DRAFT REPORT

PROJECT BLUE DRAGON – SITE 1

CARDIFF, WALES

PEDESTRIAN LEVEL WIND MICROCLIMATE ASSESSMENT

RWDI #2205854
5TH AUGUST 2022

SUBMITTED TO

Caleb Shah
Associate Director
Caleb.Shah@expediteps.com

Expedite
8 Village Way Greenmeadows,
Springs Business Park,
Cardiff
CF15 7NE
T: +44 (0) 2920 098655
M: +44 (0)7398 236 554

SUBMITTED BY

Induja Ashok
Project Engineer
Induja.Ashok@rwdi.com

Zain Khan
Project Engineer
Zain.Khan@rwdi.com

Joseph Symes
Project Manager
Joseph.Symes@rwdi.com

RWDI
Unit 1 Tilers Road
Milton Keynes
MK11 3LH
T: +44 (0)1908 776970

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VERSION HISTORY

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Project Team	Induja Ashok	Project Engineer
	Zain Khan	Project Engineer
	Joseph Symes	Project Manager

1. EXECUTIVE SUMMARY

The objective of this study was to determine the ground and terrace level wind environment within and around the proposed Project Blue Dragon development (hereafter referred to as the "Proposed Development") in Cardiff, Wales.

This report presents a description of the methodology used and the results of two configurations tested in the wind tunnel, namely:

- Configuration 1: Existing Site with Existing Surrounding Buildings; and
- Configuration 2: Proposed Development with Existing Surrounding Buildings.

The meteorological data for Cardiff indicates prevailing winds from the western quadrant throughout the year with secondary winds from the north-east direction which are more prevalent during the spring months.

In the baseline scenario (Configuration 1), the wind conditions would be suitable for the intended use in and around the Site suitable with sitting to strolling use condition during the windiest season.

With the introduction of the Proposed development (Configuration 2), all assessed areas in and around the Site would have suitable wind conditions during the windiest and summer season seasons. Terrace locations at elevated levels would also have suitable wind suitable conditions during the summer season. There would be no instances of strong wind exceedances which pose safety concerns.

2. INTRODUCTION

RWDI was retained by Expedite to conduct a pedestrian level wind microclimate assessment for Site 1 of the proposed Project Blue Dragon development (referred to as the "Proposed Development" hereafter in this report) in Cardiff, Wales. This report presents the background, objectives and methodology, which will be used for RWDI's assessment. A further report will be issued after the assessment to present the results and recommendations post wind tunnel testing.

3. BACKGROUND AND APPROACH

Wind tunnel tests were conducted on a 1:300 scale model of the Proposed Development. The investigation quantifies the wind conditions within and around the Site through comparing the measured wind velocity and frequency of occurrence with the Lawson Comfort Criteria. Meteorological data from Cardiff Airport was analysed and adjusted to the Site conditions by modelling the effect of the surrounding terrain roughness on the wind velocities approaching the Site.

Measurements will be taken on and off-site for 36 wind directions, in 10° increments. The measurements will cover ground level locations along the building façades and at corners, near main entrances, on pedestrian routes within and around the Site, bus stops and terraces within the Site. Analysis was conducted on seasonal basis, however, the report focuses primarily on the windiest season (i.e. winter) and the summer season results, when pedestrian activity generally requires calmer conditions.

This report presents a description of the methodology and the results of two configurations tested in the wind tunnel, namely:

- Configuration 1: Existing Site with the Existing Surrounding Buildings; and
- Configuration 2: Proposed Development with the Existing Surrounding Buildings.

3.1 Site Description and Surroundings

The Proposed Development is located in Cardiff, Wales, on Docks Lane, Northwest of Roald Dahl Plass. The Site is bounded by a car park to the north, Lloyd George Ave to the east, Bute Street to the west and James Street to the south. The OS Landranger reference grid for the Site is ST191746.

The Site is currently occupied by low-rise developments, up to five storeys in height. The surrounding area is predominately comprised of low-rise developments, with some mid-rise developments to the north-east of the Site. The surrounding area is characterised by 'suburban' terrain; due to the low-rise albeit dense nature of the surrounding developments, which results in a relatively lower turbulence wind environment with a higher mean wind speed compared to an equivalent site in open terrain. A satellite view of the approximate Site location is highlighted in yellow with its surroundings in Figure 1.

Figure 1: Aerial view of the existing Site (approximate extent of the Site highlighted in yellow)

3.2 The Proposed Development

The scheme proposes a seven-storey tall building and would involve construction of a teaching college and canteen facilities. Main entrances will be located on the western, eastern and southern façades of the Proposed Development. Terraces would also be situated at levels 3 and 6.

Figure 2 shows the wind tunnel model of the Proposed Development (Configuration 2) from the south.

