United Kingdom Holocaust Memorial and Learning Centre

Wind Microclimate Report
December 2018

The Secretary of State for Housing Communities and Local Government

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1 INTRODUCTION

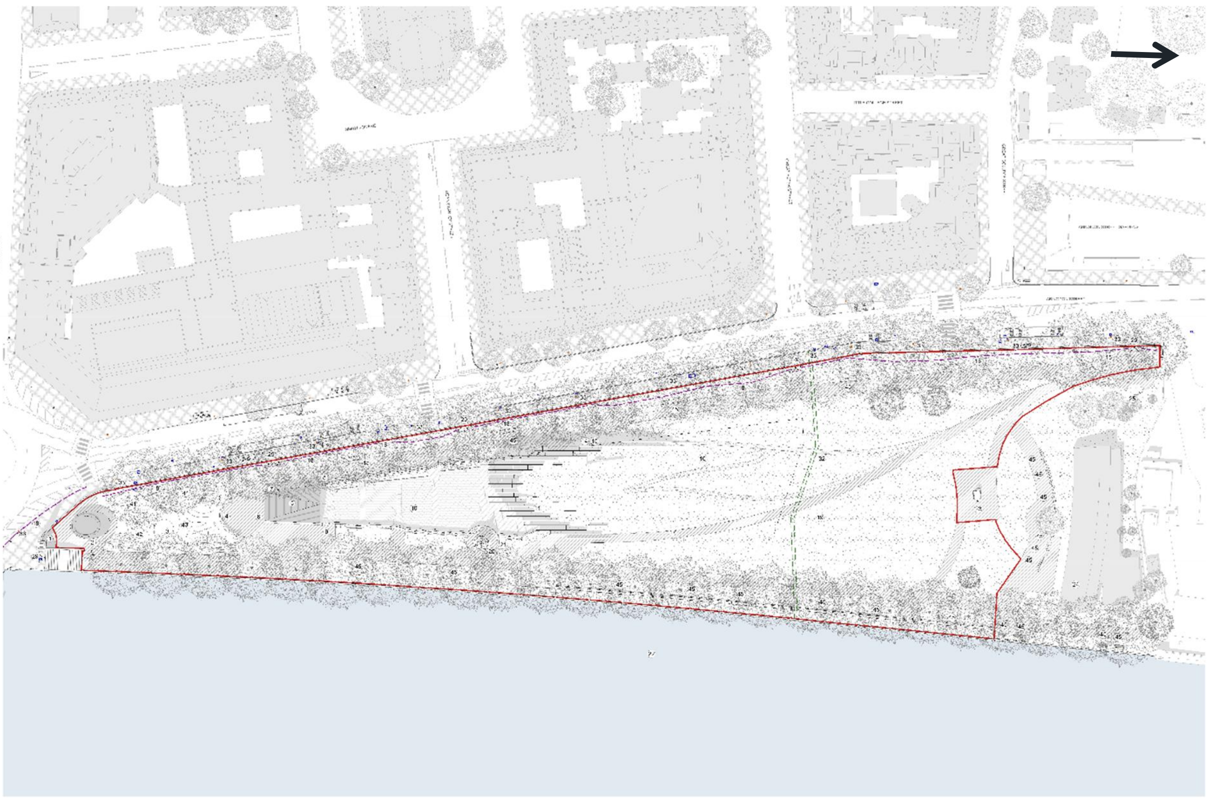
WSP have commissioned by Ministry of Housing, Communities and Local Government to undertake a wind environment assessment of the proposed development for the UK Holocaust Memorial and Learning Centre in London. This report summarises the results of the wind assessment at pedestrian level and terraces within the site and its surroundings. Full details of the results of the assessment are provided in Appendices 1 to 4.

The site is located it within the Victoria Tower Garden in Westminster. It is bounded by the Palace of Westminster to the North, by the Abingdon Street to the West, by the Lambeth Bridge to the South and the river to the east. The surrounding area is mainly characterized by mid-rise commercial buildings with some government accommodations.

The proposed development includes the installation of the United Kingdom Holocaust Memorial and Learning Centre including excavation to provide a basement and basement mezzanine for the learning centre (Class D1); erection of a single storey entrance pavilion; re-provision of the Horseferry playground and refreshments kiosk (Class A1); improvements to the Buxton Memorial and repositioning of the Spicer Memorial; new hard and soft landscaping and lighting and all ancillary and associated works.

Figure 1 below shows the location of plan of the site highlighted within the red boundary line.

Figure 1 Site plan



This report assesses the effect of the proposed development on the local microclimate against best practice guidelines for pedestrian comfort and safety. These two aspects are associated with pedestrian use of public open spaces and it is important to ensure that the design follows national good practice design guidelines developed to minimise associated negative effects.

Wind environment is defined as the wind flow experienced by people and the subsequent influence it has on their activities. It is concerned primarily with wind characteristics at pedestrian level. Other potential wind effects including wind loads, structural response and natural ventilation are not directly related to the wind environment at pedestrian level and therefore, have not been considered within this assessment.

2 LEGISLATIVE FRAMEWORK, POLICY CONTEXT AND GUIDANCE

2.1 LEGISLATIVE FRAMEWORK

There is no specific national legislation or planning policy guidance dealing with wind microclimate in terms of pedestrian comfort. However, the Lawson Criteria (2001) (Ref.1) are used to benchmark the pedestrian wind microclimate as they are well-established in the UK.

2.2 PLANNING POLICY

National

National Planning Policy Framework (2018)

The National Planning Policy Framework (Ref. 2) was published in July 2018 by the Department of Communities and Local Government (DCLG). The relevant paragraphs are as follow:

Paragraph 127 of the National Planning Policy Framework states that:

> *"Planning policies and decisions should ensure that developments:*
>
> *a) will function well and add to the overall quality of the area, not just for the short term but over the lifetime of the development;*
>
> *b) are visually attractive as a result of good architecture, layout and appropriate and effective landscaping;*
>
> *c) are sympathetic to local character and history, including the surrounding built environment and landscape setting, while not preventing or discouraging appropriate innovation or change (such as increased densities);*
>
> *d) establish or maintain a strong sense of place, using the arrangement of streets, spaces, building types and materials to create attractive, welcoming and distinctive places to live, work and visit;*

e) optimise the potential of the site to accommodate and sustain an appropriate amount and mix of development (including green and other public space) and support local facilities and transport networks; and

f) create places that are safe, inclusive and accessible and which promote health and well-being, with a high standard of amenity for existing and future users46; and where crime and disorder, and the fear of crime, do not undermine the quality of life or community cohesion and resilience."

Regional Planning Policy

The London Plan, March 2016

The London Plan (Ref.3) forms part of the development plan for Grater London. It places great importance on the creation and maintenance of a high-quality environment for London.

Policy 7.6 applies specifically in the relation to wind microclimate and states:

> *"Architecture should make a positive contribution to a coherent public realm, streetscape and wider cityscape. It should incorporate the highest quality materials and design appropriate to its context,"*

> *"' Building and structures should…Not cause unacceptable harm to the amenity of surroundings land and buildings, particularly residential buildings, in relation to privacy, overshadowing, wind and microclimate. This is particularly important for tall buildings."*

Draft New London Plan

The Draft New London Plan (Ref.4) is currently under consultation with the New London Plan due to be adopted in autumn 2019.

Paragraph 3.1.2 of Policy D1 London's form and characteristics states that:

> *"Creating a comfortable pedestrian environment with regard to levels of sunlight, shade, wind and shelter from precipitation is important."*

Policy D8 Tall Buildings: Environmental Impact goes on to state that:

"Wind, daylight, sunlight penetration and temperature conditions around building(s) and neighbourhood must be carefully considered and not compromise comfort and the enjoyment of open spaces, including water spaces, around the building.

Air movement affected by the building(s) should support the effective dispersion of pollutants, but not adversely affect street-level conditions.…"

Paragraph 3.8.5 of Policy D8 Tall Buildings states that:

"The middle of a tall building has an important effect on how much sky is visible from surrounding streets and buildings, as well as on wind flow, privacy and the amount of sunlight and shadowing there is on the public realm and by surrounding properties."

Local Planning Policy

London Borough of Westminster – City Plan 2019-2014

The City Plans (Ref. 5) sets out an ambitious strategy to make Westminster one of the best places to live, work and play. It is currently under consultation until the 21st December 2018. Policy 40 Design Criteria J states the following in relation with the wind microclimate:

"Negative local impacts must be avoided, or robustly mitigated, including on daylight, outlook, air quality, wind turbulence and other micro-climatic effects, reflected glare, aviation, navigation, telecommunications interference and character and amenity of surrounding buildings."

2.3 GUIDANCE

The Lawson Criteria

The Lawson Criteria (Ref.1) are well-established in the UK for quantifying wind conditions in relation to build developments and, although not a UK 'standard', the criteria are recognised by local authorities as a suitable benchmark for wind assessments. The Lawson Criteria have been adopted for this assessment.

Planning Practice Guidance 6th March 2014

The Department for Communities and Local Government (DCLG) web based Planning Practice Guidance resource (Ref. 6) includes a section on design and sets out how a building's size and shape can affect the wind microclimate. The section addressing Design - How should buildings and the spaces between them be considered? 'Consider scale' Paragraph O26, states that:

"Account should be taken of local climatic conditions, including daylight and sunlight, wind, temperature and frost pockets."

Sustainable Design and Construction Supplementary Planning Guidance (April 2014)

Section 2.3.1 Site Layout and Building Design, Key Guidance Areas of Chapter 2: Resource Management (Ref. 7) states that:

> *"The design of the site and building layout, footprint, scale and height of buildings as well as the location of land uses should consider: "New design of development… the potential to take advantage of natural system such as wind, sun and shading…;"*

Section 2.3.6 Site Layout of Chapter 2: Resource Management states that:

> *"Developers should ensure the layout of their site and buildings maximises the opportunities provided by natural systems, such as light and wind and the potential for sustainable drainage systems."*

Section 2.3.7 Micro-climate of Chapter 2: Resource Management states that:

> *"Large buildings have the ability to alter their local environment and affect the micro-climate. For example, not only can particularly tall buildings cast a long shadow effecting building several streets away, they can influence how wind travels across a site, potentially making it unpleasant at ground level or limiting the potential to naturally ventilate buildings. One way to assess the impact of a large building on the comfort of the street environment is the Lawson Comfort Criteria. This tool sets out a scale for assessing the suitability of wind conditions in the urban environment based upon threshold values of wind speed and frequency of occurrence. It sets out a range of pedestrian activities from sitting through to crossing the road and for each activity defines a wind speed and frequency of occurrence. Where a proposed development is significantly taller that it's surrounding environment, developers should carry out an assessment of its potential impact on the conditions at ground level, and ensure the resulting design of the development provides suitable conditions for the intended uses."*

Historic England Advice Note 4, Tall Buildings (2015)

The Guidance on Tall Buildings (Ref. 8) updates previous guidance by English Heritage and the Commission for Architecture and Built Environment (CABE), produced in 2007. It seeks to guide people involved in planning for and designing tall buildings so that they may be delivered in a sustainable and successful way through the development plan and development management process.

> *4.7 "Planning applications for tall buildings are likely to require an environmental impact assessment (EIA), which would be expected to address matters in respect of both the proposed building and its cumulative impact, including: …*
>
> *e. Other relevant environmental issues, particularly sustainability and environmental performance, eg the street level wind environment"*
>
> *4.10 "…Consideration of the impact on the local environment is also important, including microclimate, overshadowing, night-time appearance, light pollution, vehicle movements, the environment and amenity of those in the vicinity of the building, and the impact on the pedestrian experience."*

3 URBAN WIND EFFECTS

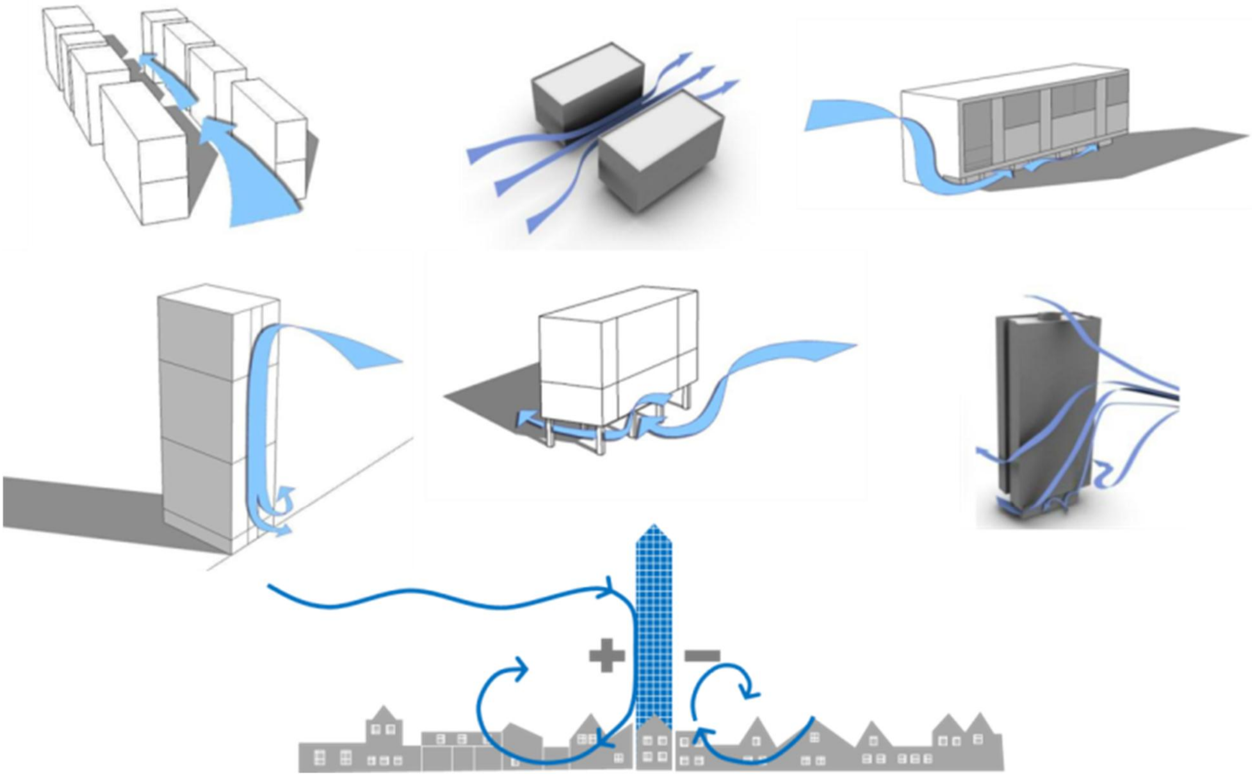
Buildings and terrain affect the speed and direction of wind flows. Over a ground surface of uniform roughness, the wind speed increases with height. In an urban context wind speeds at pedestrian level are generally low compared with upper-level wind speeds. However taller buildings can affect wind speeds in areas near the ground due to downwash flows and other local wind effects caused by buildings.

The anticipation of the likely wind conditions resulting from new developments are important considerations in the context of pedestrian comfort and the safe use of the public realm. While it is not always practical to design out all the risks associated with the wind environment, it is possible to provide local mitigation to minimise risk or discomfort where required. Potential negative effects on pedestrian safety and comfort include:

- A significant increase in wind speeds that puts the safety of pedestrians at risk.
- Localised zones of acceleration that result in pedestrian discomfort. These effects will vary according to the intended use for each area. For example, an area designated primarily as a pedestrian circulation route should aim for a wind condition suitable for strolling or leisure walking. Similarly, wind conditions at building entrances should be within the comfort range for people standing. An area designed to function as an outdoor café should have a wind environment which is suitable for a more sedentary activity such as sitting.

- Adverse wind effects can result from large flanking facades facing the prevailing wind which can cause downwash effects. Buildings of high massing will also tend to create increased windiness around its corners extending to the opposite side from the wind direction, due to pressure differences. Narrow passageways at the ground level of a building can cause funnelling effect of wind which can be uncomfortable for users and passers-by. Figure 2 shows examples of generic wind effects from buildings.

Figure 2 Wind Effects due to various buildings configurations



4 METHODOLOGY

4.1 ASSESSMENT METHODOLOGY

A three-dimensional computer model of the proposed development and adjacent areas was constructed for the assessment which comprised the following scenarios:

1. Baseline: A quantified assessment of the existing wind environment at the site was used to establish the 'Baseline Scenario'.
2. Proposed Development: An assessment of the site with the proposed development surrounded by existing buildings in order to determine the effect of the 'Proposed Scenario'.

The method for the study combines the use of Computational Fluid Dynamics (CFD) to predict wind velocities and air flow patterns, with the use of wind data from the nearest suitable meteorological station and the recommended comfort and safety standards (Lawson Criteria). The extent of the model comprises the site and a surrounding context within a radius of approximately 500 metres. The study takes into account 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 as topography, ground roughness and nearby obstructions (buildings, bridges, etc.);
- Orientation of the buildings relative to the prevailing wind direction; and
- The pedestrian activity to be expected (sitting, standing, strolling and fast walking). It should be noted that effects on pedestrian comfort and safety are only considered externally to the building. No assessment has been made of the potential effects of the wind environment inside buildings as microclimate studies are only intended to address external conditions.

The results of the assessment are presented in the form of contours of the Lawson criteria at a plane 1.5m above the ground level. This reference height is industry standard to assess comfort and safety at pedestrian level.

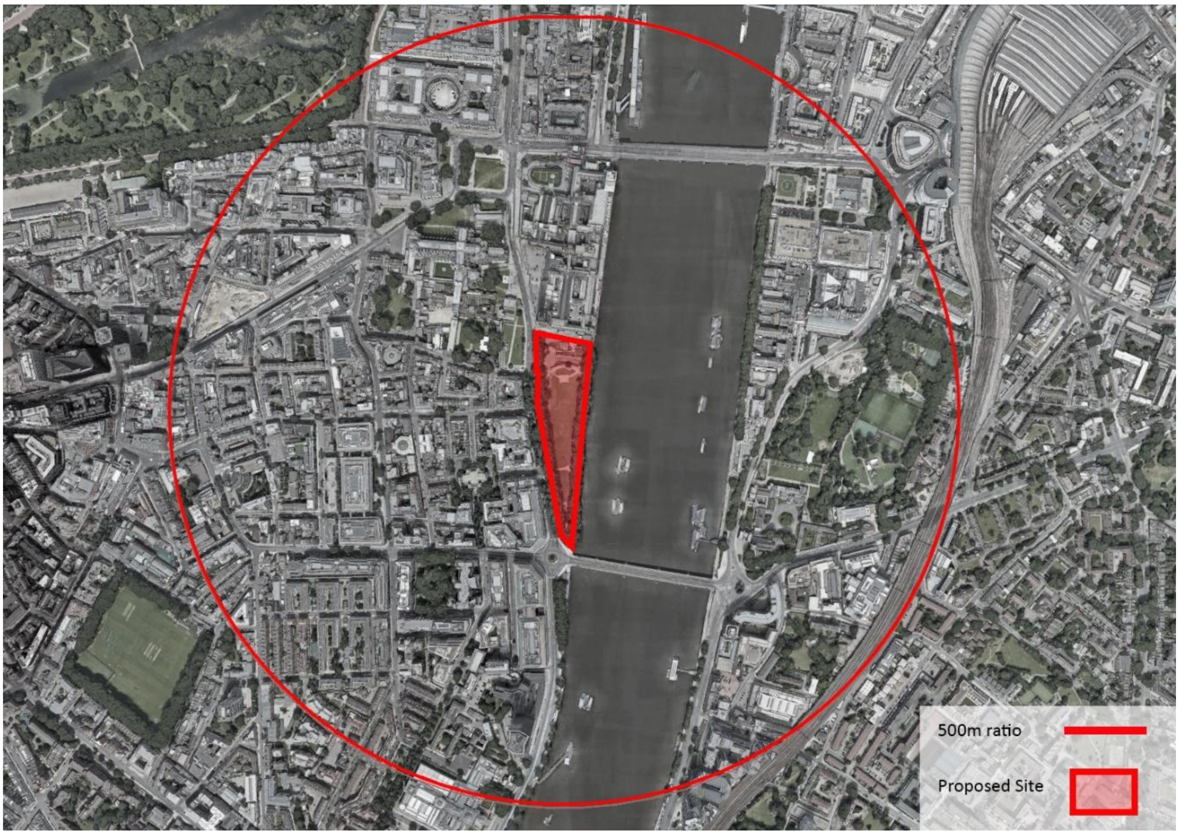
4.2 THE SITE AND STUDY AREA

The three-dimensional model constructed for the study includes the built area within a radius of approximately 500 metres from the site (Figure 3), to account for the influence of the surrounding context on the incoming winds as they reach the site. Buildings beyond this radius are only represented in the model if their distance from the site is less than 6 times their height, in line with best practice guidelines.

The model has been based on models and drawings provided by the architects and supplemented with information from the mapping database ArcGIS and available aerial photographic data for the area.

The model excludes both soft and hard landscaping (trees, street furniture etc.), which is a representation of the worst-case scenario since landscaping will generally improve the wind environment.

Figure 3 Extent of the wind study area



4.3 WIND CLIMATE ANALYSIS

Long term hourly wind data records from the Heathrow Airport Weather Centre (met station) were used to assess the local wind conditions surrounding the Site. The wind data from the met station have been adapted to the specific site at the UK Holocaust Memorial and Learning Centre Site through a detailed process described below and in Appendix 3. This process is industry standard and it is adopted for all wind assessments in the UK to account for differences in terrain roughness between the met station and the Site. For this region, the most frequent wind directions are the south-west quadrant blowing with the highest frequency. The summary of the wind data at the station can be found in Figures 4 and 5. The nomenclature adopted here and throughout this report assigns 0° to the north, and increases clockwise such that 90° is east and so on.

