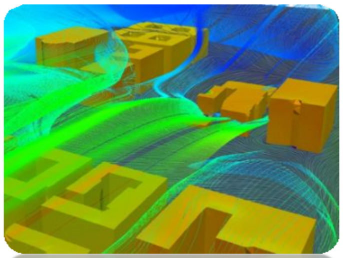
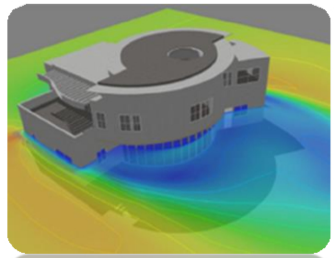
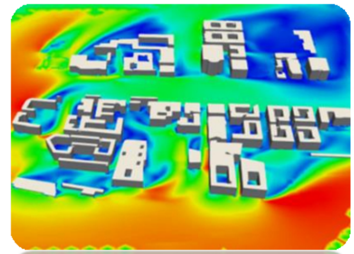

WIND MICROCLIMATE MODELLING

Proposed St. Paul's Residential Development

Raheny, Dublin 5

Prepared by: B-Fluid Ltd.| Buildings Fluid Dynamics Consultants

For: Crekav Trading GP Limited

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<tr><th colspan="3">Document Reference</th></tr>
<tr><td>Project Name</td><td colspan="2">WIND MICROCLIMATE MODELLING.
PROPOSED ST. PAUL'S RESIDENTIAL DEVELOPMENT
RAHENY, DUBLIN 5</td></tr>
<tr><td>Project Ref.</td><td colspan="2">$W\_1909118$</td></tr>
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<tr><td>CFD Study by</td><td colspan="2">B-Fluid Ltd.</td></tr>
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Contents

1. EXECUTIVE SUMMARY

Wind microclimate assessment has been carried out to identify the possible wind patterns around the proposed St. Paul's Residential Development considering mean and peak wind conditions typically occurring in Dublin. The criteria of Lawson's Wind Comfort and Distress is adopted to define if a specific area of the development could be comfortable and safe to pedestrians for its designated activity (i.e. standing/walking/strolling). A total of 18 different wind scenarios have been studied considering variation of wind magnitude and directions in line with their frequency of occurrence based on 30 years of historical weather data. An exceedance of occurrence of 5% of the duration was considered in line with the Comfort and Distress criteria. Through the wind assessment it has been possible to highlight, at design stage, areas of concern in terms of downwash/funnelling/downdraft/ and to identify critical flow accelerations that could potentially occur. Results of the wind analysis have been discussed with the design team so as to configure the optimal layout for proposed St. Paul's Residential Development for the objective of achieving a high-quality environment for the scope of use intended of each areas/building (i.e. comfortable and pleasant for potential pedestrian) and without compromising the wind impact on the surrounding areas and on the existing buildings. The wind modelling study has been performed through an Advanced Computational Fluid Dynamics (CFD) analysis; this numerical methodology simulates the movement of wind within the prescribed area. The simulations have been carried out using the concepts of Large Eddy Simulation (LES) and Reynolds Average Navier Stokes (RANS). The assessment has been carried out considering the impact of wind on the following configurations:

- The "Existing Receiving Environment": in this case the assessment has considered the impact of the local wind on the existing area / buildings prior to construction of the proposed development. For this assessment a statistical analysis of 30 years of historical weather wind data has been carried out to find the most critical wind speeds and directions and the frequency of occurrence of the same.

- The "Potential Impact of the Proposed Development": in this case the assessment has considered the impact of wind on the existing area including the proposed St. Paul's

Residential Development. For this scenario, the analysis has been used to identify the critical areas of the proposed development that requires implementation of mitigation measures.

- The ”Potential Cumulative Impact”: in this case the assessment has considered impacts of wind on the existing environment area, the proposed Development, and its immediate vicinity, with the aim to identify potential impacts on future nearby buildings. For this scenario, the proposed St. Paul’s Residential Development will introduce no negative wind effect on adjacent, nearby or future phase developments within its vicinity. Wind modelling of future phases around this development will need to be performed for all future phase developments.

The prevailing wind directions for the site were identified from the West, West South-West and South with magnitude of approximately 6m/s. In all these directions the development area has shown to not introduce critical flow speeds, hence pedestrian comfort is always satisfied. Mitigation in the form of tree landscaping within the development particularly at the corners would further improve these wind conditions. The wind microclimate study has shown that the development has been designed to be a high-quality environment for the scope of use intended of each areas/building (i.e. comfortable and pleasant for potential pedestrian), and from a quantitative point of view, it does not introduce any major or critical impact on the surrounding areas and on the existing buildings. In particular, the following conclusion were made at the end of the CFD wind analysis:

- The proposed St. Paul’s Residential Development will produce a high-quality environment that is attractive and comfortable for pedestrians of all categories.

- The Surrounding environment and development properly shield all paths/walkways around and within the development. Pedestrian footpaths are always successfully shielded and comfortable.

- The development’s communal open spaces are generally suitable for long term sitting, short term sitting, standing, walking and strolling activities.

- Shielding conditions in the South-West, South-East, North-East and North-West areas are always acceptable.

- Balconies within the development are comfortable for pedestrian sitting, standing, walking and strolling.

- The proposed development does not impact or give rise to negative or critical wind speed profiles at the nearby adjacent roads, or nearby buildings.

- Pedestrian comfort assessment, performed according to the Lawson criteria, have identified the areas that are suitable for different pedestrian activities in order to guarantee pedestrian comfort and maps have been provided within the EIAR Chapter 8. In terms of distress, no critical conditions were found for “Frail persons or cyclists” in the surrounding of the development. No critical conditions have been found for members of the ”General Public”.

2. WIND MICROCLIMATE INTRODUCTION

2.1 INTRODUCTION

B-Fluid Limited has been commissioned by 'Crekav Trading GP Limited' to carry out a wind microclimate modelling study for the proposed St. Paul's Residential Development in Raheny, Dublin 5. This Report chapter is completed as part of the proposed development and outlines the methodology used to assess the wind microclimate impacts of the proposed development.

Wind microclimate study identifies the possible wind patterns around the existing environment and proposed development under mean and peak wind conditions typically occurring in Dublin. Wind microclimate assessment is performed through advanced Computational Fluid Dynamics (CFD) which is a numerical method used to simulate wind conditions and its impact on the development and to identify areas of concern in terms of downwash/funneling/downdraft/critical flow accelerations that may likely occur. The Advanced CFD numerical algorithms applied here are solved using high speed supercomputing computer clusters.

This study results will be utilized by Crekav Trading GP Limited design team as an Report chapter as part of the proposed development. The objective is to maintain comfortable and safe pedestrian level wind conditions that are appropriate for seasons and the intended use of pedestrian areas within and close to the development. Pedestrian areas include side-walks, street frontages, pathways, building entrance areas, open spaces, amenity areas, outdoor sitting areas, and accessible roof top areas among others.

For this purpose, 18 different wind scenarios and directions have been modelled as shown in Table 2.1 in order to take into consideration all the different relevant wind directions in Dublin. In particular, a total of 18 compass directions on the wind rose are selected. For each direction, the reference wind speed is set to the 5% exceedance wind speed for that direction, i.e. the wind speed that is exceeded for over 5% of the time whenever that wind direction occurs.

DUBLIN WIND SCENARIOS AND DIRECTIONS		
Velocity (m/s)	Direction (deg)	Frequency
5.601	225	11.233
4.626	135	6.849
5.847	236.25	6.792
6.049	258.75	6.747
6.034	247.5	6.689
5.888	270	5.662
4.994	315	4.338
5.503	281.25	3.904
4.974	292.5	3.436
5.357	213.75	3.288
4.736	123.75	3.105
4.406	146.25	2.751
5.101	303.75	2.648
5.246	112.5	2.500
4.121	157.5	2.386
4.581	101.25	2.340
4.169	45	2.180
3.558	90	2.135

Table 2.1: Summary of The 18 Wind Scenarios Modelled for Proposed St. Paul's Residential Development

This modelling study focuses on reporting 9 worst case and most relevant wind speeds with cardinal directions, which are the speeds and directions showing the most critical wind speeds relevant to the development. The 9 modelled scenarios reported in this study are presented in Table 2.2

REPORTED WIND SCENARIOS AND DIRECTIONS			
	Velocity (m/s)	Direction (deg)	Frequency
1	5.601	225	11.233
2	4.626	135	6.849
3	5.847	236.25	6.792
4	6.049	258.75	6.747
5	6.034	247.5	6.689
6	5.888	270	5.662
7	4.994	315	4.338
8	5.503	281.25	3.904
9	4.169	45	2.180

Table 2.2: Reported Wind Scenarios

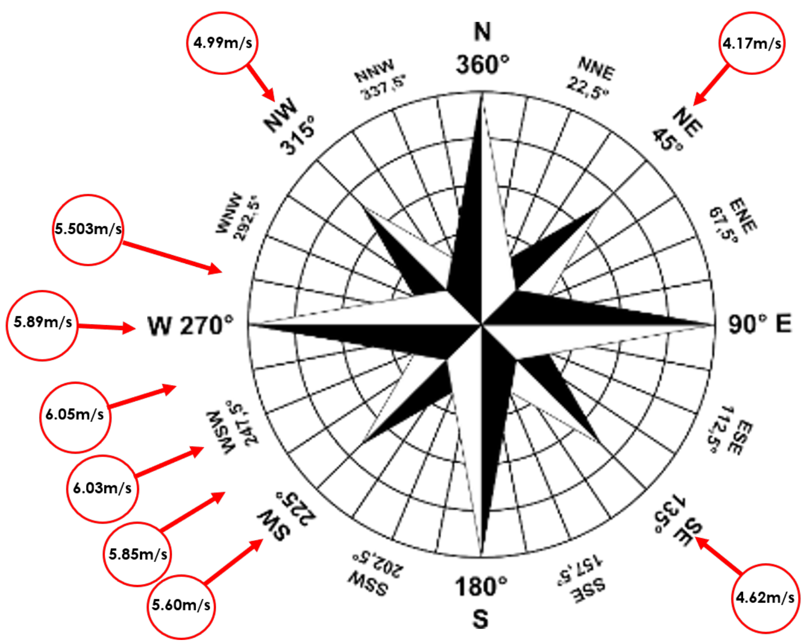


Figure 2.1: Summary of 9 Wind Scenarios Reported

Figure 2.2 shows a site layout view of the proposed development.

Figure 2.2: Site Layout of Proposed St. Paul's Residential Development

This Technical report is completed by Dr. Cristina Paduano, Dr. Patrick Okolo and Dr. Eleonora Neri.

Dr. Cristina Paduano is a Chartered Engineer (CEng) and member of Engineers Ireland who specialises in computational fluid dynamics applications for urban environment and the construction industry with over 10 years experience. She holds a PhD in Mechanical Engineering from Trinity College Dublin, with M.Eng and B.Eng in Aerospace Engineering.

Dr. Patrick Okolo is a Chartered Engineer (CEng) and member of Engineers Ireland who specialises in computational fluid dynamics applications for aerospace industry, urban environments, construction industry and marine industry. He holds a PhD in Computational Aeroacoustics branch of Mechanical Engineering from Trinity College Dublin, with M.Eng and B.Eng in Mechanical Engineering.

Dr. Eleonora Neri is a CFD Aerodynamics Engineer and member of Engineers Ireland who specialises in computational fluid dynamics applications for the urban environment, the construction industry and wind tunnel measurement techniques. She holds a PhD in Aeroacoustics branch of Mechanical Engineering from Trinity College Dublin, with M.Eng and B.Eng in Aeronautical Engineering.

3. STUDY METHODOLOGY

3.1 STUDY METHODOLOGY

The methodology adopted for the wind microclimate analysis of the proposed development is outlined as follows;

The following sections give details on the methodology utilized.

- Perform a wind desktop study of the existing environment.
- Perform computational wind microclimate analysis of the proposed development within the existing environment.

3.1.1 Wind Impact Assessment On Buildings

The construction of buildings within a development or in an existing environment can potentially calm/shield existing wind conditions within the area by providing further "urban context" to the existing topography, however, some areas can equally induce more critical wind conditions due to high/adverse wind acceleration and re-circulations and phenomena such as downwash, funnelling and downdraft can be experienced as well.

A building/development, in principle, offers more drag to the incoming wind profile as detailed in the next section (see "Planetary boundary layer and terrain roughness"). Consequently, winds at lower levels can reduce and modify its flow path and directions. However, zones of re-circulations caused by the re-direction of the wind can also be expected, especially in the West South West direction (Dublin Region) where funnelling effects could potentially occur.

Impacts of the development on the local wind microclimate is quantified through modelling of different wind scenarios and all areas of criticism is detected, appropriate mitigation is implemented and modelled to verify the reduction of potential critical winds and the suitability of all specific areas to the designated pedestrian activities are highlighted.

3.1.2 Planetary Boundary Layer And Terrain roughness

Due to aerodynamic drag, there is a wind gradient in the wind flow just a few hundred meters above the Earth's surface – "the surface layer of the planetary boundary layer".

Wind speed increases with increasing height above the ground, starting from zero, due to the no-slip condition. In particular, the wind velocity profile is parabolic. Flow near the surface encounters obstacles that reduce the wind speed, and introduce random vertical and horizontal velocity components. This turbulence causes vertical mixing between the air moving horizontally at one level, and the air at those levels immediately above and below it. For this reason, the velocity profile is given by a fluctuating velocity along a mean velocity value. Figure 3.1 shows the wind velocity profile, as described above.

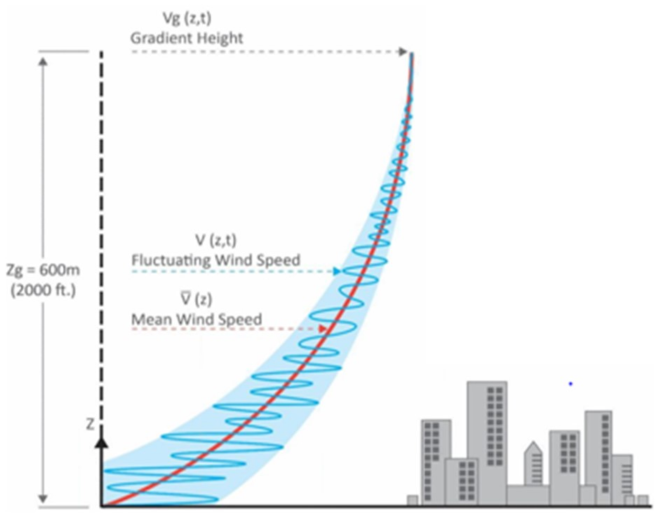


Figure 3.1: Wind Velocity Profile

Two effects influence the shape of the wind speed profile:

- Contours of the terrain: a rising terrain such as an escarpment will produce a fuller profile at the top of the slope compared with the profile of the wind approaching the slope.
- Aerodynamic 'roughness' of the upstream terrain: natural roughness in the form of woods or man-made roughness in the form of buildings. Obstructions near the ground create turbulence and friction, lowering the average wind speed. The higher the obstructions, the greater the turbulence and the lower the wind speed. As a general rule, wind speed increases with height.

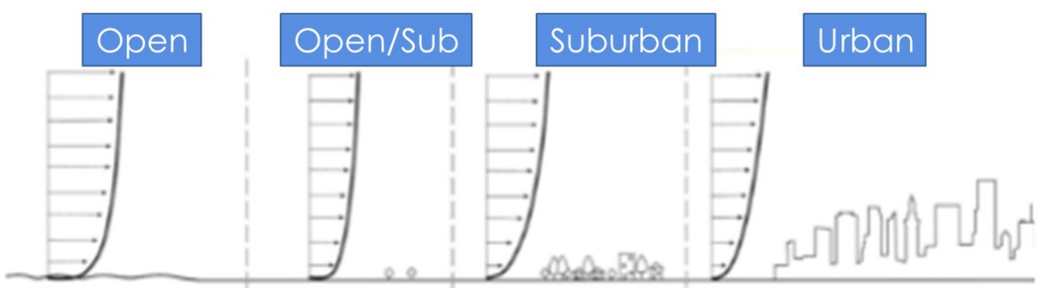


Figure 3.2: Wind Velocity Profile for different terrains

In order to assess the wind conditions in a particular area, it is important to know (Figure 3.3):

- Weather conditions in the area
- Location and orientation of the site
- Buildings distribution in the area
- Flow patterns at the building

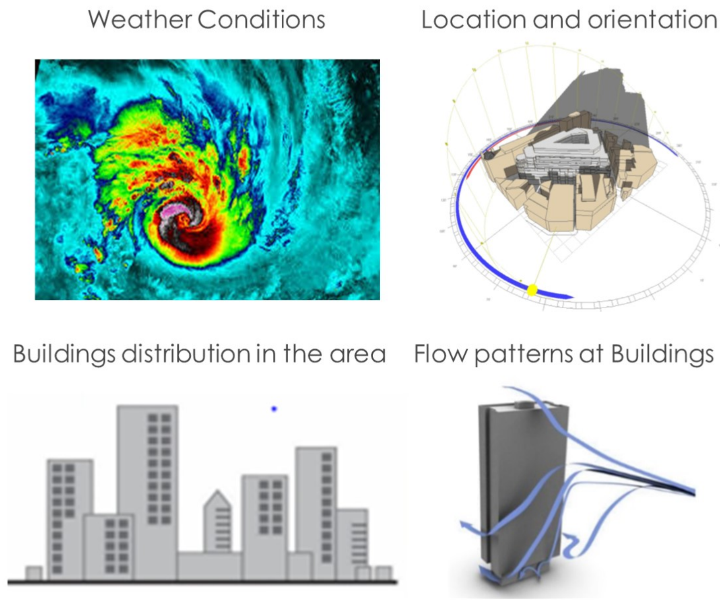


Figure 3.3: Parameters to know for Wind Conditions Assessment

Moreover, it is important to understand key flow features (Figure 3.4):

- Broad Building Face creates “DOWNWASH”
- Low Building Upwind Increases Wind Effects
- Gaps Between Buildings Increases Wind Velocity
- Low Building Upwind Increases Wind Effects

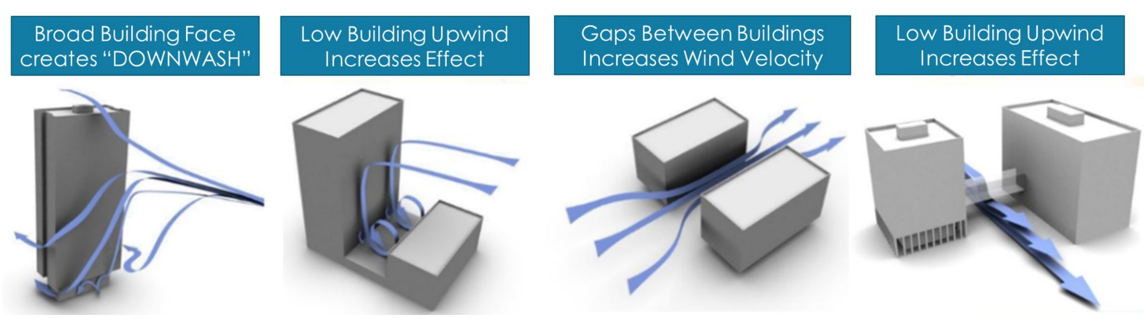


Figure 3.4: Parameters to know for Wind Conditions Assessment

3.1.3 Acceptance Criteria

Pedestrian Comfort

Pedestrian Wind Comfort is measured in function of the frequency of wind speed threshold exceeded based on the pedestrian activity. The assessment of pedestrian level wind conditions requires a standard against which measured or expected wind velocities can be compared.

Only gust winds are considered in the safety criterion. These are usually rare events, but deserve special attention in city planning and building design due to their potential impact on pedestrian safety. Gusts cause the majority of cases of annoyance and distress and are assessed in addition to average wind speeds. Gust speeds should be divided by 1.85 and these "gust equivalent mean" (GEM) speeds are compared to the same criteria as for the mean hourly wind speeds. This avoids the need for different criteria for mean and gust wind speeds.

The following criteria are widely accepted by municipal authorities as well as the international building design and city planning community:

- DISCOMFORT CRITERIA: Relates to the activity of the individual.
  Onset of discomfort:
  - Depends on the activity in which the individual is engaged and is defined in terms of a mean hourly wind speed (or GEM) which is exceeded for 5% of the time.

- DISTRESS CRITERIA: Relates to the physical well-being of the individual.
  Onset of distress:
  - 'Frail Person Or Cyclist': equivalent to an hourly mean speed of 15 m/s and a gust speed of 28 m/s (62 mph) to be exceeded less often than once a year. This is intended to identify wind conditions which less able individuals or cyclists may find physically difficult. Conditions in excess of this limit may be acceptable for optional routes and routes which less physically able individuals are unlikely to use.
  - 'General Public': A mean speed of 20 m/s and a gust speed of 37 m/s (83 mph) to be exceeded less often than once a year. Beyond this gust speed, aerodynamic forces approach body weight and it rapidly becomes impossible for anyone to remain standing. Where wind speeds exceed these values, pedestrian access should be discouraged.

The above criteria set out six pedestrian activities and notes that calm activity requires calm wind conditions, which are summarised by the Lawson scale, shown in Figure 3.5. The Lawson scale assesses pedestrian wind comfort in absolute terms and defines the reaction of an average person to the wind. Each wind type is associated to a number, corresponding to the Beaufort scale, which is represented in Figure 3.6. The Beaufort scale is an empirical measure that relates wind speed to observed conditions at sea or on land. A 20% exceedance is used in these criteria to determine the comfort category, which suggests that wind speeds would be comfortable for the corresponding activity at least 80% of the time or four out of five days.

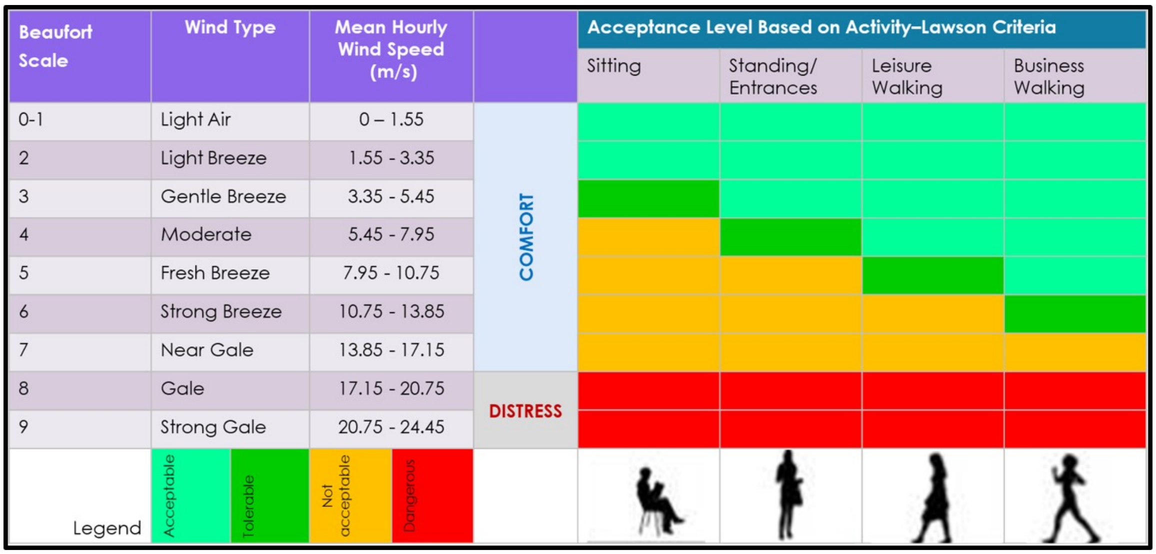
These criteria for wind forces represent average wind tolerances. They are subjective and variable depending on thermal conditions, age, health, clothing, etc. which can all affect a person's perception of a local microclimate. Moreover, pedestrian activity alters between winter and summer months. The criteria assume that people will be suitably dressed for the time of year and individual activity. It is reasonable to assume, for instance, that areas designated for outdoor seating will not be used on the windiest days of the year.

