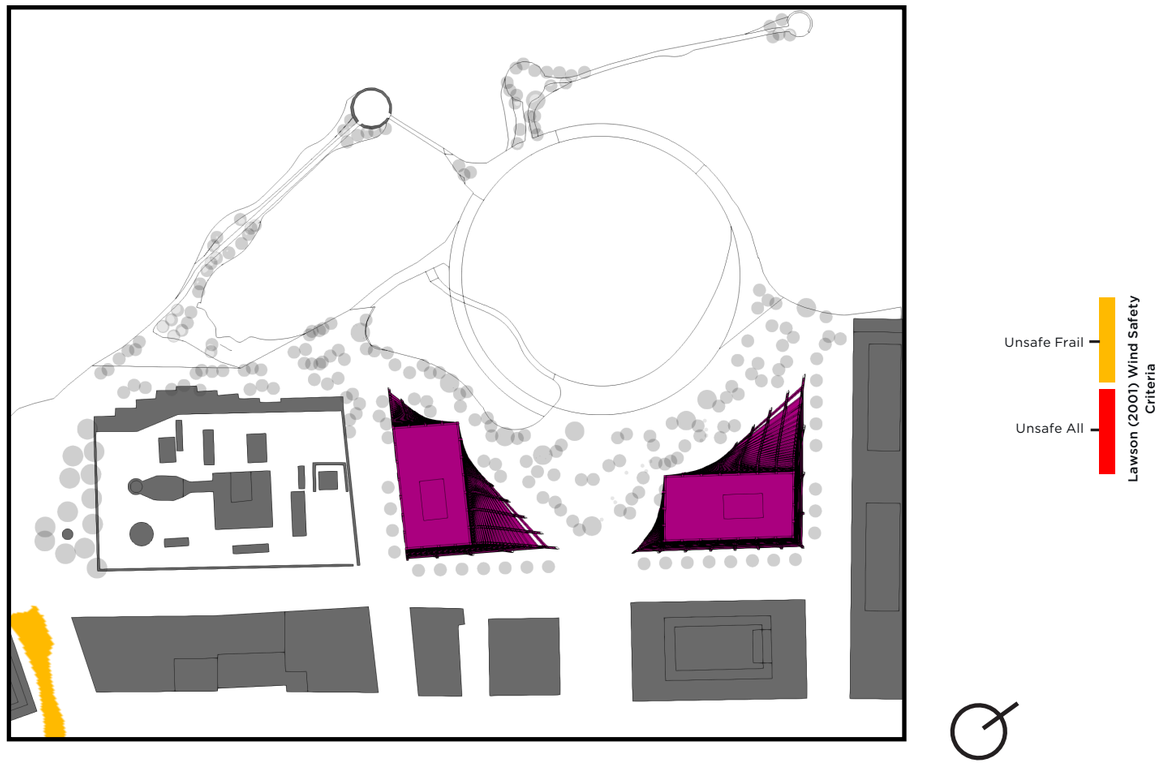


Figure 8. Lawsons (2001) Safety Contours for Proposed Site

5. Results and Discussion
Annual Lawson's Wind Comfort Criteria Fields

Mitigation Areas

On the whole, conditions around the proposed site are predicted to be suitable for sitting and standing activities. Note, the full proposed plan including waterfront open space design and landscaping was modelled as a whole. The landscape design, per the proposed plan is beneficial to the wind comfort criteria seen across the site.

The acceleration of flow was found in some areas around the site resulting in wind comfort levels that exceed the lowest program criteria (sitting).

A. Around the southern corner of the northern building there is a small area where the business walking criteria is predicted to be met. Should a lower criteria be desired in the future, mitigation recommendations would include moveable planters or trellises within the arcade area.

B. The south-eastern portion of the arcades of the northern building are predicted to see conditions suitable for strolling activities with small areas suitable for business walking activities. Should a lower criteria be desired in the future, mitigation recommendations would include moveable planters or trellises within the arcade area.