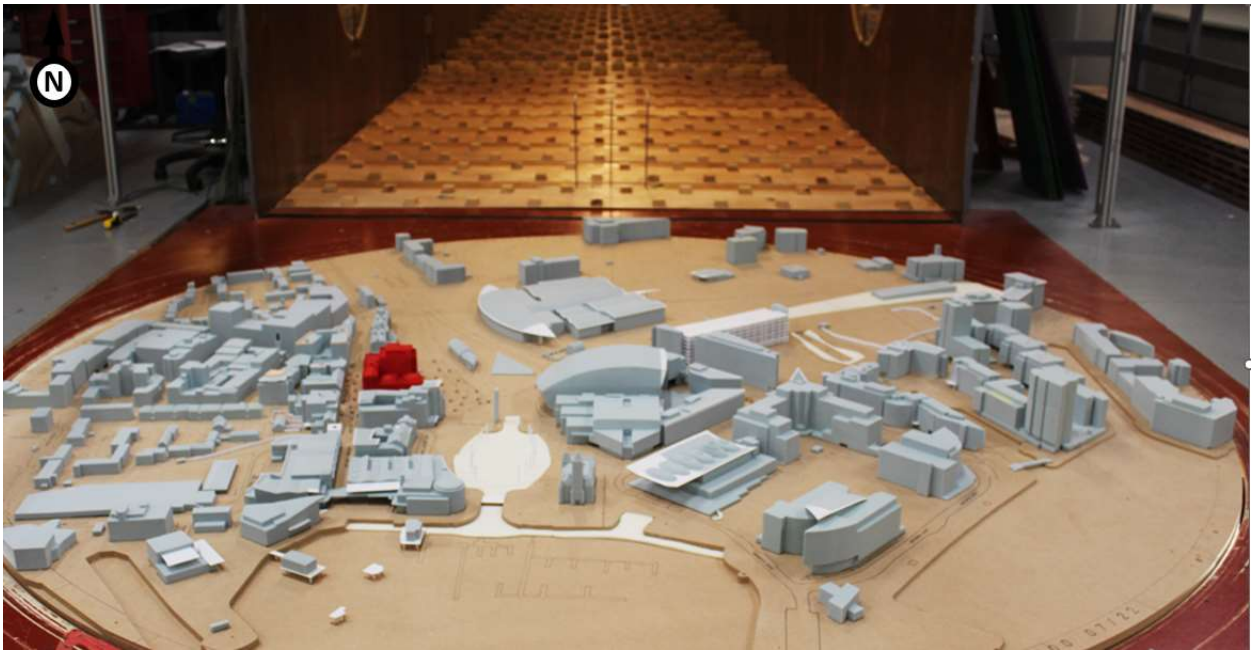


Figure 2: View from the south of the Proposed Development (in red) with existing surrounding buildings (in white) in wind tunnel

3. METHODOLOGY AND ASSESSMENT CRITERIA

Wind tunnel testing is the most well-established and robust means of assessing the pedestrian wind microclimate with the Development in place. It enables the wind conditions at the Site to be quantified and classified in accordance with the Criteria. To produce the results within the tunnel, a 1:300 scale model of the existing buildings at the Site and the surrounding area within a 360 metre (m) radius of the centre of the Site was constructed.

The basic methodology for quantifying the pedestrian level wind environment is outlined below:

1. Measure the wind speeds at pedestrian level in the wind tunnel relative to a reference wind speed;
2. Adjust standard meteorological data to account for conditions at the Site;
3. Combine these to obtain the expected frequency and magnitude of wind speeds at pedestrian level; and
4. Compare the results with the Criteria to 'grade' conditions around the Site.

3.1 Simulation of Atmospheric Winds

The wind is turbulent, or gusty, and this turbulence varies depending upon the Site. It is necessary to reflect these differences in the wind tunnel test. In addition, the atmospheric boundary layer is a shear flow which means that the mean wind speed increases with height. Modelling these effects is achieved by a combination of spires and floor roughness elements to create a naturally grown boundary layer that is representative of urban or open country conditions, as appropriate. The detailed contoured proximity model around the Site is used to fine-tune the flow and create conditions similar to those expected at full scale (as shown in Figure 2).

3.2 Measurement Technique

Wind speed measurements were made using Irwin probes. For pedestrian comfort studies, both the mean wind speed and the peak wind speed are measured at selected locations at the Site and surrounding area to represent sensitive receptors, such as entrances, amenity areas and thoroughfares, at a scaled height of 1.5m above ground level. The typical equivalent full-scale time period for measuring the mean wind speed is around 90 minutes, whereas the peak wind speed is taken as the wind speed exceeded for 1% of the time.

Wind speed at each location was measured for 36 wind directions in 10° increments, with 0° representing wind blowing from the north and 90° wind blowing from the east.

3.3 Scaling

The length scale of the model was 1:300 and the velocity scale was approximately 1:2 for strong winds. Consequently, the time scale for the tests was 1:150, or in other words 1 second in the wind tunnel is equivalent to 150 seconds at full scale.

3.4 Meteorological Data

Approximately 20 years of meteorological data for the Cardiff Airport was used in this report and is presented in Appendix B as wind roses by season (refer to Figure X, Appendix B). The radial axis indicates the directional distribution of winds. The seasons are defined as spring (March, April and May), summer (June, July and August), autumn (September, October and November) and winter (December, January and February). The data has been corrected to standard conditions of 10m above open flat level country terrain, over which pedestrian level wind speeds are greatest.

The meteorological data indicate that the prevailing wind direction throughout the year is from the west with a secondary peak from the north-east during the Spring season.

The wind data derived from the meteorological stations has been corrected to standard conditions of 10m above open flat level country terrain, over which pedestrian level wind speeds are greatest. The meteorological station data are then adjusted to the Site conditions using the methodology implemented in the ESDU software package[1].

The combination of meteorological data, the Site altitude and velocity ratios permits the percentage of time that wind speeds are exceeded at ground level on the Site to be evaluated. The locations can then be assessed using the Criteria, as described below.

3.5 Pedestrian Comfort

The assessment of the wind conditions requires a standard against which the measurements can be compared. This report uses the Lawson Comfort Criteria[2], which have been established for over thirty years. The Criteria, which seek to define the reaction of an average pedestrian to the wind, are described in Table 1. If the measured wind conditions exceed the threshold wind speed for more than 5% of the time, then they are unacceptable for the stated pedestrian activity and the expectation is that there may be complaints of nuisance or people will not use the area for its intended purpose.