Weather data measured are used to calculate how often a given wind speed will occur each year over a specified area. Pedestrian comfort criteria are assessed at 1.5m above ground level. Unless in extremely unusual circumstances, velocities at pedestrian level increase as you go higher from ground level.

A breach of the distress criteria requires a consideration of:

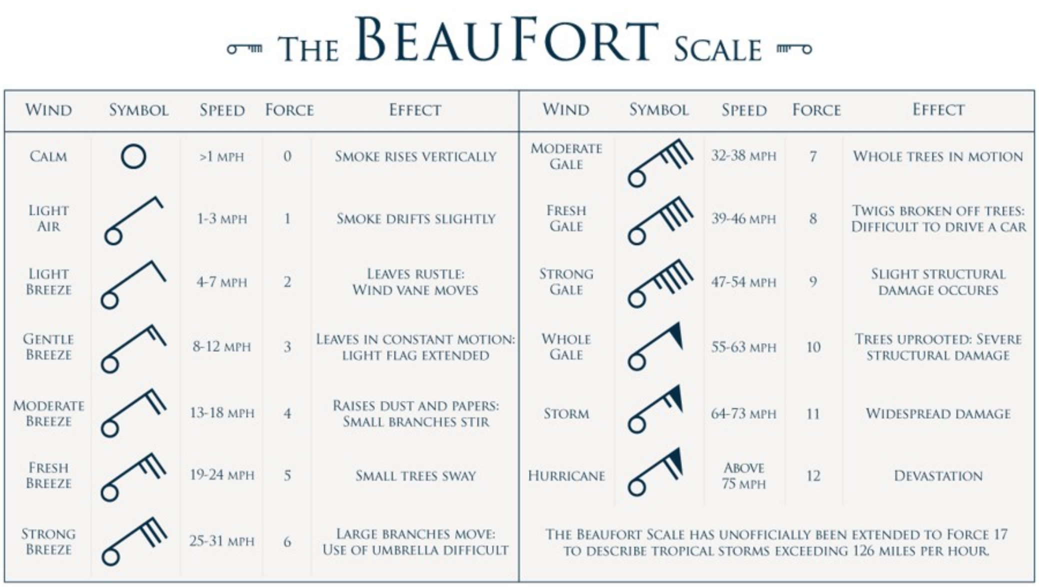
- whether the location is on a major route through the complex,
- whether there are suitable alternate routes which are not distressful.

If the predicted wind conditions exceed the threshold, then conditions are unacceptable for the type of pedestrian activity and mitigation measure should be implemented into the design.



Beaufort Scale	Wind Type	Mean Hourly Wind Speed (m/s)		Acceptance Level Based on Activity–Lawson Criteria			
				Sitting	Standing/ Entrances	Leisure Walking	Business Walking
0-1	Light Air	0 – 1.55	COMFORT				
2	Light Breeze	1.55 - 3.35					
3	Gentle Breeze	3.35 - 5.45					
4	Moderate	5.45 - 7.95					
5	Fresh Breeze	7.95 - 10.75					
6	Strong Breeze	10.75 - 13.85					
7	Near Gale	13.85 - 17.15					
8	Gale	17.15 - 20.75	DISTRESS				
9	Strong Gale	20.75 - 24.45					
Legend	Acceptable / Tolerable	Not acceptable / Dangerous					

Figure 3.5: Lawson Scale



The Beaufort Scale

Wind	Symbol	Speed	Force	Effect
Calm		>1 mph	0	Smoke rises vertically
Light Air		1-3 mph	1	Smoke drifts slightly
Light Breeze		4-7 mph	2	Leaves rustle: Wind vane moves
Gentle Breeze		8-12 mph	3	Leaves in constant motion: Light flag extended
Moderate Breeze		13-18 mph	4	Raises dust and papers: Small branches stir
Fresh Breeze		19-24 mph	5	Small trees sway
Strong Breeze		25-31 mph	6	Large branches move: Use of umbrella difficult
Moderate Gale		32-38 mph	7	Whole trees in motion
Fresh Gale		39-46 mph	8	Twigs broken off trees: Difficult to drive a car
Strong Gale		47-54 mph	9	Slight structural damage occures
Whole Gale		55-63 mph	10	Trees uprooted: Severe structural damage
Storm		64-73 mph	11	Widespread damage
Hurricane		Above 75 mph	12	Devastation

The Beaufort scale has unofficially been extended to force 17 to describe tropical storms exceeding 126 miles per hour.

Figure 3.6: BeaufortScale

3.1.4 Distress Criteria

In addition to the criteria for "discomfort" the Lawson method presents criteria for "distress". The discomfort criteria focus on wind conditions which may be encountered for hundreds of hours per year. The distress criteria require higher wind speeds to be met, but focus on two hours per year. These are rare wind conditions but with the potential for injury rather than inconvenience.

Figure 3.7 shows the hourly wind gust rose for Dublin, from 1985 to 2015. This will be necessary to assess how many hours per year on average the velocity exceed the threshold values.

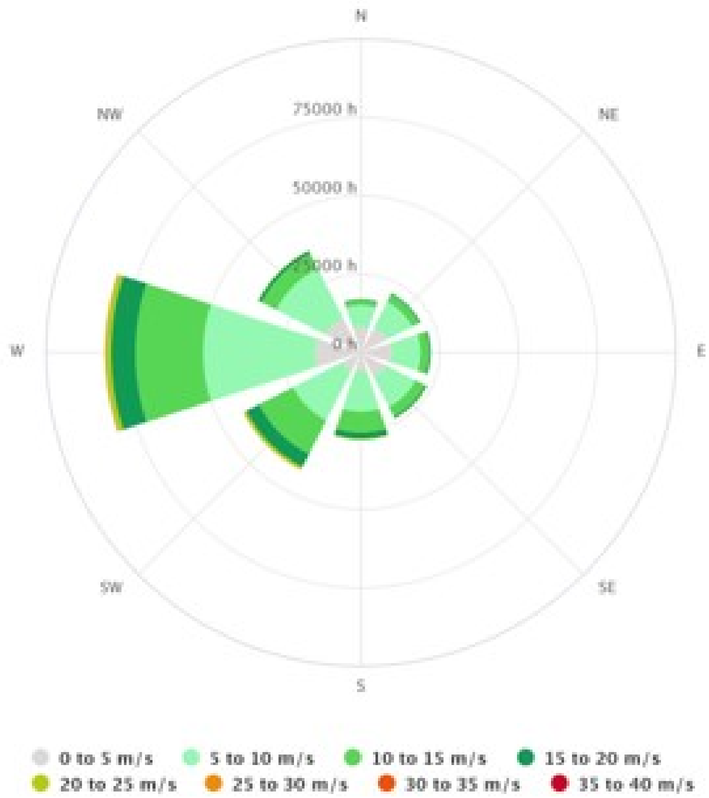


Figure 3.7: Hourly Dublin Wind Gust Rose

The criteria for distress for a frail person or cyclist is 15m/s wind occurring for more than two hours per year. Limiting the results from the above wind rose to the only values above 15m/s (as reported in Figure 3.8), it is possible to see how a gust velocity of 15m/s is exceed at pedestrian level only in the West direction, for a total of 5 hours over 30 years.

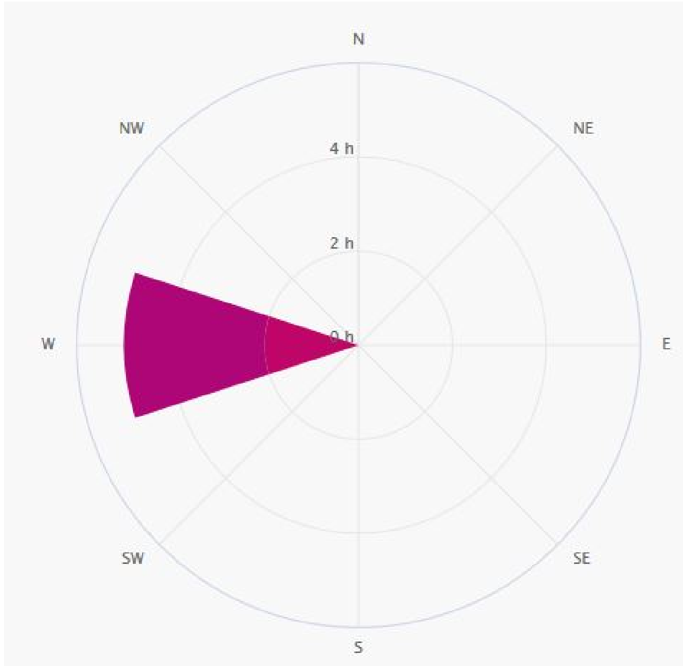


Figure 3.8: Hourly Dublin Wind Gust Rose - Cumulative hours when the velocity is above 15m/s

3.1.5 Mitigation Measures

If the wind conditions exceed the threshold, these conditions become unacceptable for favourable pedestrian activities and mitigation measure should be accounted for.

Mitigation measures include:

- **Landscaping** : the use vegetation to protect buildings from wind
- **Sculptural screening**(solid or porous): to either deflect the wind or bleed the wind by removing its energy.
- **Canopies and Wind gutters** : horizontal canopies are used to deflect the wind and redirect the wind around the building and above the canopy.

In particular, it is possible to summarise the different flow features and the corresponding mitigation option as follows (Figures 3.9 and 3.10):

- **Downwash Effects**: when wind hits the windward face of a tall building, the building tends to deflect the wind downwards, causing accelerated wind speeds at pedestrian level and around the windward corners of the building. This can occur when tall and wide building facades face the prevailing winds.
- **Downdraft Effects**: When the leeward face of a low building faces the windward face of a tall building, it causes an increase in the downward flow of wind on the windward face of the tall building. This results in accelerated winds at pedestrian level in the space between the two buildings and around the windward corners of the

tall building.

Example of Typical Mitigation Options:
- To mitigate unwanted wind effects it is recommended to introduce a base building or podium with a step back, and setting back a tower relative to the base building, the downward wind flow can be deflected, resulting in reduced wind speed at pedestrian level.
- Landscaping the base building roof and tower step back, wind speeds at grade can be further reduced, and wind conditions on the base building roof can improve.

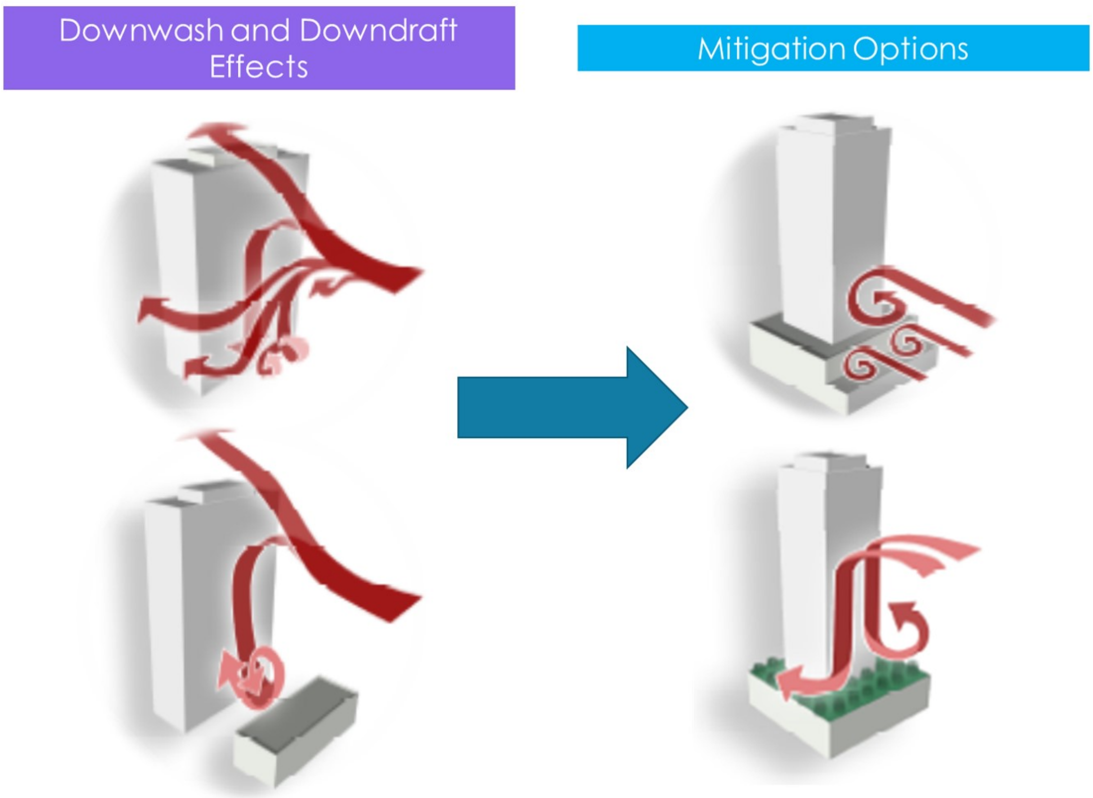


Figure 3.9: Mitigation Measures for Downwash and Downdraft Effects

- **Funneling Effects**: Wind speed is accelerated when wind is funneled between two buildings. This is referred to as the "wind canyon effect". The intensity of the acceleration is influenced by the building heights, size of the facades, building separation distance and building orientation. Similar effect can be noticed when a bridge is connecting two buildings, the wind passing below the bridge is accelerated, therefore pedestrians can experience high uncomfortable velocities of wind .

  Example of Typical Mitigation Options:
  - A horizontal canopy on the windward face of a base building can improve pedestrian level wind conditions. Parapet walls around a canopy can make the canopy more effective.

– Sloped canopies only provide partial deflection of downward wind flow.
– A colonnade on the windward face of the base building provides the pedestrian with a calm area where to walk while being protected or a breeze walking space outside the colonnade zone.

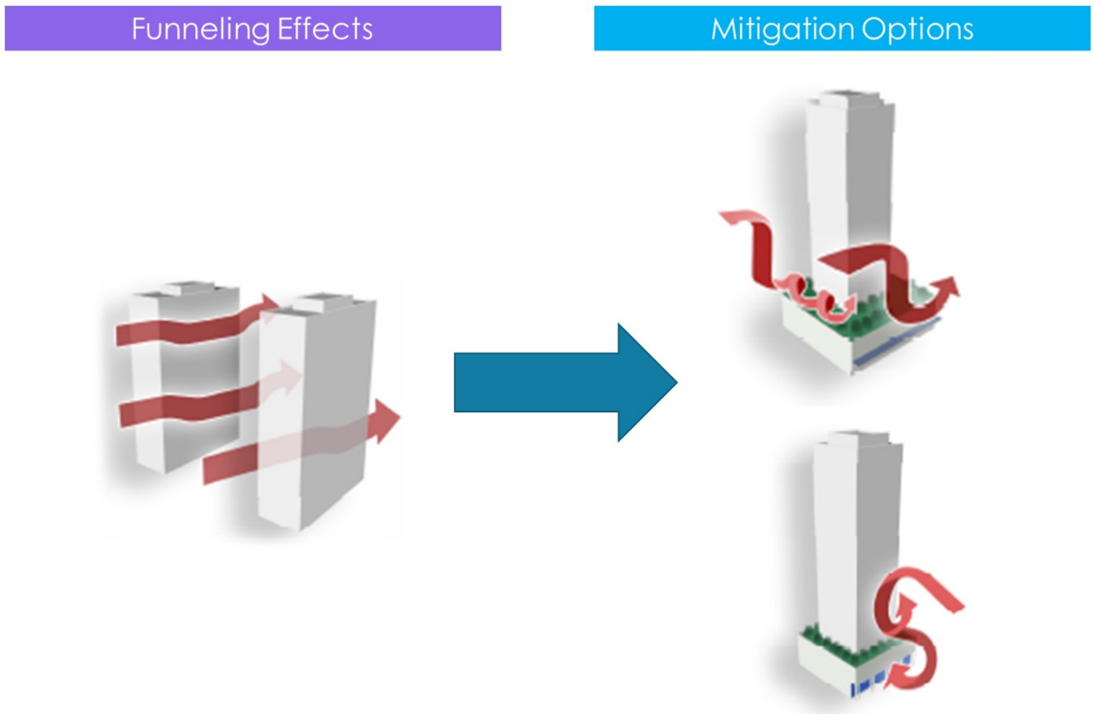


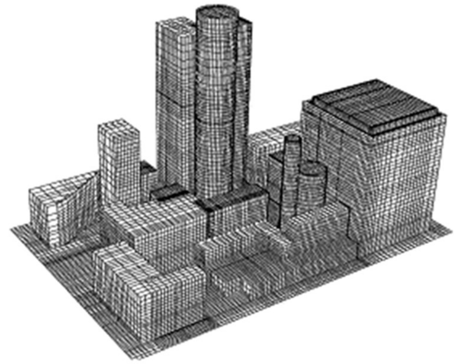
Figure 3.10: Mitigation Measures for Funnelling Effects

3.1.6 CFD Modelling Method

Computational Fluid Dynamics (CFD) is a numerical technique used to simulate fluid flow, heat and mass transfer, chemical reaction and combustion, multiphase flow, and other phenomena related to fluid flows. CFD modelling includes three main stage: pre-processing, simulation and post-processing as described in Figure 3.11. The Navier-Stokes equations, used within CFD analysis, are based entirely on the application of fundamental laws of physics and therefore produce extremely accurate results provided that the scenario modelled is a good representation of reality.

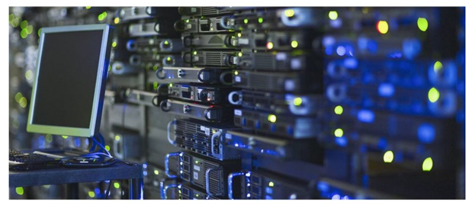
PRE-PROCESSING

This is the construction of a representative geometric model to be utilized within a flow domain of interest and the subsequent division of this domain into small control volumes (cells), a process often called "meshing." After setting up the model and mesh, the model is completed by setting appropriate boundary and initial conditions.



SIMULATION

The equations governing the behaviour of fluid particles (Navier-Stokes equations) are solved iteratively over each control volume within the computational domain, until the results change no more; i.e. a converged solution is reached. In a transient simulation this process is repeated and convergence verified at each time step, whereas in a steady-state simulation, this is only done at one time step, since it is assumed conditions do not vary over time. The field solutions of pressure, velocity, air temperature, and other properties are obtained for each control volume, at cell centre, nodal point, or face centre in order to render the flow field.



POST-PROCESSIONG

This is the plotting and viewing of the predicted flow field from the CFD model simulations at selected locations, surfaces, or planes of interest.

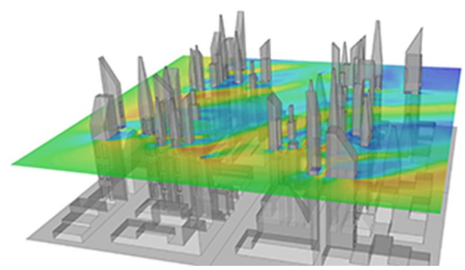


Figure 3.11: CFD Modelling Process Explanation

OpenFOAM Numerical Solver Details

This report employs OpenFoam Code, which is based on a volume averaging method of discretization and uses the post-processing visualisation toolkit Paraview version 5.5. OpenFoam is a CFD software code released and developed primarily by OpenCFD Ltd, since 2004. It has a large user base across most areas of engineering and science, from both commercial and academic organisations.

OpenFOAM CFD code has capabilities of utilizing a Reynolds Averaged Navier-Stokes (RANS) approach, Unsteady Reynolds Averaged Navier-Stokes (URANS) approach, Detached Eddy Simulation (DES) approach, Large Eddy Simulation (LES) approach or the Direct Numerical Simulation (DNS) approach, which are all used to solve anything from complex fluid flows involving chemical reactions, turbulence and heat transfer, to acoustics, solid mechanics and electromagnetics. Quality assurance is based on rigorous testing. The process of code evaluation, verification and validation includes several hundred daily unit tests, a medium-sized test battery run on a weekly basis, and large industry-based test battery run prior to new version releases. Tests are designed to assess regression behaviour, memory usage, code performance and scalability.

The OpenFOAM solver algorithm directly solves the mass and momentum equations for the large eddies that comprise most of the fluid's energy. By solving the large eddies directly no error is introduced into the calculation.

To reduce computational time and associated costs the small eddies within the flow have been solved using the widely used and recognised Smagorinsky Sub-Grid Scale (SGS) model. The small eddies only comprise a small proportion of the fluids energy therefore the errors introduced through the modelling of this component are minimal.

The error introduced by modelling the small eddies can be considered of an acceptable level. Computational time will be reduced by modelling the small eddies (compared to directly solving).

Open Area Functions

The assessment of pedestrian wind comfort in urban areas focuses on activities people are likely to perform in the open space between buildings, which are in turn related to a specific function. For example the activity sitting a longer period of time is typically associated with the location of a street café or similar. Such combinations of activity and area can be grouped in four main categories. These categories are essential and will be utilized to perform pedestrian comfort assessment needed for the environmental assessment within this Report.

A	Sitting for a long period of time; laying steady position; pedestrian sitting; *Terrace; street café or restaurant; open field theatre; pool*
B	Pedestrian standing; standing/sitting over a short period of time; short steady positions; *Public park; playing field; shopping street; mall*
C	Pedestrian walking; leisurely walking; normal walking; ramble; stroll *Walkway; building entrance; shopping street; mall*
D	Objective business walking; brisk or fast walking *Car park; avenue; sidewalk; belvedere*

Figure 3.12: Main Categories for Pedestrian Activities (Source: Lawson Categories

3.1.7 CFD Model Details Of The Proposed Development

This subsection describes all features included in the geometrical and physical representation of proposed St. Paul's Residential Development CFD model. Any object which may have significant impact on wind movement and circulation are represented within the model. To be accurate, the structural layout of the building being modelled should include only the obstacles, blockages, openings and closures which can impact the wind around the building. It is important to remember that a CFD simulation approximates reality, so providing more details of the geometry within the model will not necessarily increase the understanding of the bulk flows in the real environment.

Modelled Geometry

Proposed St. Paul's Residential Development Model consists of building blocks 1-9 as shown in Figure 3.13.

The modelled layout and dimensions of the surrounding environment are outlined in the table below (Table 3.1).

In order to represent reality and consider the actual wind impacting on the site, the modelled area for the wind modelling study comprises a wider urban area of $2km^2$ around the proposed St. Paul's Residential Development, as shown.

