Pedestrian Wind Comfort Study

Lands at Former Ted Castles Site
and DunLeary House

Project No. A591
17th Novemeber 2021

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EXECUTIVE SUMMARY

This report outlines the predicted climatic wind conditions experienced within and surrounding the proposed development at the former Ted Castles site and DunLeary House located at Old Dunleary Road, Cumberland Street, Dun Leary Hill, Dun Laoghaire, Co. Dublin.

A conscious effort was made by the design team during the design stages to mitigate the risk of localised increased wind speed conditions due to the proposed development. The introduction of mitigation measures such as the courtyard location, inset balconies, solid balcony balustrades, as well as the strategic location of extensive landscaping, all assist in reducing the potential development of local increased wind speed and the negative impact on local climatic conditions.

Based on the CFD modelling results, the proposed development will be a comfortable environment for occupants. Certain areas have been highlighted as being potentially uncomfortable for a limited period of time, however, these concerns have been largely addressed through the incorporation of landscaping which will mitigate excessive wind speeds in these areas. Certain areas around the development at street level will be uncomfortable for limited periods of time. However, the Dublin climate is largely responsible for the exceedance of the given comfort classes, especially when buildings are located close to the coast and there is little to no obstruction of the wind coming off the coast as is the case for this development.

Finally, the wind speed threshold for a certain pedestrian class is only meant to provide guidance on where to locate certain areas where a certain type of activity is expected to be performed. In practice, the experience of the outdoor climate depends on more than just wind speed. Other factors such as clothing, air temperature, solar irradiation, age and relative humidity must also be considered.

Overall, the proposed development will be a high-quality, comfortable environment for occupants throughout the year.

PEDESTRIAN WIND COMFORT STUDY

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1. INTRODUCTION

The purpose of this report is to outline the predicted climatic wind conditions experienced within and surrounding the proposed development at the former Ted Castles site at Old Dunleary Road, Cumberland Street, Dun Leary Hill, Dun Laoghaire, Co. Dublin.

The proposed method for compliance validation is via the industry best practice standard for pedestrian comfort (Lawson Criteria). The Lawson Criteria sets acceptable levels of wind speed and velocity for various human activities.

Given the specific location of the building and recorded metrological data available for the area, and standard interpolation calculation procedures, it is possible to predict the expected wind speeds and their annual occurrence.

2. PROPOSED DEVELOPMENT

The proposed development at the former Ted Castles site and DunLeary House (a proposed Protected Structure), Old Dun Leary Road, Cumberland Street and Dun Leary Hill, Dun Laoghaire will consist of:

- The provision of 146 no. apartment units (Build to Rent) and all associated ancillary facilities (including residential amenities) in a building with an overall height ranging from 6 storeys (with set backs from 4th & 5th storey) addressing Dun Leary Hill, to 5 and 8 storeys (with set back from 7th storey) addressing Old Dun Leary Road and 6-7 storeys (with set backs at 8th storey) addressing Cumberland Street. The proposal provides for private and communal open spaces in the form of balconies and terraces throughout.

- A retail unit (c.290m2) at ground floor level addressing Old Dun Leary Road and Cumberland Street

- The refurbishment, partial removal and adaptation of a 4 storey building on site known as "DunLeary House" (a proposed Protected Structure) to provide co-working office suites (c.247m2) at Levels 01,02 and 03. The works will include partial removal of original walls and floors, removal of non original extensions to DunLeary House, repointing and repair of brickwork and granite fabric, reinstatement of timber sash windows, removal of existing roof, removal; alteration and reinstatement of internal floor layouts, reinstatement of entrance point on DunLeary Hill, removal of non original level 00 and linking the existing building to the new development from level 00 to level 03 with the construction of 3 new floors of development (with set back at roof level) above the existing building. It is proposed to repair, reinstate and improve the existing boundary treatment to DunLeary House.

- Provision of 52 no. car parking spaces in total - 44 no. car parking spaces provided at level 00. At Cumberland Street 11 no. existing on street car parking spaces will be removed and 8 no. on street car parking spaces provided. Provision of 277 bicycle parking spaces (94 no. cycle parking spaces accommodated in bicycle stands and 183 no. long term bicycle parking spaces within a secure storage area) and 4 no. motorbike parking spaces, all at Level 00. A new vehicular entrance/cycle path (off the Old Dun Leary Road), ancillary plant areas, ESB substation and storage areas.

- Extensive hard and soft landscaping throughout, green roof, public lighting, signage, boundary treatments and public realm improvements.

- The demolition of the existing open fronted shed on site and all associated ancillary site services and site development works.

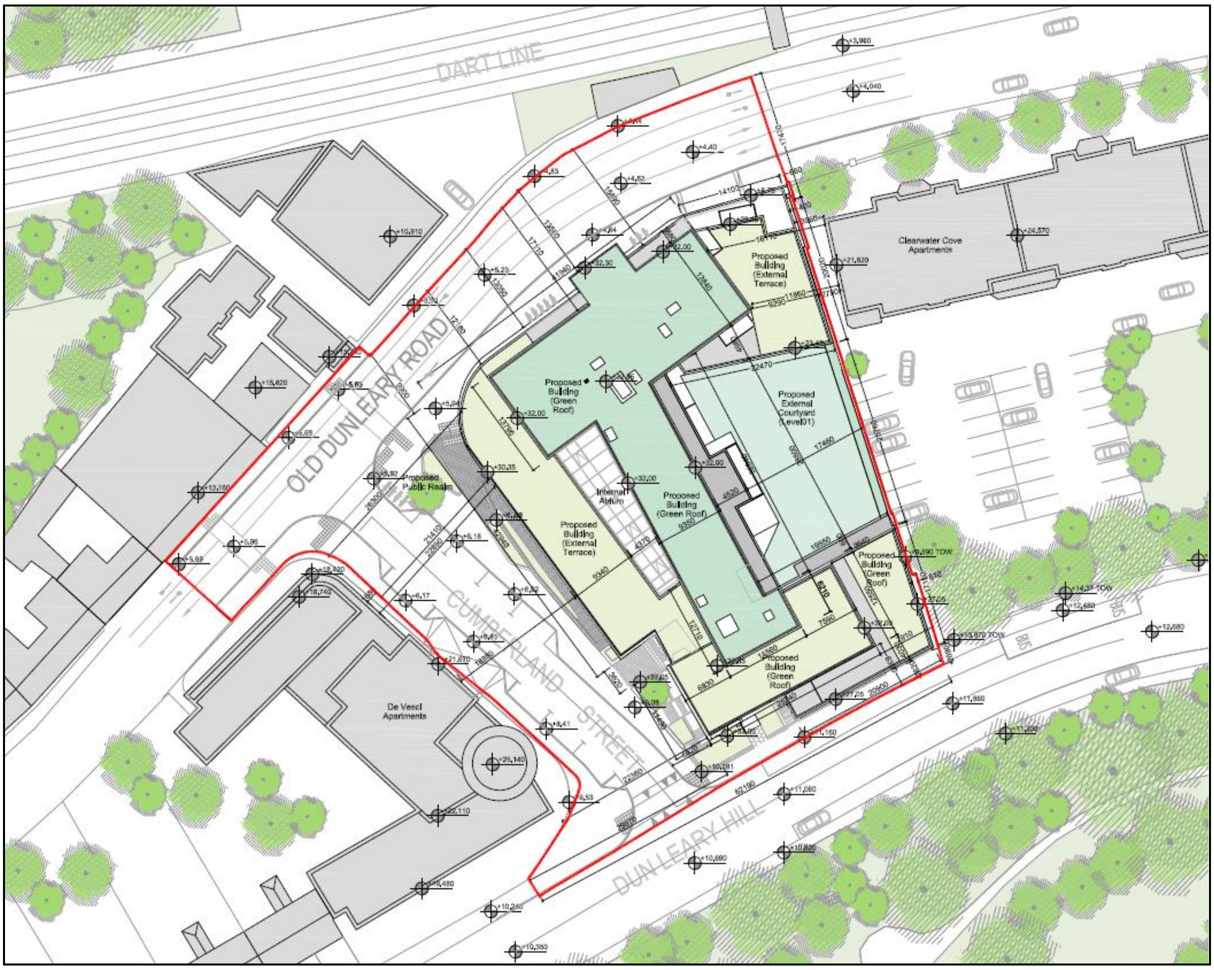

Figure 1 - Proposed Site Plan

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3. PEDESTRIAN COMFORT COMPLIANCE

The Lawson criteria gives guidance to quantify the effect of wind velocity on pedestrian comfort and safety. The Lawson recommended guidance indicates that for the comfort and safety assessment of the wind environment, it is not only the velocity of wind that is considered but also the frequency of occurrence of these velocities. The frequency of occurrences is used here as an indicator of the likely duration of certain wind speeds. The Lawson criteria indicates that the threshold mean hourly wind speed for each pedestrian activity should not be exceeded for more than 5% of the time to maintain pedestrian comfort.

Pedestrian activity	Threshold mean hourly wind speed not to be exceeded for more than 5% of the time [m/s]
Business Walking	10
Leisurely Walking	8
Standing or Short-Term Sitting	6
Long-Term Sitting	4

Table 1 – Lawson Criteria for Pedestrian Comfort

There are 2 no. additional classes to quantify the safety conditions for typical or sensitive (e.g. frail or a cyclist) pedestrians which are summarised in Table 2.

Pedestrian activity	Threshold mean hourly wind speed not to be exceeded for more than 0.023 % of the time [m/s]
Typical Pedestrian	20
Sensitive Pedestrian	15

Table 2 – Lawson Criteria for Safety Assessment

4. ASSESSMENT METHODOLOGY

The methodology adopted for the study combines the use of Computational Fluid Dynamics (CFD) to predict air flow patterns and wind velocities around the proposed development, the use of wind data from the nearest suitable meteorological station and the recommended comfort and safety standards (The Lawson Criteria).

The study considered the following factors:

- The effect of the geometry, height and massing of the proposed development and existing surroundings on local wind speed and direction;
- The wind speed as a function of the local environment such as topography, ground roughness and nearby obstacles (buildings, bridges, etc.);
- The effects of site location (open field, inner city, etc.);
- Orientation of the buildings relative to the prevailing wind direction; and
- The pedestrian activity to be expected (long term sitting, standing or short term sitting, leisure and business walking).

The wind analysis focuses on the potential variation of the wind velocities from the reference wind data due to the proposed development.

4.1. EXTENT OF CFD STUDY AREA

The extent of the built area that is represented in the computational domain is dependent on the influence of the features on the region of interest which includes the site and its nearby surroundings.

The analytical CFD model is assessed against the full Lawson Criteria to identify the pedestrian comfort and safety conditions surrounding the development.

The analytical CFD model has been constructed based on the information provided below:

- 3D AutoCAD model and plans received from MOLA Architects;
- Topographical survey drawings of surrounding buildings;
- Available aerial photographic data via Google Maps;
- Meteorological wind data for Dublin Airport.

