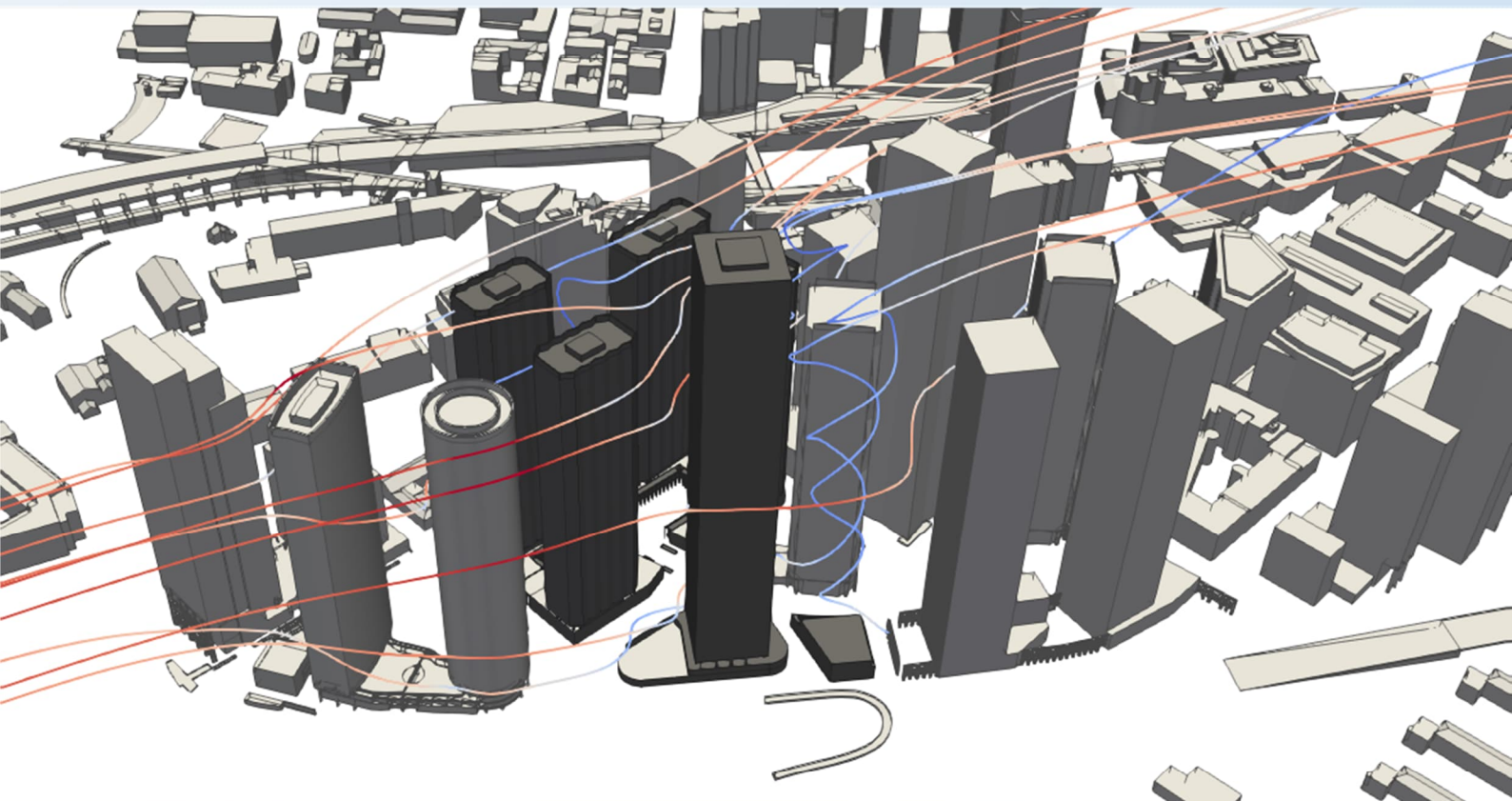




Renaker Build Ltd.

CROWN STREET PHASE 3 & GREAT JACKSON STREET PLOT D

Wind Microclimate Study





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TYPE OF DOCUMENT (VERSION) PUBLIC

PROJECT NO. 70103500

DATE: MAY 2023



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Wind Microclimate Study

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QUALITY CONTROL

Issue/revision	First issue	Revision 1	Revision 2	Revision 3
Remarks	Draft	Updated to reflect comments from Renaker	Updated to reflect further comments	Updated to reflect further comments
Date	21 March 2023	30 March 2023	5 April 2023	17 May 2023
Prepared by	Aidan McLoughlin	Aidan McLoughlin	Aidan McLoughlin	Aidan McLoughlin
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Authorised by	Stefano Cammelli	Stefano Cammelli	Stefano Cammelli	Stefano Cammelli
Signature				
Project number	70103500	70103500	70103500	70103500
Report number	1	1	1	1
File reference	Appendix 14.1 – Wind Microclimate Technical Report.pdf	Appendix 14.1 – Wind Microclimate Technical Report.pdf	Appendix 14.1 – Wind Microclimate Technical Report.pdf	Appendix 14.1 – Wind Microclimate Technical Report.pdf

CONTENTS

EXECUTIVE SUMMARY

2	INTRODUCTION	2
2.2	URBAN WIND EFFECTS	2
3	METHODOLOGY	3
3.1	ASSESSMENT METHODOLOGY	3
3.2	SITE AND STUDY AREA	5
3.3	ASSESSMENT CRITERIA	9
3.4	WIND CLIMATE ANALYSIS	10
3.5	SIMULATION DETAILS AND ASSUMPTIONS	14
4	RESULTS – SCENARIO 1: BASELINE	16
4.1	INTRODUCTION	16
	SAFETY CRITERIA ANALYSIS	16
	COMFORT CRITERIA ANALYSIS	17
5	RESULTS – SCENARIO 5: PHASES 1-4 IN EXISTING SURROUNDS	18
5.1	INTRODUCTION	18
	SAFETY CRITERIA ANALYSIS	18
	COMFORT CRITERIA ANALYSIS	20
6	RESULTS – SCENARIO 7: PHASES 1-6 IN EXISTING SURROUNDS	23
6.1	INTRODUCTION	23
	SAFETY CRITERIA ANALYSIS	23
	COMFORT CRITERIA ANALYSIS	25
7	RESULTS – SCENARIO 13: PHASES 1-6 IN CUMULATIVE SURROUNDS	28



7.1	INTRODUCTION	28
	SAFETY CRITERIA ANALYSIS	28
	COMFORT CRITERIA ANALYSIS	30
8	CONCLUSIONS	33
	REFERENCES	34



EXECUTIVE SUMMARY

A wind microclimate study has been performed for the proposed Crown Street Phase 3 & Great Jackson Street Plot D developments in Manchester. A total of four configurations (baseline included) were studied.