Figure 4. Frequency of wind speed by direction at the met station (Heathrow Airport Weather Centre)

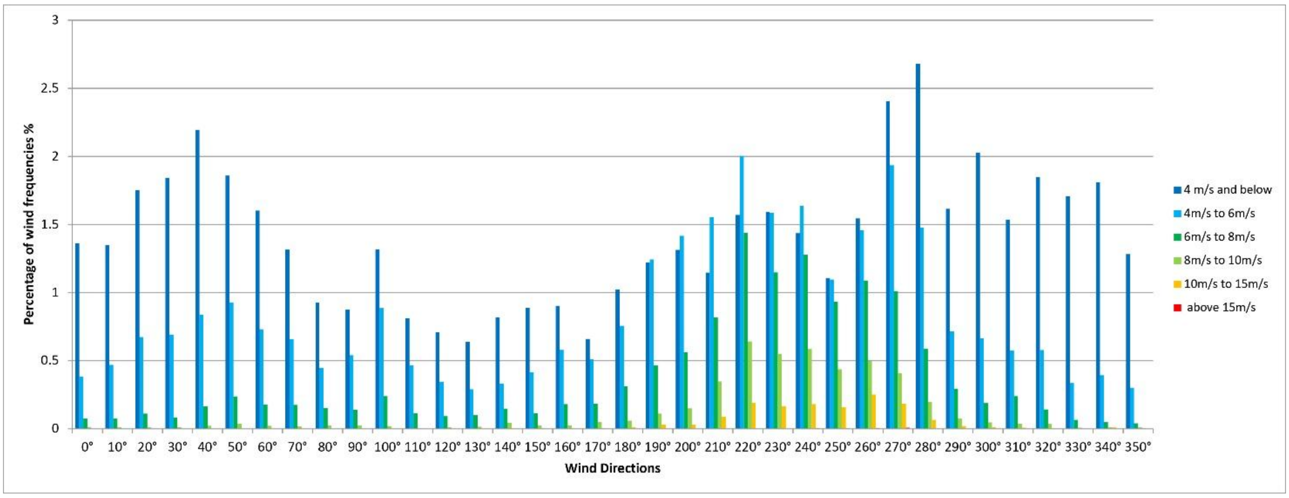
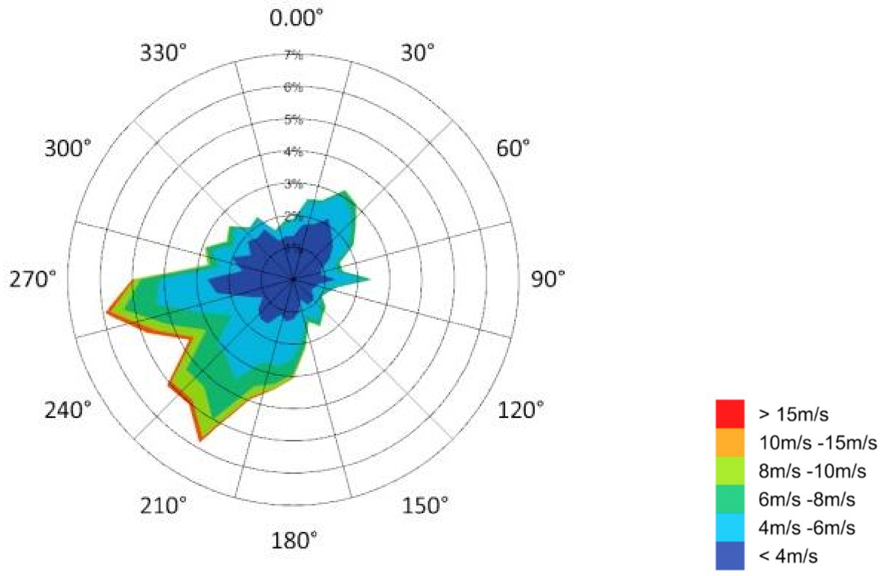


Figure 5. Wind Rose at Heathrow Airport Weather Centre



4.4 WIND DATA ADJUSTMENTS FOR SITE TERRAIN

In order to adapt the data from the weather station to the site and account for the difference in topography and terrain, a procedure to 'transpose' the wind data from the weather station onto the site was undertaken using the ESDU method (Ref. 9) which provides roughness factors and other terrain characteristics for the specific site. The methods in ESDU 82026 1 and 83045 2 allow for changes in terrain roughness to be taken into account when estimating hourly-mean wind speeds. The process provides values of the wind speed and turbulence properties of practical interest for strong winds over terrain with roughness changes including topographic effects. Further details of this process and output are given in Appendix 3.

Table 1 Adjusted Ratios per Wind Direction

Wind Direction	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
Wind speed ratios at 10m	0.80	0.90	0.69	0.55	0.86	0.79	0.80	0.97	0.58	0.72	0.89	0.76

The ratios estimated above are adopted throughout the different wind directions that are simulated around the 360° angles.

4.5 CFD SIMULATION AND INTERPRETATION OF DATA

Since the Lawson Criteria are based on frequency of occurrence of wind speeds rather than absolute wind speeds alone, a procedure to combine all wind speeds and directions is required. This process involves the following key steps:

- A reference wind speed from the meteorological station, generally measured at 10 metre height is used to generate a wind velocity profile taking into account the roughness of the site and its surroundings;
- Using the generated velocity profile, different wind directions are simulated around the 360° angles to represent all wind directions. The results are generated in the form of CFD contour plots at 1.5 m above the ground level and the magnitude of the wind velocity at each measurement point is extracted;
- A relative wind speed, or 'ratio', is derived from the simulated wind directions at each measurement point;
- The wind speed factor is scaled up by the hourly weather data measured at the meteorological station to derive the resulting wind speed experienced at each measurement point;
- A frequency distribution of all hourly wind speeds throughout the 15-year period is performed for each measurement point and a classification made based on the Lawson pedestrian safety and comfort criteria; and
- The resulting combined wind speed frequencies for the 15-year period integrated into a single combined wind contour map and classified by pedestrian activity. The results of this analysis for pedestrian safety and comfort are presented in Appendix 1.

4.6 CRITERIA FOR PEDESTRIAN SAFETY AND COMFORT

The Lawson Criteria London Docklands Development Method (LDDC) has been applied to determine the acceptability of wind conditions for pedestrian safety and comfort. The Lawson Criteria stipulates that for the comfort and safety assessment of wind effects, it is not only the velocity of wind that is considered but also the frequency of occurrence of these velocities. The frequency of occurrence is used as an indicator of the likely duration of wind speeds. The criteria provide ranges of acceptability to maintain pedestrian comfort for different activities and relate frequency of occurrence to the hourly average wind speed ranges. The criteria ranges are set out in Table 1 below.

Table 2 Lawson's Comfort Assessment Criteria (LDDC)

Comfort Category	Speeds not to be exceeded by more than 5% of the time	Description
Sitting	4 m/s	Light breezes desired for outdoor restaurants and seating areas where one can read a paper or comfortably sit for long periods.
Pedestrian Standing	6 m/s	Gentle breezes suitable for main building entrances, pick-up/drop-off points and bus stops.
Pedestrian Leisure Walk	8 m/s	Moderate breezes that would be appropriate for strolling along a city/town centre street, plaza or park.
Business Walk	10 m/s	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering.
Uncomfortable	>10 m/s	Winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended.

The Lawson LDDC method also identifies a safety criterion to identify those areas where someone could find walking difficult, or even stumble and fall. The Lawson criteria define threshold wind speeds not to be exceeded for more than 0.025% of the year. These are particularly strong winds that could cause people to have difficulties while walking and also stumble or fall. The safety criterion is set out in Table 2 below.

Table 3 Lawson's Safety Assessment Criteria (LDDC)

Safety Rating	Threshold Mean-hourly Wind Speed Exceeded Once Per Annum (0.025%)	Wind conditions as experienced by people
Unsuitable for the general public (S15)	>15 m/s	Less able and cyclists find conditions physically difficult.
Unsuitable for able-bodied (S20)	>20 m/s	Able-bodied persons find conditions difficult. Physically impossible to remain standing during gusts.

An additional category has been included to identify those areas that become windy and close to the S15 category but which does not exceed the criteria. This is used as a tool to assist in the design stages.

4.7 GENERAL TARGET WIND CONDITIONS

The wind assessment for each of these criteria has been tested taking into account the season and expected activity on the site based on the following general target wind conditions:

- Pedestrian thoroughfares: Leisure walking during windiest season;
- Building entrances, bus stops, drop off areas: Standing throughout the year; and
- Outdoor amenity and seating areas: Sitting during the summer season.

4.8 ASSESSMENT CRITERIA

The assessment of significance refers to the Lawson Comfort Criteria. In order to determine the significance of the effect of the Development on the wind environment, an assessment of the change in magnitude between the baseline and conditions with the Development is made for each receptor. However, because the pedestrian use of the Site may change between the existing and proposed uses, the assessment should also be based upon the suitability of the pedestrian use according to the Lawson Criteria. Therefore, the methodology for determining the significance of impact follows the sequence below:

- Identify the sensitive receptors around the Site;
- Identify their current use and sensitivity of each receptor;
- Identify the magnitude of change between the baseline conditions and conditions with the Development;
- Assess each receptor's compliance with Lawson Criteria for their relevant proposed uses;
- Propose and assess mitigation measures, if required.

4.9 SENSITIVE RECEPTORS

Sensitive receptors for the wind assessment are all pedestrian circulation routes, building entrances and leisure open areas within the site and in neighbouring adjacent areas. Specifically, the receptors identified for this assessment are shown in Figure 6 and listed in Table 4.

Figure 6 Sensitive Receptors

Table 4 Sensitive Receptors

Receptor Number	Location Type	Intended Pedestrian Use
1-56	Building Entrance / Pedestrian Circulation	Standing / Leisure Walking
57-59	Roads or Parking	Car Park
60-65	Amenity Space	Sitting / Standing

4.10 MODELLING ASSUMPTIONS AND LIMITATIONS

The wind speeds on the site and surroundings have been calculated through Computational Fluid Dynamics (CFD). CFD is a widely recognised method for modelling airflows both, internal and external, and as computer power develops, it increasingly improves its applicability.

CFD as a tool for pedestrian wind modelling is fairly well validated against wind tunnel tests and real-world data and is often considered advantageous due to the sophisticated visualisation and domain wide measurement characteristics. It has limitations in the same way that any other tool will have limitations. For example, CFD uses time-averaged data for its analysis which does not capture the effect of short term gusts, and it models turbulence rather than calculating it explicitly. However, the mean hourly analysis adopted in CFD provides a detailed wind distribution across the flow domain, to determine the suitability of open spaces with regards to pedestrian comfort, and provides a good indication of the areas of high speeds and wind acceleration to help identify suitable mitigation measures. Also, CFD is performed at full scale with a mesh made out of several millions of cells where speeds are calculated at each cell point of the mesh, allowing for a much larger amount of data to be used for the comfort and safety analyses. Technical assumptions of the CFD modelling are presented in Appendix 4.

The wind environment assessment focuses on conditions at pedestrian levels and terraces. Other potential wind effects such as wind loads, structural response and natural ventilation have not been considered within this assessment.

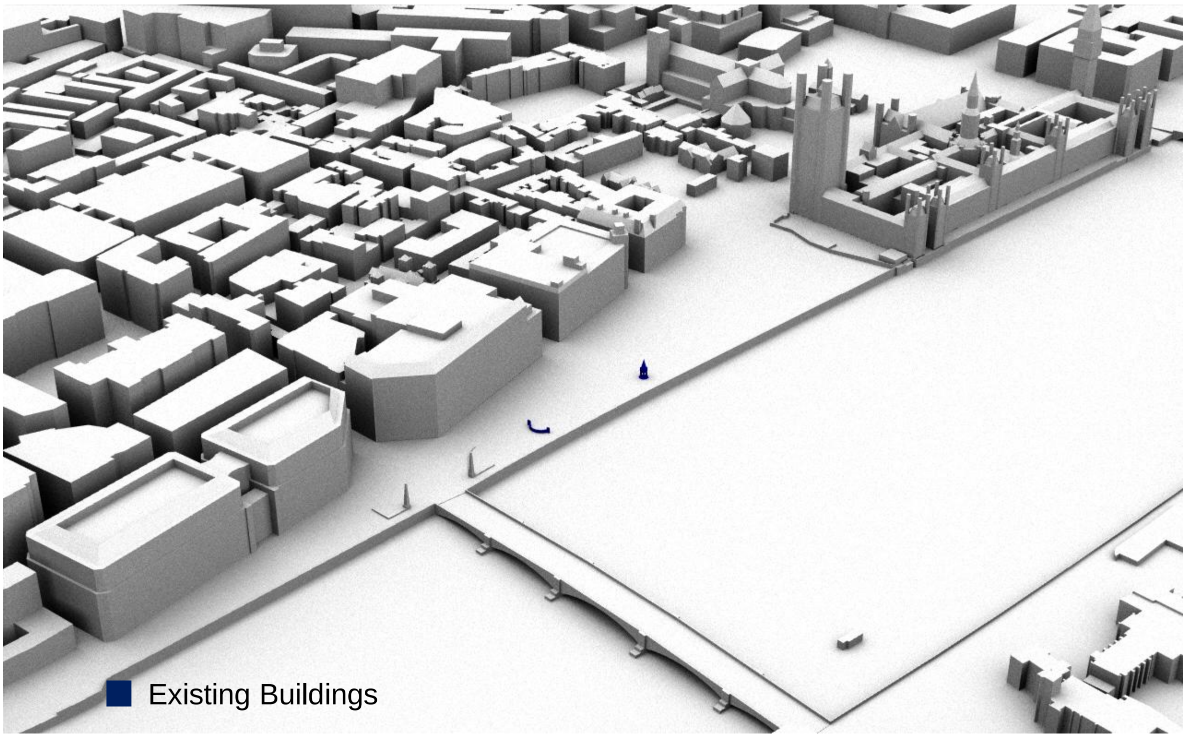
The Lawson criteria for pedestrian comfort focus on the effect of wind force on people's activities but do not factor in other environmental variables such as air temperature, solar radiation and relative humidity which also affect people's perception of comport. Overlaying all these climatic factors would be a complex process and Lawson's method presents the best available methodology for assessing wind effects in the built environment.

5 BASELINE CONDITIONS

5.1 MODEL OF THE EXISTING SITE

A 'Baseline Scenario' has been modelled to represent the conditions around the site prior to the introduction of the Proposed Development (Figure 7). The model of the existing buildings on site and the exiting surrounding buildings has been based on models provided by the Architects, and supplemented with information from the mapping database ArcGIS and available aerial photographic data for the area. The results of the wind environment assessment of the 'baseline scenario' are presented in the form of CFD contour plots in Appendices 1 and 2.

Figure 7 “3D” Model of the Baseline Scenario



5.2 PEDESTRIAN COMFORT ASSESSMENT - BASELINE CONDITION

The results of the baseline assessment indicate that the existing wind environment of the site is generally suitable for the intended pedestrian activities. The area is largely suitable for sitting and standing throughout the site indicating relatively calm wind conditions in the baseline scenario. The results of pedestrian comfort assessment for Baseline Scenario have been presented in the form of contours plots in Appendix 1- Winter scenario (worse case).

The assessment of the baseline condition identifies some zones in the surrounding areas where wind speeds tend to accelerate, particularly in the winter months. There is an indication of windier conditions along the site (Receptors 1, 5, 9,11,13,14, 16, 17, 19, 23 and 24). These areas show localised suitability for leisure walking throughout the year. The rest of the receptors show suitability for sitting and standing.

5.3 PEDESTRIAN SAFETY ASSESSMENT - BASELINE CONDITION

In addition to the comfort assessment, an appraisal of wind effects during strong wind events has also been carried out. These are short term and infrequent strong winds which can affect pedestrian safety, particularly in areas close to roads, and pose other potential hazards. These safety criteria are defined in terms of strong winds which are infrequent but are exceeded for at least one wind event per year. They are prescribed to cover situations where people might have difficulty walking during winds occurring once a year. Appendix 1 presents the pedestrian safety assessment wind maps.

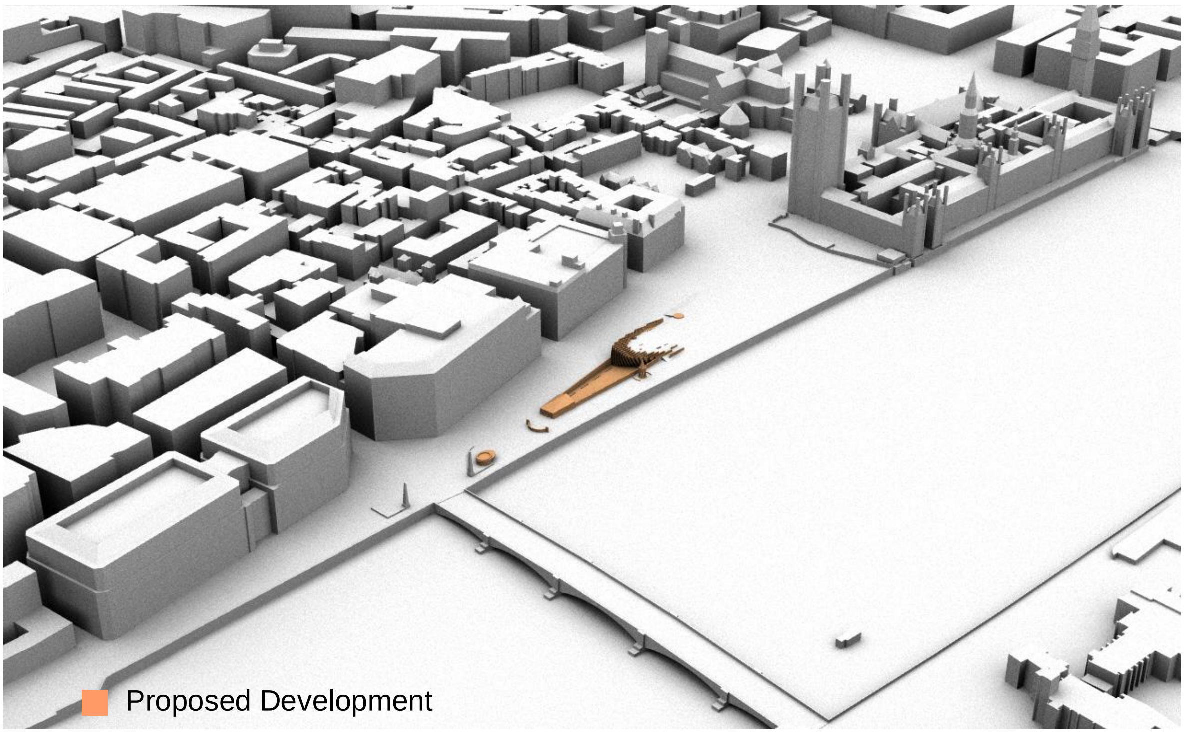
5.3.2 The results of the pedestrian safety assessment for the 'Baseline Scenario' have been presented in the form of frequency contour plots in (Appendix 1). The wind maps show the areas where wind speeds exceed 15 m/s for 0.025% of the year, in line with the Lawson criteria.

5.3.3 The results indicate that the wind environment within and outside the site in the baseline condition is within the recommended criteria for safety on the basis that the wind speeds are unlikely to exceed 15m/s for 0.025% of the year, in line with the guidance. As mentioned above, high wind speeds are registered only within the site where receptors 11 and 16 exceed the recommended safety criteria, as illustrated in the wind plots in (Appendix 1).

5.4 THE PROPOSED SCENARIO

In order to assess the effect of the Proposed Development, the proposed scheme was inserted into the CFD model to represent the 'Proposed Scenario'. The geometry, position and massing of the proposed development has been based on three-dimensional models and drawings provided by the architects. The model of the 'Proposed Scenario' was simulated under the same wind conditions as the 'Baseline Scenario' to enable a direct comparison. The results of the proposed scenario are presented in Appendices 1 and 2.

Figure 8. 3D Model of the Proposed Scenario



5.5 EFFECT OF THE PROPOSED DEVELOPMENT ON PEDESTRIAN COMFORT

The results of the assessment with the proposed scheme in place indicate that most areas remain suitable for sitting and standing with some areas shifting from leisure walking in the baseline scenario to standing and sitting such as areas within the site (receptors 1, 5, 7, 9, 11, 14, 16, 17, 19, 23 and 24). The additional massing introduced by the proposed development, compared to the existing building creates some wind deceleration in some areas of the site. This is an improvement and a beneficial effect of the proposed development on the local wind environment in this area. Additionally, the wind comfort assessment results of the proposed building show that all the amenity spaces proposed are suitable for the intended use throughout the year.

The results of the wind assessment for the winter season show that the wind conditions at highest point on the slope are mainly suitable for sitting and standing with a few areas with wind acceleration at the edge of the slope between the fins (Receptor 13) showing suitability for leisure walking. This will require mitigation through landscape or a balustrade at the edge of the slope. However, in all cases the summer season are suitable for their intended use. (See wind comfort plots for summer in Appendix1).