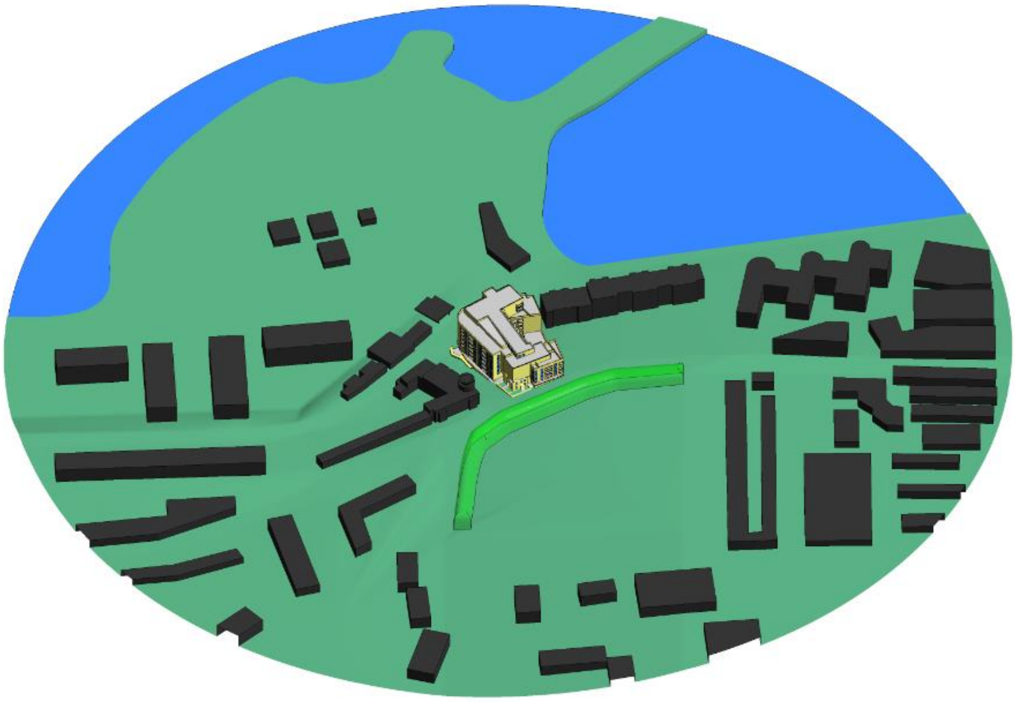

Figure 2 – Extent of CFD Study Area

4.2. WIND CLIMATE

The wind climate analysis is based on the wind data obtained from the Dublin Airport weather station which incorporates hourly wind data over a 30-year period (1990 to 2020). Based on the data outlined in Table 3, more than 93% of the total hours in the year have a wind speed between 0 – 10 m/s, while approximately 50% of the wind comes from the SSW, WSW and W direction.

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Wind dir.	N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	Total	Total
	0	30	60	90	120	150	180	210	240	270	300	330		
Speed [m/s]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[%]
0-1	24	19	12	23	31	26	16	17	23	30	30	26	92	1.1%
1-2	52	41	25	53	74	64	34	47	63	70	63	49	476	5.4%
2-3	51	54	50	87	122	108	51	94	130	143	102	63	963	11.0%
3-4	43	48	67	92	132	121	49	124	191	194	133	66	1296	14.8%
4-5	32	45	66	75	109	121	43	140	224	219	121	62	1361	15.5%
5-6	24	38	51	53	85	107	42	148	234	211	94	47	1236	14.1%
6-7	16	30	37	37	57	84	38	130	228	169	63	33	1001	11.4%
7-8	10	21	24	25	36	60	30	111	195	134	41	24	767	8.8%
8-9	6	11	17	18	22	41	22	85	159	105	25	14	564	6.4%
9-10	4	7	11	12	12	27	17	59	121	80	14	7	401	4.6%
10-11	2	4	4	8	9	16	11	39	82	56	7	3	255	2.9%
11-12	1	3	2	5	5	10	6	23	52	36	5	1	160	1.8%
12-13	0	2	1	2	2	5	3	13	32	21	2	1	89	1.0%
13-14	0	0	0	1	2	3	1	8	18	11	1	0	48	0.5%
14-15	0	0	0	1	1	1	0	5	11	6	1	0	27	0.3%
15-16	0	0	0	1	0	1	0	2	6	4	0	0	14	0.2%
16-17	0	0	0	0	0	0	0	1	2	2	0	0	6	0.1%
17-18	0	0	0	0	0	0	0	0	1	1	0	0	2	0.0%
18-19	0	0	0	0	0	0	0	0	1	1	0	0	1	0.0%
19-20	0	0	0	0	0	0	0	0	1	1	0	0	1	0.0%
Total (hrs)	252	295	350	492	717	819	339	1021	1766	1589	728	392	8760	100%
Total (%)	2.9%	3.4%	4.0%	5.6%	8.2%	9.3%	3.9%	11.7%	20.2%	18.1%	8.3%	4.5%	100%	-

Table 3 - Frequency of Wind Velocity Occurrence per Wind Direction

Figure 3 graphically illustrates the data in Table 3 above and illustrates the percentage of hours per wind direction over the 30 year period (1990 – 2020) for the 12 no. wind directions. It is evident from the figure below the predominant wind directions are SSW, WSW and W.

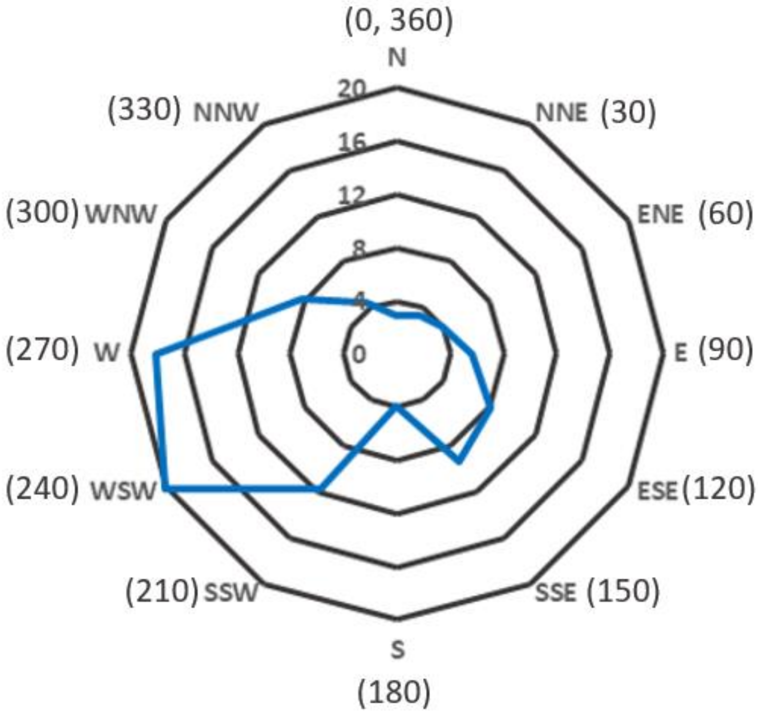

Figure 3 - Percentage of Hours per Wind Direction over 30 years

The hourly wind data is the basis for the wind climate analysis. The number of hours that wind occurs from a given wind direction and velocity influences the local wind climate. The CFD simulation is used to calculate the wind-factor (local wind velocity relative to reference wind velocity). The wind-factor is a measure to calculate the number of hours that a given threshold wind velocity is exceeded based on statistical wind data.

4.3. WIND PROFILE

A rectangular computational domain was created to simulate the effect of the atmospheric boundary layer surrounding the region of interest. The extents of the computational domain are illustrated in Figure 4, where H is the height of the highest tower within the proposed development.

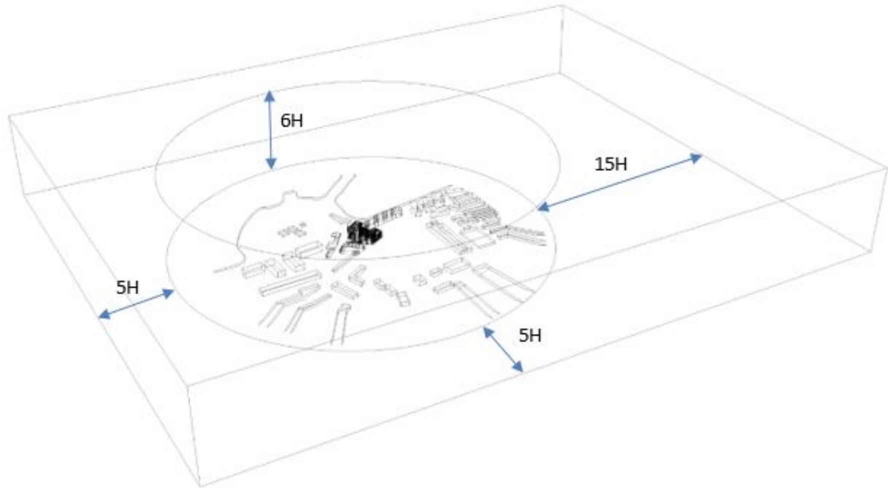

Figure 4 – Computational Domain Surrounding the Region of Interest

An atmospheric boundary layer wind profile (v_{wind}) is applied to the boundaries of the computational model. To incorporate the effect of small height differences and small objects at street level, which are not explicitly included in the model, a roughness has been applied to the ground surface of the detailed CFD model. For the wind profile a roughness length (z_0) of 0.4 m has been estimated.

Based on the reference velocity, reference height, and roughness length, a wind profile can be defined. The wind profile v_{wind} is defined as follows.

$$v_{wind} = v_{ref} \cdot \left(\frac{\ln\left(\frac{z}{z_0}\right)}{\ln\left(\frac{z_{ref}}{z_0}\right)} \right)$$

Where

v_{wind}	Wind velocity	[m/s]
v_{ref}	Reference velocity	[m/s]
z	Height above the ground	[m]
z_0	Roughness length	[m]
z_{ref}	Reference height	[m]

4.4. WIND FACTOR

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The CFD simulations are used to calculate the wind factor. The wind factor is a factor which indicates if the wind speed is locally increased (wind factor > 1.0) or decreased (wind factor < 1.0) due to buildings (or other geometry), relative to the applied reference wind speed at 10m height. The wind factor is independent of the magnitude of the reference wind speed at 10m height, making the obtained wind factor valid for all wind speeds in a specific wind direction range. Hence, one simulation can be applied per wind direction covering all wind speeds in this direction.

To explain the wind factor in more detail, the wind factor results for the 0-degree wind direction (i.e. North) are illustrated in Figure 5. The wind factor arrows that are coloured green, cyan or dark blue indicate that the local wind speed has been reduced (wind factor < 1.0), while wind factor arrows which are coloured light green/yellow indicate the local wind speed has increased (wind factor > 1.0). Using the wind factors, the quantity of hours that a wind speed is exceeded can be calculated (per wind direction) which is then used to assess compliance against the Lawson Criteria.

The wind factor results for all 12 no. wind directions are included in Appendix A.

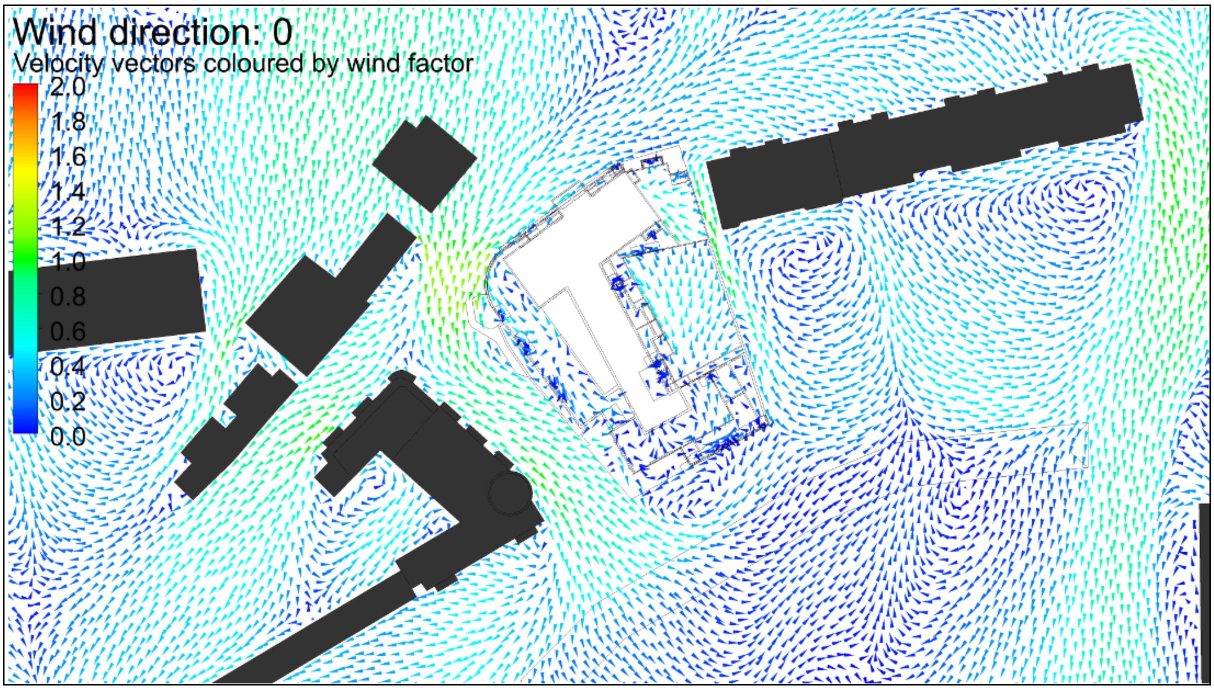


Figure 5 – Wind Factor – 0 Degree (N) Wind Orientation

4.5. CFD MODELLING

The CFD simulation has been performed using the software package ANSYS CFX version 2020 version R2. This software package can be used for a large range of applications and has been extensively validated.