Specialist wind engineering advice was provided right from the start of the design process: this allowed the wider design team to consider and take on board 'wind microclimate' input whilst the design was evolving. This process also allowed wind mitigation measures to become an integral part of the architectural and landscaping design of the proposed development: for this reason, the wind microclimate conditions within and in the vicinity of the proposed development have been presented with its fully integrated wind mitigation strategy and proposed landscaping in place.

The analyses used computational fluid dynamics (CFD) simulations to determine the aerodynamic effect that the proposed buildings have on the wind patterns around the site. This was combined with long-term wind speed data to provide a statistical representation of the wind conditions, which were then compared against pedestrian comfort and distress criteria.

Results show that, at ground level, wind conditions rate as safe for all users across all scenarios, provided that the proposed landscaping and mitigation scheme is implemented. At the elevated levels, some terraces show some small areas which rate as unsafe for pedestrians across all scenarios. However, all areas showing unsafe conditions are not accessible to residents. The amenity areas are rated as safe in terms of the pedestrian safety criteria, without the need for further mitigation measures.

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2 INTRODUCTION

- 2.1.1. WSP have been appointed by Renaker Build Ltd to perform a wind microclimate study around the proposed Crown Street Phase 3 & Great Jackson Street Plot D developments in Manchester. The developments consist of five towers (E2, E1, C8, C7 and Plot D) and an office development on the Plot D site.
- 2.1.2. This study aims to compare the pedestrian-level wind environment around the proposed development against comfort and safety criteria and to the conditions of the existing site. The study pays particular attention to pedestrian access routes, seating areas, as well as building drop-offs and entrances. The report serves as a technical Appendix to Chapter 14 of the ES on Wind Microclimate.
- 2.1.3. Specialist wind engineering advice was provided right from the start of the design process: this allowed the wider design team to consider and take on board 'wind microclimate' input whilst the design was evolving. This process also allowed wind mitigation measures to become an integral part of the architectural and landscaping design of the Proposed Development: for this reason, the wind microclimate conditions within and in the vicinity of the Proposed Development have been presented with its fully integrated wind mitigation strategy in place.

2.2 URBAN WIND EFFECTS

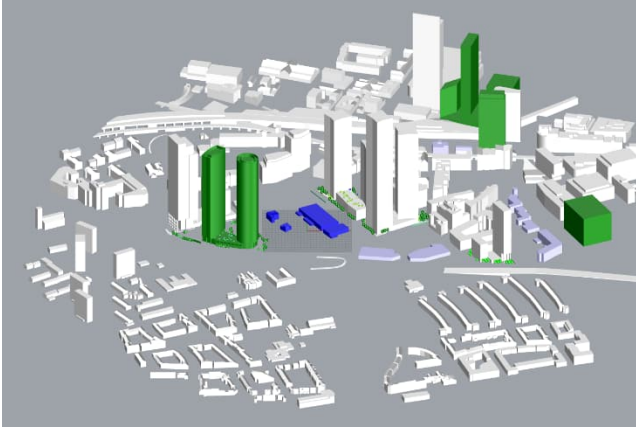
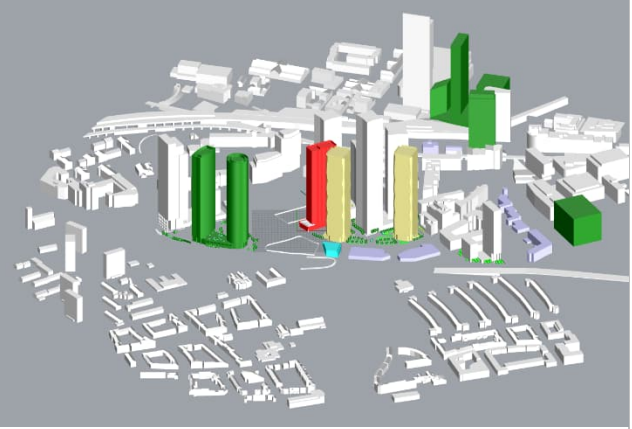
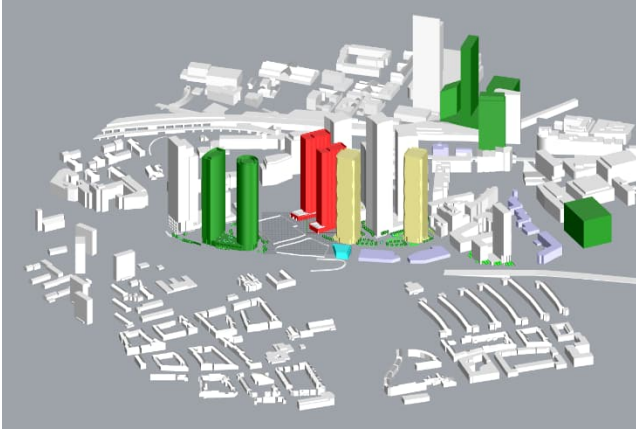
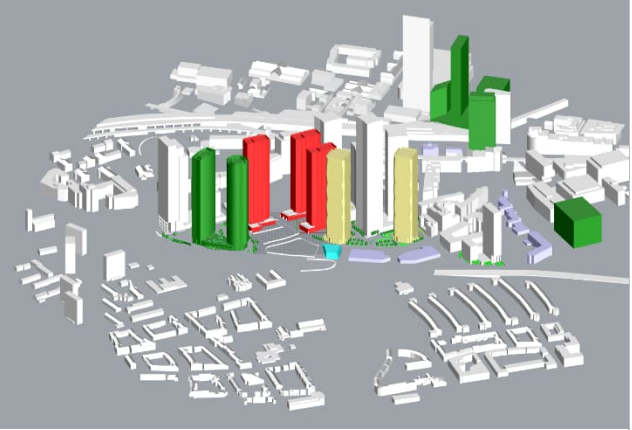
- 2.2.1. The wind microclimate around an urban environment is affected by terrain, buildings, and other obstructions. The introduction of a new building development can affect the local wind flow patterns, which can produce an uncomfortable and/or unsafe wind environment at pedestrian level.
- 2.2.2. This is particularly important for buildings which are taller than their surroundings. Fast-moving high-level winds can downdraft to street level along windward faces of buildings. As air then moves into the low-pressure wake of the building, it can accelerate around corners and/or through restrictions, causing localised regions of relatively high wind speed.
- 2.2.3. The assessment of environmental wind flows in the built environment lies outside the scope of BS EN 1991-1-4:2005¹, the current UK code of practice for the assessment of wind effects on buildings, which focuses on wind loading. Also, there are no handbooks or engineering methods from which reliable assessments of the complex environmental wind flows that shape the pedestrian level wind conditions can be derived. A detailed Computational Fluid Dynamics (CFD) study was therefore used to provide a reliable quantification of the pedestrian level wind environment at locations such as pedestrian access routes, building entrances and high-level terraces. The study combines numerically obtained pedestrian level wind speeds at key areas within and around the site of the proposed development with long-term wind frequency statistics transposed from the nearest suitable weather station to determine the probability of local wind speeds exceeding comfort and safety thresholds for a range of common pedestrian activities. The assessment is based on the LDDC version of the Lawson criteria which represents best industry practice in the UK.²