5.6 EFFECT OF THE PROPOSED DEVELOPMENT ON PEDESTRIAN SAFETY

The safety criteria are defined in terms of strong winds which are infrequent but are exceeded for at least one wind event per year. They are prescribed to cover situations where people might have difficulty walking during winds occurring once a year.

The results of the assessment with the proposed scheme in place indicate that all areas remain within the safety thresholds. There is an area of increased windiness showing a small warning area at the edge of the highest slope between the fins (Receptor 13). This is consistent with the comfort assessment and therefore, mitigation is recommended in this area to improve wind conditions, which is discussed in the next section. The results of the pedestrian safety are presented in Appendix 1.

6 MITIGATION

The wind results discussed in this study are based on a model without the effect of trees or landscape features, either proposed or existing trees, which is a representation of the worst case. Both existing trees in the surrounding area and the proposed trees within the site will provide further improvement of the wind environment as they filter the incoming wind reducing the speeds locally, especially during periods when trees are in full foliage.

The area which will most benefit from mitigation are small areas at the edge of the highest slope between the fins (Receptor 13). It is expected that landscape features and evergreen tree planting or fence in this area will improve the wind conditions to bring conditions within the safety criteria.

7 CONCLUSIONS

This report assesses the effect of the proposed development on the local microclimate against best practice guidelines for pedestrian comfort and safety.

The widely applied wind environment criteria for pedestrian comfort and safety developed by T.V. Lawson (Lawson, 2001) from Bristol University have been used in this study. This method is comparable with international guidance.

Pedestrian comfort – Baseline Scenario

The assessment of the baseline condition identifies some zones in the surrounding areas where wind speeds tend to accelerate, particularly in the winter months. There is an indication of windier conditions along the site (Receptors 1, 5, 9,11,13,14, 16, 17, 19, 23 and 24). These areas show localised suitability for leisure walking throughout the year. The rest of the receptors show suitability for sitting and standing.

Pedestrian safety – Baseline Scenario

The results indicate that the wind environment within and outside the site in the baseline condition is within the recommended criteria for safety on the basis that the wind speeds are unlikely to exceed 15m/s for 0.025% of the year, in line with the guidance. As mentioned above, high wind speeds are registered only within the site where receptors 11 and 16 exceed the recommended safety criteria, as illustrated in the wind plots in (Appendix 1).

Pedestrian Comfort – Proposed Scenario

The results of the assessment with the proposed scheme in place indicate that most areas remain suitable for sitting and standing with some areas shifting from leisure walking in the baseline scenario to standing and sitting such as areas within the site (receptors 1, 5, 7, 9, 11, 14, 16, 17, 19, 23 and 24). The additional massing introduced by the proposed development, compared to the existing building creates some wind deceleration in some areas of the site. This is an improvement and a beneficial effect of the proposed development on the local wind environment in this area. Additionally, the wind comfort assessment results of the proposed building show that all the amenity spaces proposed are suitable for the intended use throughout the year.

The results of the wind assessment for the winter season show that the wind conditions at highest point on the slope are mainly suitable for sitting and standing with a few areas with wind acceleration at the edge of the slope between the fins (Receptor 13) showing suitability for leisure walking. This will require mitigation through landscape or a balustrade at the edge of the slope. However, in all cases the summer season are suitable for their intended use. (See wind comfort plots for summer in Appendix1).

Pedestrian safety – Proposed Scenario

The results of the assessment with the proposed scheme in place indicate that all areas remain within the safety thresholds. There is an area of increased windiness showing a small warning area at the edge of the highest slope between the fins (Receptor 13). This is consistent with the comfort assessment and therefore, mitigation is recommended in this area to improve wind conditions, which is discussed in the next section. The results of the pedestrian safety are presented in Appendix 1.

Mitigation

The area which will most benefit from mitigation are small areas at the edge of the highest slope between the fins (Receptor 13). It is expected that landscape features and evergreen tree planting or fence in this area will improve the wind conditions to bring conditions within the safety criteria.

8 LIMITATIONS AND ASSUMPTIONS

The models and calculations for the wind assessment have been based on the drawings and models of proposed and existing properties provided by the architects, and desk surveys of the Study Area.

This report is intended for the sole benefit of the parties named above, WSP shall not be liable for any use of the report for any reasons other than that for which the report was originally prepared and provided.

Due to the complexity of the geometry of the model and the requirement of CFD to define a flow domain which is a closed entity, the model has been simplified particularly around the fins where a hypothetical wall had to be placed between them in order to define a boundary between the external areas which are accounted for and the internal spaces which are not. It is therefore recommended that further studies around the stairs on the main entrance and ground level are carried out during detail design to further refine the results in this area.

9 REFERENCES

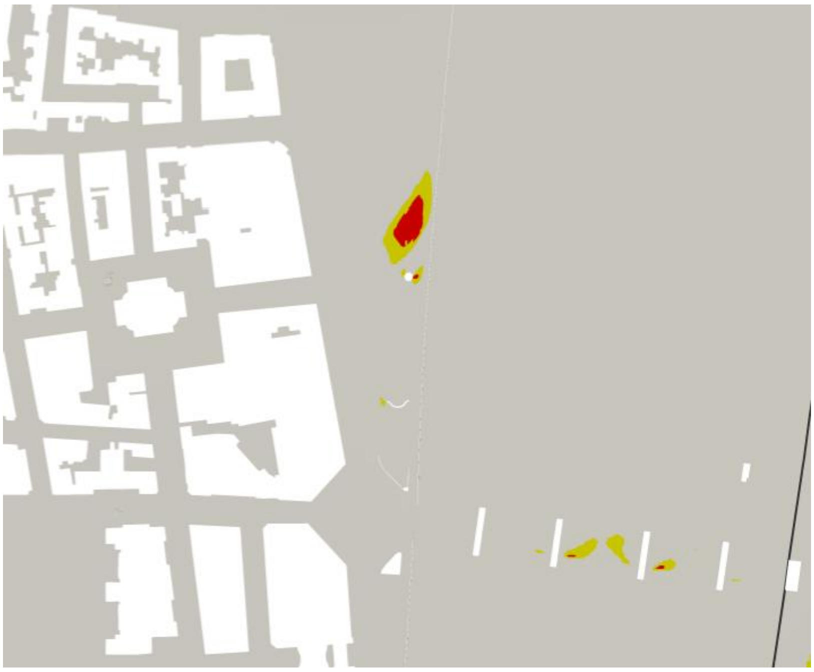
- T.V. Lawson (2001) Building Aerodynamics, Imperial College Press.
- Department of Communities and Local Government (2018), National Planning Policy Framework- available at: http://planningguidance.planningportal.gov.uk/
- Sustainable Design and Construction, Supplementary Planning Guidance (April 2014)
- Historic England Advice Note 4, Tall Buildings, 2015 Available online at https://historicengland.org.uk/images-books/publications/tall-buildings-advice-note-4/
- ESDU 84011 Wind speed profiles over terrain with roughness changes. Issued July 1984 With Amendments A to D April 1993, Re-issued February 2012

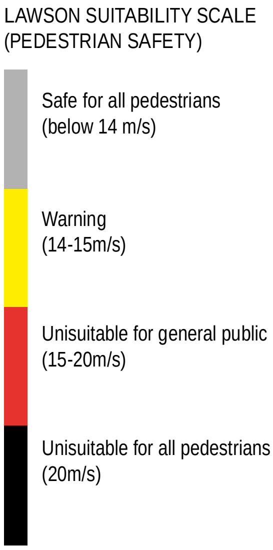
APPENDICES

Appendix 1 Contour Wind Plots - Pedestrian Safety Assessment

(Wind Speeds likely to be exceeded for 0.025% of the year)

Baseline Scenario



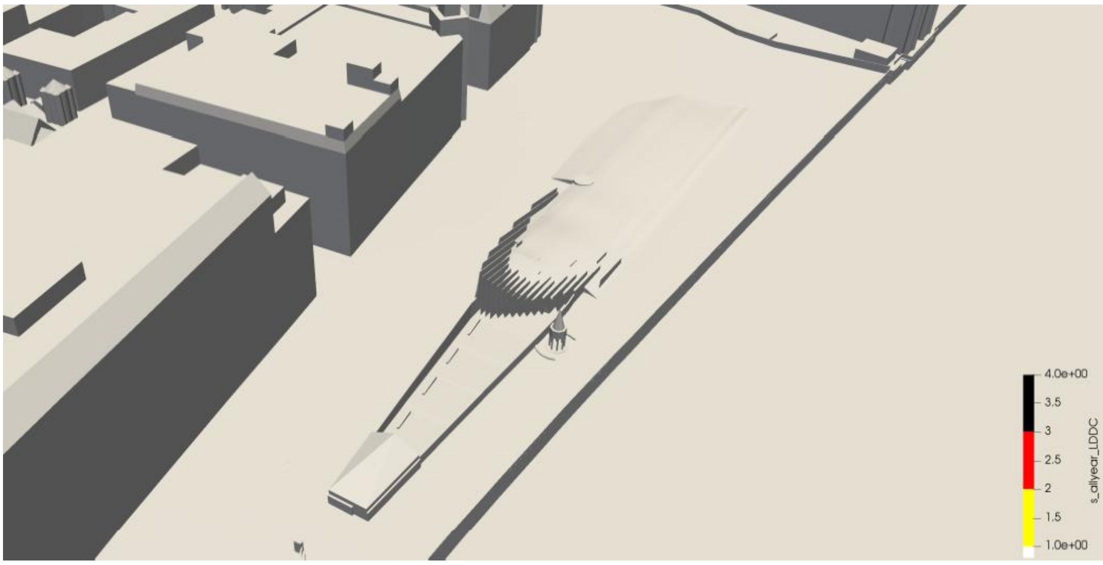


Proposed Scenario

Appendix 1 Contour Wind Plots - Pedestrian Safety Assessment

(Wind Speeds likely to be exceeded for 0.025% of the year)

Proposed Scenario



LAWSON SUITABILITY SCALE
(PEDESTRIAN SAFETY)

Safe for all pedestrians
(below 14 m/s)

Warning
(14-15m/s)

Unsuitable for general public
(15-20m/s)

Unsuitable for all pedestrians
(20m/s)

Contour Wind Plots - Seasonal Pedestrian Comfort Assessment

Winter

Baseline Scenario

Proposed Scenario

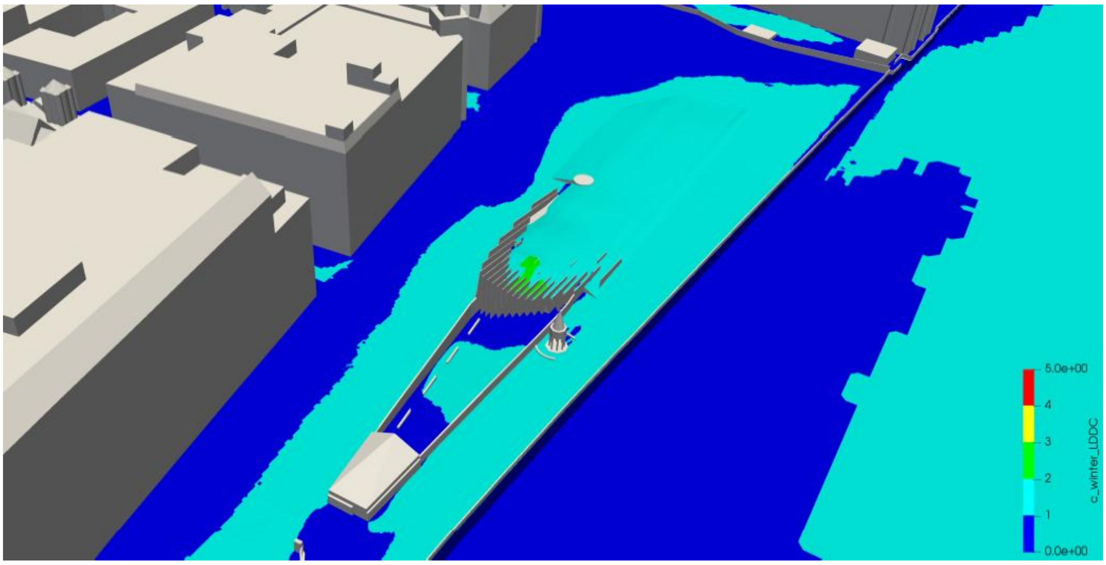
Lawson Comfort Criteria

- Sitting
- Standing
- Leisure Walking
- Business Walking
- Carpark / Roadway

Contour Wind Plots - Seasonal Pedestrian Comfort Assessment

Winter

Balconies



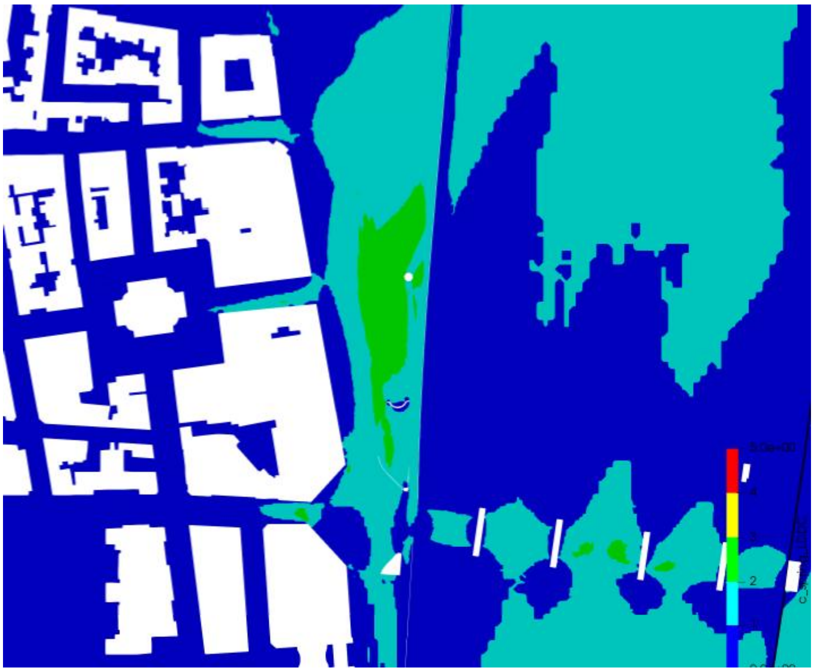
Lawson Comfort Criteria

- Sitting
- Standing
- Leisure Walking
- Business Walking
- Carpark / Roadway

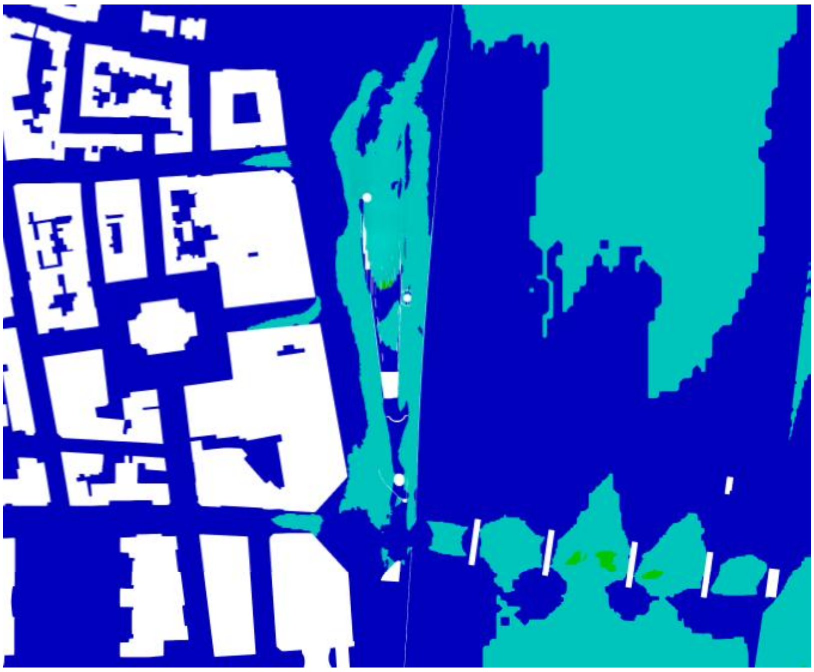
Contour Wind Plots - Seasonal Pedestrian Comfort Assessment