A full 3D CFD model of the proposed development and surrounding buildings was created and split into a large number of control volumes or cells. The standard equations for fluid motion and energy transport are applied to each cell. The equations are then solved using numerical techniques. The CFD settings used for the analysis are summarised in Table 4.

CFD settings	Description
Grid type	Hybrid, mixture of tetrahedrons, pyramids and prisms
Cell size	Dynamic, ranging from 0.025 up to 2 m at the building surfaces and streets, growing with a factor of 1.05 to a maximum of 10 m in the volume
Number of cells	50 million
Simulation type	Steady state
Convergence	RMS maximum $1 \cdot 10^{-4}$
Simulation time	2.5 s
No. iterations	1000
Fluid	Air fixed properties
Turbulence model	RANS, RNG Kappa-Epsilon model
Walls	Smooth, no slip
Wind volume	Profile for velocity and turbulence
Roughness	Volumetric sources for momentum and turbulence
Vegetation	Volumetric loss coefficient

Table 4 - Summary of CFD Model Settings

5. ASSUMPTIONS AND LIMITATIONS

Computational Fluid Dynamic (CFD) is a widely recognised method for modelling airflow problems and as computer power develops, it increasingly improves its applicability. However, there are some limitations with CFD in relation to the modelling of wind environments. The method uses mean hourly wind values and presents a limitation to capture gusts.

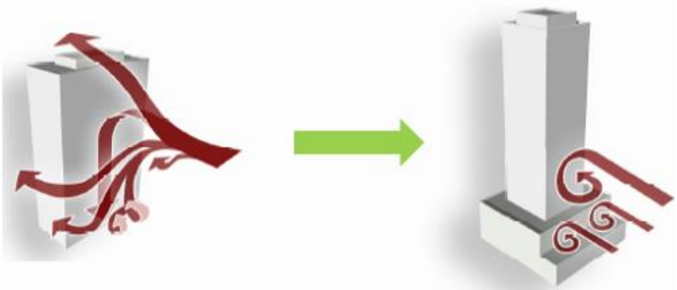
The Lawson criteria for pedestrian comfort focus on the effect of wind and do not factor in other environmental variables such as air temperature, solar radiation and relative humidity. However, overlaying all these factors would be a complex process and Lawson's simplified method presents the best available methodology for anticipating wind effects in the built environment.

The buildings were modelled as blocks, i.e. with smooth surfaces and sharp corners, which is generally sufficient detail to represent buildings in airflow modelling. This assumption is industry accepted as further detail to the model such as the window reveals and façade texture would add an impractical and unnecessary complexity to the model without adding greater quality results. Landscaping features such as pergolas and trellis structures were not modelled within the simulation as they would provide an extra level of complexity to an otherwise large CFD model. Furthermore, a very limited number of trees and hedges were modelled locally to prove their impact on mitigating wind speeds. Incorporating all balconies, trees and hedges would be impractical on a model this size.

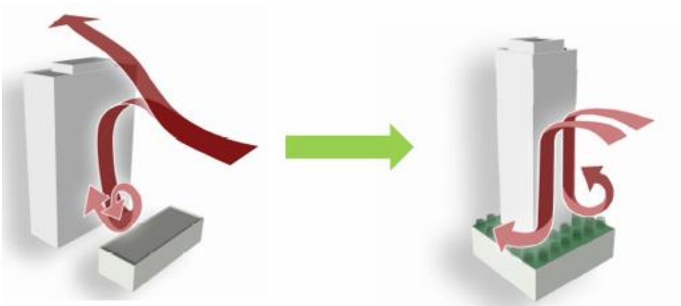
6. WIND MITIGATION MEASURES

The following are common strategies to mitigate excessive wind speeds associated with building developments[1].

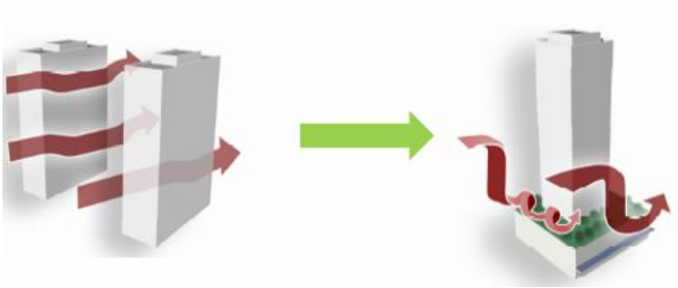
- When wind hits the windward face of a building, the building deflects the wind downwards (downwashing), causing accelerated wind speeds at pedestrian level and around the corners of the building. By introducing a base building or podium, the downward wind flow can be deflected, resulting in a reduction of wind speed at pedestrian level.



- When the leeward face of a low building faces the windward face of a tall building, it causes an increase in the downward wind flow. By landscaping the base building roof, wind speeds can be further reduced.



- Wind speed is accelerated when wind is funneled between two buildings. A horizontal canopy on the windward face of a base building can improve pedestrian comfort conditions.



[1] *Pedestrian Wind Comfort and Safety Studies,* (City of Mississauga, 2014).

The following specific mitigation measures have been incorporated into the proposed design to prevent excessive wind speeds.

6.1. COURTYARD LOCATION

The large central courtyard within the centre of the development at ground level (highlighted in orange in Figure 6) has been strategically located as it is sheltered from the predominant south-west wind direction by the proposed development resulting in a comfortable environment for pedestrians using the space.

Figure 6 – Wind Mitigation Measure – Courtyard Location

6.2. BUILDING LINE

The shape of the building façade plays a key role in helping to mitigate excessive wind speed around the proposed development. The curvature of the building onto Old Dunleary Road allows for wind to gently move around the building and eventually dissipate while the setting back of the proposed development from Cumberland Street encourages the dissipation of wind speed at the corner of Old Dunleary Road. Furthermore, protrusions along the building line help to reduce the speed of the wind as it comes off Dublin Bay and down Old Dunleary Road.

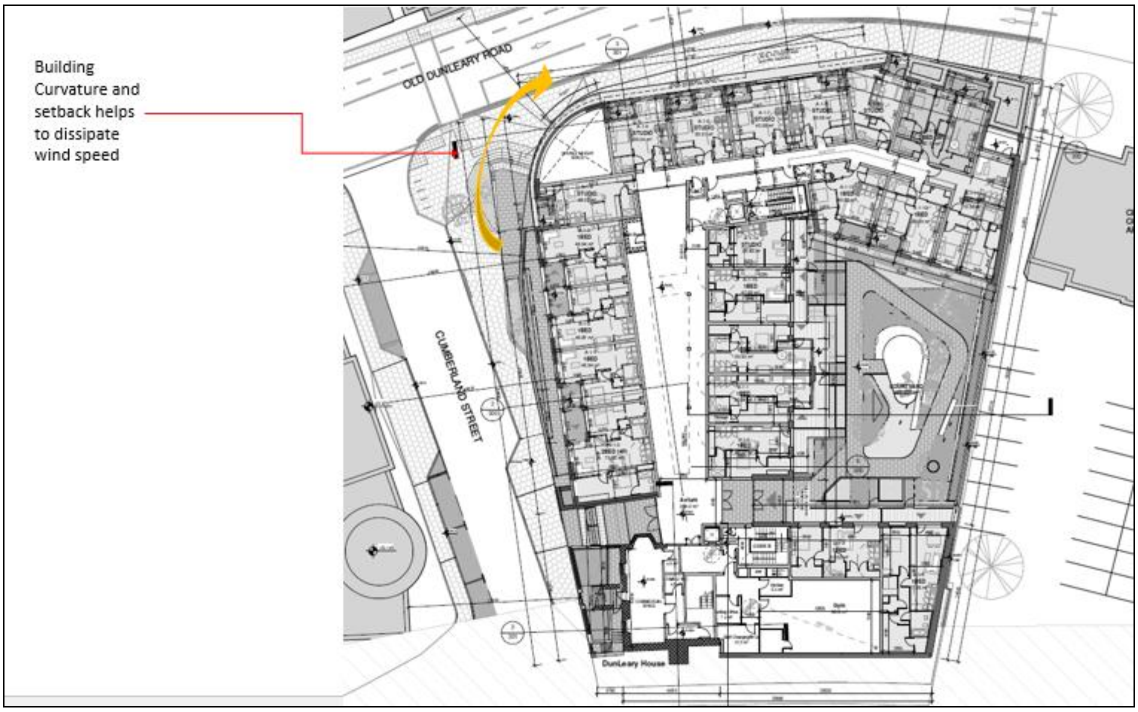


Figure 7 – Wind Mitigation Measure – Building Line

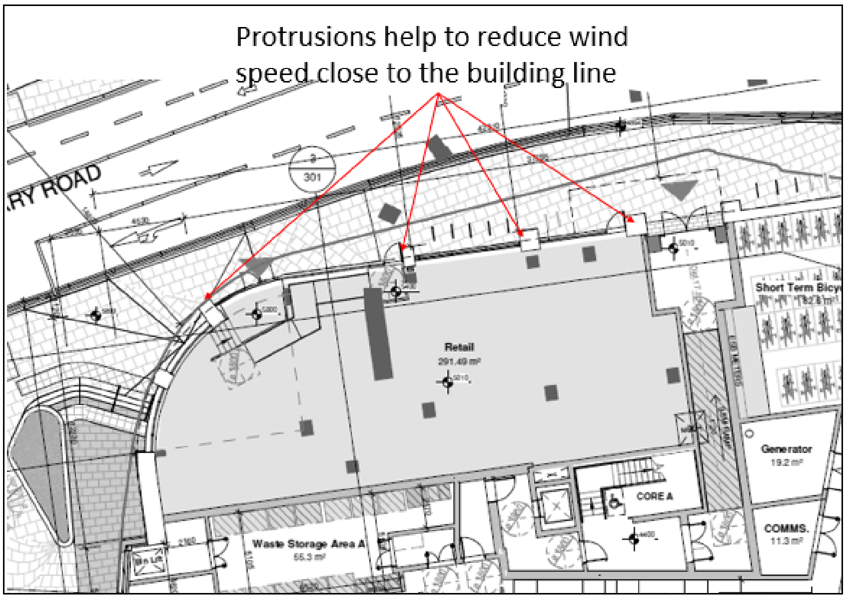


Figure 8 – Wind Mitigation Measure – Façade Protrusions

6.3. INSET BALCONIES

The majority of the balconies within the development are inset balconies as highlighted in red in Figure 9 below. Inset balconies offer increased wind protection for people utilizing the balcony spaces.

