

**TOWN AND COUNTRY PLANNING ACT 1990 (AS AMENDED) SECTION 78**

**TOWN AND COUNTRY PLANNING APPEALS (INQUIRIES PROCEDURE)  
RULES 2000**

**Appeal by: Fusion Manchester DevCo Ltd**

**Against refusal of planning permission for:**

**Full planning permission for a 28-storey purpose built student accommodation  
building (Sui Generis)**

**Land at Deansgate South  
Manchester**

**Planning Inspectorate Ref: APP/B4215/W/21/3287525  
Planning Application Ref: 129406/FO/2021**

**PROOF OF EVIDENCE APPENDICIES**

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## **Appendices**

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2. summary exported.xlsx (Wardell Armstrong, 22 Feb 2022)
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8. 12 Wind Microclimate FINAL DRAFT updated (Wardell Armstrong, 3rd March 2022)
9. Lawson, T.V. The determination of the wind environment of a building complex before construction. Bristol: University of Bristol, Department of Aeronautical Engineering, 1990 (Extract).

## **Appendix 1**

Wind Microclimate Guidelines for Development in the City of London, City of London  
and RWDI, August 2019



# WIND MICROCLIMATE GUIDELINES FOR DEVELOPMENTS IN THE CITY OF LONDON



AUGUST 2019

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# Introduction

**This document provides general guidelines for wind microclimate studies required as part of the planning applications of new development proposals in the City of London (CoL).**

Good wind microclimate conditions are necessary for creating outstanding public spaces in the City for all. Adverse wind effects can reduce the quality and usability of outdoor areas, and lead to safety concerns in extreme cases. These guidelines focus on the primary factors that affect the quality and consistency of wind microclimate studies.

Other factors such as temperature, sunlight, air quality and noise also have an influence on outdoor comfort, and some of these factors may be incorporated in a future edition of these guidelines.

The guidelines cannot cover every eventuality that may arise in such studies. Therefore, expert judgement from an experienced wind engineer will always be required in wind microclimate studies, particularly for issues that are not explicitly covered by these guidelines.

Developers are encouraged to address wind microclimate matters at an early stage before their designs are finalized. Using these guidelines, appointing experienced consultants, having dialogue with officers of the City and commissioning early-stage studies to quantify the wind microclimate conditions will help ensure good pedestrian comfort conditions around proposed development sites.

These guidelines may be updated from time to time, so users should check the City of London web site to ensure that the latest version of the guidelines are being used.

Wind studies may also be required for other purposes, such as obtaining loading conditions for the structure or for local fixings of facades and canopies. These issues are dealt with under the Building Regulations, and advice can be sought from the City's District Surveyor.





# Recommended approach for wind microclimate studies

The table below outlines the general expectations for the types of wind microclimate studies required for various building heights.

This table is specifically tailored for building proposals in the City of London. This table may not be suitable in other parts of London or in other cities where the height of general surroundings is lower than the typical building stock in the city.

Also, this table may not cover all possible eventualities and cases. Developments that feature highly sensitive pedestrian activities or affect more vulnerable groups (e.g. transport hubs, hospitals, elderly people’s homes, schools, nurseries, parks etc.) or those that are located near known windy or exposed areas (e.g. edge of Thames) may require more detailed checks. The wind consultant should use his/her judgement in consultation with the planning officers who have detailed local knowledge to determine whether the project they are working on has features that require extra care and attention.

| Building Height                                                                              | Recommended Approach to Wind Microclimate Studies                                                                                                                                                                                                         |
|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Similar or lower than the average height of surrounding buildings<br><b>Up to 25m in CoL</b> | Wind studies are not required, unless sensitive pedestrian activities are intended (e.g. around hospitals, transport hubs, etc.) or the project is located on an exposed location (e.g. edge of Thames, near a tall building)                             |
| Up to double the average height of surrounding buildings<br><b>25m to 50m in CoL</b>         | Computational (CFD) Simulations <b>OR</b> Wind Tunnel Testing                                                                                                                                                                                             |
| Up to 4 times the average height of surrounding buildings<br><b>50m to 100m for CoL</b>      | Computational (CFD) Simulations <b>AND</b> Wind Tunnel Testing                                                                                                                                                                                            |
| High-Rise<br><b>Above 100m</b>                                                               | <b>Early Stage Massing Optimization:</b> Wind Tunnel Testing OR Computational (CFD) Simulations<br><br><b>Detailed Design:</b> Wind Tunnel Testing <b>AND</b> Computational (CFD) Simulations to demonstrate the performance of the final building design |

Where both wind tunnel and CFD are required, the two wind modelling approaches must be carried out by independent consultants.

Where there are differences between wind tunnel and CFD results, a report should be prepared to identify potential reasons for differences, sensitivity checks (e.g. grid sensitivity, surround extend sensitivity, turbulence generation in the wind tunnel, etc.) and a summary of the most representative set of wind conditions around the proposed scheme.

## General technical requirements

**The wind study should include the evaluation of pedestrian level wind conditions for following scenarios;**

- Existing site,
- Proposed scheme with existing surroundings,
- Proposed scheme with planning consented schemes,
- Existing site with planning consented schemes, should the wind conditions for the previous case exceed the required Lawson comfort or safety categories,
- (If mitigation measures are required) the cases above with wind mitigation or improvement features,
- (If applicable or requested by CoL) proposed scheme with a likely future scenario, including buildings that may not be consented but are being designed at the time of planning submission. Discussion with planning officers can help identifying such future buildings.
- (If applicable or requested by CoL) the construction scenario with a demolished (vacant) site, especially if the existing building is taller than 40m in height.

**When choosing the planning consented or future schemes for inclusion in the studies, the planning consultants should liaise with CoL, and use the following guidelines;**

- Consented/future buildings that are immediately around the proposed development must be included, regardless of their height,
- Consented/future buildings that are taller than the average height of surrounding buildings and are within 300m of the site need to be included.

**Information for consented buildings is publicly available at the CoL planning portal or could be requested from the relevant design team. CoL planning officers can provide guidance on future schemes and assist in obtaining information for such schemes (if any).**

**There are four key steps to a successful wind microclimate study;**

1. Selecting appropriate wind statistics for the site (see Annex A for City of London wind statistics),
2. Determining the impact of the proposed development, through computational fluid dynamics (CFD) tools and/or wind tunnel testing, which provide a set of 'speed-up' ratios,
3. Combination of speed-up ratios with wind statistics to obtain comfort ratings,

4. Comparison of comfort ratings with intended pedestrian activities using the criteria provided in this guideline, as well as interpretation and presentation of results as covered separately in chapter 6.

**Wind characteristics:** statistical properties of wind climate are typically characterized by a Weibull probability density function. Annex A provides seasonal Weibull coefficients that can be used for projects in the heart of City of London (i.e. Terrain corrected for City of London). For projects on more exposed parts of the city – e.g. next to river Thames – an adjustment to these coefficients is required to take account of the site exposure, as described in Annex A.

**These climate properties have been calibrated for City of London, and may not be appropriate for other parts of London or other cities.**

Number of wind directions: all wind studies should be carried out for 36 equally spaced wind directions.

**Wind profile:** the variation of mean and gust wind speed with height should be modelled based on the wind profiles given in Annex A. Plots of simulated (wind tunnel or CFD) and targeted profile (Annex A) should be provided as part of the planning report.

Determination of speed-ups: computational fluid dynamics (CFD) tools or wind tunnel tests should be used to determine speed-up ratios for each individual wind direction. Speed-ups are defined as the ratio of local wind speed at pedestrian-level locations to the undisturbed reference wind speed. The pedestrian-level wind speeds should be measured at a height of 1.5m above the local ground level (or terrace/balcony level), and the reference wind speed should be determined at a height and location where the building models do not affect the reference speed measurement.

**Measurement locations:** critical pedestrian-level locations include building entrances, walkways, sitting areas, drop-off locations, bus stops, disabled parking bays, queuing areas, upper-level terraces, balconies, and other frequently used locations. Cycling paths and road crossings will also require measurements. The consultant should use expert judgement to ascertain the extent of the area to instrument and report.

**Combination of speed-ups with wind statistics:** using CFD or wind tunnel, a set of speed-ups will be determined for each wind direction simulated. These need to be combined with the Weibull probability distribution of the wind climate given in Annex A, to calculate the probability of exceedance of a given wind speed for each wind direction. Adding the probability of exceedance for all directions gives the total probability of exceedance of a given wind speed.

The estimation of comfort or safety speed usually requires a goal-seek calculation, where a certain wind speed is selected, the total probability of exceedance is calculated, and the wind speed is continually altered until the probability of exceedance reaches the desired exceedance value. Note that the CoL Lawson Criteria uses 5% exceedance for comfort and 0.022% Exceedance for safety limits, as described subsequently.



Above and below: RWDI's wind testing tunnel (RWDI)



## Wind tunnel test requirements

**Wind tunnel testing has been used to assess pedestrian microclimate conditions for the past several decades. However, significant variability in methodology can exist between different test facilities, and care should be taken to ensure the quality and consistency of wind tunnel tests.**

Wind tunnel models should accurately represent the three-dimensional geometry of the proposed development. It is noted that building features that project more than 0.5m near pedestrian areas can affect the localized wind conditions, and must therefore be modelled for the proposed building and existing buildings immediately around the site. Also, building geometry near entrances and key pedestrian areas could affect the results and must be included in the models.

It is prudent to ignore landscape features in the baseline wind studies, especially when the landscape elements are smaller than 8m in height. Larger mature trees can be included, but limited published guidance exists for modelling such landscape features, so care should be taken to provide appropriately conservative interpretation of their impacts.

The wind tunnel models should represent all surrounding buildings that are within 400m from the centre of the site. Other taller buildings outside of this zone that could have an influence on wind conditions within the project site – based on the expert opinion of the wind consultant – should be included for wind directions where they are upwind of the project site.

The overall blockage in the wind tunnel (percent of tunnel area occupied by models) should be kept below 5% for closed-circuit wind tunnels and 8% for open-jet or blockage tolerant wind tunnels (in accordance of published wind tunnel testing guidelines such as ASCE SEI and AWES QAM).

The instrumentation used in the wind tunnel should be capable of capturing both the mean (typically 10-15 minute averaged) and gust speeds, with gust values divided by 1.85 To make them comparable to mean values (also referred to as gust equivalent mean value). Instrumentation should not be blocked or impeded by the models.

Care should be taken to ensure that in areas with significant localized variation of wind speed (e.g. near corners) that there are sufficient number of probes to be able to capture the windiest conditions. This typically requires 3 probes at each corner of the proposed development, in areas of increased windiness, and increased probe densities in passageways, between closely spaced buildings, and near key pedestrian areas. Furthermore, probes should be placed on the roadways surrounding the site, to capture possible impacts on cyclists.

Probes should also be placed in areas away from the site where cumulative effects of a cluster of tall buildings could lead to adverse wind conditions. The wind consultant should be aware of the wind conditions expected around other cumulative or existing high-rise buildings, by reviewing the publicly available planning reports on the City of London planning portal.



## CFD requirements

**Computational fluid dynamics (CFD) tools can create high quality output that provide a good understanding of fundamental flow features. However, significant variability in methodology can exist between different CFD methods and care should be taken to ensure that appropriate modelling approaches are used.**

The CFD models must include a detailed three-dimensional representation of the proposed development. It is noted that building features that project more than 0.5m near pedestrian areas can affect the localized wind conditions, and must therefore be modelled for the proposed building and existing buildings immediately around the site. Also, building geometry near entrances and key pedestrian areas could affect the results and must be included in the models.

It is prudent to ignore landscape features in the baseline wind studies, especially when the landscape elements are smaller than 8m in height. Large mature trees can be included, but limited published guidance exists for modelling such landscape features, so care should be taken to provide appropriately conservative interpretation of their impacts.

Maximum cell sizes near critical locations (e.g. entrances, corners, etc.) must be 0.3m or smaller. It is also expected that sufficient cells are used between buildings with a minimum of 10 across a street canyon. However, the cell size of buildings away from the target can be larger to allow for modelling efficiency.

The CFD models should represent all surrounding buildings that are within 400m from the centre of the site. Other taller buildings outside of this zone that could have an influence on wind conditions within the project site – based on the expert opinion of the wind consultant - should be included for wind directions where they are upwind of the project site.

The models must contain at least 3 prism layers below 1.5m height, to capture near-ground effects.

The standard k-epsilon model, or 0 or 1 equation models, should be avoided. The realisable k-epsilon model is currently a robust industry standard, and other turbulence models - such as k-omega SST - can be used if the user can demonstrate that the mesh is suitable for that model.

CFD analysis should report conditions in areas away from the site where cumulative effects of a cluster of tall buildings could lead to adverse wind conditions. The wind consultant should be aware of the wind conditions expected around other cumulative or existing high-rise buildings, by reviewing the publicly available planning reports on the City of London planning portal.



## Using wind tunnel and CFD in combination

**On some projects wind tunnel testing and CFD are both required for a more comprehensive evaluation. In these situations, two aspects need to be considered;**

It is possible to use the two tools to get a more comprehensive understanding of wind effects around a site. For example, CFD results can guide the placement of wind tunnel probes, or highlight the mechanisms of the fundamental wind patterns which can then be further studied in the wind tunnel. Similarly, the transient data collection provided by the wind tunnel tests may identify areas of high turbulence (gusts) which could inform the type of detail of CFD modelling.

Where there are differences between wind tunnel and CFD results, an experienced wind engineer should carry out sensitivity checks (e.g. grid sensitivity, surround extend sensitivity, turbulence generation in the wind tunnel, etc.) To better understand the likely reasons for the differences and summarize the most representative set of wind conditions around the proposed scheme.

# Presentation of results and reporting

**Wind comfort criteria:** a modified version of the Lawson LDDC criteria referred to as the City Lawson Criteria - is to be used for all wind studies as summarized table below;

| Category           | Mean and GEM wind speed (5% exceedance) | Description                                                                                                                             |
|--------------------|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Frequent Sitting   | 2.5m/s                                  | Acceptable for frequent outdoor sitting use, e.g. restaurant, café.                                                                     |
| Occasional Sitting | 4m/s                                    | Acceptable for occasional outdoor seating, e.g. general public outdoor spaces, balconies and terraces intended for occasional use, etc. |
| Standing           | 6m/s                                    | Acceptable for entrances, bus stops, covered walkways or passageways beneath buildings.                                                 |
| Walking            | 8m/s                                    | Acceptable for external pavements, walkways.                                                                                            |
| Uncomfortable      | >8m/s                                   | Not comfortable for regular pedestrian access.                                                                                          |

The table above deviates from the original Lawson LDDC Criteria in a couple of areas,

- The ‘Frequent Sitting’ category is based on City of London’s desire to create more active public spaces with amenable cafés/restaurant sitting areas in the future.
- The ‘Uncomfortable’ category is based on experience that Lawson business walking conditions often lead to complaints in the City of London. Therefore, this category is now re-named as ‘uncomfortable’. This category is only suitable for areas that are not expected to receive regular public footfall, like service areas, back-of-house areas, etc.
- Discussions with City of London planning officers about the categorisation of sensitive areas would be highly recommended.

**Wind safety criteria:** a separate safety criteria is to be applied to ascertain the safety risks to pedestrians and cyclists as follows;

| Category                | Mean and GEM wind speed from any wind direction (0.022% exceedance) | Description                                                                                  |
|-------------------------|---------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| Pedestrian Safety Limit | 15m/s                                                               | Presents a safety risk for pedestrians, especially to more vulnerable members of the public. |

The criteria do not cover wind effects on other activities such as recreation (e.g. sailing) or impact on specific vehicles. More research needs to be conducted to expand the applicability of the criteria for such cases.

**Seasonal results:** a ‘worst season’ scenario should be presented, where the worst comfort conditions at each location are provided regardless of the season. Separately a summer season (June-July-August) results should be presented, for areas that are to be used mainly in warmer months of the year. Other seasonal results can be provided at the discretion of the wind consultant.

**Safety conditions should be reported annually.**

**Presentation of results:** the comfort conditions should be presented using a colour-coded diagram using the colour coding below. Wind safety results can be overlaid on top of the comfort results, such that any red zone indicates unacceptable or unsafe condition. Alternatively, a separate plot showing the safety conditions can be provided, in addition to the comfort plot.

| Comfort Category            | Colour |
|-----------------------------|--------|
| Frequent Sitting            | Grey   |
| Occasional Sitting          | Blue   |
| Standing                    | Green  |
| Walking                     | Yellow |
| Uncomfortable and/or Unsafe | Red    |

**Acceptability of wind conditions:** a detailed review of the intended pedestrian activities around the site should be carried out, and graphically presented and described in the planning submission. This should include the expected pedestrian activities around the proposed development, as well as the pedestrian activities experienced or proposed around existing buildings in the area. The review should take in to account of groups who are more vulnerable to wind conditions such as wheelchair users, people with ambulant mobility impairment, people who are blind, partially sighted or have sensory/neurological processing difficulties, elderly people, pregnant women and young children. If the conditions at any location exceed the levels required for the intended pedestrian activities - or are unsafe - because of the impact of the proposed development, mitigation measures will be required.

**Existing wind problems:** if the existing site or the consented schemes give rise to exceedances of the comfort or safety criteria for the intended pedestrian uses, this should be clearly demonstrated by testing these configurations (i.e. without proposed scheme). The proposed development should not increase the comfort or safety conditions beyond the levels observed for these scenarios.

**Presentation of the test configurations:** the report should contain detailed photographs or images of the 3D CFD or wind tunnel used in the analysis. This is expected to include;

- Far-field views of the entire model from north, south, east and west as a minimum,
- Plan view of the entire model,
- Close-up images of the proposed scheme and surrounding buildings within 1 block away from the site,
- Close-up views of key pedestrian areas, such as entrances, key pedestrian walkways, outdoor seating areas, etc.,
- Other building details or appendages that are relevant for wind conditions.

**Presentation of mitigation measures:** the following details of each mitigation measure or improvement feature should be provided;

- Plan showing the location of each mitigation measure, with each measure given an identifier number,
- Images of each mitigation measure as tested in the wind tunnel or CFD model (preferably accompanied by an architectural diagram/interpretation),
- Table containing the size (height, width, depth), porosity and other relevant aerodynamic parameters (e.g. tree trunk and crown heights).

These requirements apply even if the design feature is not materially categorized as a mitigation measure, but helps to improve the wind conditions. It is intended that all features that improve the wind conditions become an intrinsic part of the building design and are fully implemented on-site.

**Significance criteria:** it is noted that environmental impact assessments (EIA) require a description of the significance of wind effects at a particular location. This section is intended to provide consistency in these significance descriptors.

Whether a condition is significant or not depends on whether the condition requires mitigation. The tables in the following sections also include a column that defines if mitigation measures are necessary.

The significance of on-site measurement locations are defined by comparing the wind comfort/safety levels with the intended pedestrian activity at each location, using the table opposite;

| On-site Receptors   |                                                                                                         |                      |
|---------------------|---------------------------------------------------------------------------------------------------------|----------------------|
| Significance        | Trigger                                                                                                 | Mitigation required? |
| Major Adverse       | Conditions are 'unsafe'.                                                                                | Yes                  |
| Moderate Adverse    | Conditions are 'unsuitable' (in terms of comfort) for the intended pedestrian use.                      | Yes                  |
| Negligible          | Conditions are 'suitable' for the intended pedestrian use.                                              | No                   |
| Moderate Beneficial | Conditions are calmer than required for the intended pedestrian use (by at least one comfort category). | No                   |

The significance of off-site measurement locations are defined not only by comparing the wind comfort levels with the intended pedestrian activity, but also by comparing the conditions to those experienced prior to the introduction of the proposed development (baseline), using the table below;

| Off-site Receptors  |                                                                                                                                                                                                                                                                                                                                                                                          |                      |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|
| Significance        | Trigger                                                                                                                                                                                                                                                                                                                                                                                  | Mitigation required? |
| Major Adverse       | Conditions that were 'safe' in the baseline scenario become 'unsafe' as a result of the Proposed Development.<br>OR<br>Conditions that were 'suitable' in terms of comfort in the baseline scenario become 'unsuitable' as a result of the Proposed Development.<br>OR<br>Conditions that were 'unsafe' in the baseline scenario are made worse as a result of the Proposed Development. | Yes                  |
| Moderate Adverse    | Conditions that were 'suitable' in terms of comfort in the baseline scenario are made windier (by at least one comfort category) as a result of the Proposed Development, but remain 'suitable' for the intended pedestrian activity.                                                                                                                                                    | No                   |
| Negligible          | Conditions remain the same as in the baseline scenario.                                                                                                                                                                                                                                                                                                                                  | No                   |
| Major Beneficial    | Conditions that were 'unsafe' in the baseline scenario become 'safe' as a result of the Proposed Development.                                                                                                                                                                                                                                                                            | No                   |
| Moderate Beneficial | Conditions that were 'unsuitable' in terms of comfort in the baseline scenario become 'suitable' as a result of the Proposed Development.<br>OR<br>Conditions that were 'unsafe' in the baseline scenario are made better as a result of the Proposed Development (but not so as to make them 'safe').                                                                                   | No                   |

## Cyclist comfort

**Background:** cycling is an increasingly important way of moving around and through the city and is proactively promoted by the city. As a result, ensuring comfort and safety for those cycling is a priority for the city. Wind effects can have a major impact on cycling comfort and safety. In extreme cases, particularly the cross-winds can destabilize or push the cyclist into the path of vehicles. With increasing number of cyclists in the City of London this is an important consideration.

There are other factors that influence the stability of a cyclist, such as weight, side area, proximity to other vehicles/cyclists, speed of travel and the ability/experience of the rider. It is also likely that most cyclists will take some precautions on windy days. However, it is not possible to statistically quantify many of these parameters.

But it is possible to use local wind speed, wind direction and gust duration to make informed decisions on cyclist safety.

**Cyclist safety criterion:** the LDDC Lawson Criteria notes that the 15m/s safety criteria (from any wind direction exceeded at least once a year) is applicable for cyclists but does not provide a detailed description of how such wind conditions affect riders.

CoL wishes to provide a higher degree of comfort and safety for the increasing number of cyclists on the roads. This section of the guideline builds upon the Lawson criteria to provide a more robust assessment, particularly focussing on the cross-wind gust effects.

CoL wishes to ensure that design teams carefully consider the impact of a local wind conditions on cyclists. The following key considerations are recommended;

The wind consultants should ensure that adequate number of instruments or data collection points are placed along the main roadways, cycle paths and road/pedestrian crossings. For wind tunnel studies this will typically involve one probe at least every 40m on cycling paths immediately around the proposed development.

Areas where the wind speeds rapidly change along a cyclist path (e.g. cyclist travels from a sheltered zone to a wind zone in a short space) can cause distress for cyclists. Therefore, it is expected that wind consultants will focus their attention to such zones – typically near building corners – by increasing the density of measurements and modelling detail in these areas.

The gustiness of local wind conditions also influences cyclist safety and comfort. It is expected that wind tunnel and CFD studies will be carefully interpreted to assess gust effects on all cycling paths.



If the Lawson safety limit is exceeded at any cycling location, appropriate mitigation measures will need to be implemented to improve the conditions.

It is noted that these simplified guidelines do not take account of rider speed, effective angle of wind direction and other important parameters. In the future editions of these guidelines it is hoped that a more comprehensive cyclist safety limit can be defined.

It is also noted that the above limits only apply to commuter cyclists, and not for special cycling events (such as races) where the speed of riders may be a much more significant factor.

# Annex A: Wind climate properties

## Introduction

The parameters in the tables below should be used to generate a statistical model of the wind frequency (by speed and direction) for the City of London. Please note that these parameters have been scaled specifically to account for the terrain around the City of London, and are not valid for use in other areas.

## Usage

Parameters  $c$  and  $k$  are the scale and shape factors respectively for use in calculating a Weibull probability distribution. Parameter  $p$  is the probability that wind will approach from a given direction. These parameters can be used in combination with the measured local wind speeds from a wind tunnel test or CFD simulation to determine the probability of exceeding a given wind speed at a given measurement location during a given season.

Probability of exceedance at a given location (for comparison against the CoL Lawson Criteria) is calculated as follows. For each measurement location:

1. Measure the local wind speed for each wind angle using wind tunnel testing or CFD simulation, and express this speed as a ratio over the wind speed at a known reference height upwind of the site;

Note: the reference height should ideally be greater than 100m above the ground, and should be sufficiently far upwind so as not to be directly influenced by the modelled surrounding buildings.

2. Multiply the wind speed ratio by the factor in table 1 corresponding to the chosen reference height.

Note: the probability distributions have been scaled to reference height of 120m above ground, hence the factor in table 1 for 120m is equal to 1.

Note: for reference heights not specified in table 1, you may interpolate between the specified values.

3. Multiply the factored wind speed ratio for each angle by the corresponding parameter  $c$  in table 2 (or use table 3 if using more than 18 wind directions). Repeat for each season and annually.
4. For each angle, calculate the probability of exceedance of each threshold in the criteria (using the parameters for each season for comfort, and using the annual parameters for the safety threshold) using the following formula:

$$f_{(x)} = p \cdot e^{-\left(\frac{x}{c}\right)^k}$$

and sum across all angles to arrive at the total probability of exceedance for that season.

