FINAL REPORT

55 VASTERN ROAD

READING, UK

PEDESTRIAN LEVEL WIND MICROCLIMATE ASSESSMENT

RWDI #1901994

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SUBMITTED TO

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VERSION HISTORY

RWDI Project #1901994	55 Vastern Road, Reading, UK	
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Reports	Rev A	January 13th, 2020
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1 EXECUTIVE SUMMARY

RWDI was retained to conduct a pedestrian level wind assessment of the proposed Vastern Road development in Reading, UK. This report presents a description of the methodology used and the results of three configurations tested using Computational Fluid Dynamics (CFD) simulations, namely:

- Configuration 1: Existing Site with Existing Surrounding Buildings;
- Configuration 2: Proposed Development with Existing Surrounding Buildings; and
- Configuration 3: Proposed Development with Cumulative Surrounding Buildings.

Each configuration was assessed devoid of existing or proposed landscaping, or wind mitigation measures in order to present a worst-case (i.e. windy) scenario. Results are presented in terms of the Lawson Comfort Criteria with the main focus on the windiest (generally winter) season and the summer season, when amenity spaces are expected to be most frequently used.

Meteorological data representative of Reading indicates prevailing winds from the south-west throughout the year with a secondary peak from the north-east (typically during the spring season).

The existing Site has wind conditions ranging from sitting to standing use during the windiest season. Wind conditions during the summer season are suitable for sitting use with standing use on the Christchurch Bridge to the north of the Site and in localised areas between buildings on Vastern Road. Winds at the existing Site would be unlikely to exceed the safety criteria and result in a possible safety concern to cyclists and more vulnerable pedestrians.

Wind conditions at the Proposed Development would be windier than at the existing Site, ranging from suitable for sitting to strolling use during the windiest season. All thoroughfare locations would have suitable wind conditions, however, entrances to Building B and the café at the north of the Site would be windier than suitable for the intended use and would require mitigation. During the summer season wind conditions would be suitable for sitting to strolling use at ground and podium level. The designated seating area for the café would have standing use wind conditions making it unsuitable for its intended use. At terrace and balcony levels, conditions would be windier than suitable at balconies on Buildings B and D and at the terrace levels of Buildings D and E. These locations would require mitigation measures to ensure a comfortable wind environment for pedestrians. All remaining balconies would have conditions suitable for the intended use. Strong winds with the potential to be a safety concern for occupants would be expected to occur at Buildings B and D balcony and terrace levels. Wind mitigation measures have been suggested which would be expected to improve wind conditions in these areas.

The cumulative schemes would not be expected to provide shelter to the Proposed Development, as such the southern areas of the Proposed Development and areas on Vastern Road would have become windier conditions than in the context of the existing surrounds. In addition to the areas identified in the existing context, there would be a thoroughfare area around the south-east of the Site and balconies on Building B with unsuitable wind conditions for their intended use with the cumulative schemes in place. There would also likely be occurrences of strong winds exceeding the safety threshold associated with the thoroughfare area at the south-east of the Site. These locations would require further mitigation measures on top of those developed in the context of the existing surroundings.

The entrance to the south-west of Building B is to be moved north which, in addition to the proposed landscaping scheme, would be expected to improve wind conditions at ground level such that they would be suitable for the intended use. In the context of the existing surrounds, windy conditions would be expected to persist at balcony and terrace levels around the Site. With the cumulative schemes in place, a section of Vastern Road as well as balconies and terrace levels would be windier than suitable for the intended use. Wind mitigation expected to improve wind conditions at ground level, balcony and terrace level areas has been suggested in Section 7 'Mitigation Measures' of this report.

Overall, wind conditions around the majority of the Proposed Development would be suitable for the intended use, however, there would be locations at both ground and at elevated levels that would be winder than suitable and as such would require wind mitigation measures. With the proposed landscaping and entrance mitigation in place, it is expected that wind conditions at the ground level in the existing context would be suitable for the intended pedestrian use, however, in the context of the cumulative schemes there would be ground level locations with windy conditions that would also require mitigation. Windy conditions would persist at elevated levels in both the context of the existing and cumulative surrounds, requiring wind mitigation. Due to the likely occurrence of strong winds with the potential to be a safety concern for cyclists and pedestrians, it is recommended that further wind mitigation measures are developed, and quantitative testing is conducted to ensure an appropriate wind microclimate at the Proposed Development.

2 INTRODUCTION

RWDI was retained by Berkeley Homes (Western) Ltd to conduct a pedestrian level microclimate assessment for the Proposed 55 Vastern Road Development in Reading, UK. This report presents the background and objectives from RWDI's assessment. A summary of the overall recommendations from the study are presented in Section 8 "Concluding Remarks".

3 BACKGROUND AND APPROACH

Computational Fluid Dynamics (CFD) simulations were conducted on the Proposed 55 Vastern Road Development, (referred to as the "Proposed Development" hereafter in this report), in Reading, UK. The assessment quantifies the wind conditions within and around the Site, by comparing the measured wind speed and frequency of occurrence with the Lawson Comfort Criteria. Meteorological data for Reading has been analysed and adjusted to the Site conditions by modelling the effect of terrain roughness in the computational domain.

Three configurations were simulated, as follows:

- Configuration 1: Existing Site with Existing Surrounding Buildings;
- Configuration 2: Proposed Development with Existing Surrounding Buildings; and
- Configuration 3: Proposed Development with Cumulative Surrounding Buildings.

3.1 Site Description and Surroundings

The development Site is located in Reading, UK, approximately 300m north of Reading train station. The OS Landranger grid reference is SU715741.

The Site is bound by the A739 Vastern Road to the south, two to three storey residential developments on Lynmouth Road to the west, the River Thames, Thames Path and the Christchurch Bridge pedestrian route to the north, and the four to five storey office developments on Norman Place to the east. The existing substation would be retained. The surrounding area is a mix of low-rise suburban development and the more open areas of the Christchurch Meadows, King's Meadows and the River Thames to the north and the east of the Site. Reading town centre is located to the south of the Site and consists of predominantly low- to mid-rise developments punctuated by occasional high-rise buildings. The general openness from the northern and eastern regions, and low-rise buildings from the southern and western regions results in a higher mean wind speed approaching the Site and relatively low turbulence when compared to a site surrounded by more urban terrain.

Figure 1 below shows an aerial view of the Site and surroundings, with the approximate Site location highlighted in yellow.

Figure 1: Aerial view of the Existing Site (Approximate extent of the Site highlighted in yellow)

3.2 The Proposed Development

Demolition of existing structures and erection of a series of buildings ranging in height from two to 11 storeys, comprising residential units, parking spaces and amenity areas, together with a new north-south pedestrian link, connecting Christchurch Bridge to Vastern Road.

Buildings A and B, located along Vastern Road, would be six storeys and part four, nine, and 11 storeys in height respectively. Building C would be a four-storey terraced block located along the eastern Site boundary between Building B and Building C. Buildings D and E, located to the north of the Site, would be part six and 11 storeys and part four and eight storeys in height respectively. Building F, adjoining to the south of Building E, would be three storeys with the two storey Building G adjoining to the south. A raised podium level would be located between Building D and E with a single storey café and associated spill out seating as well as a link bridge to the Christchurch Bridge to the north.

There are terrace level amenity spaces at the sixth and seventh floors of Building E, and at the eighth and ninth floors of Building D. Additionally, there are balconies located on Buildings A – F of the Proposed Development, Building A and E would have balconies from the first floor to the fifth floor; Building B would have balconies from the first to the eighth floor; Building C would have balconies from the first to the fourth floor; Building D would have balconies from the first to the ninth floor; and Building F would have balconies on the first and second floors.

A 3D view of the Proposed Development is shown in Figure 2 below.

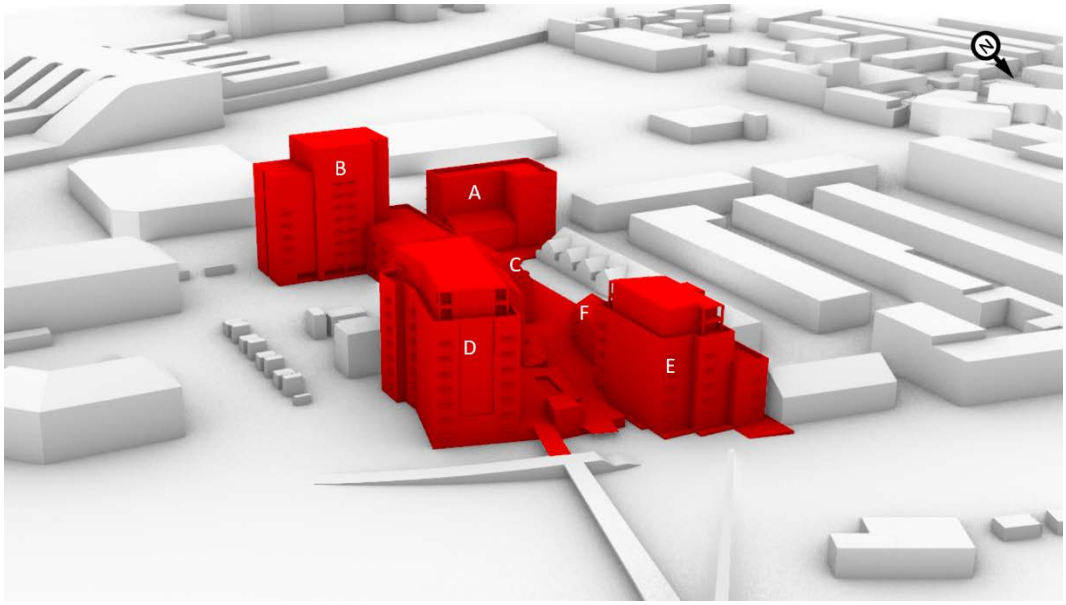

Figure 2: 3D model of the Proposed Development (in the context of the existing surrounding buildings) used for CFD simulations (view from north-east)

4 METHODOLOGY AND ASSESSMENT CRITERIA

The computational model of the Proposed Development in the context of the existing surrounding buildings used for CFD simulations of Configuration 2 is shown in Figure 2. Additional images of the 3D model in Configuration 1 (existing Site with the existing surrounding buildings) and Configuration 3 (Proposed Development with the cumulative surrounding buildings) are presented in Appendix A. In each of the three assessed scenarios surrounding buildings within a 400m radius of the centre of the Site were included.

The 'Results' section, shows the windiest season (typically winter) and the summer season (June to August) comfort plots. The comfort results are assessed at a height of 1.5m above the ground or building surface to represent conditions around people. The colours correspond to the Lawson Comfort Criteria described below in 5.2 'Pedestrian Comfort'.

CFD is a computer modelling technique for numerically simulating wind flow in complex environments. For this study, computational modelling was undertaken using OpenFOAM version 4.1 with 18 wind angles tested for each scenario, equally spaced out around the compass (equal 20 degrees intervals). Although the strongest winds originate from the south-westerly sector, this quantity of wind angles will provide sufficient coverage of all aerodynamic interactions from winds from all angles.

The individual cases of the Proposed Development were solved using RANS approach with an RNG k-ε turbulence model. The steady state RANS type model with the RNG k- ε turbulence model is chosen over other turbulence models or transient type schemes for wind microclimate studies by RWDI for its ability to approximate highly complex flows within urban environments to a high level of accuracy against a practical computational time. The statistically steady solution obtained by RANS simulations does not have the ability to predict the fluctuating or gusty nature of wind. As comfort is a function of average conditions, this model is more suited to help analyse this.

The potential for strong winds leading to potential safety issues is assessed using informed engineering judgement.

The computational model was discretized into approximately 20 million hexahedral cells with refinement close to the areas of expected high velocity gradients.

All configurations were simulated in the absence of any landscaping elements in order to provide a worst-case wind environment.

4.1 Meteorological Data

Figure 3 shows the seasonal wind roses (meteorological data) for Reading area which are based on data obtained from the meteorological station at London Heathrow airport. 0 Degrees represents wind blowing from the north and 90 degrees represents wind blowing from the east.

Approximately 30 years of meteorological data for London Heathrow was used in this report, presented in the seasonal wind roses with the wind speed divided into wind speed thresholds (Figure 3). The radial axis indicates the cumulative number of hours per season that the wind speed exceeds the wind speed threshold as a percentage. 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 meteorological data indicate that the prevailing wind direction throughout the year is from the south-west. This is typical for many areas of southern England. There is a secondary peak from the north-westerly winds, especially during the spring; however, these tend to be colder winds.

The combination of meteorological data and velocity ratios permits the percentage of time that wind speeds are exceeded on the site to be evaluated. The locations can then be assessed using 'comfort criteria', as described below.