C. The north-eastern arcades of the southern building are predicted to see conditions suitable for strolling activities with small areas suitable for business walking activities. Should a lower criteria be desired in the future, mitigation recommendations would include moveable planters or trellises within the arcade area.

D. The north-western corner of the northern building sees a small area predicted to be unsuitable for standing activities. Should a lower criteria be desired in the future, mitigation recommendations would include moveable planters or trellises within the arcade area.

E. The area to the north of the northern building is predicted to be suitable for business walking activities. As this area is a public street and specifically pertains to the streetbeds this area is thought to be suitable for its intended use.

F. Certain areas of the waterfront park walkways are predicted to exceed the sitting criteria. Should a lower criteria be desired in the future, mitigation recommendations would include moveable planters or ballustrades.

G. An area exceeding the comfort limit is predicted to the south-west of the site (outside of the proposed development site). This is likely as a result of south-westerly winds accelerating around the corner of an existing neighborhood building found here and not as a result of the proposed development.

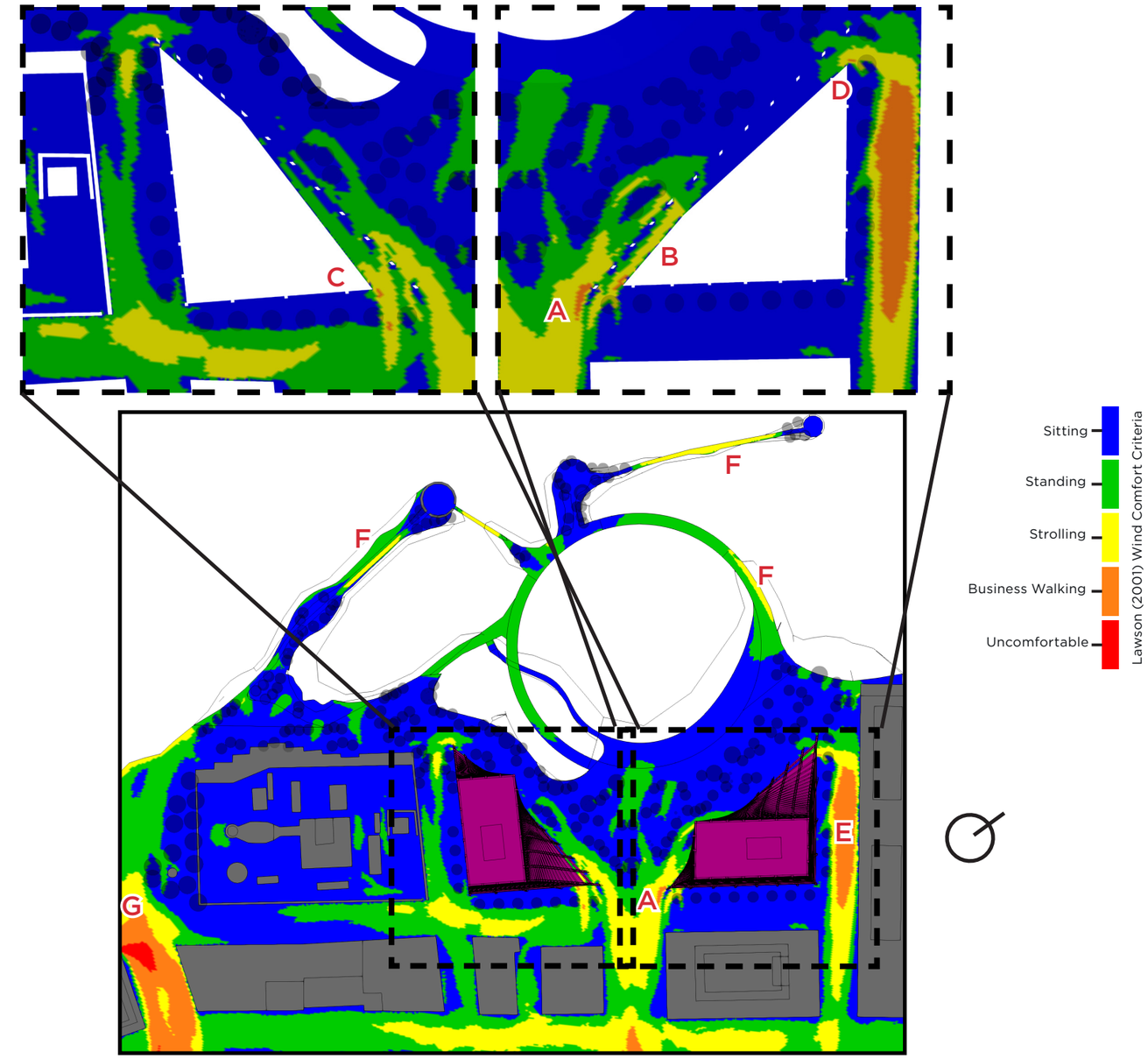


Figure 9. Lawsons (2001) Comfort Contours for Proposed Site

5. Results and Discussion
Annual Lawson's Wind Comfort Criteria Fields

Mitigation Measures

The majority of the conditions around the proposed development site are predicted to be suitable for sitting and standing activities. Note, the inclusion of modeled vegetation is thought to aid the wind comfort criteria seen across the site and has been modeled per the proposed plan.

In order to further improve wind comfort conditions across the site the following mitigation measures could be considered:

A. Addition of vegetation, such as evergreen trees or planters over 6.5ft (~2m) in height would act to mitigate wind speeds around the south corner of the northern building.

B. Airflow has been shown to enter the double height arcades through the mechanism of downwash. For the prevailing north-westerly wind direction the incoming air travels over the downwind vegetation. Therefore, the installation of trellises, and high moveable planters at specific locations would mitigate wind speeds within the arcades.

Furthermore, in order to mitigate wind speeds within the arcades at locations directly next to building entrances placement of 5.2ft (~1.6m) tall planters on the northern side of an entrance would likely successfully mitigate wind speeds at the entrance.

C. Walkways within the waterfront area are predicted to see conditions suitable for strolling activities. In the event that the required use case at any of these locations should become standing or sitting activities, the addition of balustrades with a height of 5ft (~1.5m) and a porosity of at most 40% is predicted to successfully mitigate wind speeds at these areas. This would bring the wind comfort conditions at these areas closer to the sitting comfort conditions that are present at the circular platforms.