Spring

Baseline Scenario



Proposed Scenario



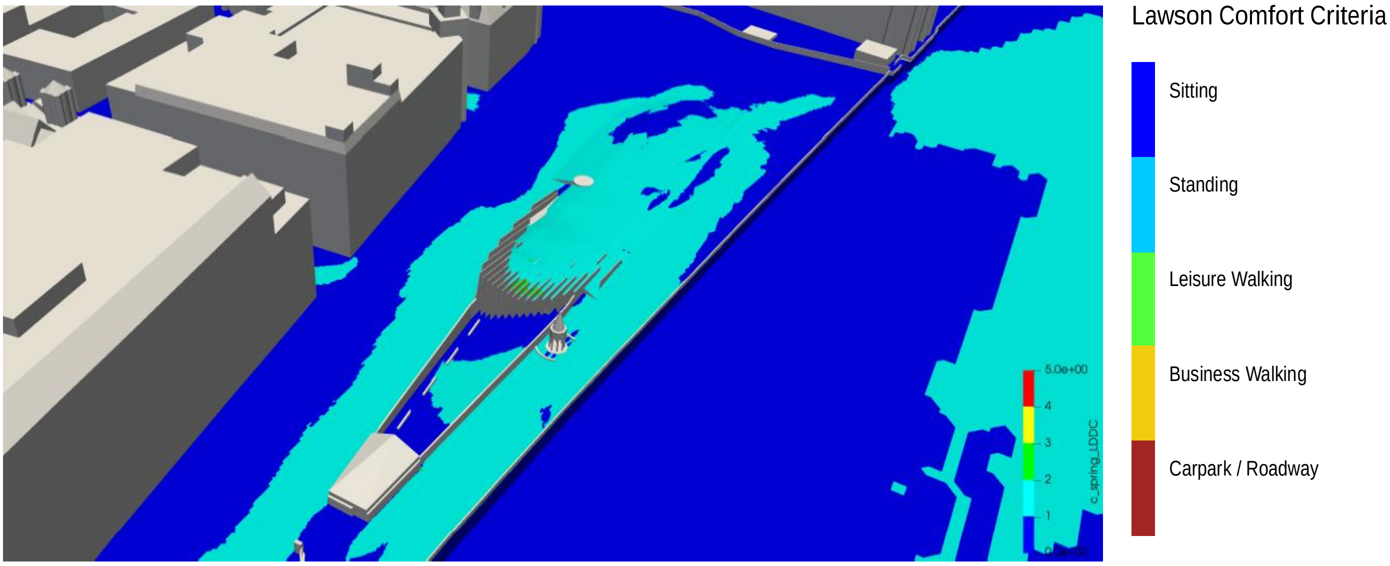
Lawson Comfort Criteria

- Sitting
- Standing
- Leisure Walking
- Business Walking
- Carpark / Roadway

Contour Wind Plots - Seasonal Pedestrian Comfort Assessment

Spring

Balconies

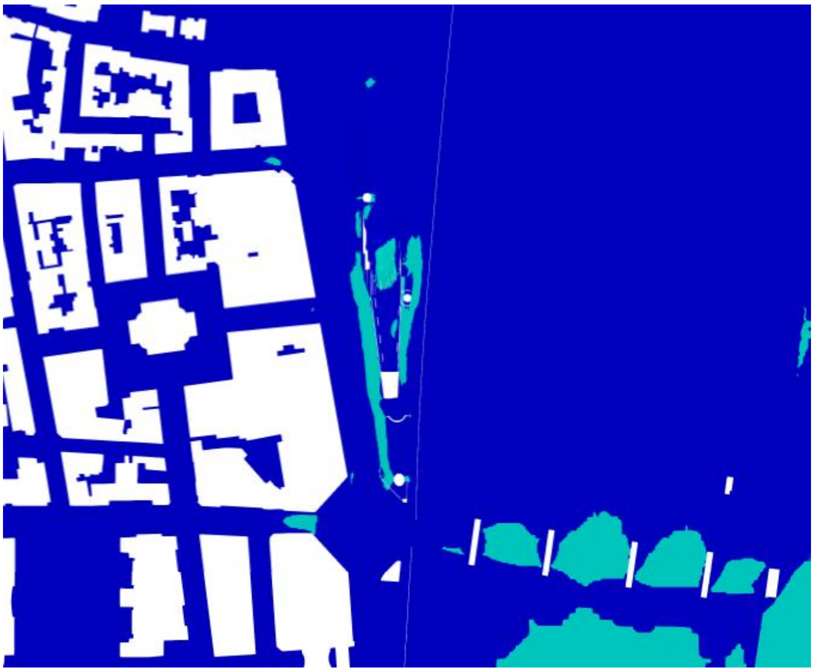


Contour Wind Plots - Seasonal Pedestrian Comfort Assessment

Summer

Baseline Scenario

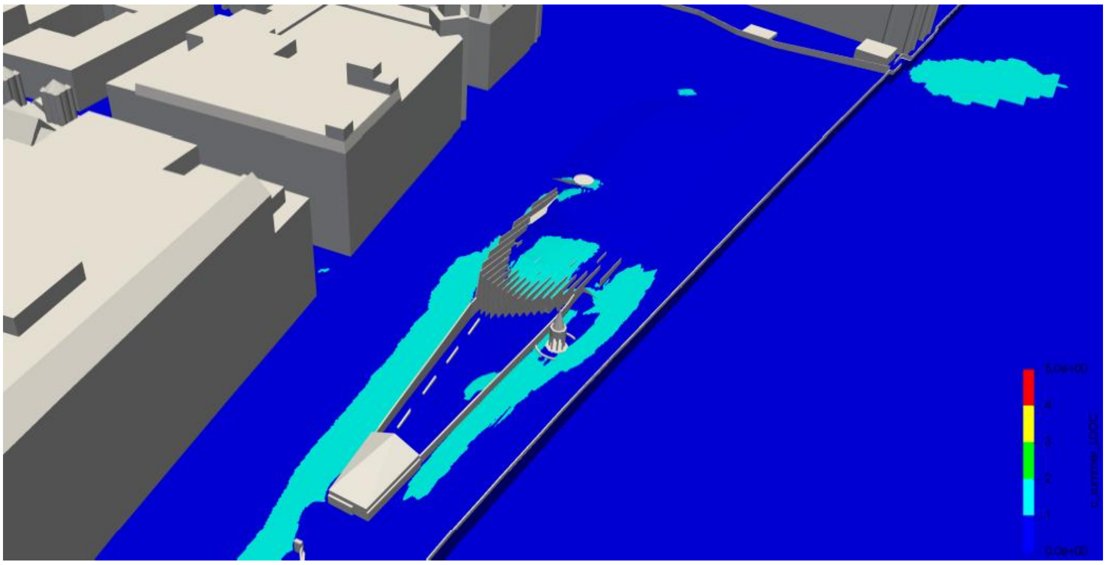
Proposed Scenario



Contour Wind Plots - Seasonal Pedestrian Comfort Assessment

Summer

Balconies



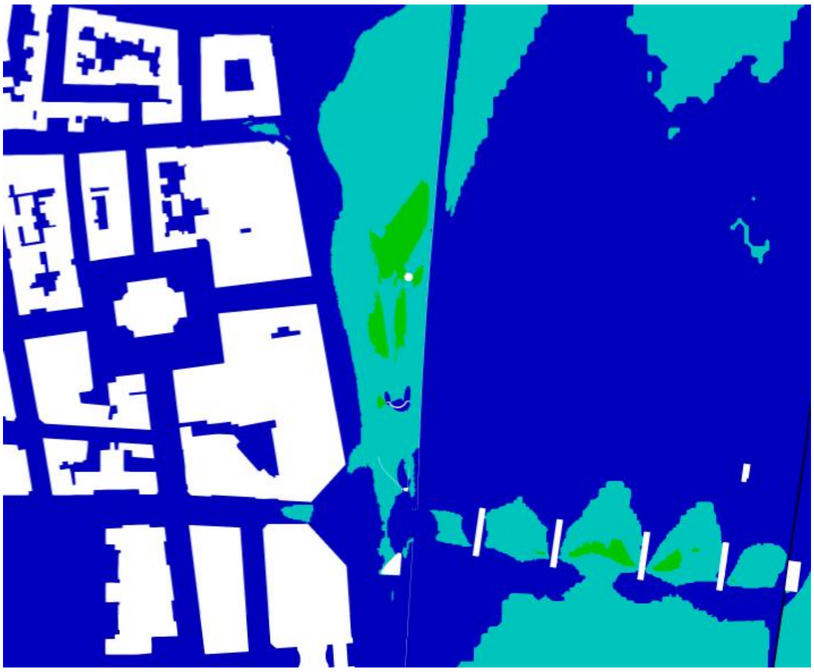
Lawson Comfort Criteria

- Sitting
- Standing
- Leisure Walking
- Business Walking
- Carpark / Roadway

Contour Wind Plots - Seasonal Pedestrian Comfort Assessment

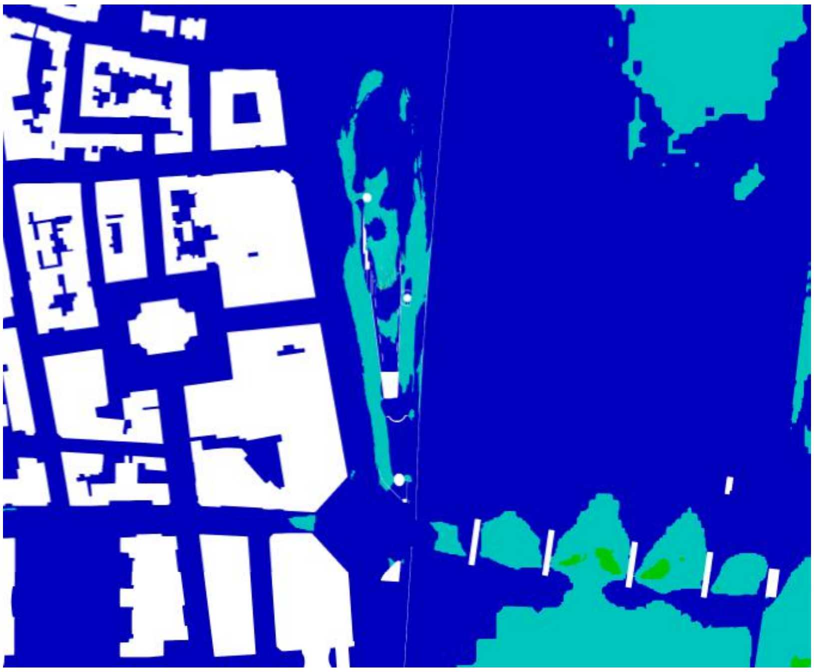
Autumn

Baseline Scenario



Lawson Comfort Criteria

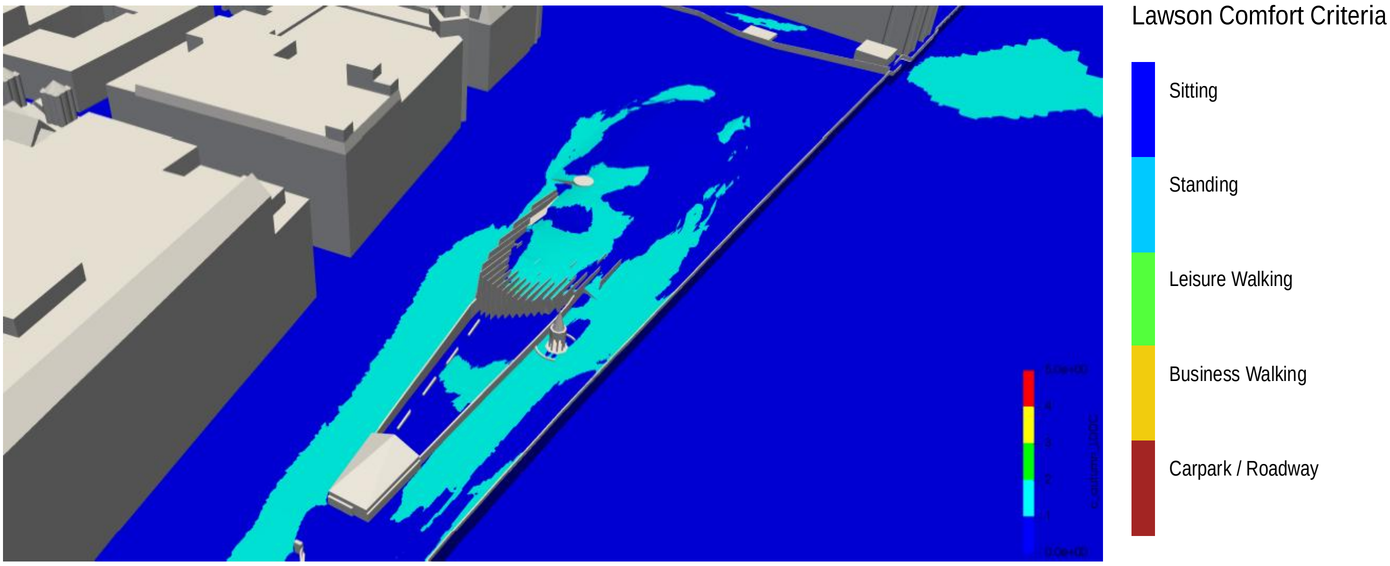
Proposed Scenario



Contour Wind Plots - Seasonal Pedestrian Comfort Assessment

Autumn

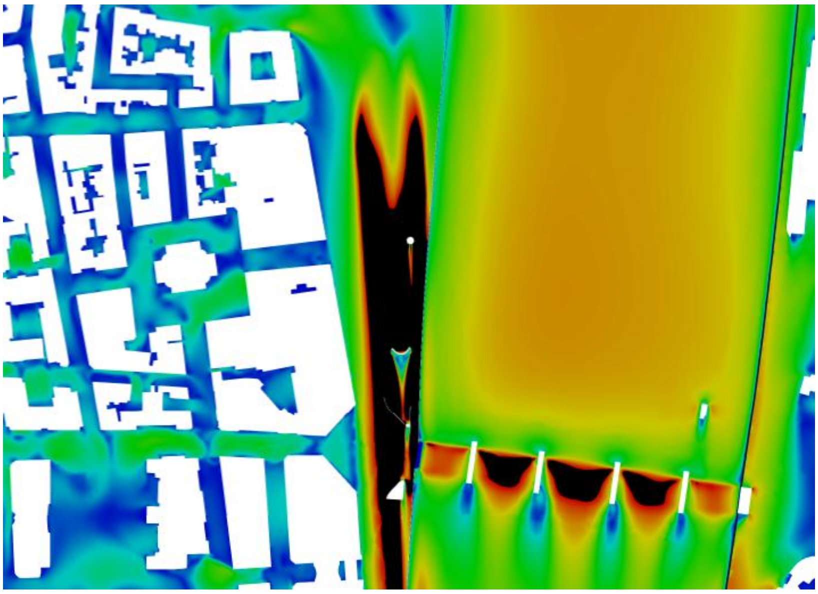
Balconies

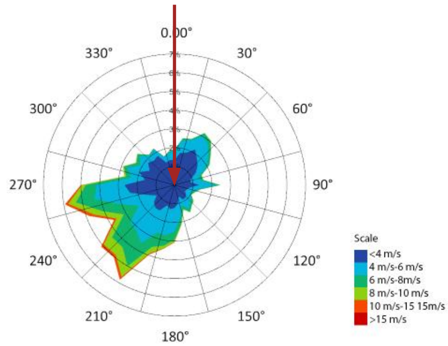


Appendix 2 Contour Plots for Individual Wind Directions

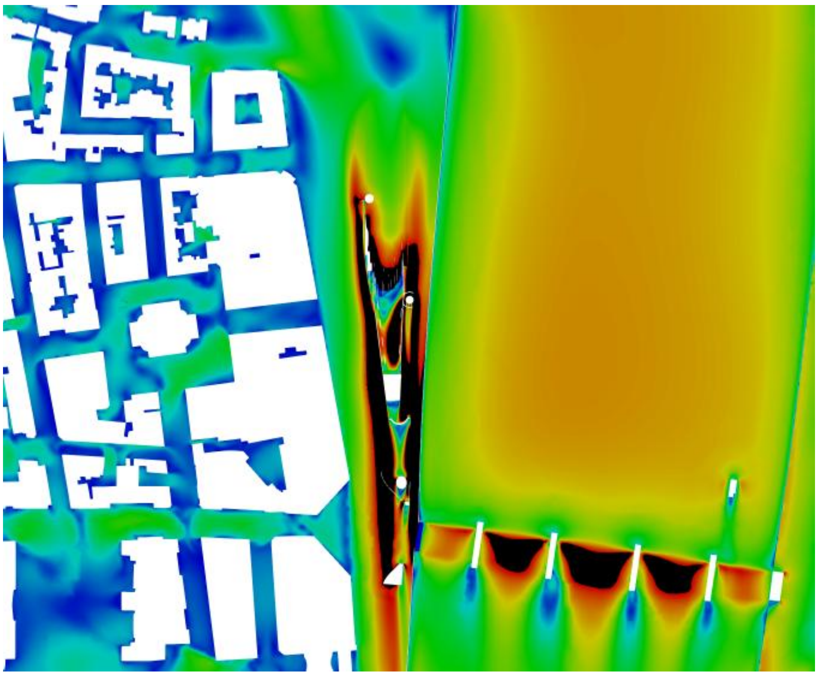
Condition 1: Northerly wind direction (0°)

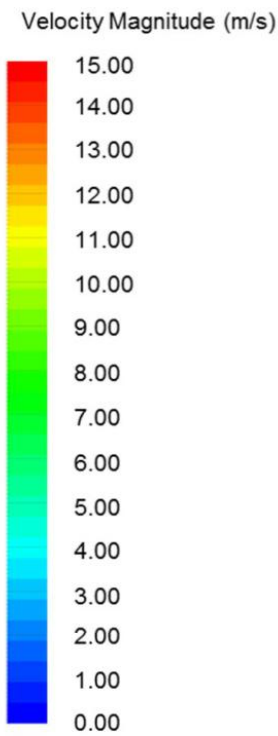
Baseline Scenario





Proposed Scenario

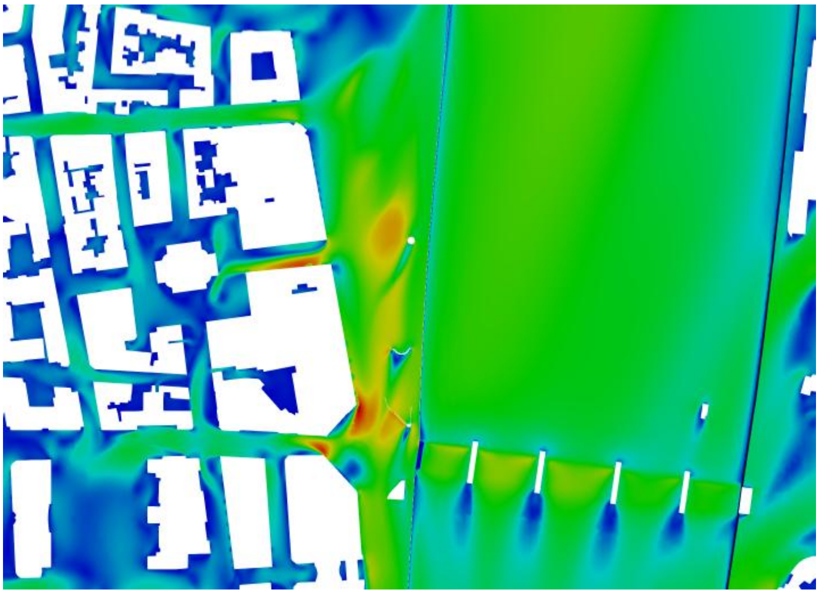


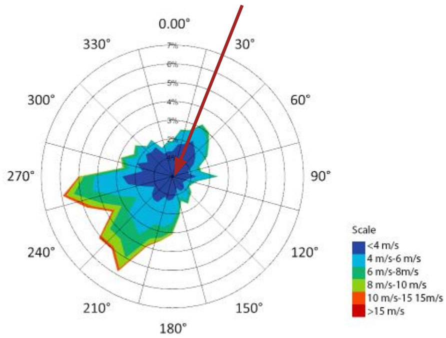


Contour Plots for Individual Wind Directions

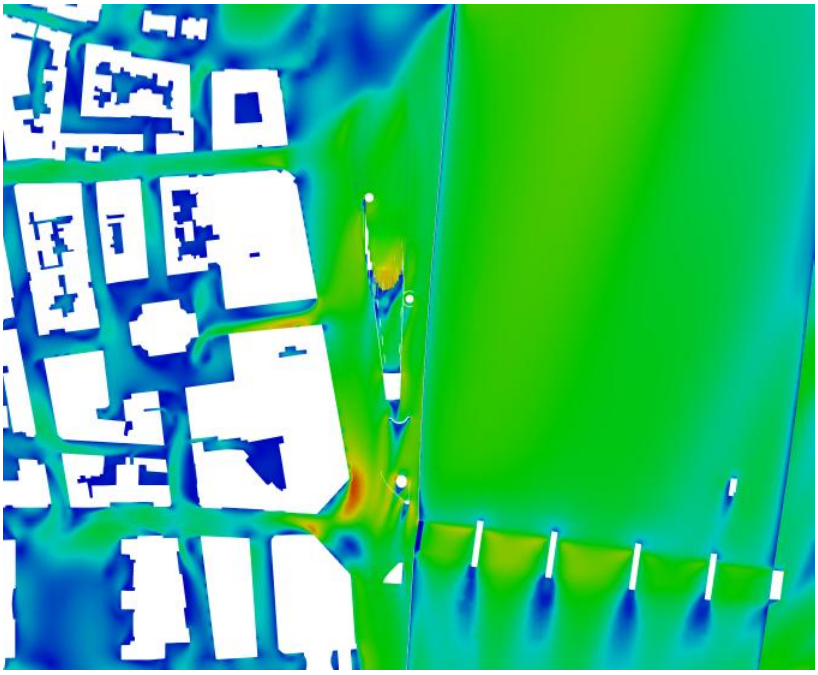
Condition 2: North, North-East wind direction (25°)

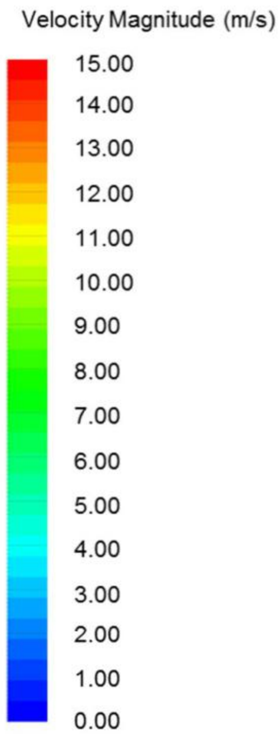
Baseline Scenario





Proposed Scenario

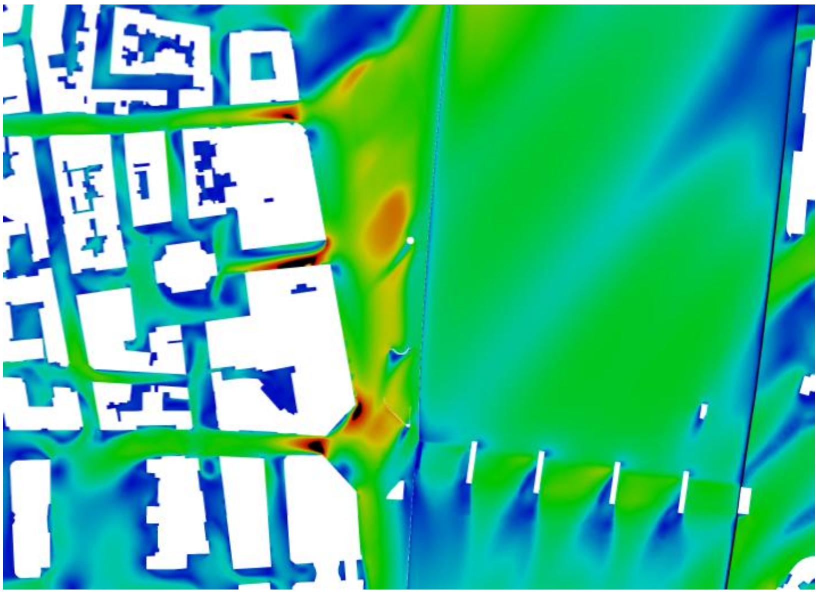


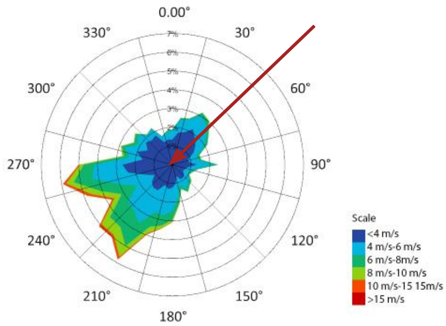


Contour Plots for Individual Wind Directions

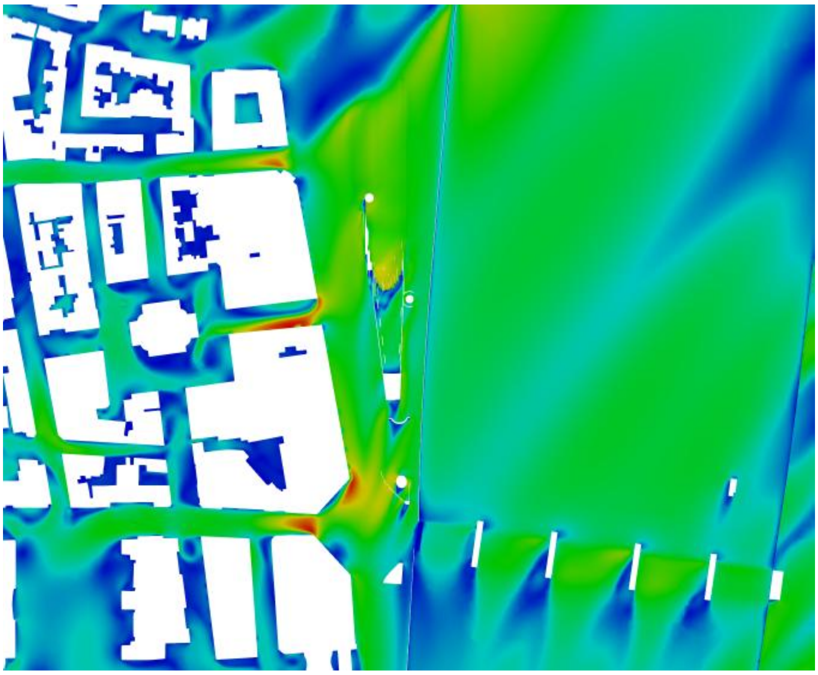
Condition 3: East, North-East wind direction (45^{o})