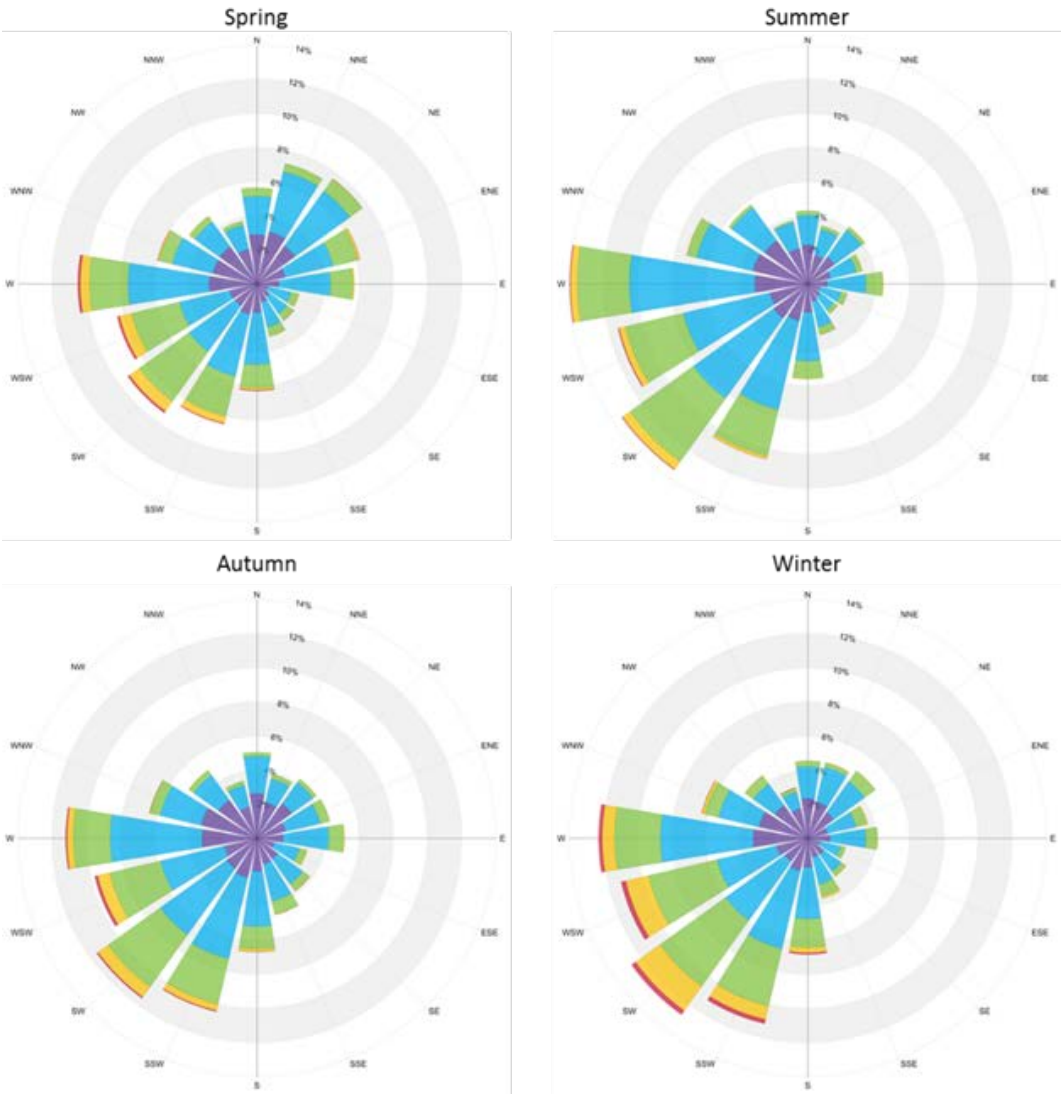

Figure 3: Seasonal Wind Roses for London Heathrow airport (in m/s) (Radial axis indicated the percentage time for which the stated wind speed threshold is exceeded)

4.2 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, 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.

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 simulation results described later in 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 window shopping and strolling along a city/town centre 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

4.3 Strong Winds

Lawson[1] also specified a lower limit strong wind threshold when winds exceed 15m/s for more than 0.025% of the time (approximately two hours per year). When winds exceed this threshold remedial measures or a careful assessment of the expected use of that location would be required; 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 approximately two hours per year represent a safety issue for all members of the population, which would require mitigation to provide an appropriate wind environment.

[1] Lawson T.V. (April 2001), Building Aerodynamics, Imperial College Press

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.

It should be noted that the CFD simulations will provide an average expected wind speed for the windiest (typically the winter months - December to February) and summer season in regard to pedestrian comfort. Areas which would have wind conditions suitable for walking use would be likely to have instances of strong winds. As such, professional judgement incorporating RWDI's experience of a large number of similar projects both within the UK and internationally has been applied, informed by the CFD results to identify areas of the Proposed Development likely to have instances of strong winds.

5 RESULTS

5.1 Details of Analysis

To account for the difference in height and terrain roughness between meteorological conditions at the airports and the Site, which is taken into account during the CFD simulations. For the Proposed Development, a suburban roughness factor was used to adjust the meteorological data due to the relatively built up surroundings of the Site.

5.2 Desired Pedestrian Activity around the Development

Generally, for the Development, the target conditions are:

1. Strolling during the windiest season on pedestrian thoroughfares;
2. Standing conditions at main entrances, drop off areas or taxi ranks, and bus stops throughout the year; and
3. Sitting conditions at outdoor seating and amenity areas 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.

Achieving a sitting classification in the summer usually means that the same receptor would be acceptable for standing in the windiest season because winds are stronger at this time.

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 windiest season.

It should be noted that a mixture of sitting use and standing use is acceptable for larger amenity spaces, should designated seating not be located at the windier locations suitable for standing use. Furthermore, 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.

5.3 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 4 – 13.

5.3.1 Configuration 1 – Existing Site with Existing Surrounding Buildings

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

- Figure 4: Winter Season: Ground Level; and
- Figure 5: Summer Season: Ground Level.

This configuration includes the existing Site in the context of existing surrounding buildings devoid of landscaping in order to assess a worst-case (i.e. windy) scenario.

5.3.2 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;
- Figure 8: Summer Season: Terrace/Balcony Levels (view from north-west); and
- Figure 9: Summer Season: Terrace/Balcony Levels (view from south-east).

This configuration includes the Proposed Development in the context of existing surrounding buildings devoid of landscaping or wind mitigation measures in order to assess a worst-case (i.e. windy) scenario.

5.3.3 Configuration 3 – Proposed Development with the Cumulative Surrounding Buildings

The wind microclimate results for Configuration 3 are shown in the following figures:

- Figure 10: Windiest Season: Ground Level;
- Figure 11: Summer Season: Ground Level;
- Figure 12: Summer Season: Terrace/Balcony Levels (view from south-west); and
- Figure 13: Summer Season: Terrace/Balcony Levels (view from north-west).

This configuration includes the Proposed Development in the context of cumulative surrounding buildings devoid of landscaping or wind mitigation measures in order to assess a worst-case (i.e. windy) scenario.

6 DISCUSSION

This discussion compares the measured wind conditions (shown in the contour plots) to the anticipated use of the Site, to provide an assessment of whether the conditions would be suitable or too windy for the intended use.

Any areas not specifically mentioned would be suitable, or calmer than required, for the desired pedestrian use. Areas that are windier than suitable for the intended pedestrian use would require mitigation.

No landscaping was included in any tested configuration, in order to present a worst-case (i.e. windy) scenario.

6.1 Configuration 1: Existing Site with the Existing Surrounding Buildings

Results for the existing Site with existing surrounding buildings at ground level are presented in Figures 4 and 5 for the windiest and summer season respectively.

6.1.1 Pedestrian Comfort

Wind conditions for the baseline scenario (existing Site with existing surrounding buildings) range from suitable for sitting to standing use at the-Site and in the nearby surrounding area during the windiest season. Wind conditions on Vastern Road to the south, the Thames path and Christchurch Bridge are one to two categories calmer than required for thoroughfare use (Figure 4). Conditions at all entrance locations to the surrounding buildings are suitable for standing use or calmer, acceptable conditions for entrance use. During the summer season (Figure 5) the proportion of the surrounding area suitable for sitting use increases with conditions in the gardens of residential properties on Lynmouth Road and De Montfort Road, to the west of the Site, suitable for sitting use, acceptable conditions for amenity use.

6.1.2 Strong Winds

Strong wind exceedances of 15m/s for more than 0.025% of the time (approximately 2 hours per year) would be anticipated to occur when wind conditions during the windiest season are suitable for walking use or uncomfortable for all pedestrian use. As no walking use or uncomfortable conditions occur at the existing Site, no strong winds would be expected to occur at the existing Site.

Figure 4: Configuration 1 – Existing Site with the Existing Surrounding Buildings – Windiest Season

Figure 5: Configuration 1 – Existing Site with the Existing Surrounding Buildings – Summer Season

6.2 Configuration 2: Proposed Development with the Existing Surrounding Buildings

Results for the Proposed Development with the existing surrounding buildings are presented in Figure 6 for ground and podium level during the windiest season. Figure 7 presents results for ground and podium level and Figures 8 and 9 present results for the terrace and balcony levels during the summer season, when amenity spaces are expected to be most frequently used.

6.2.1 Pedestrian Comfort

Wind conditions around the Proposed Development during the windiest season would range from suitable for sitting to strolling use with localised walking use conditions at balcony and terrace levels. These conditions would be suitable for thoroughfares, however, strolling conditions would be windier than suitable for entrance locations. During the summer season, wind conditions would range from suitable for sitting to strolling use at ground level and sitting to strolling use at podium terrace and balcony levels, up to one category windier than suitable. Wind mitigation measures to ensure that wind conditions are comfortable for the intended pedestrian use have been suggested in Section 7 “Mitigation Measures”.

6.2.1.1 Thoroughfares (Figure 6)

All thoroughfare locations in and around the Proposed Development would have strolling use, or calmer, wind conditions throughout the year. Therefore, these areas would be suitable for the intended use and would not require wind mitigation measures.

6.2.1.2 Entrances (Figure 6)

Entrances to the Proposed Development and the surrounding buildings would require wind conditions suitable for standing use or calmer during the windiest season to be suitable for the intended use. An entrance location at the south-west corner of Building B would have wind conditions suitable for strolling use during the windiest season and would therefore be windier than suitable for the intended use. Likewise, the eastern entrance to the podium level café at the western corner of Building D would have strolling use wind conditions during the windiest season, one category windier than suitable for the intended use. Wind mitigation measures that would improve wind conditions at these locations have been discussed in Section 7 “Mitigation Measures”.

All other entrance locations around the Proposed Development and to existing buildings would have standing use or calmer wind conditions throughout the year. As such, these areas would have conditions be suitable for the intended pedestrian use and require no wind mitigation measures.

6.2.1.3 Podium Level Amenity Space (Figure 7)

The elevated café seating area located to the east of the Building E would have wind conditions suitable for standing use during the summer season. Standing use wind conditions would be one category windier than suitable for the intended use and this area would therefore require mitigation measures to ensure a suitable wind comfort environment for pedestrians. Wind mitigation measures that would improve wind conditions in this area have been discussed in Section 7 "Mitigation Measures".

6.2.1.4 Upper Level Amenity Spaces (Figures 8 and 9)

The terrace area at the northern corner of levels eight and nine of Building D and at the northern and southern corners of levels six and seven of Building E would have strolling use wind conditions during the summer season. These conditions would be one category windier than suitable for private amenity use and would therefore require wind mitigation measures.

All other terrace locations around the Proposed Development would standing or sitting use conditions during the summer season. Standing or sitting use conditions would be suitable for private amenity use.

All balconies on Building A would have wind conditions suitable for standing or sitting use during the summer season and as such, would be suitable for the intended occupant use. Likewise, balconies on Buildings C, E and F would all have wind conditions suitable for standing or sitting use during the summer season and would therefore be suitable for the intended occupant use.

The south-eastern set of balconies on Building B would have wind conditions suitable for strolling use during the summer season. Strolling use conditions would be one category windier than suitable for the intended occupant use. Therefore, wind mitigation measures would be required to ensure a safe and comfortable wind environment for residents.

There would be a single balcony on seventh floor on the western elevation of Building D (the more northern of the two sets of balconies) which would have strolling use wind conditions during the summer season. Strolling use conditions would be one category windiest than suitable for the intended use. Wind mitigation measures have been suggested to improve wind conditions in Section 7 "Mitigation Measures". All other balconies on Building D of the Proposed Development would be suitable for the intended use.

6.2.2 Strong Winds

Winds exceeding the 15m/s for more than 0.025% of the time (approximately two hours per year) would be expected to occur where wind conditions would be suitable for walking use during the windiest season. As such, strong winds with the potential to be a safety concern to occupants would be likely to occur on balconies at the south-eastern corner of Building B as well as at the terrace levels on Buildings D and E. Wind mitigation measures would be required to reduce the likely occurrence of winds exceeding 15m/s in these areas. Wind mitigation measures to ensure that wind conditions are safe for pedestrian use have been suggested in Section 7 "Mitigation Measures".

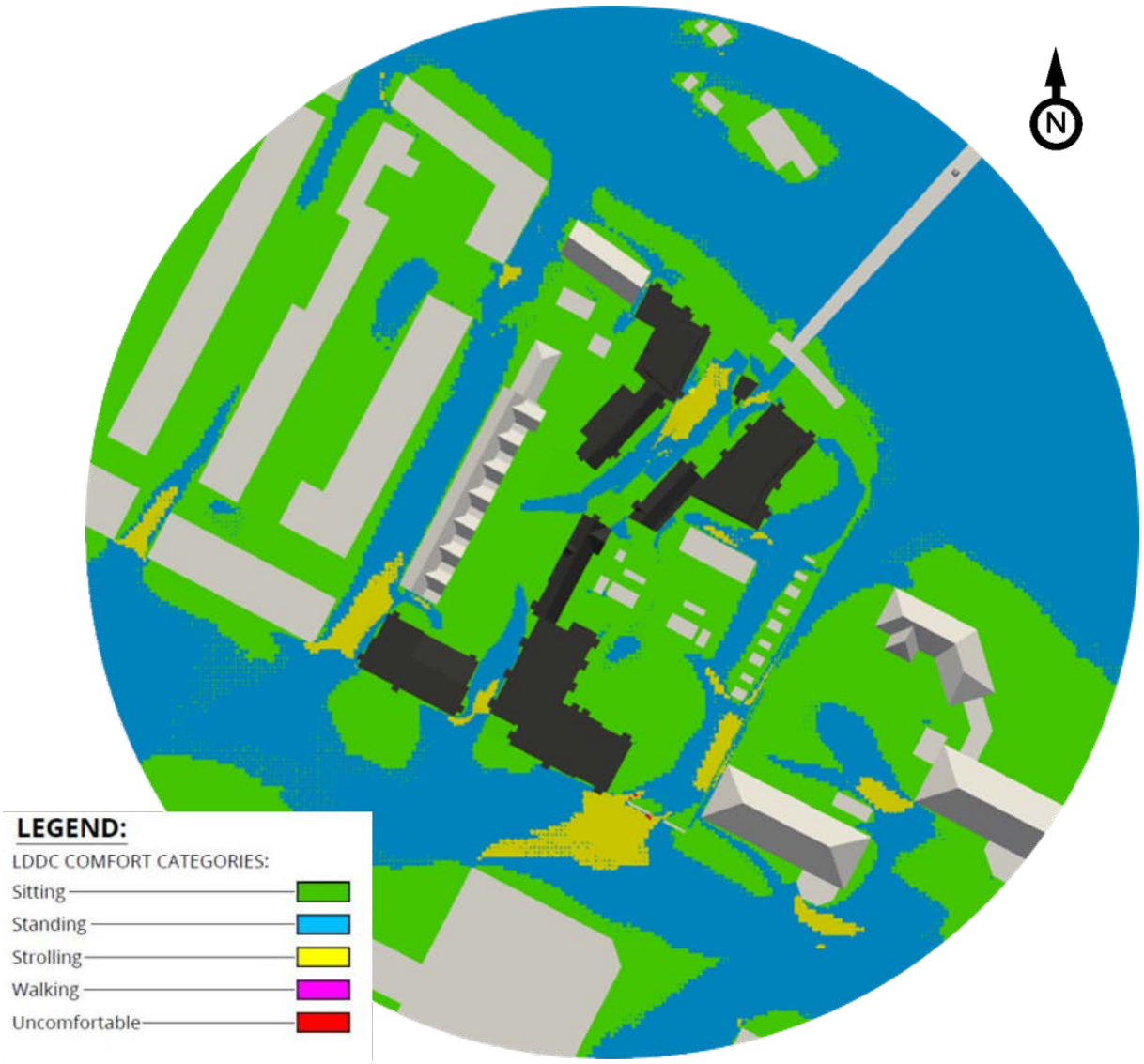

Figure 6: Configuration 2 – Proposed Development with the Existing Surrounding Buildings – Ground and Podium Level, Windiest Season