3 METHODOLOGY

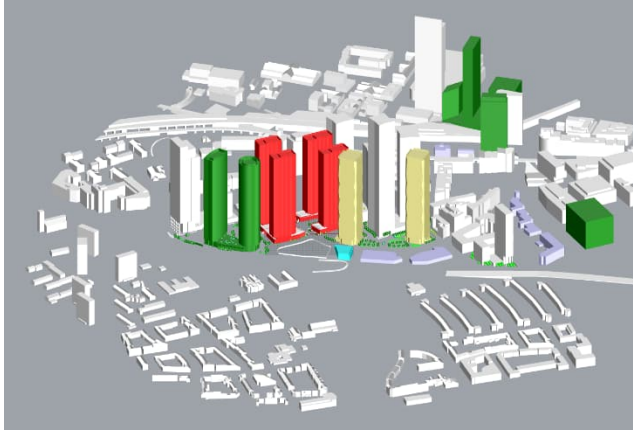
3.1 ASSESSMENT METHODOLOGY

- 3.1.1. The pedestrian-level wind environment in an urban setting will depend on the general wind conditions, as well as on the effects of the urban environment itself. Therefore, the assessment consists of three main parts: calculation of the urban environment's **aerodynamic effect on the wind**; which is then **combined with historical wind data**; and, finally, **compared against criteria** to quantify the discomfort and/or level of distress caused by the wind.
- 3.1.2. From a wind microclimate standpoint, the following eight (8) EIA scenarios were originally identified in the Scoping Report and are depicted in Table 2-1.
- Scenario 1: Baseline (existing Site in existing surrounds)
 - Scenario 3: 'Phase 1' + 'Phase 2' in existing surrounds (including projects under construction)
 - Scenario 4: 'Phase 1' + 'Phase 2' + 'Phase 3' in existing surrounds (including projects under construction)
 - Scenario 5: 'Phase 1' + 'Phase 2' + 'Phase 3' + 'Phase 4' in existing surrounds (including projects under construction)
 - Scenario 6: 'Phase 1' + 'Phase 2' + 'Phase 3' + 'Phase 4' + 'Phase 5' in existing surrounds (including projects under construction)
 - Scenario 12: 'Phase 1' + 'Phase 2' + 'Phase 3' + 'Phase 4' + 'Phase 5' in existing surrounds (including projects under construction) with the inclusion of consented schemes
 - Scenario 7: 'Phase 1' + 'Phase 2' + 'Phase 3' + 'Phase 4' + 'Phase 5' + 'Phase 6' in existing surrounds (including projects under construction)
 - Scenario 13: 'Phase 1' + 'Phase 2' + 'Phase 3' + 'Phase 4' + 'Phase 5' + 'Phase 6' in existing surrounds (including projects under construction) with the inclusion of consented schemes
- 3.1.3. The CFD simulations that were carried out during the early stages of the project allowed the most critical scenarios for the wind microclimate assessment to be identified. These four (4) scenarios, on which this technical report focuses, are:
- Scenario 1: Baseline (existing Site in existing surrounds)
 - Scenario 5: 'Phase 1' + 'Phase 2' + 'Phase 3' + 'Phase 4' in existing surrounds (including projects under construction)
 - Scenario 7: 'Phase 1' + 'Phase 2' + 'Phase 3' + 'Phase 4' + 'Phase 5' + 'Phase 6' in existing surrounds (including projects under construction)
 - Scenario 13: 'Phase 1' + 'Phase 2' + 'Phase 3' + 'Phase 4' + 'Phase 5' + 'Phase 6' in existing surrounds (including projects under construction) with the inclusion of consented schemes

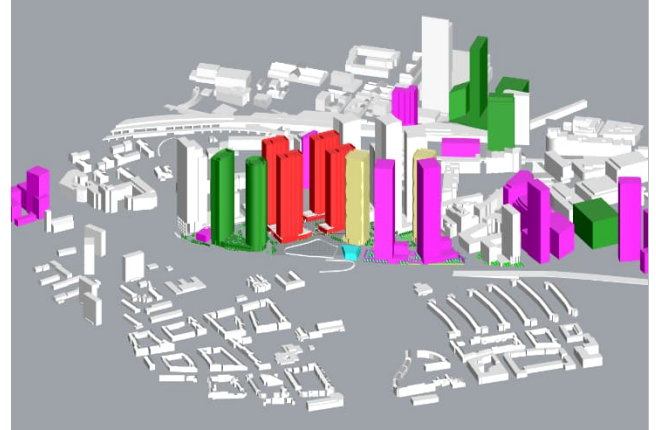
Table 3-1 – Original EIA scenarios.