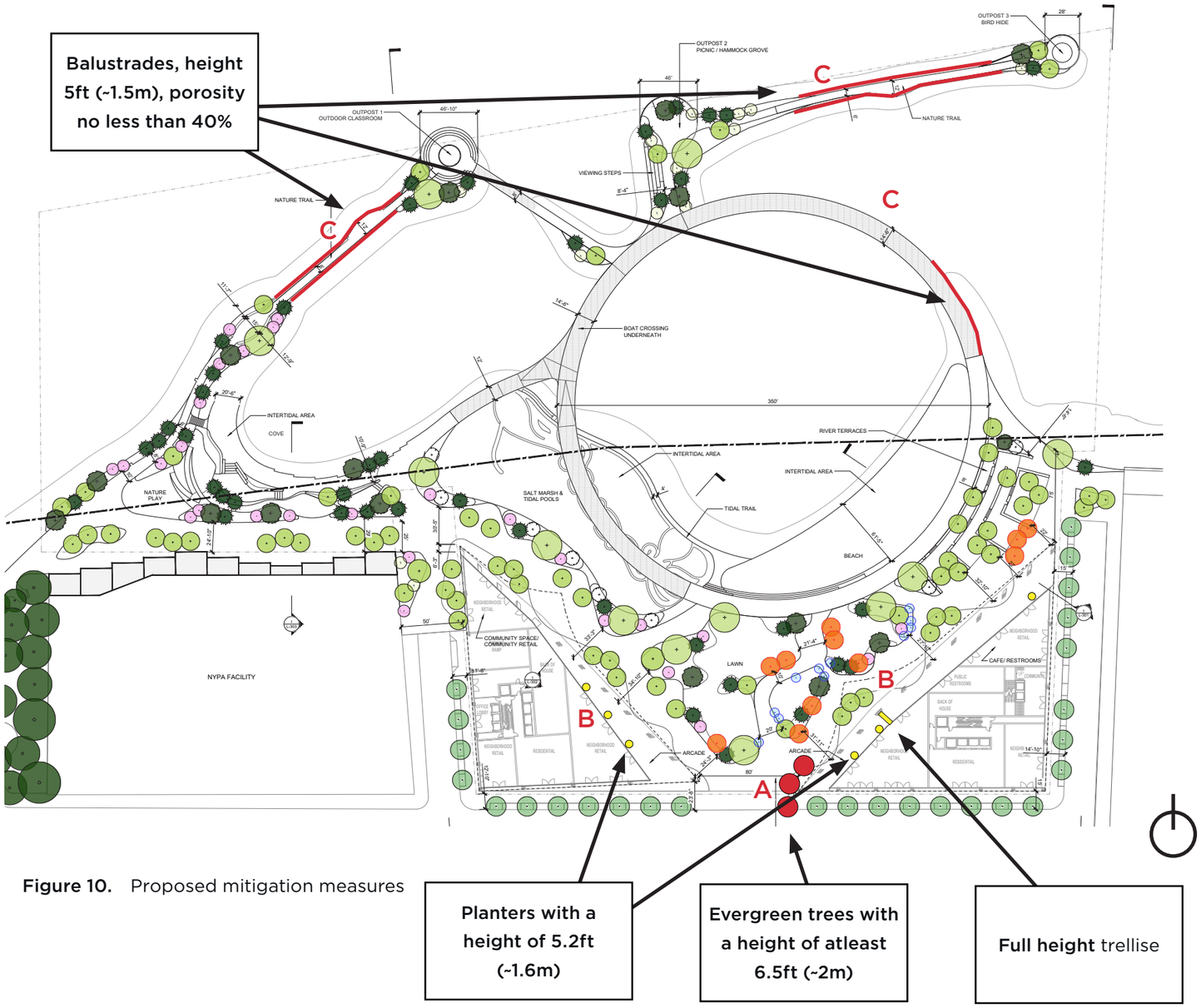


Figure 10. Proposed mitigation measures

6. References

1. Australian and New Zealand Standard, AS/NZS1170.2:2011, “Structural Design Actions”
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Appendix A