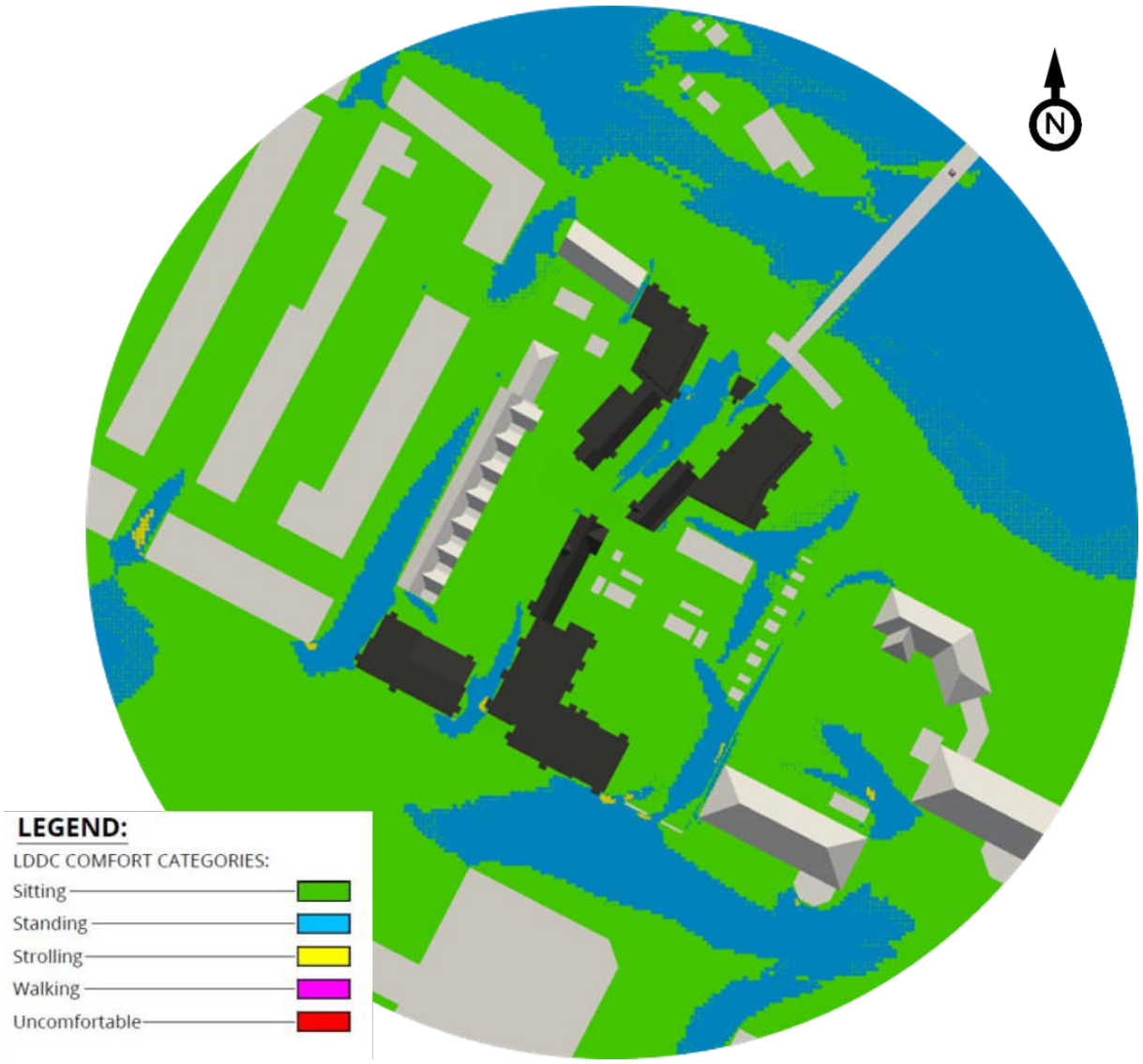

Figure 7: Configuration 2 – Proposed Development with the Existing Surrounding Buildings – Ground and Podium Level, Summer Season

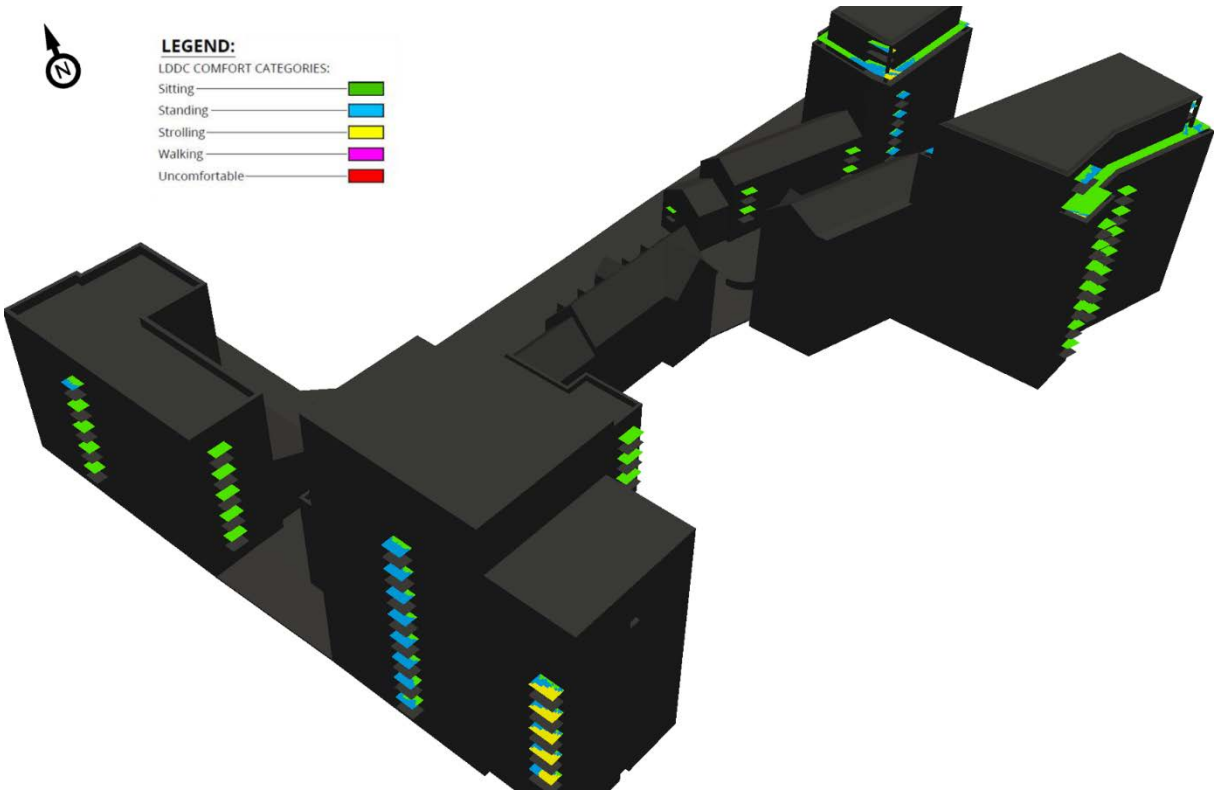

Figure 8: Configuration 2 – Proposed Development with the Existing Surrounding Buildings – Terrace/Balcony Levels (view from the north-west), Summer Season

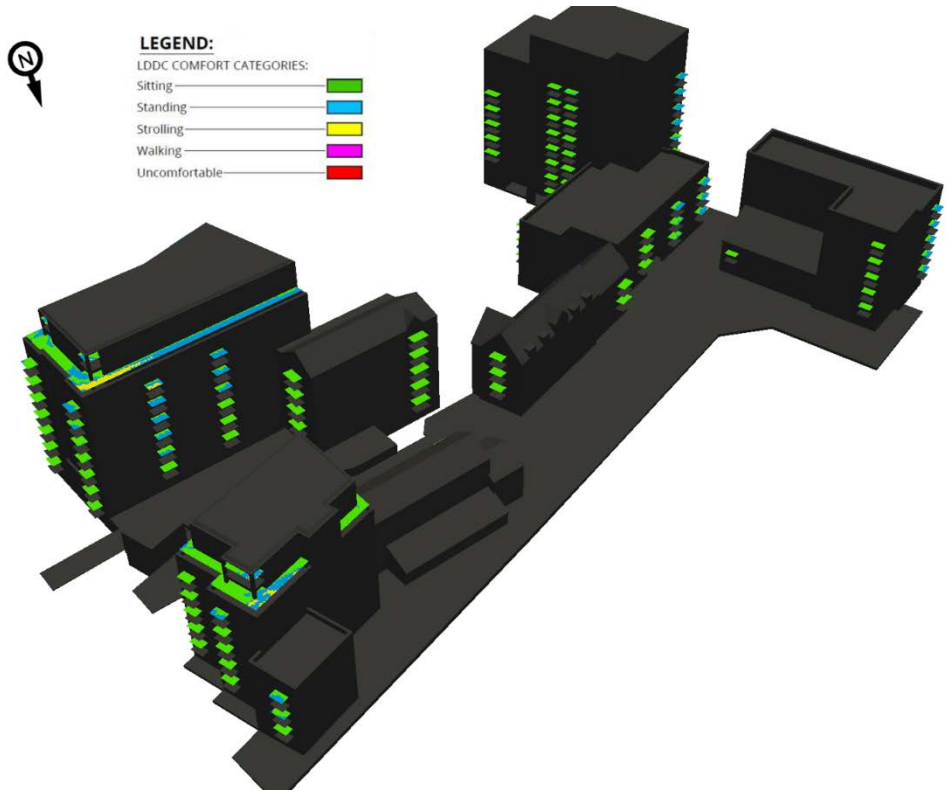

Figure 9: Configuration 2 – Proposed Development with the Existing Surrounding Buildings – Terrace/Balcony Levels (view from the south-east), Summer Season

6.3 Configuration 3: Proposed Development with the Cumulative Surrounding Buildings

In Configuration 3 the Proposed Development was assessed with the addition of known cumulative schemes to the surrounding context. The following two schemes were within 400m of the Site and included within the assessment:

- Station Hill Development (Refs. 190466 and 190465); and
- Former Cooper Reading BMW scheme (Ref. 162166).

Results for the Proposed Development with the above cumulative schemes are presented in Figures 10 and 11 for ground and podium level during the windiest season and summer seasons respectively. Figures 12 and 13 present results for the terrace and balcony levels during the summer season, when amenity spaces are expected to be most frequently used.

6.3.1 Pedestrian Comfort

Wind conditions around the Proposed Development during the windiest season would range from suitable for sitting to walking use. These conditions would be suitable for all entrance locations as they would have conditions suitable for standing use or calmer. There would be a small thoroughfare area on Vastern Road with walking use conditions, making it unsuitable for the intended use. During the summer season, wind conditions would range from suitable for sitting to strolling use at ground level and sitting to strolling use at terrace and balcony levels, up to one category windier than suitable.

6.3.1.1 Thoroughfares (Figure 10)

Wind conditions at thoroughfares around the Proposed Development would stay mostly the same as those in Configuration 2, suitable for the intended use, however, an area to the south-east of Building B would have walking use wind conditions during the windiest season, one category windier than the desired strolling use, and as such would require mitigation measures. Wind mitigation measures have been suggested to improve wind conditions in Section 7 “Mitigation Measures”.

6.3.1.2 Entrances (Figure 10)

Wind conditions at entrances around the Proposed Development and the surrounding buildings would be the same as those in Configuration 2. As such the entrance location at the south-west corner of Building B and the eastern entrance to the podium level café at the north of the Site would have wind conditions suitable for strolling use during the windiest season and would therefore be windier than suitable for the intended use, requiring mitigation measures. Wind mitigation measures to improve wind conditions at these locations have been discussed in Section 7 “Mitigation Measures”.

All other entrance locations in the context of the cumulative surrounds would be suitable for the intended use and require no mitigation.

6.3.1.3 Podium Level Amenity Space (Figure 11)

The podium level café seating area located to the east of the Building E would have similar wind conditions to those in Configuration 2, suitable for standing use during the summer season. Standing use wind conditions would be one category windier than suitable for the intended use and this area would therefore require mitigation measures to ensure a suitable wind comfort environment for pedestrians. Wind mitigation measures that would improve wind conditions in this area has been discussed in Section 7 "Mitigation Measures".