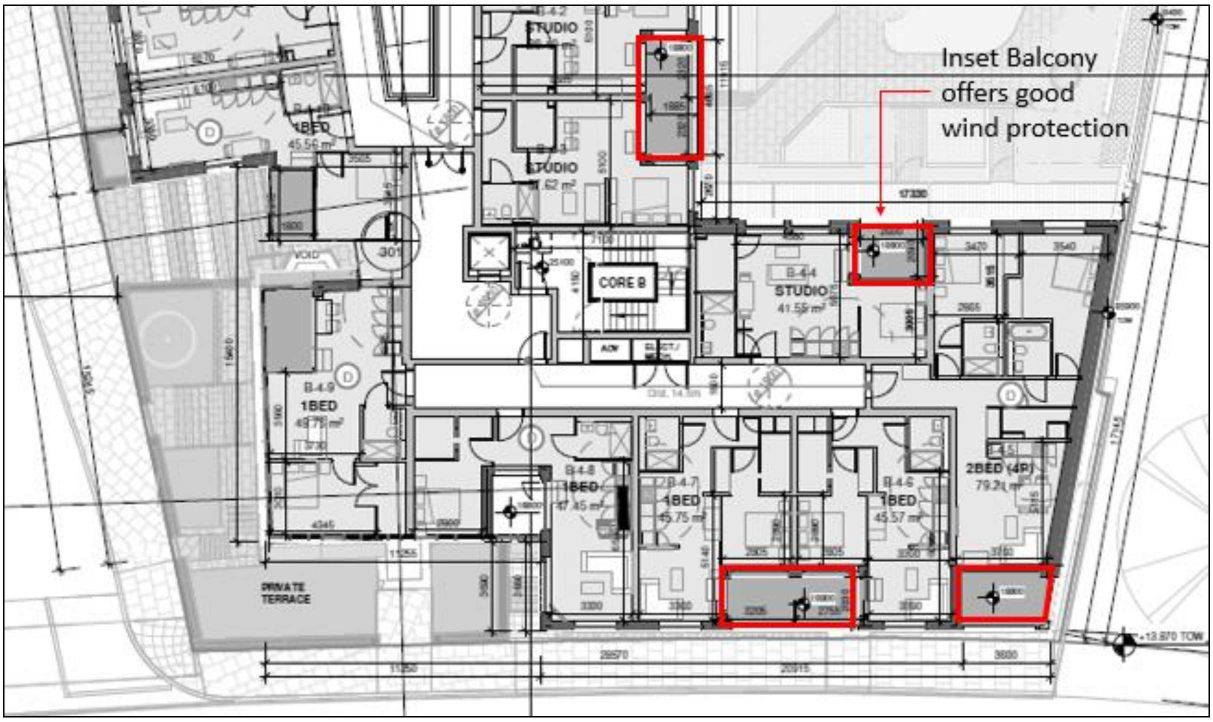


Figure 9 – Wind Mitigation Measure – Inset Balconies

6.4. SOLID BALCONY BALUSTRADES

Full length solid glazed balustrades will be installed on the most exposed balconies. Full length glazing balustrades block wind directly entering the balcony space, slowing the wind speed down within the balcony area.

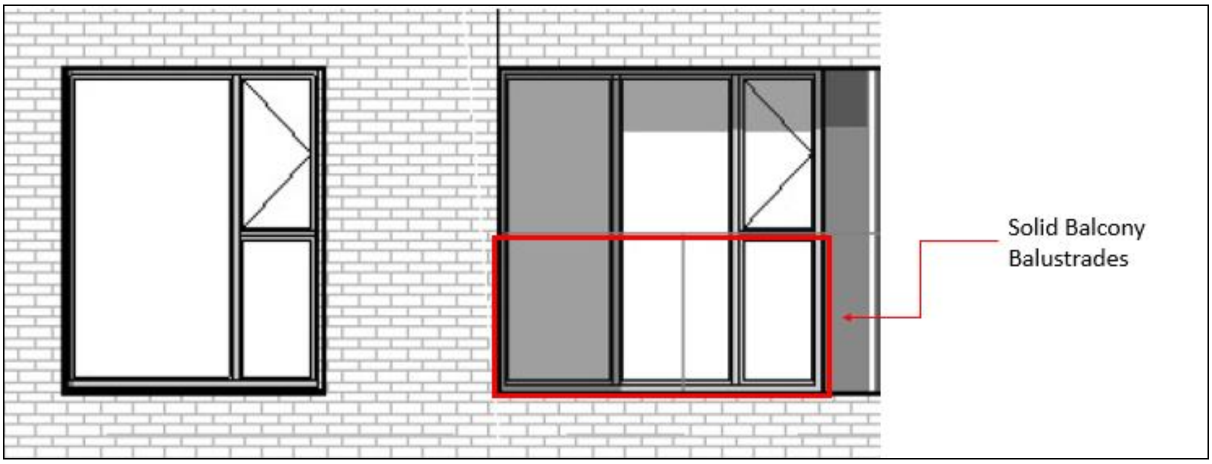


Figure 10 – Wind Mitigation Measure – Solid Balcony Balustrades on Exposed Orientations

6.5. LANDSCAPING

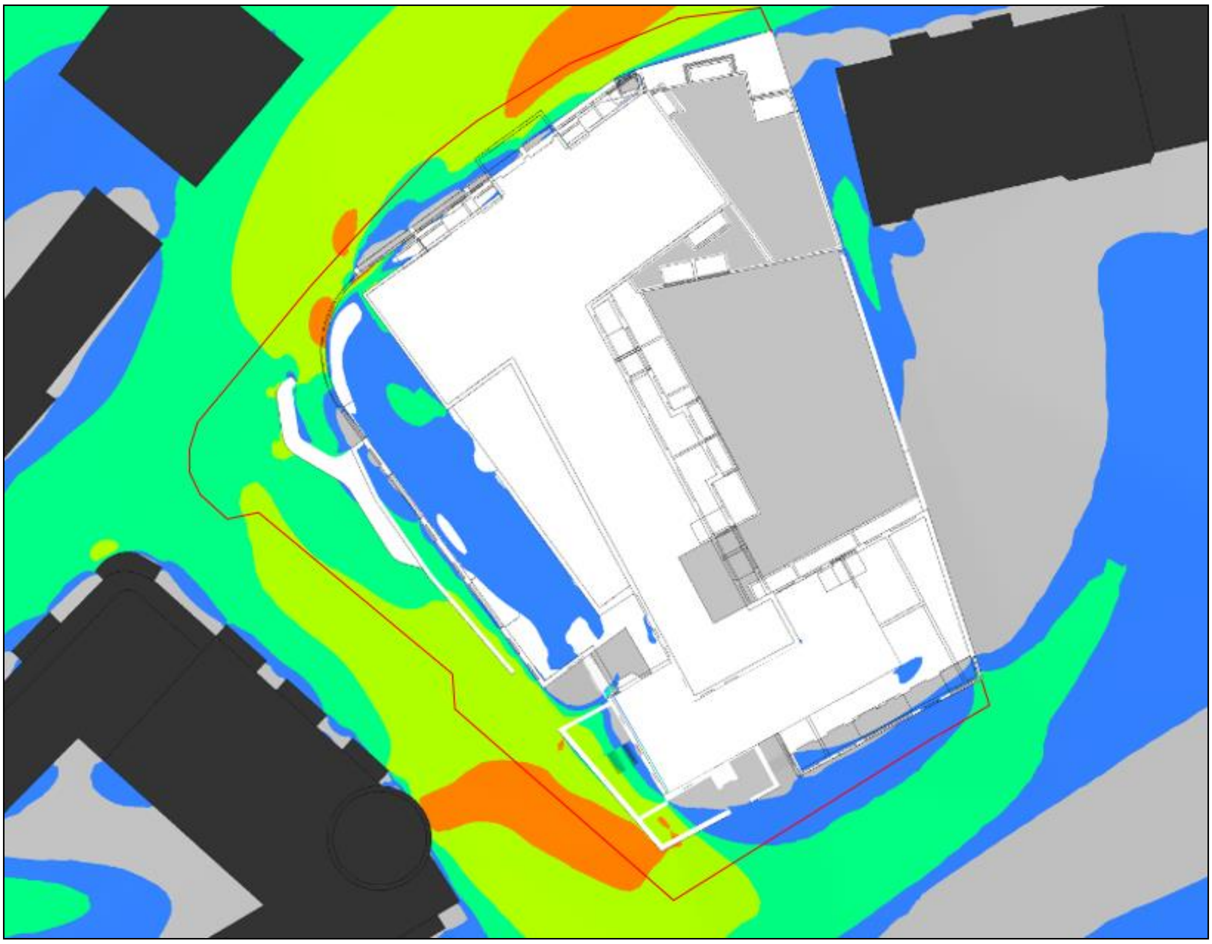
The landscaping has been strategically designed to mitigate increased wind speeds and to provide shelter for pedestrians at street level, in the central courtyard and on the rooftop amenity areas. The landscaping design incorporates covered and sheltered seating, hedge and raised planters as wind breakers, sheltered seating pockets, and pergola and trellis structures to act as wind mitigation measures.

The proposed landscaping design for all levels is illustrated in Figure 11. Trees are to be planted close to primary entrance ways and along the streetscape, mitigating excessive wind speeds and providing shelter for pedestrians at street level. The use of trees and low-level shrubs all assist in the localised reduction of wind speed. Within the central courtyard and rooftop amenity areas, the landscaping design incorporates covered and sheltered seating, hedge and raised planters as wind breakers, sheltered seating pockets, and pergola and trellis structures to act as wind mitigation measures.

Figure 11 – Wind Mitigation Measure – Landscaping Design (All Levels)

7. PEDESTRIAN COMFORT RESULTS

The number of hours for all wind directions are summed to calculate the total number of hours that a given pedestrian activity class exceeds the 5% yearly threshold with the results presented in Figure 12.



Pedestrian activity	
Business Walking	Comfort class exceeded
Leisurely Walking	Comfort class exceeded
Standing or Short Term Sitting	Comfort class exceeded
Long Term Sitting	Comfort class exceeded
-	None of the classes exceeded

Figure 12 – Pedestrian Wind Comfort Results
(approximate extent of footpath outlined in red)

The results of the simulations are explained as follows:

- **Level 7 Public Terrace:** The level 7 terrace is exposed to the predominant south-west wind as it is at a higher elevation compared to the surrounding buildings. The CFD results show that the majority of the terrace will satisfy the Standing or Short Term Sitting class. However, as outlined within the limitations section of this report, landscaping features such as pergolas, trellises, small trees and hedging were not modelled due to the complexity they would add to the CFD model. The landscaping design incorporates hedges and raised planters to act as wind breakers, sheltered seating pockets, and pergola and trellis structures to provide further shelter form the wind. This will ensure the Level 7 terrace will be a comfortable environment for occupants year-round.

- **Level 5 Public Terrace:** All of the Level 5 terrace complies with the "Long Term Sitting" class. Small areas of localised planting will mitigate increased wind speeds in this area and provide a comfortable environment for occupants year-round.

- **Terrace:** The majority of terraces comply with the "Long Term Sitting" class. There are some small pockets exceeding the "Long Term Sitting" and "Standing or Short Term Sitting" class on the 6th Floor. However, small areas of localised planting at the south-west and south-east corner of these terraces will mitigate increased wind speeds in this area and provide a comfortable environment for occupants year-round.

- **Ground Floor Courtyard:** All ground floor courtyard areas comply with the "Long Term Sitting" class. Thus, this will be a very comfortable area for occupants year-round.

- **Street Level:** The majority of the footpath surrounding the development complies with the "Business Walking" class. The predominant reason why the areas at the north of the development exceed the "Business Walking" class are due to the north-east wind, which is unhindered coming directly off Dublin Bay, rather than being due to the development itself. Similarly, the area at the south-west of the site that exceeds the "Business Walking" class is due to the south wind being unhindered due to a lack of development directly to the south of the proposed development.

  It is important to note that the Dublin climate is largely responsible for the exceedance of the given comfort classes, especially when buildings are located close to the coast and there is little to no obstruction of the wind coming off the coast as is the case for this development.

Following on from the above summary, it should also be noted that a pedestrian activity class is only a statistical assessment of the local wind climate. When a region does not meet a certain criterion (e.g. sitting), this does not mean that one can never do this activity in this region. It only means that for more than 5% of the time per year the wind speed for this activity is exceeded. The remaining time of the year this activity is possible. For this reason, the percentage of time that "Standing or Short Term Sitting" is comfortable is illustrated in Figure 13. It is evident from this image that "Standing or Short Term Sitting" is comfortable for more than 90% of the year on the vast majority of rooftop and podium levels, with certain areas at the street level being less comfortable. However, as outlined above, landscaping features such as pergolas, trellises, small trees and hedging were not modelled due to the complexity they would add to the CFD model. The landscaping design will ensure the areas that exceed the pedestrian classes will be comfortable spaces and will mitigate excessive wind speeds.