Scenario 1: Baseline 	Scenario 3: Phase 1 + Phase 2 in existing surrounds 
Scenario 4: Phase 1 + Phase 2 + Phase 3 in existing surrounds 	Scenario 5: Phase 1+ Phase 2 + Phase 3 + Phase 4 in existing surrounds 

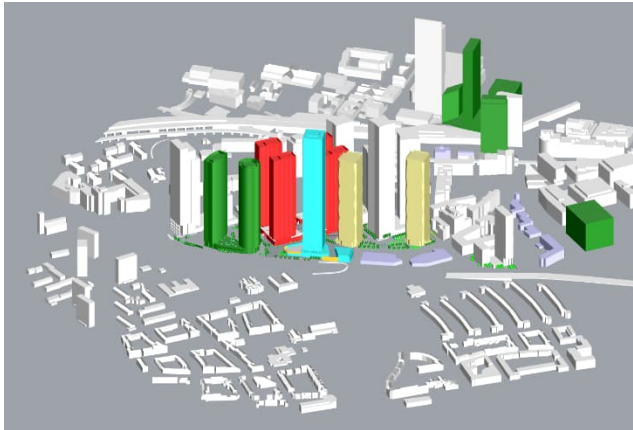
Scenario 6: Phase 1 + Phase 2 + Phase 3 + Phase 4 + Phase 5 in existing surrounds



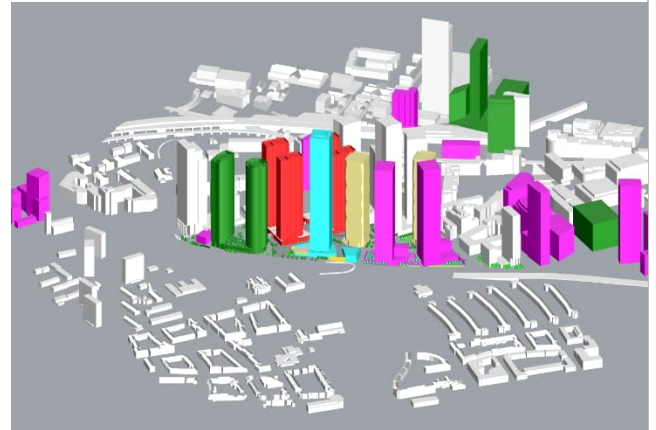
Scenario 12: Phase 1 + Phase 2 + Phase 3 + Phase 4 + Phase 5 in cumulative surrounds



Scenario 7: Phase 1 + Phase 2 + Phase 3 + Phase 4 + Phase 5 + Phase 6 in existing surrounds



Scenario 13: Phase 1 + Phase 2 + Phase 3 + Phase 4 + Phase 5 + Phase 6 in cumulative surrounds



3.2 SITE AND STUDY AREA

- 3.2.1. The project site is bisected by Great Jackson Street, and is bound by Silvercroft Street, Owen Street, and Melbourne Street. The Great Jackson Street area consists of high-rise buildings. Further away to the east of the site consists of medium- and high-rise buildings while other directions consist primarily of low- and medium-rise buildings.

A three-dimensional CAD model of the site and surrounding buildings has been constructed using the following drawing sets:

Table 3-2 - Drawing sets used to construct the model.

Date issued (dd/mm/yy)	Title	Filename	Usage
14/12/2022	Crown Street Phase 3 Massing Model	Crown Street Phase 3 Model.dwg	Construction of Phase 3 buildings

16/02/2023	Plot D Massing Model	10419-A-SHP-G200-3-Massing.dwg	Construction of Plot D and office buildings
10/03/2023	Ground level landscaping plan	PR-TPM-G710-PL-GRD-4156-101.pdf	Placement of proposed landscaping and mitigation

- 3.2.2. The model includes the site and all buildings within an approx. 500m radius of the site as shown in Figure 2-1. The surrounds included in the model were agreed with Deloitte and include buildings that are under construction, including Great Jackson Street Plot F, in the 'existing surrounds'. The flow around these buildings and terrain is explicitly modelled within the 500m radius, whilst outside this region obstructions are accounted for using mathematical models which assign a 'roughness length' depending on the terrain type.
- 3.2.3. The detail of the CAD model increases from approximately 1m for the surrounding buildings to 0.2m around the site. The landscaping and mitigation plan, which was informed by a series of wind mitigation workshops between WSP, Renaker, SimpsonHaugh and TPM Landscaping, was included in the computational model and is shown in Figure 3-2 and Figure 3-3. It was assumed that the landscaping scheme associated with Crown Street Phase 3 and Plot D will only be delivered upon completion of the respective developments. There are no additional mitigation measures, outside of the proposed trees, required around Plot D. Therefore, Figure 3-2 and Figure 3-3 only show the mitigation measures around Crown Street Phase 3. Figure 3-4 highlights (in green) the terraces which are accessible to residents.