6.3.1.4 Terrace and Balcony Level Amenity Spaces (Figures 12 and 13)

As in Configuration 2, the terrace area at the northern corner of levels eight and nine of Building D and at the northern and southern corners of levels six and seven of Building E would have strolling use wind conditions during the summer season. These conditions would be one category windier than suitable for private amenity use and would therefore require wind mitigation measures.

All other terrace locations around the Proposed Development in the context of the cumulative surrounds would standing or sitting use conditions during the summer season. Standing or sitting use conditions would be suitable for private amenity use.

Balconies on Buildings C, E and F would all have wind conditions suitable for standing or sitting use during the summer season and would therefore be suitable for the intended occupant use, the same as in Configuration 2.

There would be a single balcony at the fifth floor on the western façade of Building A that would have strolling use wind conditions during the summer season, making it unsuitable for the intended use and requiring mitigation measures. All other balconies on Building A would have suitable wind conditions, requiring no mitigation measures.

The balcony on seventh floor on the western elevation of Building D (the more northern of the two sets of balconies) which would have strolling use wind conditions during the summer season in Configuration 2, would also have strolling use wind conditions during the summer season in Configuration 3, and therefore would require mitigation measures. All other balconies on Building D of the Proposed Development would be suitable for the intended use.

The south-eastern and a western (the most southern of the three) set of balconies on Building B would have wind conditions suitable for strolling use during the summer season making them unsuitable for the intended use. Therefore, wind mitigation measures would be required to ensure comfortable wind environment for residents. Wind mitigation measures that would improve wind conditions at balconies and terraces around the Proposed Development have been suggested in Section 7 "Mitigation Measures".

6.3.2 Strong Winds

Winds exceeding the 15m/s for more than 0.025% of the time (approximately two hours per year) would be expected to occur where wind conditions would be suitable for walking use during the windiest season. As such, strong winds with the potential to be a safety concern to occupants would be likely to occur at ground level around the south-east of Building B and on balconies at the south-eastern corner of Building B as well as at the terrace levels on Buildings D and E. Wind mitigation measures would be required to reduce the likely occurrence of winds exceeding 15m/s in these areas. Wind mitigation measures to ensure that wind conditions are safe for pedestrian use have been suggested in Section 7 “Mitigation Measures”.

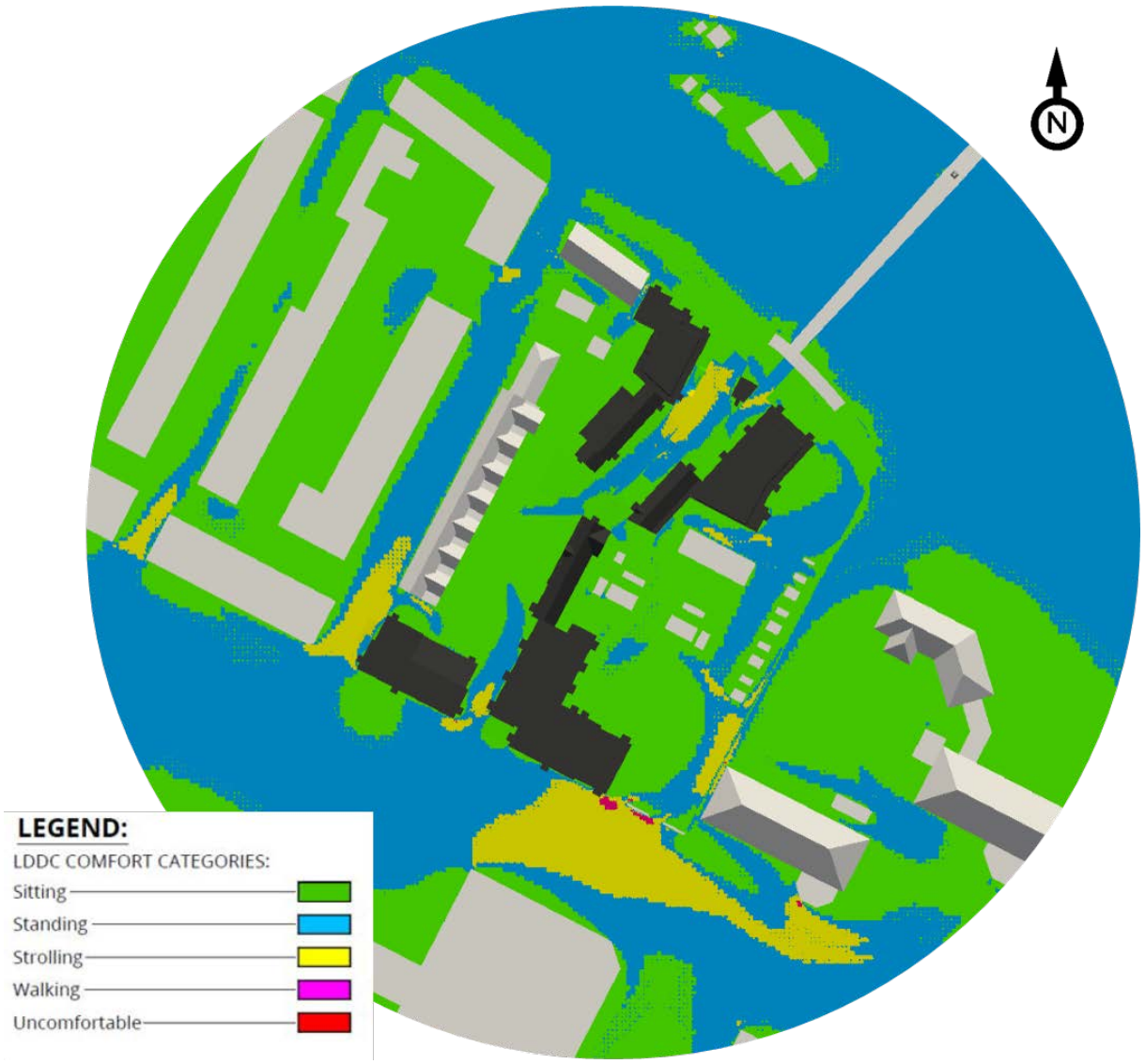

Figure 10: Configuration 3 – Proposed Development with the Cumulative Surrounding Buildings – Ground and Podium Level, Windiest Season

Figure 11: Configuration 3 – Proposed Development with the Cumulative Surrounding Buildings – Ground and Podium Level, Summer Season

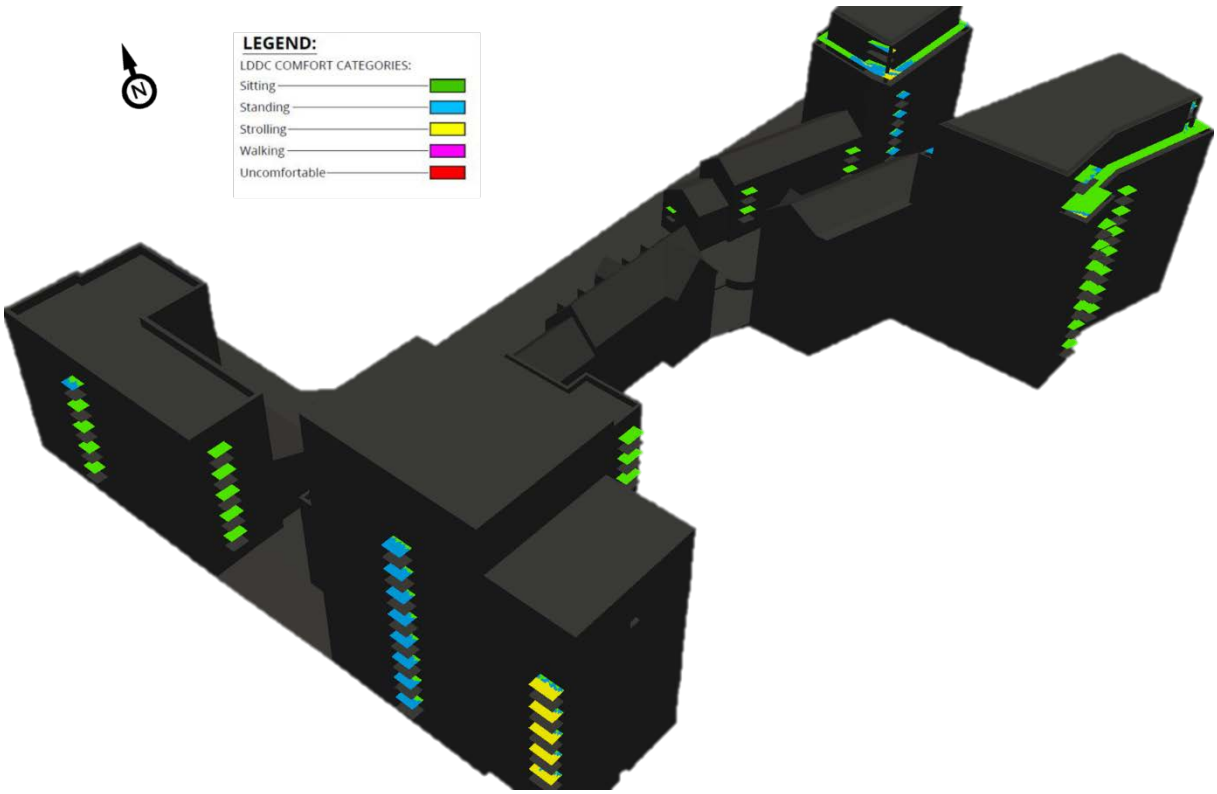

Figure 12: Configuration 3 – Proposed Development with the Cumulative Surrounding Buildings –Terrace/Balcony Levels (view from the north-west), Summer Season

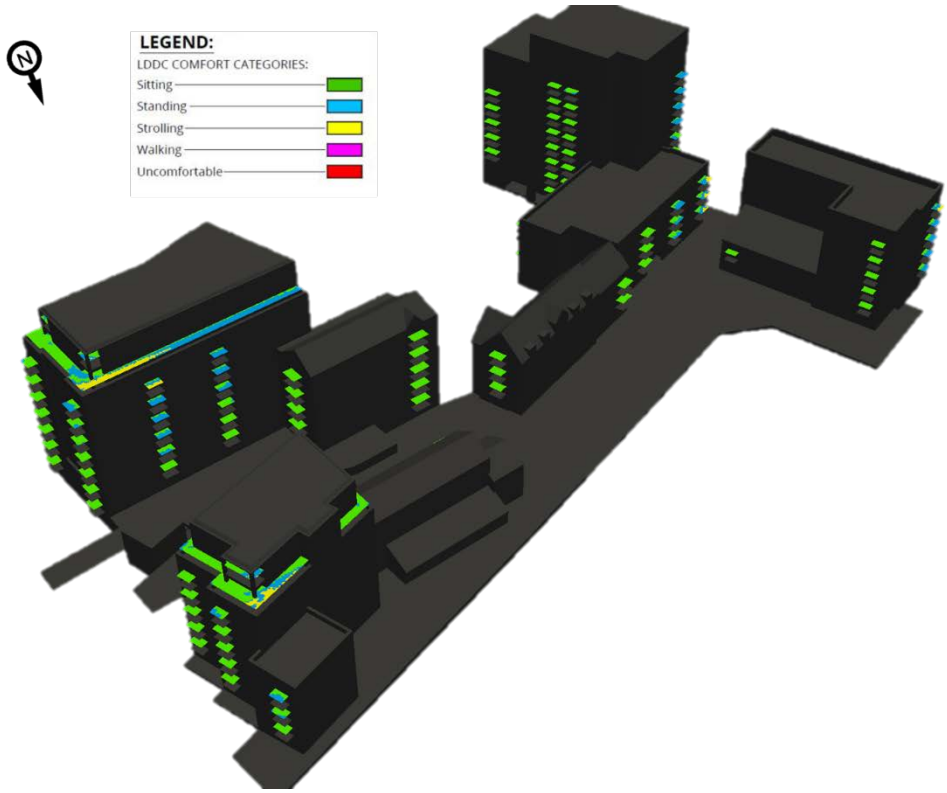

Figure 13: Configuration 3 – Proposed Development with the Cumulative Surrounding Buildings –Terrace/Balcony Levels (view from the south-east), Summer Season

7 MITIGATION MEASURES

Wind conditions around the Proposed Development were assessed devoid of landscaping or wind mitigation measures in order to assess a worst-case (i.e. windy) scenario.

Without landscaping, in Configuration 2, wind conditions at the south-western entrance to Building B, the entrance to the podium level café at the north of the Site and the associated seating area, the terrace level amenity spaces of Buildings D and E, a balcony on the western façade of Building D, and the south-eastern balconies of Building B would be one category windier than suitable for the intended uses. Strong winds associated with walking use conditions during the windiest season and with the potential to be a safety concern for users would be likely to occur on the terrace levels of Buildings D and E and at the south-eastern balconies of Building B. See Figures 18 to 28 of Appendix C for further detail.

The areas that would require mitigation in Configuration 2 would also require mitigation in Configuration 3. In addition to this, balconies on the western façade of Building B and a ground level area around the south-east of Building B would also have unsuitable wind conditions and would also require mitigation in Configuration 3. See Figures 29 and 30.

The proposed landscaping scheme (Figure 17 of Appendix B) would be expected to improve wind conditions at ground level such that the entrance to the café at the north of the Site and its associated seating area would be expected to be suitable for the intended use.

Following the assessment detailed above, the south-western entrance to Building B would be relocated north to an area which would have wind conditions suitable for standing use. This amendment, in conjunction with the proposed landscaping scheme would be expected to ensure that this entrance would have suitable wind conditions all year round in both the existing scenario and the cumulative scenario.

For the remaining locations identified, wind mitigation measures have been detailed below (with example Figures 31 to 35 in Appendix D) which would be expected to improve wind conditions such that they would be suitable for the intended uses of each location. Due to the likely presence of strong winds at the terrace levels of Buildings D and E and at the south-eastern balconies on Building B, further testing is recommended to assess if safety concerns are likely to have been fully mitigated.