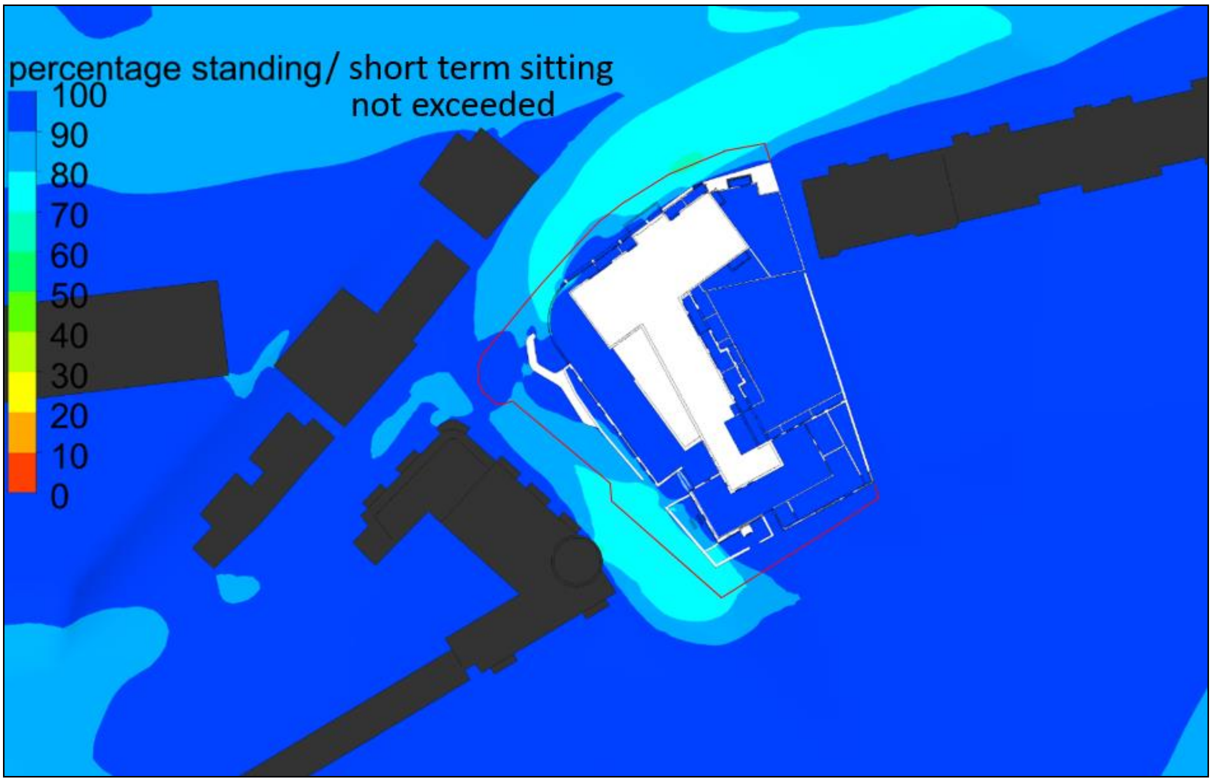
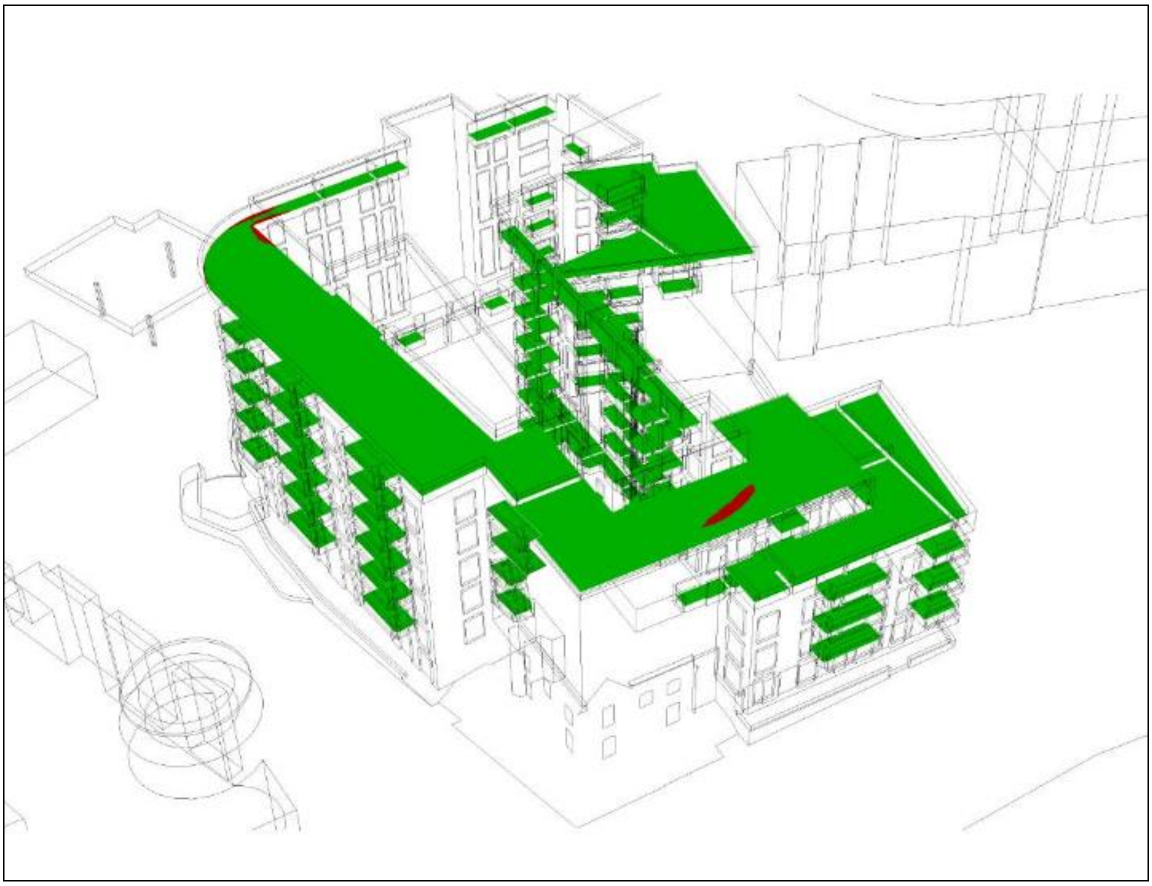


Figure 13 – Percentage of Time per Year that Standing or Short-Term Sitting is Comfortable
(approximate extent of footpath outlined in red)

Finally, the wind speed threshold for a certain pedestrian class is only meant to provide guidance on where to locate certain areas where a certain type of activity is expected to be performed. In practice, the experience of the outdoor climate depends on more than just wind speed. Other factors such as clothing, air temperature, solar irradiation, age and relative humidity must also be considered.

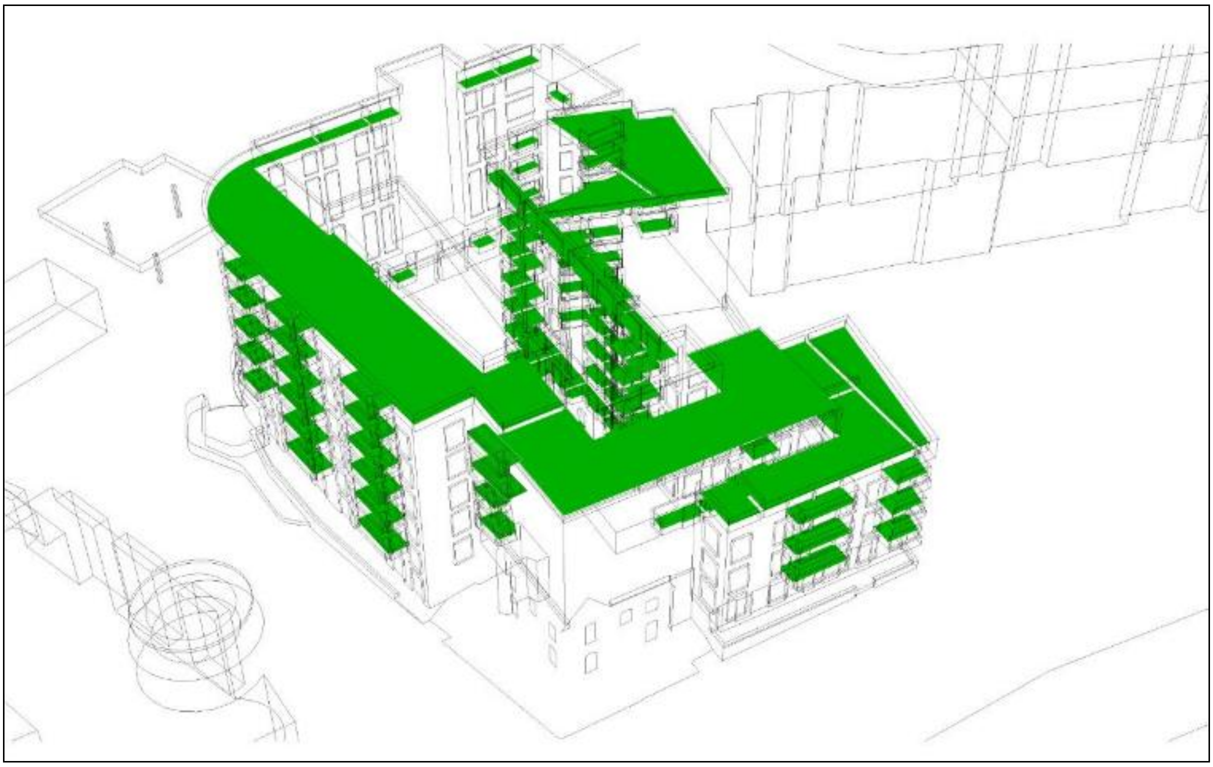
Private Balconies:

As private balconies are not considered common pedestrian areas they have not been assessed against the typical comfort classes for pedestrian comfort. However, they have been assessed based on the safety criteria with the most stringent condition being considered, i.e. "sensitive" (refer to Table 2). Based on the sensitive class, all private balconies are considered safe as illustrated in Figure 14, there are only two minor areas on the roof top terrace that are considered unsafe. However, that only means that for more than 0.023% of the time per year the wind speed is exceeded. The remaining time of the year, the area is safe. It must also be noted that this analysis has been assessed under the most stringent condition being considered, i.e. "sensitive", when the analysis is based on typical pedestrian, all areas are considered safe as illustrated in Figure 15.



Safe
Unsafe

Figure 14 - Pedestrian Wind Comfort Results Frail Pedestrian– Private Balconies & Terraces



Safe
Unsafe

Figure 15 - Pedestrian Wind Comfort Results Typical Pedestrian– Private Balconies & Terraces

8. CONCLUSION

This report outlines the predicted climatic wind conditions experienced within and surrounding the proposed development at the former Ted Castles site and DunLeary House at Old Dunleary Road, Cumberland Street, Dun Leary Hill, Dun Laoghaire, Co. Dublin.

As part of this assessment, the industry accepted standard of the Lawson Criteria was utilised. The Lawson Criteria gives guidance to quantify the effect of wind velocity on pedestrian comfort and safety. The wind climate analysis is based on the wind data obtained from the Dublin Airport weather station which incorporates hourly wind data over a 30-year period (1989 until 2019).

A conscious effort was made by the design team during the design stages to mitigate the risk of localised increased wind speed conditions due to the proposed development. The introduction of mitigation measures such as the courtyard location, building line, façade protrusions, inset balconies, solid balcony balustrades, as well as the strategic location of extensive landscaping, all assist in reducing the potential development of local increased wind speed and the negative impact on local climatic conditions.