Note: alternatively, you may choose to calculate the wind speed  $x$  exceeded for 5% and 0.022% of the time. In this case please note that the wind speed should be calculated for a total probability across all wind angles, and not for individual angles. This would likely require a “goal seek” or “solver”-type method, depending on how and in what programming language the calculation is implemented.

5. Compare the seasonal results against the comfort criteria to determine the suitability of the location in terms of comfort, and the annual result against the safety criterion to determine whether the location is safe or not.

Note: if both mean and gust-equivalent mean velocities have been measured (as in the methodology for wind tunnel testing, set out in the main document), then this process should be repeated for both sets of velocities. The worse category of the two assessments should be taken to determine comfort and safety.

## Background

These probability distributions have been developed based on historical wind data from London Heathrow Airport (LHR) and London City Airport (LCY). The data range from LHR covers the period from 1973 to 2017, and the data from LYC covers the period from 1988 to 2017. Both data sets have been checked for data quality, with erroneous data points being removed from the set prior to fitting a Weibull distribution curve.

Data from each airport has been corrected to “open country” conditions at 10m height, to account for the effects of nearby terrain, using the methodology set out in ESDU 01008. The terrain-corrected data has subsequently been scaled again to represent specific terrain conditions in and around the City of London (again using the methodology set out in ESDU 01008).

| Reference height [m] | Scale factor |
|----------------------|--------------|
| 100                  | 0.96         |
| 120                  | 1.00         |
| 160                  | 1.07         |
| 200                  | 1.13         |
| 250                  | 1.19         |
| 300                  | 1.24         |
| 450                  | 1.37         |
| 600                  | 1.48         |

Table 1: Reference height scale factors

**Table 2:** Weibull parameters (c scaled to reference height of 120m above ground)

36 Wind directions (10° increments)

| Season                | Annual |       |       |       |       |       |       |       |       |       |       |       |
|-----------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Direction             | 0      | 10    | 20    | 30    | 40    | 50    | 60    | 70    | 80    | 90    | 100   | 110   |
| p                     | 0.021  | 0.020 | 0.024 | 0.026 | 0.023 | 0.021 | 0.020 | 0.020 | 0.021 | 0.028 | 0.021 | 0.015 |
| c [ms <sup>-1</sup> ] | 4.63   | 5.06  | 5.40  | 5.65  | 5.85  | 6.07  | 6.29  | 6.45  | 6.77  | 6.66  | 6.38  | 5.71  |
| k                     | 1.70   | 1.80  | 1.87  | 1.92  | 1.99  | 2.07  | 2.08  | 2.06  | 2.09  | 2.16  | 2.20  | 2.18  |
| Direction             | 120    | 130   | 140   | 150   | 160   | 170   | 180   | 190   | 200   | 210   | 220   | 230   |
| p                     | 0.013  | 0.013 | 0.013 | 0.014 | 0.015 | 0.020 | 0.025 | 0.033 | 0.041 | 0.056 | 0.057 | 0.053 |
| c [ms <sup>-1</sup> ] | 5.36   | 5.26  | 5.21  | 5.27  | 5.50  | 5.72  | 5.98  | 6.34  | 6.67  | 6.89  | 6.91  | 7.03  |
| k                     | 2.11   | 2.08  | 2.03  | 1.92  | 1.83  | 1.79  | 1.81  | 1.87  | 1.92  | 1.96  | 1.99  | 2.04  |
| Direction             | 240    | 250   | 260   | 270   | 280   | 290   | 300   | 310   | 320   | 330   | 340   | 350   |
| p                     | 0.055  | 0.058 | 0.044 | 0.043 | 0.034 | 0.030 | 0.025 | 0.023 | 0.020 | 0.020 | 0.018 | 0.020 |
| c [ms <sup>-1</sup> ] | 7.06   | 6.90  | 6.58  | 6.02  | 5.67  | 5.37  | 5.13  | 5.02  | 4.86  | 4.79  | 4.72  | 4.64  |
| k                     | 2.01   | 1.88  | 1.78  | 1.64  | 1.58  | 1.57  | 1.63  | 1.69  | 1.73  | 1.70  | 1.65  | 1.64  |

| Season                | Spring |       |       |       |       |       |       |       |       |       |       |       |
|-----------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Direction             | 0      | 10    | 20    | 30    | 40    | 50    | 60    | 70    | 80    | 90    | 100   | 110   |
| p                     | 0.024  | 0.026 | 0.035 | 0.038 | 0.034 | 0.030 | 0.028 | 0.027 | 0.028 | 0.033 | 0.022 | 0.014 |
| c [ms <sup>2</sup> ]  | 5.02   | 5.47  | 5.94  | 6.24  | 6.46  | 6.62  | 6.79  | 6.84  | 7.08  | 6.94  | 6.65  | 6.00  |
| k                     | 1.83   | 1.92  | 2.01  | 2.06  | 2.14  | 2.20  | 2.23  | 2.21  | 2.22  | 2.28  | 2.30  | 2.25  |
| Direction             | 120    | 130   | 140   | 150   | 160   | 170   | 180   | 190   | 200   | 210   | 220   | 230   |
| p                     | 0.011  | 0.012 | 0.012 | 0.013 | 0.014 | 0.019 | 0.024 | 0.030 | 0.037 | 0.048 | 0.046 | 0.041 |
| c [ms <sup>-1</sup> ] | 5.63   | 5.53  | 5.48  | 5.44  | 5.55  | 5.80  | 6.01  | 6.28  | 6.65  | 6.92  | 6.92  | 6.98  |
| k                     | 2.15   | 2.13  | 2.14  | 2.03  | 1.93  | 1.89  | 1.91  | 1.96  | 2.02  | 2.05  | 2.04  | 2.06  |
| Direction             | 240    | 250   | 260   | 270   | 280   | 290   | 300   | 310   | 320   | 330   | 340   | 350   |
| p                     | 0.041  | 0.049 | 0.040 | 0.039 | 0.030 | 0.027 | 0.023 | 0.022 | 0.020 | 0.020 | 0.020 | 0.022 |
| c [ms <sup>-1</sup> ] | 7.08   | 7.19  | 6.97  | 6.52  | 6.20  | 5.89  | 5.50  | 5.23  | 5.00  | 4.97  | 5.04  | 5.02  |
| k                     | 2.09   | 2.04  | 1.90  | 1.78  | 1.69  | 1.64  | 1.66  | 1.71  | 1.77  | 1.78  | 1.82  | 1.82  |

| Season                | Summer |       |       |       |       |       |       |       |       |       |       |       |
|-----------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Direction             | 0      | 10    | 20    | 30    | 40    | 50    | 60    | 70    | 80    | 90    | 100   | 110   |
| p                     | 0.020  | 0.018 | 0.020 | 0.022 | 0.020 | 0.017 | 0.016 | 0.015 | 0.019 | 0.028 | 0.021 | 0.014 |
| c [ms <sup>-1</sup> ] | 4.42   | 4.85  | 5.16  | 5.41  | 5.60  | 5.81  | 5.90  | 6.05  | 6.57  | 6.76  | 6.66  | 5.94  |
| k                     | 1.98   | 2.08  | 2.18  | 2.21  | 2.21  | 2.19  | 2.14  | 2.17  | 2.28  | 2.38  | 2.40  | 2.34  |
| Direction             | 120    | 130   | 140   | 150   | 160   | 170   | 180   | 190   | 200   | 210   | 220   | 230   |
| p                     | 0.010  | 0.009 | 0.008 | 0.010 | 0.011 | 0.015 | 0.021 | 0.029 | 0.041 | 0.063 | 0.064 | 0.056 |
| c [ms <sup>-1</sup> ] | 5.44   | 5.18  | 4.96  | 4.94  | 5.08  | 5.22  | 5.41  | 5.74  | 6.15  | 6.47  | 6.49  | 6.51  |
| k                     | 2.21   | 2.10  | 2.10  | 2.06  | 2.04  | 2.05  | 2.13  | 2.24  | 2.30  | 2.26  | 2.24  | 2.25  |
| Direction             | 240    | 250   | 260   | 270   | 280   | 290   | 300   | 310   | 320   | 330   | 340   | 350   |
| p                     | 0.059  | 0.064 | 0.050 | 0.050 | 0.039 | 0.033 | 0.029 | 0.025 | 0.023 | 0.022 | 0.019 | 0.019 |
| c [ms <sup>-1</sup> ] | 6.55   | 6.54  | 6.34  | 6.02  | 5.67  | 5.37  | 5.08  | 4.86  | 4.64  | 4.49  | 4.42  | 4.38  |
| k                     | 2.23   | 2.20  | 2.15  | 2.10  | 2.07  | 2.00  | 1.92  | 1.90  | 1.93  | 1.97  | 1.96  | 1.95  |

| Season                | Autumn |       |       |       |       |       |       |       |       |       |       |       |
|-----------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Direction             | 0      | 10    | 20    | 30    | 40    | 50    | 60    | 70    | 80    | 90    | 100   | 110   |
| p                     | 0.021  | 0.020 | 0.020 | 0.020 | 0.017 | 0.016 | 0.017 | 0.018 | 0.019 | 0.027 | 0.021 | 0.017 |
| c [ms <sup>-1</sup> ] | 4.42   | 4.79  | 4.90  | 4.86  | 4.87  | 5.07  | 5.39  | 5.76  | 6.20  | 6.18  | 5.96  | 5.43  |
| k                     | 1.67   | 1.75  | 1.74  | 1.78  | 1.86  | 1.98  | 2.02  | 2.04  | 2.08  | 2.15  | 2.14  | 2.08  |
| Direction             | 120    | 130   | 140   | 150   | 160   | 170   | 180   | 190   | 200   | 210   | 220   | 230   |
| p                     | 0.016  | 0.017 | 0.016 | 0.018 | 0.019 | 0.023 | 0.028 | 0.035 | 0.043 | 0.058 | 0.059 | 0.055 |
| c [ms <sup>-1</sup> ] | 5.25   | 5.24  | 5.17  | 5.13  | 5.30  | 5.43  | 5.66  | 6.00  | 6.33  | 6.48  | 6.49  | 6.72  |
| k                     | 2.02   | 2.07  | 2.10  | 1.98  | 1.89  | 1.85  | 1.86  | 1.87  | 1.91  | 1.94  | 1.99  | 2.03  |
| Direction             | 240    | 250   | 260   | 270   | 280   | 290   | 300   | 310   | 320   | 330   | 340   | 350   |
| p                     | 0.056  | 0.057 | 0.040 | 0.039 | 0.033 | 0.030 | 0.026 | 0.024 | 0.020 | 0.019 | 0.017 | 0.021 |
| c [ms <sup>-1</sup> ] | 6.88   | 6.75  | 6.26  | 5.82  | 5.51  | 5.16  | 4.87  | 4.76  | 4.74  | 4.73  | 4.60  | 4.46  |
| k                     | 2.03   | 1.93  | 1.79  | 1.68  | 1.66  | 1.64  | 1.67  | 1.68  | 1.70  | 1.69  | 1.63  | 1.63  |

| Season                | Winter |       |       |       |       |       |       |       |       |       |       |       |
|-----------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Direction             | 0      | 10    | 20    | 30    | 40    | 50    | 60    | 70    | 80    | 90    | 100   | 110   |
| p                     | 0.018  | 0.018 | 0.022 | 0.023 | 0.021 | 0.020 | 0.020 | 0.019 | 0.019 | 0.023 | 0.019 | 0.014 |
| c [ms <sup>-1</sup> ] | 4.50   | 4.82  | 5.07  | 5.45  | 5.82  | 6.20  | 6.60  | 6.76  | 6.89  | 6.56  | 6.20  | 5.44  |
| k                     | 1.51   | 1.62  | 1.68  | 1.77  | 1.91  | 2.04  | 2.07  | 1.98  | 1.93  | 1.97  | 2.07  | 2.15  |
| Direction             | 120    | 130   | 140   | 150   | 160   | 170   | 180   | 190   | 200   | 210   | 220   | 230   |
| p                     | 0.013  | 0.014 | 0.014 | 0.015 | 0.017 | 0.023 | 0.028 | 0.037 | 0.044 | 0.057 | 0.060 | 0.059 |
| c [ms <sup>-1</sup> ] | 5.06   | 5.00  | 5.11  | 5.49  | 6.01  | 6.27  | 6.60  | 7.04  | 7.32  | 7.53  | 7.52  | 7.65  |
| k                     | 2.11   | 2.04  | 1.91  | 1.83  | 1.82  | 1.78  | 1.80  | 1.86  | 1.90  | 1.95  | 1.99  | 2.05  |
| Direction             | 240    | 250   | 260   | 270   | 280   | 290   | 300   | 310   | 320   | 330   | 340   | 350   |
| p                     | 0.062  | 0.065 | 0.045 | 0.042 | 0.035 | 0.029 | 0.023 | 0.020 | 0.017 | 0.016 | 0.015 | 0.017 |
| c [ms <sup>-1</sup> ] | 7.77   | 7.67  | 7.21  | 6.71  | 6.29  | 5.89  | 5.53  | 5.34  | 5.08  | 4.98  | 4.79  | 4.55  |
| k                     | 2.05   | 1.93  | 1.78  | 1.67  | 1.63  | 1.61  | 1.62  | 1.65  | 1.64  | 1.58  | 1.49  | 1.44  |

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## **Appendix 2**

summary exported.xlsx (Wardell Armstrong, 22 Feb 2022)

## Summary

|                   |             |            |           | Comfort Criteria |             |            | Safety Criteria |          |             |          |
|-------------------|-------------|------------|-----------|------------------|-------------|------------|-----------------|----------|-------------|----------|
| Reference Station |             |            |           | DataCount        | AvRefWSpd   | MaxRefWSpd | Probability     | RefWSpd  | Probability | RefWSpd  |
| Direction         | Probability | Scale (c)  | Shape (k) |                  | Upot = V    |            | Exceeded 1      | Vref 1   | Exceeded 2  | Vref 2   |
| 0                 | 0.008960452 | 2.52575987 | 2.072527  | 2389             | 2.237289494 | 7.4411     | 0.05            | 4.288506 | 0.00022     | 8.869546 |
| 10                | 0.010862064 | 2.6396951  | 2.060388  | 2896             | 2.338353971 | 7.8357     | 0.05            | 4.495959 | 0.00022     | 8.869546 |
| 20                | 0.014248957 | 2.88962317 | 2.027365  | 3799             | 2.560285891 | 8.2624     | 0.05            | 4.964515 | 0.00022     | 8.869546 |
| 30                | 0.017583341 | 2.9844245  | 2.160995  | 4688             | 2.64301747  | 7.5023     | 0.05            | 4.958636 | 0.00022     | 8.869546 |
| 40                | 0.020872716 | 3.15855937 | 2.219566  | 5565             | 2.797397394 | 8.3588     | 0.05            | 5.178119 | 0.00022     | 8.869546 |
| 50                | 0.023760765 | 3.17683839 | 2.395419  | 6335             | 2.816111586 | 7.3019     | 0.05            | 5.022474 | 0.00022     | 8.869546 |
| 60                | 0.024510907 | 3.21805178 | 2.515001  | 6535             | 2.855687437 | 8.1826     | 0.05            | 4.978028 | 0.00022     | 8.869546 |
| 70                | 0.023074384 | 3.3401496  | 2.444225  | 6152             | 2.962060013 | 7.3856     | 0.05            | 5.232587 | 0.00022     | 8.869546 |
| 80                | 0.019923786 | 3.24008852 | 2.254178  | 5312             | 2.869885674 | 7.7256     | 0.05            | 5.271612 | 0.00022     | 8.869546 |
| 90                | 0.018265971 | 3.01046185 | 2.153003  | 4870             | 2.66608499  | 7.3017     | 0.05            | 5.011334 | 0.00022     | 8.869546 |
| 100               | 0.019991298 | 2.7994951  | 2.172528  | 5330             | 2.479243959 | 9.3152     | 0.05            | 4.638855 | 0.00022     | 8.869546 |
| 110               | 0.02383953  | 2.80686603 | 2.354095  | 6356             | 2.487421051 | 7.2782     | 0.05            | 4.473384 | 0.00022     | 8.869546 |
| 120               | 0.025006001 | 2.80233333 | 2.382269  | 6667             | 2.483888121 | 7.2718     | 0.05            | 4.44161  | 0.00022     | 8.869546 |
| 130               | 0.021300297 | 2.70432088 | 2.200543  | 5679             | 2.39501539  | 7.1613     | 0.05            | 4.45243  | 0.00022     | 8.869546 |
| 140               | 0.017879647 | 2.71179354 | 2.028106  | 4767             | 2.402710908 | 7.5358     | 0.05            | 4.658074 | 0.00022     | 8.869546 |
| 150               | 0.019308669 | 2.91376029 | 1.981334  | 5148             | 2.582723446 | 8.3936     | 0.05            | 5.069321 | 0.00022     | 8.869546 |
| 160               | 0.026307498 | 3.23964837 | 2.106137  | 7014             | 2.869282792 | 9.0881     | 0.05            | 5.454349 | 0.00022     | 8.869546 |
| 170               | 0.039693792 | 3.51710628 | 2.295808  | 10583            | 3.115792082 | 9.8242     | 0.05            | 5.672036 | 0.00022     | 8.869546 |
| 180               | 0.053008822 | 3.70315824 | 2.469468  | 14133            | 3.284722118 | 10.0689    | 0.05            | 5.774708 | 0.00022     | 8.869546 |
| 190               | 0.058571129 | 3.83048926 | 2.695242  | 15616            | 3.406184689 | 9.8298     | 0.05            | 5.75504  | 0.00022     | 8.869546 |
| 200               | 0.055413028 | 3.87913084 | 2.732333  | 14774            | 2.560285891 | 9.1271     | 0.05            | 5.796003 | 0.00022     | 8.869546 |
| 210               | 0.039393735 | 3.80145396 | 2.548313  | 10503            | 3.374562782 | 9.5473     | 0.05            | 5.847057 | 0.00022     | 8.869546 |
| 220               | 0.032826237 | 3.63699542 | 2.533613  | 8752             | 3.228072486 | 8.8922     | 0.05            | 5.608094 | 0.00022     | 8.869546 |
| 230               | 0.034101479 | 3.83589604 | 2.533908  | 9092             | 3.404620315 | 9.9537     | 0.05            | 5.914492 | 0.00022     | 8.869546 |
| 240               | 0.031115912 | 3.85635884 | 2.369562  | 8296             | 3.417829556 | 10.8559    | 0.05            | 6.127322 | 0.00022     | 8.869546 |
| 250               | 0.025084766 | 3.66610665 | 2.154453  | 6688             | 3.246725748 | 11.8106    | 0.05            | 6.100652 | 0.00022     | 8.869546 |
| 260               | 0.032627449 | 3.97073552 | 2.153246  | 8699             | 3.516509231 | 10.7603    | 0.05            | 6.609463 | 0.00022     | 8.869546 |
| 270               | 0.04620878  | 4.22120083 | 2.428994  | 12320            | 3.7428928   | 11.3373    | 0.05            | 6.631458 | 0.00022     | 8.869546 |
| 280               | 0.047382753 | 3.958945   | 2.471963  | 12633            | 3.511687564 | 10.4344    | 0.05            | 6.170814 | 0.00022     | 8.869546 |
| 290               | 0.042146758 | 3.71098748 | 2.491995  | 11237            | 3.292367999 | 10.8979    | 0.05            | 5.763721 | 0.00022     | 8.869546 |
| 300               | 0.037364599 | 3.54077562 | 2.580144  | 9962             | 3.144248906 | 10.4807    | 0.05            | 5.417254 | 0.00022     | 8.869546 |
| 310               | 0.029799412 | 3.39011318 | 2.574471  | 7945             | 3.010269314 | 8.5717     | 0.05            | 5.191609 | 0.00022     | 8.869546 |
| 320               | 0.023153149 | 3.23823832 | 2.585788  | 6173             | 2.875773935 | 9.0141     | 0.05            | 4.949786 | 0.00022     | 8.869546 |
| 330               | 0.015291655 | 2.95888667 | 2.426651  | 4077             | 2.623561221 | 7.9524     | 0.05            | 4.650404 | 0.00022     | 8.869546 |
| 340               | 0.011544693 | 2.80773189 | 2.134438  | 3078             | 2.48659308  | 7.3914     | 0.05            | 4.694624 | 0.00022     | 8.869546 |
| 350               | 0.009575569 | 2.672553   | 2.00583   | 2553             | 2.368365178 | 8.3252     | 0.05            | 4.618334 | 0.00022     | 8.869546 |

1 Comfort threshold set for wind speed exceeded 5% of time from each direction individually

2 Safety threshold set for wind speed exceeded once a year (0.022% of time) from any direction

Totals 1 3.4744286 2.273632 266616

### **Appendix 3**

Appendix 2 - Modelling Parameters and Wind Data.docx (Wardell Armstrong, 22 Feb 2022)

|                     |                                                           |
|---------------------|-----------------------------------------------------------|
| <b>CLIENT:</b>      | Fusion Students                                           |
| <b>PROJECT:</b>     | Deansgate South                                           |
| <b>SUBJECT:</b>     | CFD Modelling Parameters for Wind Microclimate Assessment |
| <b>JOB NO.:</b>     | GM11393                                                   |
| <b>DATE:</b>        | 20/02/2022                                                |
| <b>PREPARED BY:</b> | Paul Evans BSc(Hons) MEI CEnv                             |

## 1 CFD MODELLING PARAMATERS

1.1.1 The modelling was undertaken using openFoam V7 CFD software using the following parameters.

|                                                  |                                                                                                                                                                                                                                                                                                         |
|--------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Solver</b>                                    | simpleFoam                                                                                                                                                                                                                                                                                              |
| <b>turbulence model</b>                          | RAS Realizable K-Epsilon                                                                                                                                                                                                                                                                                |
| <b>gradSchemes</b>                               | cellLimited Gauss Linear                                                                                                                                                                                                                                                                                |
| <b>divSchemes (phi, U)</b>                       | bounded gauss linear upwind limited                                                                                                                                                                                                                                                                     |
| <b>divSchemes (turbulence, Phi, k , epsilon)</b> | bounded gauss limited linear                                                                                                                                                                                                                                                                            |
| <b>wall distance calculation</b>                 | meshwave                                                                                                                                                                                                                                                                                                |
| <b>atmospheric boundary layer</b>                | $U = \left[ \frac{U^*}{K} \right] * \ln \left[ \frac{z - z_{Ground} + Z_0}{Z_0} \right]$ <p>U^* is the frictional velocity;<br/>K is Karman's Constant;<br/>z_0 is the surface roughness length;<br/>z is the vertical coordinate; and<br/>z_Ground is the minimum coordinate value in z-direction.</p> |
| <b>wall boundary field (U)</b>                   | noslip                                                                                                                                                                                                                                                                                                  |
| <b>wall boundary field (epsilon)</b>             | epsilon wall function                                                                                                                                                                                                                                                                                   |
| <b>wall boundary field (p)</b>                   | zero gradient                                                                                                                                                                                                                                                                                           |
| <b>wall boundary field (nut)</b>                 | nut atm rough wall function                                                                                                                                                                                                                                                                             |
| <b>wall boundary field (k)</b>                   | kqr wall function                                                                                                                                                                                                                                                                                       |

## 2 WIND DATA

A summary of the wind data used in the modelling is presented below, reference height is **20m**:

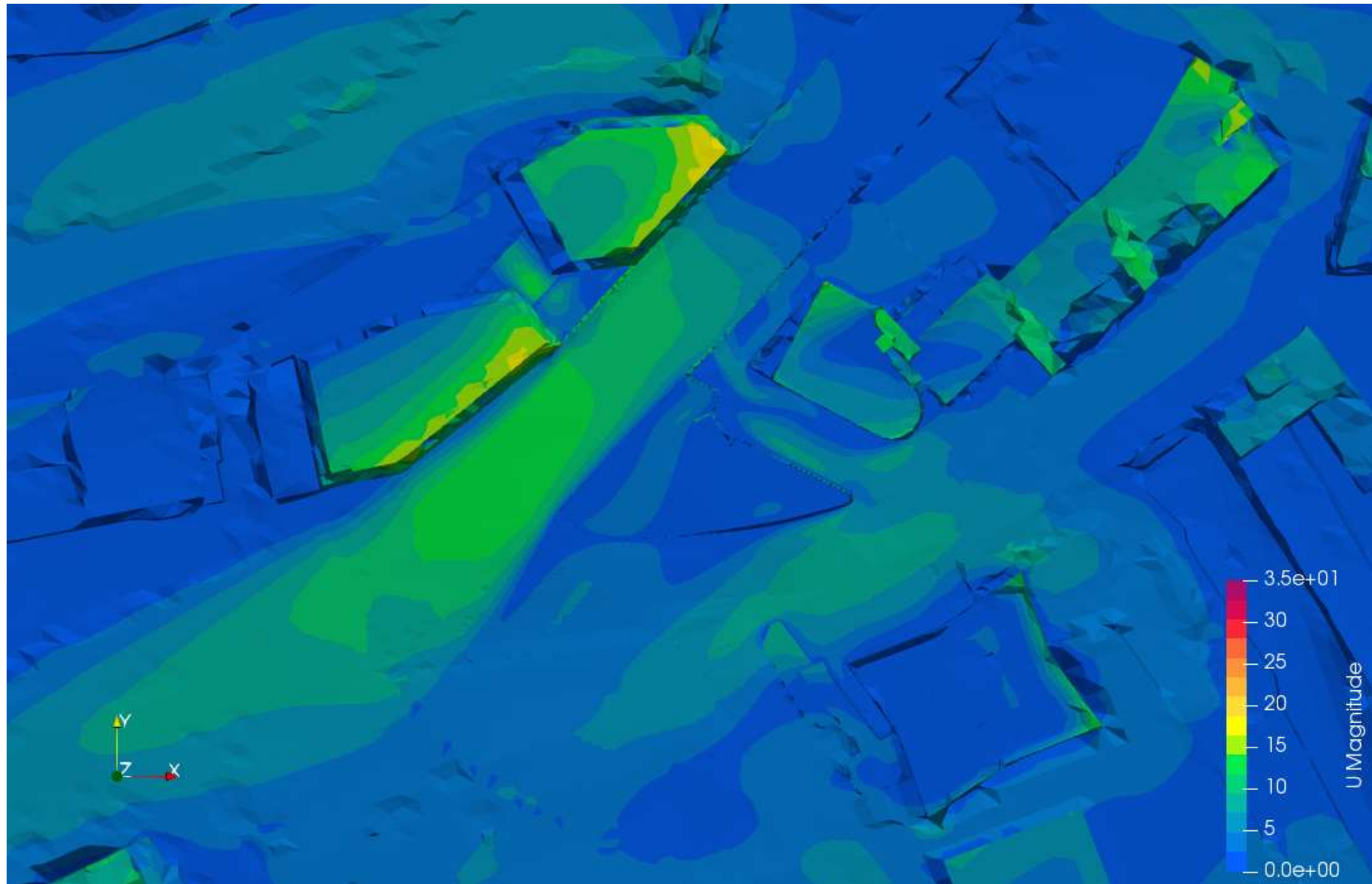
# Technical Note



|                   |             |           |           |           | Comfort Criteria |            |                       |         | Safety Criteria       |         |
|-------------------|-------------|-----------|-----------|-----------|------------------|------------|-----------------------|---------|-----------------------|---------|
| Reference Station |             |           |           | DataCount | AvRefWSpd        | MaxRefWSpd | Probability           | RefWSpd | Probability           | RefWSpd |
| Direction         | Probability | Scale (c) | Shape (k) |           | Upot = V         |            | Exceeded <sup>1</sup> | Vref 1  | Exceeded <sup>2</sup> | Vref 2  |
| 0                 | 0.90%       | 2.53      | 2.07      | 2,389     | 2.24             | 7.44       | 5%                    | 4.289   | 0.022%                | 8.870   |
| 10                | 1.09%       | 2.64      | 2.06      | 2,896     | 2.34             | 7.84       | 5%                    | 4.496   | 0.022%                | 8.870   |
| 20                | 1.42%       | 2.89      | 2.03      | 3,799     | 2.56             | 8.26       | 5%                    | 4.965   | 0.022%                | 8.870   |
| 30                | 1.76%       | 2.98      | 2.16      | 4,688     | 2.64             | 7.50       | 5%                    | 4.959   | 0.022%                | 8.870   |
| 40                | 2.09%       | 3.16      | 2.22      | 5,565     | 2.80             | 8.36       | 5%                    | 5.178   | 0.022%                | 8.870   |
| 50                | 2.38%       | 3.18      | 2.40      | 6,335     | 2.82             | 7.30       | 5%                    | 5.022   | 0.022%                | 8.870   |
| 60                | 2.45%       | 3.22      | 2.52      | 6,535     | 2.86             | 8.18       | 5%                    | 4.978   | 0.022%                | 8.870   |
| 70                | 2.31%       | 3.34      | 2.44      | 6,152     | 2.96             | 7.39       | 5%                    | 5.233   | 0.022%                | 8.870   |
| 80                | 1.99%       | 3.24      | 2.25      | 5,312     | 2.87             | 7.73       | 5%                    | 5.272   | 0.022%                | 8.870   |
| 90                | 1.83%       | 3.01      | 2.15      | 4,870     | 2.67             | 7.30       | 5%                    | 5.011   | 0.022%                | 8.870   |
| 100               | 2.00%       | 2.80      | 2.17      | 5,330     | 2.48             | 9.32       | 5%                    | 4.639   | 0.022%                | 8.870   |
| 110               | 2.38%       | 2.81      | 2.35      | 6,356     | 2.49             | 7.28       | 5%                    | 4.473   | 0.022%                | 8.870   |
| 120               | 2.50%       | 2.80      | 2.38      | 6,667     | 2.48             | 7.27       | 5%                    | 4.442   | 0.022%                | 8.870   |
| 130               | 2.13%       | 2.70      | 2.20      | 5,679     | 2.40             | 7.16       | 5%                    | 4.452   | 0.022%                | 8.870   |
| 140               | 1.79%       | 2.71      | 2.03      | 4,767     | 2.40             | 7.54       | 5%                    | 4.658   | 0.022%                | 8.870   |
| 150               | 1.93%       | 2.91      | 1.98      | 5,148     | 2.58             | 8.39       | 5%                    | 5.069   | 0.022%                | 8.870   |
| 160               | 2.63%       | 3.24      | 2.11      | 7,014     | 2.87             | 9.09       | 5%                    | 5.454   | 0.022%                | 8.870   |
| 170               | 3.97%       | 3.52      | 2.30      | 10,583    | 3.12             | 9.82       | 5%                    | 5.672   | 0.022%                | 8.870   |
| 180               | 5.30%       | 3.70      | 2.47      | 14,133    | 3.28             | 10.07      | 5%                    | 5.775   | 0.022%                | 8.870   |
| 190               | 5.86%       | 3.83      | 2.70      | 15,616    | 3.41             | 9.83       | 5%                    | 5.755   | 0.022%                | 8.870   |
| 200               | 5.54%       | 3.88      | 2.73      | 14,774    | 2.56             | 9.13       | 5%                    | 5.796   | 0.022%                | 8.870   |
| 210               | 3.94%       | 3.80      | 2.55      | 10,503    | 3.37             | 9.55       | 5%                    | 5.847   | 0.022%                | 8.870   |
| 220               | 3.28%       | 3.64      | 2.53      | 8,752     | 3.23             | 8.89       | 5%                    | 5.608   | 0.022%                | 8.870   |
| 230               | 3.41%       | 3.84      | 2.53      | 9,092     | 3.40             | 9.95       | 5%                    | 5.914   | 0.022%                | 8.870   |
| 240               | 3.11%       | 3.86      | 2.37      | 8,296     | 3.42             | 10.86      | 5%                    | 6.127   | 0.022%                | 8.870   |
| 250               | 2.51%       | 3.67      | 2.15      | 6,688     | 3.25             | 11.81      | 5%                    | 6.101   | 0.022%                | 8.870   |
| 260               | 3.26%       | 3.97      | 2.15      | 8,699     | 3.52             | 10.76      | 5%                    | 6.609   | 0.022%                | 8.870   |
| 270               | 4.62%       | 4.22      | 2.43      | 12,320    | 3.74             | 11.34      | 5%                    | 6.631   | 0.022%                | 8.870   |
| 280               | 4.74%       | 3.96      | 2.47      | 12,633    | 3.51             | 10.43      | 5%                    | 6.171   | 0.022%                | 8.870   |
| 290               | 4.21%       | 3.71      | 2.49      | 11,237    | 3.29             | 10.90      | 5%                    | 5.764   | 0.022%                | 8.870   |
| 300               | 3.74%       | 3.54      | 2.58      | 9,962     | 3.14             | 10.48      | 5%                    | 5.417   | 0.022%                | 8.870   |
| 310               | 2.98%       | 3.39      | 2.57      | 7,945     | 3.01             | 8.57       | 5%                    | 5.192   | 0.022%                | 8.870   |
| 320               | 2.32%       | 3.24      | 2.59      | 6,173     | 2.88             | 9.01       | 5%                    | 4.950   | 0.022%                | 8.870   |
| 330               | 1.53%       | 2.96      | 2.43      | 4,077     | 2.62             | 7.95       | 5%                    | 4.650   | 0.022%                | 8.870   |
| 340               | 1.15%       | 2.81      | 2.13      | 3,078     | 2.49             | 7.39       | 5%                    | 4.695   | 0.022%                | 8.870   |
| 350               | 0.96%       | 2.67      | 2.01      | 2,553     | 2.37             | 8.33       | 5%                    | 4.618   | 0.022%                | 8.870   |

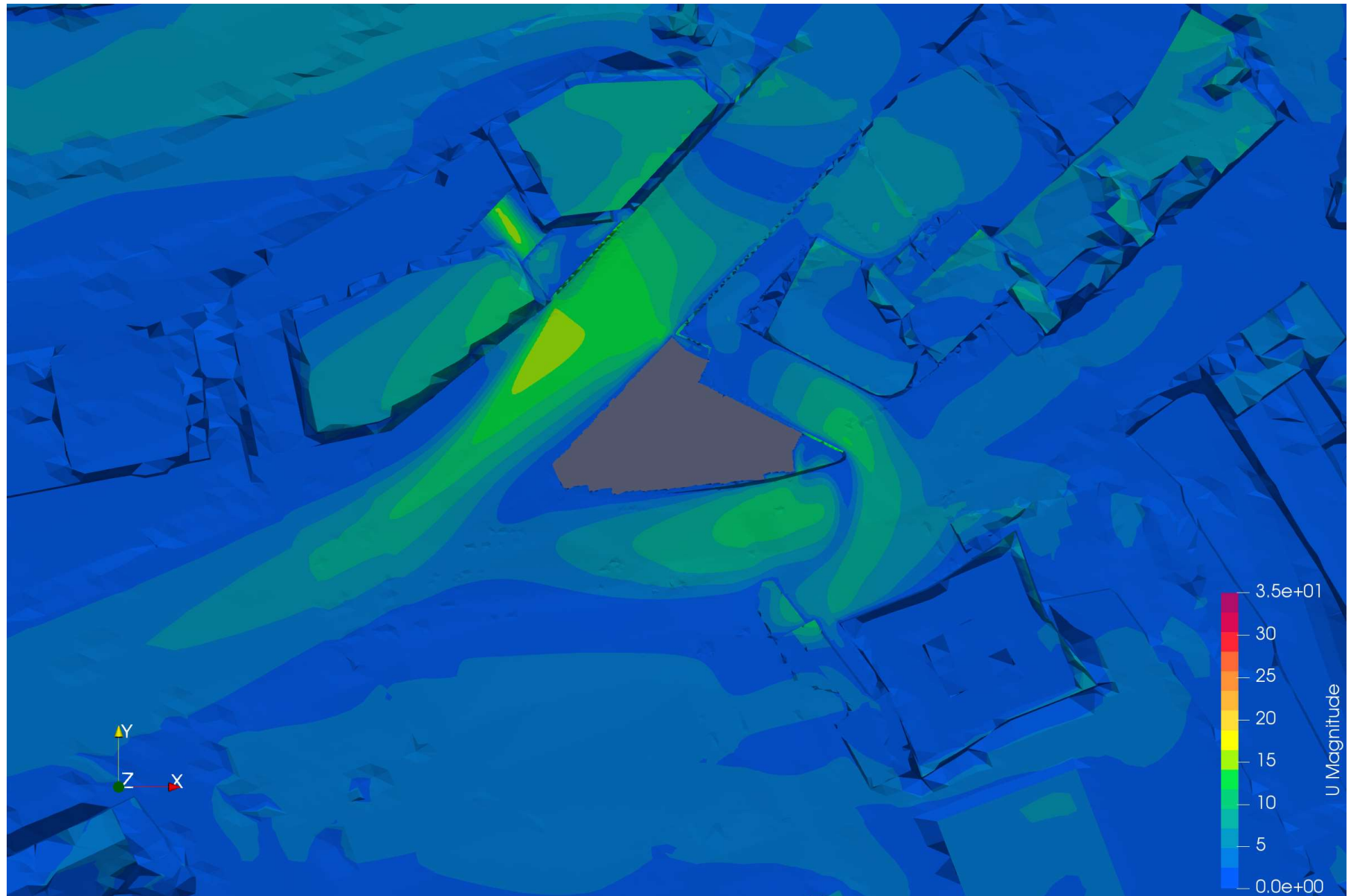
## **Appendix 4**

70deg safety baseline.png (Wardell Armstrong, 22 Feb 2022)



## **Appendix 5**

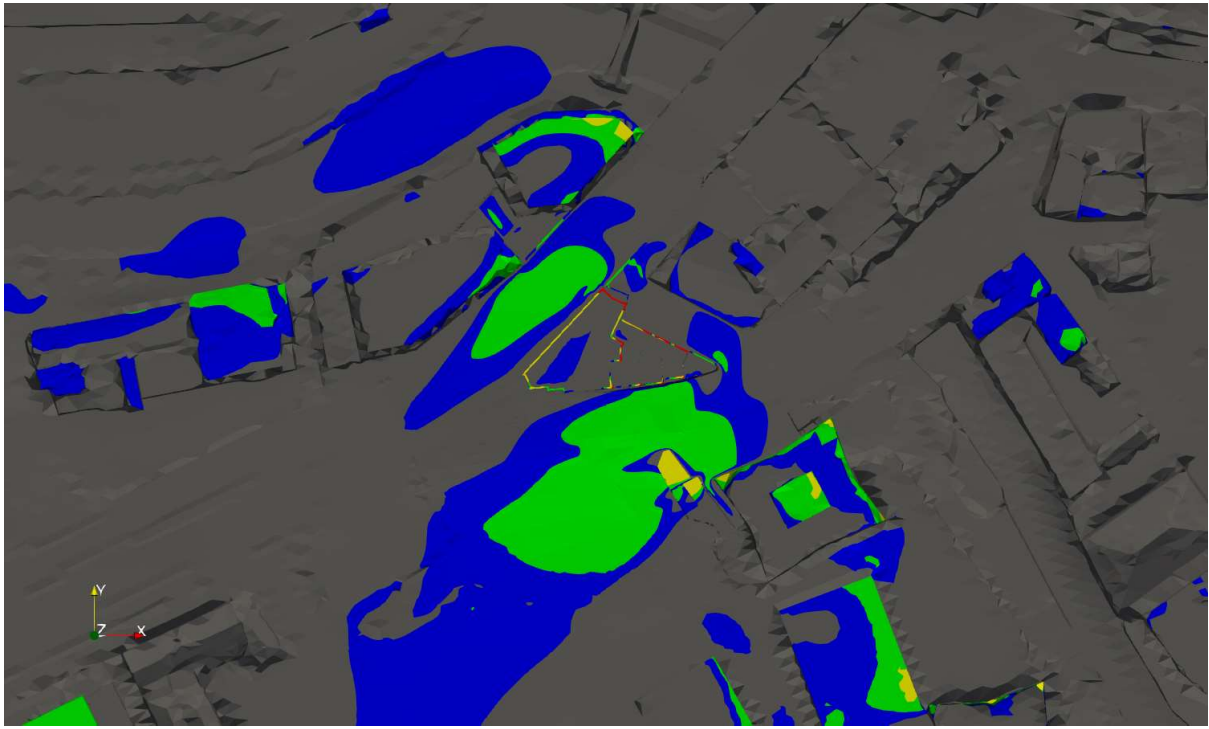
70deg safety.png (Wardell Armstrong, 22 Feb 2022)



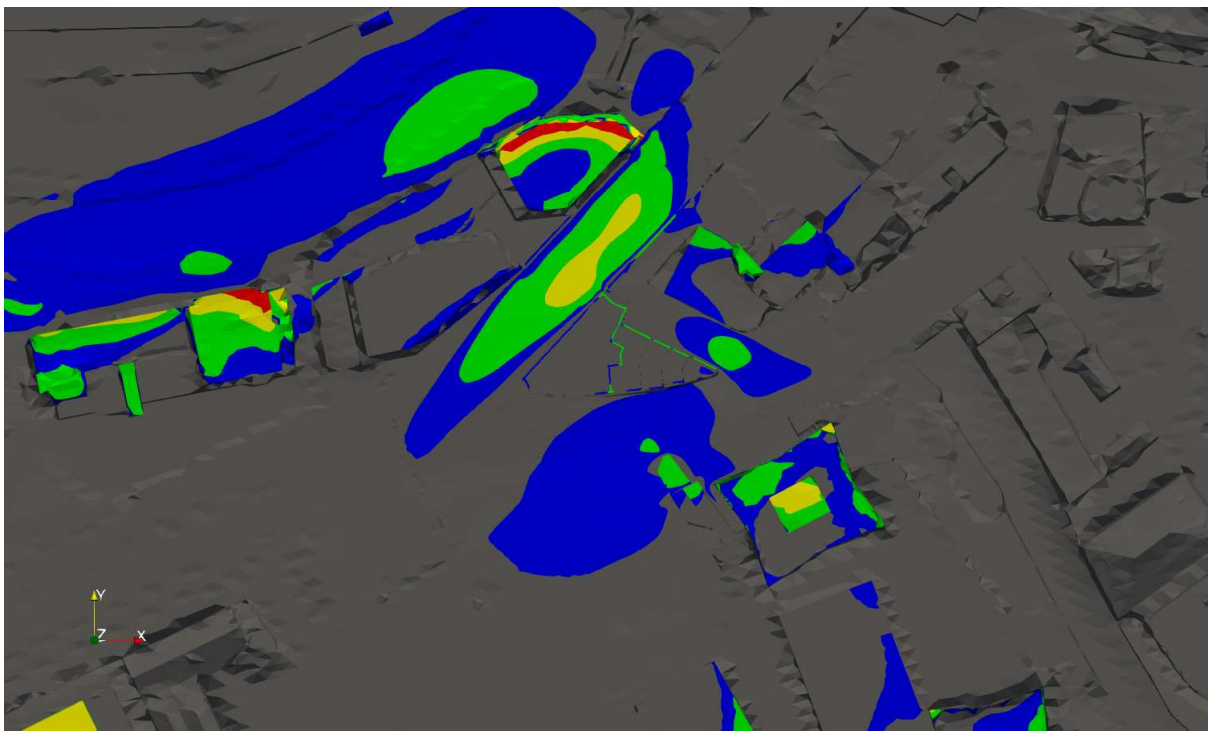
## **Appendix 6**

New Comfort Screenshots (Wardell Armstrong, 3rd March 2022)

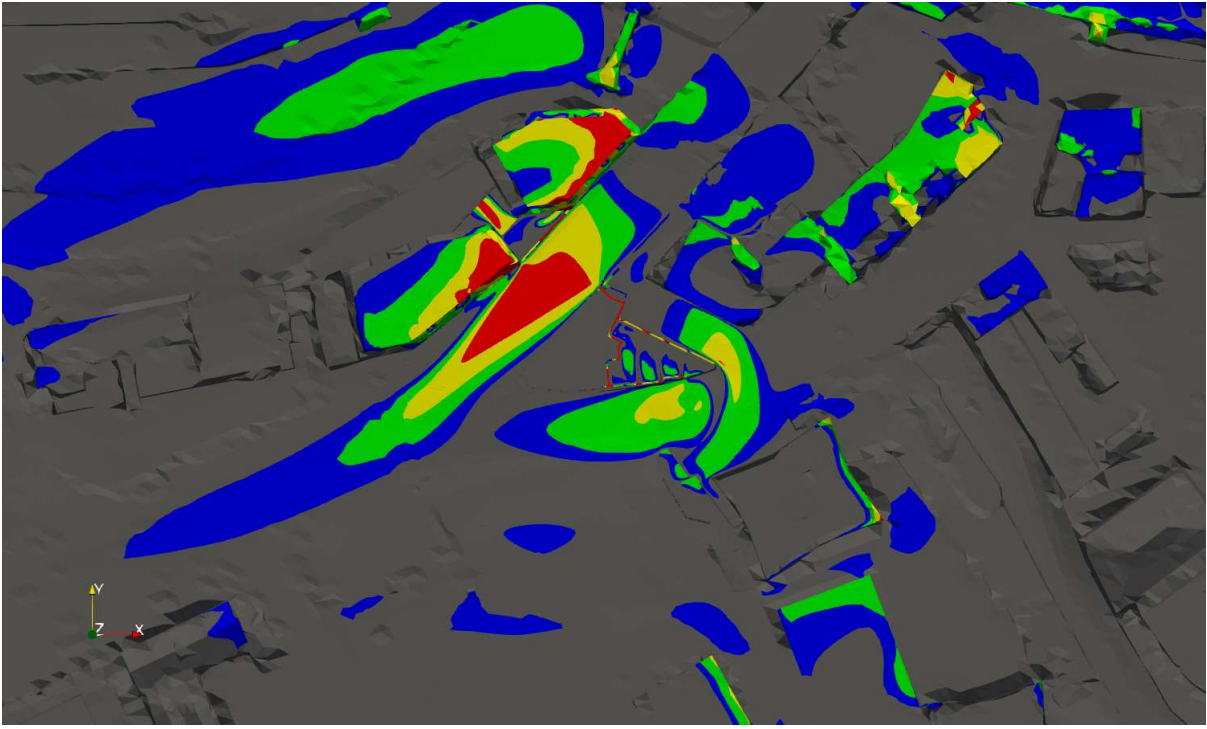
**New Comfort Screenshots (Wardell Armstrong, 3rd March 2022)**