The Criteria sets out four pedestrian activities and reflect the fact that less active pursuits require more benign wind conditions. The four categories are sitting, standing, strolling and walking, in ascending order of activity level, with a fifth category for conditions that are uncomfortable for all uses. In other words, the wind conditions in an area for sitting need to be calmer than a location that people merely walk past.

The distinction between strolling and walking is that in the strolling scenario pedestrians are more likely to take on a leisurely pace, with the intention of taking time to move through the area, whereas in the walking scenario pedestrians are intending to move through the area quickly and are therefore expected to be more tolerant of stronger winds.

[1] ESDU International, 2001. Computer program for wind speeds and turbulence properties: flat or hilly sites in terrain with roughness changes, ESDU 01008, 2001 01008.
[2] Lawson T.V. (April 2001), Building Aerodynamics, Imperial College Press

The Criteria are derived for open air conditions and assume that pedestrians will be suitably dressed for the season. Thermal comfort is discussed with reference to acceptable wind environments but not evaluated as part of the assessment.

The coloured key in Table 1 corresponds to the presentation of wind tunnel test results described in the results section of this report.

Table 1: Lawson Comfort Criteria

Key	Comfort Category	Threshold	Description
	Sitting	0-4 m/s	Light breezes desired for outdoor restaurants and seating areas where one can read a paper or comfortably sit for long periods
	Standing	4-6 m/s	Gentle breezes acceptable for main building entrances, pick-up/drop-off points and bus stops
	Strolling	6-8 m/s	Moderate breezes that would be appropriate for strolling along a city/town street, plaza or park
	Walking	8-10 m/s	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering
	Uncomfortable	>10 m/s	Winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended

3.6 Strong Winds

Lawson also specified a lower limit strong wind threshold when winds exceed 15m/s for more than 2.2 hours of the year. Exceedance of this threshold may indicate a need for remedial measures or a careful assessment of the expected use of that location; e.g. is it reasonable to expect elderly or very young pedestrians to be present at the location on the windiest day of the year?

Wind speeds that exceed 20m/s for more than 2.2 hours of the year represent a safety issue for all members of the population, which would require mitigation to provide an appropriate wind environment.

Strong winds are generally associated with areas which would be classified as acceptable for walking or as uncomfortable. In a mixed-use urban development scheme, walking and uncomfortable conditions would not usually form part of the 'target' wind environment and would usually require mitigation due to pedestrian comfort considerations. This mitigation would also reduce the frequency of, or even eliminate, any strong winds.

4. RESULTS

4.1 Details of Analysis

To account for the difference in height and terrain roughness between meteorological conditions at the airports and the Site, it is necessary to apply adjustment factors to the wind tunnel velocity ratios. Adjustment factors (mean factors) were computed for wind directions from 0° through to 360°. The reference height in the wind tunnel was at the equivalent full-scale height of 120 metres. Table X in Appendix B presents the mean factors for the Site.

4.2 Desired Pedestrian Activity around the Development

For the Proposed Development, the target conditions are:

1. Strolling during the windiest season on pedestrian thoroughfares;
2. Standing conditions at main entrances throughout the year;
3. Standing use conditions at private amenity spaces such as balconies or larger amenity areas where seating is not intended; and
4. Sitting conditions at outdoor seating during the summer season when these areas are more likely to be frequently used by pedestrians.

The walking and uncomfortable classifications are usually avoided because of their association with occasional strong winds, unless they are on a minor pedestrian route or a route where pedestrian access could be controlled in the event of strong winds. Walking use wind conditions are also acceptable at crossings as pedestrians do not linger, however wind conditions must be safe.

Achieving a sitting classification in the summer usually means that the same location would be acceptable for standing in the windiest season because winds are stronger at this time of year. This is considered an acceptable occurrence for the majority of external amenity spaces because other factors such as air temperature and precipitation influence people's perceptions about the 'need' to use seating in the middle of winter.

Standing use wind conditions are the target conditions for main entrances, however strolling use wind conditions are considered acceptable at secondary entrances and fire exits.

It should be noted that a mixture of sitting and standing uses is acceptable for large terrace spaces, provided that any desired seating areas are situated in areas having sitting wind conditions. In addition, standing use conditions are also considered tolerable at private amenity areas (such as balconies) where the occupant has control over the use of the space.

4.3 Performance against the Lawson Comfort Criteria

The wind microclimate within and around the Site has been assessed and classified using the Lawson Comfort Criteria defined in Table 1. The results of the assessment for each configuration are described below and presented graphically in Figures X to X (to be provided post wind tunnel testing).

4.3.1 Configuration 1: Existing Site with the Existing Surrounding Buildings

The wind microclimate results for Configuration 1 are shown in the following figures:

- Figure 3: Windiest Season (Ground Level); and
- Figure 4: Summer Season (Ground Level).

4.3.2 Configuration 2: Proposed Development with the Existing Surrounding Buildings

The wind microclimate results for Configuration 2 are shown in the following figures:

- Figure 6: Windiest Season (Ground Level);
- Figure 7: Summer Season (Ground Level); and
- Figure 8: Summer Season (Upper Levels).

4.4 Occurrence of Strong Winds

There would be no instances of strong wind exceeding the threshold in both the configuration.

5. DISCUSSION

This discussion compares the measured wind conditions (shown in Figures 6-8) to the anticipated usage of the Site, as well as the baseline conditions (presented in Figures 3-4), to provide an assessment of whether the conditions are suitable, or too windy, for the intended use.

5.1 Configuration 1: Error! Reference source not found.

The following discussion of the wind microclimate is based on the results shown in Figures 3 and 4 during the windiest and summer seasons for ground level respectively.