	MODELLED CFD ENVIRONMENT DIMENSIONS		
	Width	Length	Height
CFD Mesh Domain	950m approx	950m approx	120m approx

Table 3.1: Modelled Environment Dimensions

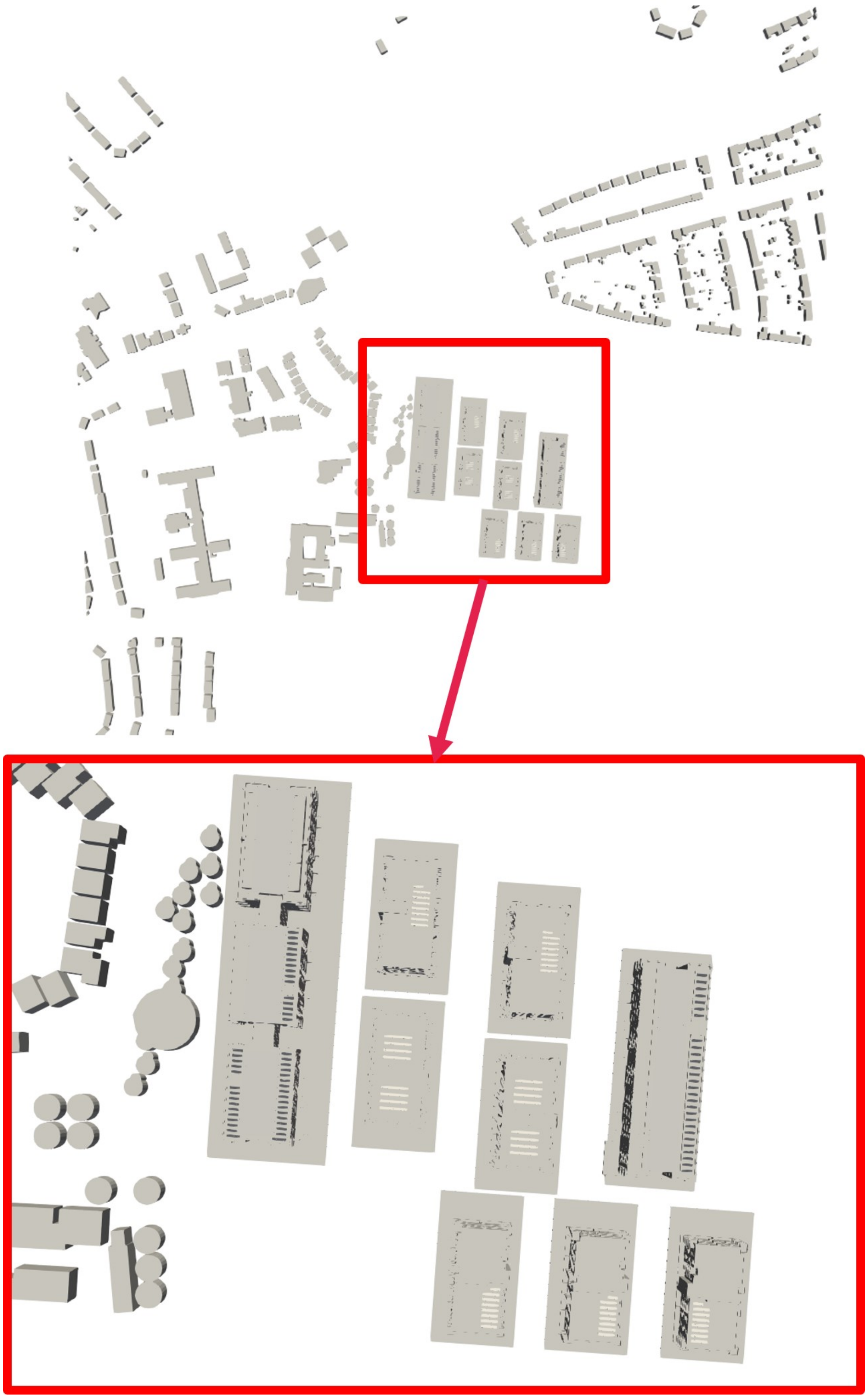


Figure 3.13: Proposed St. Paul's Residential Development Extents of Modelled Area: Blocks 1-9: Top View

3.1.8 Boundary Conditions

A rectangular computational domain was used for the analysis. The wind directions were altered without changing the computational mesh. For each simulation scenario, an initial wind velocity was set according to the statistical weather data collected in order to consider the worst case scenario. Building surfaces within the model are specified as 'no slip' boundary conditions. This condition ensures that flow moving parallel to a surface is brought to rest at the point where it meets the surface. Air flow inlet boundaries possess the 'Inlet' wind profile velocity patch boundary condition with its appropriate inflow turbulence intensity and dissipation rates. Air exits the domain at the 'pressure outlet' boundary condition.

The wind velocity data provided by the historical data collection and by the local data measuring are used in the formula below for the logarithmic wind profile to specify the wind velocity profile (wind velocity at different heights) to be applied within the CFD model:

$$v_2 = v_1 \cdot \frac{ln\frac{h_2}{z_0}}{ln\frac{h_1}{z_0}} \tag{3.1}$$

where:

- v_1 = wind speed measured at the reference height h_1
- h_1 = reference height to measure v_1
- h_2 = height of the wind speed v_2 calculated for the wind profile
- z_0 = 0.4 [m] roughness length selected (see table in Figure 3.14 below)

Roughness Classes and Lengths

Roughness class	Roughness length z_0	Land cover types
0	0.0002 m	Water surfaces: seas and Lakes
0.5	0.0024 m	Open terrain with smooth surface, e.g. concrete, airport runways, mown grass etc.
1	0.03 m	Open agricultural land without fences and hedges; maybe some far apart buildings and very gentle hills
1.5	0.055 m	Agricultural land with a few buildings and 8 m high hedges seperated by more than 1 km
2	0.1 m	Agricultural land with a few buildings and 8 m high hedges seperated by approx. 500 m
2.5	0.2 m	Agricultural land with many trees, bushes and plants, or 8 m high hedges seperated by approx. 250 m
3	0.4 m	Towns, villages, agricultural land with many or high hedges, forests and very rough and uneven terrain
3.5	0.6 m	Large towns with high buildings
4	1.6 m	Large cities with high buildings and skyscrapers

Figure 3.14: Roughness length and class to be used for the logarithmic wind profile

The wind profile used in the model has been calculated using the formula above and is represented in Figure 3.15.

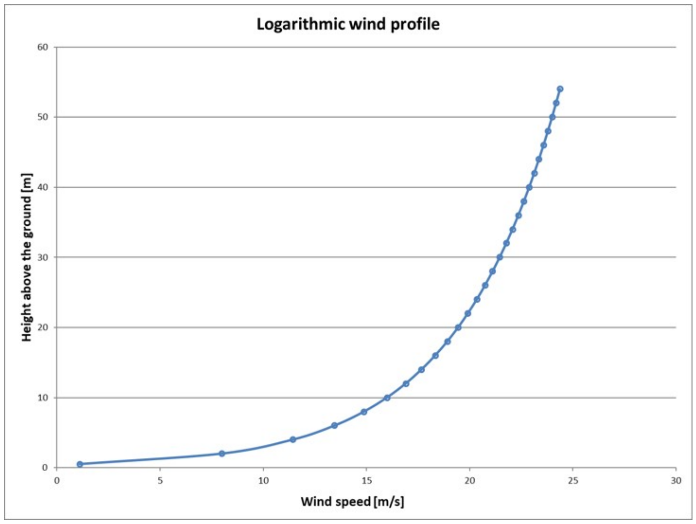


Figure 3.15: Wind profile used in the model

3.1.9 Computational Mesh

The level of accuracy of the CFD results are determined by the level of refinement of the computational mesh. A mesh independent analysis is carried out prior to detailed simulation for final results. Details of parameters utilized for air and the computational mesh are presented in Table 3.2, while an example of the utilized computational mesh grid is as shown in Figure 3.16 to 3.17.

The grid follows the principles of the 'Finite Volume Method', which implies that the solution of the model equations is calculated at discrete points (nodes) on a three-dimensional grid, which includes all the flow volume of interest. The mathematical solution for the flow is calculated at the center of each of these cells and then an interpolation function is used by the software to provide the results in the entire domain.

AIR AND COMPUTATIONAL MESH PARAMETERS	
Air Density ρ	$1.2kg/m^3$
Ambient Temperature (T)	$288K(approx.15C^{\circ})$
Min mesh cell size	0.1 m At Development Building 0.5m In The Refined Volume Surroundings 1.5m At Other Environment Buildings 2m Elsewhere
Min cell size ratio	1:1:1 (dx:dy:dz)
Total mesh size	Approx. cells number = 20 million

Table 3.2: Air and Computational Mesh Paramenters

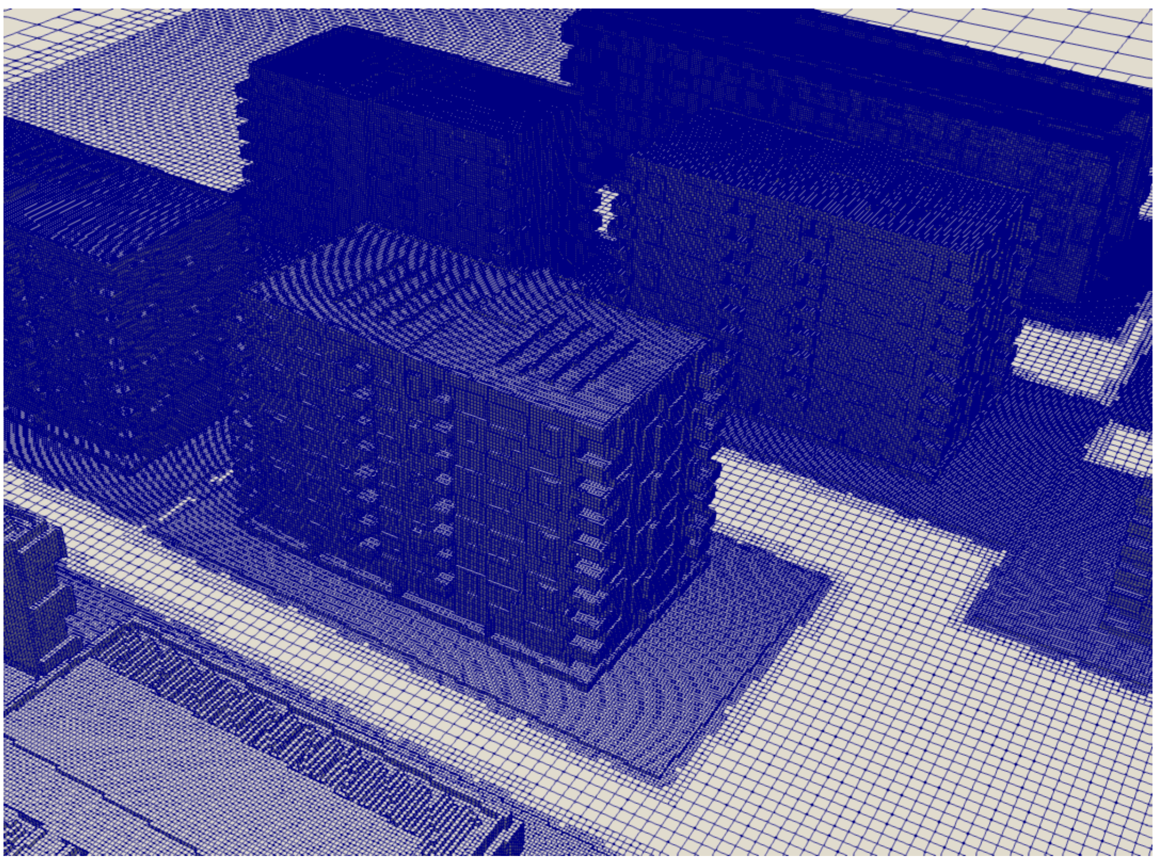


Figure 3.16: Proposed St. Paul's Residential Development Computational Mesh Utilized: South West Isometric View

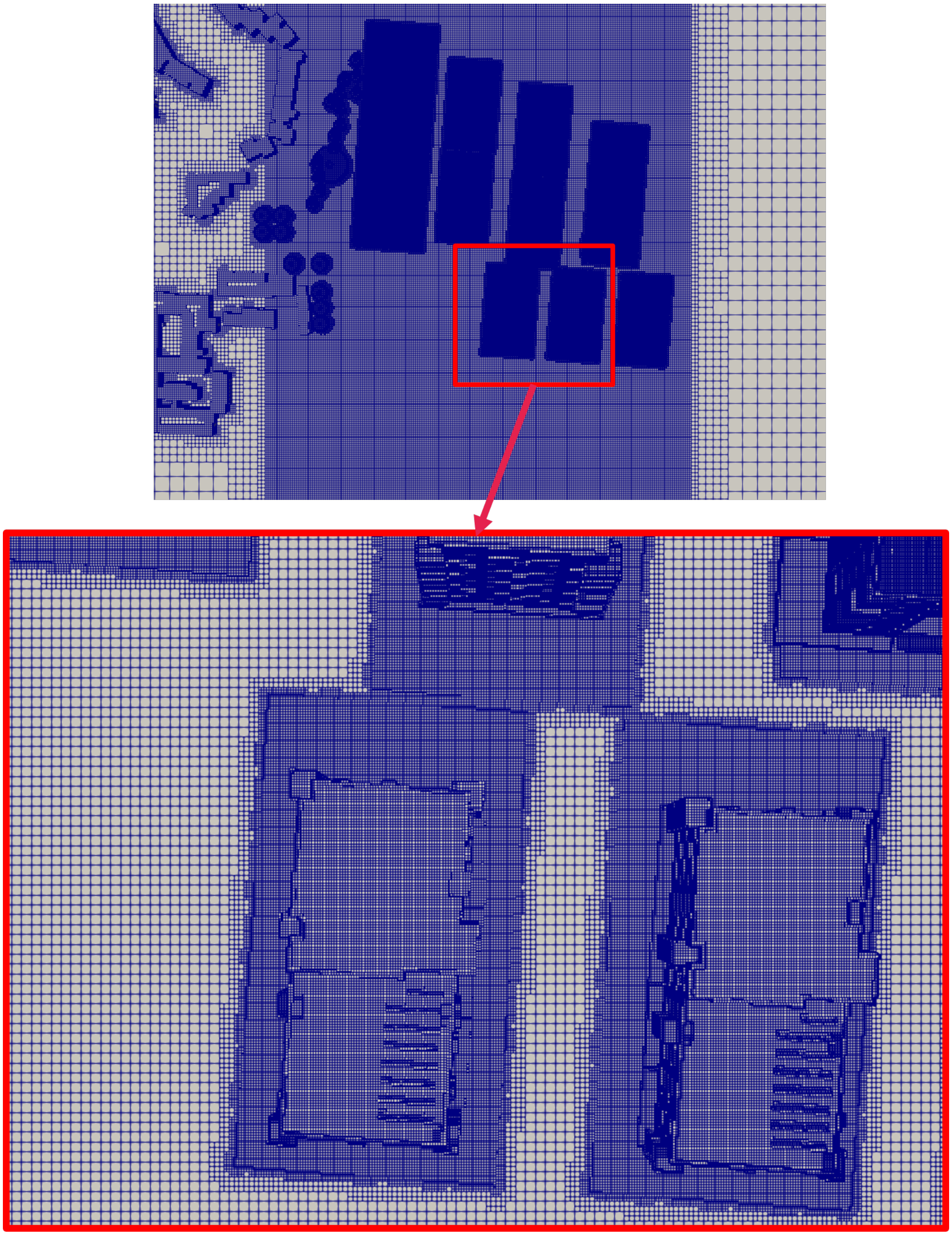


Figure 3.17: Proposed St. Paul's Residential Development Computational Mesh Utilized: Top View

A summary of CFD model input data used in this project is given in the table shown in Figure 3.18. This summarizes the numerical modelling technique and parameters utilized.

Parameter	ST. PAUL'S DEVELOPMENT CFD MODEL DATA
Environment Conditions	
Ambient pressure	101325 Pa
Wind profile	Logarithmic atmospheric profile
Ambient temperature	15°C
Analysis type	Steady state
Computational Details	
Total cells used	> 20,000,000
Development Mesh size	0.2 m
Turbulence treatment	K-epsilon turbulence model
Convergence Criteria	$< 10^{-6}$
Boundary Conditions	
CFD Domain Inlet	Statistical Wind Profile
CFD Domain Outlet	Pressure Outlet condition (zero pressure gradient)
All Buildings	Zero velocity gradient (No-slip condition)

Figure 3.18: Summary of CFD Model Input Data

4. PROPOSED DEVELOPMENT

4.1 DESCRIPTION OF PROPOSED DEVELOPMENT

The development will consist of the construction of a residential development set out in 9 no. blocks, ranging in height from 5 to 9 storeys accommodating 657no. apartments, residential tenant amenity spaces and a crèche. At basement level the site will accommodate car parking spaces, bicycle parking, storage, services and plant areas. Landscaping will include extensive communal amenity areas, and a proposed significant area of public open space. The proposed development also includes for the widening and realignment of an existing vehicular access onto Sybil Hill Road and the demolition of an existing pre-fab building to facilitate the construction of an access road from Sybil Hill Road between Sybil Hill House (a Protected Structure) and St Paul's College incorporating upgraded accesses to Sybil Hill House and St Paul's College and a proposed pedestrian crossing on Sybil Hill Road. The proposed development also includes for the laying of a foul water sewer in Sybil Hill Road and the routing of surface water discharge from the site via St. Anne's Park to the Naniken River and the demolition and reconstruction of existing pedestrian stream crossing in St. Anne's Park with integral surface water discharge to Naniken River.

Figures 4.1 and 4.2 shows views of the entire proposed development while Figure 4.3 shows generic views of the public spaces. Figure 4.4 shows the generic apartments (top) Layout.

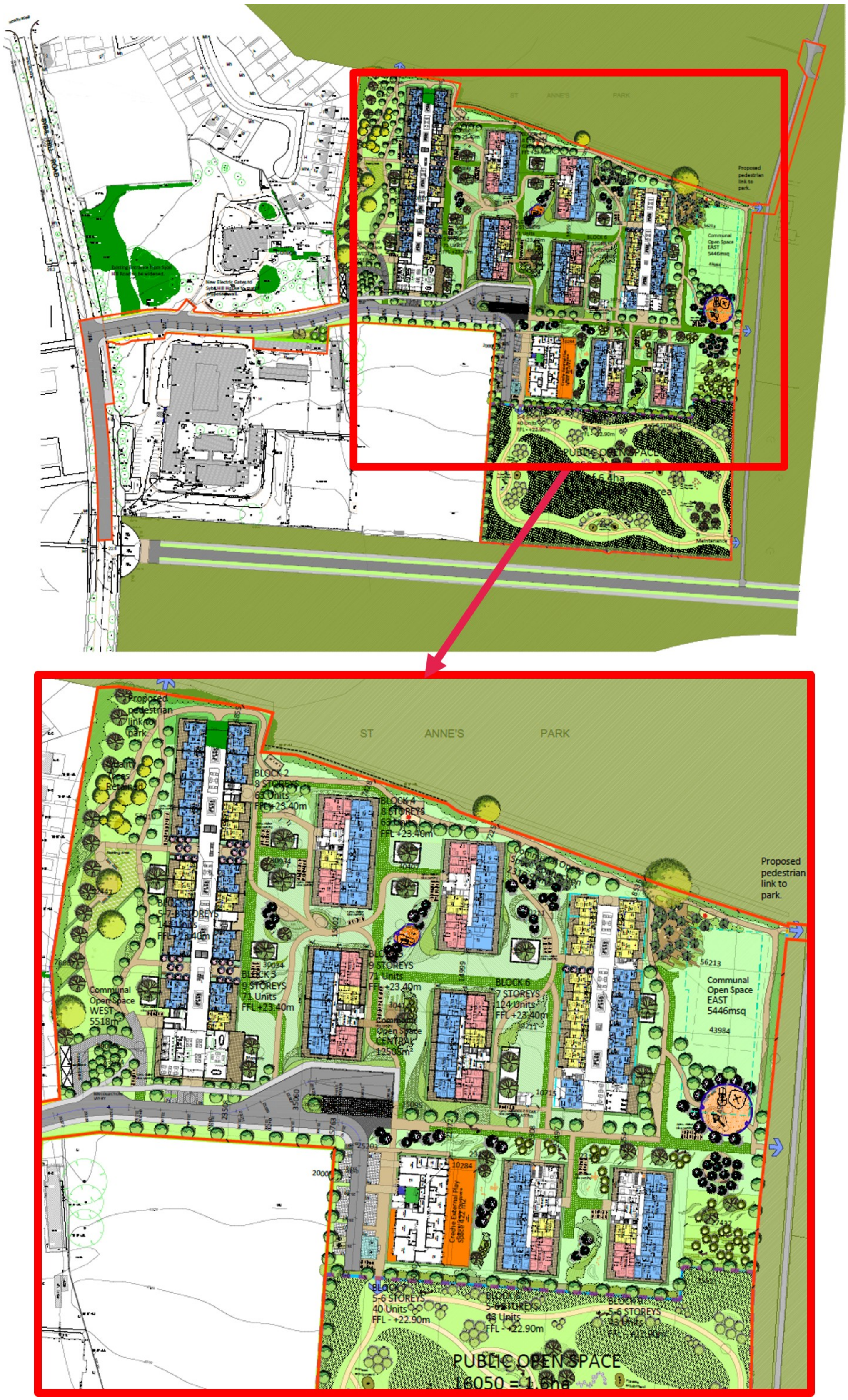


Figure 4.1: Proposed St. Paul's Residential Development (Zoomed View)

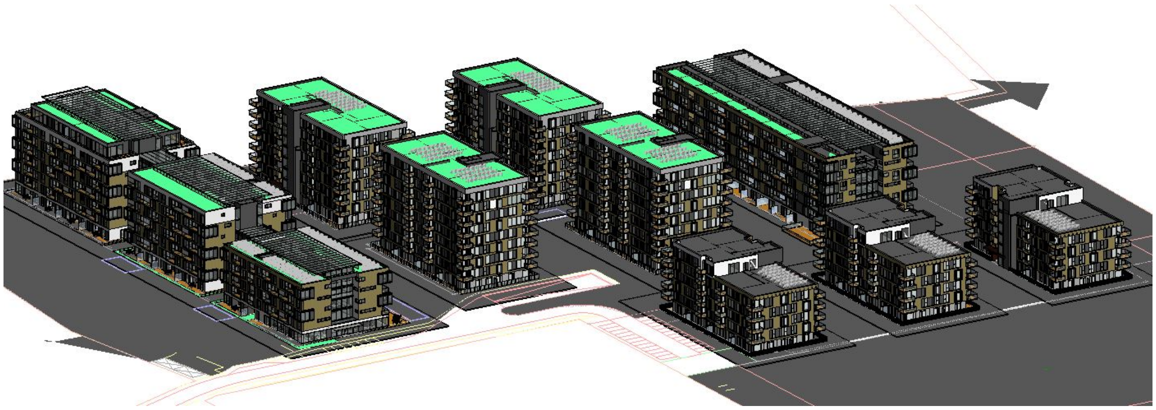


Figure 4.2: Proposed St. Paul's Residential Development 3D Model Showing Blocks 1-9: S-W ISO View

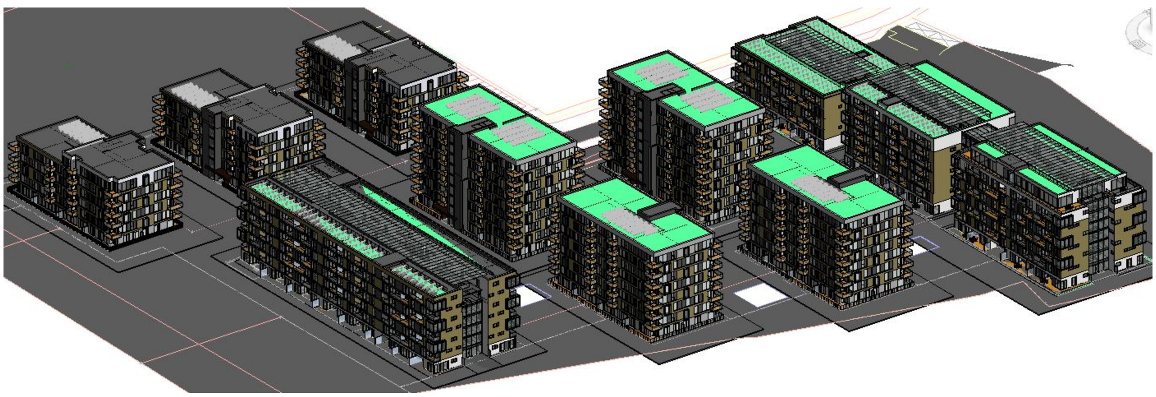


Figure 4.3: Proposed St. Paul's Residential Development 3D Model Showing Blocks 1-9: N-E ISO View

Figure 4.4: Proposed St. Paul's Residential Development - Rendered View Of Apartments

5. WIND DESKTOP STUDY

5.1 EXISTING RECEIVING BASELINE ENVIRONMENT ASSESSMENT

In this section, wind impact has been assessed on the existing receiving environment considered as the existing buildings and the topography of the site prior to construction of the proposed development. A statistical analysis of 30 years historical weather wind data has been carried out to assess the most critical wind speeds, directions and frequency of occurrence of the same. The aim of this assessment has been to identify the wind microclimate of the area.