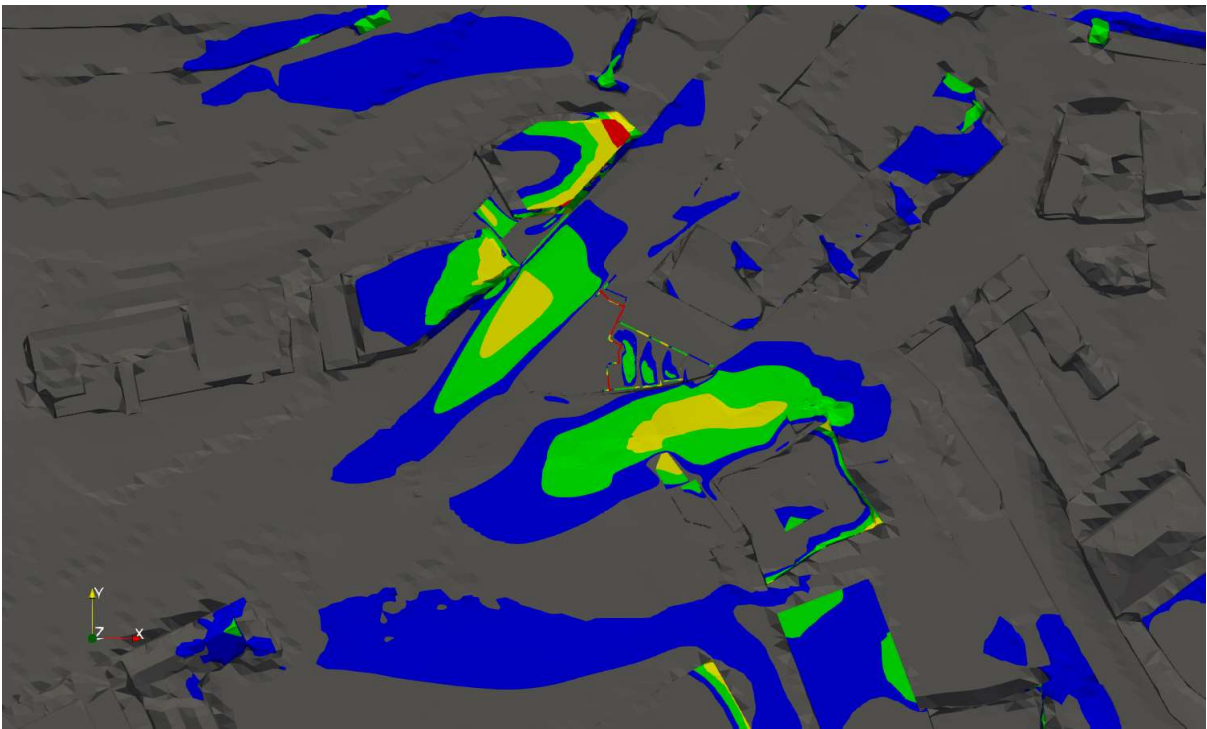
**20 Deg**



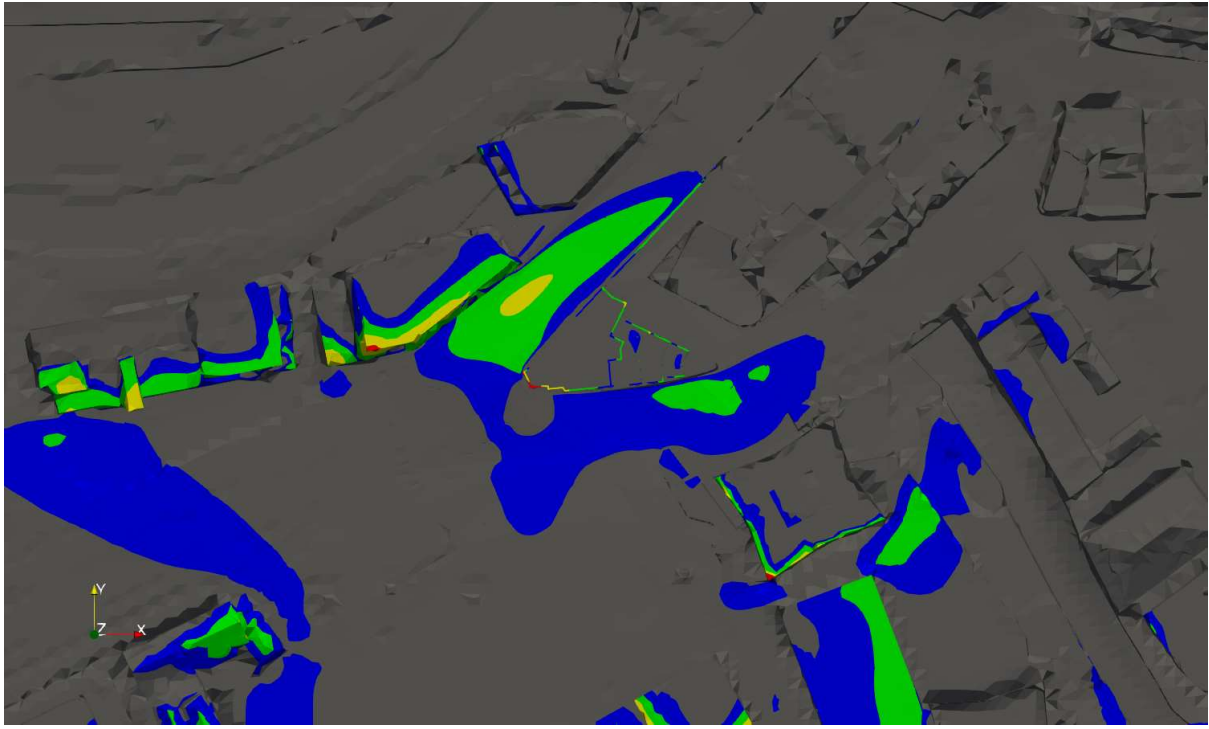
**30 Deg**



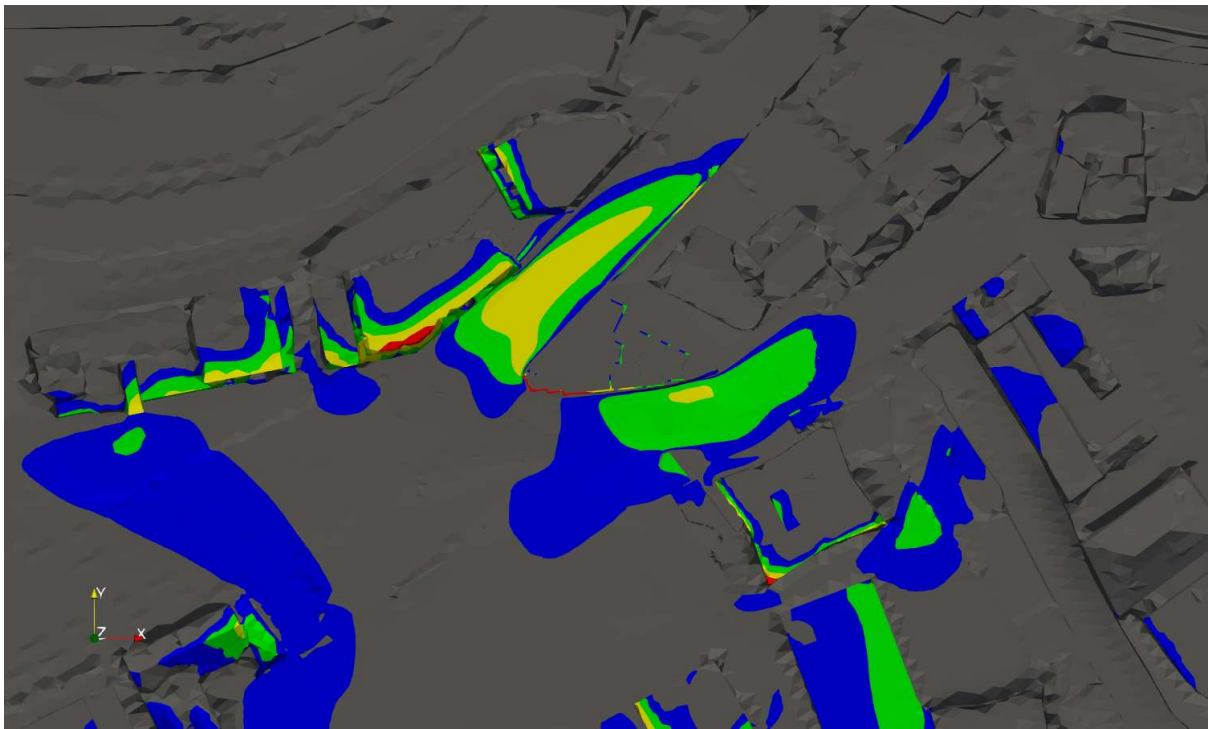
**70 Deg**



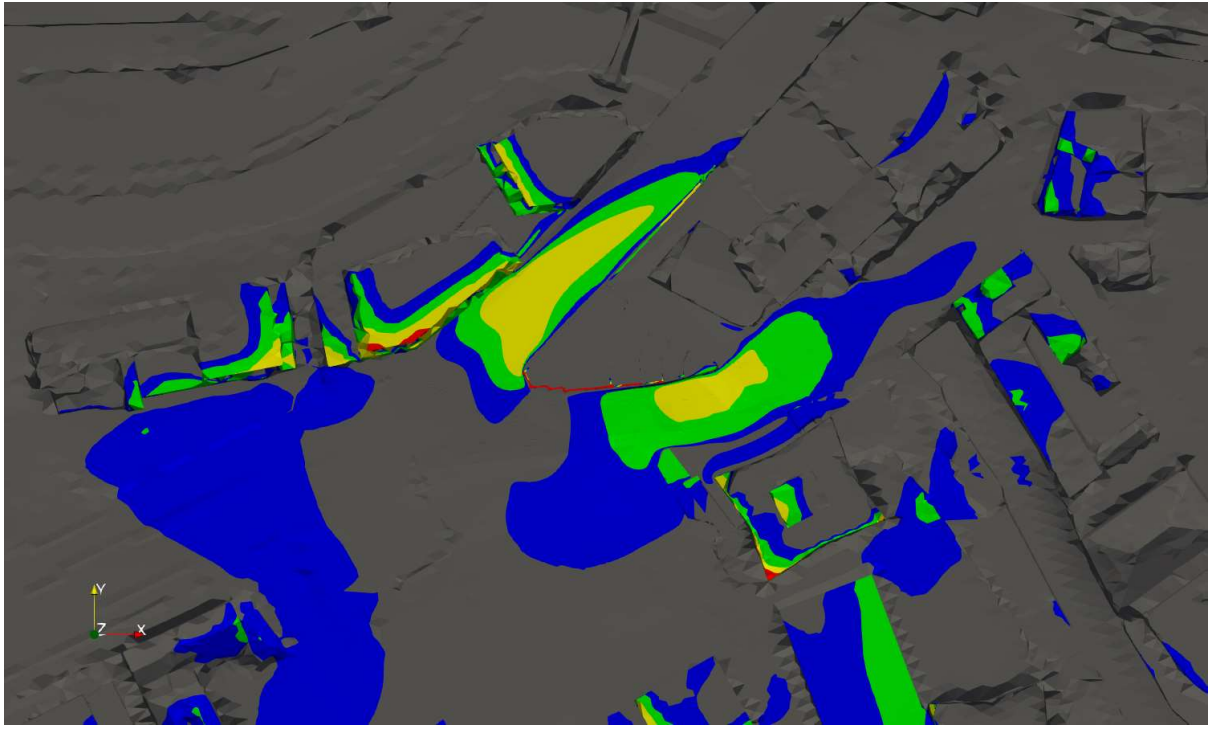
**80 Deg**



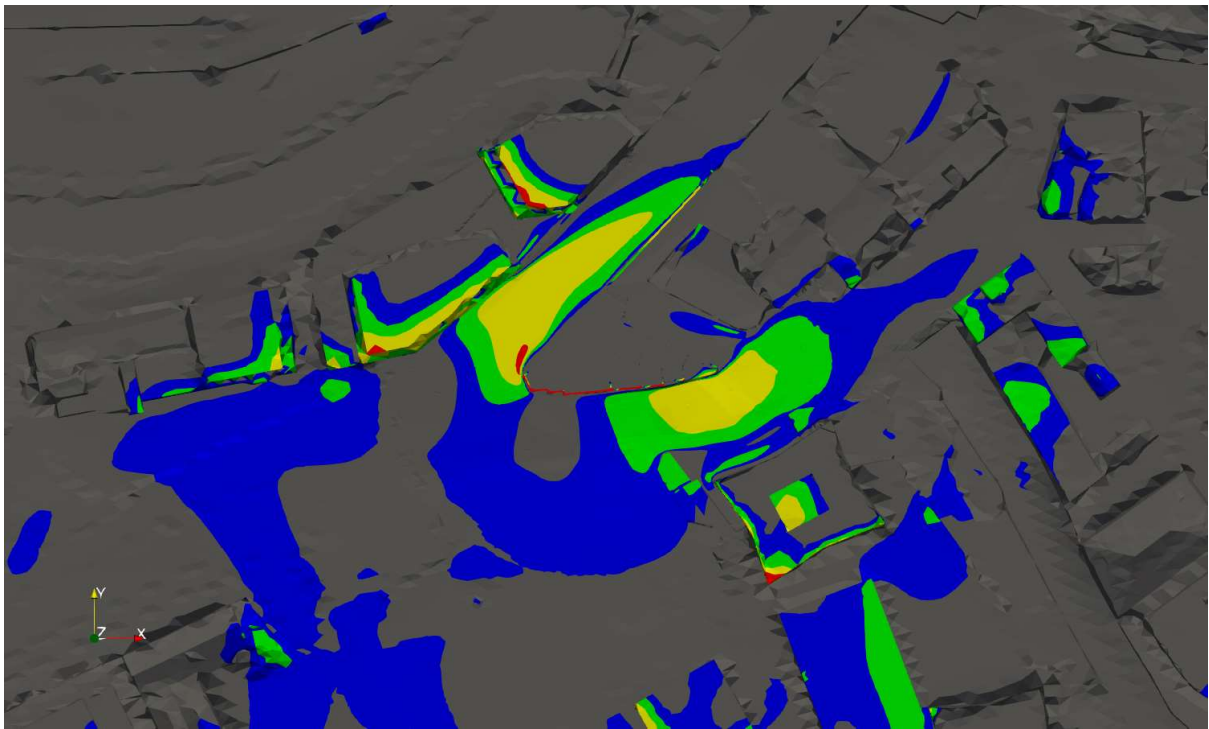
180 Deg



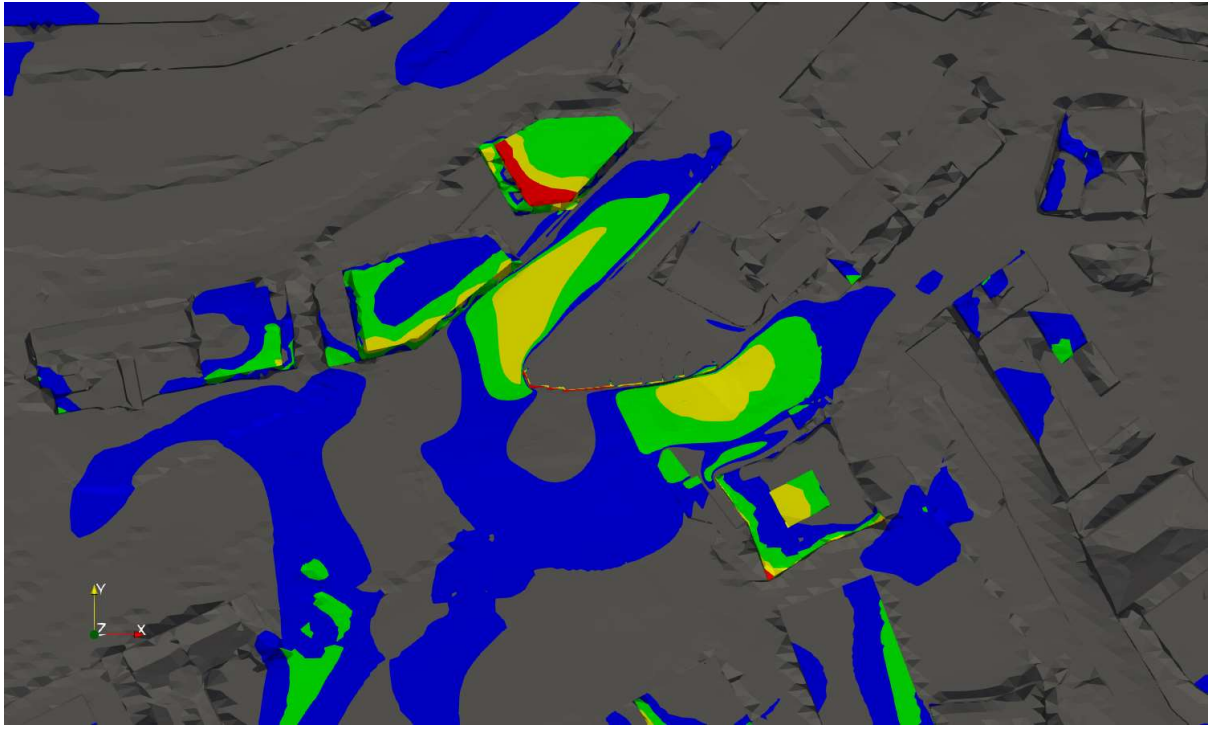
190 Deg



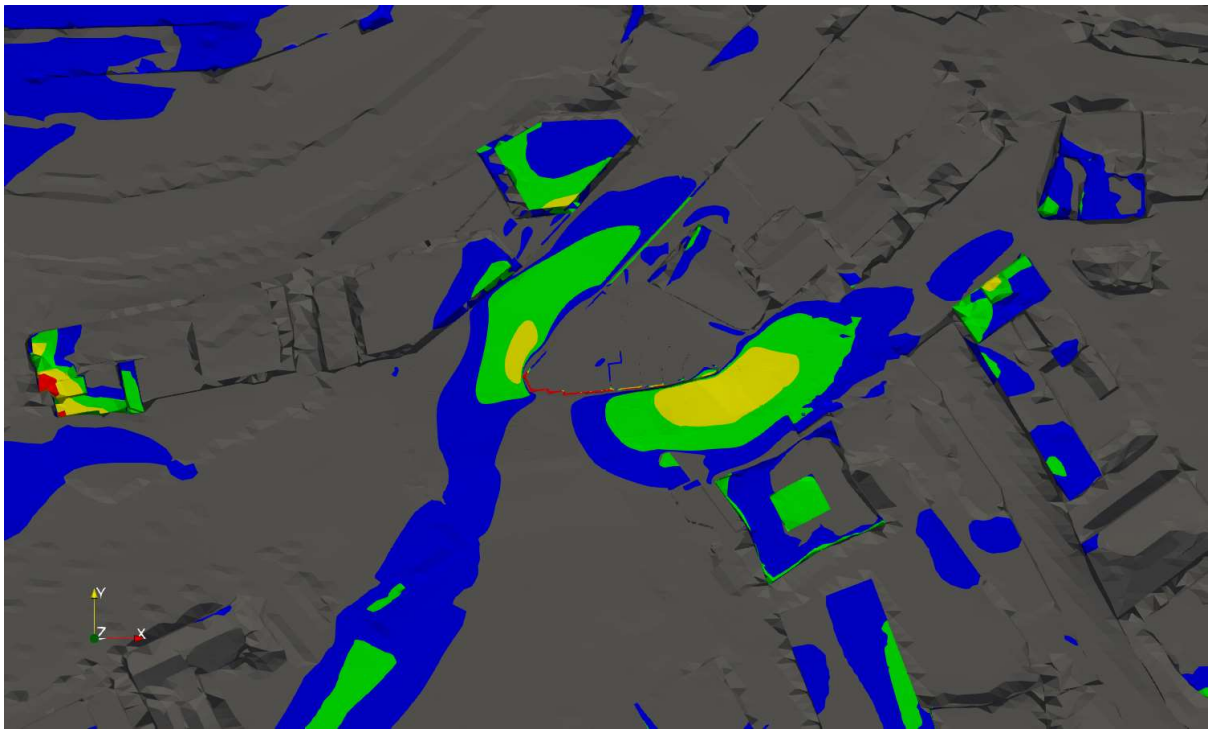
200 Deg



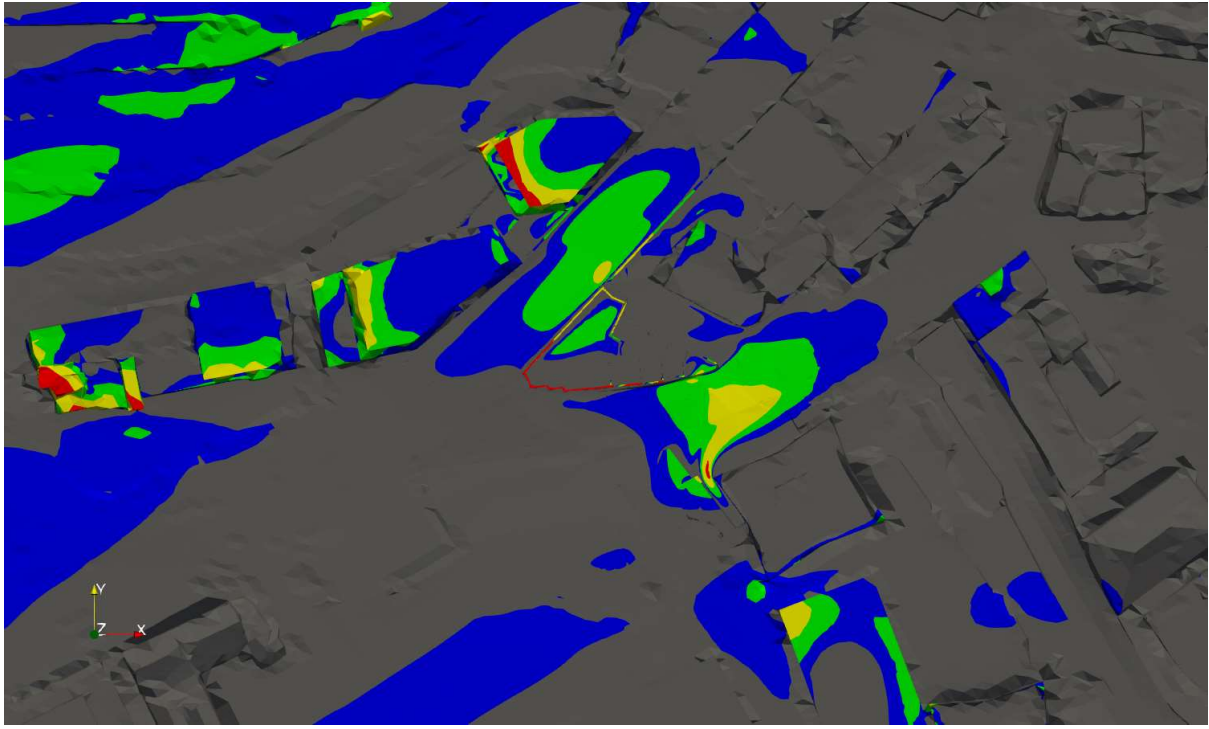
210 Deg



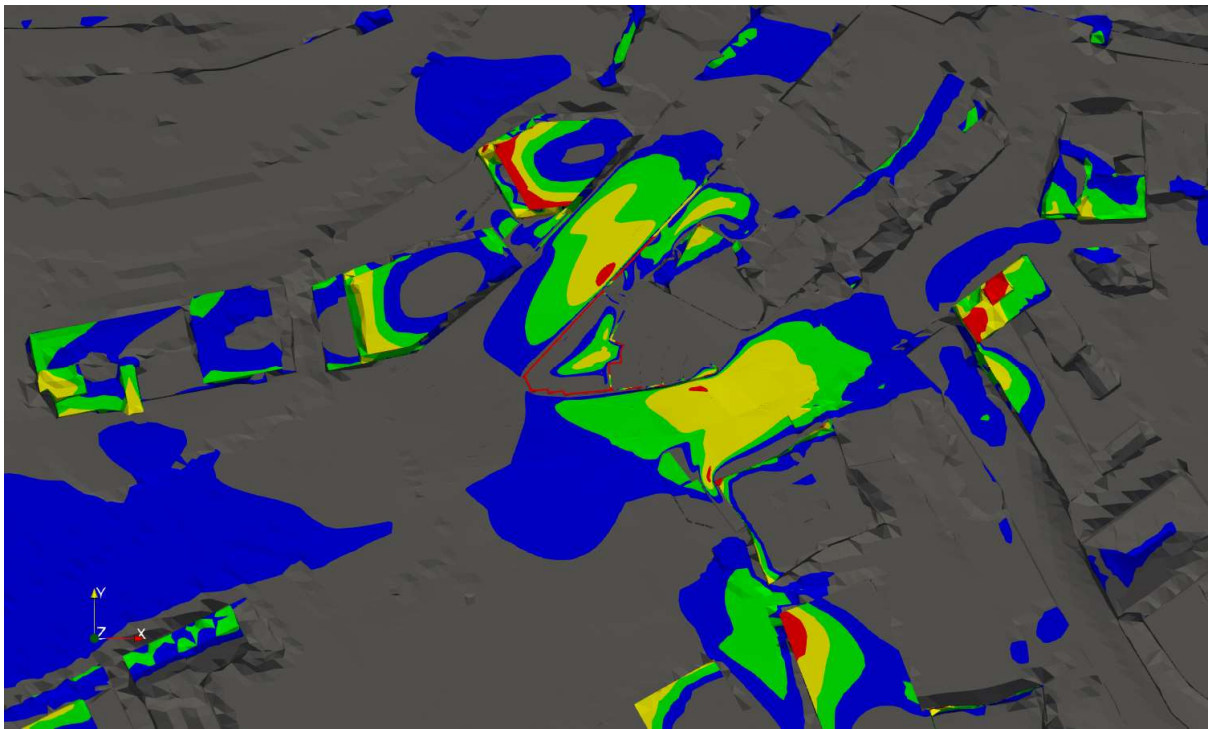
220 Deg



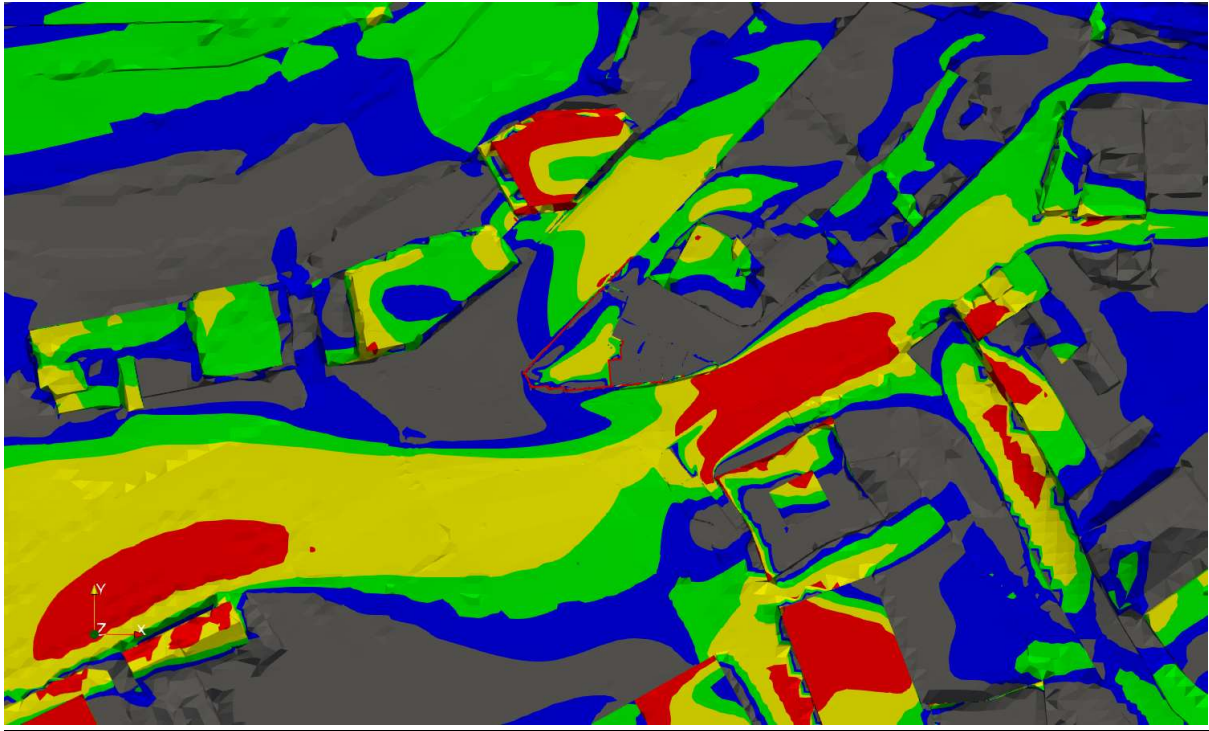
230 Deg



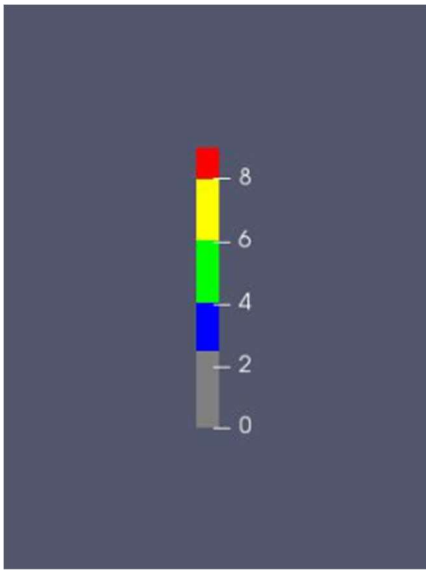
240 Deg



260 Deg



270 Deg

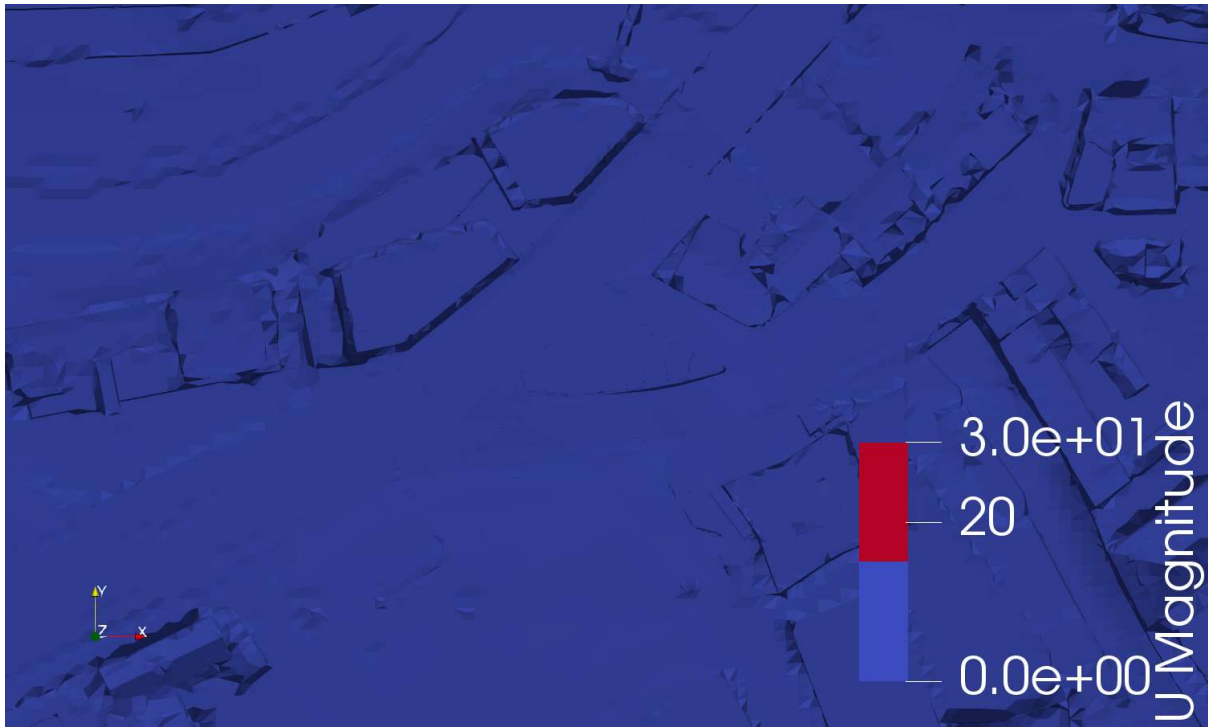


WMC Comfort

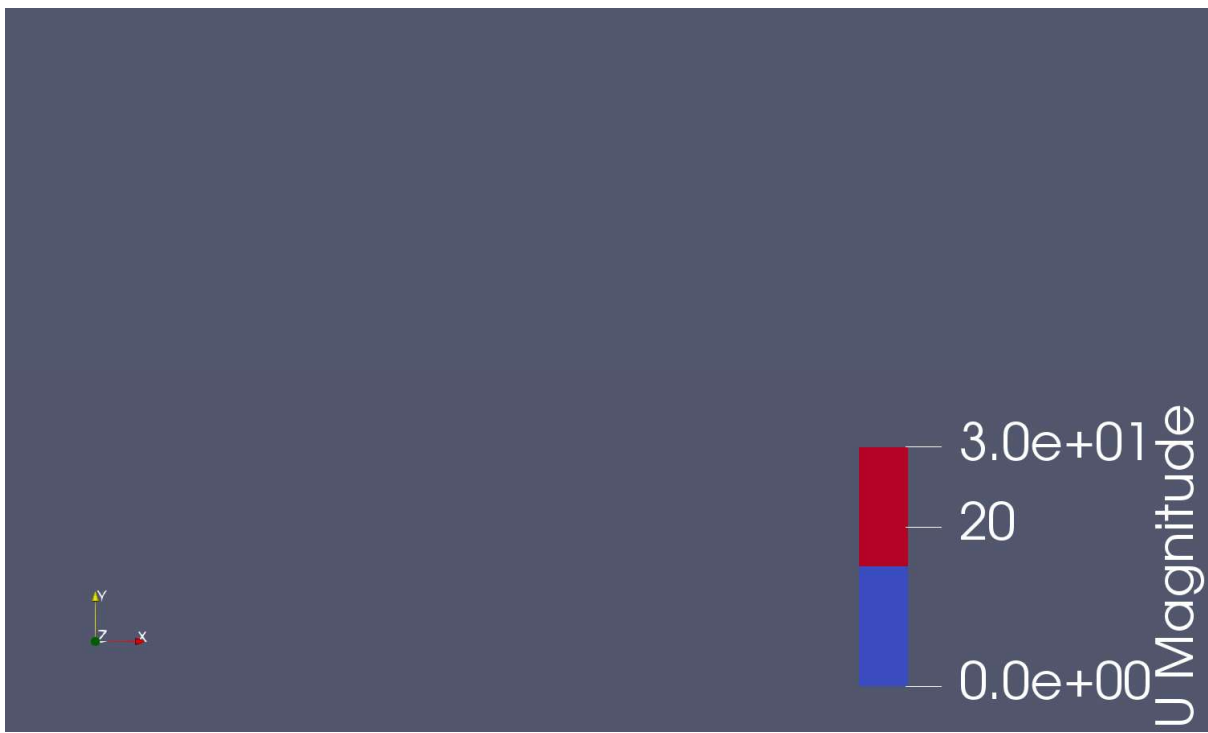
## **Appendix 7**

New Safety Screenshots (Wardell Armstrong, 3rd March 2022)

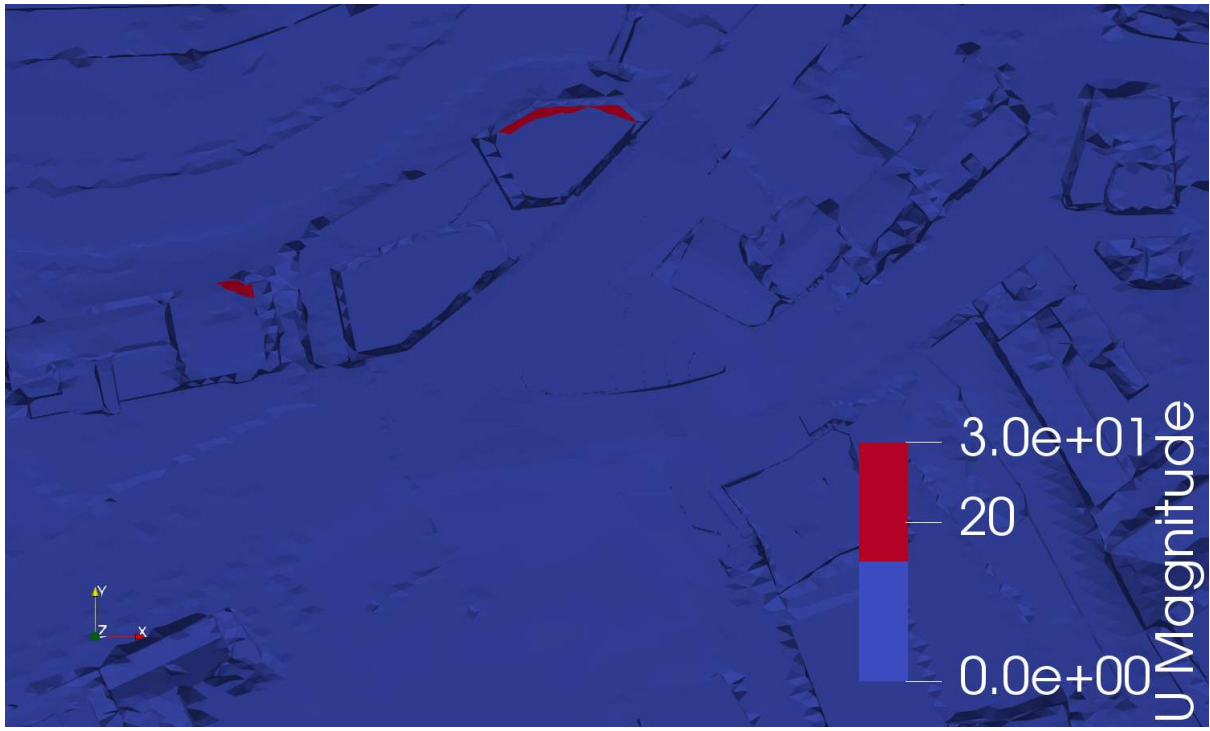
**New Safety Screenshots (Wardell Armstrong, 3rd March 2022)**