Wind Speed Up Fields

Appendix A - Wind Speed Up Fields

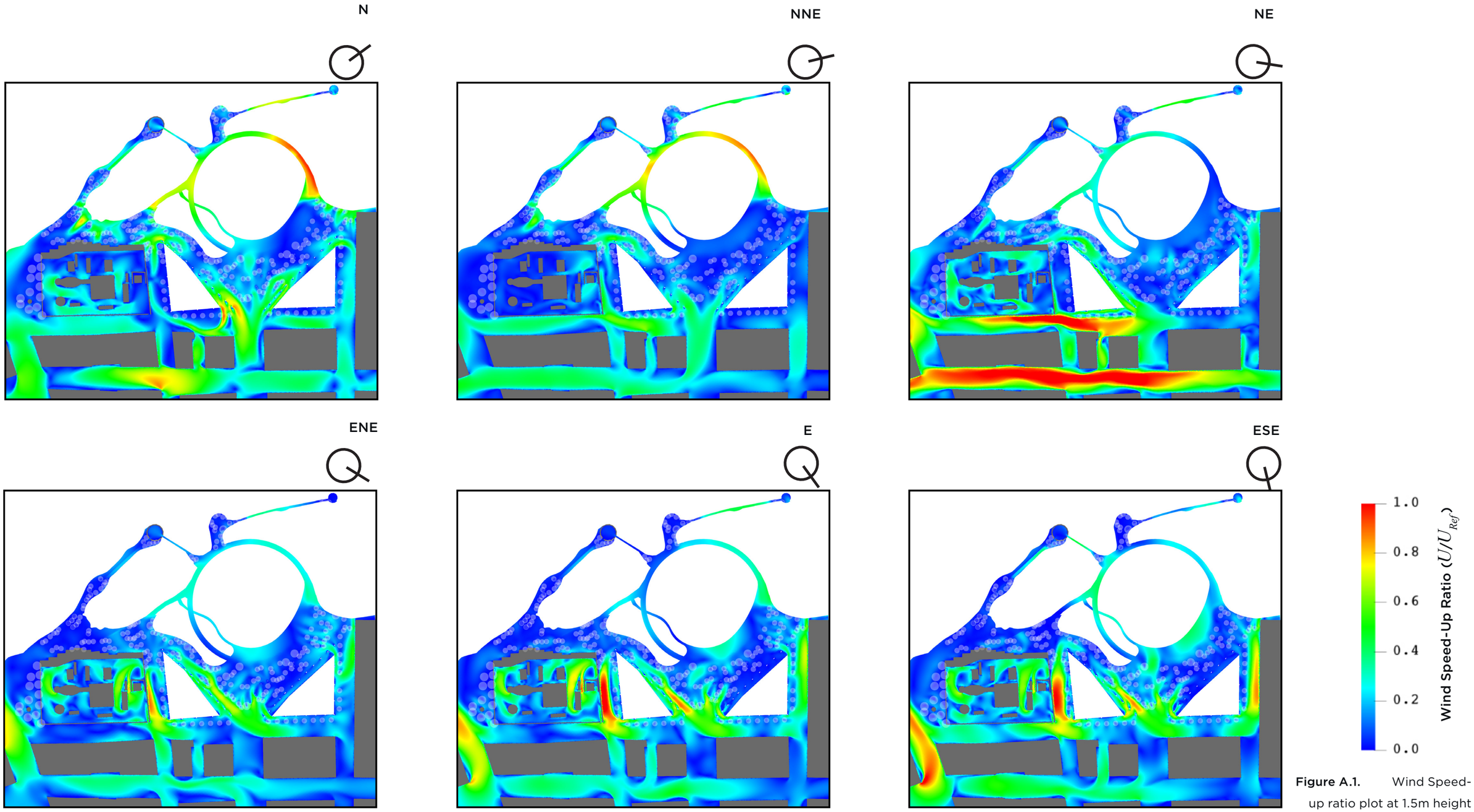


Figure A.1. Wind