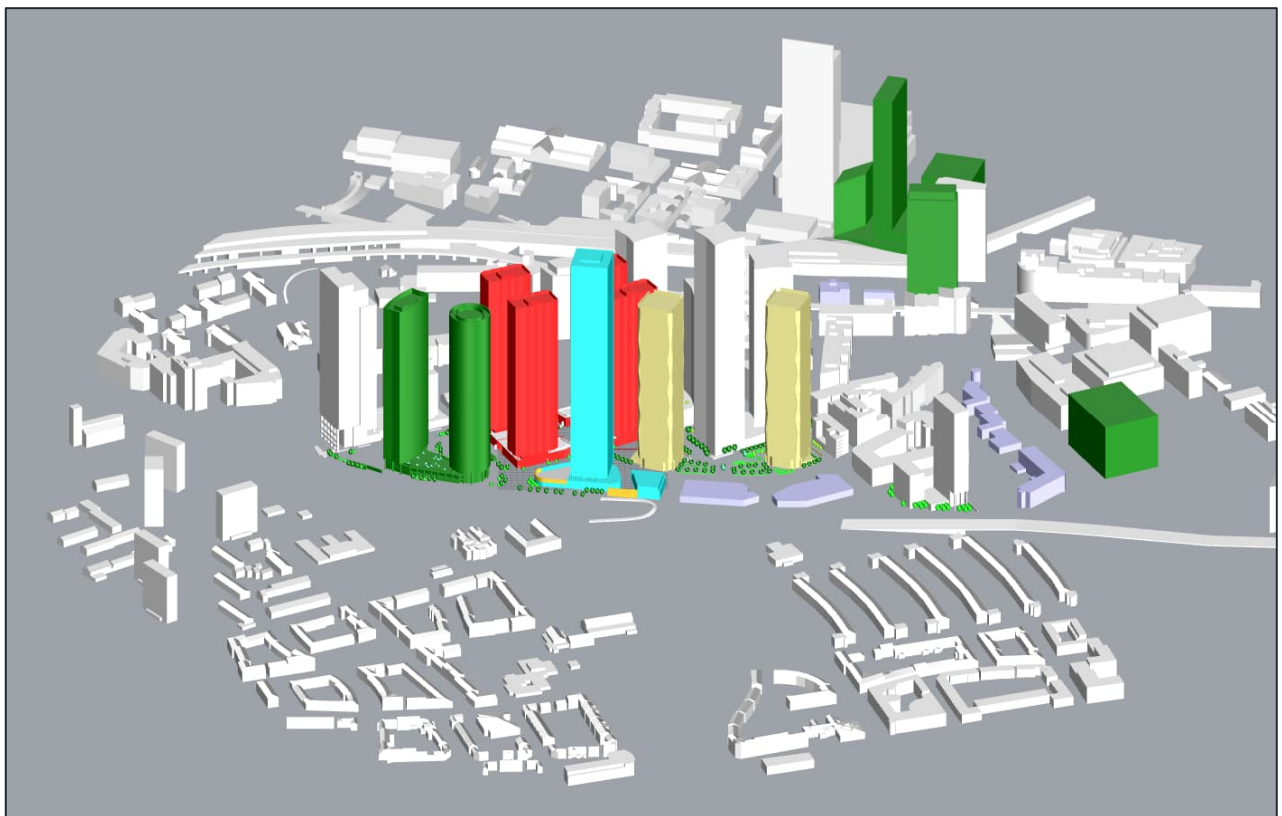


Figure 3-1 - 3D CAD model showing the explicitly-modelled surrounding buildings.

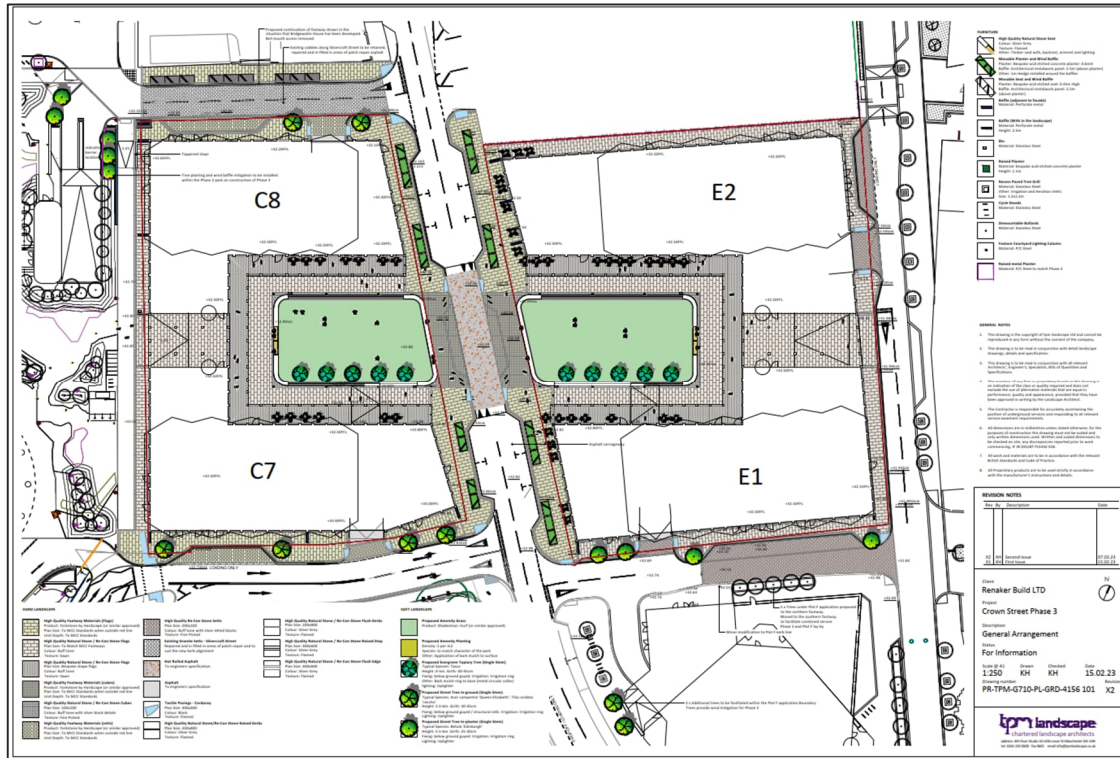


Figure 3-2 - Landscaping plan modelled in the CFD simulations.