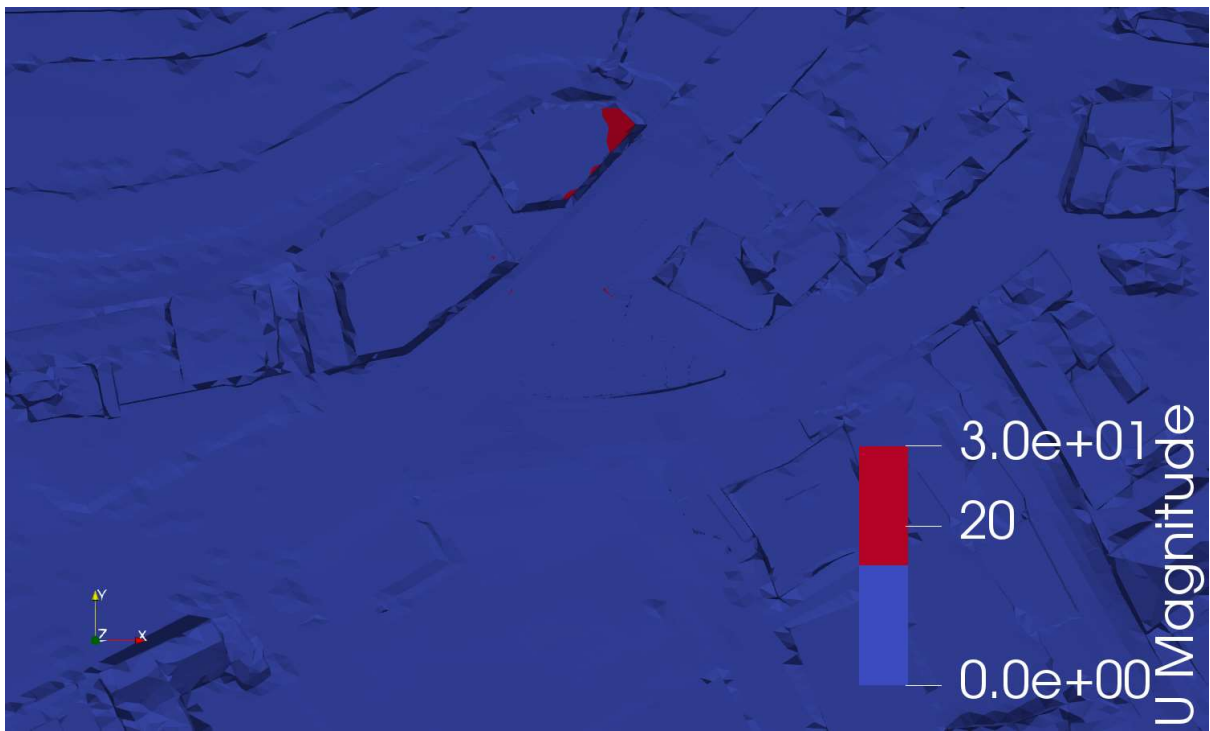
**0 Deg**



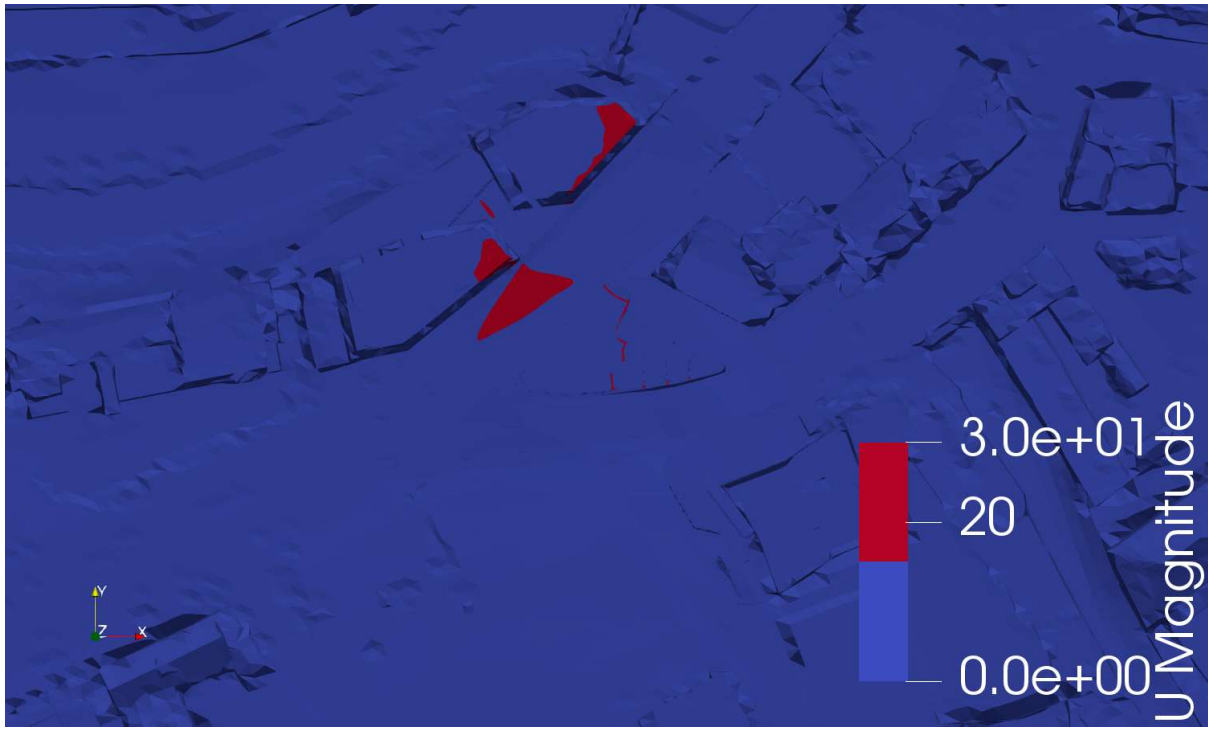
**20 Deg**



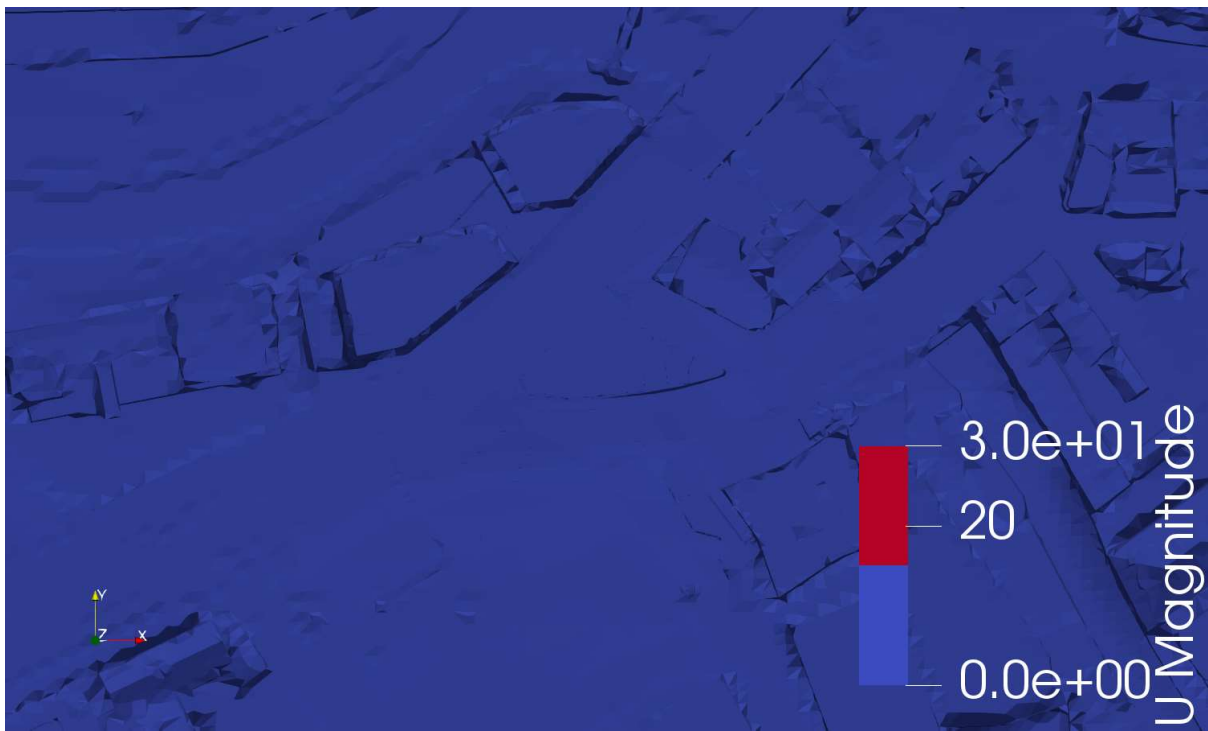
**30 Deg**



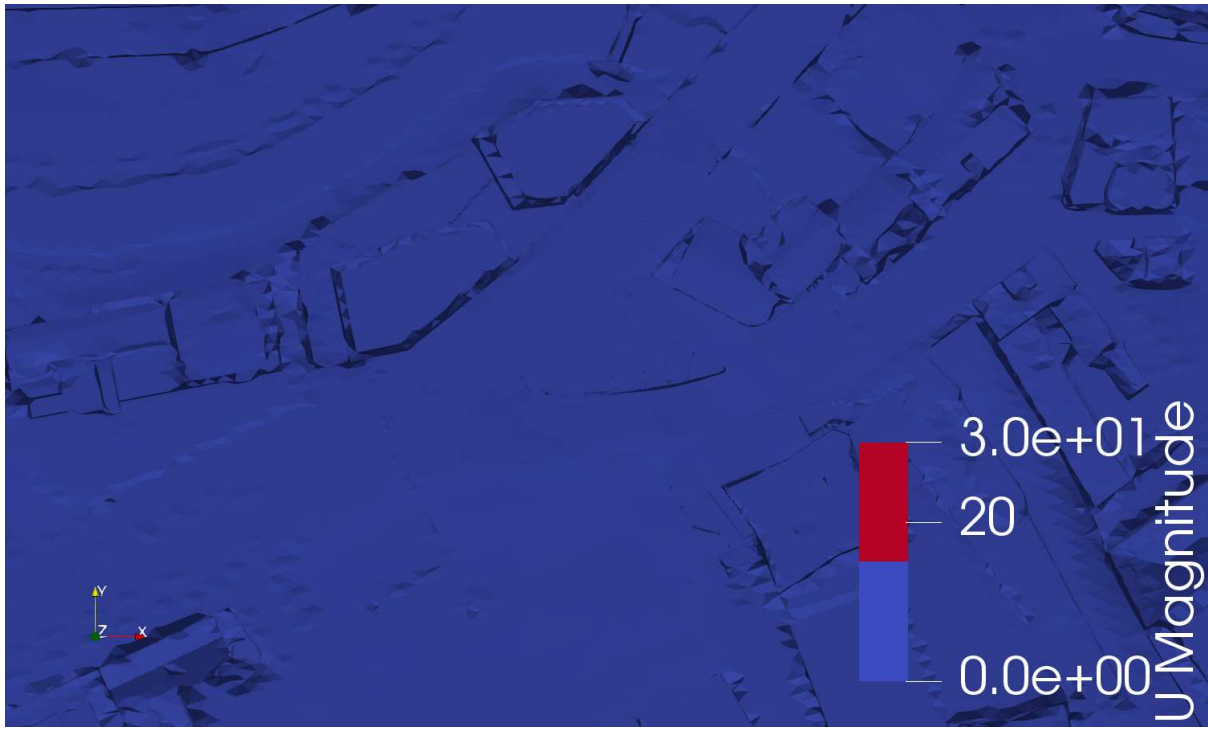
**60 Deg**



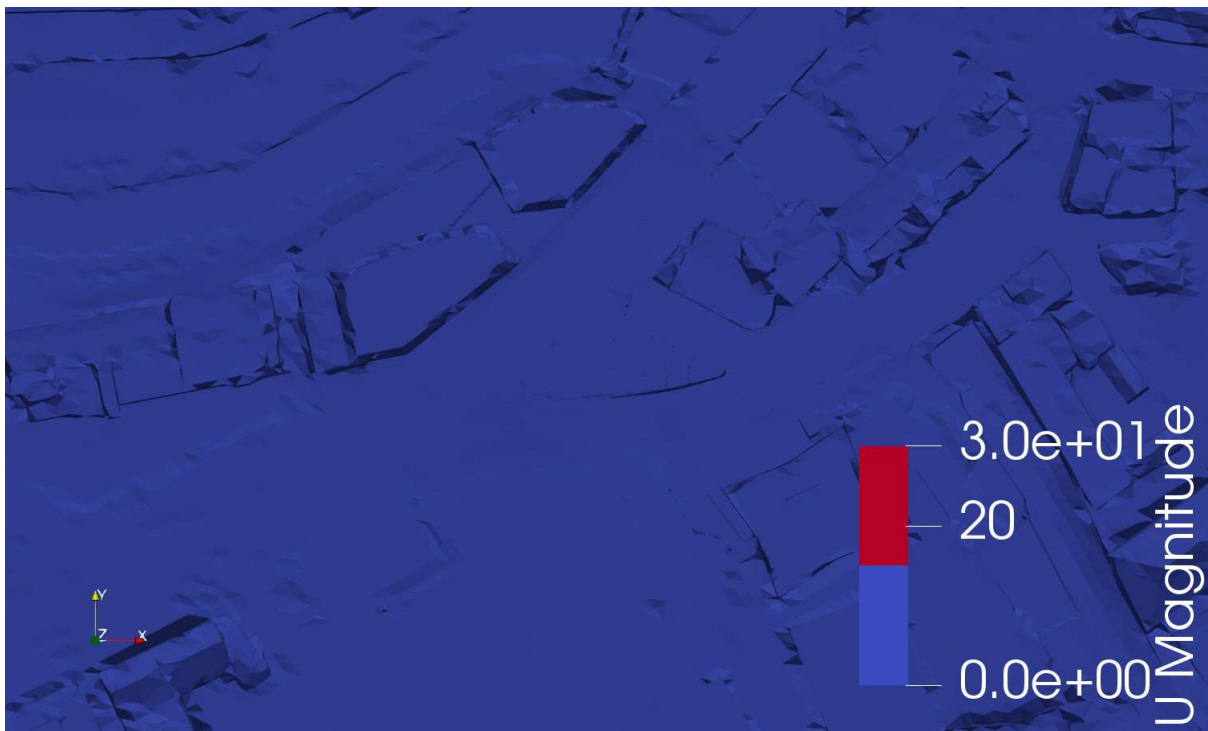
**70 Deg**



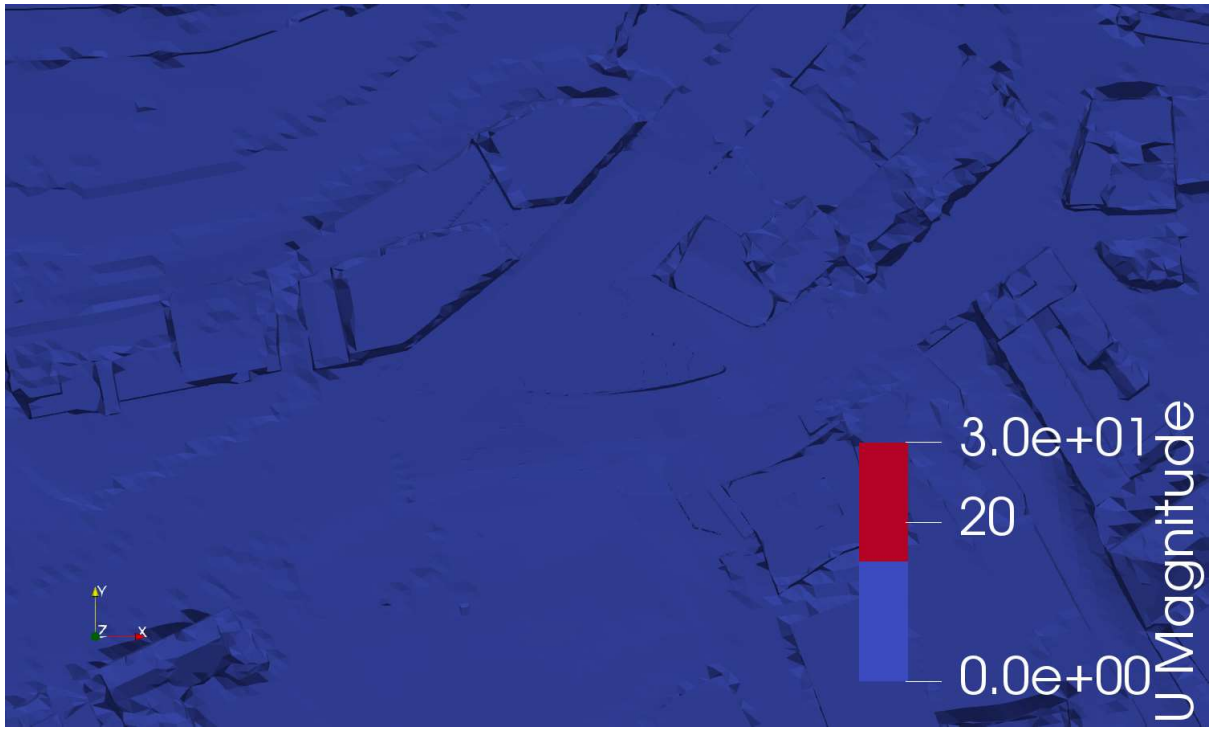
**90 Deg**



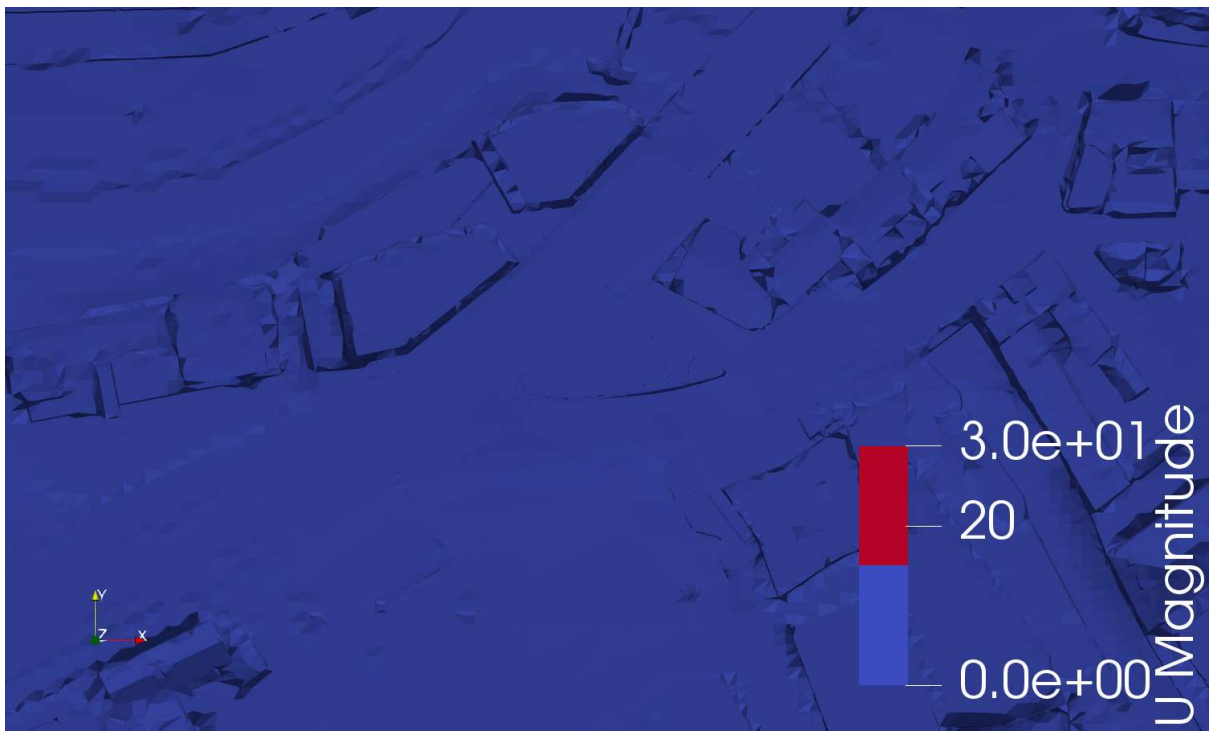
**120 Deg**



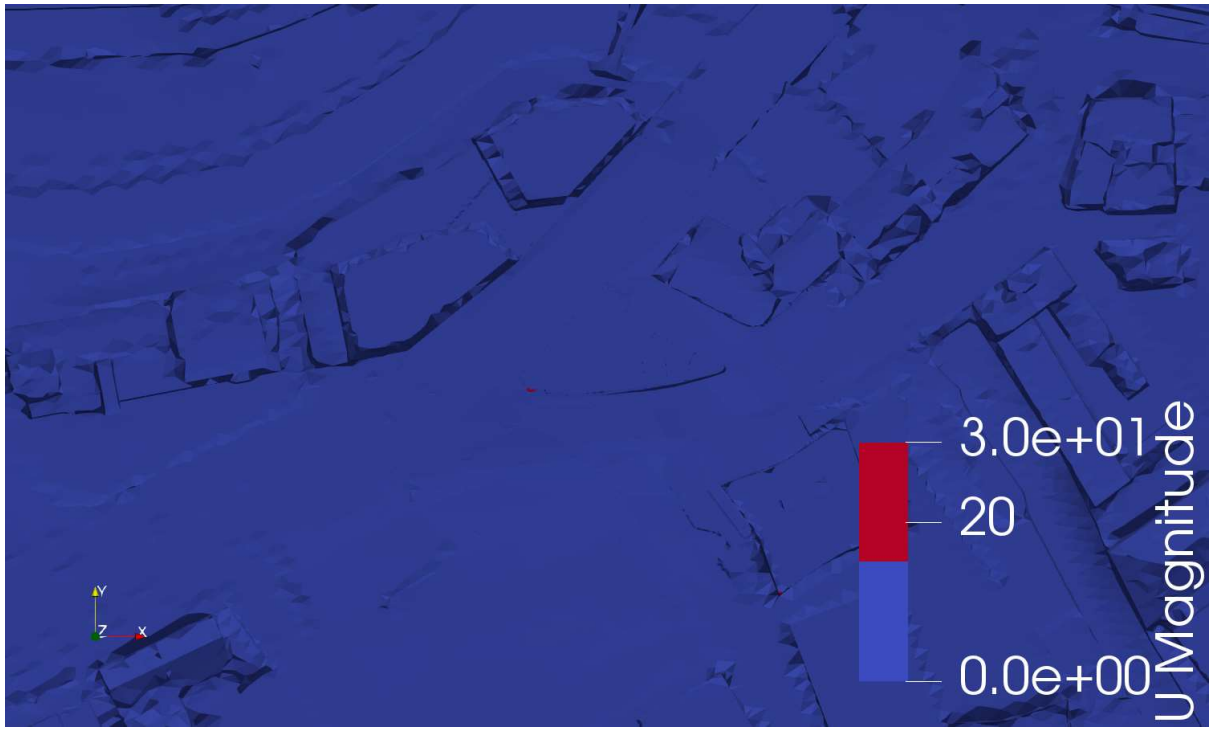
**150 Deg**



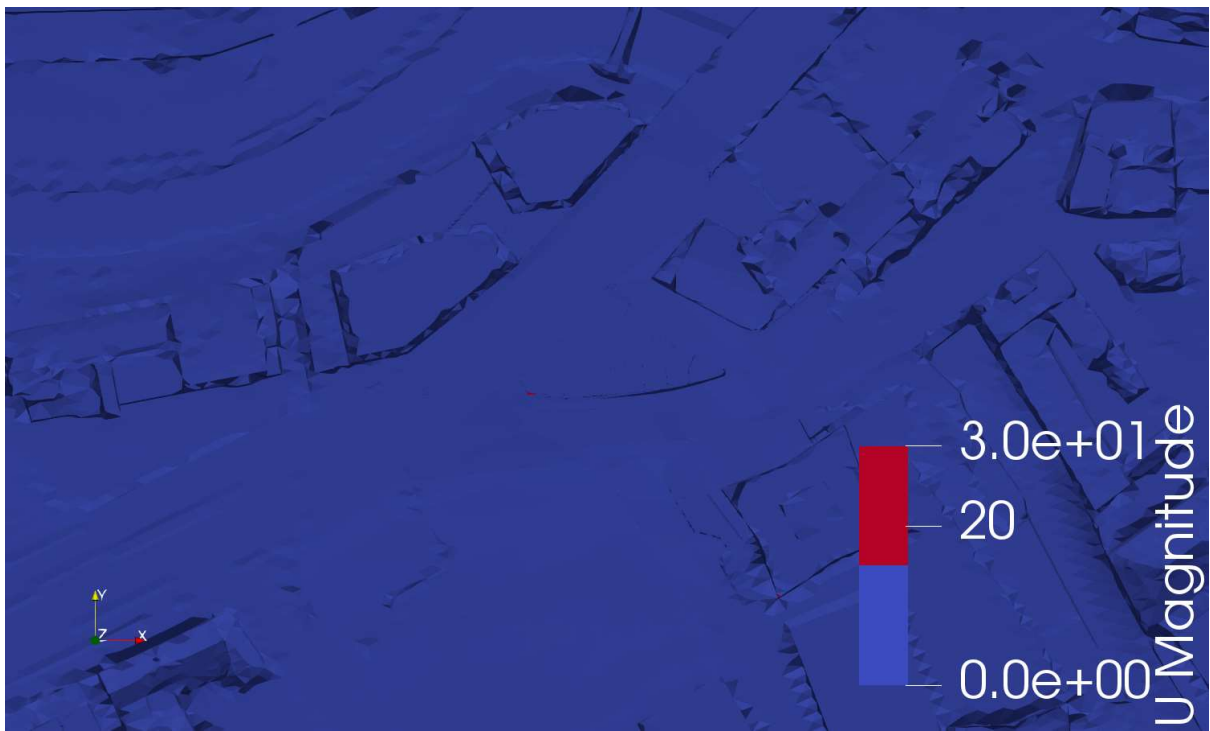
**170 Deg**



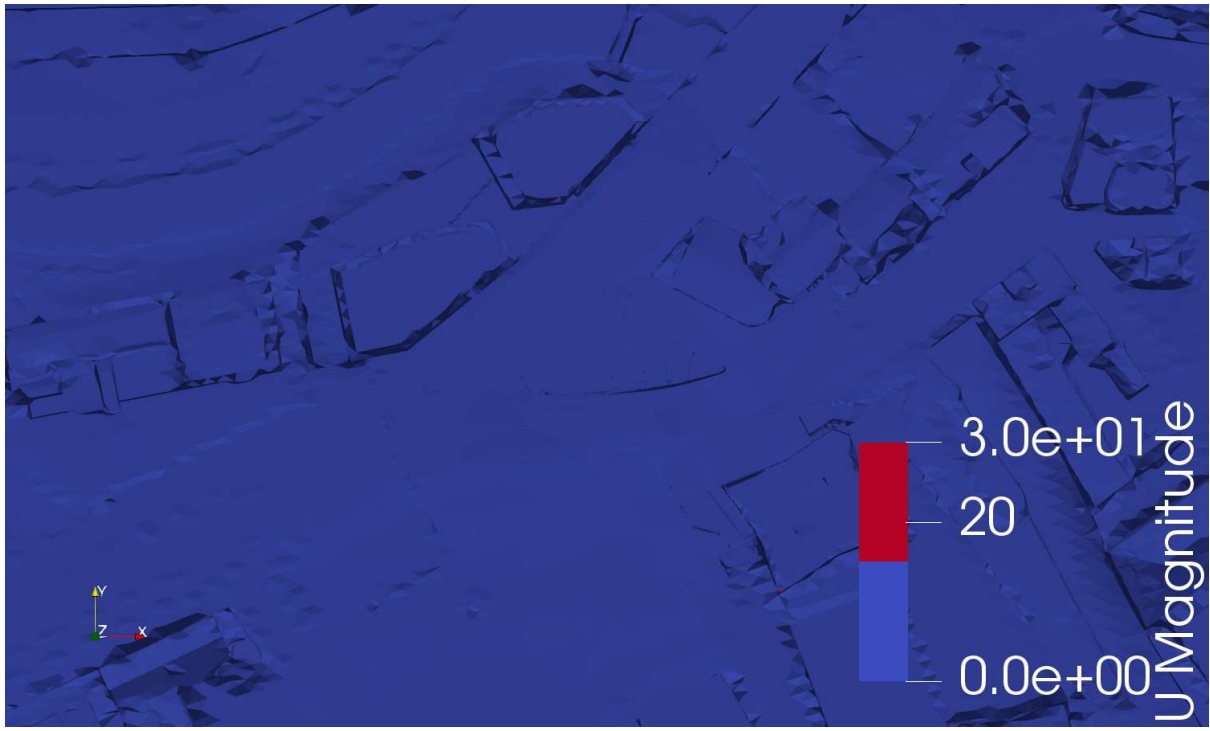
**180 Deg**



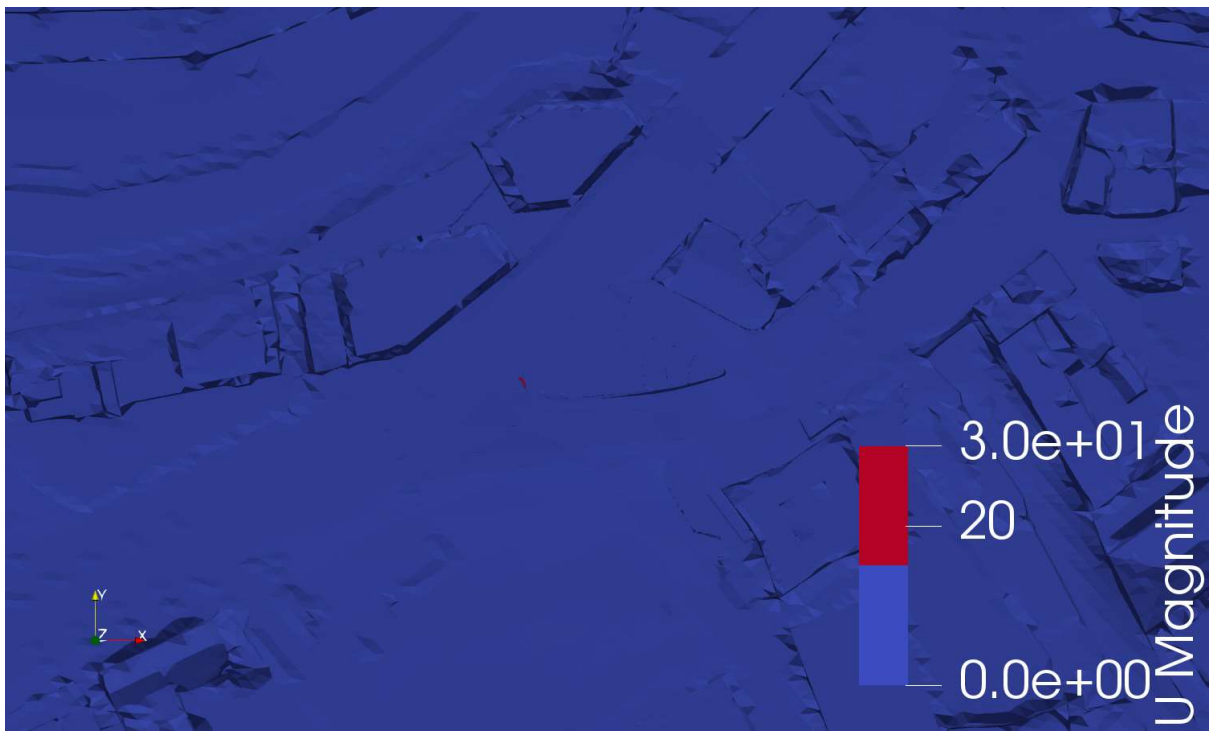
**190 Deg**



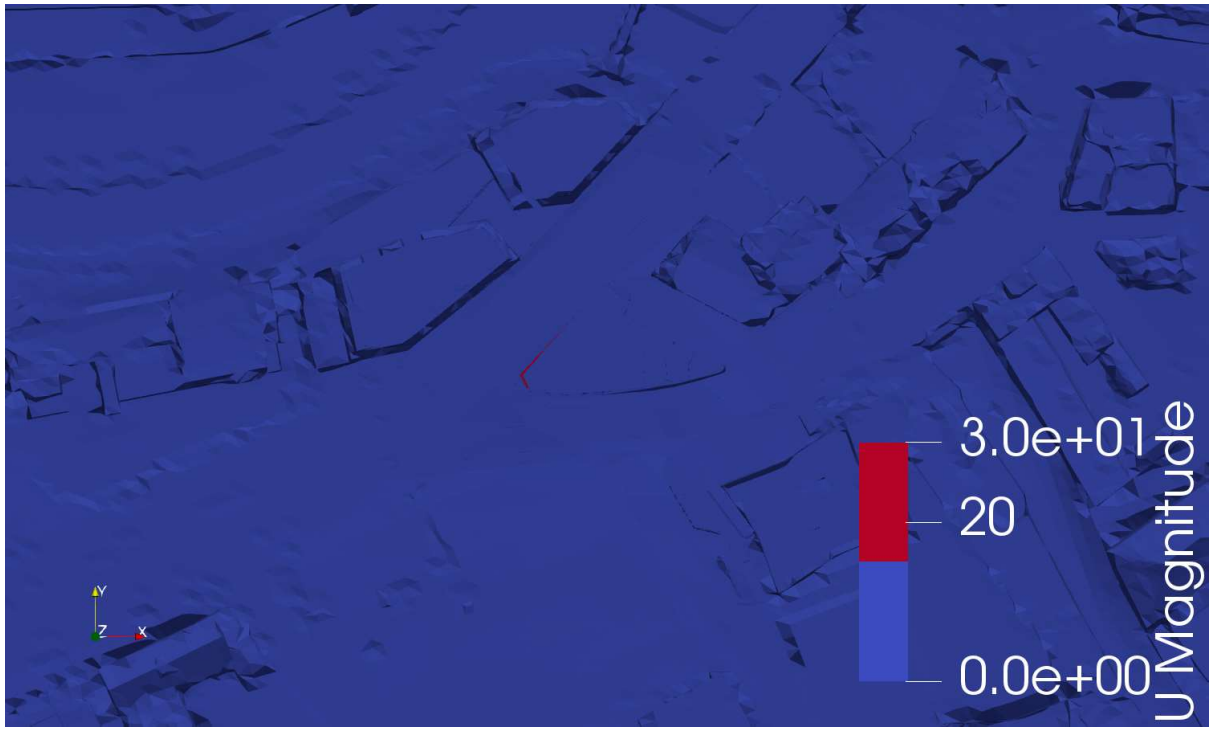
**200 Deg**



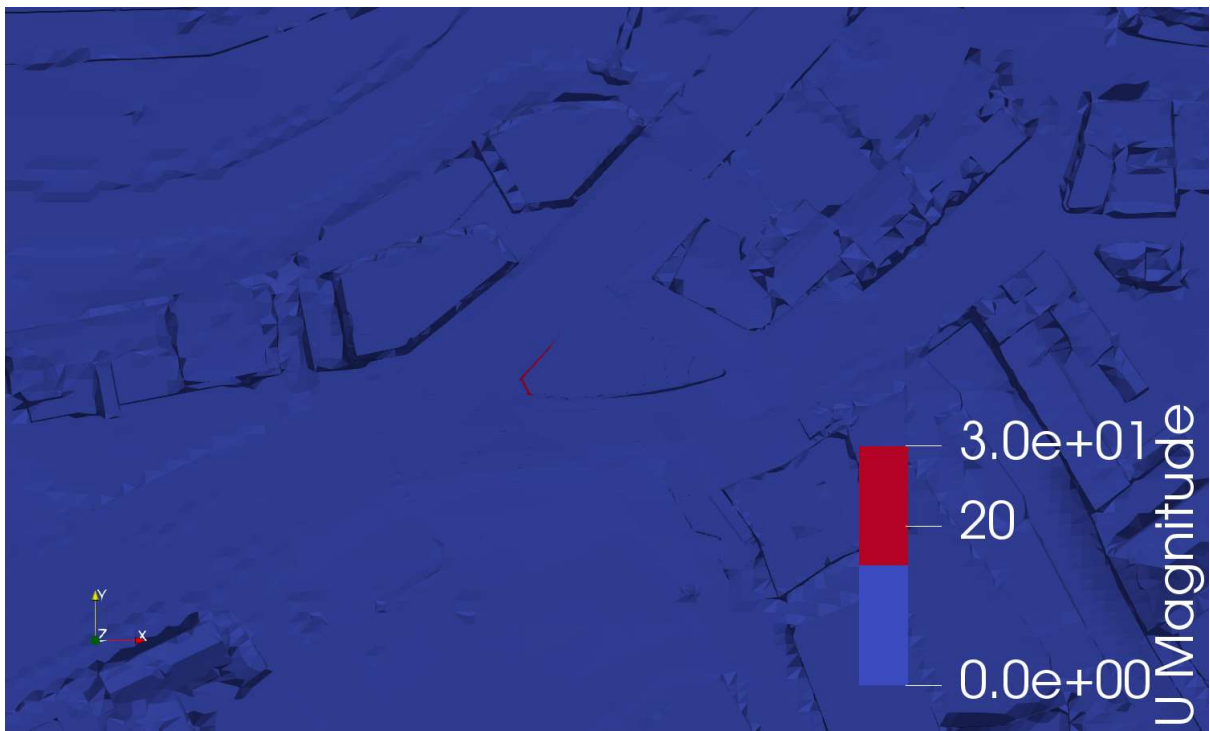
**210 Deg**



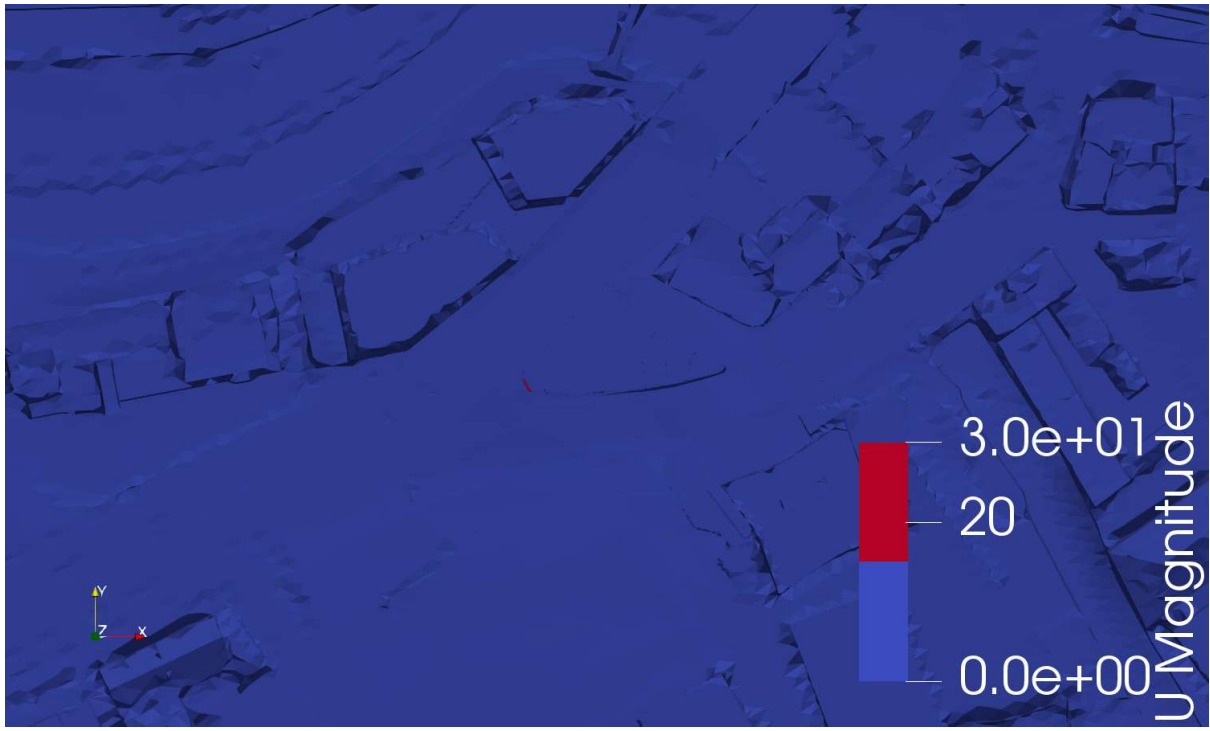
**230 Deg**



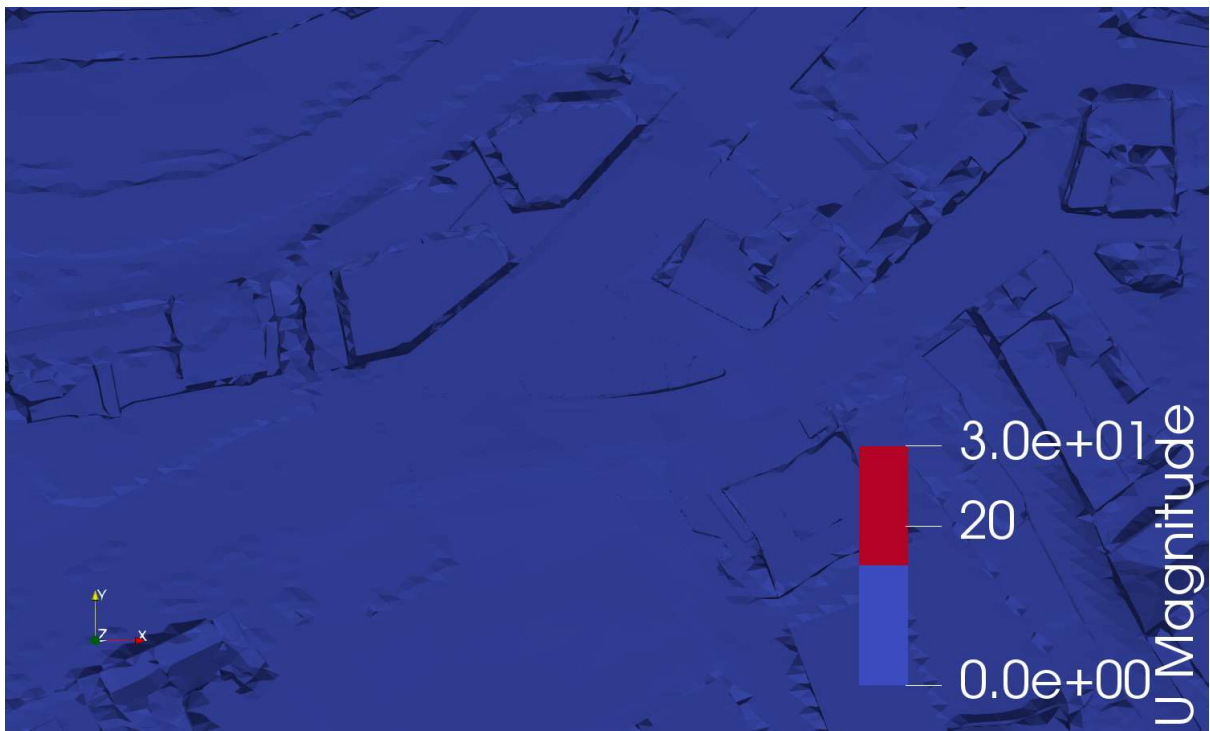
**250 Deg**



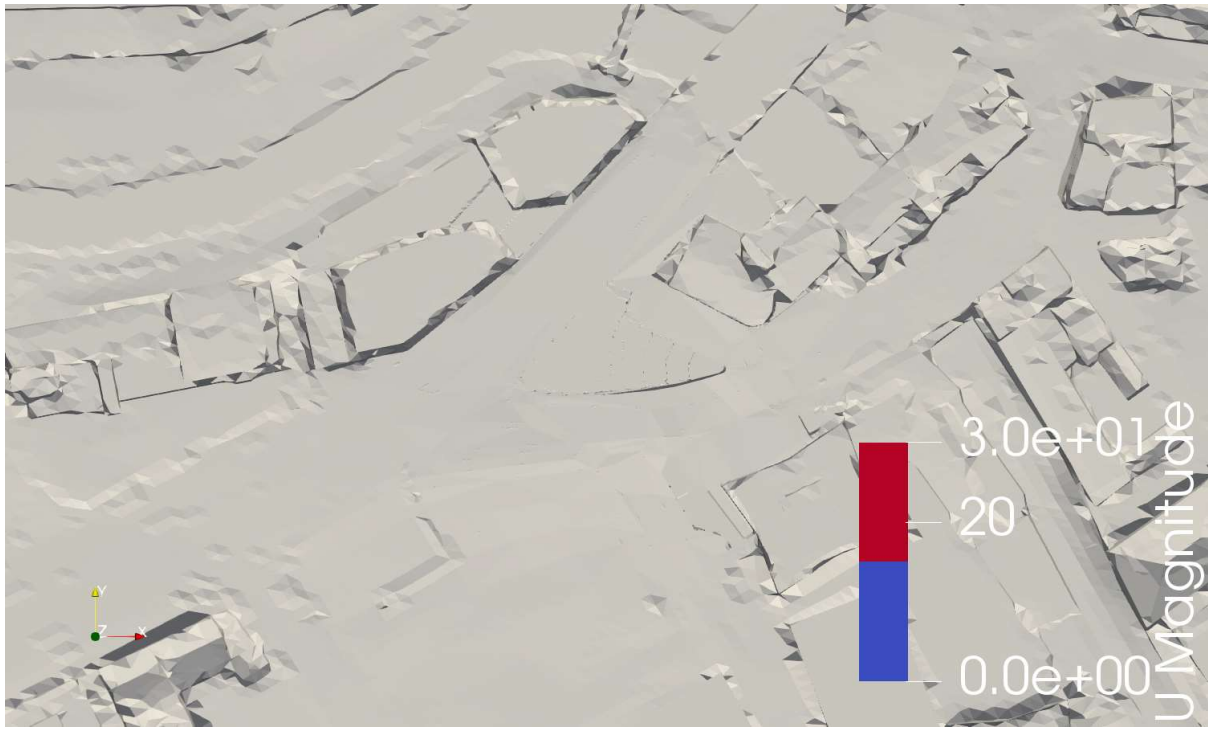
**270 Deg**



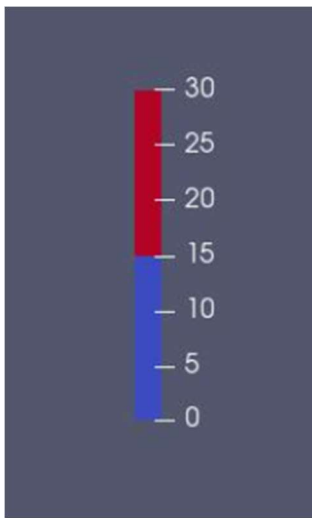
**280 Deg**



**310 Deg**



**330 Deg**



**WMC Safety**

## **Appendix 8**

12 Wind Microclimate FINAL DRAFT updated (Wardell Armstrong, 3rd March 2022)

## 12 WIND MICROCLIMATE

### 12.1 Introduction

12.1.1 This Chapter reports the likely significant effects of the Proposed Development in terms of wind microclimate in the context of the Site and surrounding area. In particular it considers the likely significant effects of changes in wind microclimate on pedestrian activities within and around the Proposed Development.

12.1.2 This chapter is a revised version issued in February 2022 to correct some minor errors relating to the mesh refinement on the bridge over the A56. The cumulative sites have not been updated as part of this revision. All directions that previously showed either comfort or safety exceedances have been re-modelled alongside a selection of other key directions to ensure accuracy.

12.1.3 These directions are 20°, 30°, 70°, 80°, 180°, 190°, 200°, 210°, 220°, 230°, 260° and 270° for comfort and 0°, 20°, 30°, 60°, 70°, 90°, 120°, 150°, 170°, 180°, 190°, 200°, 210°, 230°, 250°, 270°, 280°, 310° and 330° for safety. All other results presented in the appendices are as per the original report.

12.1.4 In general observed windspeeds are lower with the revised modelling.

12.1.5 This Chapter (and its associated figures and appendices) is not intended to be read as a standalone assessment and reference should be made to the front end of this ES (Chapters 1 – 6), as well as the final chapter, ‘Summary of Residual and Cumulative Effects’ (Chapter 14).

### 12.2 Legislation, Policy and Guidance

12.2.1 The relevant legislation, policy and guidance are listed below.

#### ***Legislative Framework***

12.2.2 There is no legislation relating to the impacts on wind microclimate.

#### ***Planning Policy***

12.2.3 The applicable planning policy is summarised as follows:

- The National Planning Policy Framework (NPPF) was published in March 2012 and revised in February 2019 and establishes a presumption in favour of sustainable development. There are no direct policies relating to wind microclimate within the NPPF.

- Local guidance comes in the form of the Manchester Core Strategy 2012 to 2027. Policy EN 2 relates to tall buildings and states that *“By their very size tall buildings can have a significant impact on the local environment and its micro-climate. It is therefore expected that this impact be modelled and that submissions for tall buildings also include appropriate measures to create an attractive, pedestrian friendly local environment.”*. Paragraph 12.14 of the strategy goes on to say that *“Tall buildings by their very nature can dominate the street scene and be highly visible over long distances. They can also have an impact on the local micro-climatic conditions, for example, by creating wind tunnels. It is for these reasons that it is considered particularly important that they are designed to the highest quality, both in terms of appearance and their impact on the functioning of surrounding space.”*

#### **Guidance**

12.2.4 The applicable guidance is summarised as follows:

- Wind Microclimate Guidelines for Developments in the City of London – City of London Corporation and RWDI.

12.2.5 This guidance has been applied where it is appropriate for Manchester and the study being undertaken.

### **12.3 Assessment Methodology and Significance Criteria**

#### **Scope of the Assessment**

12.3.1 This assessment considers the likely significant effects of changes in wind microclimate on pedestrian activities within and around the Proposed Development.

12.3.2 The scope of this assessment has been established through the EIA Scoping process, as set out in Chapter 2.

#### **Extent of the Study Area**

12.3.3 The wind model covers an area that extends to 650m radius from the Site boundary in order to capture all upstream and downstream wind effects. The full computational domain is shown in Figure 12.1, below.



**Figure 12.1: Computation Domain**

### ***Assessment Methodology***

- 12.3.4 To identify the likely effects of the Proposed Development on the pedestrian level wind environment, a 3D Computational Fluid Dynamic (CFD) model of the Proposed Development and surrounding wider area has been created. This section describes the methodology for the creation of this model and the inputs used.
- 12.3.5 Wind directions always indicate the direction that the wind blows from. For instance, a wind direction of 90 degrees (°) denotes a wind blowing from the east.
- 12.3.6 Simulations of the microclimate have been conducted using OpenFOAM CFD software. CFD simulation of likely wind patterns requires the generation of a three-dimensional computer model of the site and surrounding buildings.
- 12.3.7 A 3D model of the Proposed Development and terrain was provided by Gordan Ingram Associates (GIA).
- 12.3.8 Porous structures and vegetation have been excluded from the safety and comfort modelling. However, these will be discussed as part of any mitigation strategy should one be required.
- 12.3.9 OpenFOAM CFD software has been used to obtain a solution to the fundamental equations of fluid motion as applied to each cell in the model through intensely