Speed-up ratio plot at 1.5m height

Appendix A - Wind Speed Up Fields

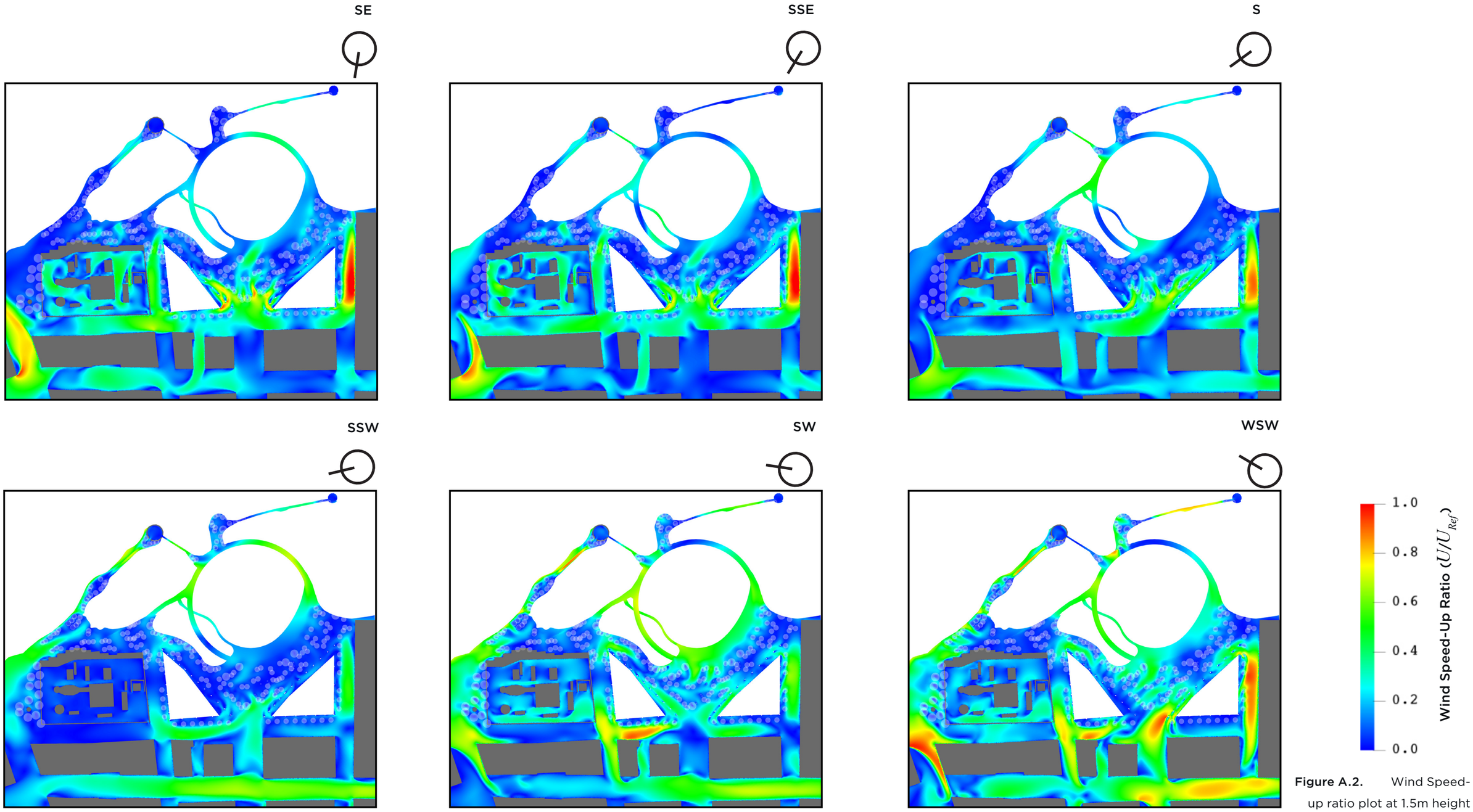