Pedestrian Comfort

In the baseline scenario the wind conditions would range from suitable for sitting to strolling use condition during the windiest season. Wind conditions during the summer season would generally be one comfort category calmer due to the calmer winds experienced during this time of year.

5.2 Configuration 2: Error! Reference source not found.

The following discussion of the wind microclimate is based on the results shown in Figures 5 and 6 during the windiest and summer seasons for ground level respectively. Figure 7 shows the summer season results for elevated levels.

Pedestrian Comfort

With the introduction of the Proposed development (Configuration 2), all assessed areas in and around the Site would have suitable wind conditions during the windiest and summer seasons. Terrace locations at elevated levels would also have suitable wind suitable conditions during the summer season. There would be no instances of strong wind exceedances which pose safety concerns.

Thoroughfares (Figure 5)

Wind conditions along both on- site and off- site thoroughfares would have wind conditions ranging from sitting to strolling use condition during the windiest season, suitable for the intended use.

Roads and Car Parks (Figure 5)

Wind conditions along roads and within car parks would have wind condition ranging from sitting to strolling use condition during the windiest season, suitable for the intended use.

Entrances (Figure 5)

Entrances to the Proposed Development and Off-site entrances would have sitting use condition during the windiest season. would have standing use condition during the windiest season suitable for the intended use.

Bus Stops (Figure 5)

Bus stops would also have sitting to standing use condition during the windiest season, suitable for the intended use

Terrace Amenity (Figure 7)

All the accessible terrace locations would have sitting use conditions during the summer season suitable for the intended use.

Strong Winds

There would be no instances of strong wind exceedances which pose safety concerns.

6. CONCLUSION

In conclusion:

- The meteorological data for the Site indicates prevailing winds from the western quadrant throughout the year with secondary winds from the north-east which are more prevalent during the spring months.

- In the baseline scenario the wind conditions would range from suitable for sitting to strolling use condition during the windiest season. Wind conditions during the summer season would generally be one comfort category calmer due to the calmer winds experienced during this time of year.

- With the introduction of the Proposed development (Configuration 2), all assessed areas in and around the Site would have suitable wind conditions during the windiest and summer season seasons. Terrace locations at elevated levels would also have suitable wind suitable conditions during the summer season. There would be no instances of strong wind exceedances which pose safety concerns.

True North

BUTE STREET / STRYD BUTE

WEST BUTE STREET

JAMES STREET

PLAS BUTE / BUTE PLACE

LEGEND:

LDDC COMFORT CATEGORIES:

- Sitting
- Standing
- Strolling
- Walking
- Uncomfortable

1:600

Pedestrian Wind Conditions - Windiest Season

Configuration - C1

RWDI#2205854 - Project Blue Dragon

Figure: C1 - 1-B

Date: 05/08/2022

True North

BUTE STREET / STRYD BUTE

WEST BUTE STREET

JAMES STREET

PLAS BUTE / BUTE PLACE

LEGEND:

LDDC COMFORT CATEGORIES:

- Sitting
- Standing
- Strolling
- Walking
- Uncomfortable

1:600

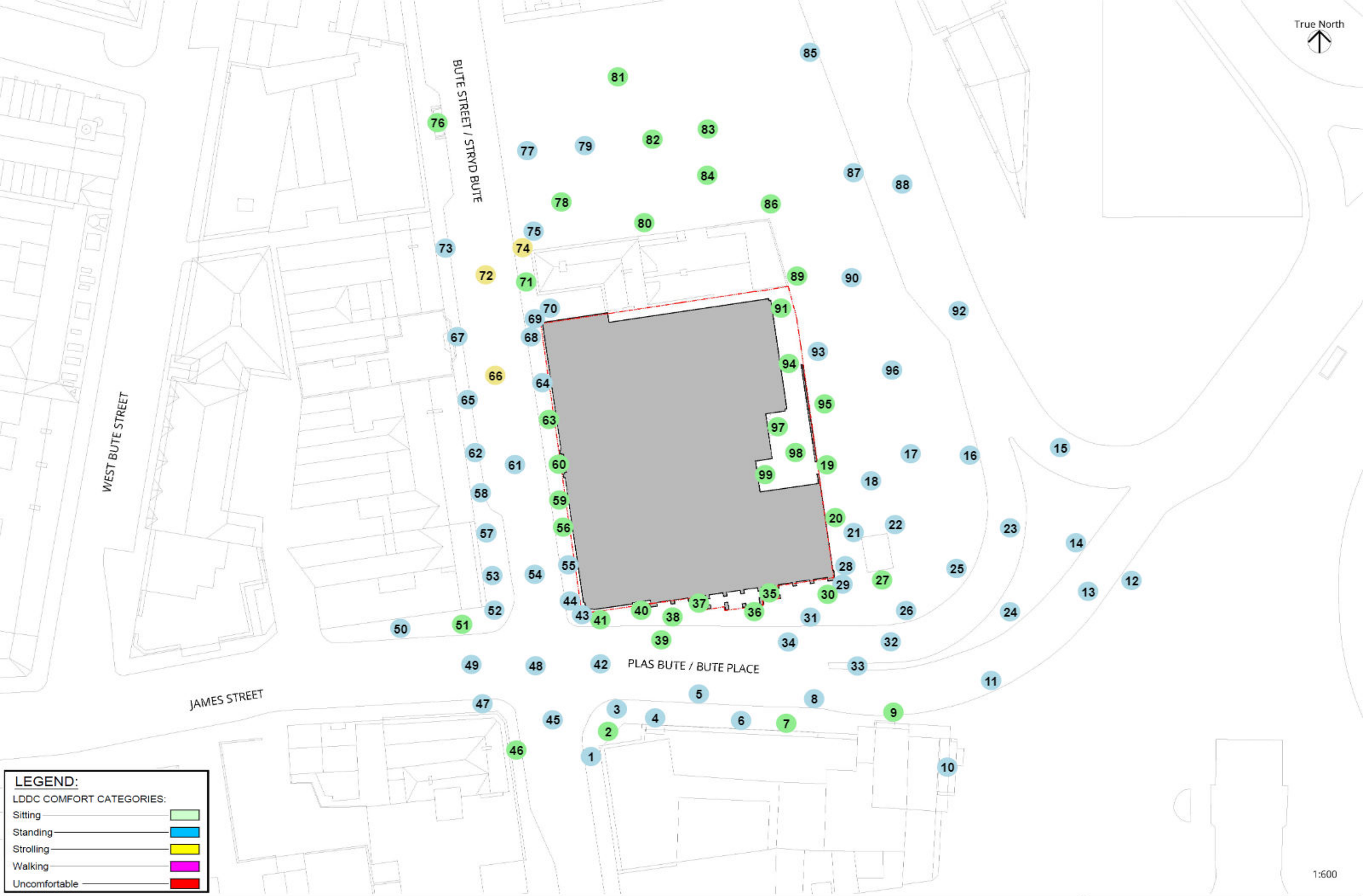
Pedestrian Wind Conditions - Summer Season