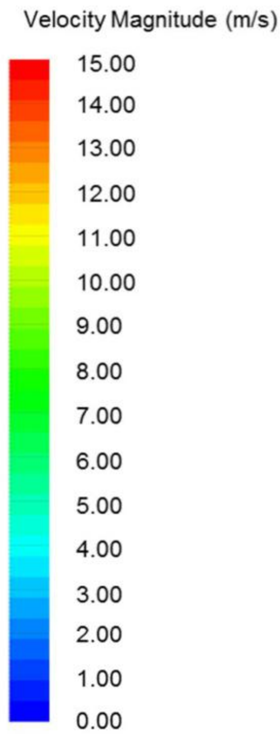
Baseline Scenario





Proposed Scenario

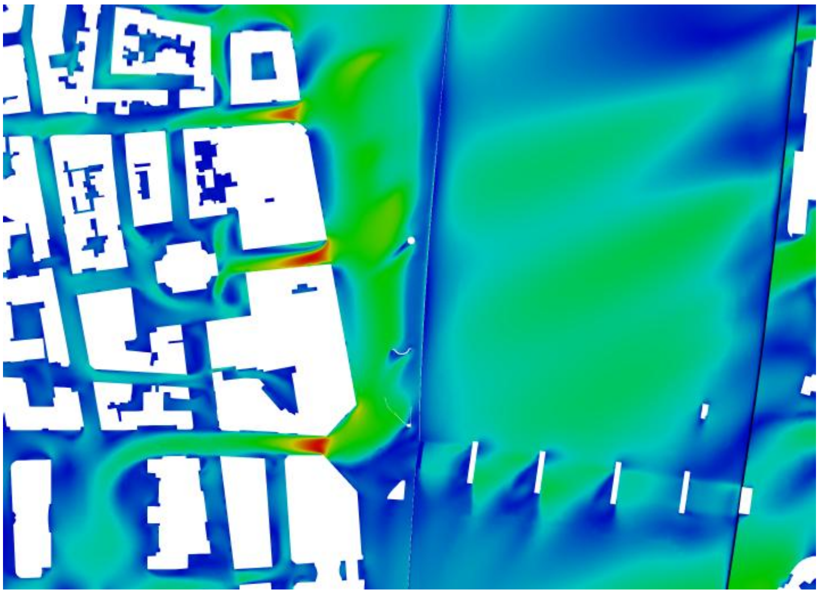


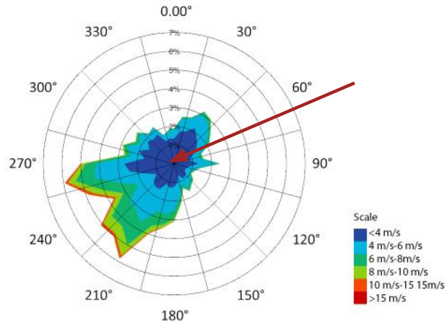


Contour Plots for Individual Wind Directions

Condition 4: Easterly wind direction (70°)

Baseline Scenario





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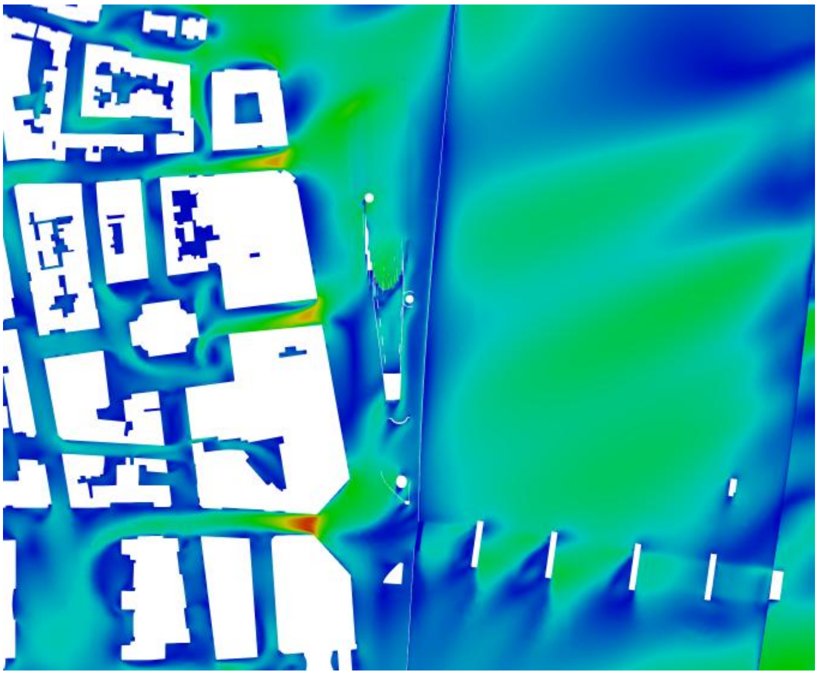
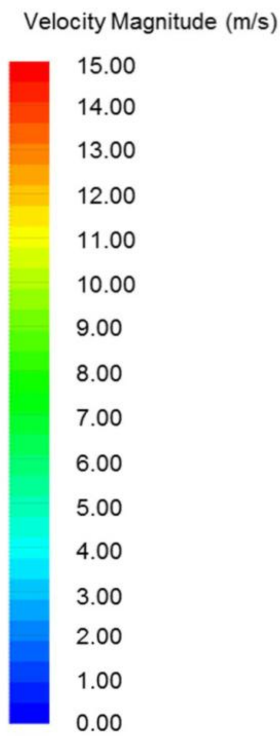
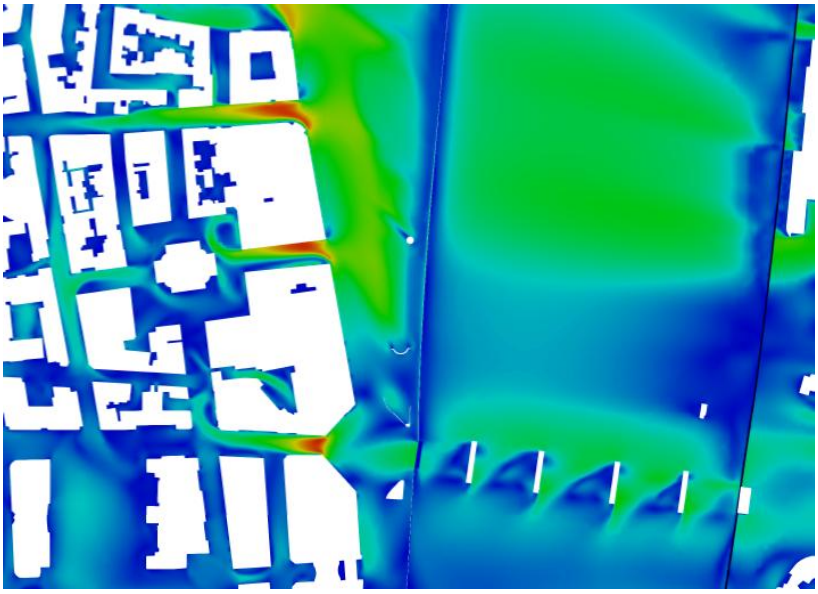


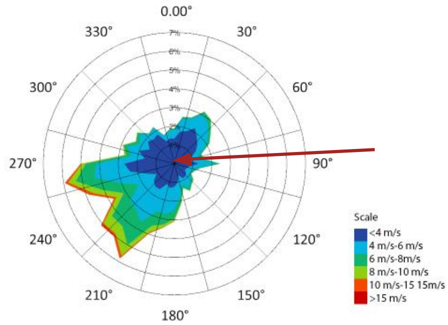


Contour Plots for Individual Wind Directions

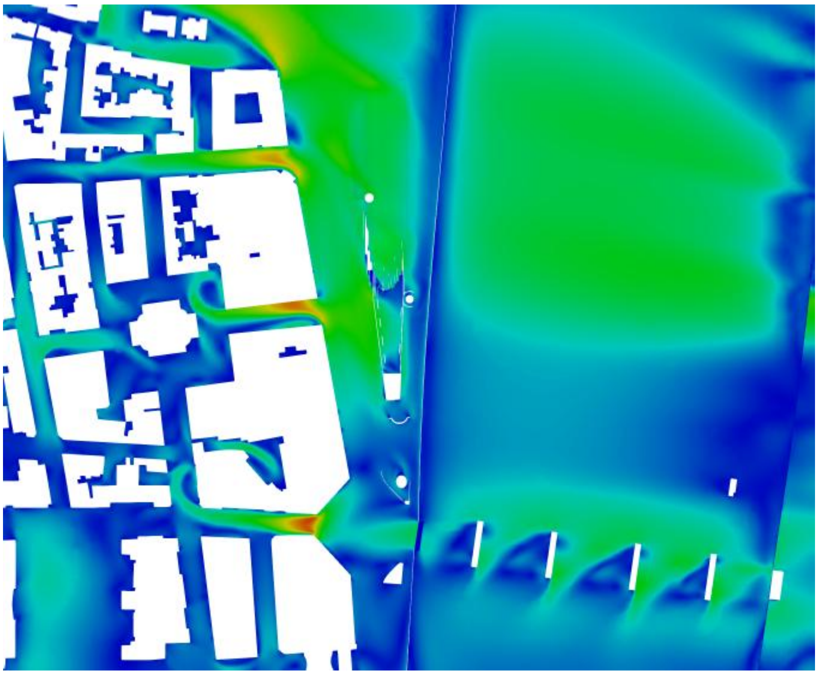
Condition 5: East, South-East wind direction (100º)

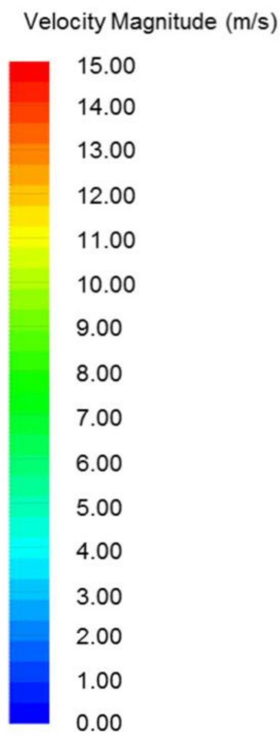
Baseline Scenario





Proposed Scenario

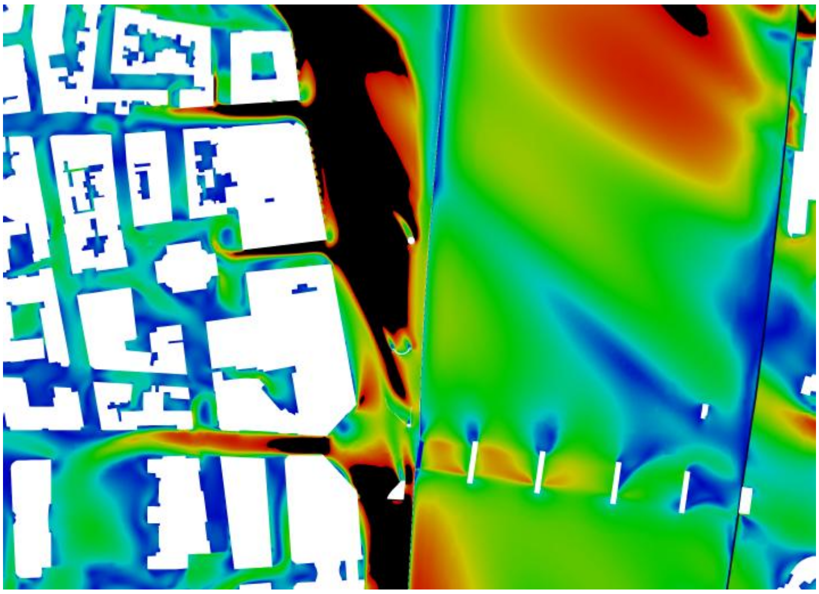


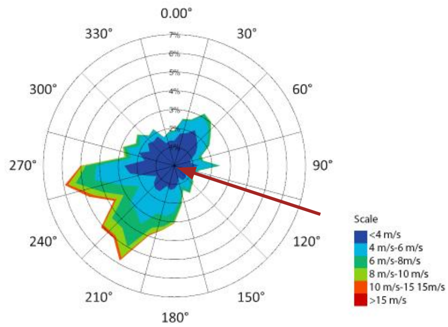


Contour Plots for Individual Wind Directions

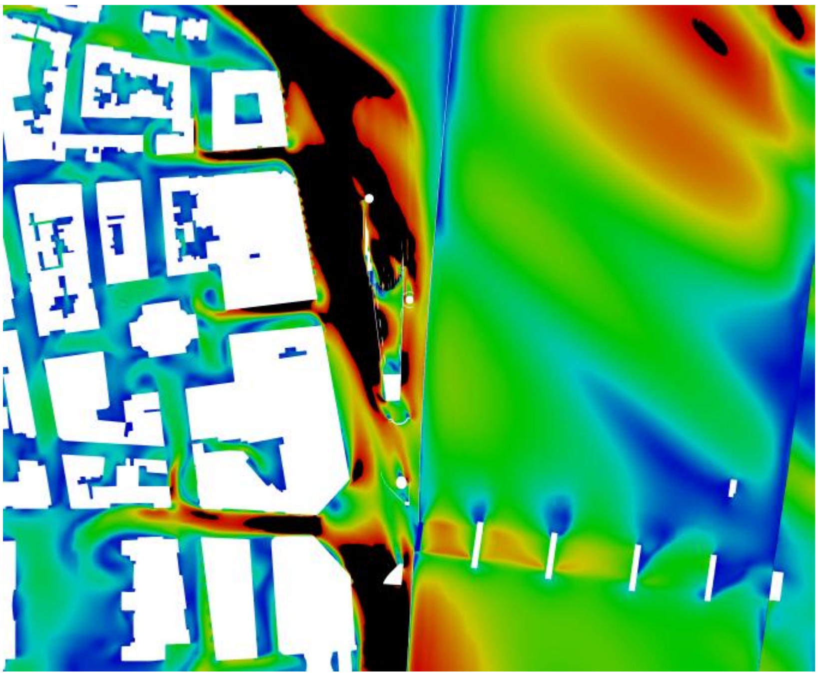
Condition 7: South, South-East wind direction (130°)

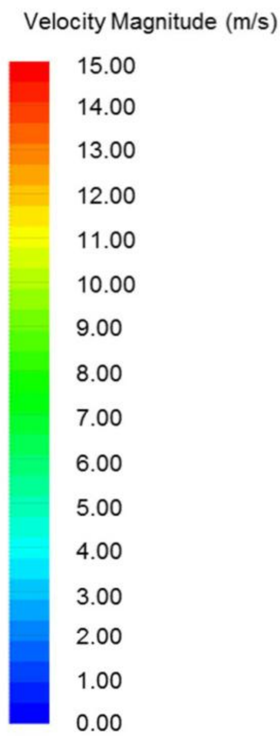
Baseline Scenario





Proposed Scenario

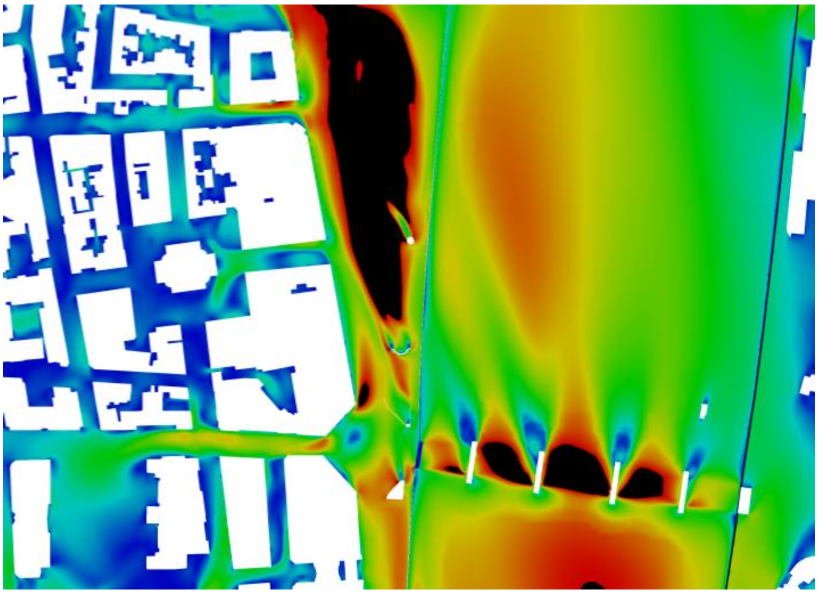


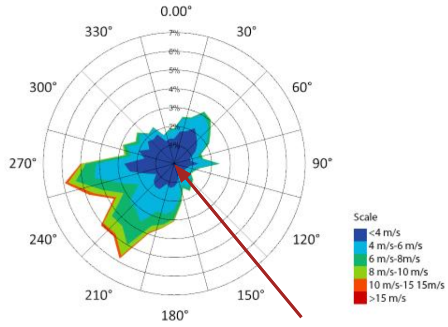


Contour Plots for Individual Wind Directions

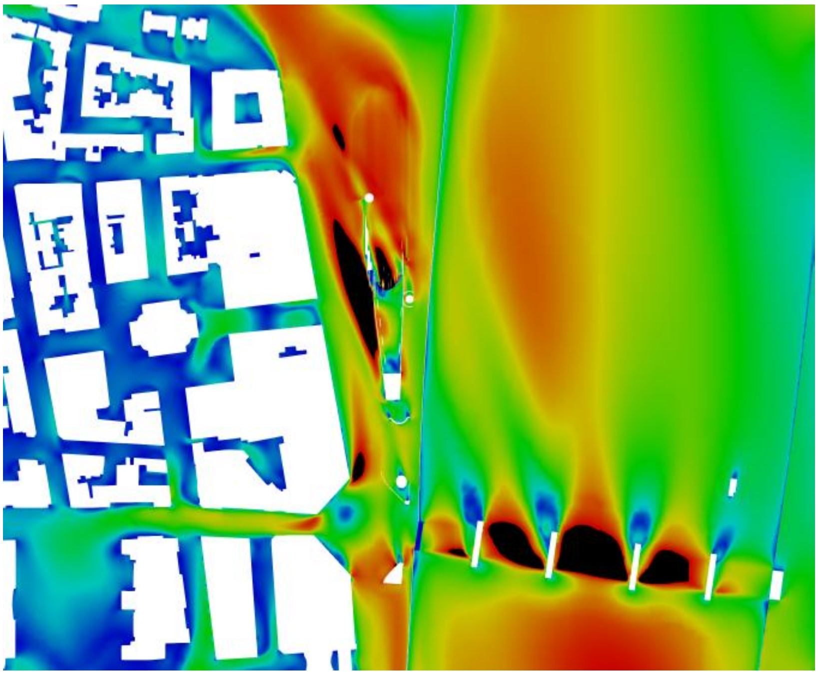
Condition 7: Southerly wind direction (160°)

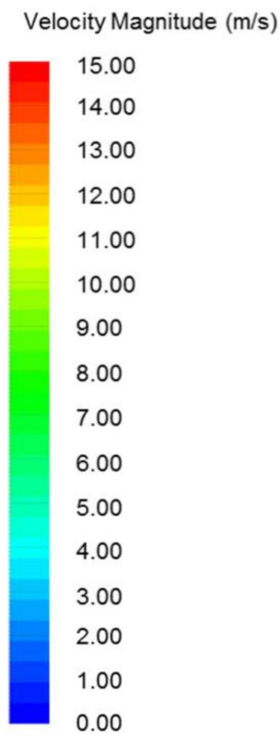
Baseline Scenario





Proposed Scenario

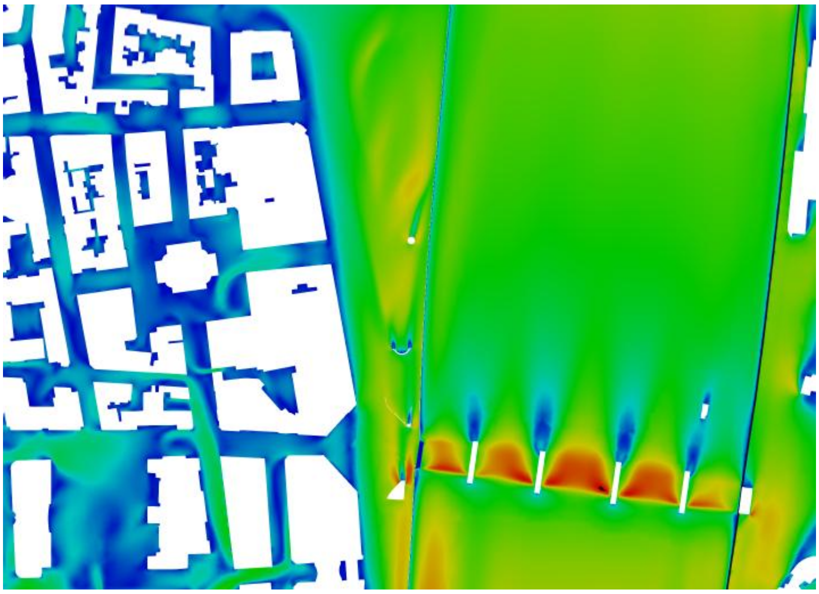


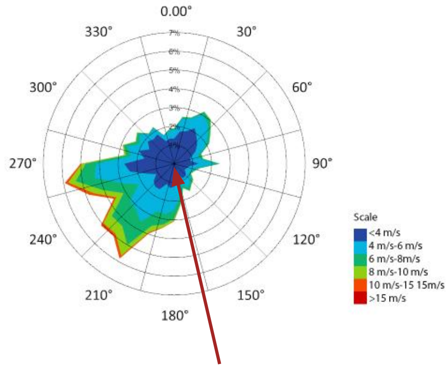


Contour Plots for Individual Wind Directions

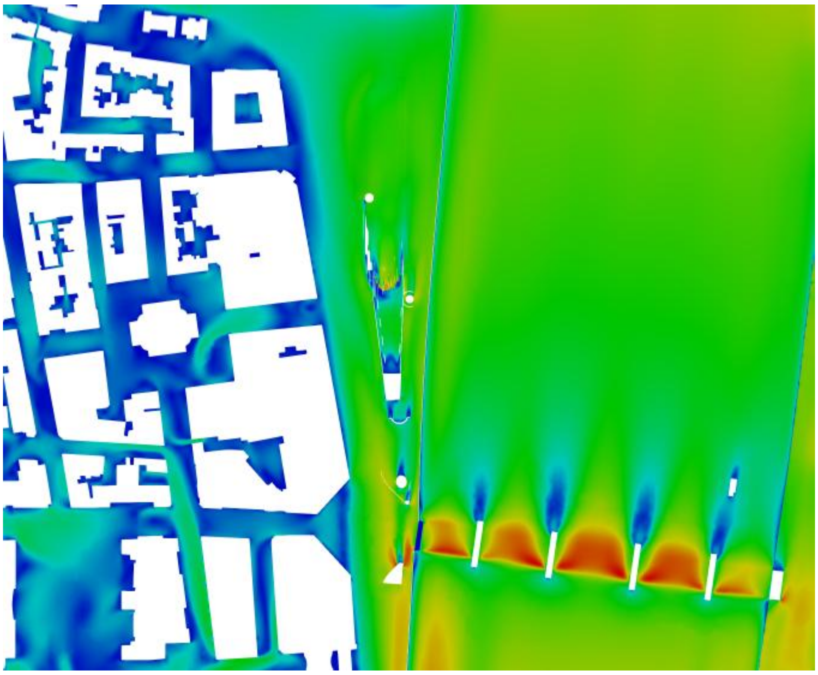
Condition 8: South, South-West wind direction (185°)