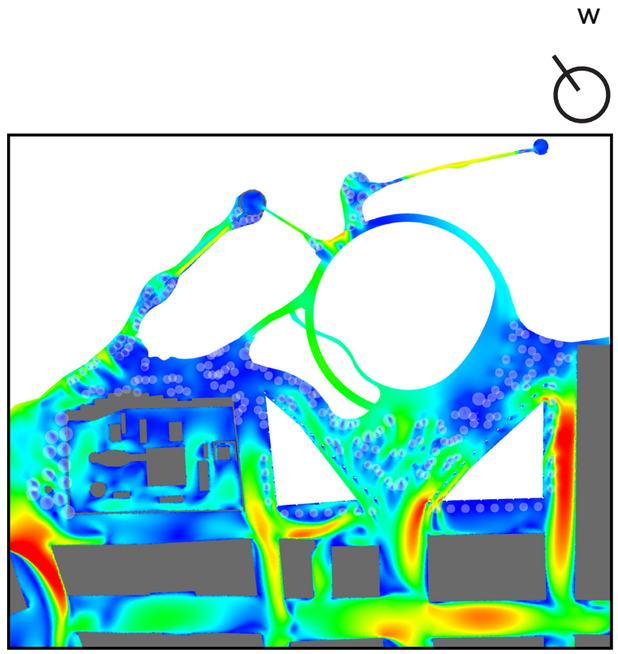
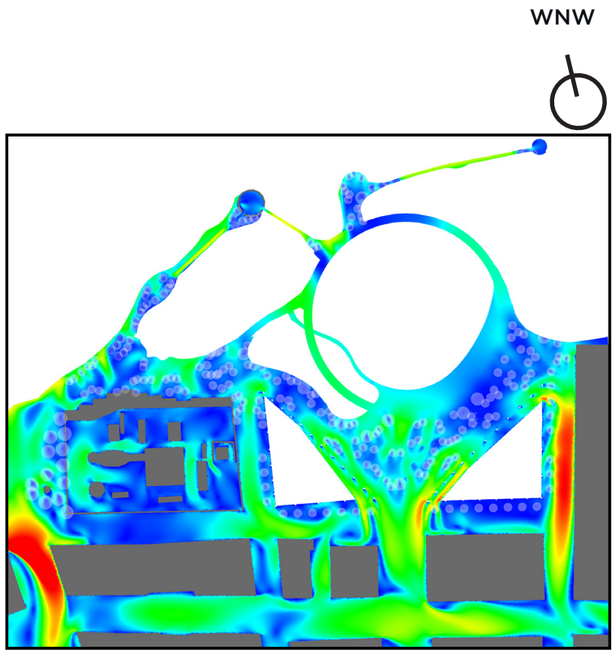
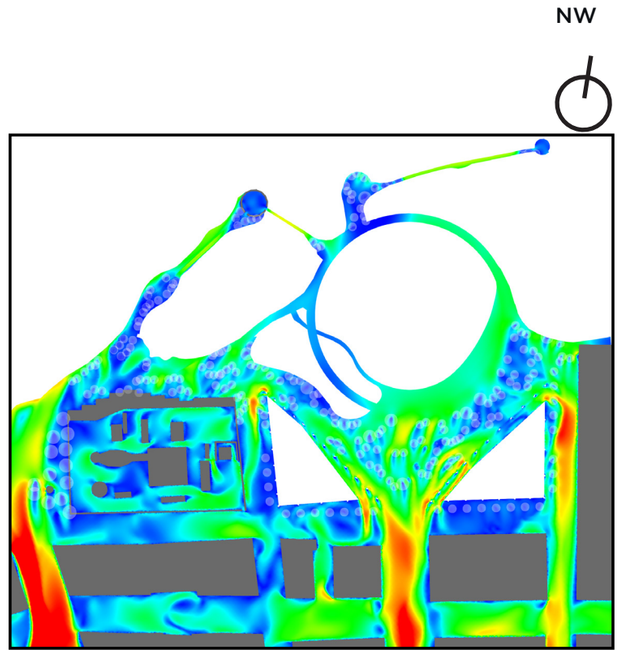