Configuration - C1

RWDI#2205854 - Project Blue Dragon

Figure: C1 - 1-C

Date: 05/08/2022



Pedestrian Wind Conditions - Windiest Season

Configuration - C2

RWDI#2205854 - Project Blue Dragon

Figure: C2 - 1-B

Date: 04/08/2022

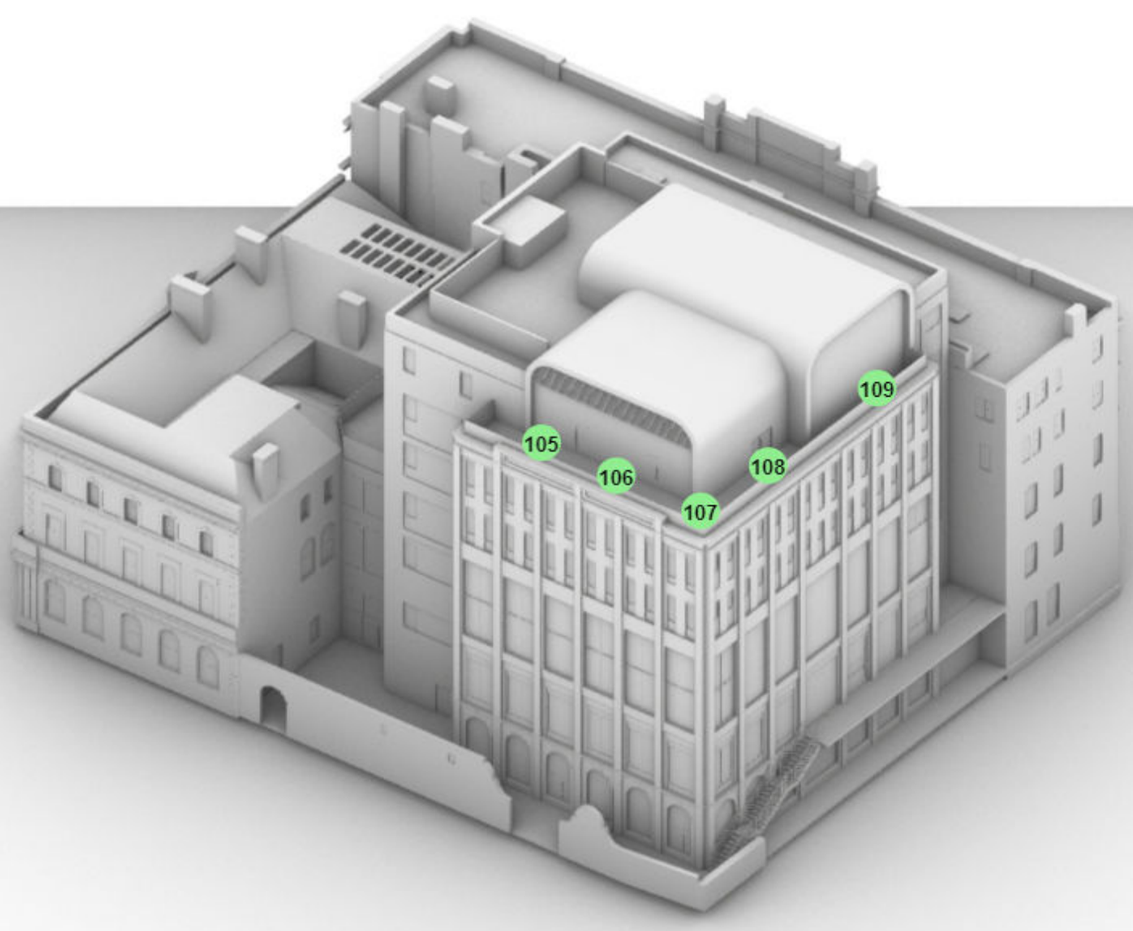
Pedestrian Wind Conditions - Summer Season