computational numerical processing. A computational ‘mesh’ has been created to represent the geometry by dividing the domain into a large number of cell volumes. During the simulation, the values of each variable are determined in each cell of the mesh and so a comprehensive assessment of velocity and scalar variation within the calculation domain is obtained.

12.3.10 The dependent variables are as follows:

- **Velocities in the three co-ordinate directions (X, Y, Z);**
- **Pressure (P);**
- **Turbulence Kinetic Energy (k);**
- **Turbulence Dissipation Rate (ε); and**
- **Turbulence Specific Dissipation (ω).**

12.3.11 To improve the resolution of the results, the mesh has been concentrated in the areas of most interest (at pedestrian level around the Proposed Development) and around any significant small-scale flow features. This ensures greater accuracy of the variables under investigation. The minimum cell size is 0.325m, very slightly above the recommended cell size of 0.3cm for areas of interest. This has been selected as a compromise to limit the overall size of the model due to the complex terrain surrounding the site. Given the marginal increase in cell size we do not believe it will have a material impact on the results.

12.3.12 The modelling domain is cuboid with inlet and outlet boundary conditions specified for the relevant portions of the domain for the wind direction being modelled.

12.3.13 The inlet boundary condition is adjusted for each wind direction to account for the threshold wind speed for each wind direction at 20m above ground level.

12.3.14 The atmospheric boundary layer (ABL) is also approximated for each wind direction. The ABL is defined as the part of the atmosphere that is directly influenced by the earth’s surface. Surface heating, surface roughness, and especially surface friction are the main actors on the ABL mechanism. The main consequence of this is that the earth continuously extracts momentum from the wind and the resulting flow is turbulent.

12.3.15 The effect of the ABL is approximated within OpenFOAM using the following equation:

$$U = \left[ \frac{U^*}{K} \right] * \ln \left[ \frac{z - z_{Ground} + Z_0}{Z_0} \right]$$

#### 12.3.16 Where:

- $U^*$  is the frictional velocity;
- $K$  is Karman's Constant;
- $z_0$  is the surface roughness length;
- $z$  is the vertical coordinate; and
- $z_{Ground}$  is the minimum coordinate value in z-direction.

12.3.17 No-slip wall functions for wind speed have been applied to both the terrain and building surfaces as part of the modelling process. Porous structures and vegetation have been excluded from the safety and comfort modelling. However, these will be discussed as part of any mitigation strategy should one be required.

#### *Interpretation*

12.3.18 The methods used to interpret the results of the modelling, detailed above, and to forecast potential effects on the environment are detailed below.

12.3.19 The receptors considered within this assessment are pedestrians carrying out their usual activities within the area of wind influence of the Proposed Development. These activities are broken down into categories as per the Lawson Criteria.

12.3.20 The Lawson Criteria provide threshold wind speeds which should not be exceeded 95% of the time for given pedestrian activities to be carried out comfortably. This assessment uses the London Docklands Development Corporation (LDDC) version of the criteria, as outlined in the City of London planning advice note, which are reproduced in Table 12- and Table 12-, below.

**Table 12-1 – Lawsons LDDC Criteria - Comfort**

| Comfort Category   | Threshold (m/s) | Description                                                                                                                             |
|--------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Frequent Sitting   | 2.5             | Acceptable for frequent outdoor sitting use, e.g. restaurant, cafe                                                                      |
| Occasional Sitting | 4               | Acceptable for occasional outdoor seating, e.g. general public outdoor spaces, balconies and terraces intended for occasional use, etc. |
| Standing           | 6               | Acceptable for entrances, bus stops, covered walkways or                                                                                |

| Comfort Category | Threshold (m/s) | Description                                   |
|------------------|-----------------|-----------------------------------------------|
|                  |                 | passageways beneath buildings                 |
| Walking          | 8               | Acceptable for external pavements, walkways   |
| Uncomfortable    | >8              | Not comfortable for regular pedestrian access |

12.3.21 In addition, a safety threshold is set for the wind speed exceeded twice per year or 0.022% of the time from any wind direction.

**Table 12-2 – Lawsons LDDC Criteria - Safety**

| Comfort Category | Threshold (m/s) | Description                                                                                                               |
|------------------|-----------------|---------------------------------------------------------------------------------------------------------------------------|
| Unsafe           | >15             | Winds above this threshold will pose safety risks, particularly for more vulnerable pedestrians (elderly, cyclists, etc.) |

### *Significance Criteria*

12.3.22 The significance criteria to measure the impact on pedestrians from wind microclimate are presented below in Table 12-3.

12.3.23 Effects that are classified as moderate or above are considered to be **significant**. Effects classified as below moderate are considered to be **not significant**.

**Table 12-3 – Significance Criteria**

| Effect     | Trigger                                                                                                 | Mitigation Required |