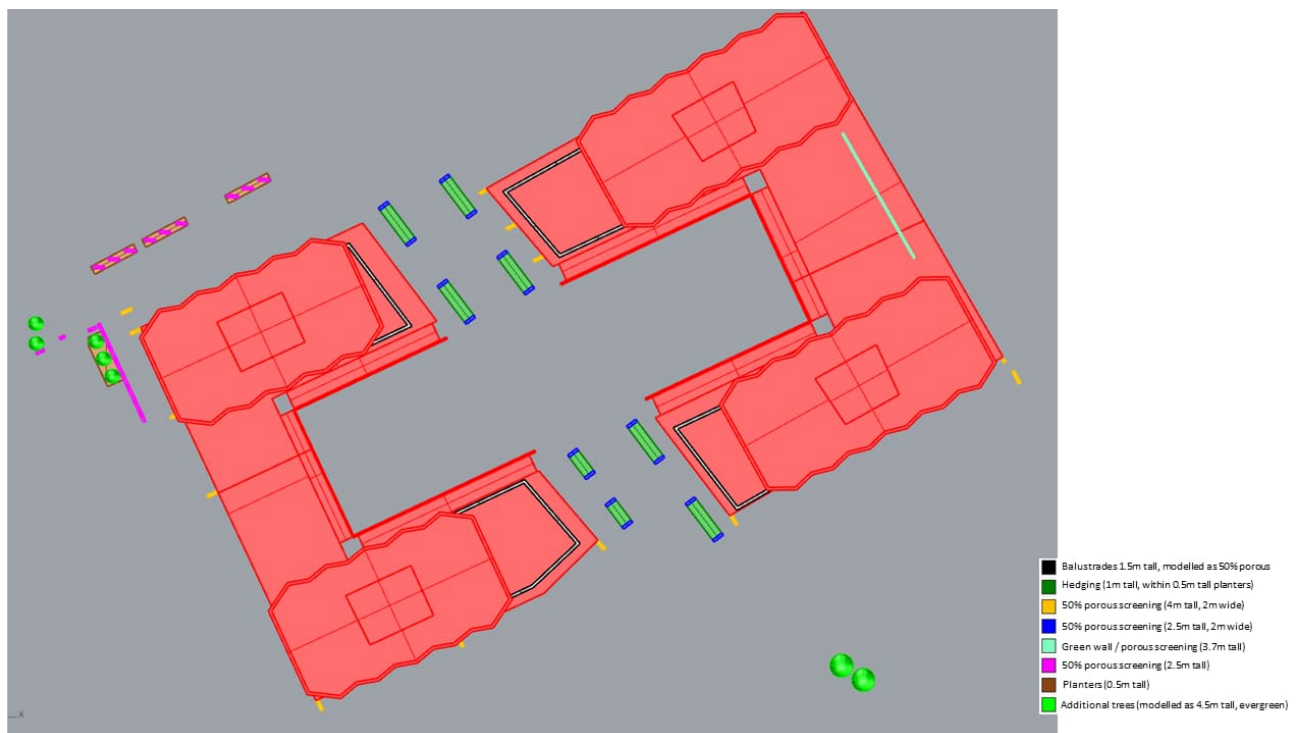


Figure 3-3 - Mitigation modelled in the CFD simulations (including podium levels, excluding proposed trees at ground level).



Figure 3-4 - Mark-up showing the terraces which are accessible to residents.

3.3 ASSESSMENT CRITERIA

- 3.3.1. The criteria used in this study were developed by Lawson², and have been reproduced in Table 3-3. Like most criteria used in assessments of pedestrian wind conditions, they relate a threshold wind speed and a threshold frequency to the suitability of an activity.
- 3.3.2. The frequency threshold for each criterion is 5% - or about three weeks per year. It is also useful to assess frequency on a seasonal basis. For example, an outdoor seating area may require wind conditions suitable for sitting or standing in summer, but not in winter when the seating is unlikely to be used. For season-specific results, the criteria are based on 5% of hours across the months in that season.

Table 3-3 - Comfort criteria used in this study.

Criteria	Suitability	Threshold mean wind for 5% of hours [ms^{-1}]
Pedestrian sitting	Outdoor seating and areas one can occupy comfortably for long periods	4
Pedestrian standing	Main building entrances, pickup/drop-off points	6
Pedestrian walking	Appropriate for strolling	8
Business walking	Can be tolerated if one's objective is to walk, run or cycle without lingering	10
Unsuitable	Nuisance for most pedestrian activities	>10

- 3.3.3. Additionally, criteria for safety have been defined based on 2.2 hours' exceedance per year. These are areas where someone could find walking difficult or even lose their footing. These criteria are reproduced in Table 3-4.

Table 3-4 - Safety criteria used in this study.

Criteria	Description	Threshold mean wind speed for 2.2hrs/year [ms^{-1}]
S15	Unsuitable for frail persons, cyclists etc	15
S20	Unsuitable for all pedestrians	20

3.4 WIND CLIMATE ANALYSIS

- 3.4.1. Wind data was collected from the nearby meteorological station at Manchester airport, which is approximately 13km to the south of the site. The data consisted of mean hourly wind speeds and directions over the last 20 years. The data was discretised into 36 bins, representing 10° sectors. The nomenclature adopted in this report assigns 0° to winds coming from north and increases clockwise such that 90° refers to winds blowing from east, 180° from south and 270° from west.
- 3.4.2. Figure 2-2 shows a summary of the wind data at 10m height in open country for the whole year in the form of a wind rose. Wind direction is shown on the angular axes, with percentage of hours on the radial axes. From this plot, it can be deduced that the prevailing strong winds from the south, which blow over relatively flat terrain, will be the dominant winds for the site.

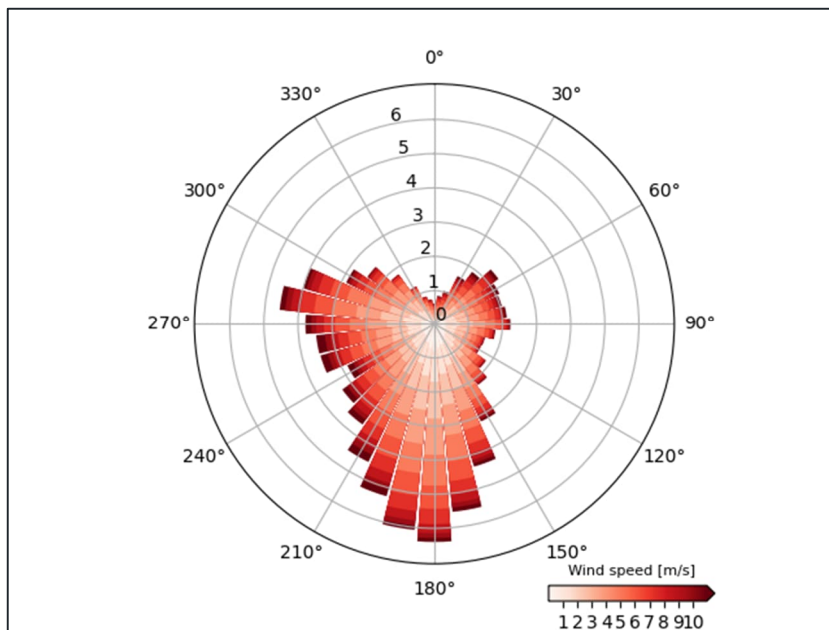


Figure 3-5 - Annual wind rose for Manchester (10m height in open country terrain), showing the frequency and magnitude of mean-hourly wind speeds.