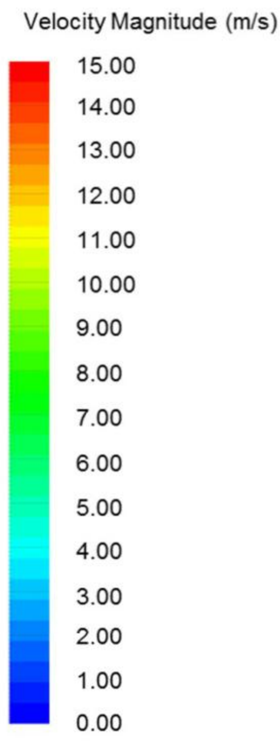
Baseline Scenario





Proposed Scenario

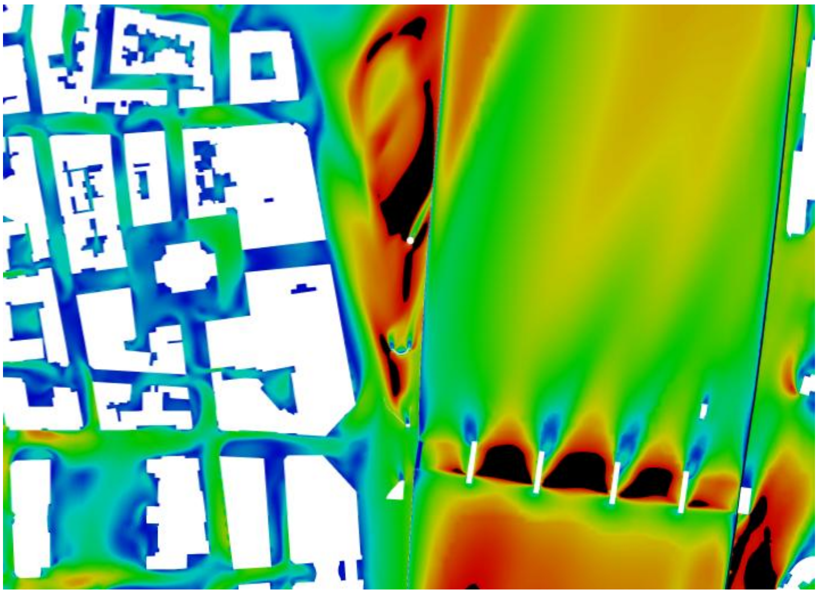


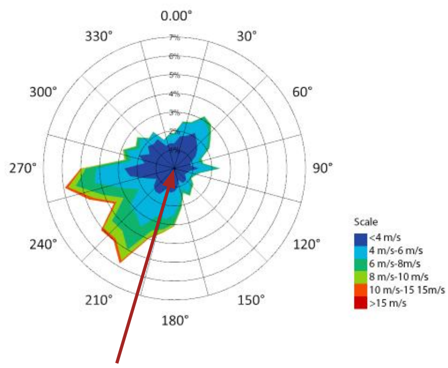


Contour Plots for Individual Wind Directions

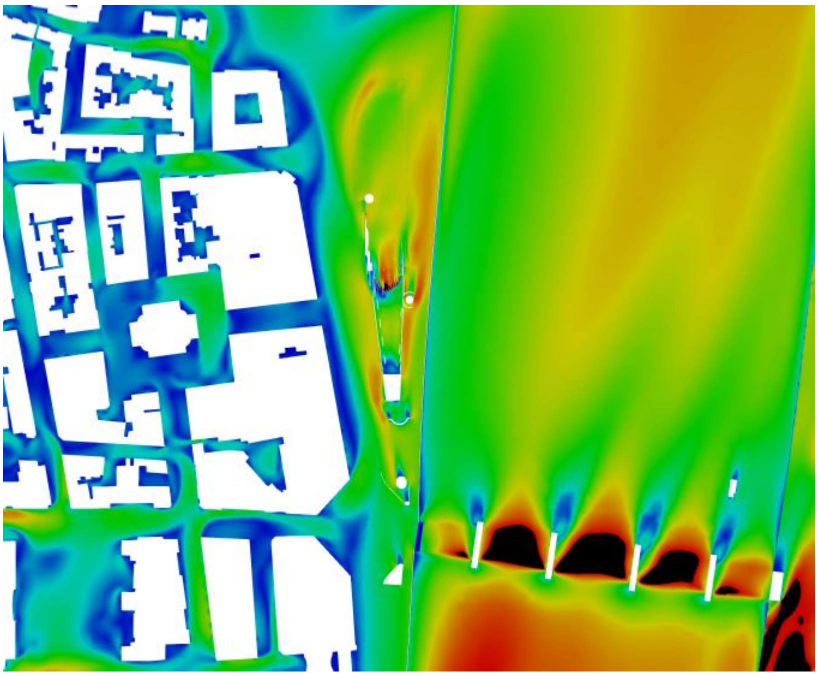
Condition 9: South-West wind direction (200°)

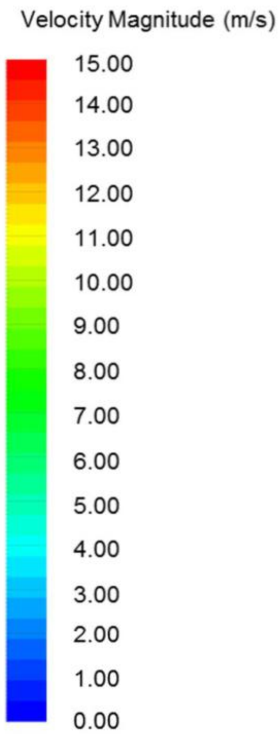
Baseline Scenario





Proposed Scenario

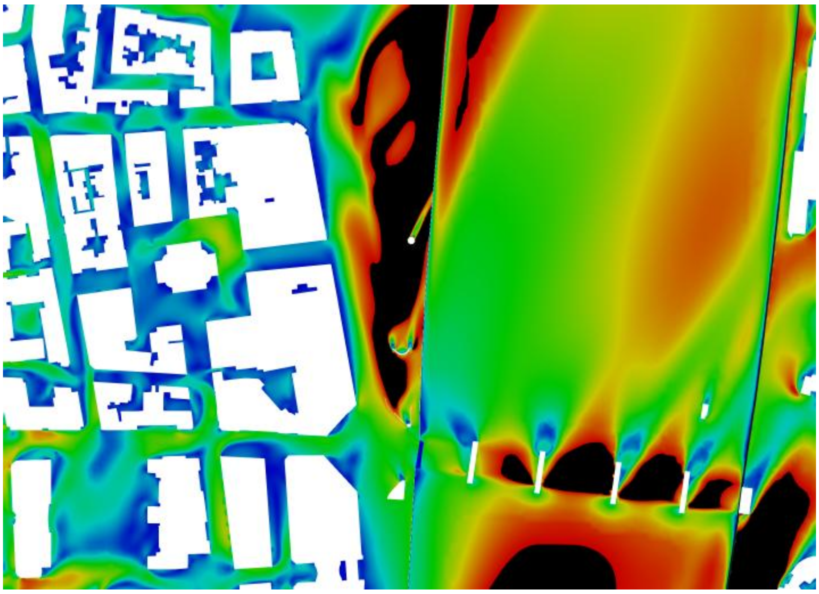


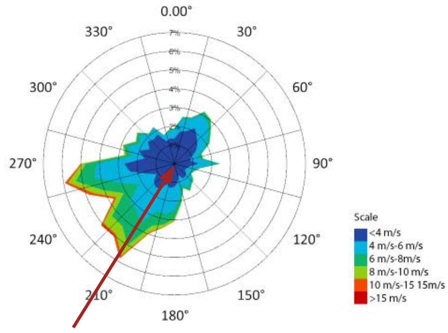


Contour Plots for Individual Wind Directions

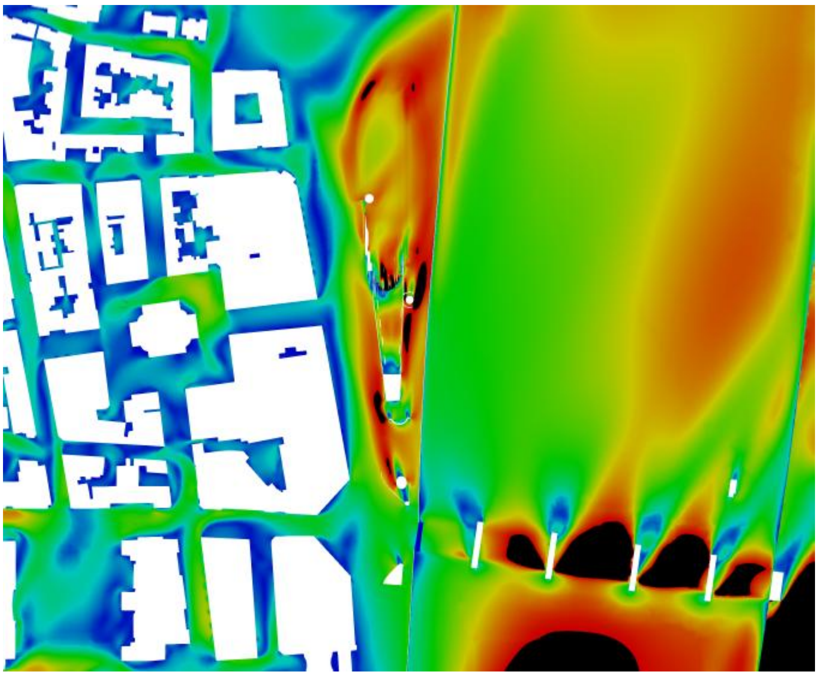
Condition 10: South-West wind direction (210º)

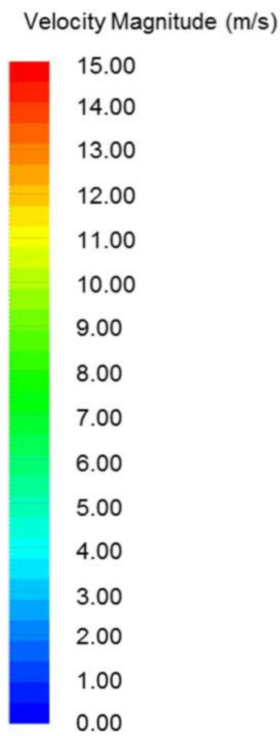
Baseline Scenario





Proposed Scenario

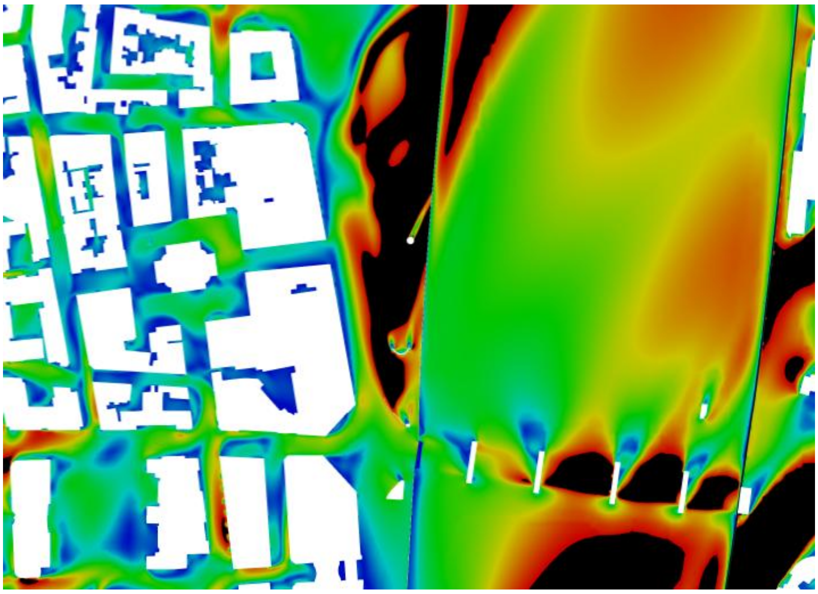


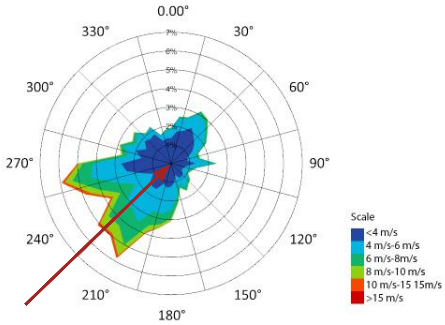


Contour Plots for Individual Wind Directions

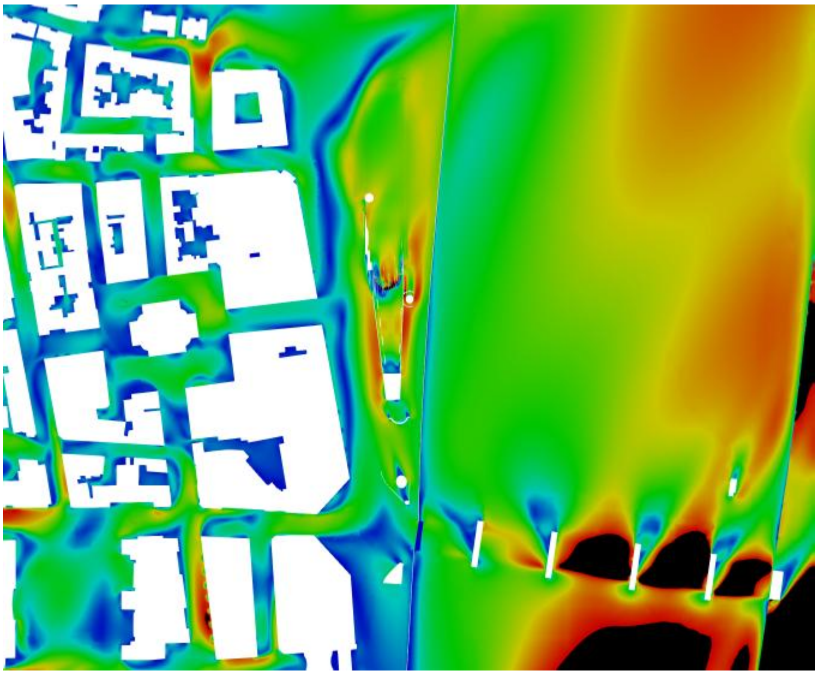
Condition 11: West, South-West wind direction (220^{o})

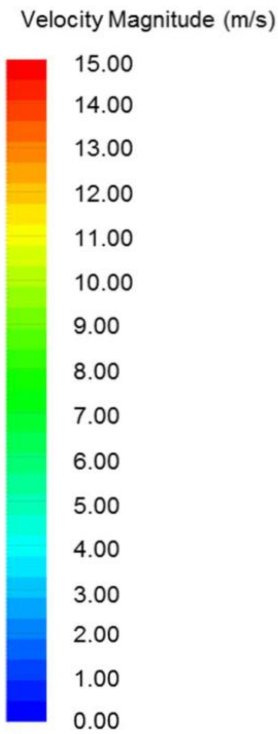
Baseline Scenario





Proposed Scenario

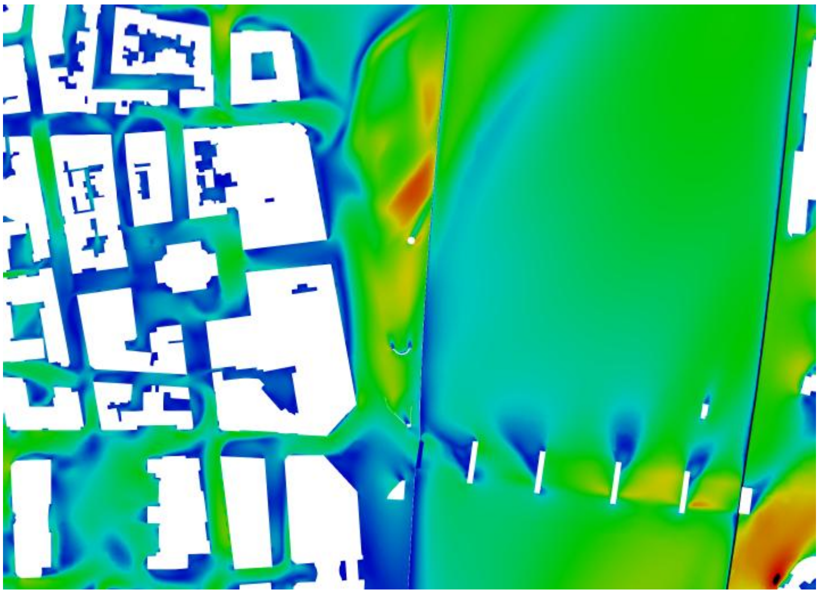


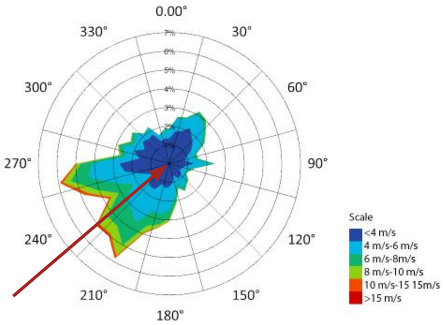


Contour Plots for Individual Wind Directions

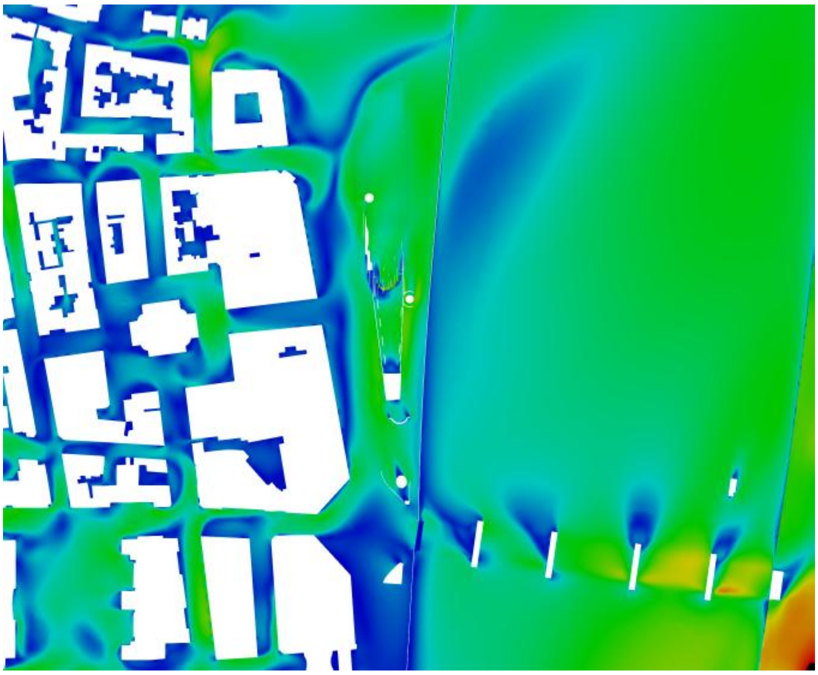
Condition 12: Westerly wind direction (230º)