7.1.1 Ground Level around the south-east of Building B

In the context of cumulative surrounds, a thoroughfare area around the south-eastern corner of Building B would have walking use wind conditions during the windiest season. These wind conditions would be windier than suitable for a pedestrian thoroughfare and would have the potential to be a safety concern for pedestrians and cyclists. Additional trees of at least 5m in height located at the southern façade of Building B around the south-east corner would be expected to improve wind conditions in this area.

Alternatively, a 50% porous screen of at least 2m in height and 2m in width place perpendicular to the southern façade of Building B at the south-east corner of the building would be expected to improve wind speeds around this corner.

7.1.2 Building B and D Balconies

Unsuitable wind conditions and the likely occurrence of strong winds at the balcony on the western facade of Building D, on balconies at the western façade of Building B (the south-most set of balconies), and at the south-eastern balconies located on Building B would likely benefit from a solid balustrade of at least 1.5m in height or a 1.8m tall side screen with a porosity no greater than 50%. These measures would be expected to ensure a safe and comfortable wind environment on the balconies around the Proposed Development.

7.1.3 Terrace Level Amenity Spaces

Walking use wind conditions and the likely occurrence of strong winds at the terrace levels of Buildings D and E would likely require a solid balustrade of at least 1.5m in height. Additionally, planting of at least 1.5m in height or porous screens of 2m in height surrounding or breaking up the terrace space would be expected to provide adequate shelter to pedestrians in the effected areas. These measures would be expected to ensure a safe and comfortable wind environment at the terrace levels of Building D and E.

8 CONCLUDING REMARKS

This report has identified the wind microclimate effects on the Proposed Development, based on an assessment conducted using Computational Fluid Dynamics (CFD) simulations. The following is a summary of the key points described in the report:

- The meteorological data for the Site indicates prevailing winds blowing from the south-west throughout the year. There is a secondary wind from the north-east most common during the late spring season.
- Wind conditions at the existing Site with existing surrounding buildings range from suitable for sitting to standing use on-Site and in the nearby surrounding area during the windiest season. During the summer season there is an increase in the proportion of sitting use conditions. No strong winds would be likely to occur at the existing Site.
- With the Proposed Development, wind conditions would range from suitable for sitting to strolling use on- and off-Site at ground and podium levels during the windiest season. Entrances to Building B and the café at the north of the Site would be windier than suitable. During the summer season, wind conditions at the seating area to the west of the café as well as terrace level areas on Buildings D and E, and balconies of Buildings B and D would have windier than suitable conditions. Strong winds would be likely to occur at the terrace levels of Buildings D and E and at the south-eastern balconies on Building B, which would be a potential safety concern for occupants.
- Windier than suitable conditions identified around the Proposed Development would persist with the introduction of the cumulative schemes. Additionally, a ground level thoroughfare area on Vastern Road and a set of balconies along the western façade of Building B would have windy conditions and would require mitigation measures. Instances of strong winds with the potential to be a safety concern for cyclists and pedestrians would also be likely to occur at this location of Vastern Road to the south-east of Building B.
- The assessment of wind conditions at the Proposed Development have been conducted devoid of landscaping or wind mitigation measures in order to present a worst-case (i.e. windy) scenario. It is expected that with the introduction of the proposed landscaping scheme and relocation the entrance at the south-west of Building B, that all locations at ground level would have wind conditions suitable for the intended use.
- Wind mitigation measures have been suggested to improve wind conditions identified at ground level, balconies and terrace level areas around the Proposed Development that would be windier than suitable. Suggested wind mitigation measures include:
    - The addition of at least two trees which are at least 5m in height, at the south-east corner of Building B;
    - The addition of a 50% porous screen of at least 2m in height and 2m in width placed perpendicular to the southern facade of Building B at the south-east corner;
    - Solid balustrades at least 1.5m in height at terrace levels and balconies expected to experience adverse wind conditions;
    - 1.8m tall side screens that are no more than 50% porous at balconies that are expected to have unsittable wind conditions;
    - Strategically placed planting of at least 1.5m in height in terrace level areas with unsuitable wind conditions; and

- Strategically placed planted trellises or porous screens of 2m in height in terrace level areas with unsuitable wind conditions.

- Prior to the development of wind mitigation measures wind conditions at the Proposed Development would be windier than suitable for the intended pedestrian uses, with instances of strong winds with the potential to be a safety concern at ground level and to balcony and terrace occupants likely to occur. Wind mitigation measures likely to improve wind conditions and reduce the occurrence of strong winds at ground, balcony and terrace levels have been suggested. It is recommended that these measures would be assessed through further quantitative testing to ensure a suitable wind environment at the Proposed Development for the intended uses.

9 REFERENCES

1. Lawson T.V. (April 2001), Building Aerodynamics, Imperial College Press

APPENDIX A

APPENDIX A: 3D MODEL IMAGES

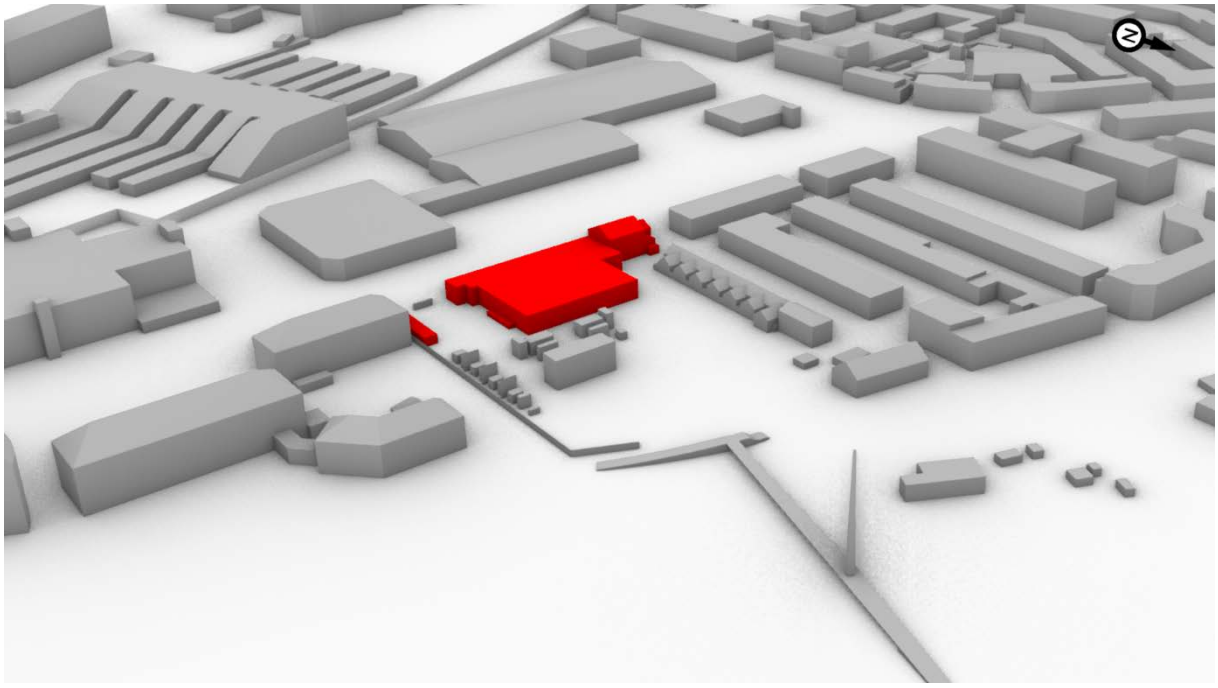

Figure 14 Existing Site with Existing Surrounding Buildings (Configuration 1) – View from the north-east

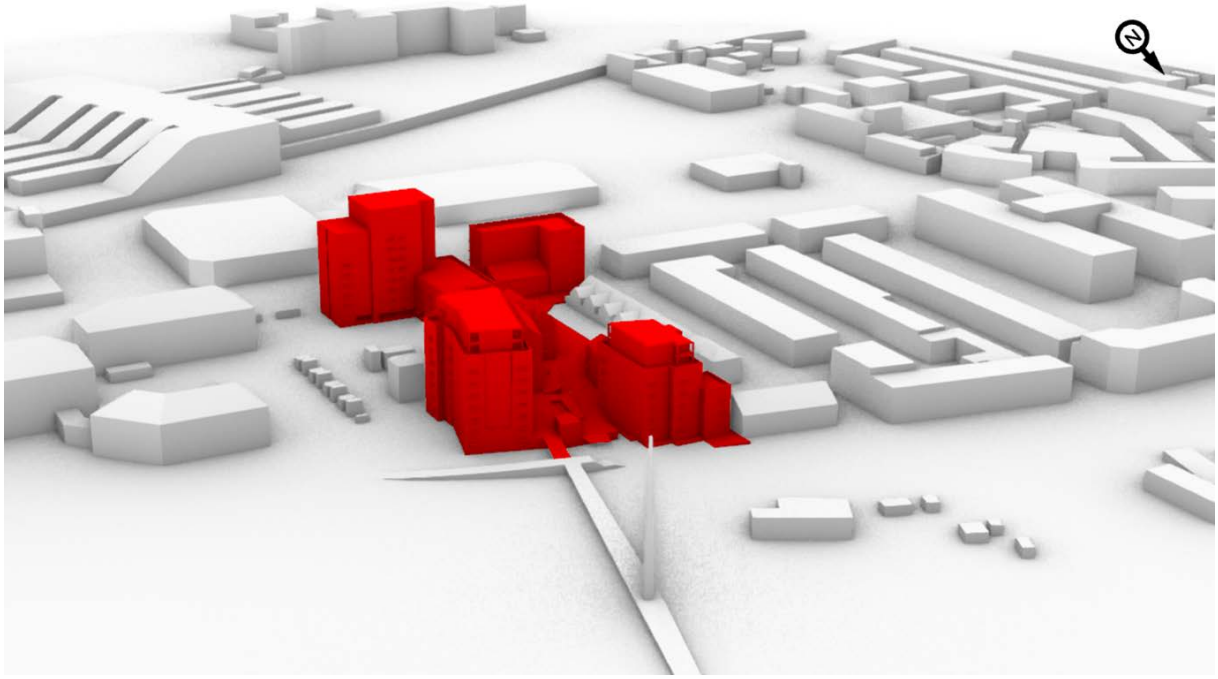

Figure 15 Proposed Development with Existing Surrounding Buildings (Configuration 2) – View from the north-east

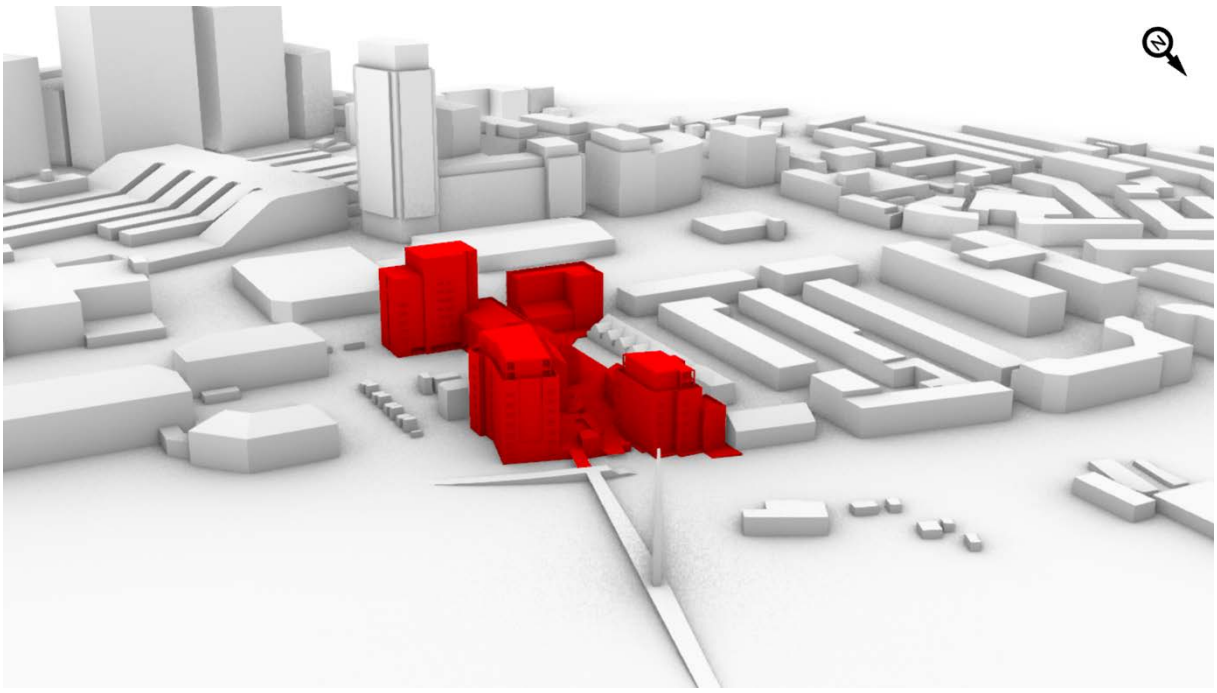

Figure 16 Proposed Development with Cumulative Surrounding Buildings (Configuration 3) – View in the Wind Tunnel View from the north-east

APPENDIX B

APPENDIX B: PROPOSED LANDSCAPING SCHEME

Figure 17 Proposed Landscaping scheme (BHOC.448_Landscape General Arrangement DRAFT.pdf)