3.4.3. Figure 2-3 shows similar wind roses split into three-month seasons. It shows that during spring, the north-easterly sector provides additional strong and frequent winds while during summer, westerly winds are frequent.

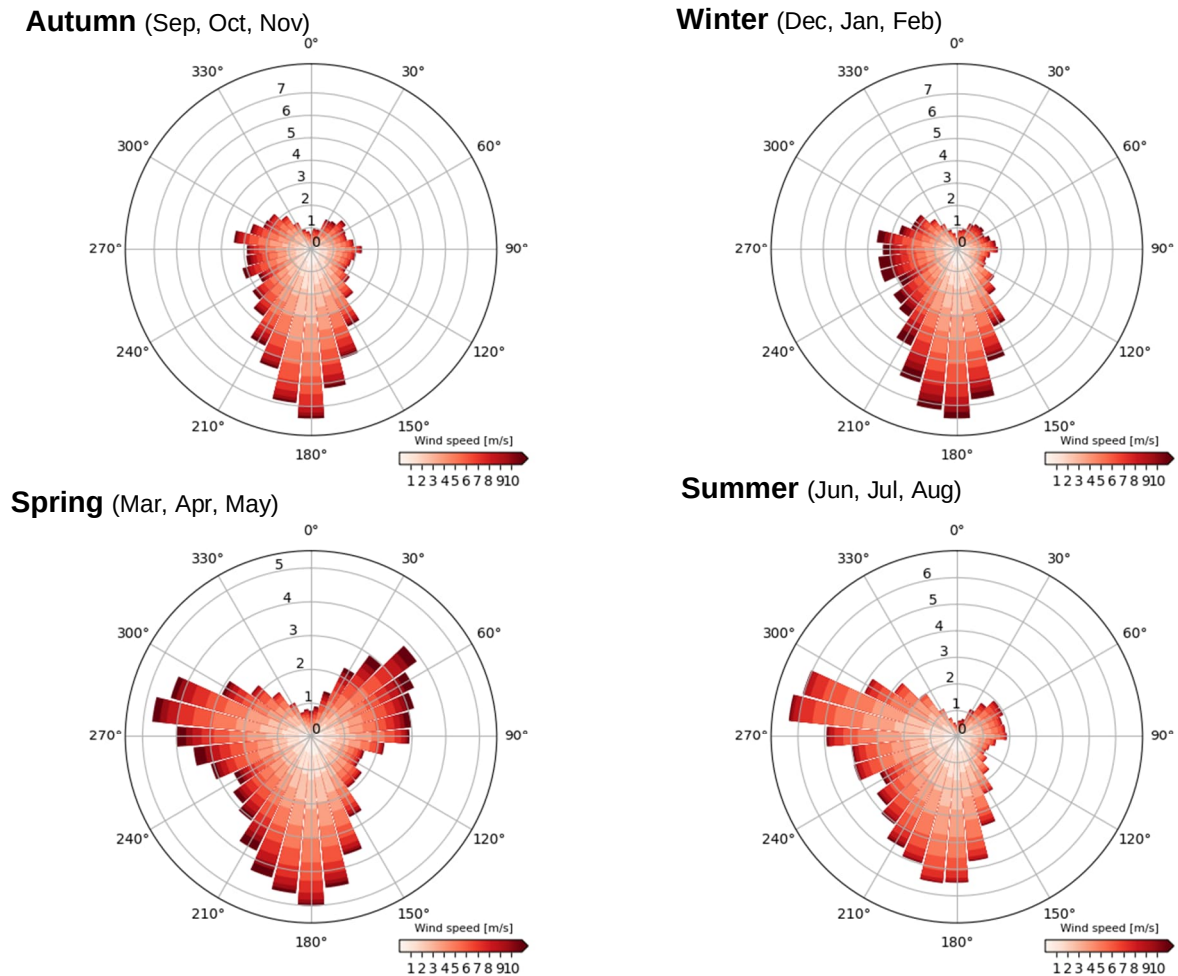


Figure 3-6 - Wind roses for each season.

3.4.4. Linear regression methods were used to fit the data to a Weibull probability distribution, i.e.:

$$P(U) = pe^{-\left(\frac{U}{c}\right)^k}$$

where the p , c and k coefficients are the probability of the wind direction occurring, the dispersion parameter and the shape parameter respectively.

3.4.5. To account for the differences in terrain surrounding the weather station at Manchester airport and the project site, adjustments were made using the wind model proposed by ESDU, an engineering advisory organisation based in the UK³. This method assigns transposition factors to the c term in the Weibull distribution of the data at the meteorological site, based on upwind aerodynamic roughness of the terrain. The weather centre data was initially transposed to open country terrain and subsequently transposed to a reference height of 160m at the site of the proposed development, accounting for upwind terrain and topographical features. This terrain analysis was based on the CORINE Land Cover (CLC) dataset⁴ which is shown in Figure 3-7. This resulted in the transposition factors shown in Table 2.5.