|------------|---------------------------------------------------------------------------------------------------------|---------------------|
| Very Large | Conditions are 'unsafe' or 'uncomfortable'                                                              | Yes                 |
| Large      | Conditions are 3 categories windier than desired                                                        | Yes                 |
| Moderate   | Conditions are 2 categories windier than desired                                                        | Yes                 |
| Slight     | Conditions are 1 category windier than desired                                                          | No                  |
| Neutral    | Conditions are calmer than required for the intended pedestrian use (by at least one comfort category). | No                  |

### ***Limitations***

12.3.24 In common with other forms of modelling, such as the use of wind tunnels, there are various limitations that can affect the accuracy of modelling carried out in support of this assessment.

- CFD modelling is a mathematical approximation of real-world conditions and is not to be considered an exact representation of conditions on site at any specific point in time. Instead, it uses time-averaged data that gives a good understanding of flow across the calculation domain under commonly occurring conditions. It is an excellent tool for assessing likely issues in relation to pedestrian comfort and safety as it balances accuracy with visualisation tools;
- The CFD simulation is steady state and does not explicitly quantify short-term gusts;
- Certain landscaping features, including porous structures under 8m in height, have not been included within the 3D model;
- The consented buildings in the area have been included in the 3D model, however, if their designs were to change this could impact upon the wind speeds at the application site;
- The 3D model does not include those buildings currently in planning that have not yet been consented; and
- Analysis is based on virtual met mast wind data, provided by the Met Office and covers a 30-year period. It is assumed to be representative of the wind conditions present at the application site. Future increases in wind speed, and gusting and increased volatility in weather patterns as a result of climate change or other unforeseen factors are not accounted for in the modelling.

## **12.4 Baseline Conditions**

12.4.1 The Site is currently composed of an area of brownfield land. There are no known problems arising from strong wind conditions affecting the public. Further information regarding the current site conditions are set out in Chapter 3. Where exceedances in the wind speed criteria have been identified some baseline models have been run for comparison. These are presented alongside the results.

### ***Sensitive Receptors***

12.4.2 The receptors within a wind microclimate assessment are the pedestrians using the public realm and outdoor facilities within and surrounding the Proposed Development.

## **12.5 Assessment of Effects**

### ***Design Solutions and Assumptions***

12.5.1 Within and immediately surrounding the Proposed Development area there are multiple locations where there are high wind speeds present. In some cases, embedded mitigation, in the form of trees, will reduce the wind speeds experienced. Landscaping has not been included in the CFD model as it is difficult to accurately quantify the effect of landscaping features, such as trees. However, it is acknowledged that trees will have an overall effect in lowering wind speeds within the pedestrian environment. As landscaping features have not been included with the CFD model, expert judgement has been used to establish how landscaping will affect wind speeds.

### ***Assessment of Effects***

12.5.2 This section highlights some of the exceedances identified at the Proposed Development and establishes their significance criteria.

12.5.3 All directional results for both safety and comfort modelling are contained within Appendix 12.1 and 12.2.

### ***Safety***

#### ***Bridgewater Viaduct (A56)***

12.5.4 Analysis of the CFD model indicates the production of a funnelling effect of wind over A56 Bridgewater viaduct which joins winds already flowing down the A56 street canyon. This generates areas of high wind speed between the Proposed Development and the developments to the north of the A56 under certain modelling conditions. 2 safety exceedances are identified as a result of this phenomenon.

12.5.5 Direction 60° identifies a very small area of safety exceedance located directly to the north of the Proposed Development on the north side of the A56 as seen in Figure

12.1. The peak windspeeds are modelled at 15.025m/s and so the exceedance is extremely marginal.

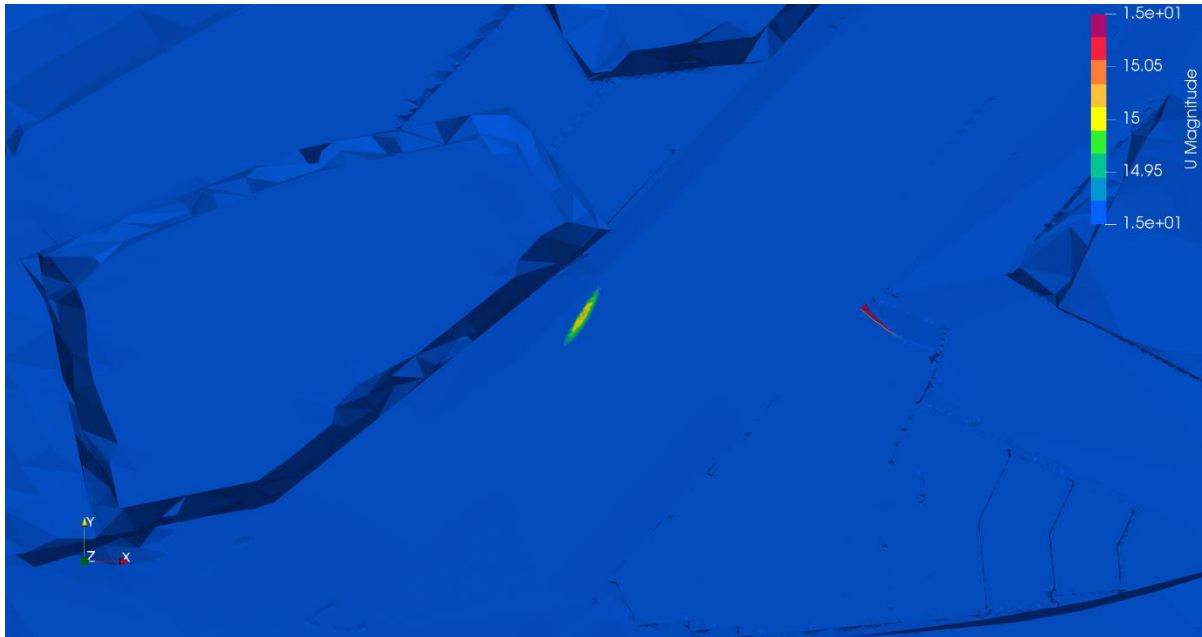


Figure 12.1 – Safety 30°(legend from 15 to 15.1m/s)

12.5.6 Wind from 70° indicates a larger exceedance along the A56 to the northwest of the development as seen in Figure 12.2. The peak windspeed is 17.4m/s. This exceedance is largely located within the central area of the A56 carriageway, however this may present an issue for cyclists who could be particularly vulnerable under the conditions modelled.

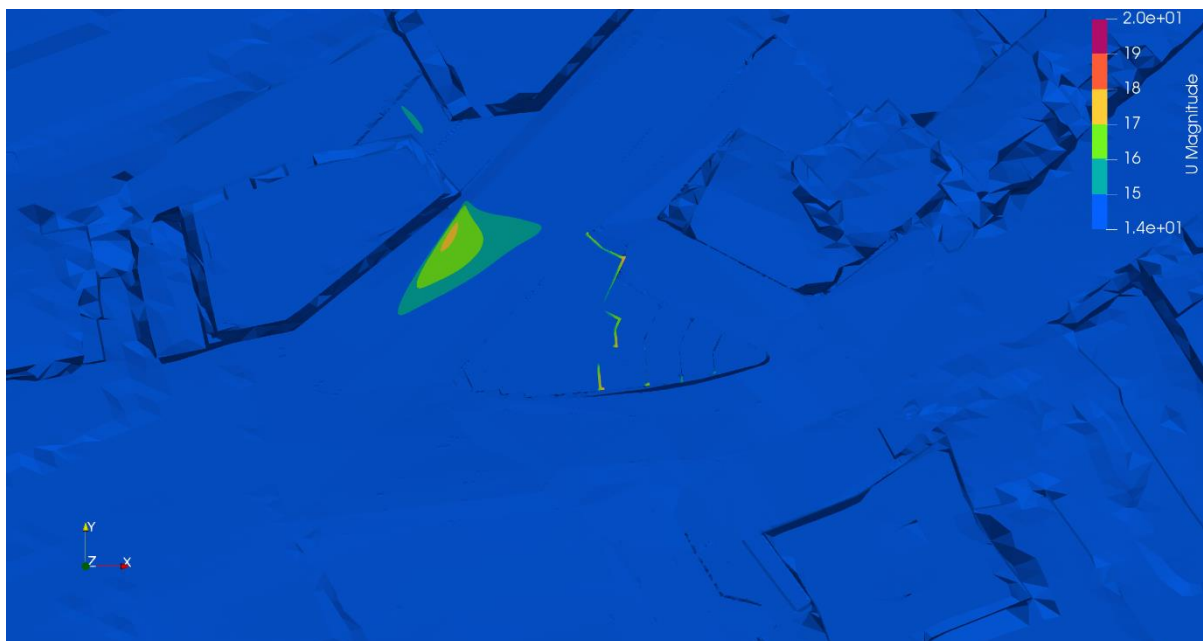


Figure 12.2 – Safety 70°.

12.5.7 The safety modelling requires that the safety modelling is carried out using the windspeed exceeded 0.022% of the time from all directions. In the direction being modelled the highest windspeed in the 30 year dataset is 20% below windspeed modelled as storm force easterly winds tend not to occur in the UK. As such the likelihood of these conditions being experienced are negligible.

12.5.8 A baseline safety run has also been undertaken for the 70° wind direction, the results of which are shown below. This shows that there is already a large area of the A56 which would experience windspeed above the safety criteria under the conditions modelled. As such the significance of effect for both the existing and proposed conditions would be considered **Very High** and **Significant**.