APPENDIX C

APPENDIX C: LOCATIONS AROUND THE PROPOSED DEVELOPMENT WITH WIND MICROCLIMATE ISSUES

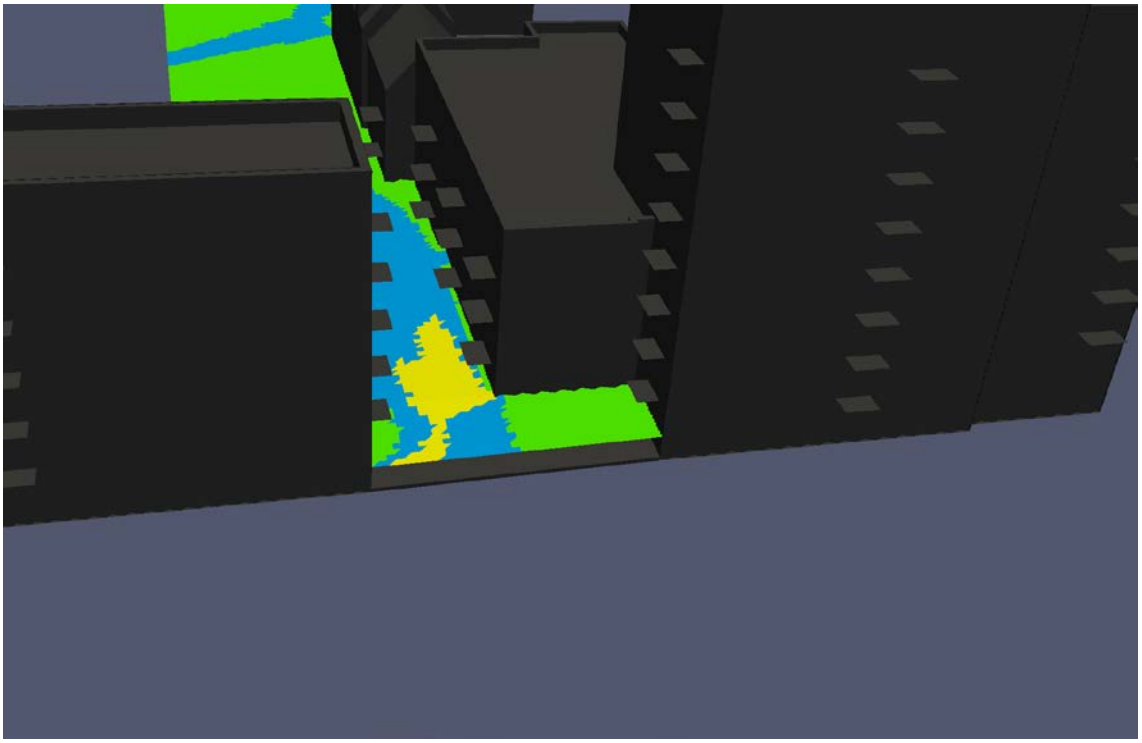

Figure 18 Image showing strolling use wind conditions around south-western entrance to Building B

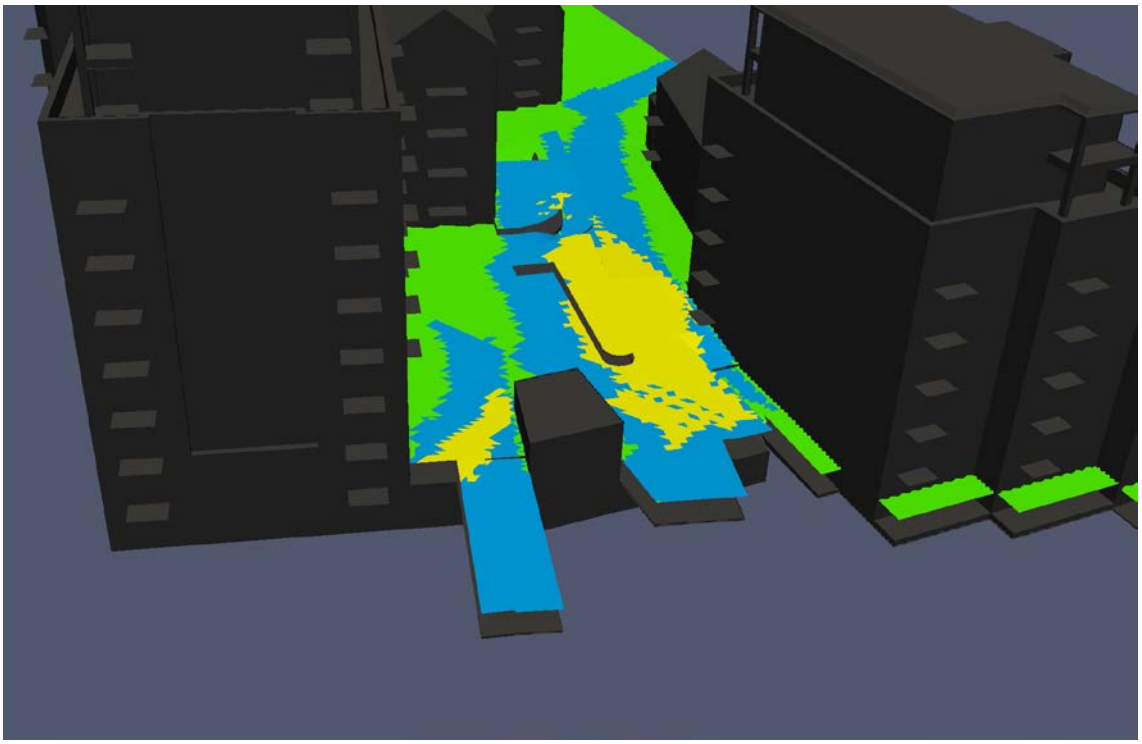

Figure 19 Image showing strolling use wind conditions around café entrance

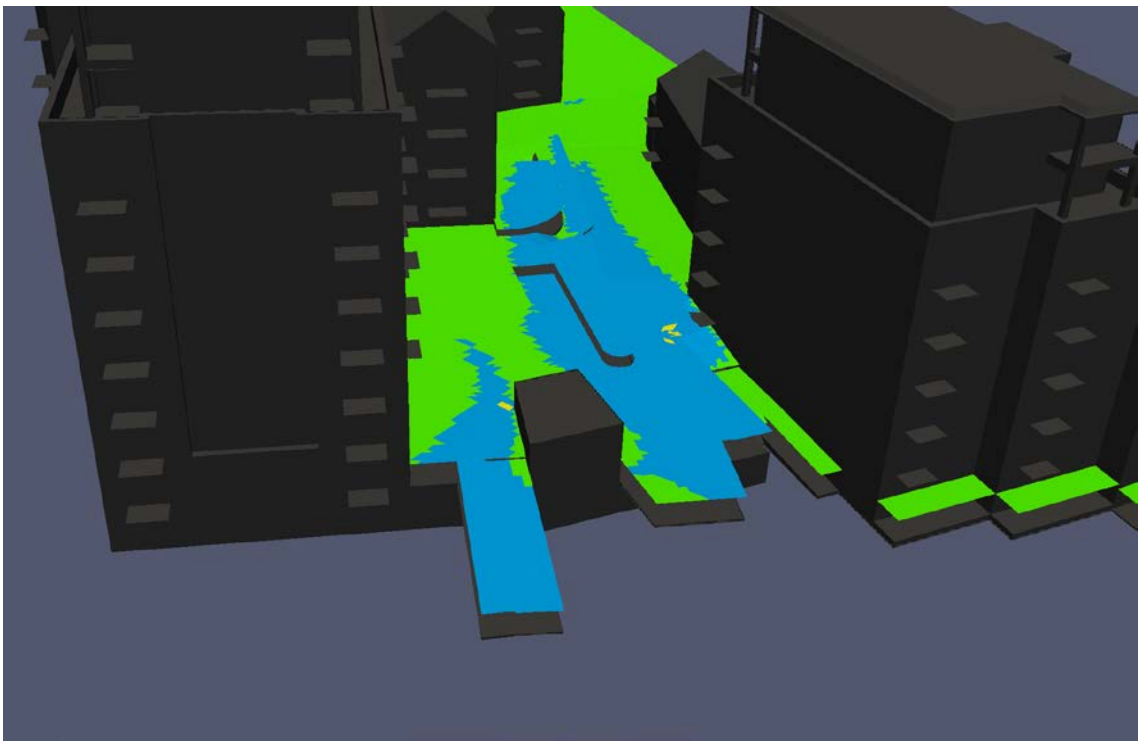

Figure 20 Image showing standing use wind conditions in café seating area during summer season

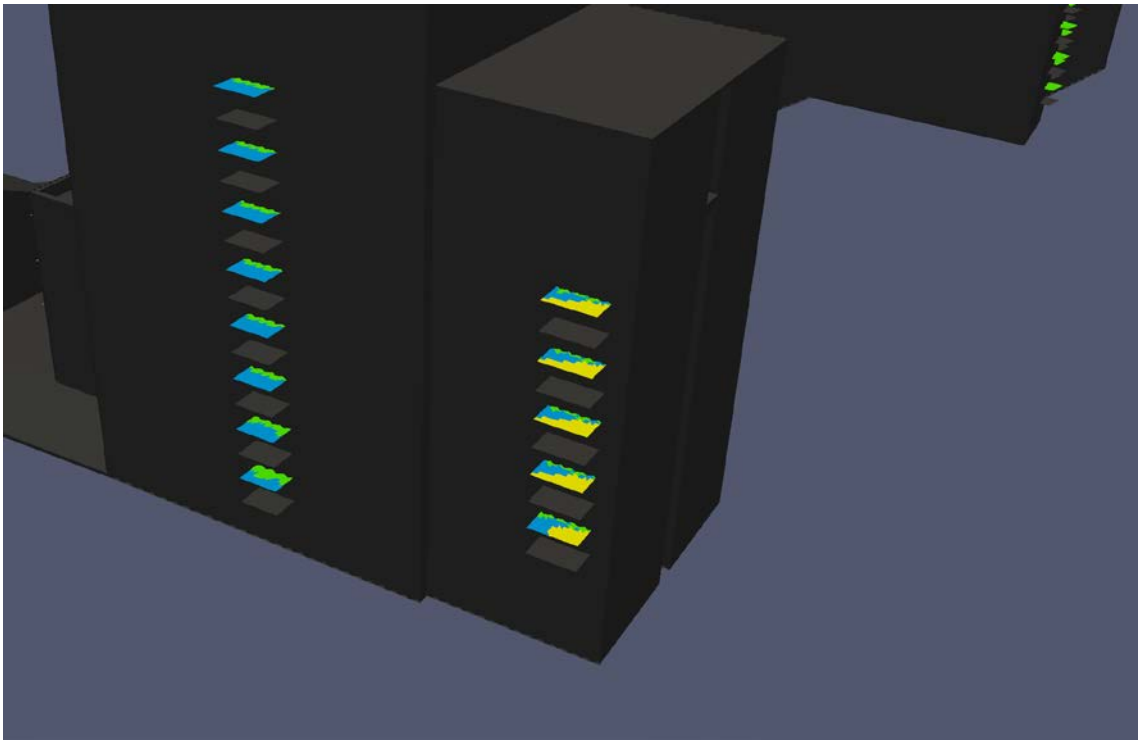

Figure 21 Image showing strolling use wind conditions at south-east balconies on Building B during summer season

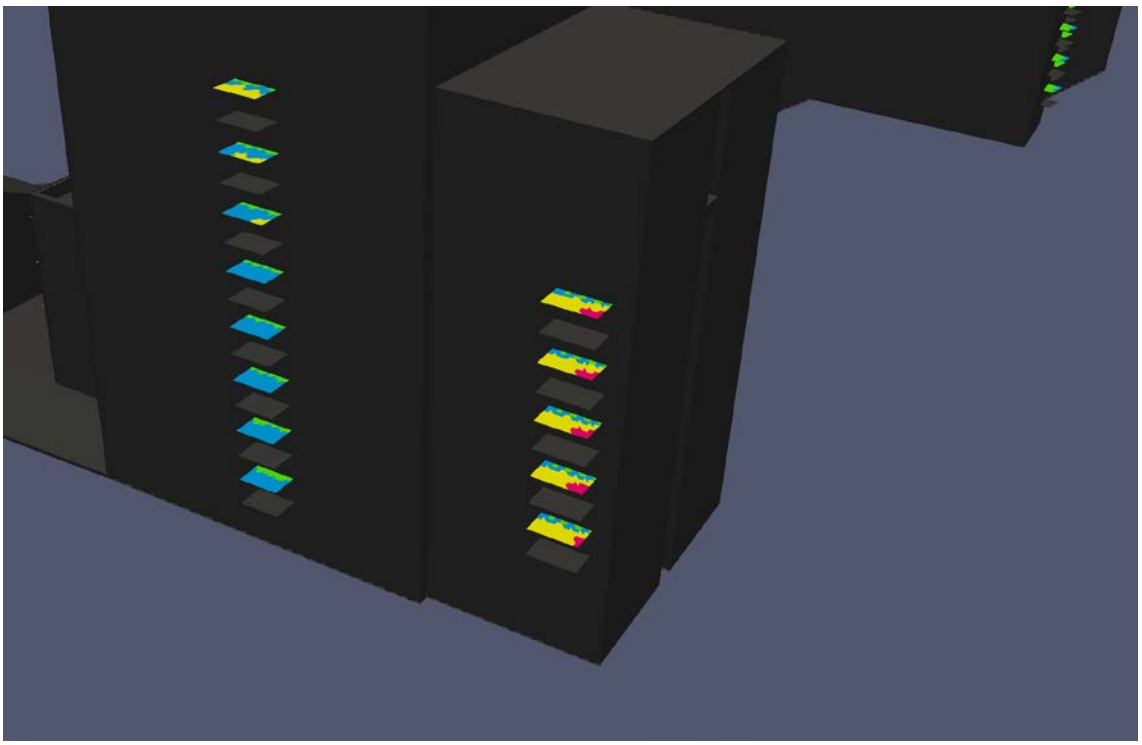

Figure 22 Image showing walking use wind conditions at south-east balconies on Building B during windiest season