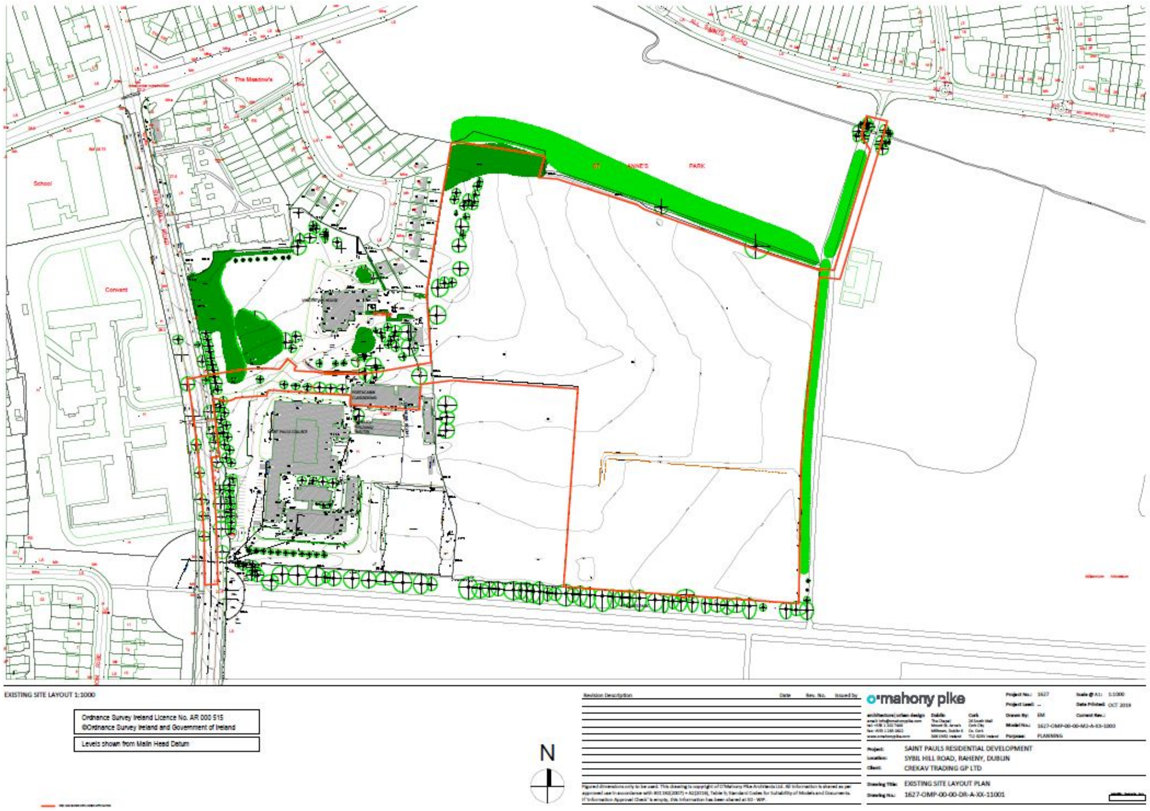


Figure 5.1: Existing Receiving Baseline Environment (Source: O'Mahony Pike Architects)

An initial wind desktop study of the existing receiving environment showed that:

- The wind profile was built using the annual average of meteorology data collected at Dublin Airport Weather Station. In particular, the local wind climate was determined from historical meteorological data recorded 10 m above ground level at Dublin Airport.
  18 different scenarios were selected in order to take into consideration all the different relevant wind directions. In particular, a total of 18 compass directions on the wind rose are selected. For each direction, the reference wind speed is set to the 5% exceedance wind speed for that direction, i.e. the wind speed that is exceeded for over 5% of the time whenever that wind direction occurs.

- The site is surrounded by landscaping. This has a beneficial effect in mitigating the impact of the incoming wind. The prevailing wind directions for the site are identified in the West, West South-West and South-East with magnitude of approximately 6m/s. In all these directions the development benefits from a good shielding through landscaping. The trees are beneficial in calming the incoming wind and deviating it.

- Areas where velocities can be potentially higher and some funnelling/recirculation effects experienced have been highlighted. However, these are mitigated by the proposed mitigation measures, with particular attention to the corners of the proposed development buildings.

5.1.1 Site Location And Surrounding Area

The proposed St. Paul's Residential Development will be situated in Raheny, Dublin 5. The Existing Environment site is shown in Figure 5.1 and Figure 5.2. The area considered for the existing environment and proposed development assessment comprises a 2km^2 area around the proposed St. Paul's Residential Development as represented in Figure 5.3.

Figure 5.2: Proposed St. Paul's Residential Development Site Location and Existing Environment (Source: Google Earth and Google Map Views)

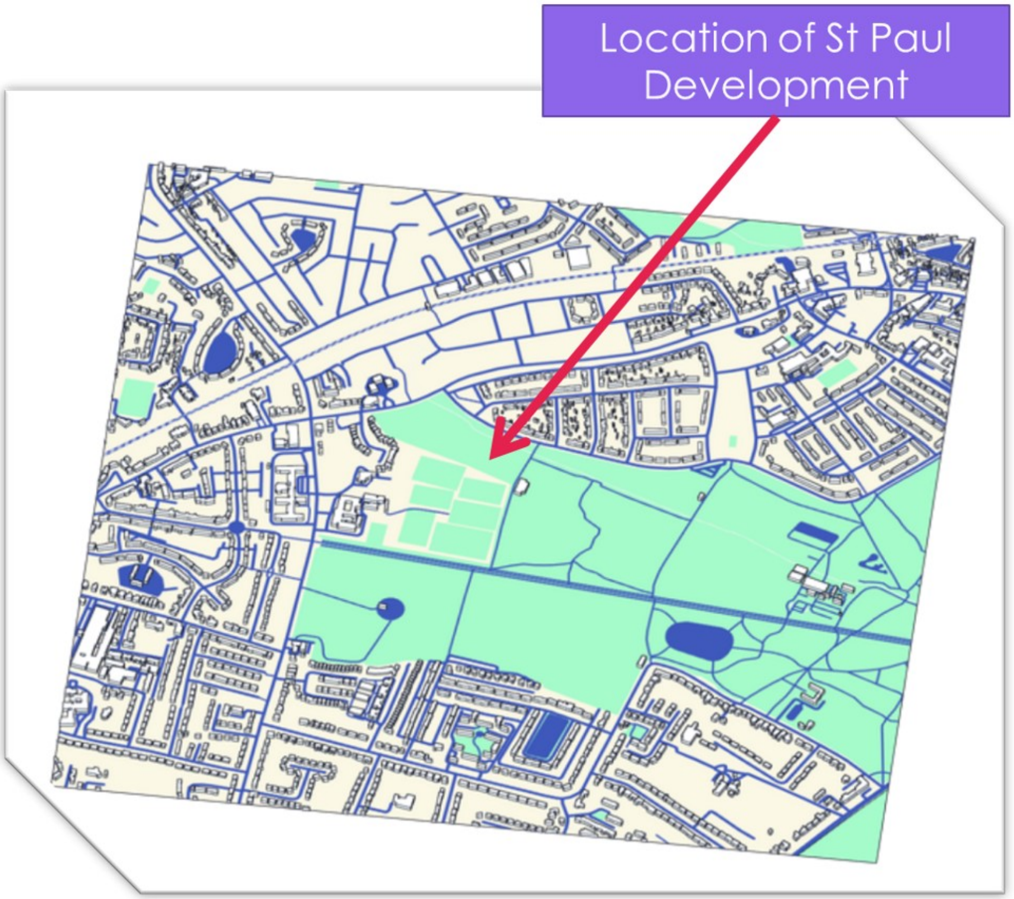


Figure 5.3: Extents of Analysed Existing Environment Around Proposed St. Paul's Residential Development (Source: Google Earth and Google Map Views)

5.1.2 Topography And Built In Environment

Figure 5.4 shows an aerial photograph of the terrain surrounding the site at proposed St. Paul's Residential Development.

The area surrounding the site can be characterised as urban environment. Some shelter effect can be expected for wind approaching from directions within this sector. For the study considered, the main wind directions of west to South-West and South-East are in classified "urban winds". The site is located near a coastal area however, between the sea and the site, there is an urban environment so the effect of the sea is expected to be mitigated.

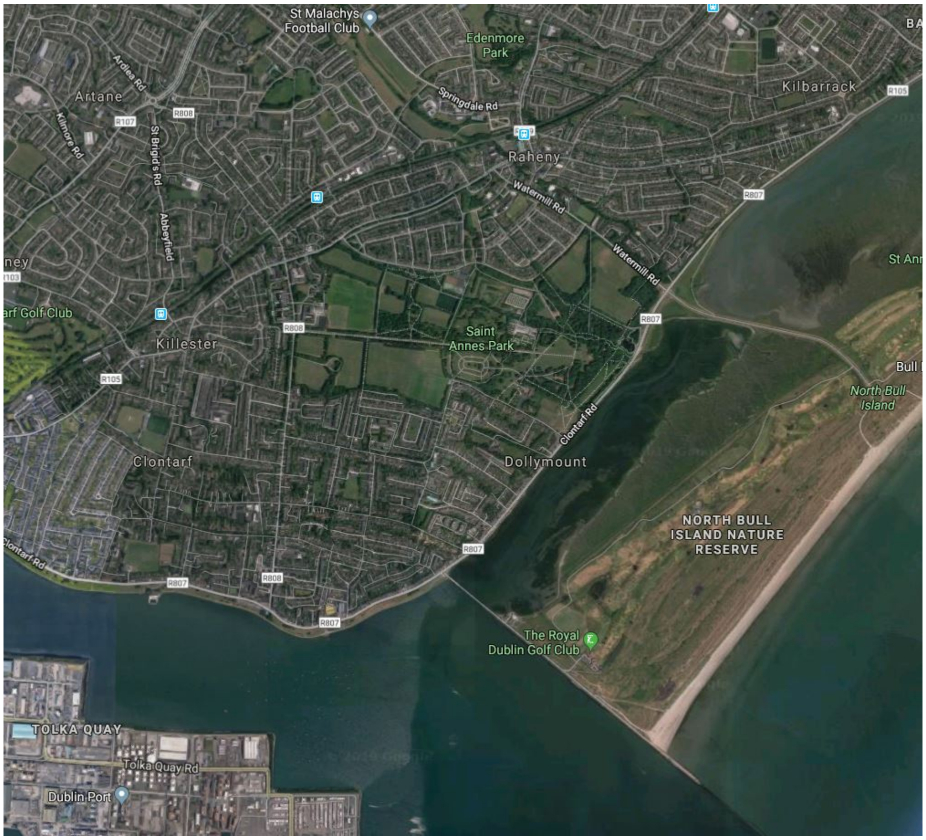


Figure 5.4: Built-in Environment Around Proposed St. Paul's Residential Development (Source: Google Earth View)

5.1.3 Wind Microclimate Conditions

This analysis considers the existing environment being exposed to typical wind conditions of the site. The buildings are oriented as shown in the previous sections. The wind profile is built using the annual average of meteorology data collected at Dublin Airport Weather Station. Figure 5.5 shows on the map the position of proposed St. Paul's Residential Development and the position of Dublin Airport.

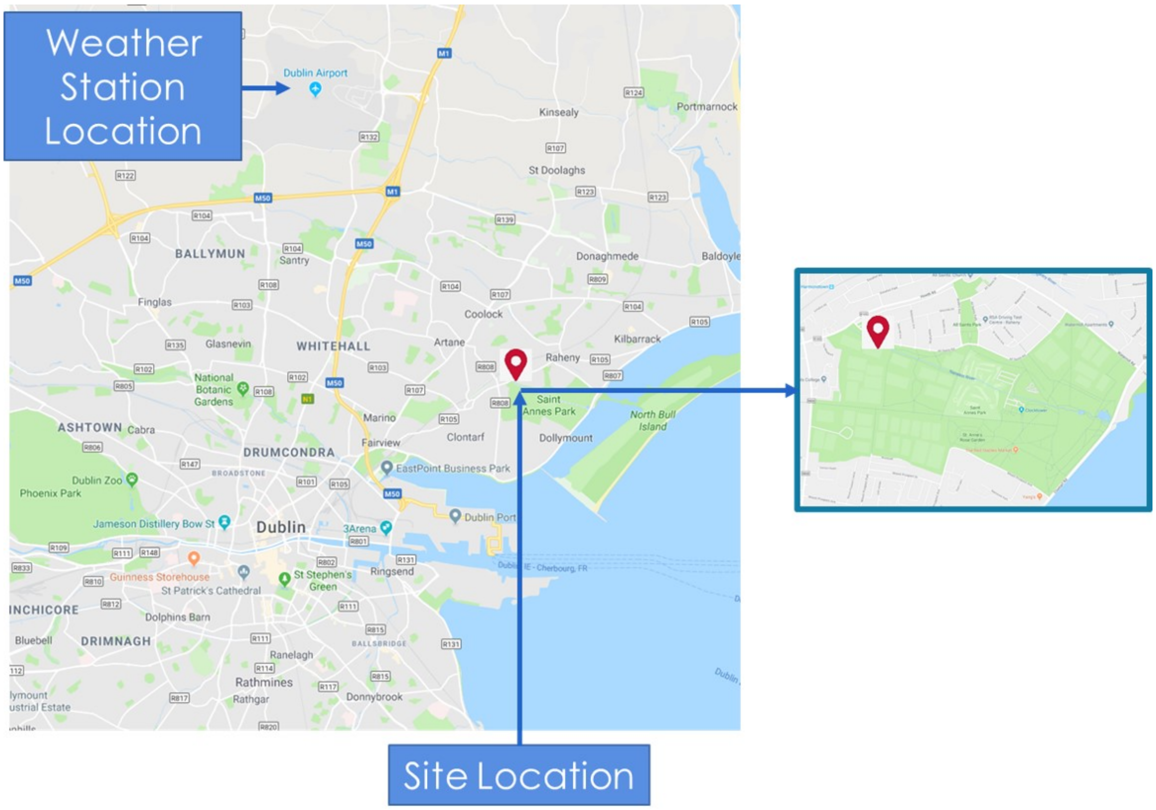


Figure 5.5: Map showing the position of Proposed St. Paul's Residential Development and Dublin Airport

Regarding the transferability of the available wind climate data, the following considerations have been made:

- **Terrain**: The meteorological station is located in the flat open terrain of the airport, whereas the development site is located in urban area with dense built-in structure with buildings of at least 15m height in average.

- **Mean Wind Speeds**: Due to the different terrain environment, the ground-near wind speeds (at pedestrian level) will be lower at the construction site compared to the meteorological station at the airport.

- **Wind Directions**: The landscape around the development site can in principle be characterized as flat terrain. Isolated elevations in the near area of the development should have no influence on the wind speed and wind directions. With respect to the general wind climate no significant influence is expected. Based on the above considerations it can be concluded that the data from the meteorological station at Dublin Airport are applicable for the desktop assessment of the wind comfort at the development site.

5.1.4 Wind Conditions

The assessment of the wind comfort conditions at the new development will be based on the dominating wind directions throughout a year (annual wind statistic).

As stated above, the local wind climate is determined from historical meteorological data recorded at Dublin Airport. Two different data sets are analyzed for this assessment as follows:

- The meteorological data associated with the maximum daily wind speeds recorded over a 30 year period between 1985 and 2015 and,
- The mean hourly wind speeds recorded over a 10 year period between 2005 and 2015. The data is recorded at a weather station at the airport, which is located 10m above ground or 71mOD.

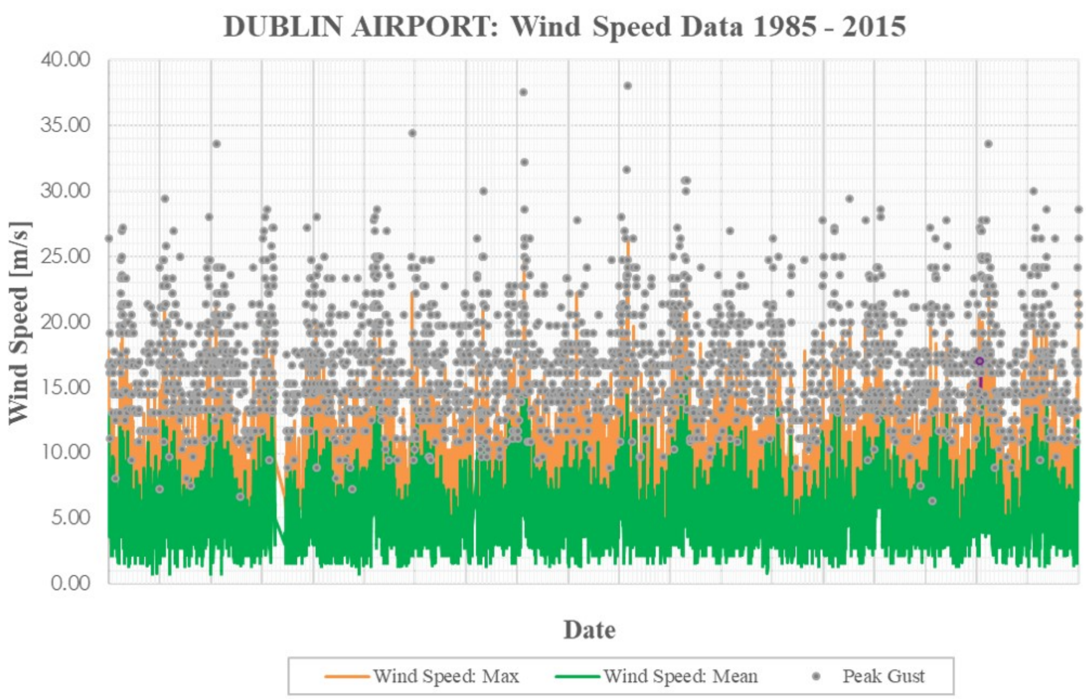


Figure 5.6: Local Wind Conditions (Source: Dublin Airport Weather Station)

Figure 5.7, presenting the wind speed diagram for Dublin, shows the days per month, during which the wind reaches a certain speed. In Figure 5.8, the wind rose for Dublin shows how many hours per year the wind blows from the indicated direction, confirming how the predominant directions are WSW, W, and SW.

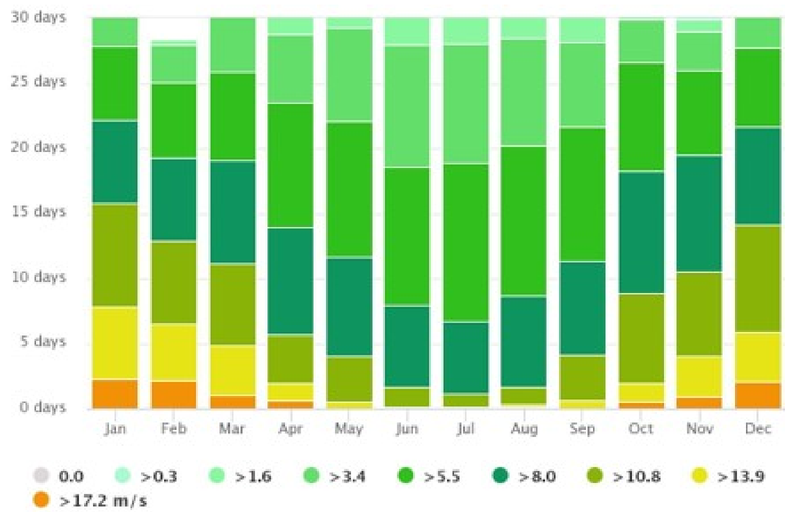


Figure 5.7: Dublin Wind Speed Diagram (Source: Dublin Airport Weather Station)

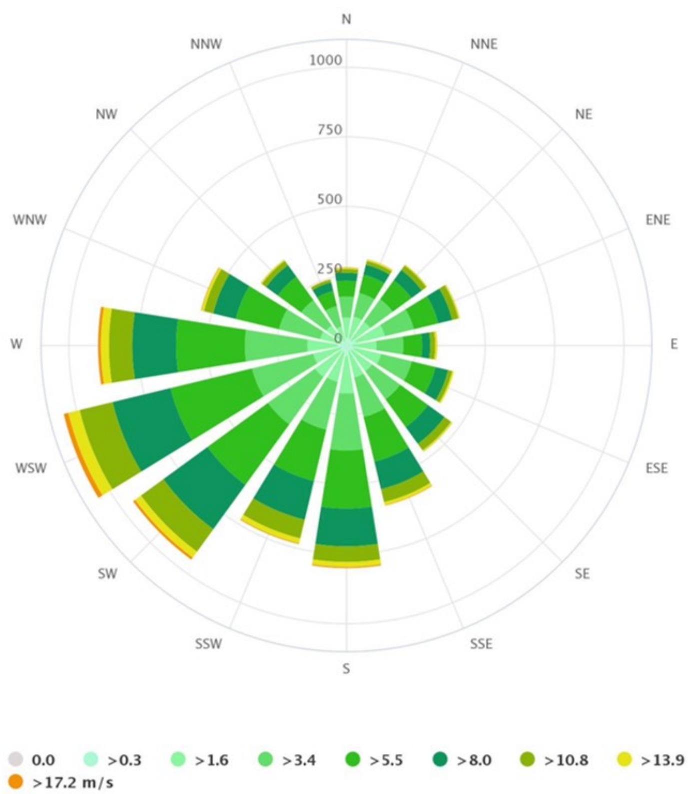


Figure 5.8: Dublin Wind Rose (Source: Dublin Airport Weather Station)

Based on the criterion of occurrence frequency the main wind directions to be considered in pedestrian wind comfort assessment are presented in Figure 5.9 and listed below in descending order of dominance:

1. Southwest with most frequent wind speeds around 6m/s (all year).

2. South-East
3. West-Southwest.

Velocity (m/s)	Direction (°)	Frequency
5.601	225	11.233
4.626	135	6.849
5.847	236.25	6.792
6.049	258.75	6.747
6.034	247.5	6.689
5.888	270	5.662
4.994	315	4.338
5.503	281.25	3.904
4.974	292.5	3.436
5.357	213.75	3.288
4.736	123.75	3.105
4.406	146.25	2.751
5.101	303.75	2.648
5.246	112.5	2.500
4.121	157.5	2.386
4.581	101.25	2.340
4.169	45	2.180
3.558	90	2.135
4.801	202.5	2.021
3.689	78.75	1.963
3.627	168.75	1.495
4.285	67.5	1.370
4.863	56.25	1.279
4.042	191.25	1.199
4.630	326.25	1.164
3.844	11.25	1.142
4.418	337.5	1.062
4.787	348.75	0.982
4.006	22.5	0.959
3.555	180	0.879
4.059	33.75	0.845
0.700	0	0.011
Selected Conditions : 32	Total Coverage : 95.35 %	

Figure 5.9: Main Wind Directions Occurrence Frequency (Source: Dublin Airport Weather Station)

5.1.5 Mean And Maximum Wind Conditions

Examination of the daily wind data reveals that the wind predominantly blows from West and Southwest directions, however, there is a secondary wind from the Southeast. It is apparent that winds from other directions are rare. Maximum daily wind speeds of nearly 30 m/s were recorded in the past 30 years, however, the maximum daily winds are commonly found between 6 m/s and 15 m/s. the strongest winds arise from the West and Southwest.