Based on the CFD modelling results, the proposed development will be a comfortable environment for occupants. Certain areas have been highlighted as being potentially uncomfortable for a limited period of time, however, these concerns have been largely addressed through the incorporation of landscaping which will mitigate excessive wind speeds in these areas. Certain areas around the development at street level will be uncomfortable for limited periods of time. However, the Dublin climate is largely responsible for the exceedance of the given comfort classes, especially when buildings are located close to the coast and there is little to no obstruction of the wind coming off the coast as is the case for this development.

Overall, the proposed development will be a high-quality, comfortable environment for occupants throughout the year.

APPENDIX A – CFD SIMULATION RESULTS

The CFD wind factor results included in this section are for all 12 No. wind directions as referenced within the body of the report. The wind directions referenced in the wind rose below correspond to the wind directions referenced in the CFD results.

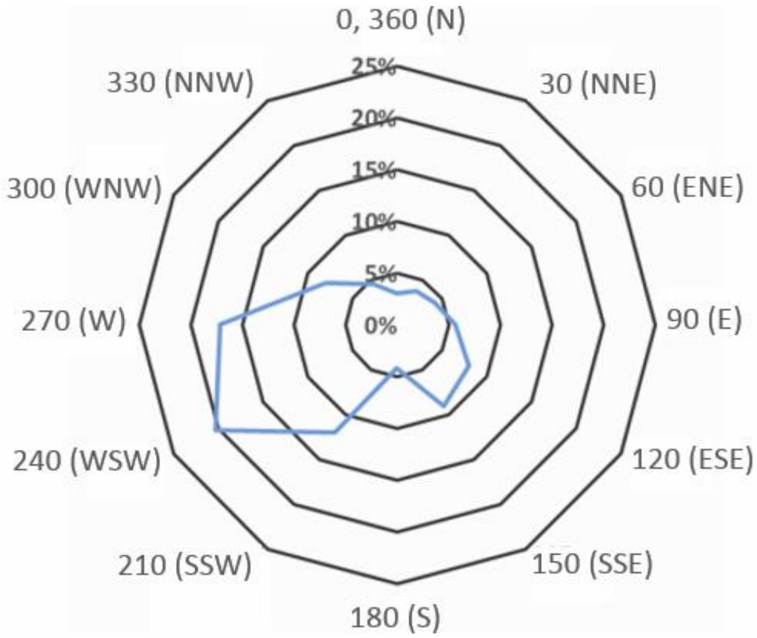


Figure A.1 – Dublin Airport Wind Rose Data (1989 – 2019)

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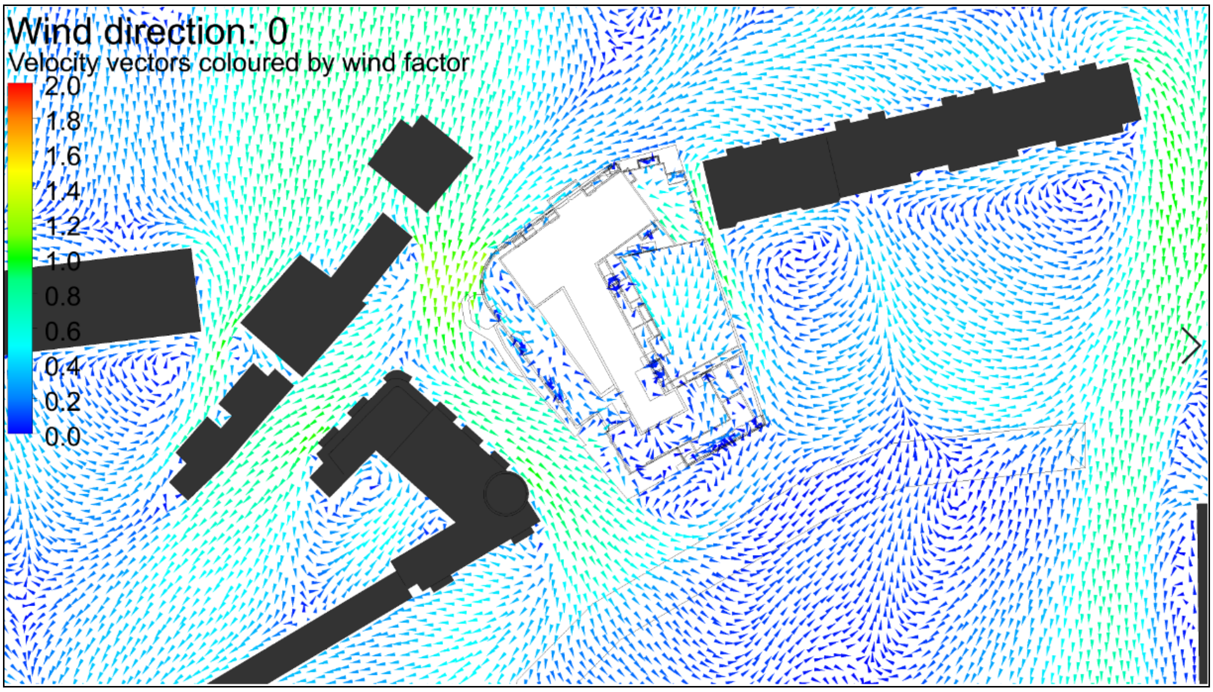