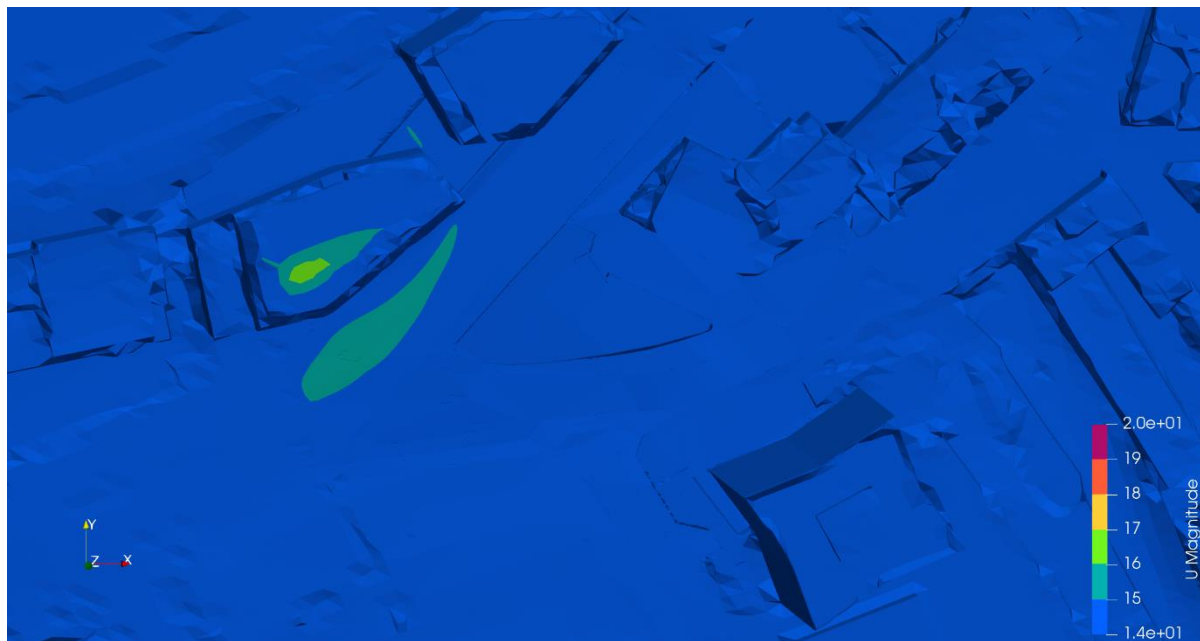


Figure 12.3 – Safety 70° Baseline.

#### ***Rooftop and External Terraces***

- 12.5.9 No safety exceedances were observed on the main areas of the rooftop and the three external terraces. All exceedances in these areas were identified along the outsides of the 1.5m high parapet walls indicating that the parapet walls are currently mitigating against any safety exceedances within the main rooftop and external terrace areas.
- 12.5.10 The significance of the effect in these areas are **Neutral** and therefore **Not Significant**. Mitigation is not required.
- 12.5.11 No other safety exceedances were identified within the Proposed Development and immediate surrounding area.

#### ***Comfort***

##### ***Bridgewater Viaduct (A56)***

- 12.5.12 Due to a funnelling effect between the existing buildings, Bridgewater Viaduct itself and the Proposed Development, wind directions 70° and 210° show wind speeds along the A56 Bridgewater Viaduct immediately to the north of the Proposed Development which could have an impact on pedestrian comfort. This is in the areas as seen in Figures 12.3 and 12.4. Wind speeds in the 70° wind direction peak at just

under 11 m/s. Therefore, in this direction wind speeds fall within the comfort criteria of Uncomfortable, meaning that these wind speeds may be uncomfortable for some users the intended pedestrian use of walking or cycling. As the speeds over 8 m/s mainly fall on the roadway cyclists will be the main users affected. Mitigation is considered below in section 12.6.

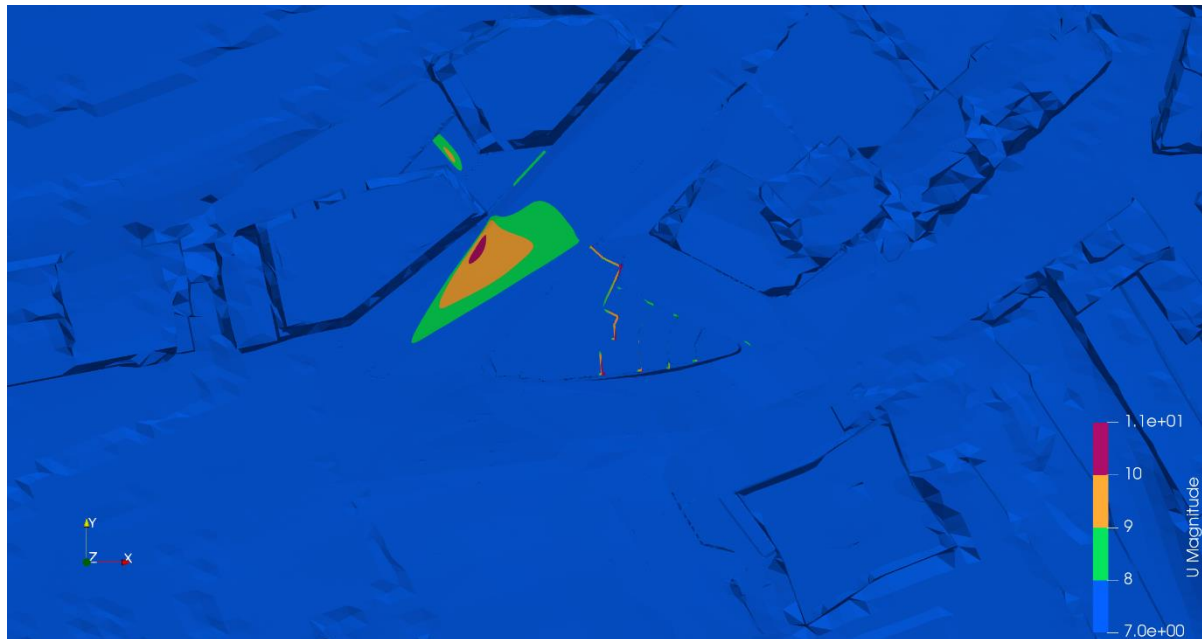


Figure 12.3 – Comfort 70° (scale 7 – 11m/s)

- 12.5.13 For the 210° wind direction, speeds only just exceed 8m/s in a very small area. The maximum wind speed is 8.25m/s. As such, although the comfort criteria is exceeded very slightly, the likelihood is that this would go unnoticed by most users. Nonetheless mitigation is discussed below.
- 12.5.14 In addition, there is a minor exceedance of the comfort criteria in the 260° wind direction. As above this is very minor but is covered in the mitigation section below.

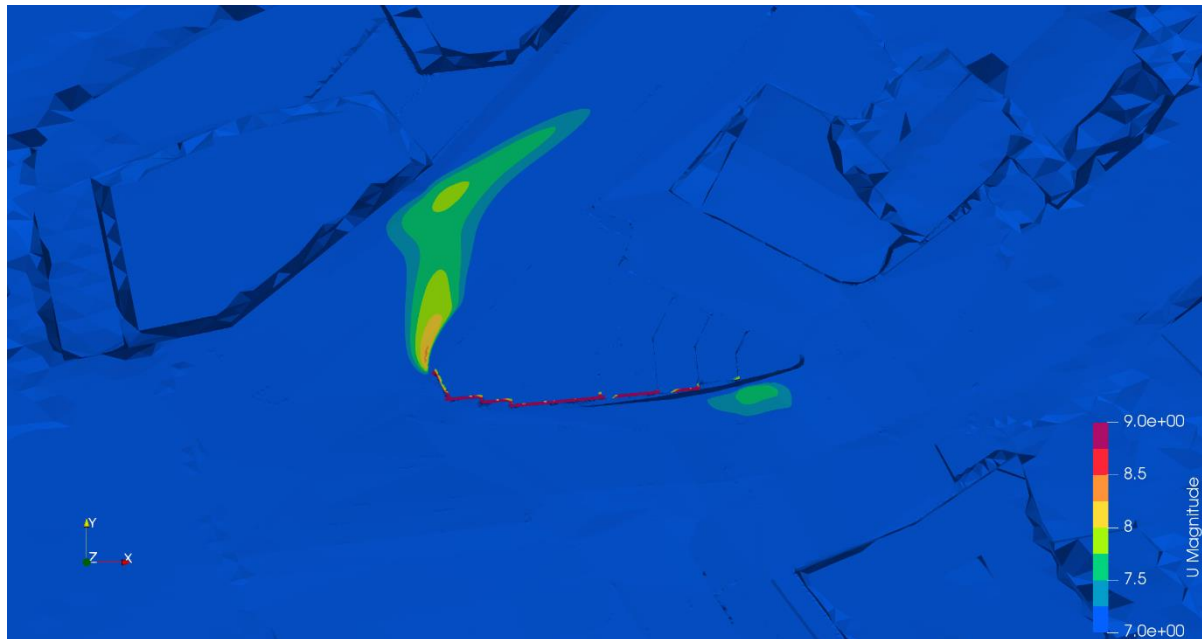


Figure 12.4 – Comfort 210° (Scale 7-9m/s)

12.5.15 For reference a baseline comfort model has also been run in the 70degree wind direction. This is shown in figure 12.4 below and indicates that the comfort criteria are already exceeded in this location.

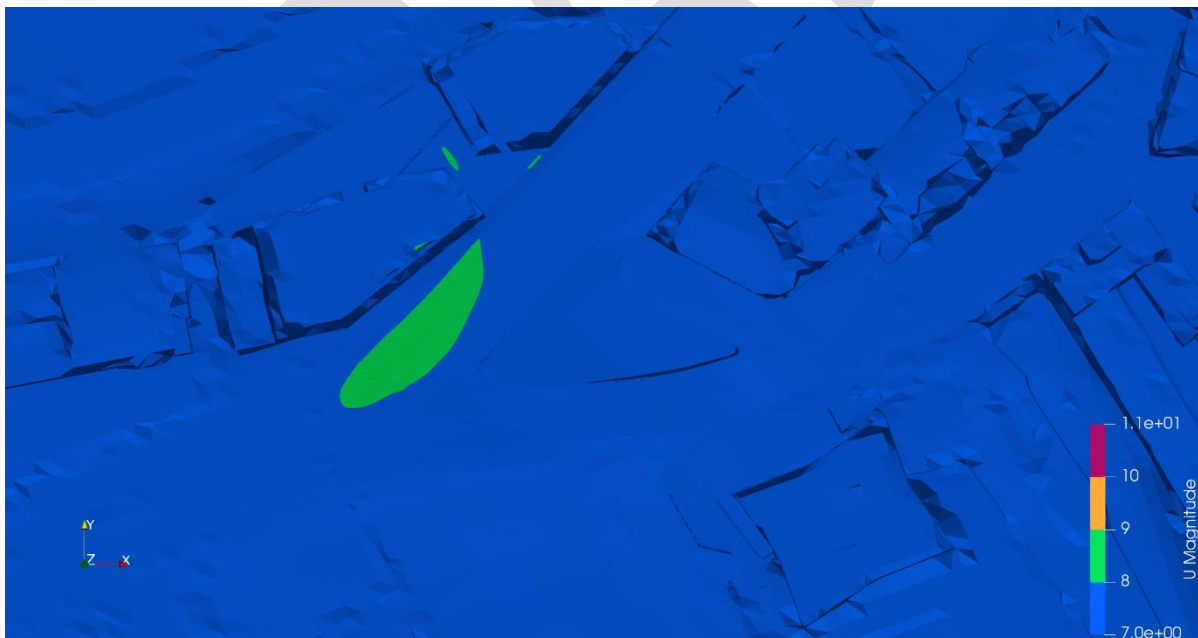


Figure 12.4 – Comfort 70° Baseline (Scale 7-11m/s)

12.5.16 The significance of the effect in these areas are **Very Large** and therefore **Significant** for both the baseline and proposed scenarios.

### ***Deansgate Road***

12.5.17 There are three directions where wind speeds could be considered ‘uncomfortable’ for pedestrians and cyclists on Deansgate road. These are 260°, 270° and 280°.

12.5.18 The 260° wind direction shows two very minor comfort exceedances, one on the A56 and one on Deansgate. Although very minor these are covered under mitigation below.

12.5.19 The 270° and 280° directions show similar results, with winds being funnelled between the proposed scheme and the existing Deansgate Square West Tower. Speeds in the 280° direction are mostly due to the existing Deansgate Square West Tower as the proposed scheme is offered some protection from the buildings to the north of the A56. In the 270° direction the proposed building has a greater influence on the wind speeds observed. The modelling results for 280° are available in appendix 12.2. The modelling results for the 270° direction are shown below.

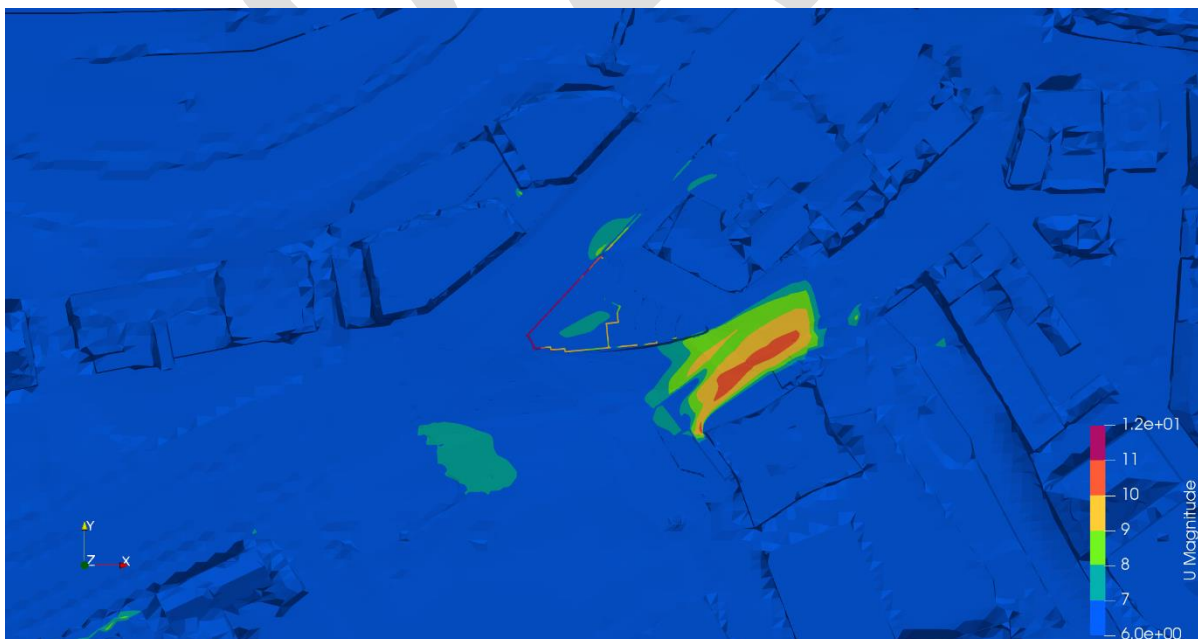


Figure 12.5 – Comfort 270° (Scale 6-12m/s)

- 12.5.20 The results show winds from the west being squeezed between the gap in the buildings. As with the 280° direction the Deansgate Square West Tower is the primary cause of this as it faces ‘corner on’ to the wind, forcing it to change direction by 45 degrees whereas the proposed scheme presents a fairly narrow profile to the wind in this direction. Wind speeds peak at 10.3m/s
- 12.5.21 As with the A56 results downdraft plays almost no part in the wind speeds observed and so any building in this location would result in similar windspeeds being observed on the ground.

### ***External Roof Terraces***

- 12.5.22 In general the three external roof terraces located on the 22<sup>nd</sup>, 24<sup>th</sup> and 26<sup>th</sup> floors experience comfort levels of Frequent Sitting criteria (0-2.5m/s), Occasional Sitting (2.5-4m/s) and Standing criteria (4-6m/s) which are acceptable for the intended use..
- 12.5.23 The three external terrace areas in general will experience comfort levels suitable for their intended use as **Slight** and therefore **Not Significant**. Mitigation is not required.
- 12.5.24 It is understood that the rooftop area of the Proposed Development will not be used for public access. The rooftop area does however, contain equipment such as generators, condensers, PV arrays and smoke vent fans which will all have to be maintained. The necessary health and safety measures should be implemented for any maintenance person working on the rooftop. This may include not carrying out maintenance works on the rooftop during periods of high winds.

### ***Main Entrance***

- 12.5.25 The main entrance located within the west of the Proposed Development is generally identified as being within acceptable comfort levels for main entrances at 0-6m/s. The comfort level for the main entrance is exceeded however, from direction 230° where speeds increase to Walking levels (6-8m/s). In general, for directions 180° to 240°, the funnelling effect generated along the A56 Bridgewater Viaduct creates a zone immediately to the north of the main entrance where comfort criteria levels are at Strolling criteria speeds.

- 12.5.26 As a small number of directions give a comfort category one windier than desired, the significance of the effect in this area is identified as **Slight** and therefore **Not Significant**. Mitigation is not required.

#### ***Car Park***

- 12.5.27 In the car park are immediately to the east of the Proposed Development, wind speeds 0-6m/s were generally recorded meaning the area is suitable for its intended pedestrian use. Direction 70° however, indicated an area of Walking criteria (6-8m/s) at the entrance to the car park, which is slightly windier than desired.
- 12.5.28 As the comfort category for direction 70° showed gave a comfort category of one more than desired, the significance of the effect in these areas are **Slight** and therefore **Not Significant**. Mitigation is not required.

## **12.6 Mitigation**

### ***Bridgewater Viaduct (A56)***

- 12.6.1 Embedded mitigation is included along the pavement immediately to the north of the Proposed Development in the form of tree planting with four specifically positioned trees. Wind Microclimate Guidelines for Developments in the City of London, which has been used as guidance for this assessment, states it is prudent to ignore landscape elements that are smaller than 8m in height and therefore the effect that these trees will have on the wind microclimate cannot easily be modelled.
- 12.6.2 From our experience in previous Wind Microclimate assessments we anticipate that the planting of trees in this area will allow the break-up of wind flow channelled between the Proposed Development and the development to the north of the A56. This will therefore reduce wind speeds to safer and more comfortable levels for both pedestrians and cyclists. It is predicted that with the revised embedded mitigation in place, isolated areas of safety and comfort exceedance will be reduced but not eliminated.
- 12.6.3 As noted above the conditions that would need to arise for the safety criteria to be exceeded are extremely unlikely to occur and the actual risk chance of speeds exceeding 15m/s is negligible. Nonetheless the mitigation scheme will still improve wind conditions around the site.

### ***Deansgate Road***

- 12.6.4 Some features already exist that will reduce the windspeeds modelled. These are in the form of a number of trees, vegetation and a small porous screen located immediately to the north of the Deansgate Square development. The Proposed Development will also improve three existing trees which will be replaced and are located along the pavement immediately to the south, up to the layby area.
- 12.6.5 The existing and proposed features will help reduce wind speeds in the 260°, 270° and 280° wind directions and make them more comfortable. In the 260° direction the exceedance will be eliminated entirely. For the remaining two directions the existing mitigation at Deansgate Square in conjunction with the proposed mitigation will improve conditions on Deansgate and should significantly reduce the wind speeds observed. If the Deansgate Square mitigation is working as designed then there should be no comfort exceedances in these directions following mitigation.
- 12.6.6 No safety criteria exceedances have been identified on Deansgate.
- 12.6.7 The use of trees within both Bridgewater Viaduct (A56) and Deansgate Road as natural wind mitigation measure is based on the fact that the porous nature of trees allow the soft dispersal of high strength winds and therefore reduce the energy and the speed of the wind. The aim is to allow some wind to pass through the area rather than completely block the wind, which could create problems elsewhere.
- 12.6.8 The trees planted will have a managed height of 6m and a canopy of between 1.5-3m. Due to their proximity to both the A56 and Deansgate Road, the trees will be maintained to ensure that tree growth does not represent a hazard to road users. Any tree loss due to disease or damage will be replaced to maintain wind mitigation effectiveness.

## **12.7 Residual Effects**

### ***Bridgewater Viaduct (A56)***

- 12.7.1 Following implementation of the embedded mitigation in the form of tree planting along the pavement directly to the north of the Proposed Development, it is predicted that isolated areas of safety will be reduced but not eliminated. Although there will be some residual effects in terms of safety in the 70° wind direction the odds of these occurring are negligible as wind speeds in this direction do not get

within 20% of the safety assessment wind speed at any point in the 30 year data record.

12.7.2 It is also predicted that pedestrian areas in the 70° which were identified as uncomfortable (>8m/s), will be reduced but not eliminated with mitigation in place.

12.7.3 It is anticipated that based on the rigid application of the safety criteria the significance of effect in this area in terms safety will remain above 15m/s and therefore would be Very Large and Significant. However these windspeeds have never occurred over a 10 minute average in the 30 year dataset used in the assessment.

12.7.4 The safety exceedance at 30° is only 0.025m/s over the safety criteria.

12.7.5 In addition to the above, with the mitigation implemented the conditions are likely to be only slightly above the baseline (which already exceeds the safety and comfort criteria). As such the effect is considered to be **Slight** and therefore **Not Significant** with regards to safety.

12.7.6 With regards to comfort in the 70° and 210° wind directions, the mitigation will likely reduce windspeeds but there will still be areas that could be considered uncomfortable for cyclists and pedestrians. As such the residual effect in this location is considered **Very Large** and **Significant**. It should be noted that any building on this plot would result in similar effects to those modelled and that high winds from the east occur infrequently. The average wind speed in this direction is almost half the modelled wind speed.

12.7.7 The comfort exceedance at 260° will be eliminated by the proposed mitigation, as such, with mitigation in place the conditions will be overall similar to the existing situation and as such the residual effect is considered **Slight** and **Not Significant** with regards to comfort.

### ***Deansgate Road***

12.7.8 Three trees will be planted along the pavement directly to the south of the Proposed Development as part of the embedded mitigation strategy. The additional trees in combination with trees currently present to the south of the site and the trees, raised vegetation areas and small porous screen located to the north of the

Deansgate Square development will act to lower the significance of effect in the Deansgate Road area to **Neutral** and therefore **Not Significant**.

## 12.8 Assessment of Cumulative Effects

12.8.1 Cumulative developments will have an impact on the wind speeds experienced at the Proposed Development. The key cumulative developments are the development directly to the northwest of the Proposed Development located on the northern side of the A56 and the Deansgate Square Development located to the south on the southern side of Deansgate Road.

12.8.2 The potential cumulative effects have already been considered as part of the main assessment, by including cumulative developments within the modelling domain. The cumulative effects are as set out in the residual effects section.

## 12.9 Summary

12.9.1 A number of areas within the immediate vicinity of the Proposed Development were identified as having significant effects. These were either along Bridgewater Viaduct (A56) to the north or Deansgate Road to the south.

12.9.2 Following detailed CFD wind microclimate modelling two safety exceedances and two comfort exceedances were identified along Bridgewater Viaduct (A56) as a result of the funnelling of wind between the Proposed Development and the Bridgewater Viaduct with wind being forced up and over the bridge and then joining a stream of air already travelling down the road canyon. The significance of this effect was seen as **Very Large (Significant)** and as a result, mitigation will be required.

12.9.3 Mitigation for this effect has already been included to some extent within the Proposed Development design in the form of tree planting along the pavement immediately to the north of the Proposed Development. We anticipate that these trees will allow the break-up of wind flowing through this area but will not eliminate high wind speeds completely. The baseline safety and comfort results observed in this wind direction also exceed the relevant criteria making eliminated the exceedances entirely very challenging. With regards to safety, as the wind speeds modelled are extremely unlikely to occur in reality the significance of effect is

considered **Slight (Not Significant)**. With regard to comfort in the 70 degree wind direction the wind speeds will still remain slightly higher than the baseline after mitigation and so the effect is considered **Very Large** and **Significant**. It should be noted that any building on this plot would result in similar effects to those modelled and that high winds from the east occur infrequently. The average wind speed in this direction is almost half the modelled wind speed.

12.9.4 Other comfort exceedances on the A56 are considered **Slight** and **Not Significant** following mitigation.

12.9.5 Along Deansgate Road three comfort exceedances were identified. When taking into account the existing mitigation at Deansgate Square alongside the mitigation proposed it is considered that the residual effect will be **Slight (Not Significant)**.

12.9.6 No safety exceedances or major comfort exceedances were identified on the external terraces indicating that the current designed parapets are working correctly.

12.9.7 No other safety exceedances were encountered either within or immediately outwith the Proposed Development.

12.9.8 It is understood that the rooftop area will not have public access. This area will be used for maintenance of generators, condensers and smoke vents etc. Health and Safety precautions should be established for maintenance personnel including restricted access to the rooftop during periods of high winds.

## **Appendix 9**

Lawson, T.V. The determination of the wind environment of a building complex before construction. Bristol: University of Bristol, Department of Aeronautical Engineering, 1990 (Extract)

## 2.2 Local and reference wind speeds

Two values of local head-height wind speed ratio shall be made;

- 1) An hourly average value called the "Windspeed Ratio".
- 2) A Gustspeed Ratio, which are values averaged over 3 seconds.

Because annoyance caused by the wind can arise for two different reasons;

- i) The effort required to walk across the site.
- ii) Gusts which can turn an umbrella inside-out or remove a hat.

it is necessary to produce two numerical values representing the windspeed at a location; these are the hourly average Windspeed Ratio and the Gustspeed Ratio

## 4.4 Gustspeeds

### 4.4 Gustspeeds.

As gusts cause the majority of cases of annoyance and distress these shall be assessed in addition to hourly average windspeeds. Two separate sets of criteria for gustspeeds are required; the first for general locations and the second for locations immediately overlooking water. However, rather than give two additional sets of criteria, it is proposed that in general locations all "Gustspeeds" be divided by 1.85 and compared to the criteria given in Sections 4.2 and 4.3. For locations immediately overlooking water the "Gustspeeds" shall be divided by 2.0. These shall be called "Equivalent Hourly Average Windspeeds" and must be presented in the same tables where the values of Hourly Average Windspeeds are presented