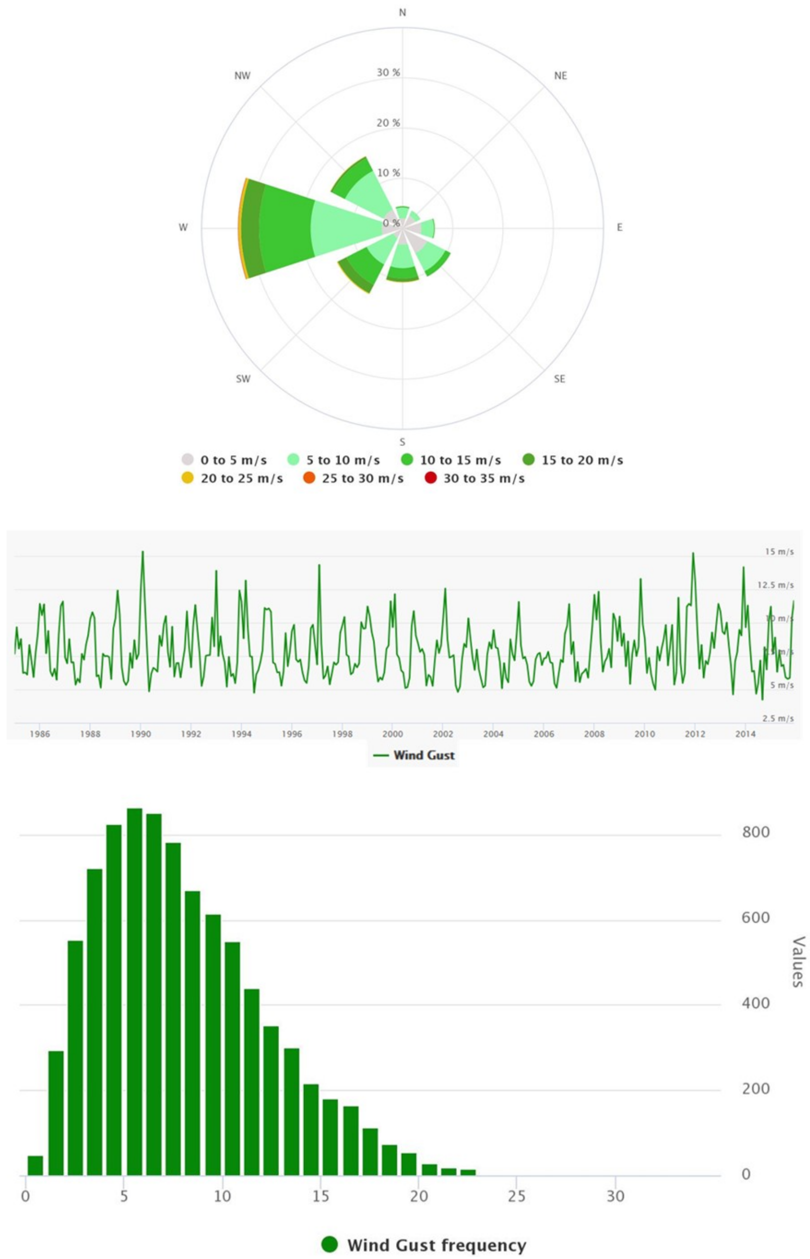


Figure 5.10: Maximum Wind Conditions (Source: Dublin Airport Weather Station)

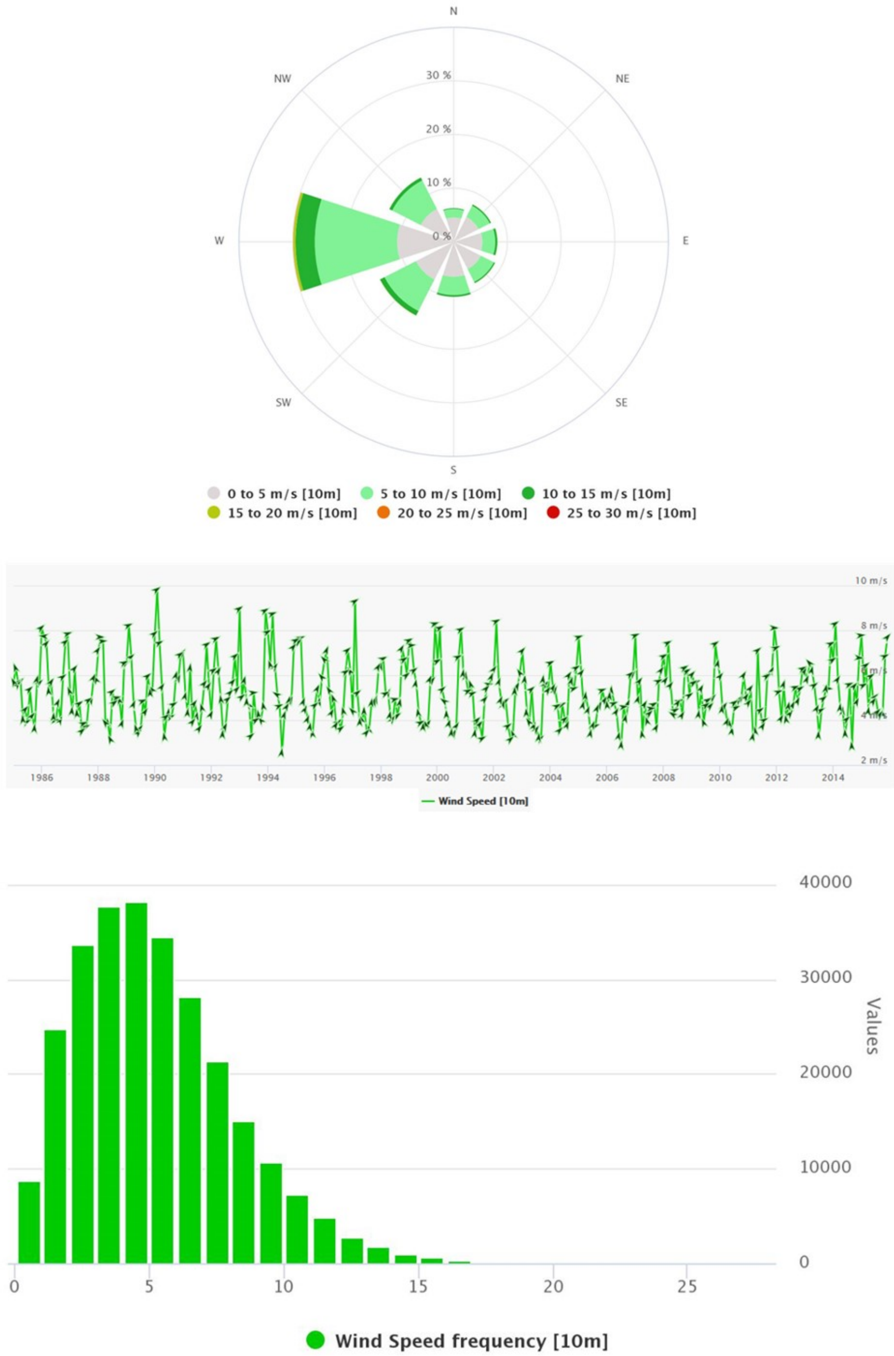


Figure 5.11: Mean Wind Conditions (Source: Dublin Airport Weather Station)

6. IMPACTS OF PROPOSED DEVELOPMENT

6.1 IMPACTS OF PROPOSED DEVELOPMENT

This section assessed the potential impact of the proposed development on the already existing environment, and the suitability of the proposed development to create and maintain a suitable and comfortable environment for different pedestrian activities.

6.1.1 Developments Impact On Wind

This section shows CFD results of wind microclimate assessment carried out considering the ”Operational Phase” of proposed St. Paul’s Residential Development. In this case the assessment has considered the impact of wind on the existing area including the proposed St. Paul’s Residential Development. For this scenario, the proposed St. Paul’s Residential Development has been simulated. Wind simulations have been carried out on all the various directions for which the development could show critical areas in terms of pedestrian comfort and safety. For this, the Lawson and Distress Maps have been presented to identify the suitability of each areas to its prescribed level of usage and activity. The results present parameters outlined within the acceptance criteria previously described in section 3.1.3 (Lawson Scale).

It is also of interest at this point to underline once more the objectives of simulations performed. In particular:

- Pedestrian Wind Comfort and Safety Studies are conducted to predict, assess and, where necessary, mitigate the impact of the development on pedestrian level wind conditions.

- To assess comfortable and safe pedestrian level wind conditions that are appropriate for the intended use of pedestrian areas. Pedestrian areas include sidewalks and street frontages, pathways, building entrance areas, open spaces, public spaces, amenity areas, outdoor sitting areas, etc.

Results of simulations carried out are detailed in the following sections. These results present parameters as outlined in the acceptance criteria section described previously for proposed St. Paul’s Residential development. Results of wind flow speeds are collected throughout the simulation and analysed based on the Lawson Discomfort Criteria.

Figure 6.1 shows an example of wind speed results collected at 1.5m height above ground floor level of the development. Red colors generally indicate critical values while blue colors indicate tenable conditions.

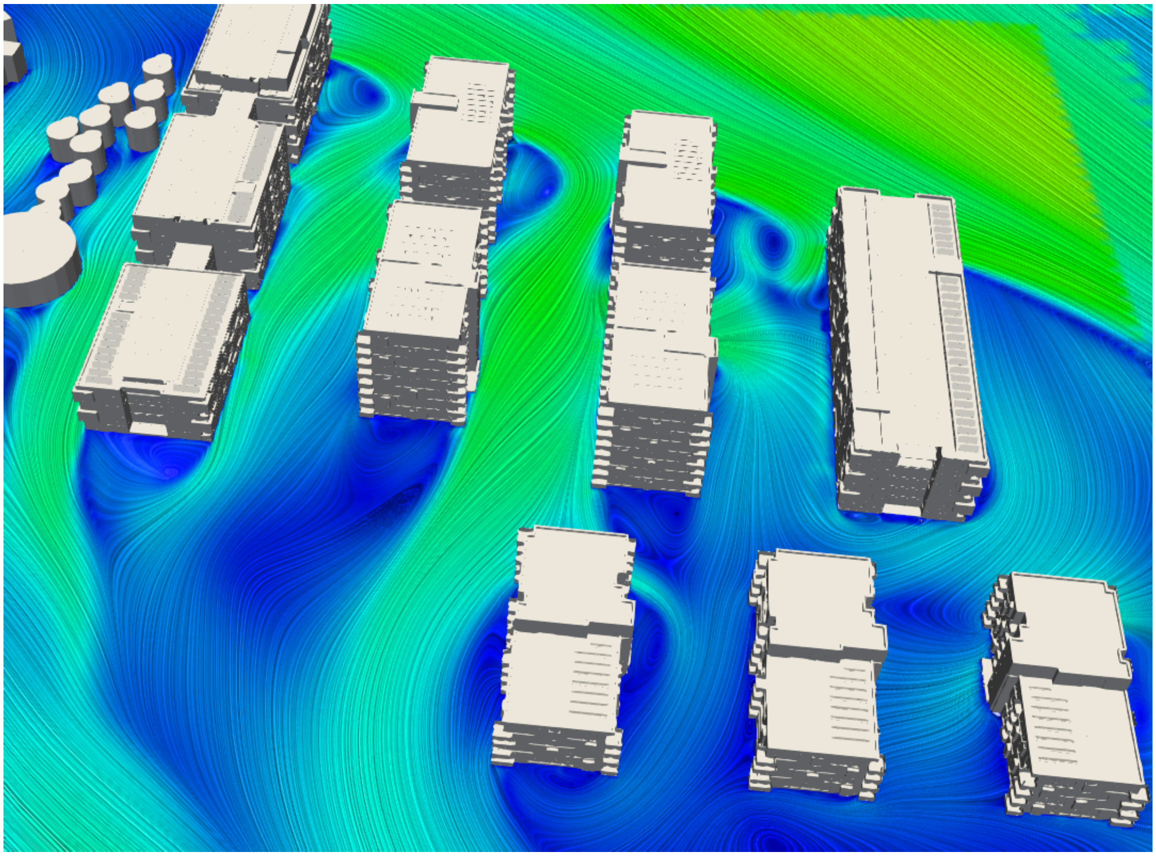


Figure 6.1: Wind Flow Results Collected At 1.5m Height Above Ground Floor

Wind microclimate model assessment of proposed St. Paul's Residential Development and it's environment was performed utilizing a CFD (Computational Fluid Dynamics) methodology. 9 worst case wind scenarios are selected for presentation in this report, as these scenarios and directions showed to be the most relevant wind speeds and cardinal directions.

CFD modelled results of the development scheme showed that:

- The proposed St. Paul's Residential Development will produce a high quality environment that is attractive and comfortable for pedestrians of all categories.
- The Surrounding environment and development properly shields all paths/walkways around and within the development. Pedestrian footpaths are always successfully shielded and comfortable.
- The development communal open spaces are generally suitable for long term sitting, short term sitting, standing, walking and strolling activities.
- Shielding conditions in the South-West, South-East, North-East and North-West areas

are always acceptable.

- Balconies within the development are comfortable for pedestrian sitting, standing, walking and strolling.

- The proposed development does not impact or give rise to negative or critical wind speed profiles at the nearby adjacent roads, or nearby buildings.

- Pedestrian comfort assessment, performed according to the Lawson criteria, identified the areas that are suitable for different pedestrian activities in order to guarantee pedestrian comfort. In terms of distress, no critical conditions were found for "Frail persons or cyclists" in the surrounding of the development. No critical conditions have been found for members of the "General Public".

- During proposed St. Paul's Residential Development construction phase the predicted impacts are classified as negligible.

Flow Velocity Results - Ground Floor Level

Results of wind speeds and their circulations at pedestrian level of 1.5m above the development ground are presented in Figures 6.2 to 6.6 for Cardinal and Ordinal Directions respectively in order to assess wind flows at ground floor level of proposed St. Paul's Residential Development. Wind flow speeds are shown to be within tenable conditions.

Therefore, it can be concluded that the wind speeds that do not attain critical levels.

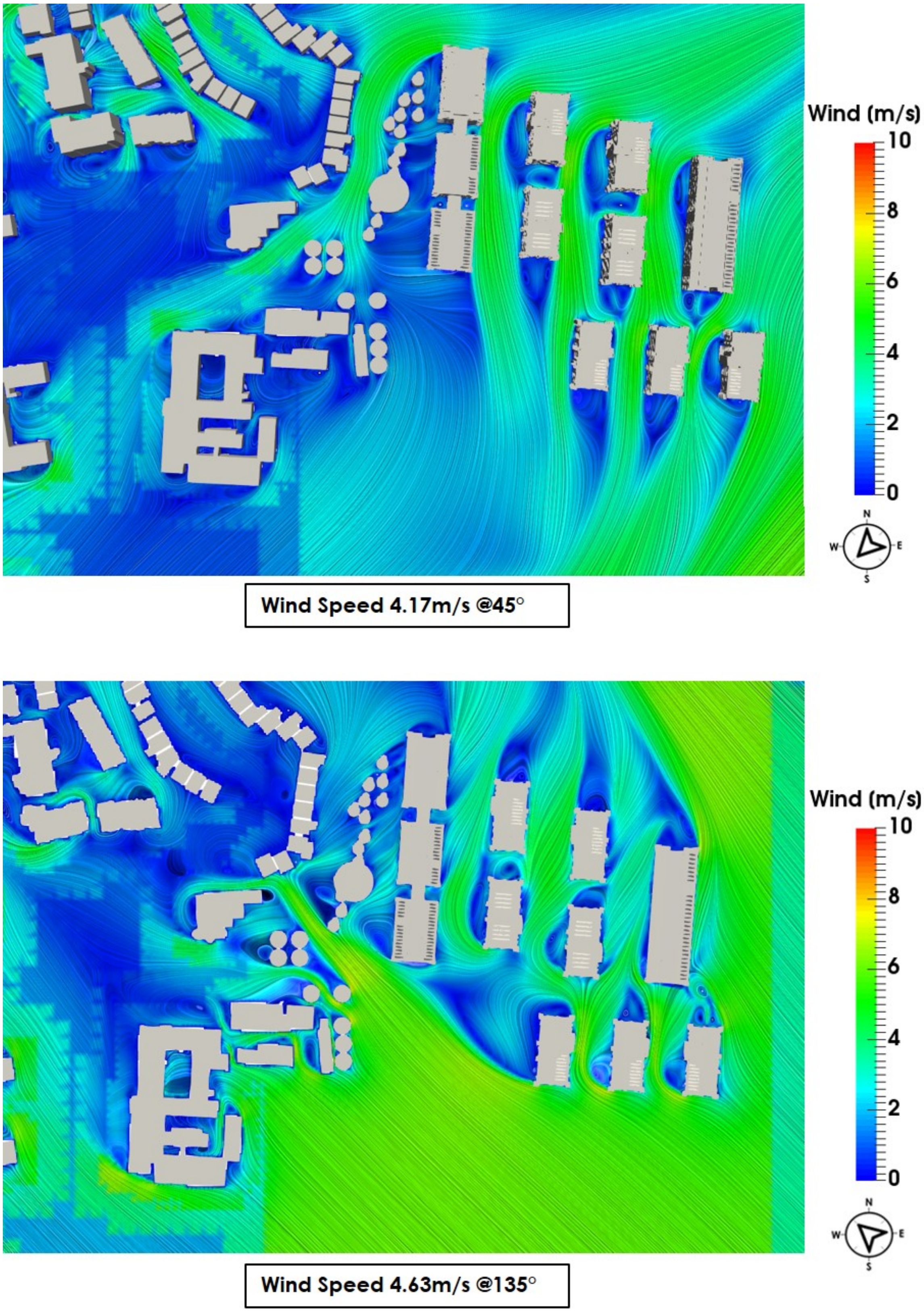
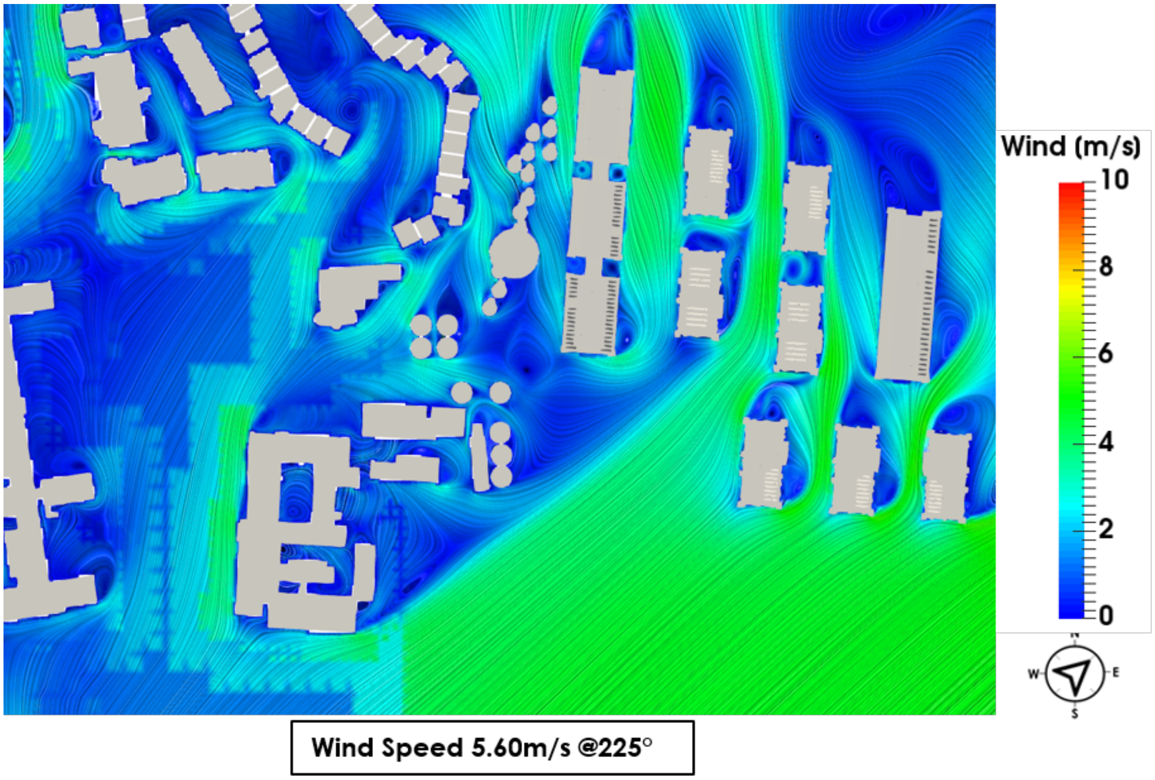


Figure 6.2: Wind Speed Results at 1.5m Above Ground-Top View: 45°, 135°



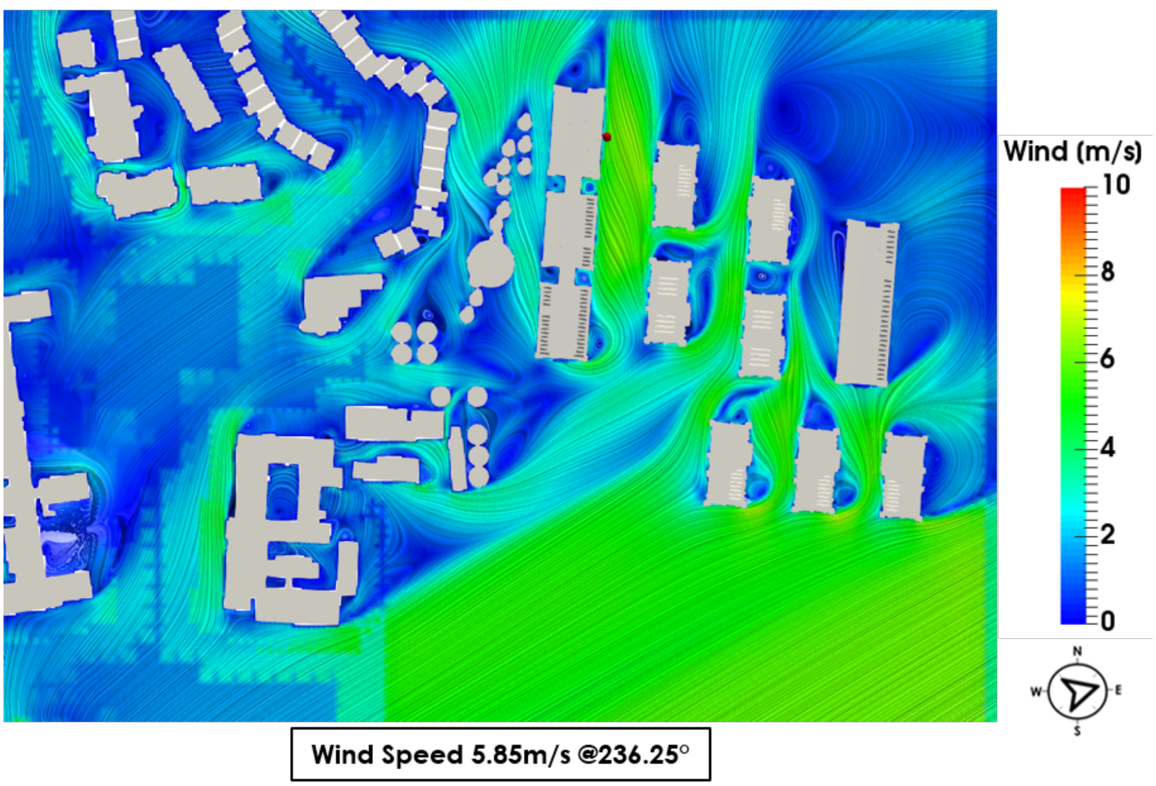
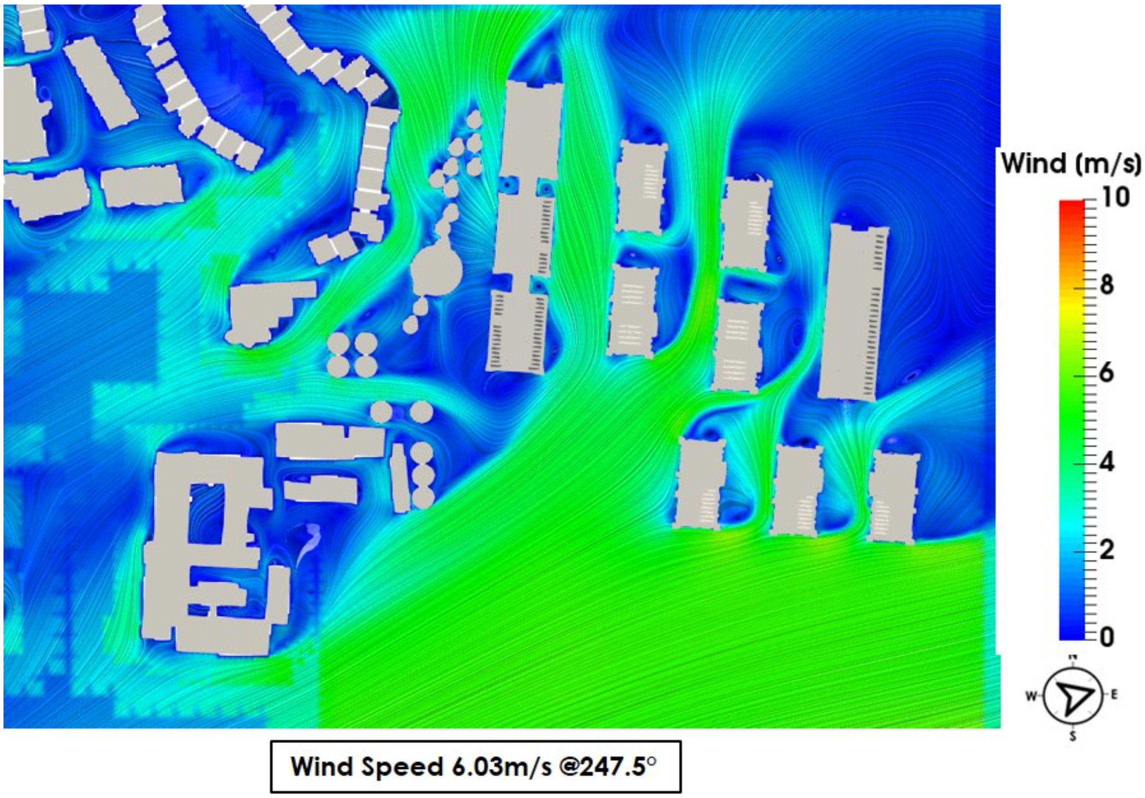