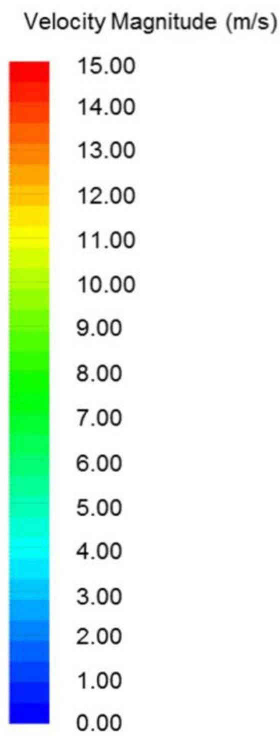
Baseline Scenario





Proposed Scenario

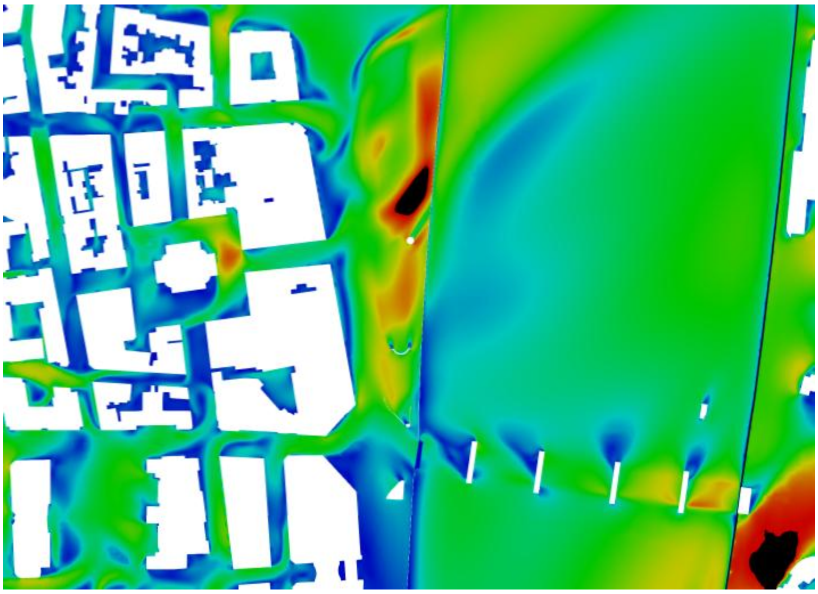


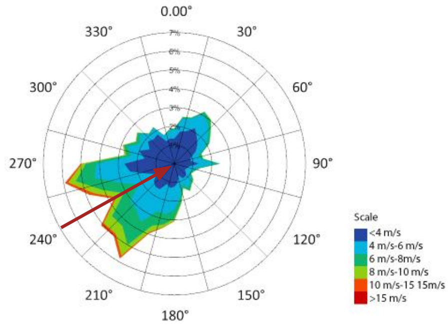


Contour Plots for Individual Wind Directions

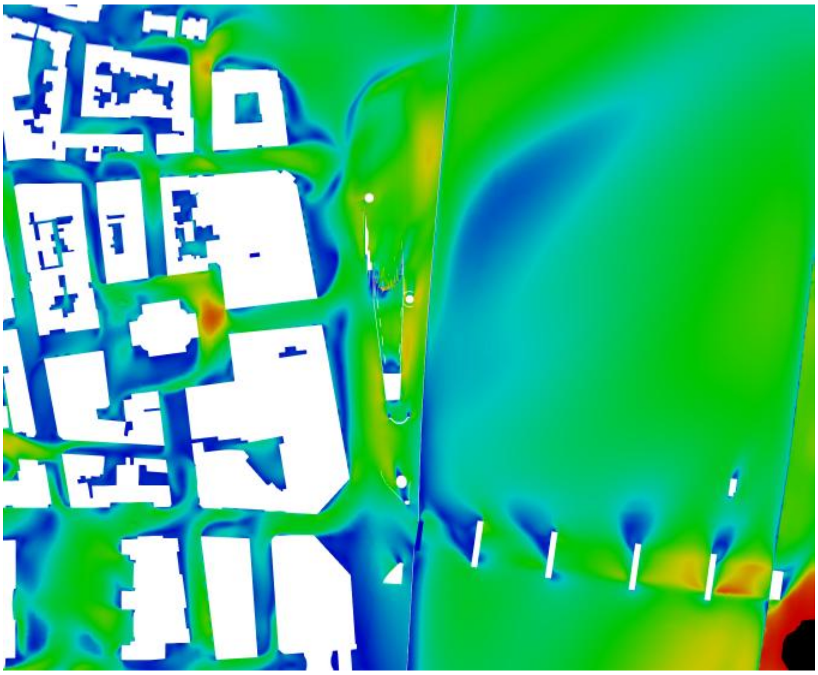
Condition 13: Westerly wind direction (240º)

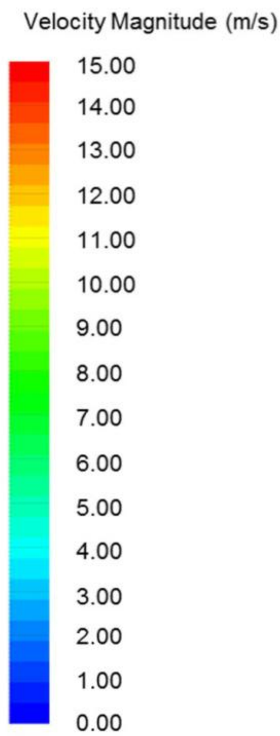
Baseline Scenario





Proposed Scenario

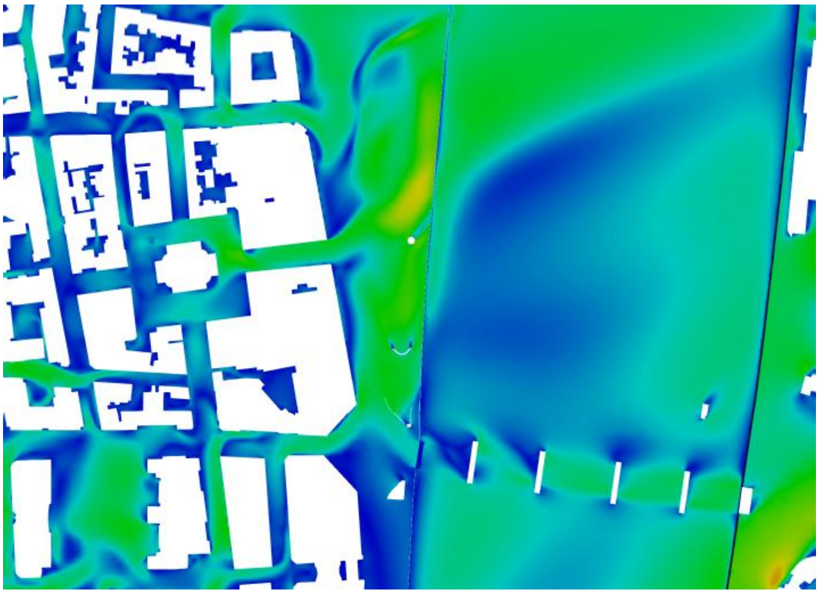


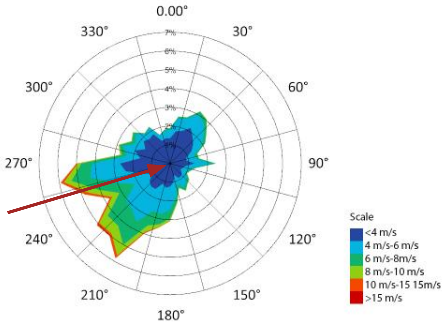


Contour Plots for Individual Wind Directions

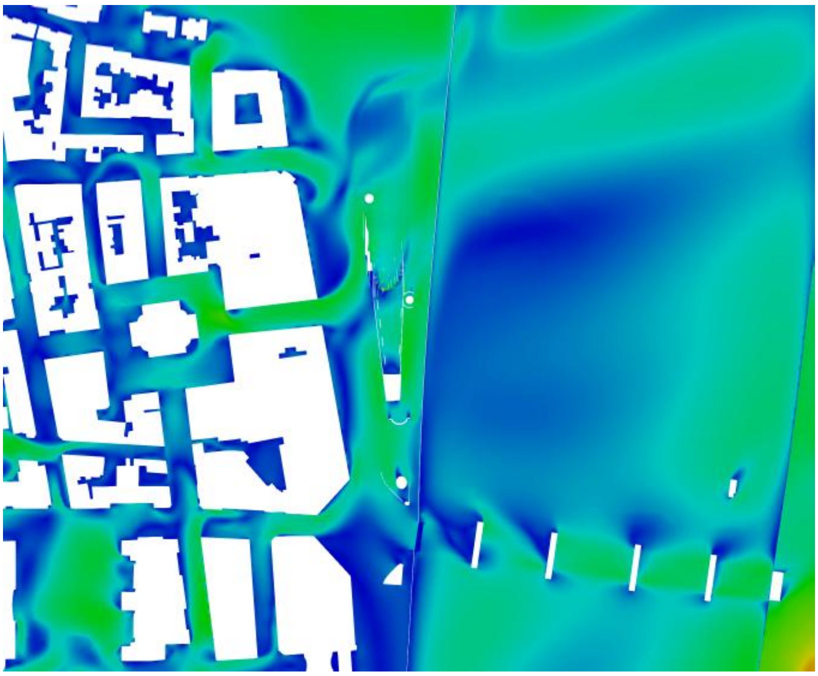
Condition 14: Westerly wind direction (250°)

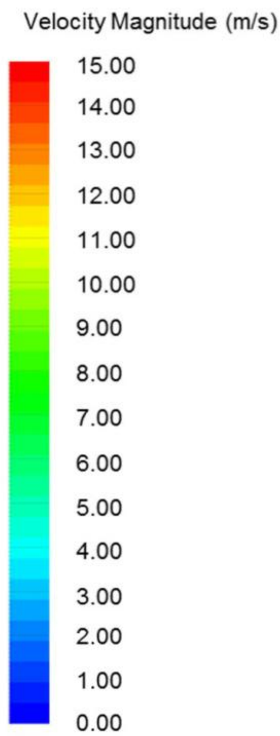
Baseline Scenario





Proposed Scenario

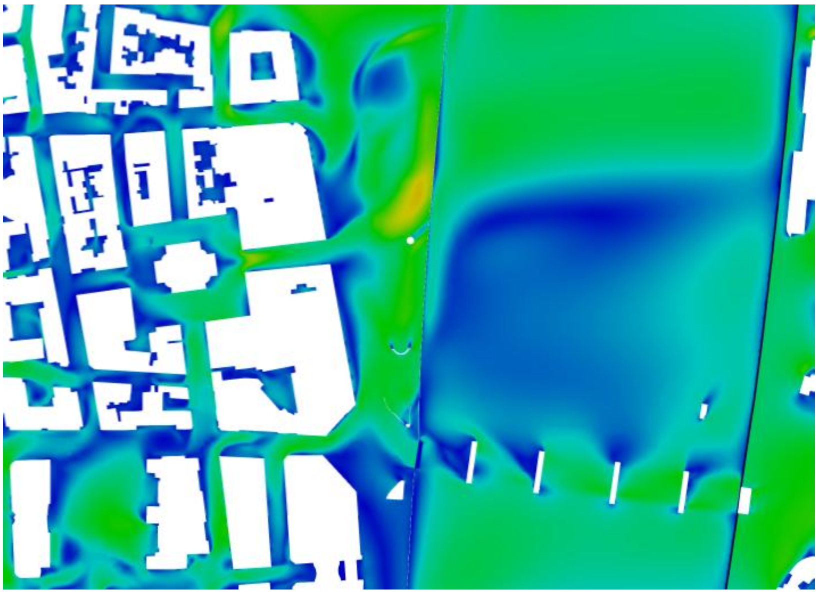


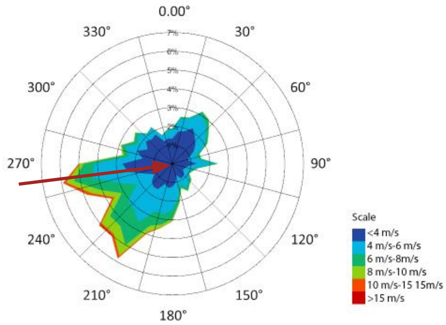


Contour Plots for Individual Wind Directions

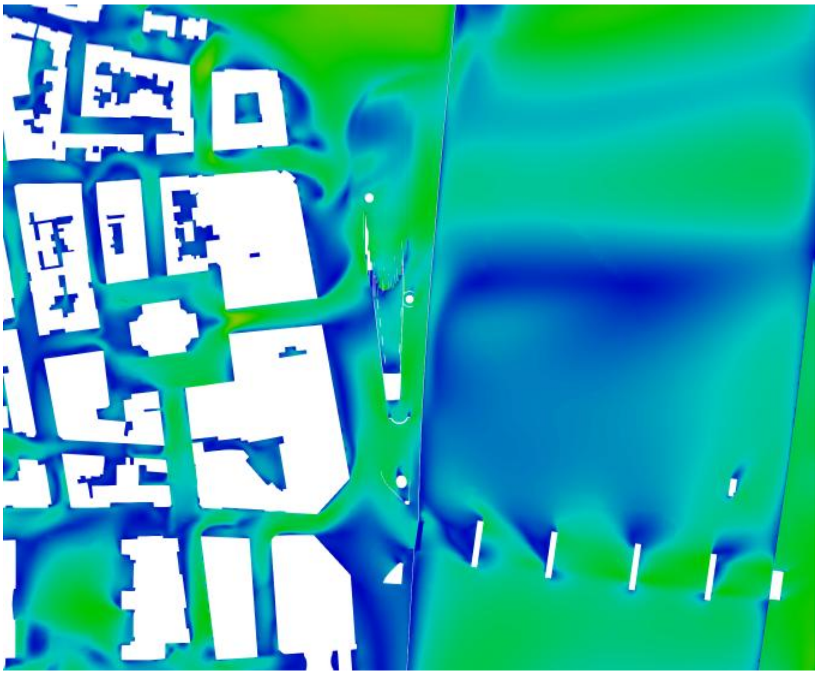
Condition 15: Westerly wind direction (260º)

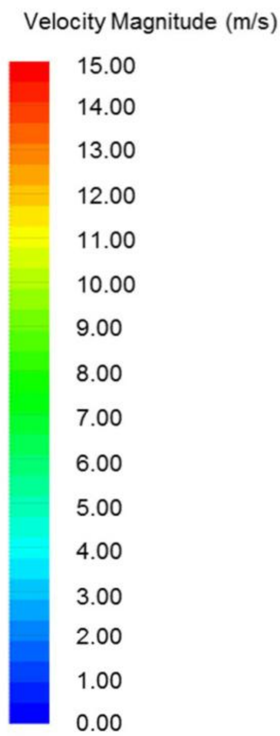
Baseline Scenario





Proposed Scenario

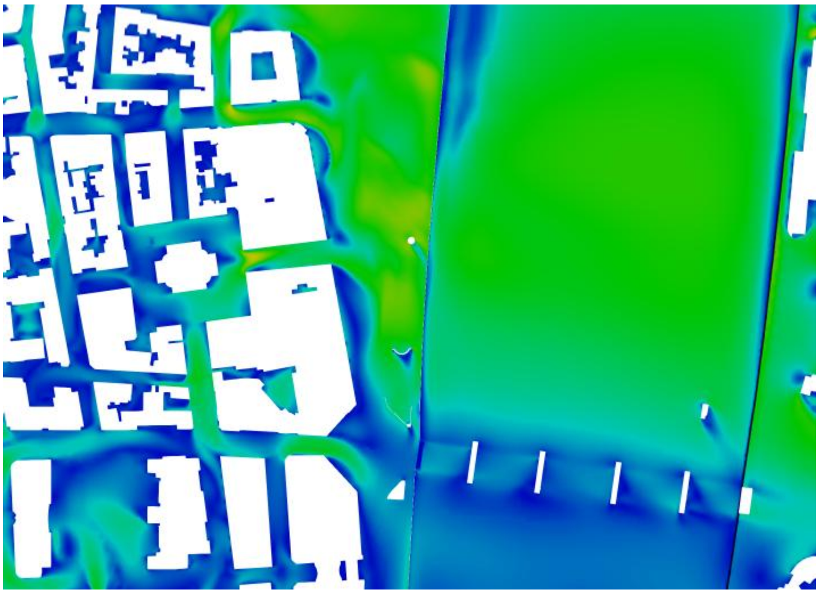


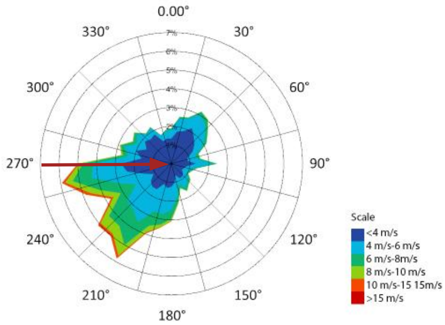


Contour Plots for Individual Wind Directions

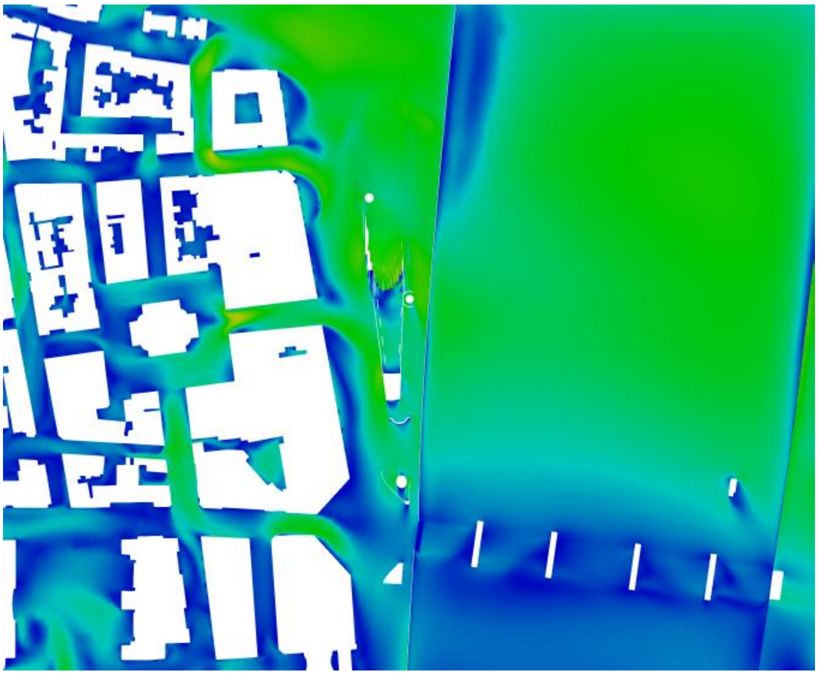
Condition 16: Westerly wind direction (275º)

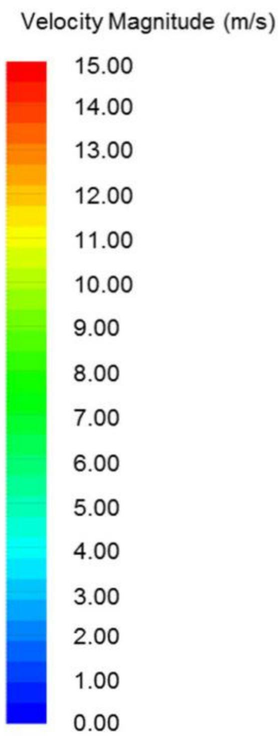
Baseline Scenario





Proposed Scenario

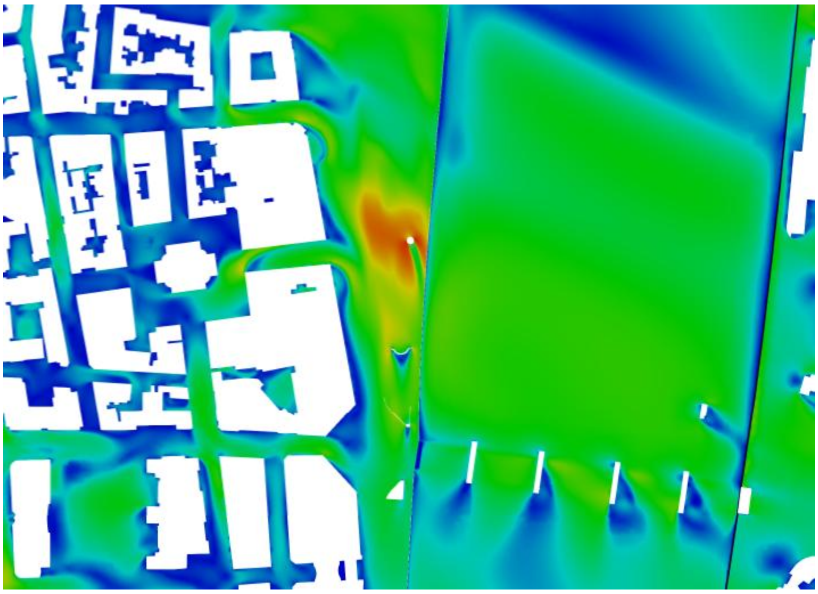


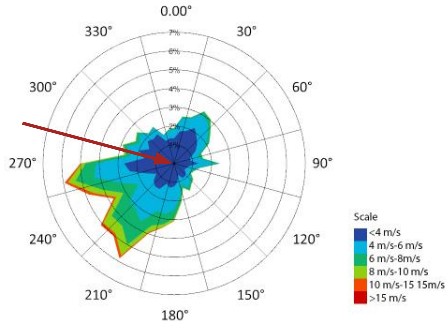


Contour Plots for Individual Wind Directions

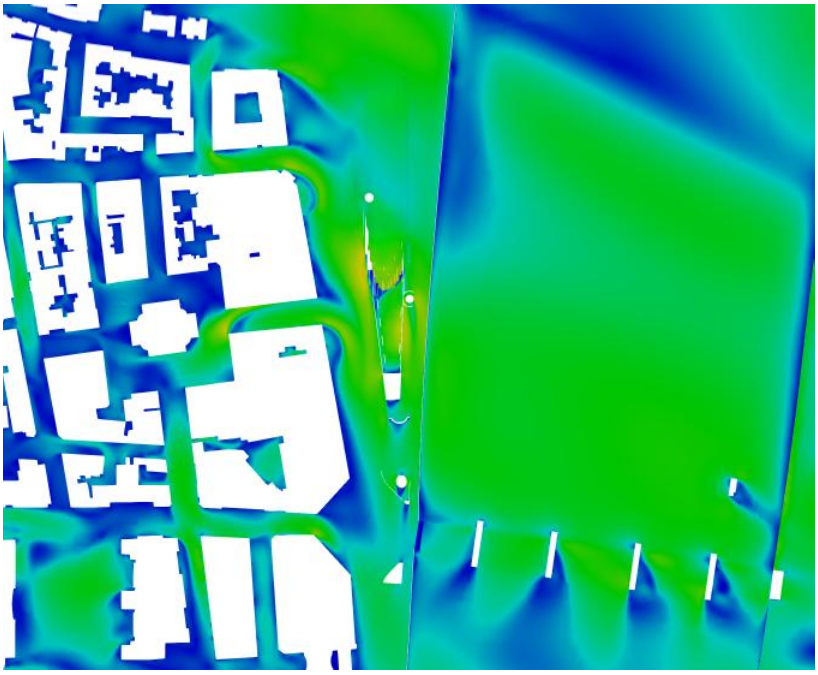
Condition 17: West, West-North wind direction (295°)