Figure A.2 – Wind Factor – 0 Degree (N) Wind Direction

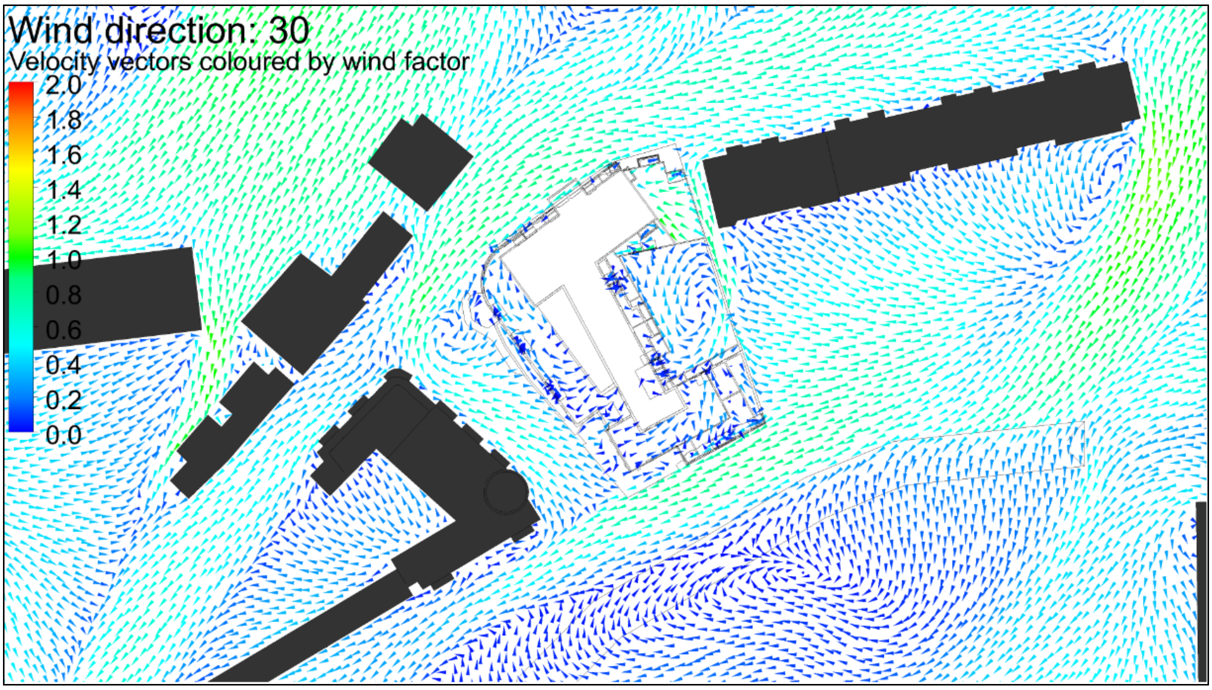

Figure A.3 – Wind Factor – 30 Degree (NNE) Wind Direction

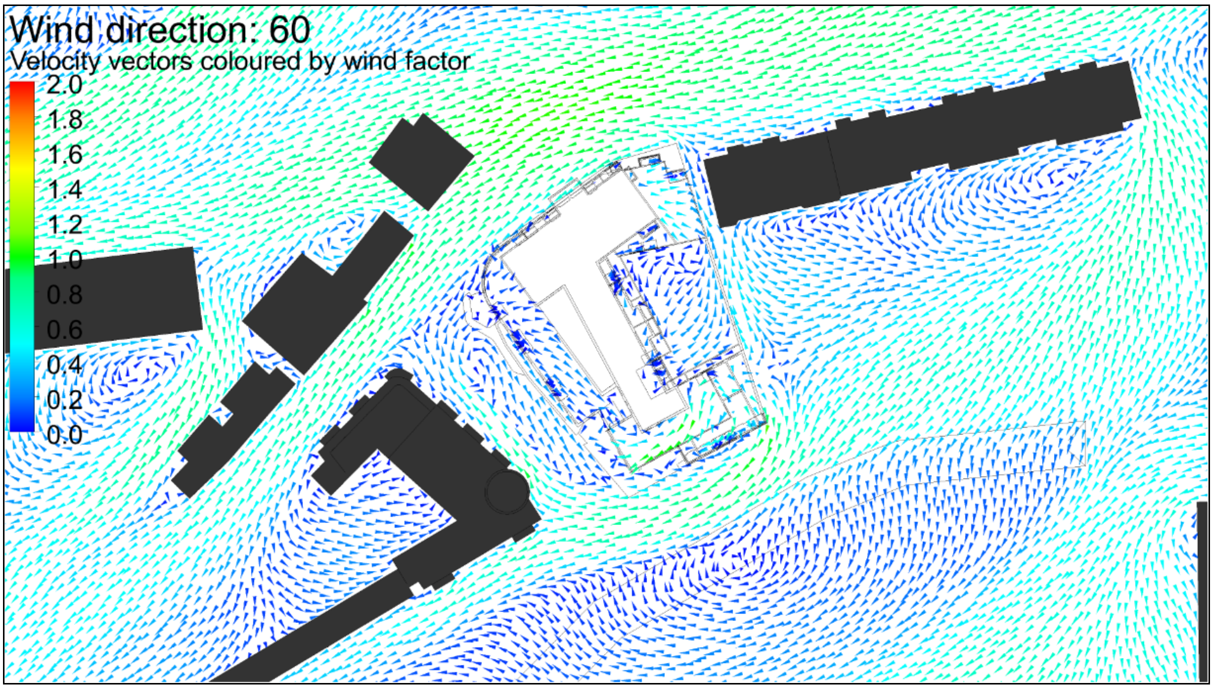

Figure A.4 – Wind Factor – 60 Degree (ENE) Wind Direction

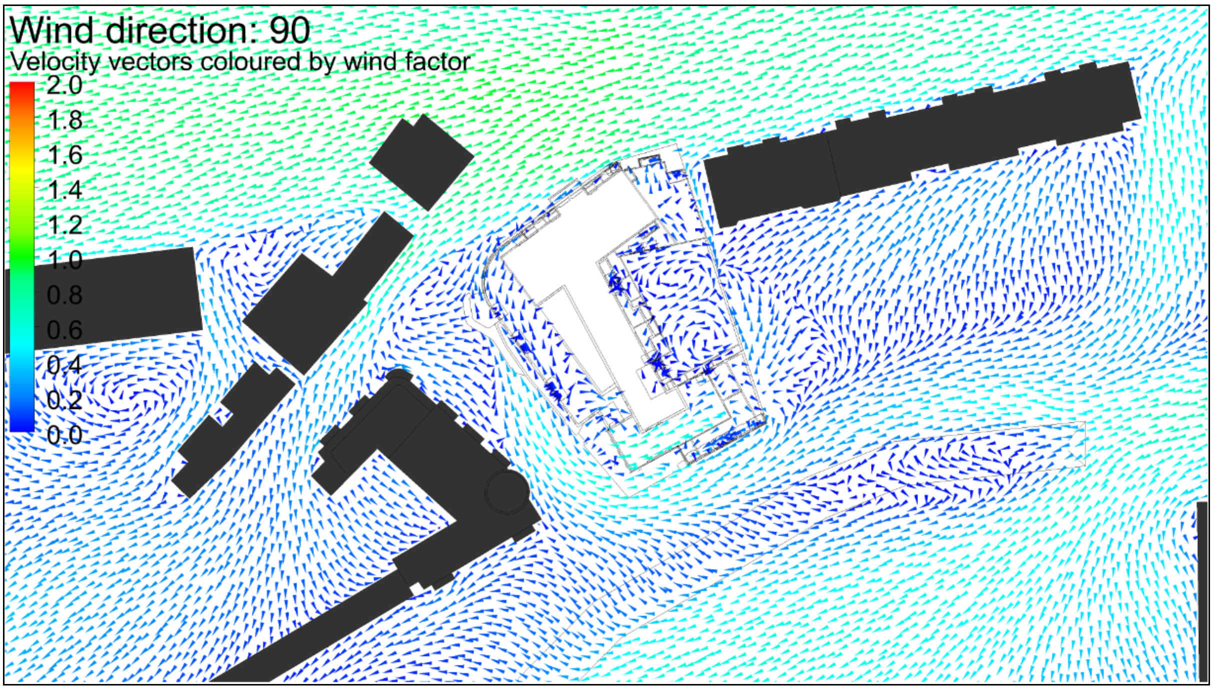

Figure A.5 – Wind Factor – 90 Degree (E) Wind Direction

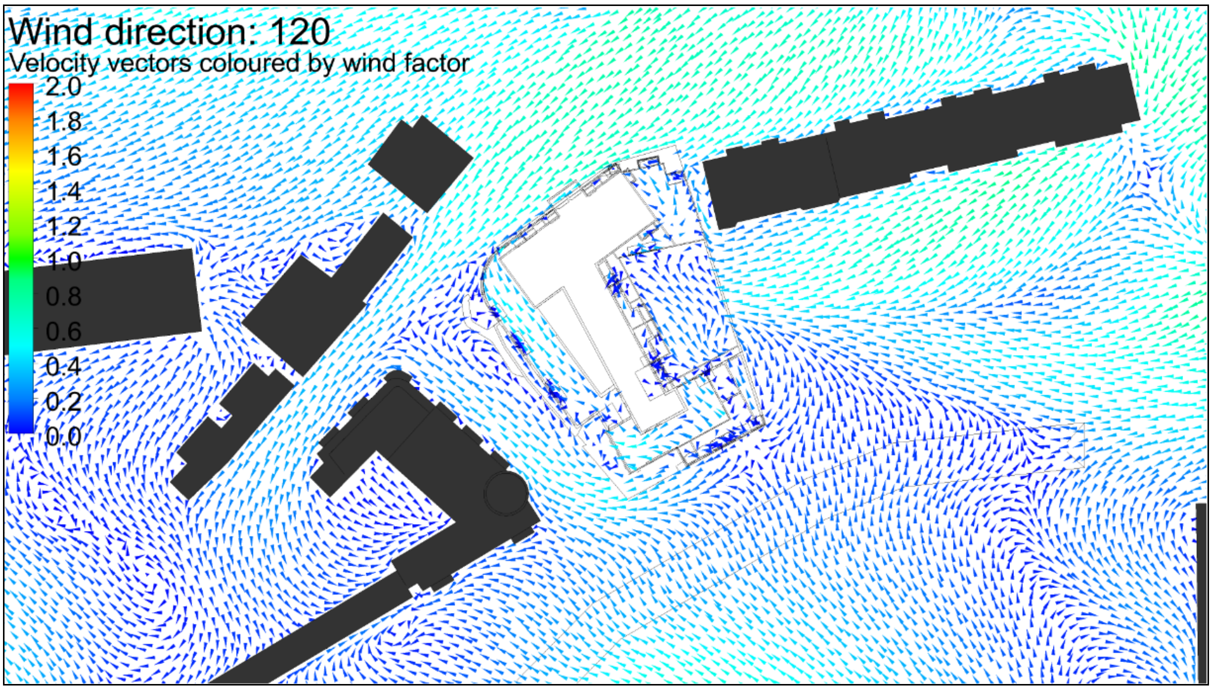

Figure A.6 – Wind Factor – 120 Degree (ESE) Wind Direction

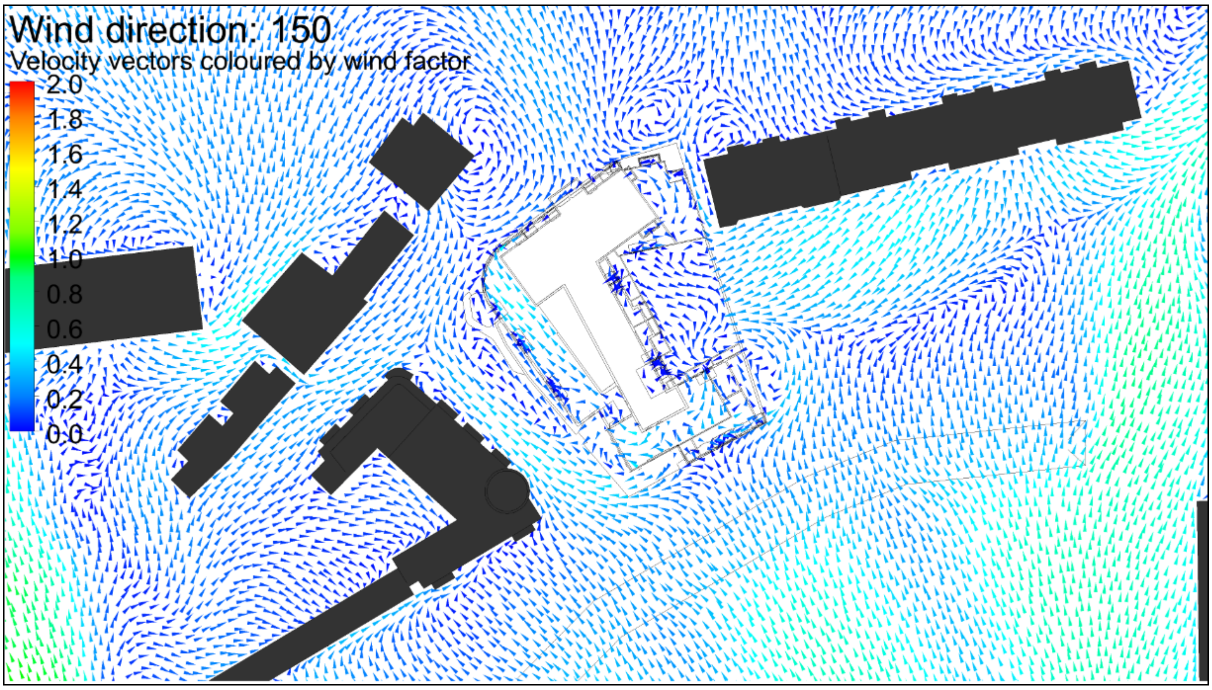

Figure A.7 – Wind Factor – 150 Degree (SSE) Wind Direction

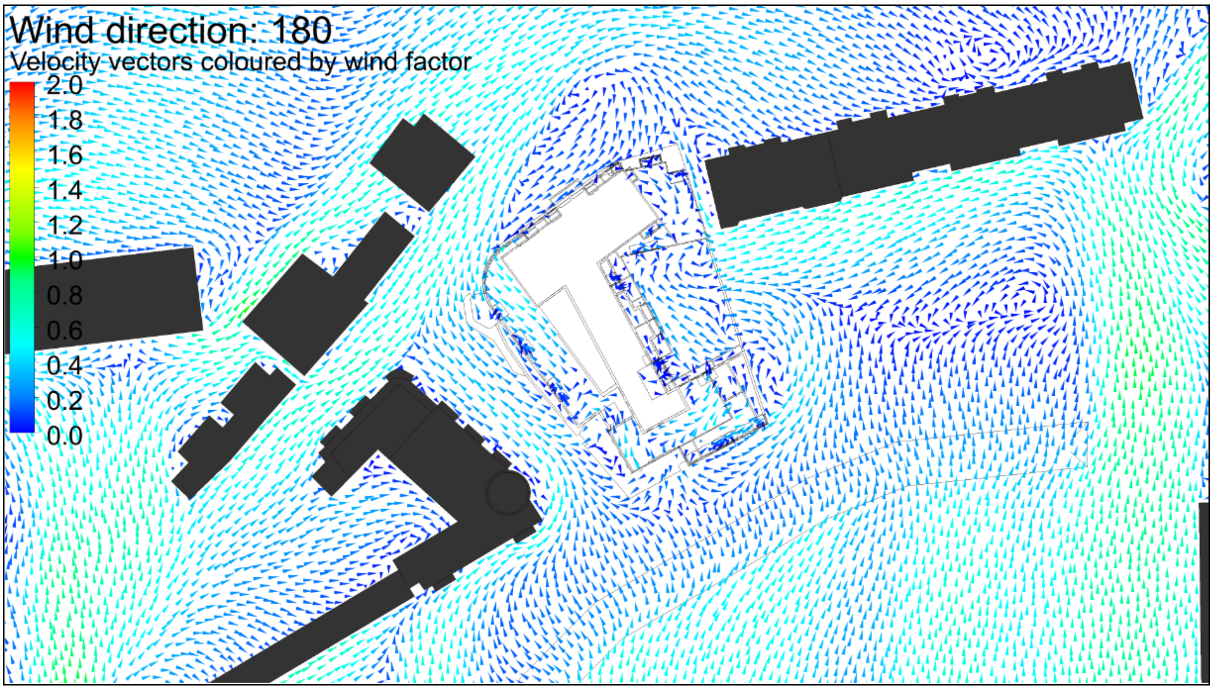

Figure A.8 – Wind Factor – 180 Degree (S) Wind Direction