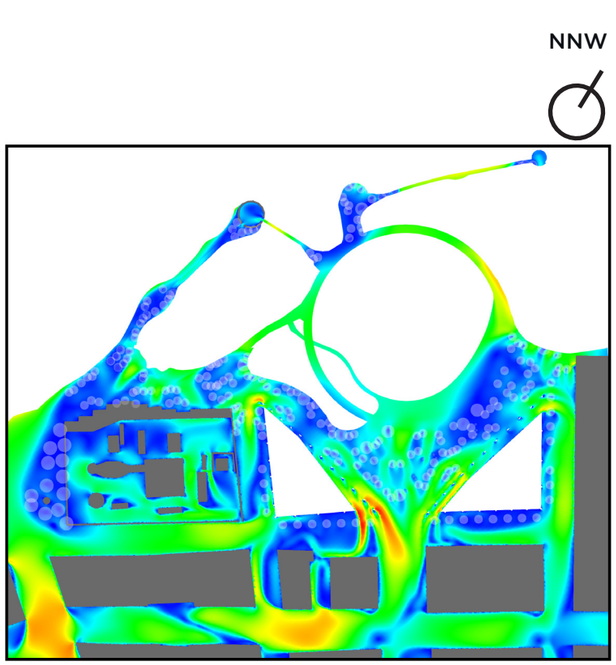
Figure A.2. Wind Speed-up ratio plot at 1.5m height

Appendix A - Wind Speed Up Fields









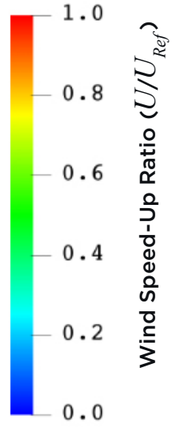


Figure A.3. Wind Speed-up ratio plot at 1.5m height