Figure 6.3: Wind Speed Results at 1.5m Above Development Ground-Top View: 225°, 236.25°



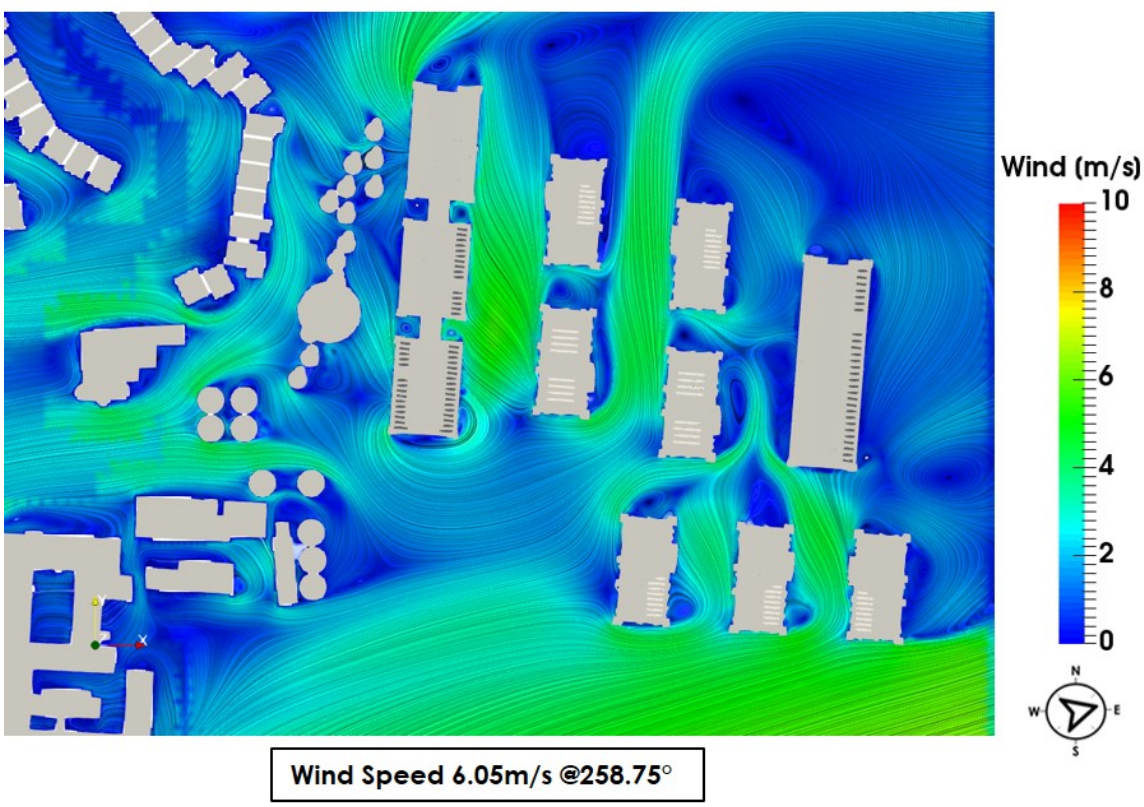
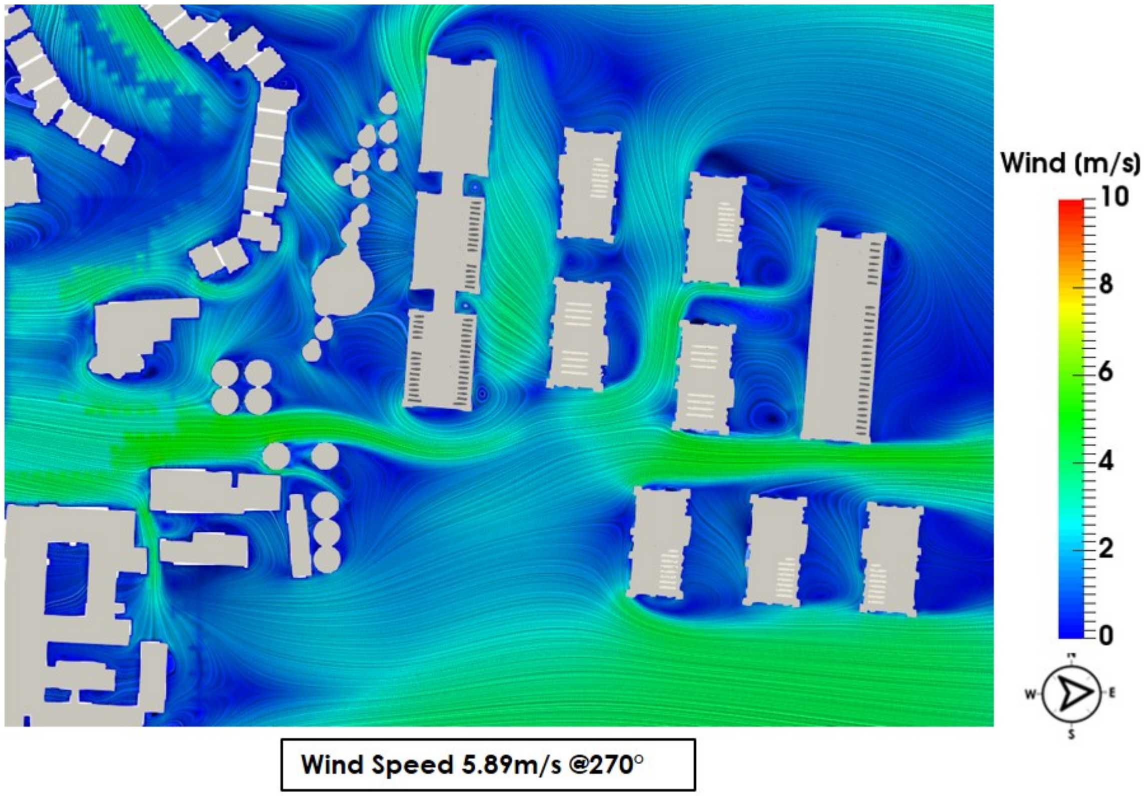


Figure 6.4: Wind Speed Results at 1.5m Above Development Ground-Top View: 247.5°.258.75°



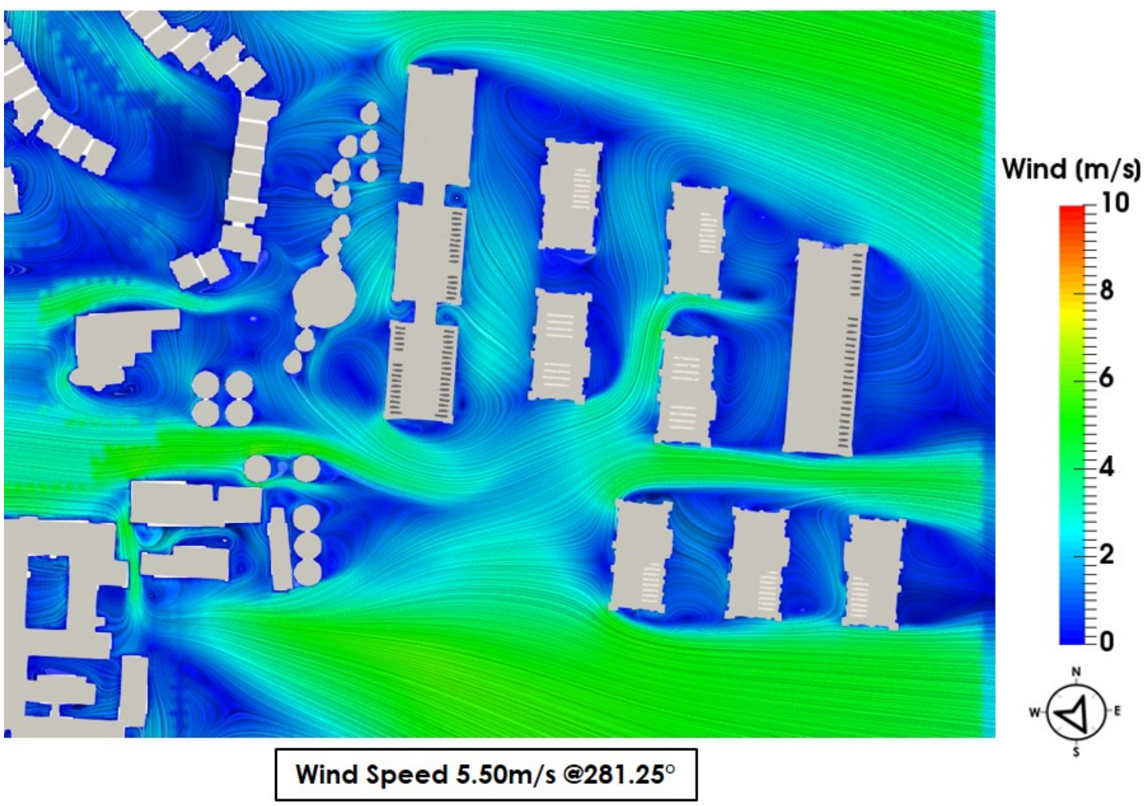


Figure 6.5: Wind Speed Results at 1.5m Above Development Ground-Top View: 270°,281.25°

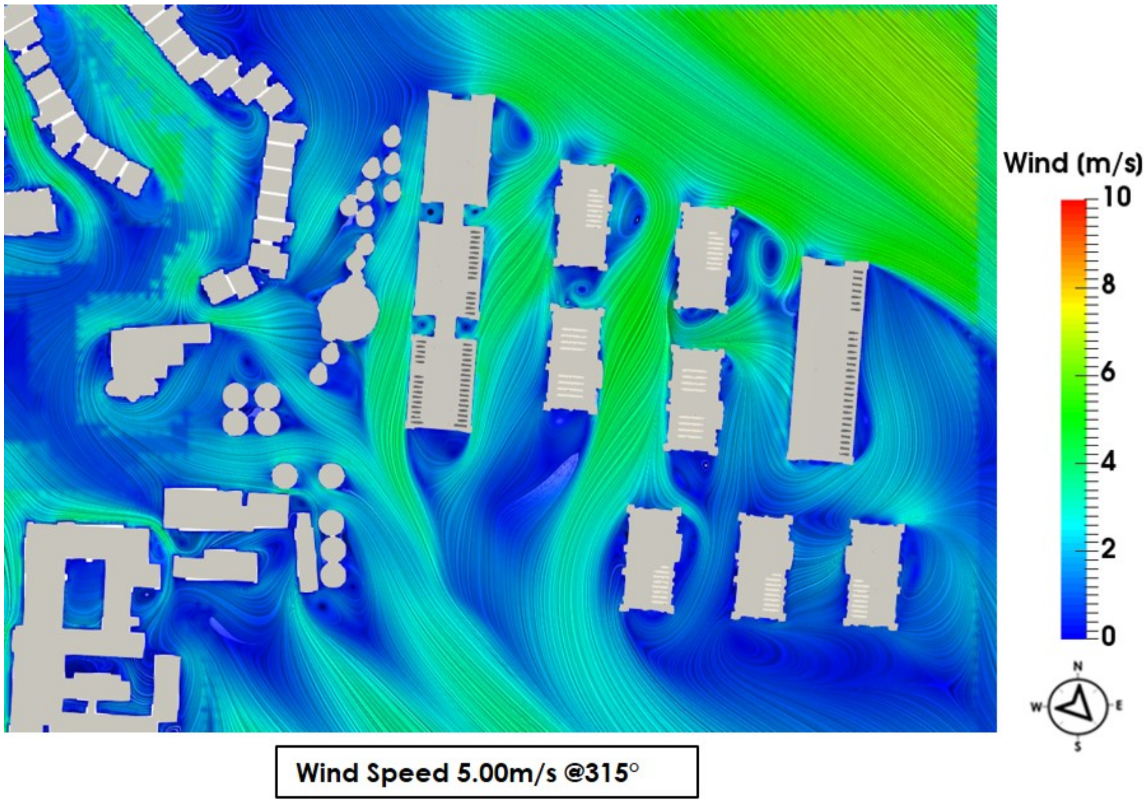
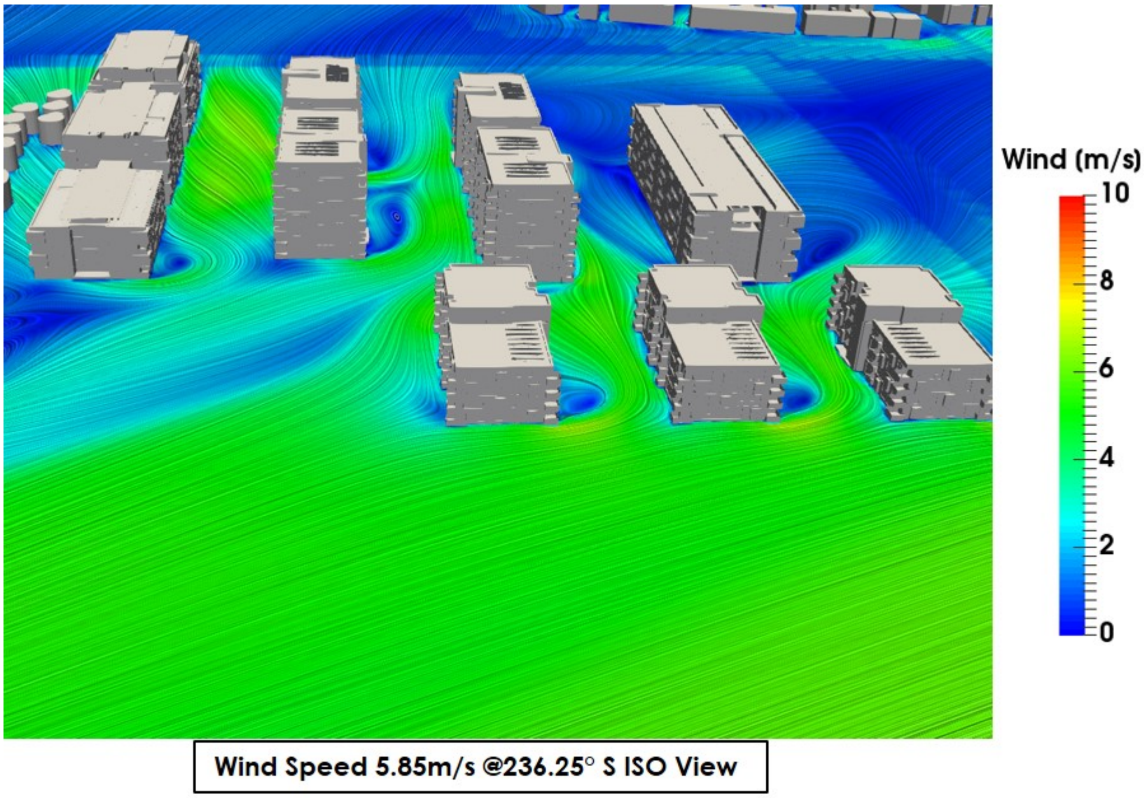


Figure 6.6: Wind Speed Results at 1.5m Above Development Ground-Top View: 315°



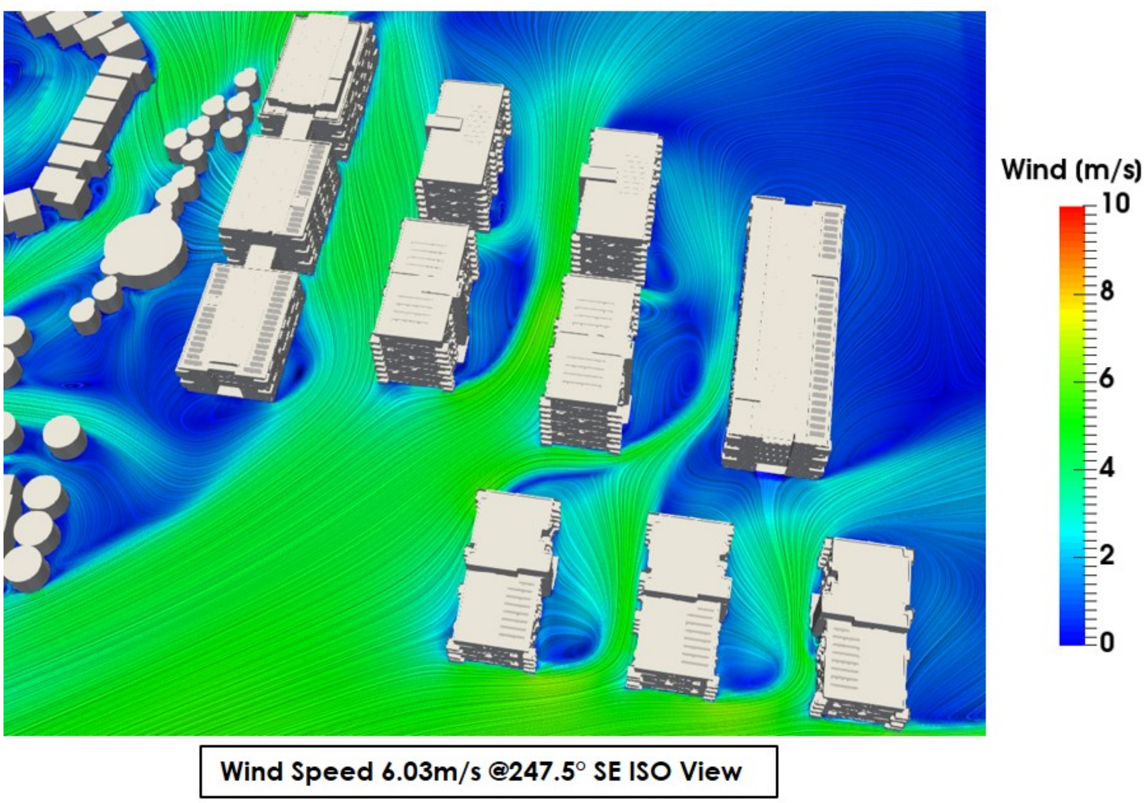
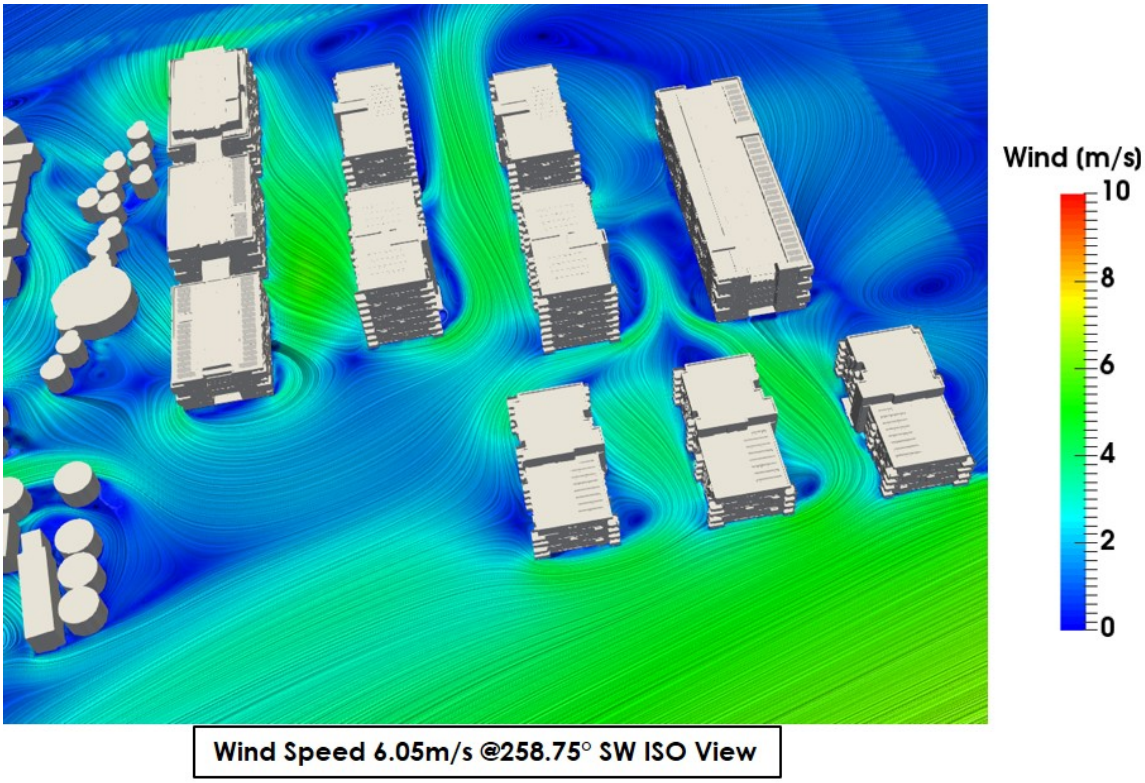


Figure 6.7: Wind Speed Results at 1.5m Above Development Ground-Isometric View: 236.25°, 247.5°