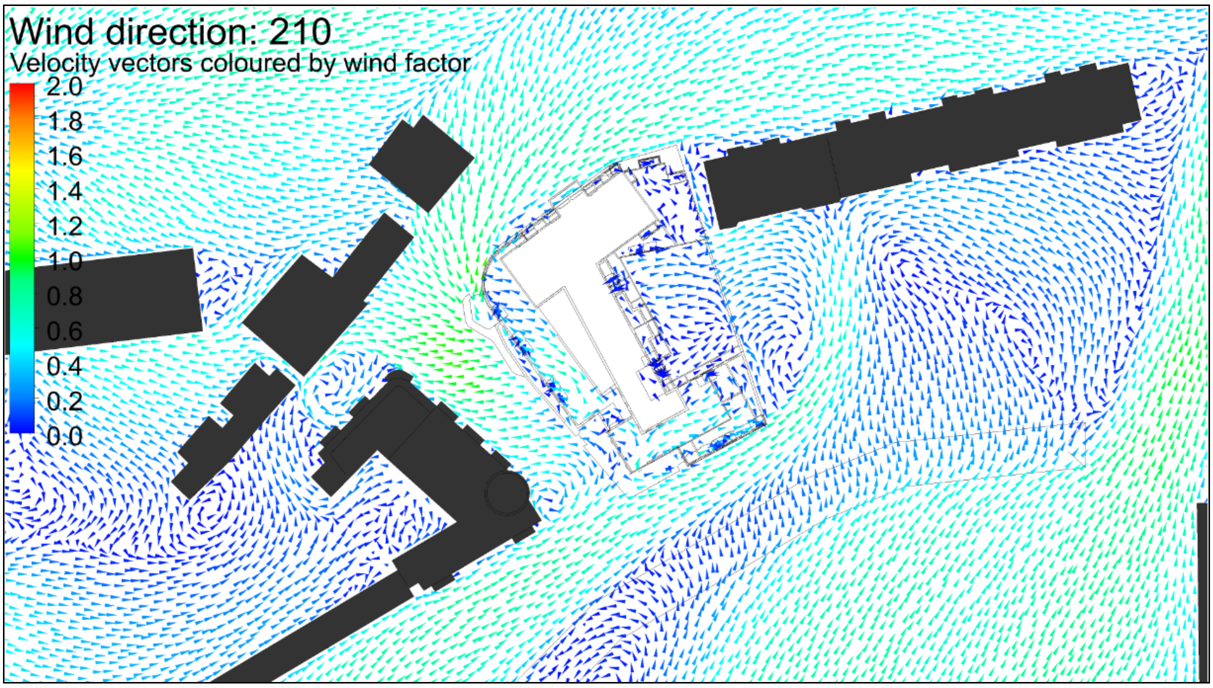

Figure A.9 – Wind Factor – 210 Degree (SSW) Wind Direction

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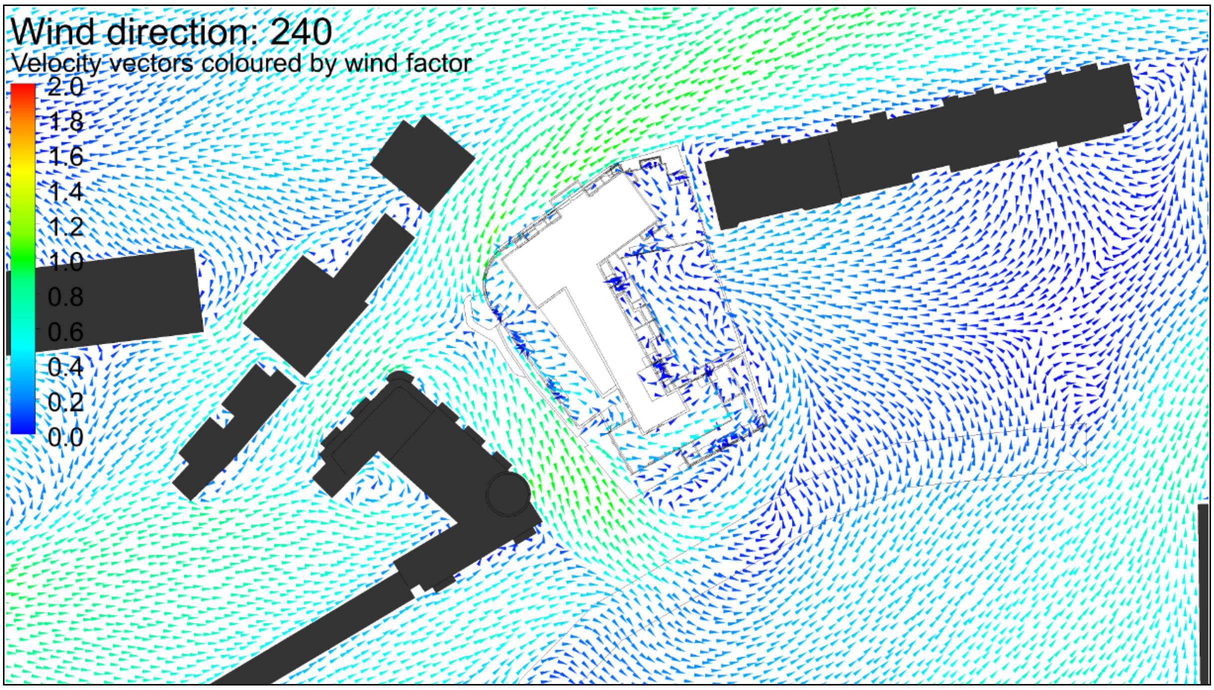

Figure A.10 – Wind Factor – 240 Degree (WSW) Wind Direction

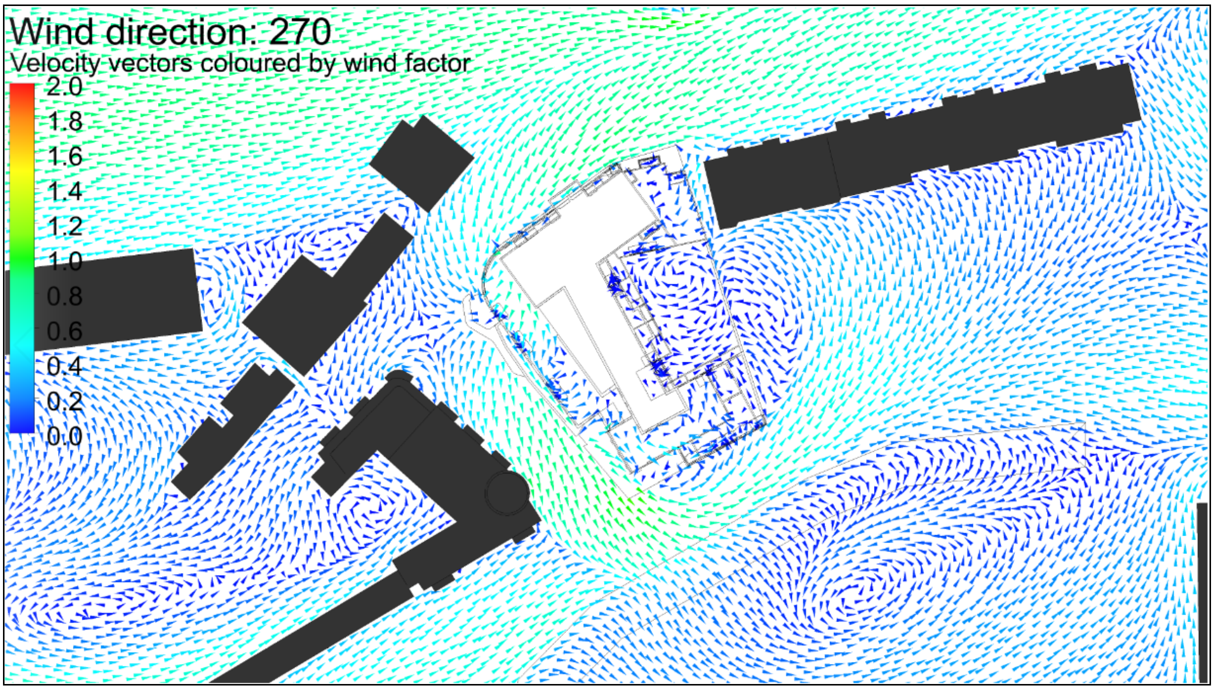

Figure A.11 – Wind Factor – 270 Degree (W) Wind Direction

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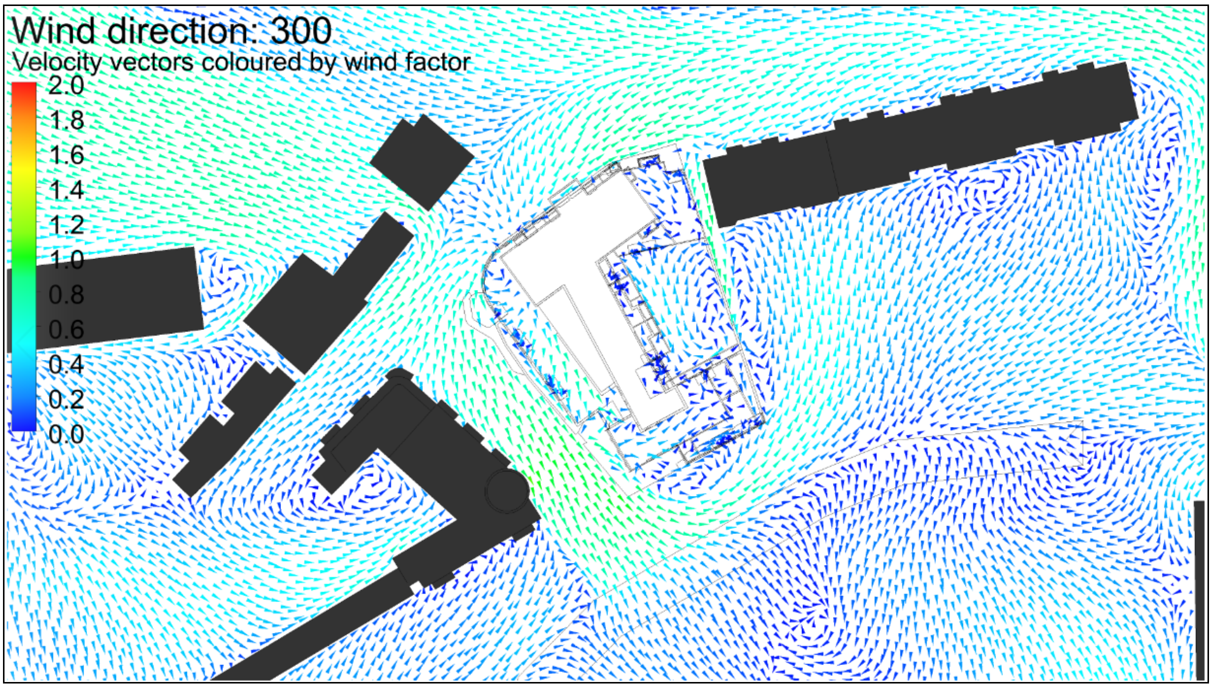

Figure A.12 – Wind Factor – 300 Degree (WNW) Wind Direction

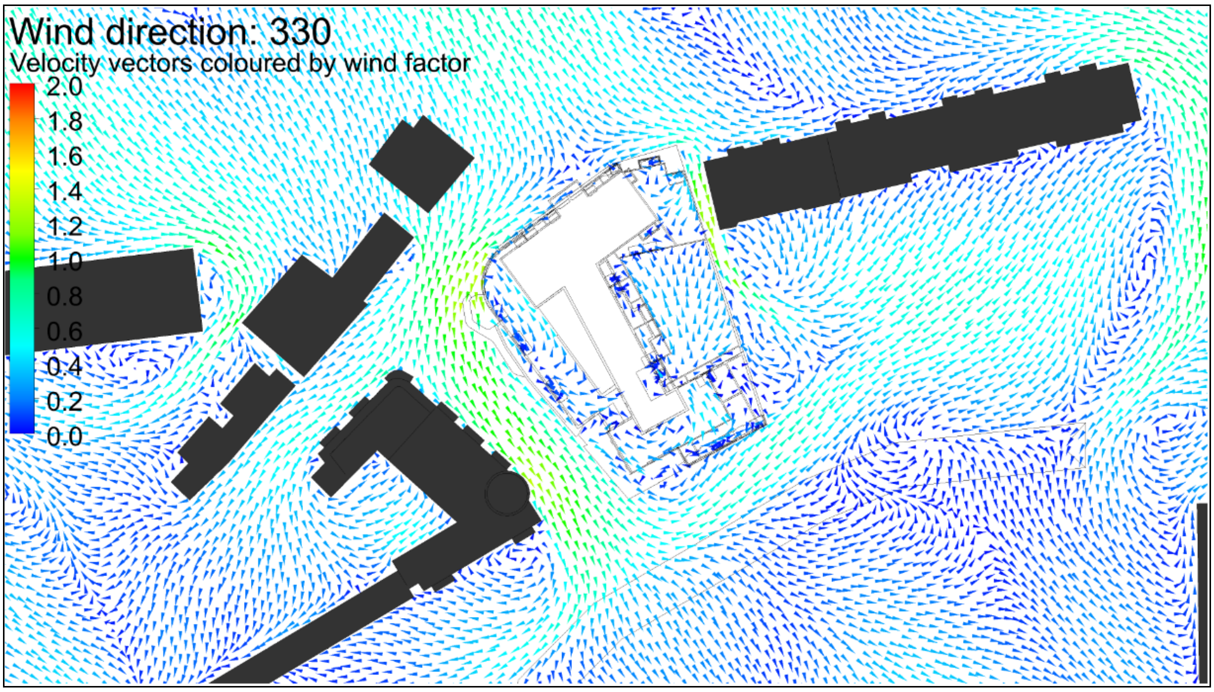

Figure A.13 – Wind Factor – 330 Degree (NNW) Wind Direction

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