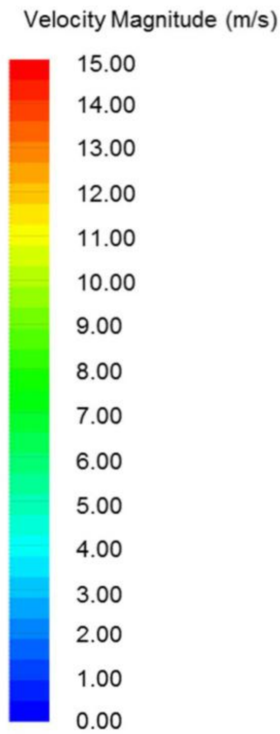
Baseline Scenario





Proposed Scenario

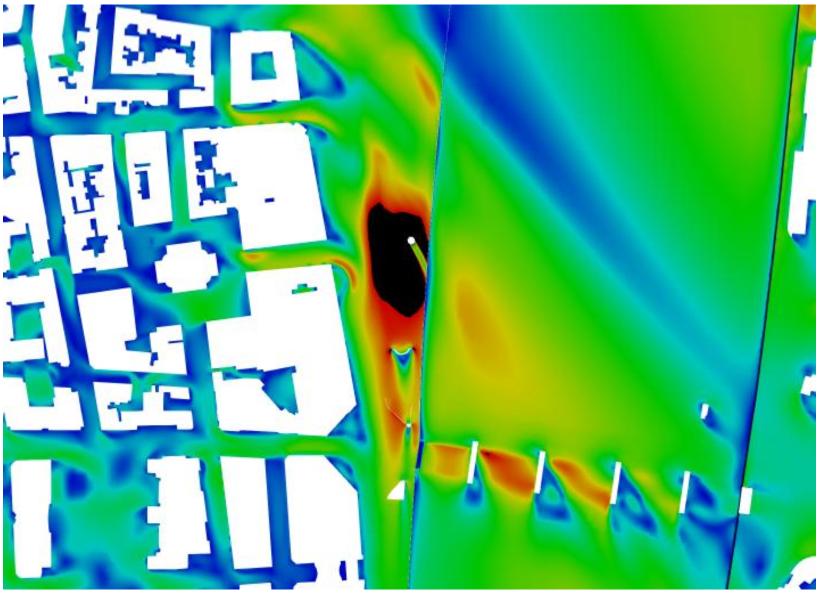


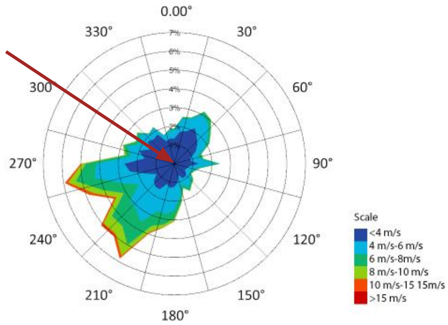


Contour Plots for Individual Wind Directions

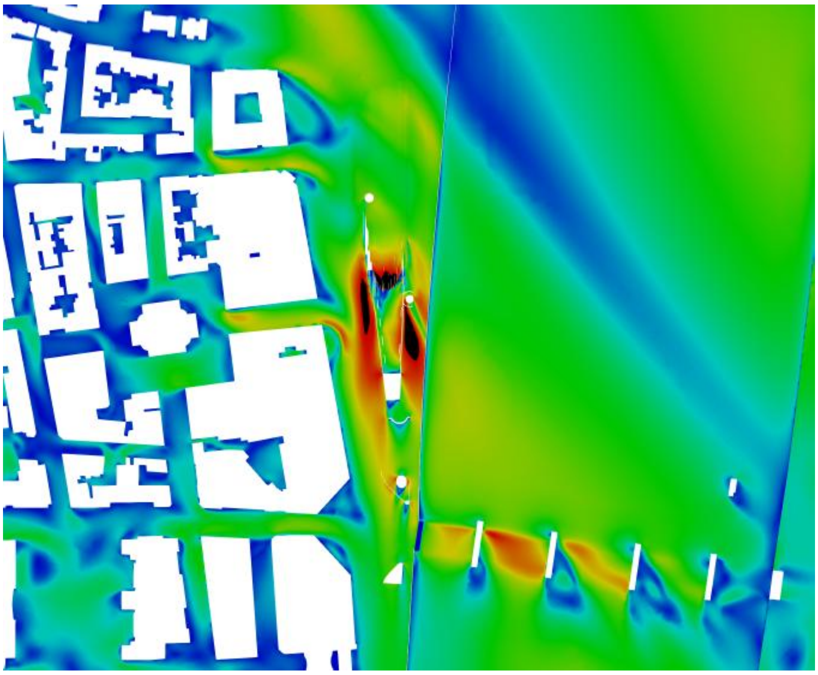
Condition 18: West, West-North wind direction (315^{o})

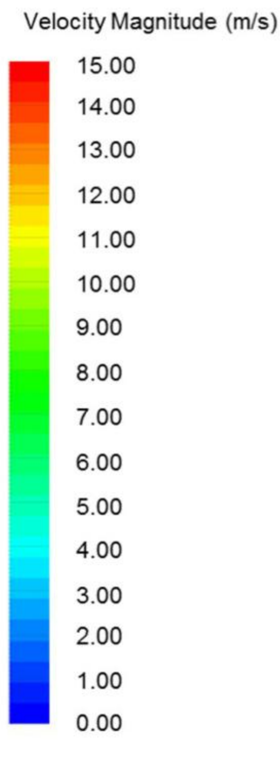
Baseline Scenario





Proposed Scenario

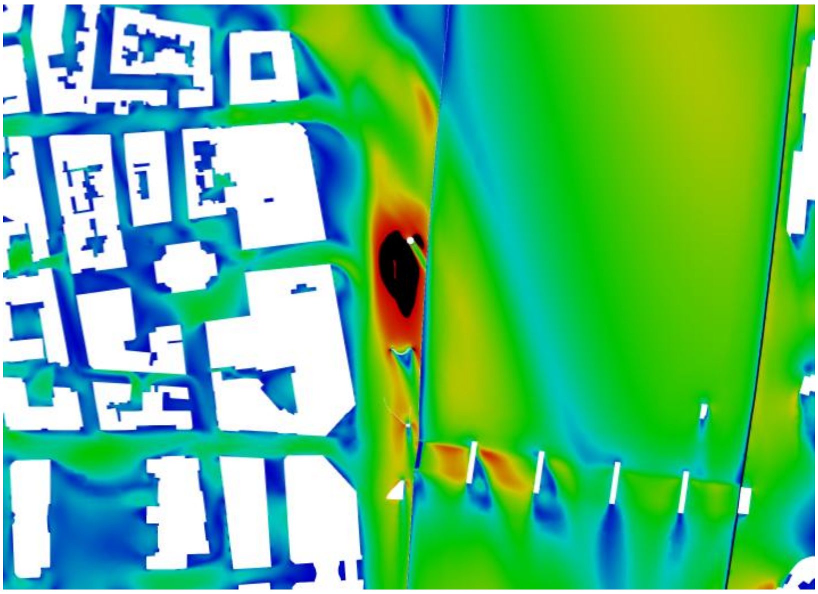


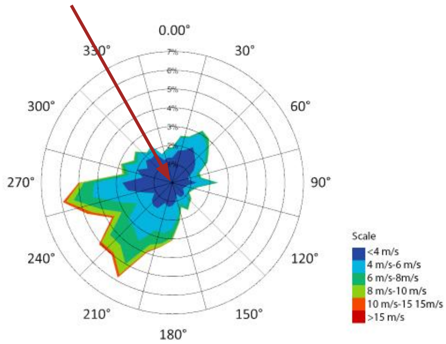


Contour Plots for Individual Wind Directions

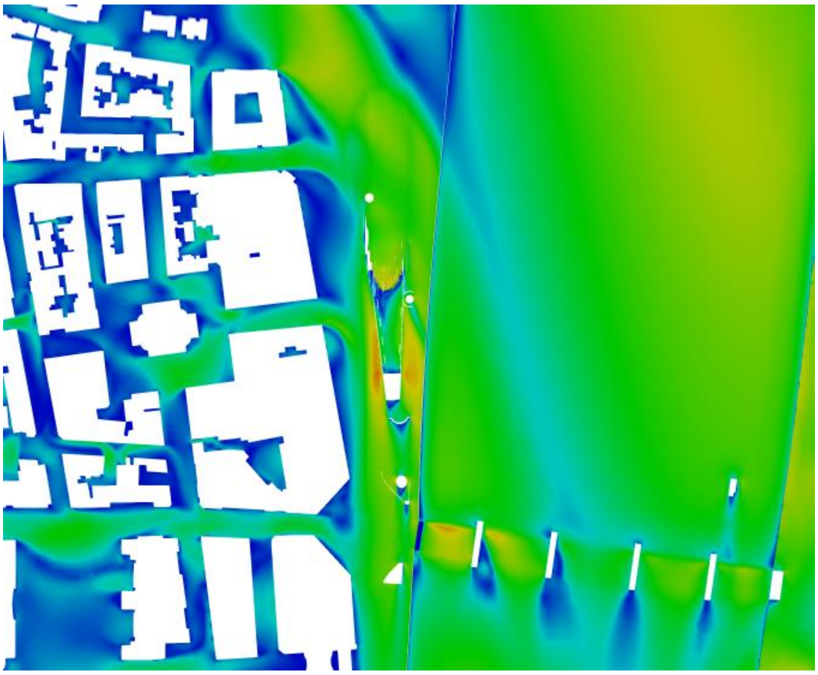
Condition 19: North, North-West wind direction (335°)

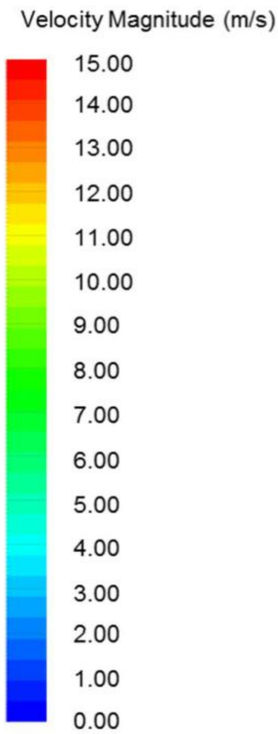
Baseline Scenario





Proposed Scenario

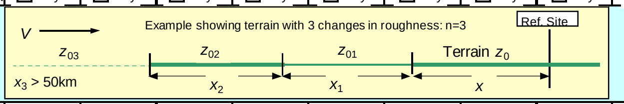




Appendix 3 Site Terrain Adjustment

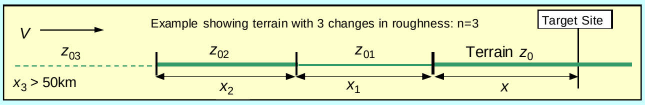
Wind condition at weather station

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	20/08/2018 17:26														
2				**REFERENCE WIND SPEED AND CORRESPONDING TERRAIN**											
3				**LOCATION/NAME: Heatrow Airport**											
4															
5		Case	1	2	3	4	5	6	7	8	9	10	11	12	13
6		Wind direction (degree from N):	0	30	60	90	120	150	180	210	240	270	300	330	
7		Range of Cases to be calculated:	As in Sheet "Target Site"												
8		Latitude (degree)	50	50	50	50	50	50	50	50	50	50	50	50	
9		Reference wind speed (m/s)	100	100	100	100	100	100	100	100	100	100	100	100	
10		If gust, averaging time (s)													
11		Ht above ground (m)	10	10	10	10	10	10	10	10	10	10	10	10	
12		Zero plane ht d (m)	0	0	0	0	0	0	0	0	0	0	0	0	
13		If hilly terrain at ref site, check box	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly
14															
15															
16															
17															
18															
19		No. of terrain changes: n_{ref}	3	4	2	4	3	4	2	2	2	2	2	1	
20		Terrain roughness, z_0 (m)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
21		Patch length, x (m)	1600.00	1600.00	3000.00	3000.00	1600.00	1600.00	1600.00	1600.00	1600.00	3000.00	3000.00	3000.00	
22		z_{01} (m)	0.08	0.10	0.14	0.33	0.11	0.13	0.09	0.08	0.07	0.09	0.12	0.11	
23		x_1 (m)	1400.00	1400.00	5600.00	7000.00	1400.00	1400.00	5500.00	3600.00	3600.00	3700.00	13000.00		
24		z_{02} (m)	0.25	0.22	0.32	0.10	0.23	0.08	0.02	0.13	0.11	0.05	0.04		
25		x_2 (m)	6300.00	6300.00		6000.00	7000.00	8000.00							
26		z_{03} (m)	0.15	0.34		0.27	0.35	0.22							
27		x_3 (m)		10000.00		4000.00		10000.00							
28		z_{04} (m)		0.15		0.52		0.05							
29		x_4 (m)													
30		z_{05} (m)													
31		x_5 (m)													
32															
33															
34															
35															
36															
37															
38															
39															
40															



Wind condition at the proposed site

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	28/11/2018 17:55	Wind speeds are always calculated. Other calculation options: ☑ I_u, ${}^xL_u$, ${}^yL_u$, ${}^zL_u$, S_{uu} ☐ I_v, ${}^xL_v$, ${}^yL_v$, ${}^zL_v$, S_{vv} ☐ I_w, ${}^xL_w$, ${}^yL_w$, ${}^zL_w$, S_{ww} ☑ On re-run, delete all old results		**TARGET SITE DETAILS** **LOCATION/NAME: National Holocaust Memorial**										
2–7	To calculate spectral densities (S_{uu} etc), enter frequencies on Worksheet 'Spectral densities'.													
8	Heights above ground for calculations (m)	Case	1	2	3	4	5	6	7	8	9	10	11	12
9		Wind direction (degree from N):	0	30	60	90	120	150	180	210	240	270	300	330
10		Range of Cases to be calculated:	Case No.	1	to	12								
11	5	If gust, averaging time, *t* (s)	3	3	3	3	3	3	3	3	3	3	3	3
12	10	Zero plane ht, *d* (m)												
13	30	If hilly terrain at site, check box	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly	☐ Hilly
14														



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
21		No. of terrain changes: *n*	4	4	6	8	2	2	2	3	5	2	5	3
22		Terrain roughness, z_0 (m)	0.45	0.005	0.50	0.50	0.50	0.50	0.50	0.005	0.50	0.50	0.10	0.50
23		Patch length, *x* (m)	500.00	300.00	900.00	4800.00	1500.00	4000.00	1000.00	300.00	1400.00	3100.00	300.00	2000.00
24		z_{01} (m)	0.70	0.70	0.005	0.005	0.30	0.30	0.30	0.50	0.005	0.30	0.50	0.10
25		x_1 (m)	400.00	400.00	400.00	400.00	17000.00	12000.00	16000.00	900.00	1400.00	20400.00	400.00	2100.00
26		z_{02} (m)	0.45	0.45	0.45	0.50	0.03	0.03	0.03	0.30	0.50	0.10	0.10	0.30
27		x_2 (m)	3600.00	4700.00	400.00	1400.00				18800.00	600.00		1300.00	11900.00
28		z_{03} (m)	0.30	0.30	0.70	0.005				0.10	0.30		0.50	0.10
29		x_3 (m)	12800.00	12600.00	600.00	400.00					1800.00		1800.00	
30		z_{04} (m)	0.03	0.03	0.45	0.30					0.005		0.30	
31		x_4 (m)			6200.00	1200.00					200.00		20300.00	
32		z_{05} (m)			0.30	0.005					0.20		0.10	
33		x_5 (m)			15000.00	4200.00								
34		z_{06} (m)			0.03	0.30								
35		x_6 (m)				6600								
36		z_{07} (m)				0.005								
37		x_7 (m)				400								
38		z_{08} (m)				0.03								

Appendix 4 CFD Technical Assumptions

Overview and application in pedestrian comfort

Analyses of pedestrian comfort generally consist of three components; historical wind data, aerodynamic measurements of the influence of the buildings, and comparison to a comfort criteria. In this case, the aerodynamic component has been calculated using computational fluid dynamics (CFD).

CFD is the general name for the simulation of fluid flows using computational numerical methods. In this case turbulent, isothermal, boundary-layer flows are computed around buildings in the region of interest. The resolved flow field can be sampled at points of interest, and incorporated with the historical weather data to compare to comfort criteria. The use of CFD for this application has been performed for decades, and with increases in computational power is becoming an increasingly attractive alternative to wind tunnel assessments. An overview of the field is provided by Blocken (2014).

Software, mesh and numerical method

The open-source tool OpenFOAM (version 2.4.x) has been used for the CFD simulations. OpenFOAM is a collection of C++ libraries which can be used to solve various fluid dynamics problems, along with utilities to perform axillary tasks. It is widely used across many fields in industry and academia.

The buildings of interest are placed inside a fluid domain which represents a subset of the earth's atmosphere. This domain is discretised, and the governing equations of fluid mechanics are approximated numerically at each location. The solvers in OpenFOAM are finite-volume based, and so require this discretisation to be similarly volume-based. The size of these discretised volumes, or "cells", affects the accuracy of the results and so studies have been performed to arrive at an acceptable volume size. Relatively large cells in the far filed have been reduced in size close to buildings of interest by the successive splitting of hexahedral cells in half in each dimension. Around the building of interest, the cell size is significantly smaller, such that the cube root of the volume is approximately 0.2m.

The Navier-Stokes equations are a set of partial differential equations describing motion of fluids. When average fields are of interest, these equations can be time-averaged using a method known as Reynolds-averaging to produce the Reynolds-Averaged Navier-Stokes (RANS) equations. These are the equations solved in the models in this case. In the RANS equations, the flow's unsteadiness is modelled using mathematical relationships known as closure models or turbulence models. Turbulence models are regarded as engineering approximations, and like any assumption used in a (physical or numerical) model will introduce discrepancy when compared to reality. For flows around bluff bodies, RANS methods generally perform well around high-velocity, geometry-driven separation zones, but struggle to accurately predict wake flow regions. However, simulations using these approximations have been shown to agree closely to experiment in most regions of interest, providing sufficient grid resolution is maintained (Millar 2016; Tominaga et. Al. 2005). In this case, the renormalized group theory (RNG) version (Yakhot et. Al. 1992) of the k-ε model, which introduce equations for turbulent kinetic energy and turbulent dissipation rate, is used as the turbulence model. This model and its coefficient values were selected based on the literature and comparison to experiment.

Inputs and assumptions

The building of interest is constructed at the centre of the domain, along with surrounding buildings to a radius of approximately 500m. A non-slip boundary condition is applied to these faces and the flow field is explicitly modelled around these obstructions. In the far-field, obstructions are approximated using a mathematical model which adjusts the flow field to approximate the roughness of the urban environment (ESDU 2012). The outlet and sides of the domain are extended a sufficient distance such that gradients at boundaries are minimal. Faces parallel to the flow are assigned a slip condition, and the downstream face a zero-gradient pressure outlet.

The velocity and turbulence specified at the inlet is specific to the site's topography and terrain. The velocity profile is dependent on vertical height (z) through:

$$u(z) = \frac{u_\tau}{\kappa} \ln \frac{z}{z + z_0}$$

where u_т is the friction velocity, κ=0.41 is the von Karman constant and z_0is the (sand grain) roughness height, which is dependent on the mean height of urban terrain surrounding the site. The boundary conditions for the turbulent fields k and ϵ follow guideline values which also are site-specific.

References

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ESDU 84011, 2012, 'Wind speed profiles over terrain with roughness changes', ESDU International.

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Yakhot, V., Orszag, S.A., Thangam, S., Gatski, T.B. & Speziale, C.G. (1992), 'Development of turbulence models for shear flows by a double expansion technique; Physics of Fluids A, Vol 4, No 7, pp 1510-1520.

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