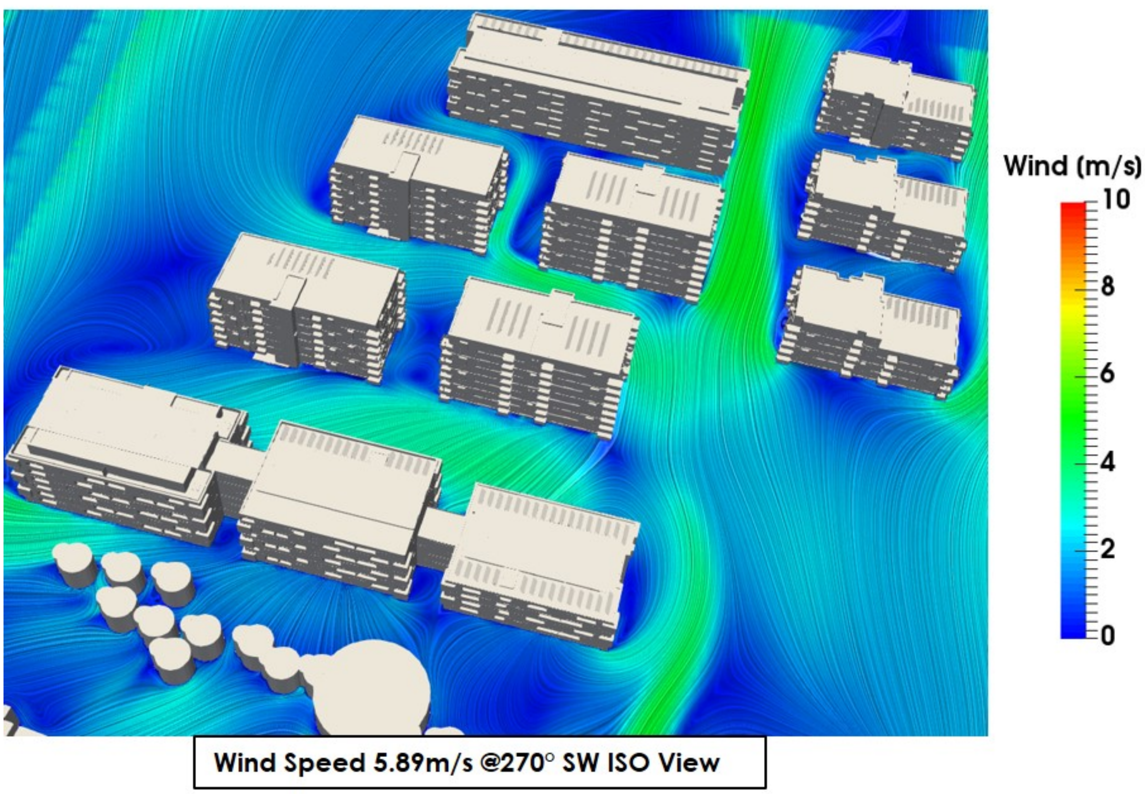
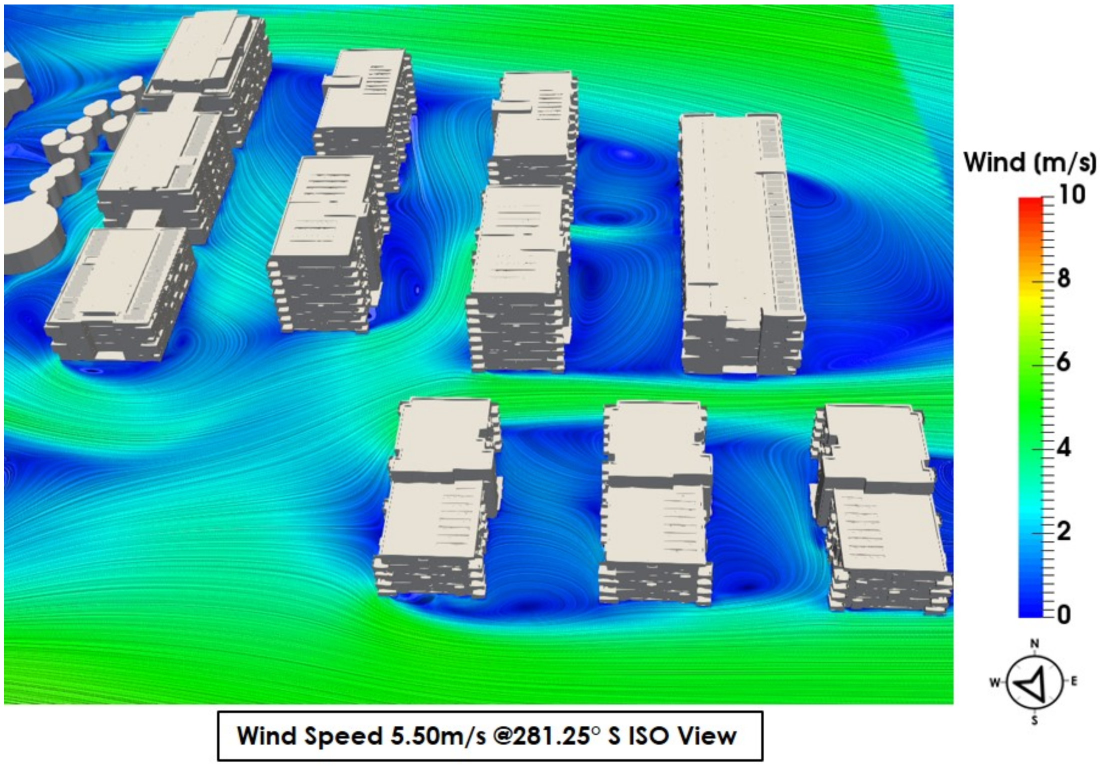


Figure 6.8: Wind Speed Results at 1.5m Above Development Ground-Isometric View: 258.75°, 270°



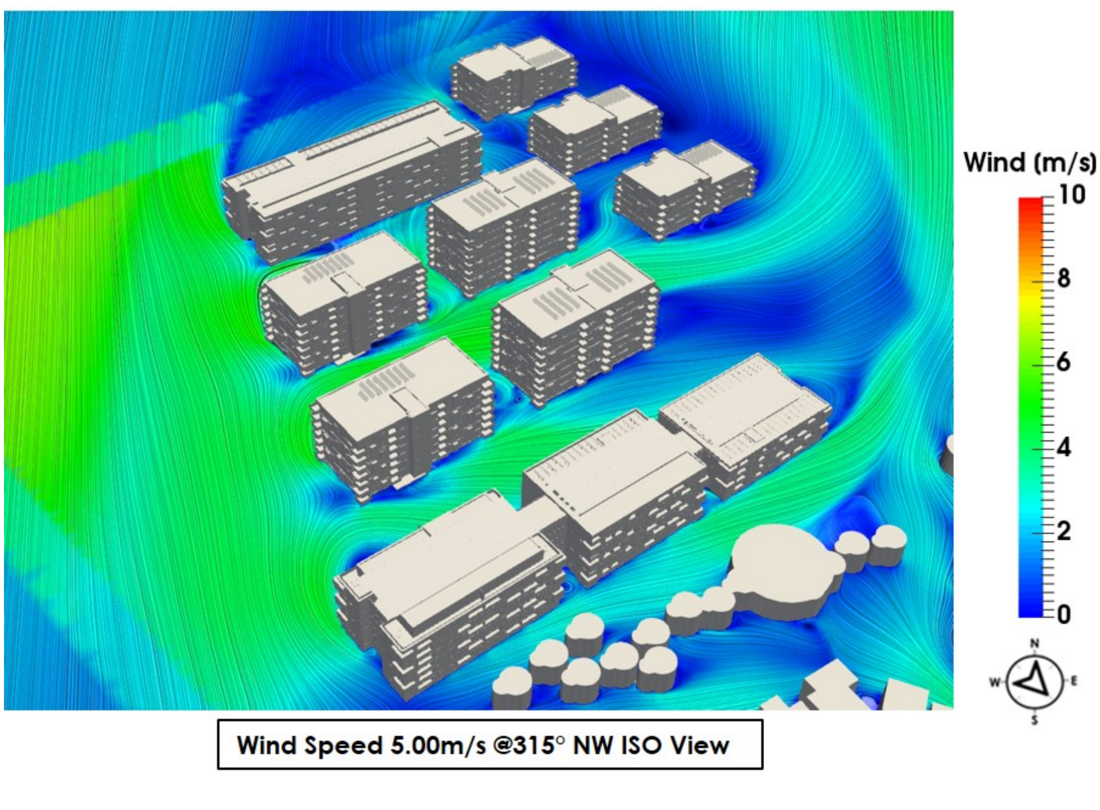


Figure 6.9: Wind Speed Results at 1.5m Above Development Ground-Isometric View: 281.25°, 315°

Flow Velocity Results - Balconies

Results of wind speeds and their circulations at balconies within the proposed development are presented in Figures 6.10 to 6.13 in order to assess wind flows at balconies within the proposed development. Wind flow speeds at balconies show to be at comfortable levels.

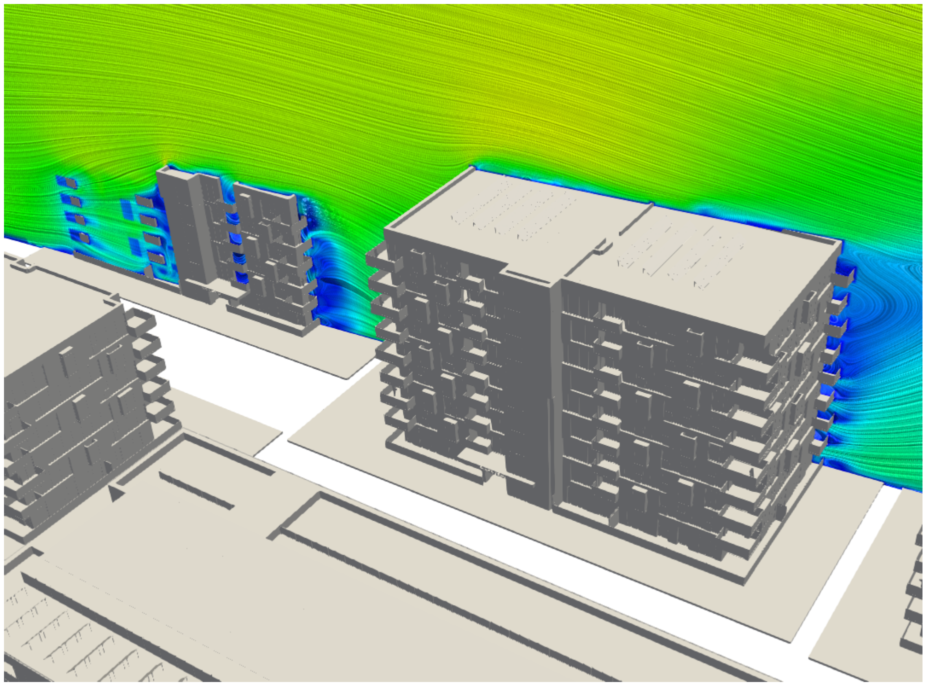


Figure 6.10: Balcony Wind Speed For 135°: Blocks 5 and 7

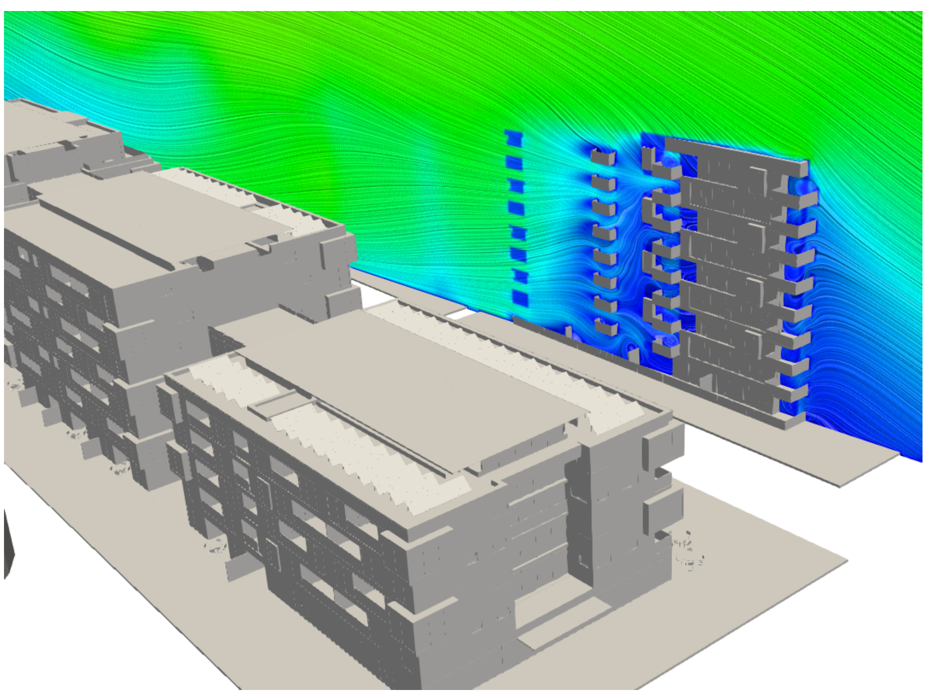


Figure 6.11: Balcony Wind Speed For 225°: Block 3

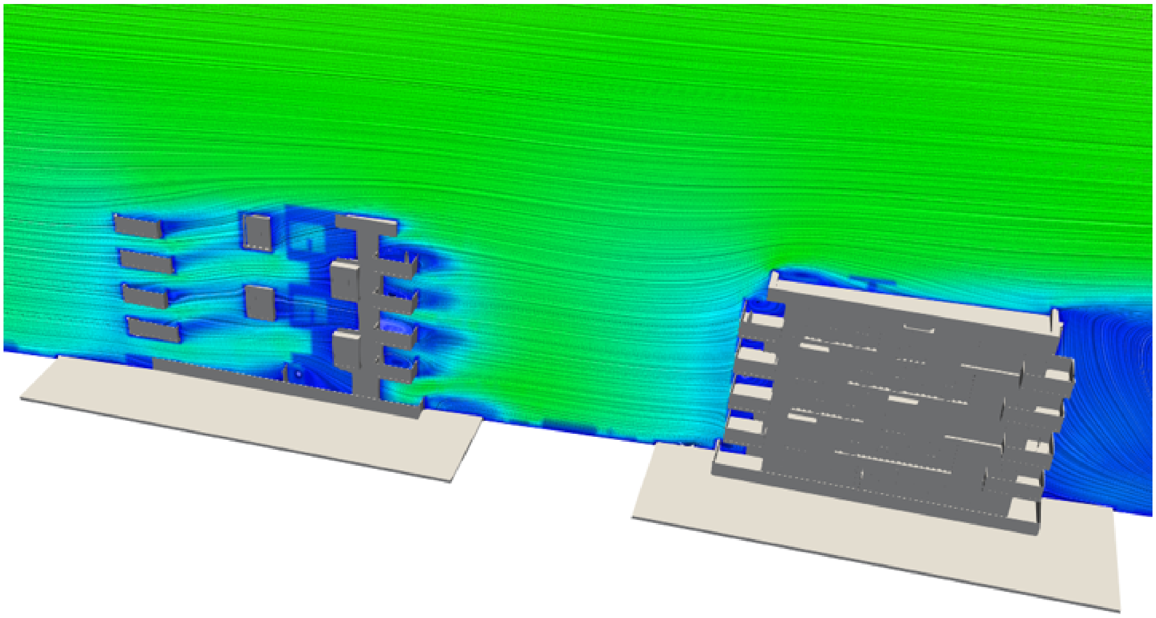


Figure 6.12: Balcony Wind Speed For 258.75°: Blocks 8 and 9

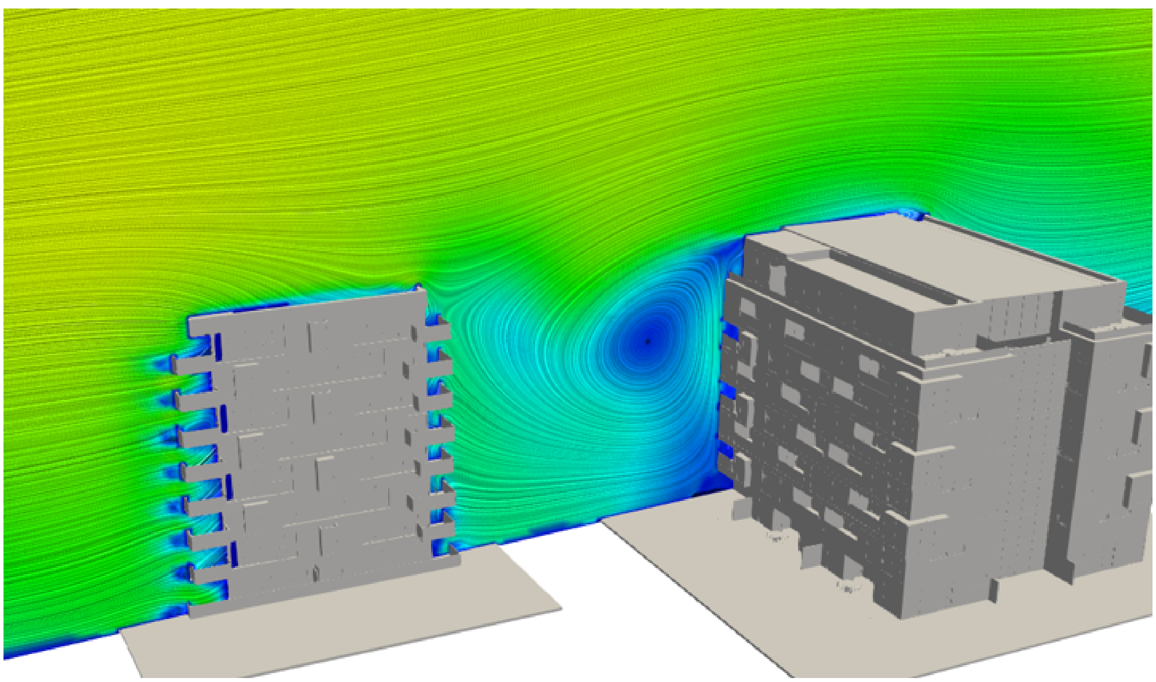


Figure 6.13: Balcony Wind Speed For 315°: Block 2

7. PEDESTRIAN COMFORT ASSESSMENT

7.1 Risk to Human Health-Discomfort Criteria

This section aims to identify areas of proposed St. Paul's Residential Development where the pedestrian safety and comfort could be compromised (in accordance with the Lawson Acceptance Criteria). Pedestrian comfort criteria are assessed at 1.5m above ground level level.

7.1.1 Discomfort Analysis

Figures 7.2 to 7.6 shows the Lawson comfort categories over the ground floor area around proposed St. Paul's Residential Development during its operational phase. In all cases, the scale used is set out in Figure 7.1.

Thus, depending on the wind direction, the suitability of the different areas are assessed using these maps. It can be seen from the results that the wind conditions range from "suitable for long term sitting" to "suitable for walking and strolling" and really rarely are only suitable for "business walking" or "unacceptable for pedestrian comfort".

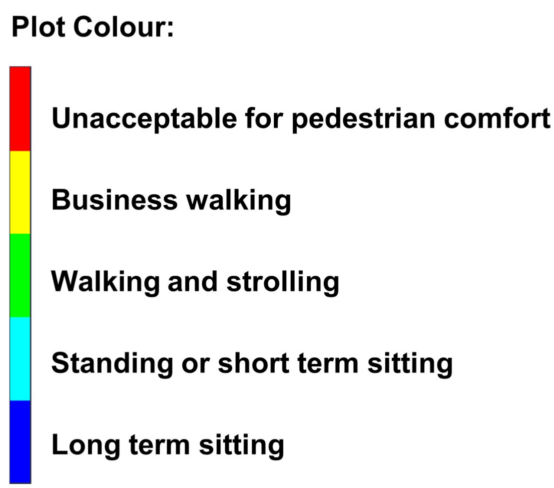
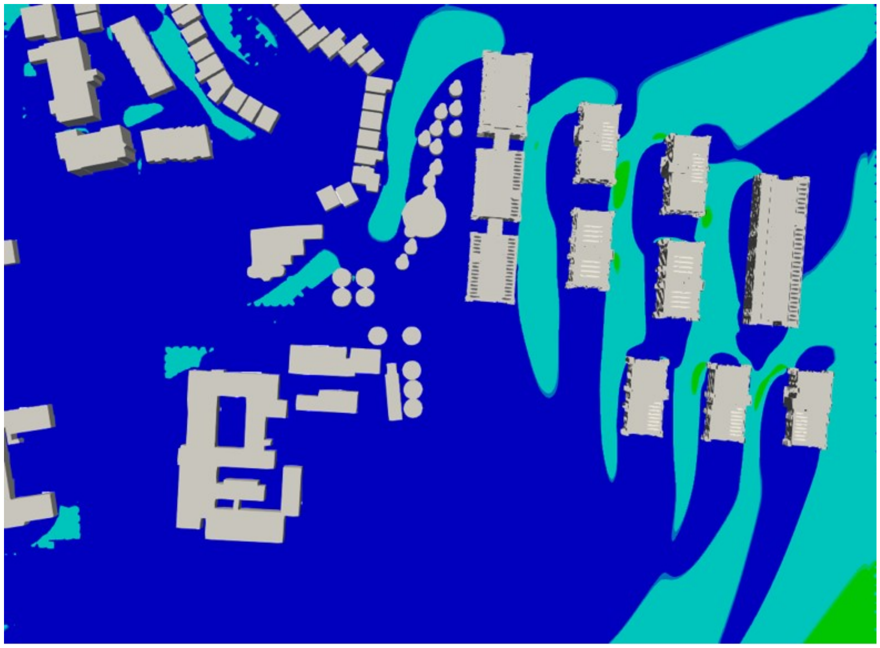
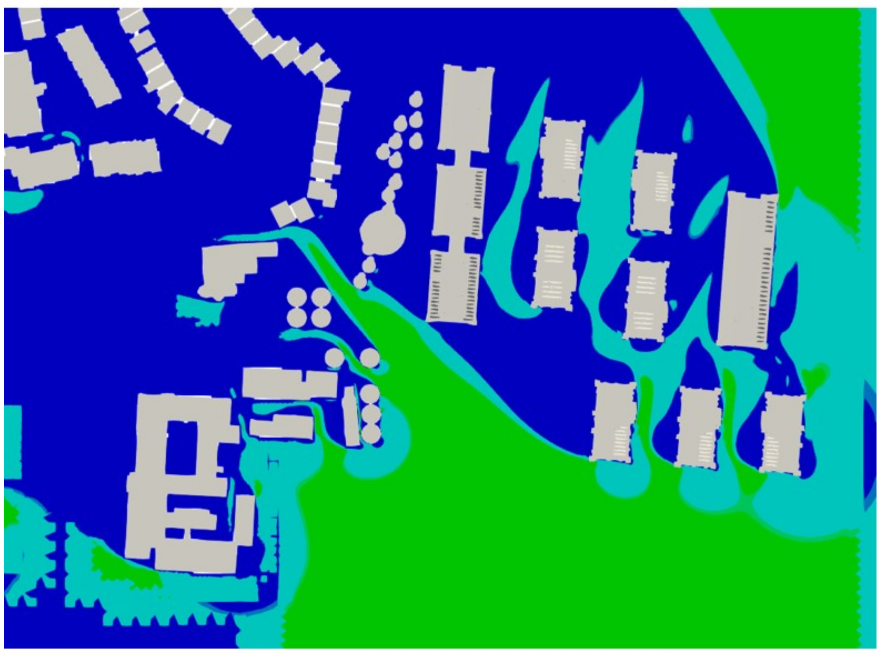


Figure 7.1: Lawson Comfort Categories



Lawson Discomfort Map For 4.17m/s @45°



Lawson Discomfort Map for 4.63m/s @135°

Plot Colour:

- Unacceptable for pedestrian comfort
- Business walking
- Walking and strolling
- Standing or short term sitting
- Long term sitting