Configuration - C2

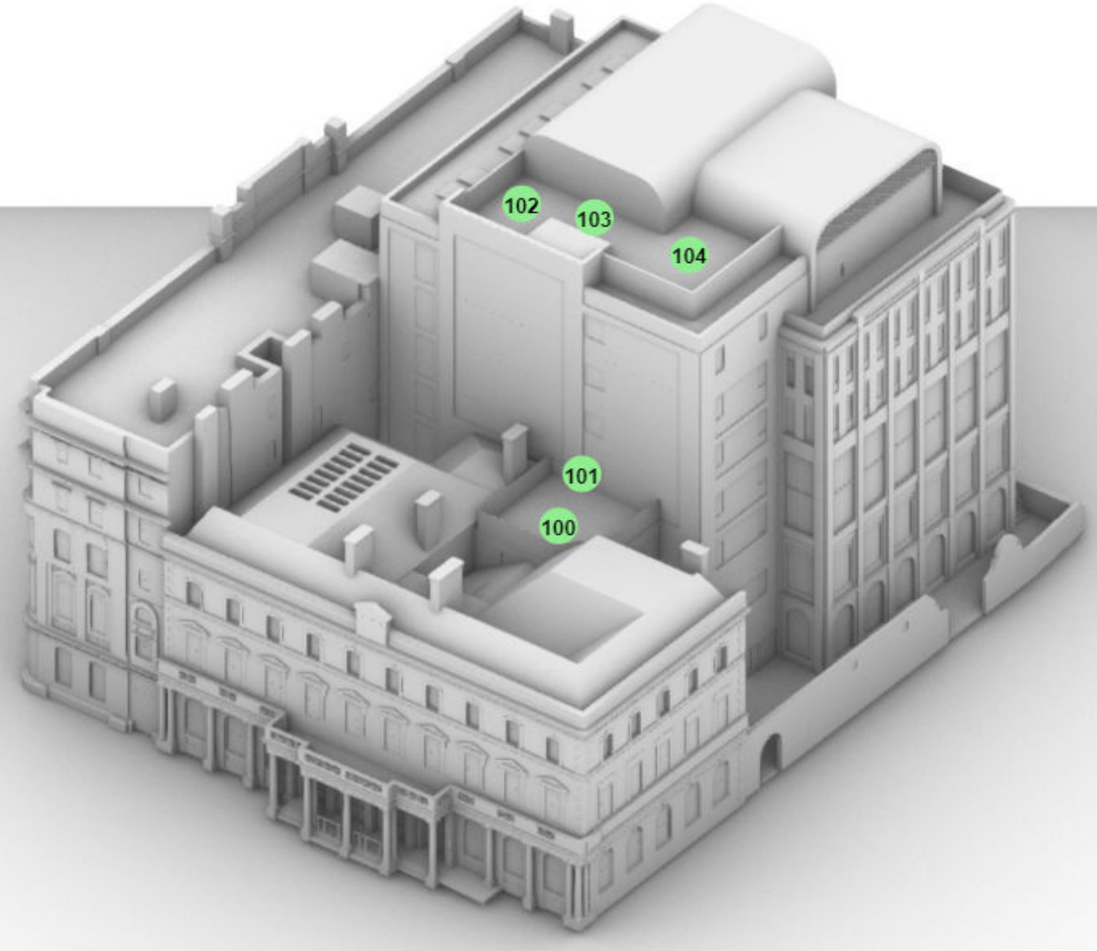
RWDI#2205854 - Project Blue Dragon

Figure: C2 - 1-C

Date: 04/08/2022



NORTH / EAST



SOUTH / EAST

LEGEND:

LDDC COMFORT CATEGORIES:

- Sitting
- Standing
- Strolling
- Walking
- Uncomfortable

1:400

Pedestrian Wind Conditions - Summer Season
Configuration - C2

RWDI#2205854 - Project Blue Dragon

Figure: C2 - 2-C

Date: 04/08/2022

APPENDIX A: WIND TUNNEL PHOTOS

Figure 8: Existing Site with Existing Surrounding Buildings (Configuration 1) – View in the Wind Tunnel from the south