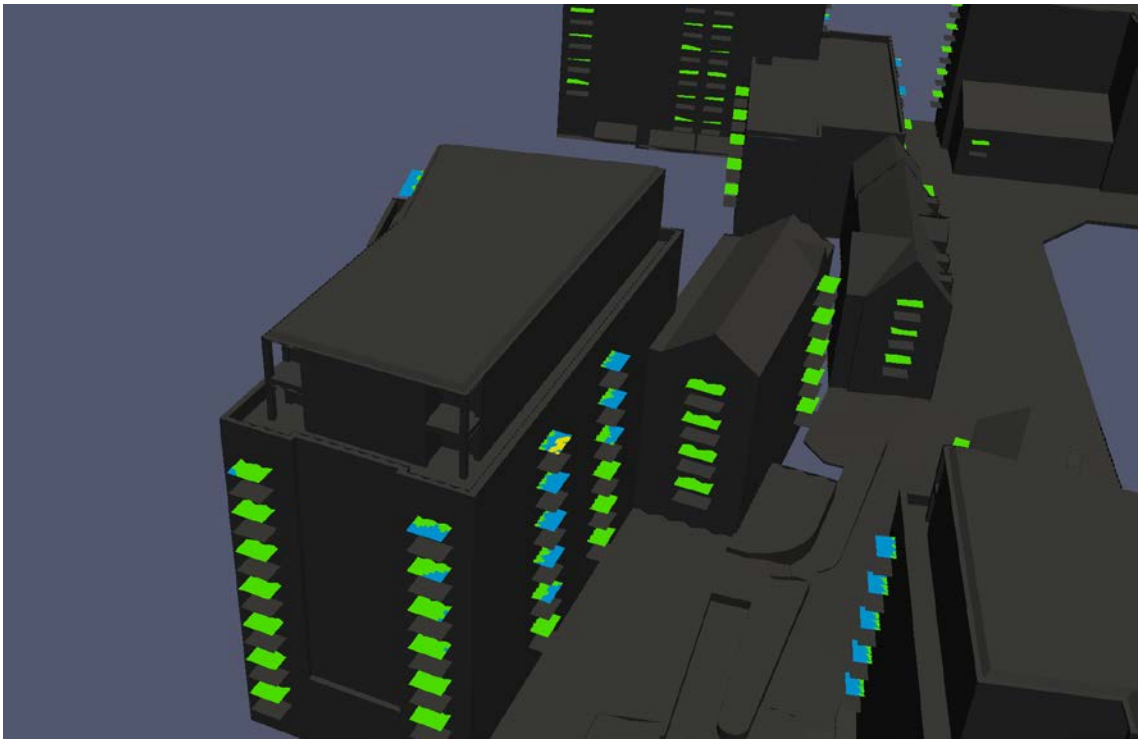

Figure 23 Image showing strolling use wind conditions at balcony on the western façade of Building D during summer season

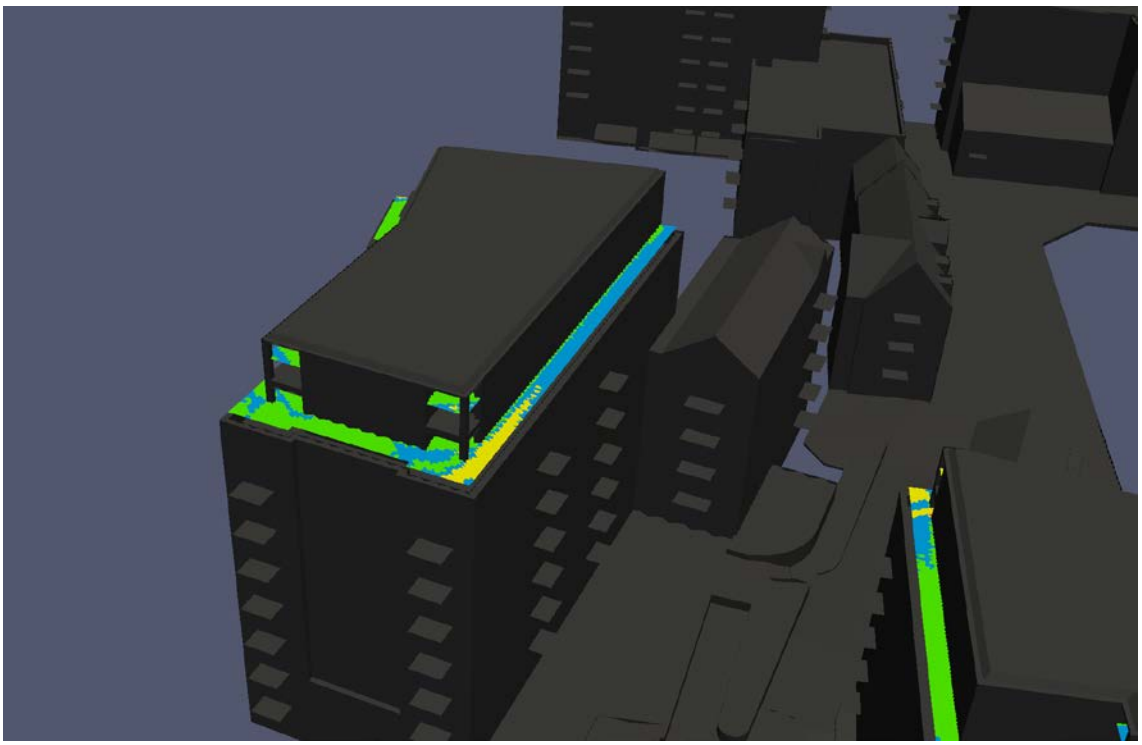

Figure 24 Image showing strolling use wind conditions at terrace level of Building D during summer season

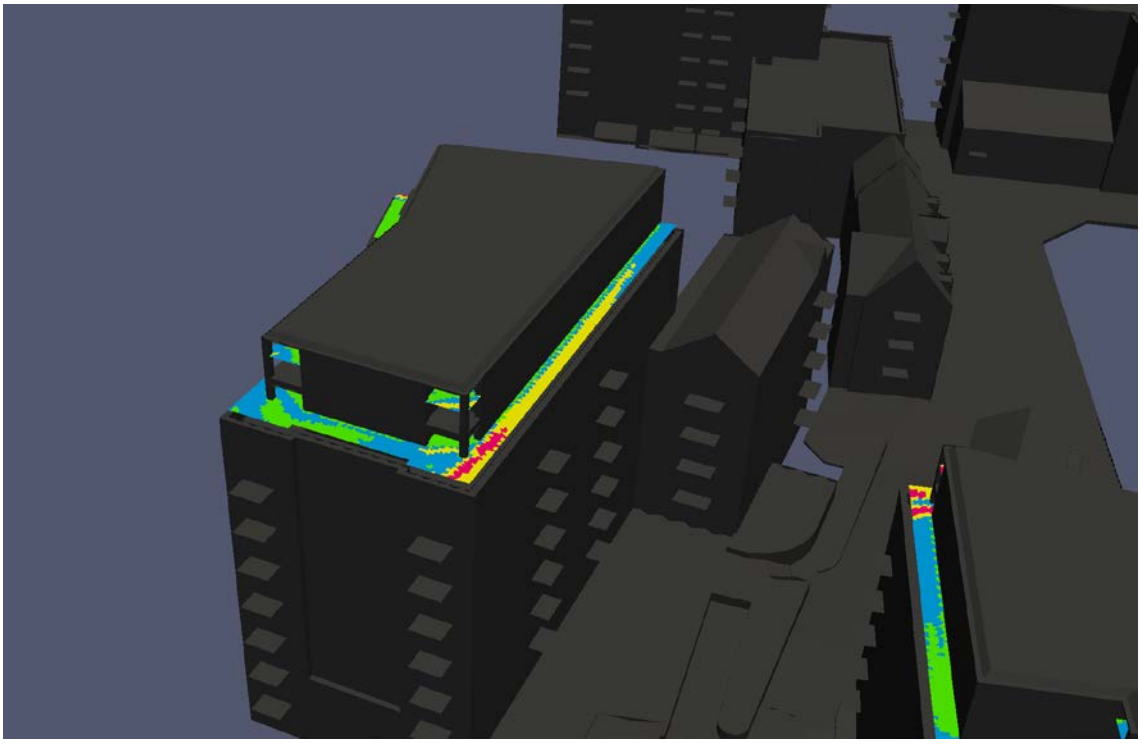

Figure 25 Image showing walking use wind conditions at terrace level of Building D during windiest season

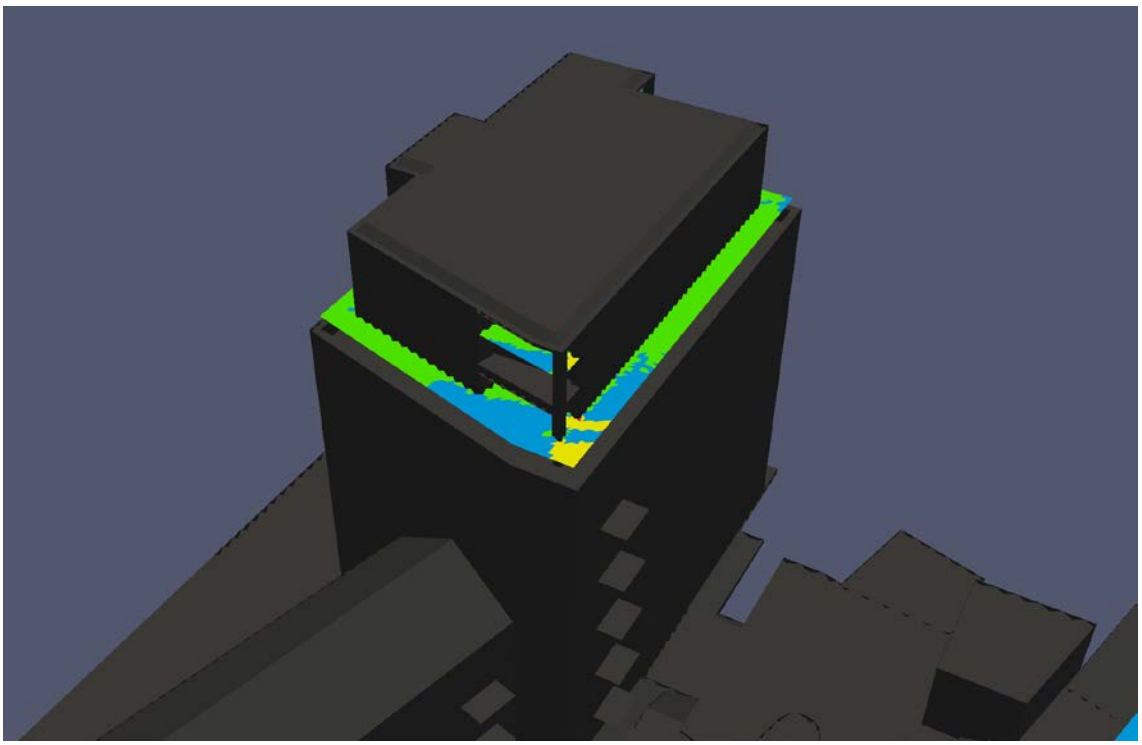

Figure 26 Image showing strolling use wind conditions at terrace level of Building E during summer season

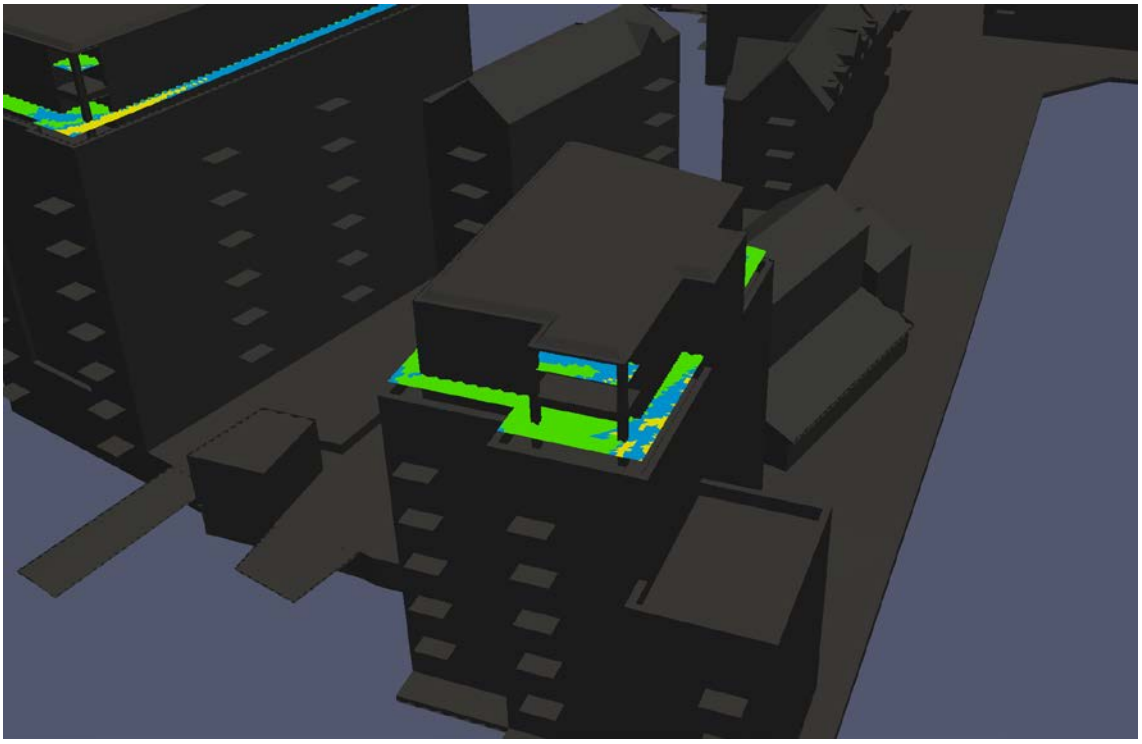

Figure 27 Image showing strolling use wind conditions at terrace level of Building E during summer season