Figure 7.2: Ground Floor - Lawson Discomfort Map - Cardinal Directions

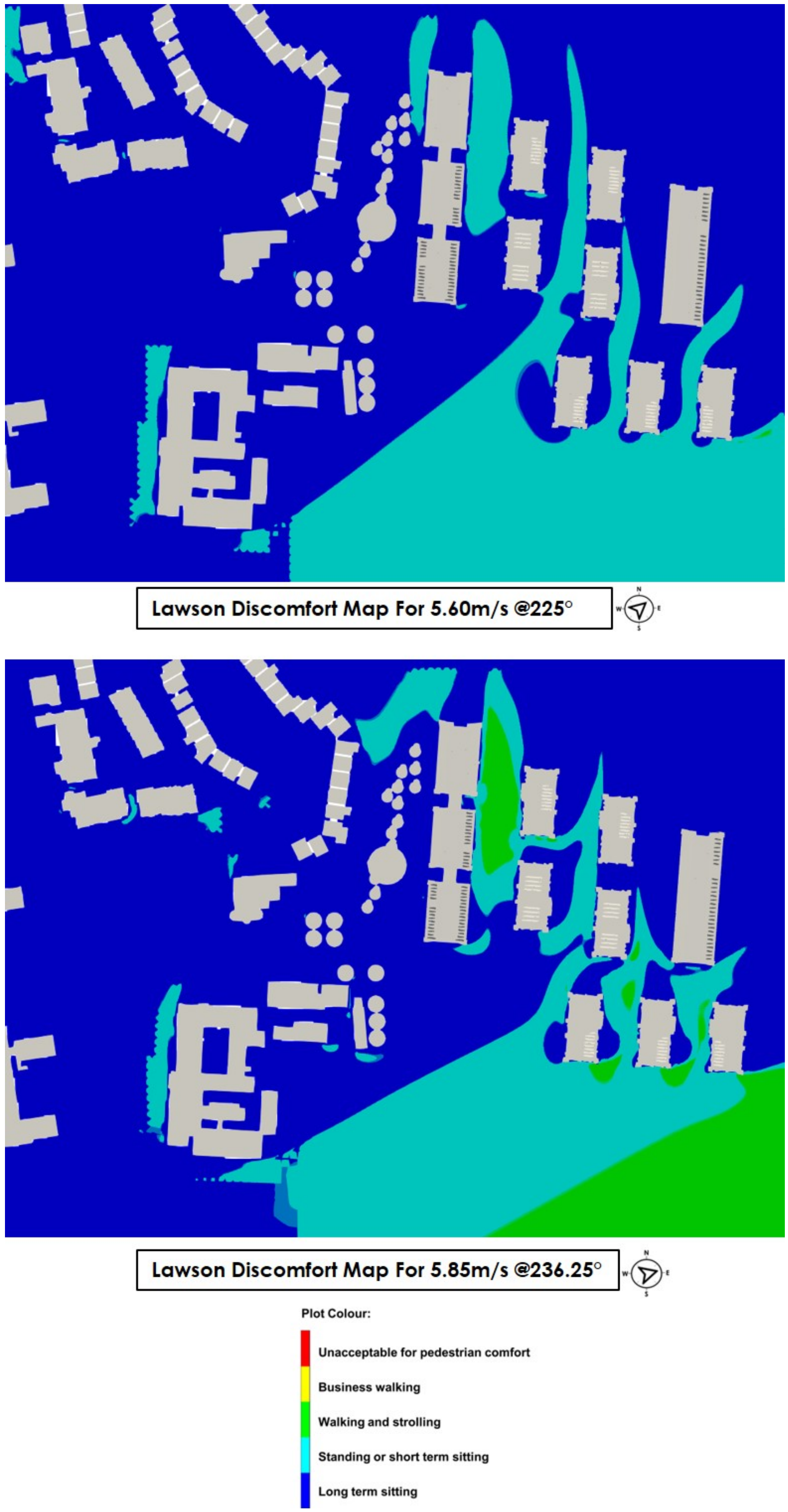


Figure 7.3: Ground Floor - Lawson Discomfort Map - Cardinal Directions

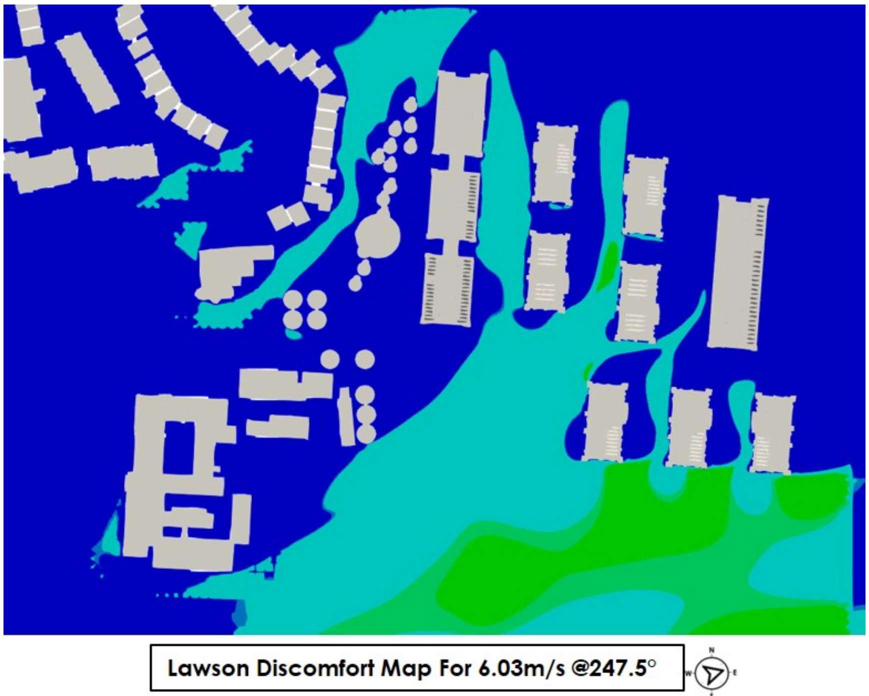


Figure 7.4: Ground Floor - Lawson Discomfort Map - Cardinal Directions

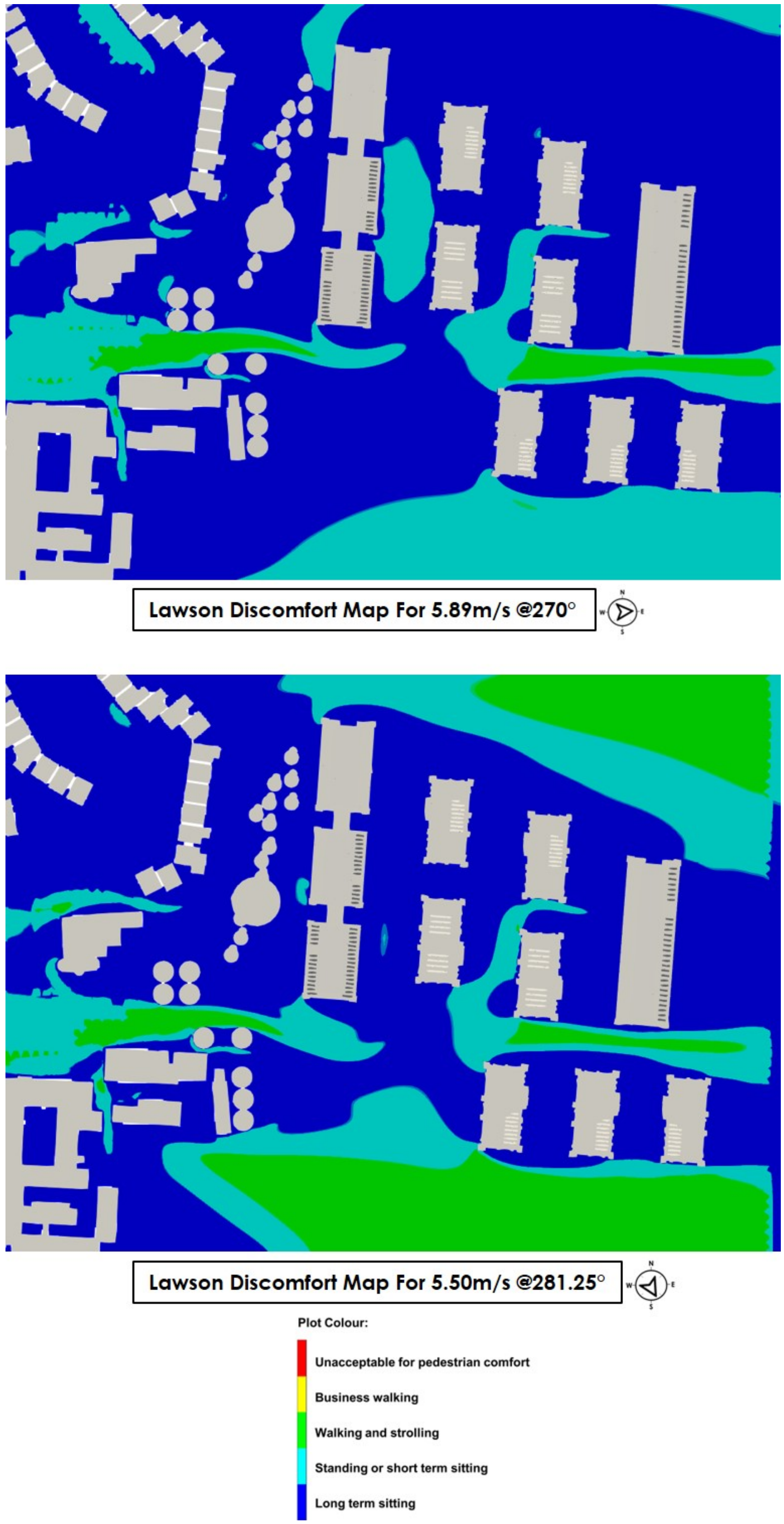


Figure 7.5: Ground Floor - Lawson Discomfort Map - Cardinal Directions

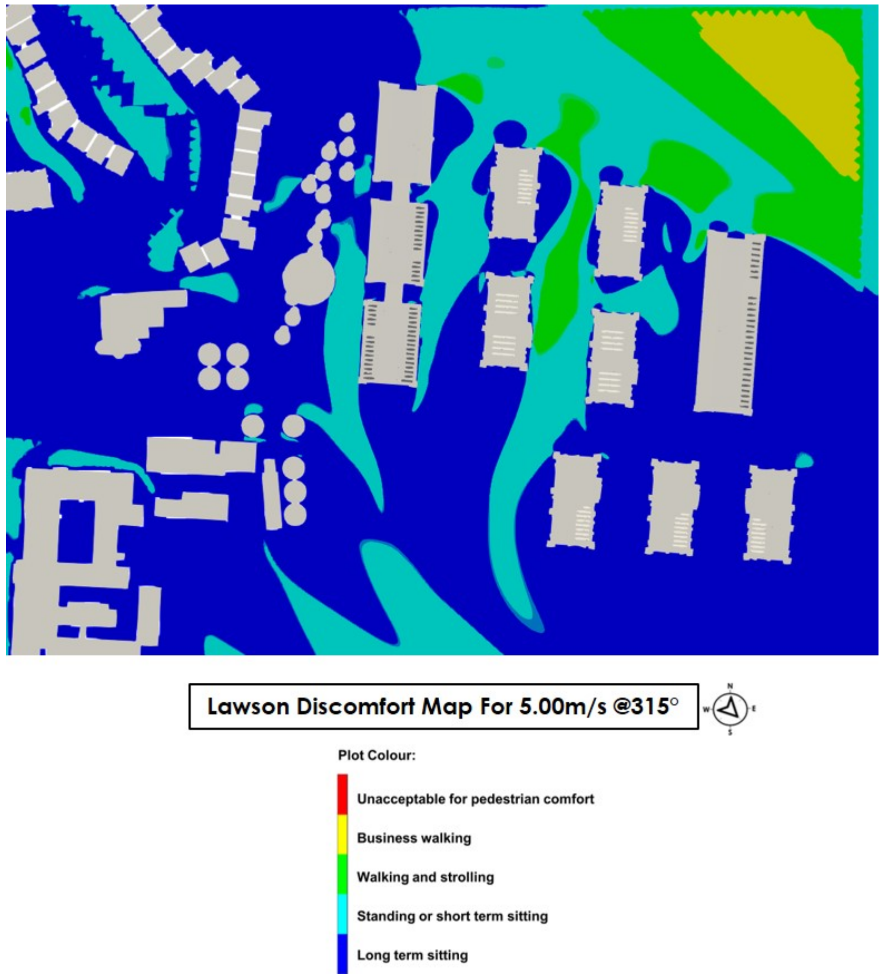


Figure 7.6: Ground Floor - Lawson Discomfort Map - Ordinal Directions

For the Lawson discomfort criteria, the onset of discomfort depends on the activity in which the individual is engaged and it is defined in terms of a mean hourly wind speed (or GEM) which is exceeded for 5% of the time. However, the results shown in these maps show that there are no critical area which are unacceptable for pedestrian comfort. Thus, the discomfort criteria is satisfied for all the different cases and in all directions.

Figures 7.8 below shows the areas where the measured wind speeds are potentially above 15 m/s in all directions. Figure 7.7 shows the scale used in this case. In all these cases, there is no or little risk of attaining critical wind levels in terms of distress.

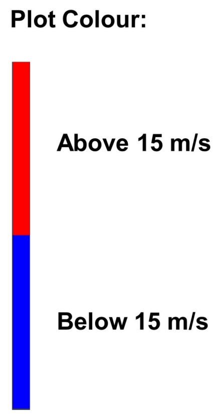


Figure 7.7: Lawson Distress Categories - Frail Person or Cyclist

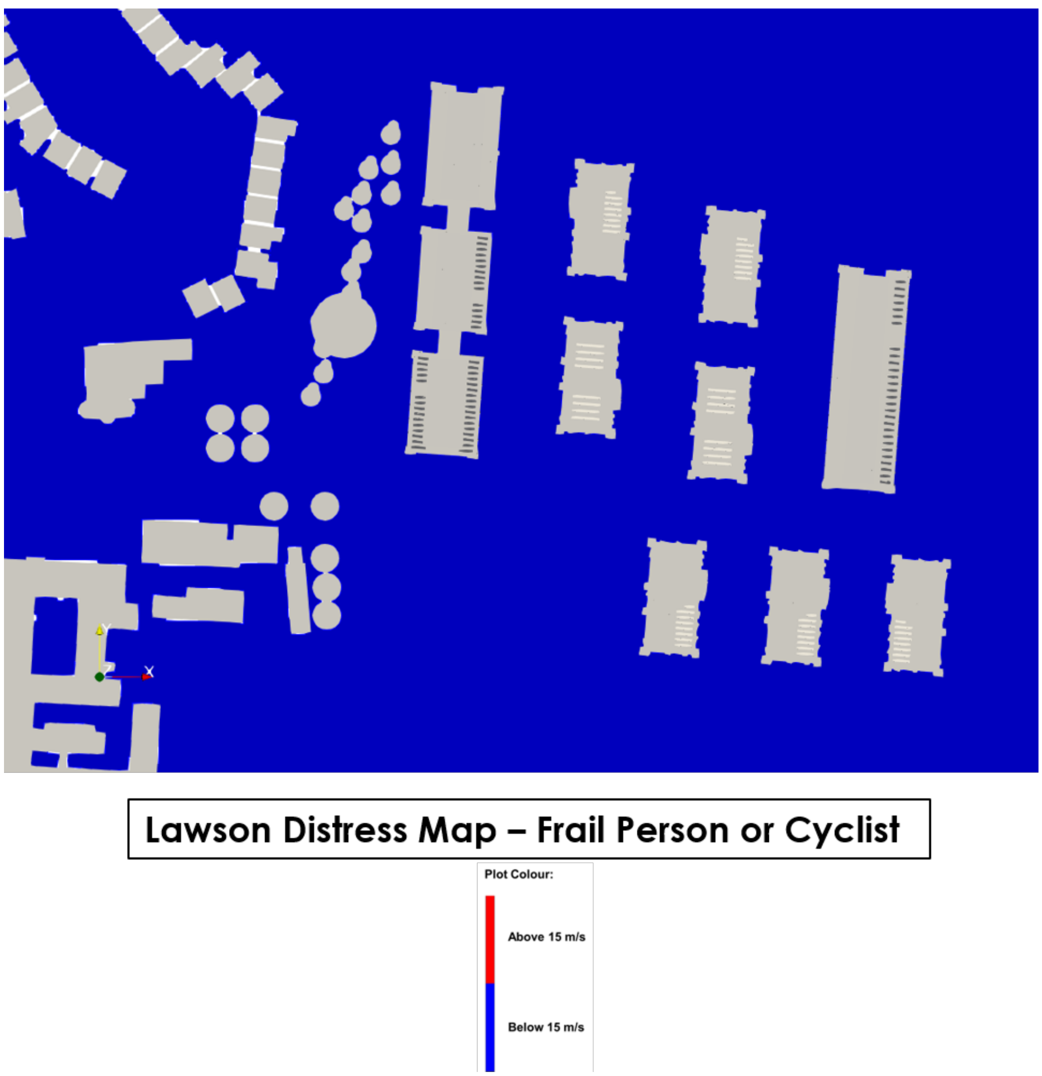


Figure 7.8: Ground Floor Level - Lawson Distress Map - Frail Person or Cyclist - All Directions

8. MITIGATION MEASURES

8.1 MITIGATION MEASURES

The proposed mitigation measures for this development is landscaping using tree plantings as shown in Figure 8.3, which creates a further reduced vorticity, making it possible to reduce incoming velocities, thus further reducing wind impacts on the buildings, public spaces or pedestrian paths. Small particles randomly distributed within an area are normally used in numerical modelling to model trees, as shown in Figure 8.1. These introduce a pressure drop in the model and therefore causes the wind to reduce its speed when passing through the trees, as expected in reality. The CFD plot shown in Figure 8.2 demonstrate this effect.

This proposed tree planting mitigation measures are needed to be implemented within the development, particularly at the south, south-west, and west corners of the development, and also to mitigate some funnelling effects as noticed in Figure 7.5 of the development.

Figure 8.3 shows the proposed mitigation measures for the Development.

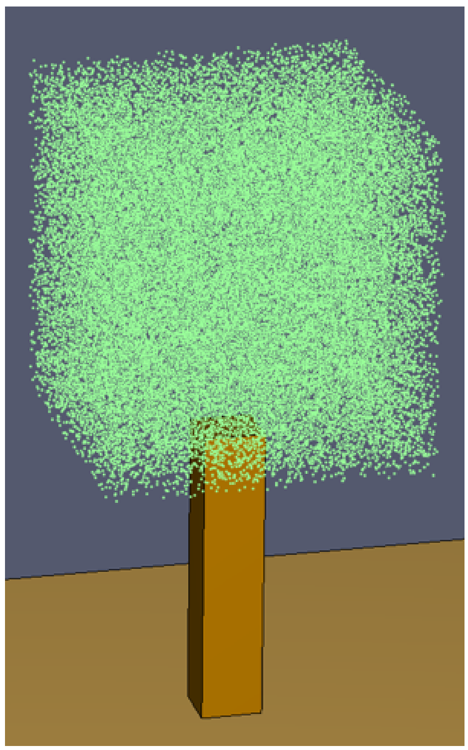


Figure 8.1: CFD Modelleling of a tree

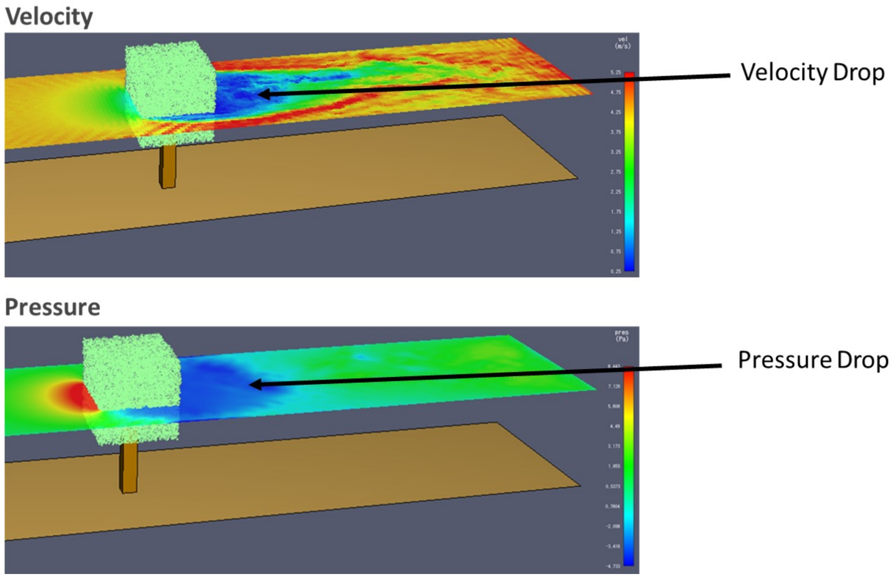


Figure 8.2: Generic Result of Wind Impacting on a Tree

Figure 8.3: Proposed Mitigation Measures for Development

9. CONCLUSIONS

9.1 CONCLUSIONS and COMMENTS ON MICROCLIMATE STUDY

This report presents the CFD modelling assumptions and results of wind microclimate Modelling of the proposed St. Paul's Residential Development, Raheny, Dublin 5.

Results of this are utilized by the design team to configure the optimal layout for proposed St. Paul's Residential Development for the aim of achieving a high-quality environment for the scope of use intended for each areas/building (i.e. comfortable and pleasant for potential pedestrian) and do not introduce any critical wind impact on the surrounding areas and on the existing buildings (in accordance with the Lawson Acceptance Criteria).

1. **EXISTING RECEIVING ENVIRONMENT SUMMARY:**
   The wind desktop study of the existing receiving environment showed that:

   - The wind profile was built using the annual average of meteorology data collected at Dublin Airport Weather Station. In particular, the local wind climate was determined from historical meteorological data recorded 10 m above ground level at Dublin Airport.
     18 different scenarios were selected in order to take into consideration all the different relevant wind directions. In particular, a total of 18 compass directions on the wind rose are selected. For each direction, the reference wind speed is set to the 5% exceedance wind speed for that direction, i.e. the wind speed that is exceeded for over 5% of the time whenever that wind direction occurs.

   - The site is surrounded by landscaping. This has a beneficial effect in mitigating the impact of the incoming wind. The prevailing wind directions for the site are identified in the West, West South-West and South-East with magnitude of approximately 6m/s. In all these directions the development benefits from a good shielding through landscaping. The trees are beneficial in calming the incoming wind and deviating it.

   - Areas where velocities can be potentially higher and some funnelling/recirculation effects experienced have been highlighted. However, these are mitigated by the proposed mitigation measures, with particular attention to the corners of the buildings.

2. **POTENTIAL AND CUMULATIVE IMPACT OF THE PROPOSED DEVELOPMENT SUMMARY:**
   Microclimate model assessment of proposed St. Paul's Residential Development and it's environment was performed utilizing a CFD (Computational Fluid Dynamics) methodology. 9 worst case wind scenarios are selected for presentation in this report, as these scenarios and directions showed to be the most relevant wind speeds and cardinal directions.

   CFD modelled results of the development scheme showed that:

   - The proposed St. Paul's Residential Development will produce a high quality environment that is attractive and comfortable for pedestrians of all categories.

- The Surrounding environment and development properly shields all paths/walkways around and within the development. Pedestrian footpaths are always successfully shielded and comfortable.

- The development communal open spaces are generally suitable for long term sitting, short term sitting, standing, walking and strolling activities.

- Shielding conditions in the South-West, South-East, North-East and North-West areas are always acceptable.

- Balconies within the development are comfortable for pedestrian sitting, standing, walking and strolling.

- The proposed development does not impact or give rise to negative or critical wind speed profiles at the nearby adjacent roads, or nearby buildings.

- Pedestrian comfort assessment, performed according to the Lawson criteria, identified the areas that are suitable for different pedestrian activities in order to guarantee pedestrian comfort. In terms of distress, no critical conditions were found for "Frail persons or cyclists" in the surrounding of the development. No critical conditions have been found for members of the "General Public".

- During St. Paul's Residential Development construction phase the predicted impacts are classified as negligible.

Therefore, the CFD study carried out has shown that under the assumed wind conditions typically occurring within Dublin for the past 30 years:

- **The development is designed to be a high-quality environment for the scope of use intended of each areas/building (i.e. comfortable and pleasant for potential pedestrian), and,**

- **The development does not introduce any critical impact on the surrounding buildings, or nearby adjacent roads.**

10. REFERENCES

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