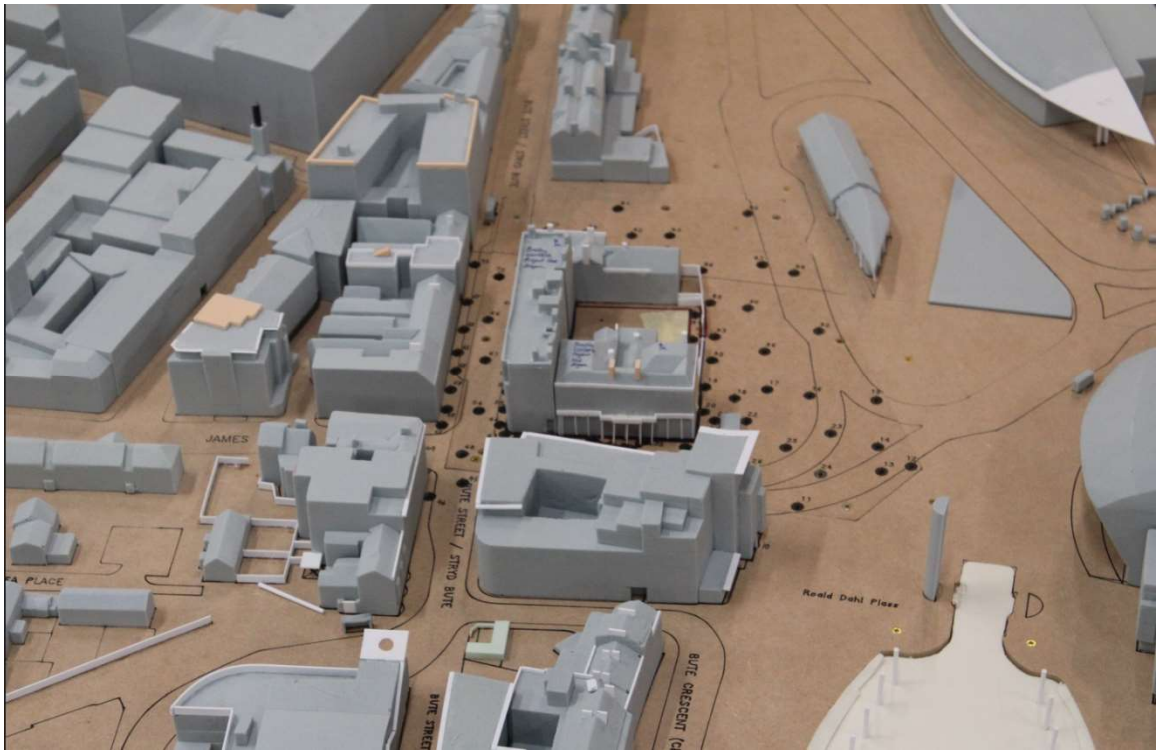


Figure 9: Existing Site with Existing Surrounding Buildings (Configuration 1) – View in the Wind Tunnel from the south

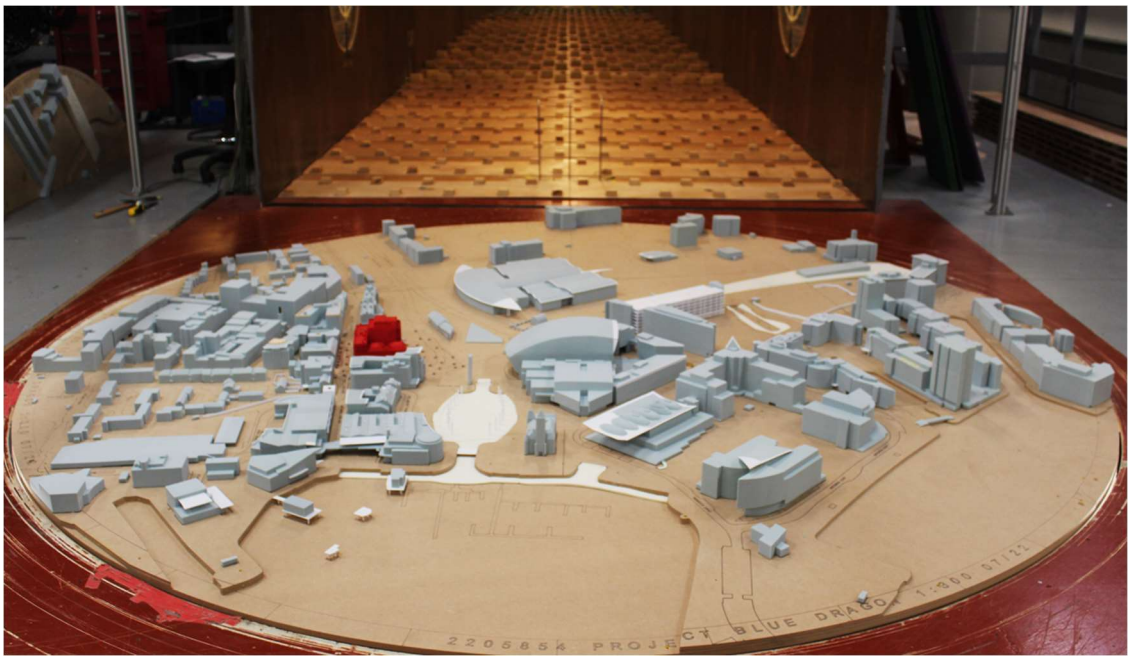


Figure 10: Proposed Development with Existing Surrounding Buildings and Mitigation Measures (Configuration 2) – View in the Wind Tunnel from the south