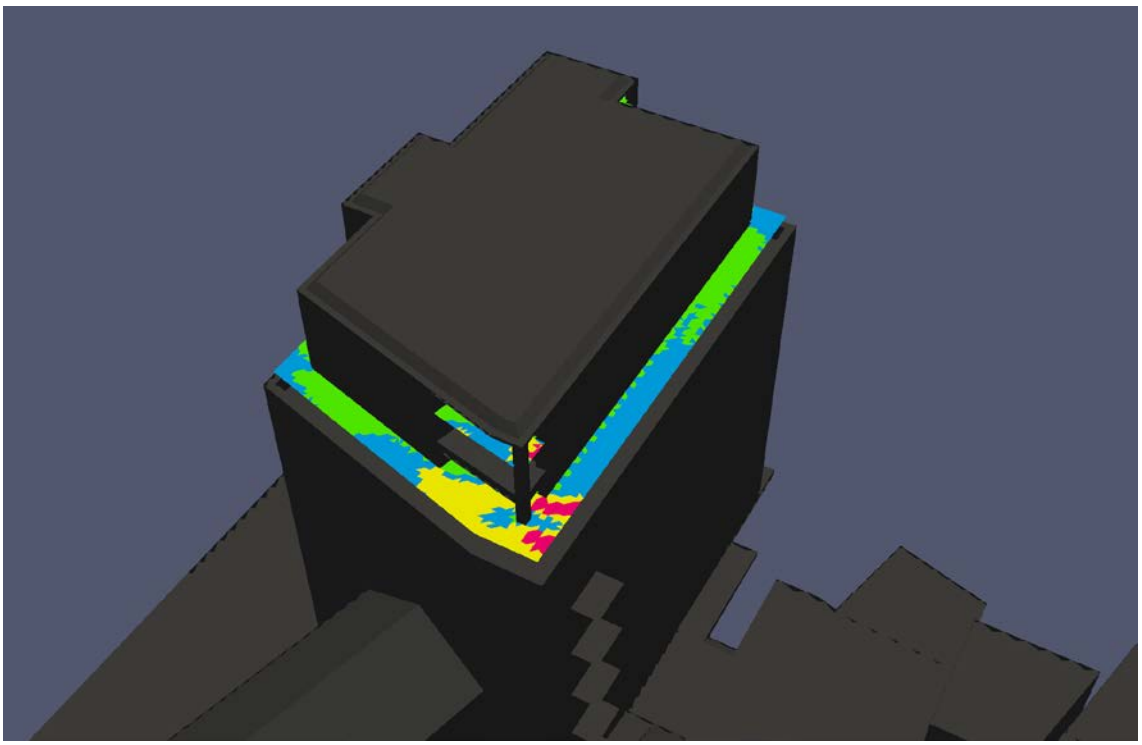

Figure 28 Image showing walking use wind conditions at terrace level of Building E during windiest season

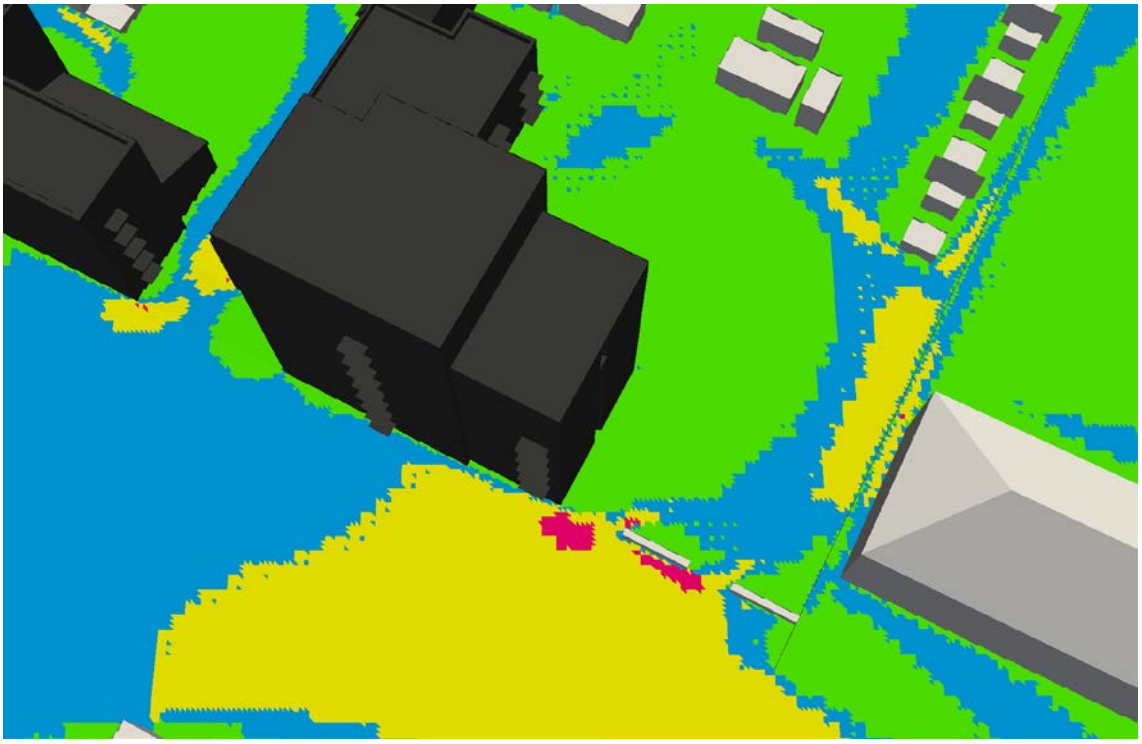

Figure 29 Image showing walking use wind conditions at south-east corner of Building B during windiest season, in context of the cumulative surrounds

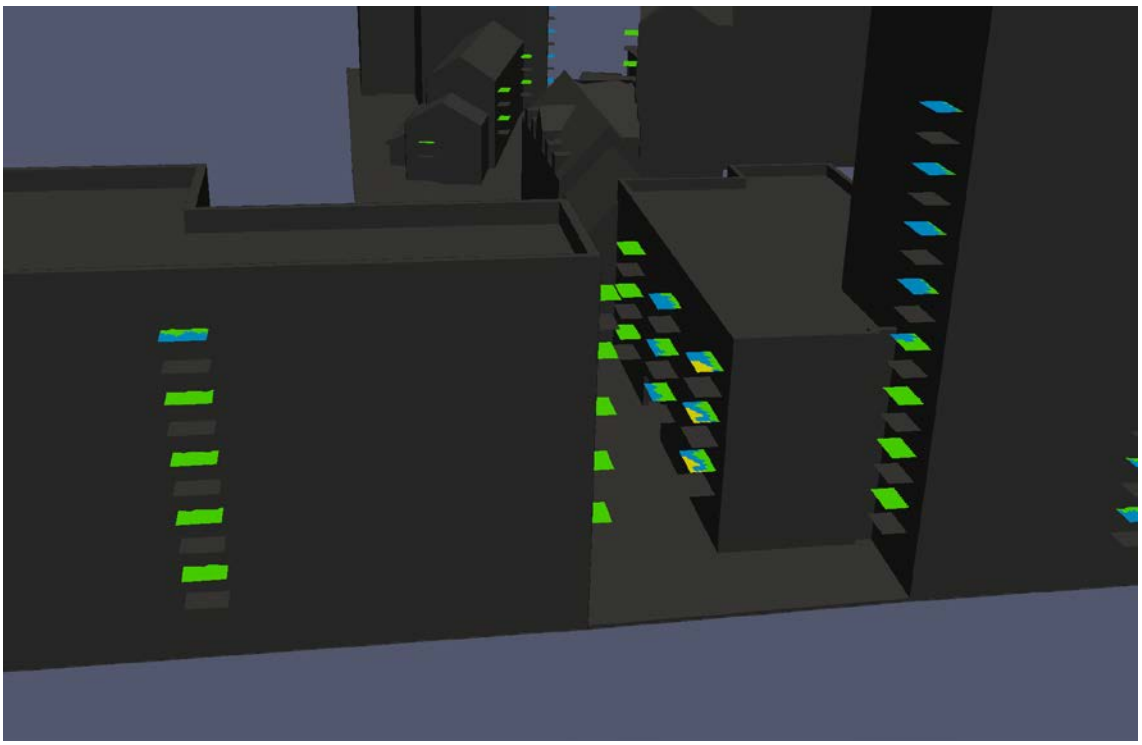

Figure 30 Image showing strolling use wind conditions at balconies on the western façade of Building B during summer season, in the context of the cumulative surrounds

APPENDIX D

APPENDIX D: EXAMPLE WIND MITIGATION IMAGES

Figure 31 **Examples of terrace level mitigation – planted trellis**

Figure 32 **Examples of balcony mitigation – Side Screen**

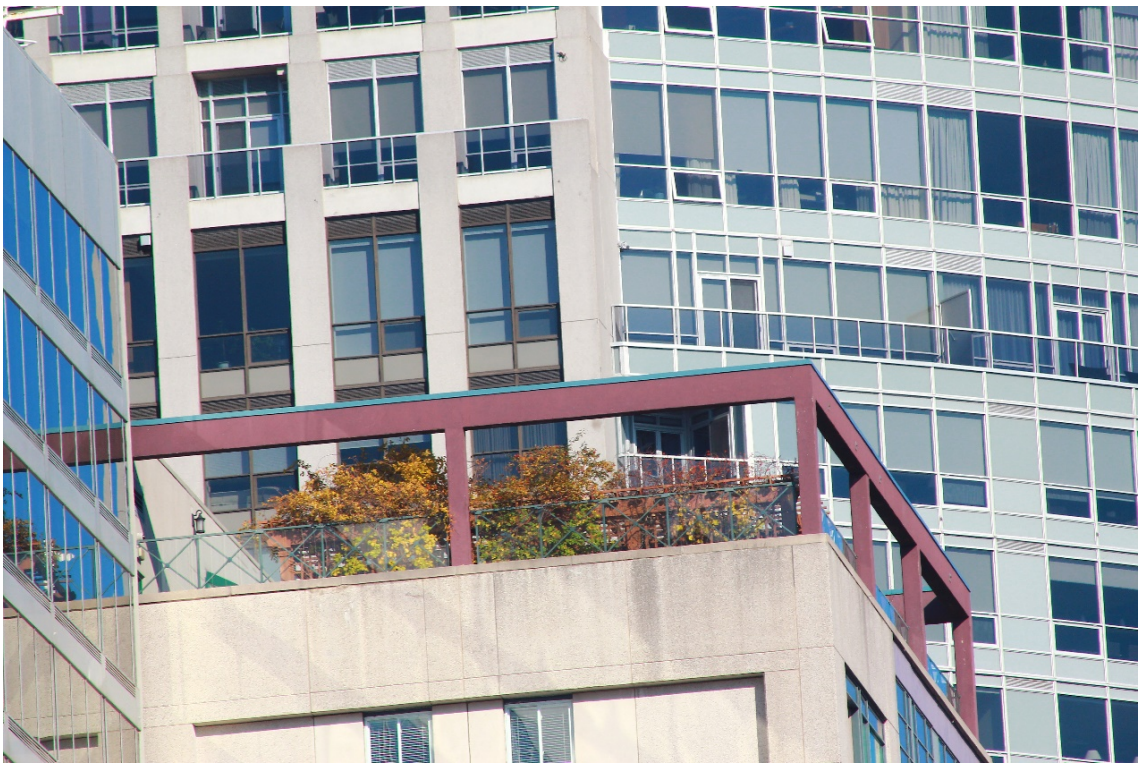

Figure 33 Example of terrace level mitigation – 1.5m tall balustrade and strategically placed planting

Figure 34 Example of ground level mitigation – porous screens

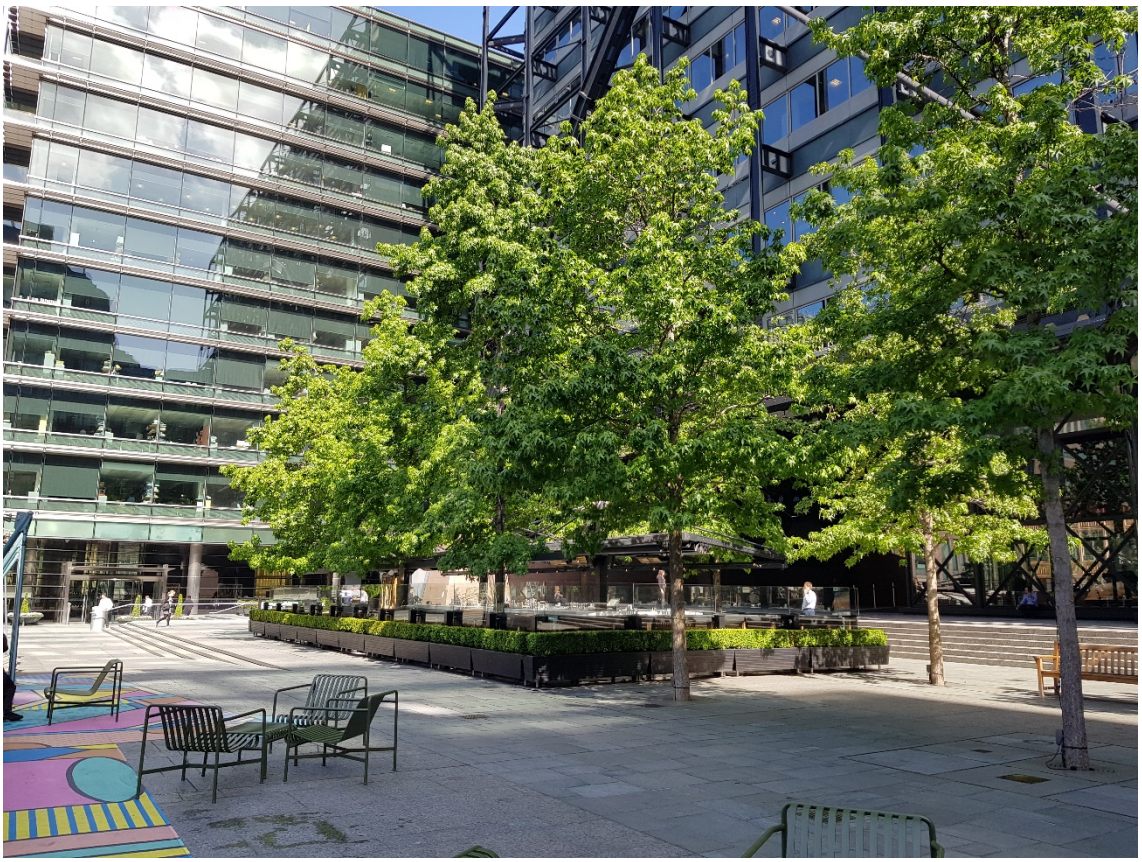

Figure 35 Example of ground level mitigation – 5m tall trees