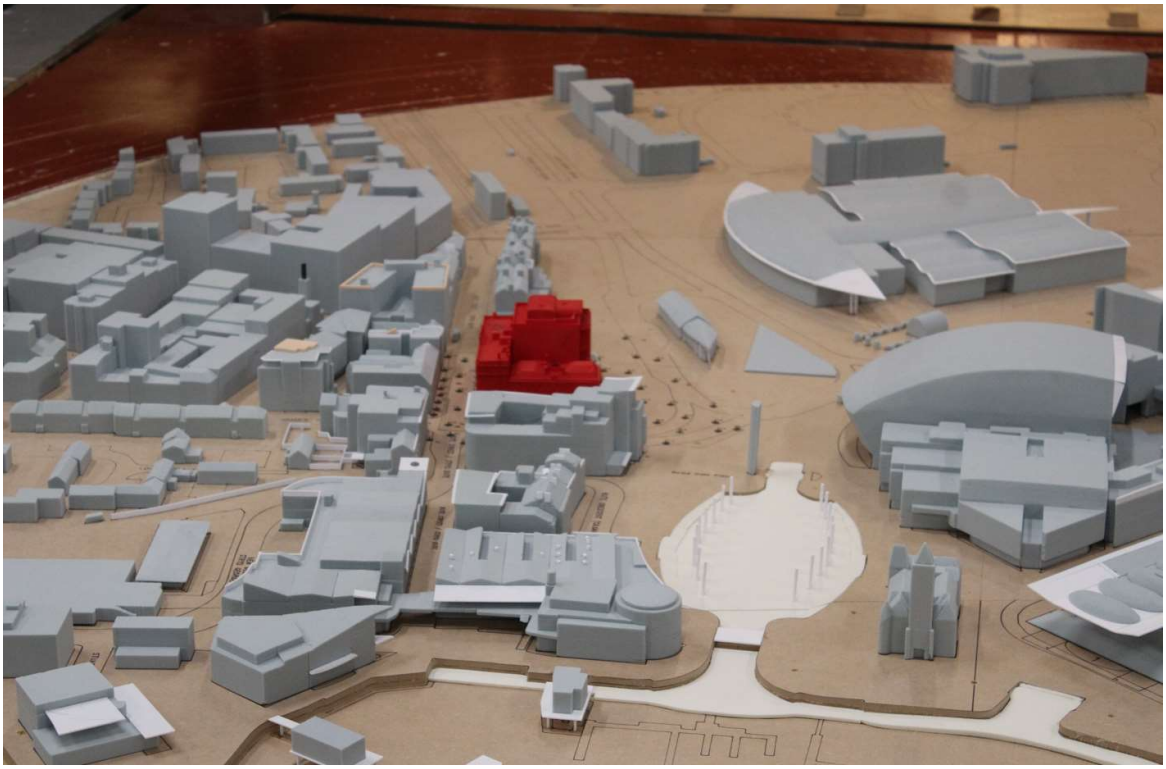
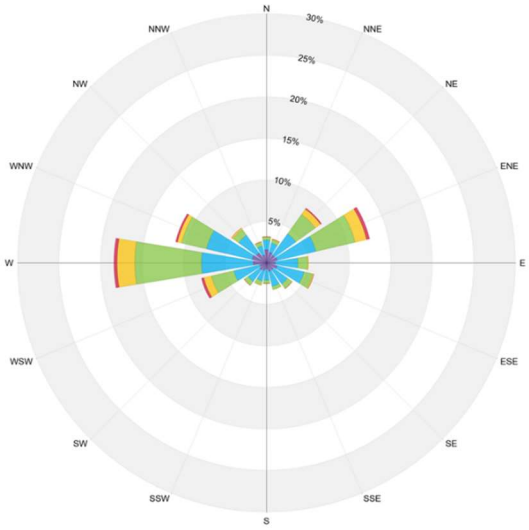
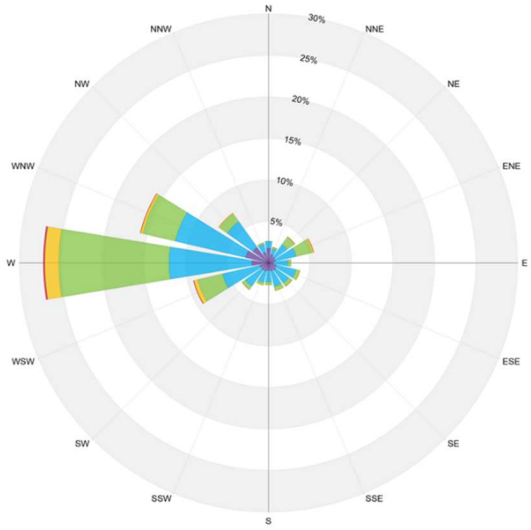


Figure 11: Proposed Development with Existing Surrounding Buildings and Mitigation Measures (Configuration 2) – View in the Wind Tunnel from the south

APPENDIX B: METEOROLOGICAL DATA

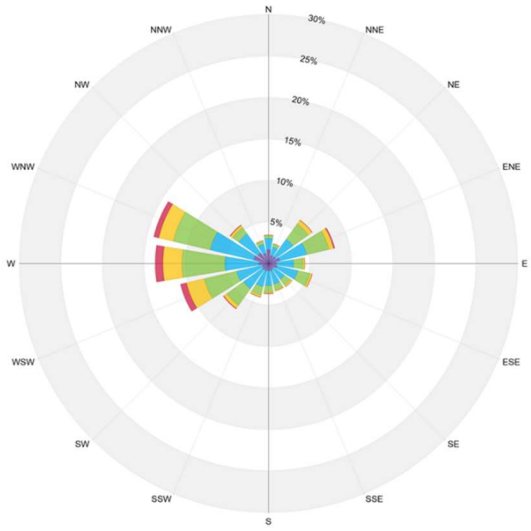


Spring
(March - May)



Summer
(June – August)

Autumn
(September - November)



Winter
(December - February)

Wind Speed (km/h)	Probability (%) Spring	Summer	Autumn	Winter
Calm	0.7	0.7	0.6	0.8
1-10	19.5	21.0	20.1	18.1
11-20	43.3	47.1	44.1	39.6
21-30	28.4	27.7	28.3	29.3
31-40	6.5	3.1	5.6	9.4
>40	1.6	0.3	1.3	2.8

Figure 12: Seasonal wind roses from Cardiff Airport (1998 – 2021) (in km/h) – (Radial axis indicates the percentage of time for which the stated threshold is exceeded)

Table 4: ESDU mean factors at 120m above ground level

Wind Direction	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°
Mean Factor at 120 m	1.23	1.23	1.23	1.23	1.23	1.30	1.40	1.44	1.44	1.44	1.44	1.44
Wind Direction	**120°**	**130°**	**140°**	**150°**	**160°**	**170°**	**180°**	**190°**	**200°**	**210°**	**220°**	**230°**
Mean Factor at 120 m	1.44	1.44	1.44	1.44	1.44	1.45	1.45	1.39	1.39	1.39	1.33	1.33
Wind Direction	**240°**	**250°**	**260°**	**270°**	**280°**	**290°**	**300°**	**310°**	**320°**	**330°**	**340°**	**350°**
Mean Factor at 120 m	1.31	1.30	1.30	1.30	1.26	1.26	1.26	1.26	1.26	1.23	1.23	1.23