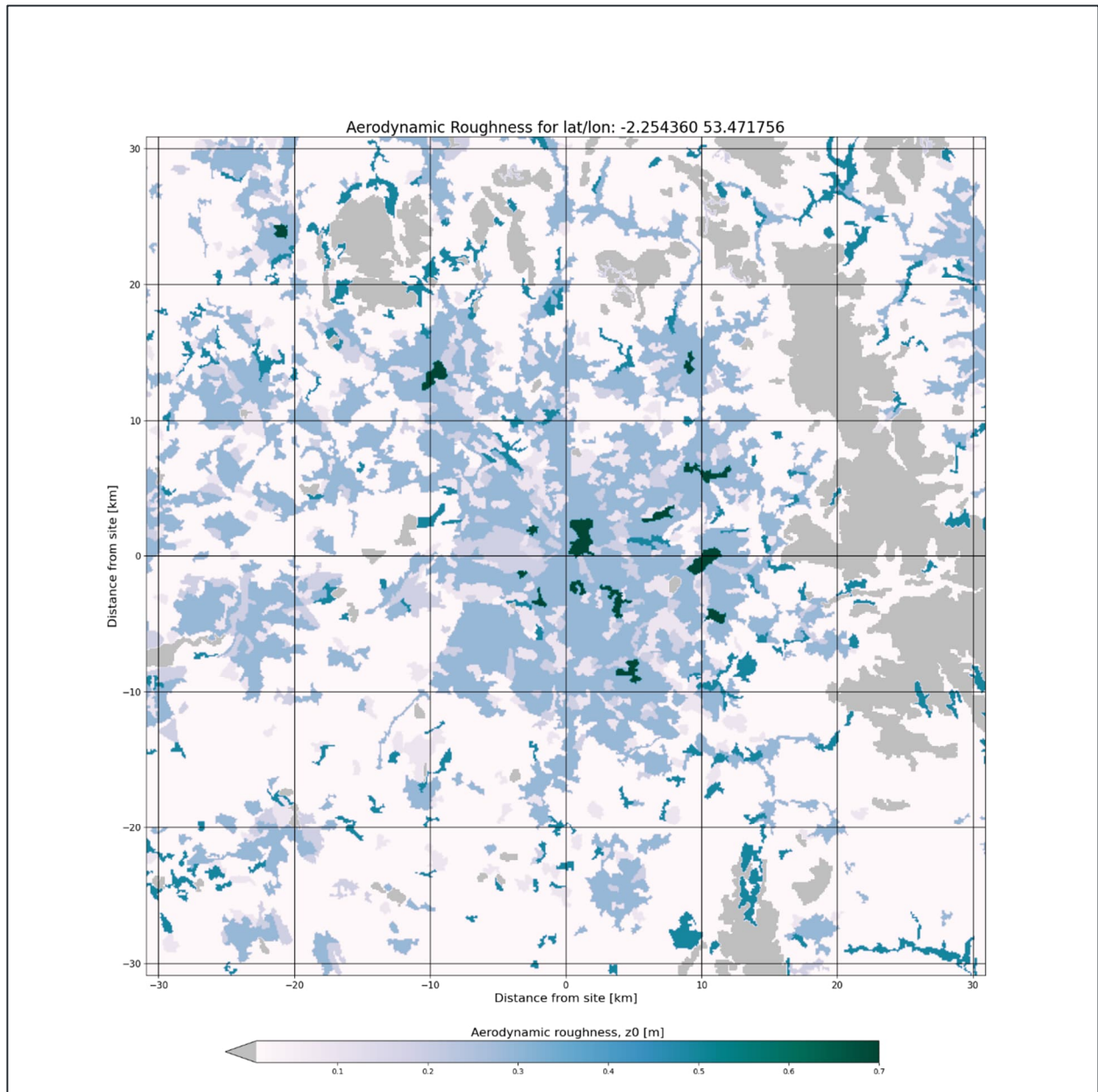


Figure 3-7 - Categorisation of the terrain surrounding the site.

Table 3-5 - Transposition factors from 10m open country to 160m reference height at the project site.

0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
1.380	1.352	1.352	1.363	1.359	1.356	1.373	1.361	1.394	1.399	1.369	1.377

- 3.4.6. The aerodynamic effect from all wind directions must be accounted for and, as the weather data has an azimuthal resolution of 10°, 36 simulated directions will provide the best possible resolution. However, this can be computationally expensive and infrequent wind directions will not contribute significantly to the final outcome. Therefore, some adjacent infrequent directions have been grouped together such that each simulated direction has a similar frequency of occurrence. The grouping

methodology is such that the frequency of grouped wind directions should generally not exceed that of the most frequent (prevailing) wind directions.

3.4.7. In this case, 22 wind directions were explicitly simulated (see Table 3-6).

Table 3-6 - Wind directions simulated.

Simulated direction [°]	Bins included [°]	Combined frequency [%]
0	350,0,10	2.3
30	20,30,40	4.3
55	50,60	4.2
75	70,80	4.1
95	90,100	4.1
120	110,120,130	5.2
145	140,150	5.6
160	160	4.7
170	170	6.2
180	180	6.0
190	190	6.2
200	200	5.2
210	210	4.5
220	220	3.5
235	230,240	6.2
250	250	3.7
260	260	3.5
270	270	3.8
280	280	4.4
290	290	3.6
305	300,310	5.0
330	320,330,340	3.9

3.5 SIMULATION DETAILS AND ASSUMPTIONS

- 3.5.1. A CFD numerical simulation has been performed for each of the directions shown in Table 3-6. Relative wind speeds were sampled at a plane 1.5m from the ground. These values were then combined with the weather data shown in 3.4 and compared against criteria discussed in section 2.3.
- 3.5.2. Each simulation uses numerical methods to solve the governing equations of fluid mechanics around the site of interest. The site of interest in this case is the geometry discussed in section 3.2, surrounded by a volume which extends 3km in the horizontal directions and 700m in the vertical direction. The CFD method employed requires this volume to be split into smaller volumes or 'cells'. These cells are nominally hexahedral and reduce in size from approximately 25m in the far field to 0.1m near the building in order to sufficiently resolve the fluid flow. Thin prismatic layers of cells were added to the ground and buildings to resolve the large gradients in the flow near the solid obstructions. In this case, the total number of cells ranged from between 45-71 million.
- 3.5.3. As time-averaged results are of interest, the equations in the model have been time-averaged using Reynolds averaging to produce the Reynolds-Averaged Navier-Stokes (RANS) equations. The realizable version of the $k - \epsilon$ model (Shih et. al., 1995)⁵ has been used to describe the statistical effect of turbulence by solving transport equations for the turbulent kinetic energy (k) and turbulent dissipation rate (ϵ).
- 3.5.4. The velocity magnitude output from the CFD is a mean velocity defined as:

$$\bar{U} = (\bar{u}^2 + \bar{v}^2 + \bar{w}^2)^{\frac{1}{2}}$$

where the overbar represents a time-averaged quantity and u, v, w are the velocity components in the x, y, z directions, respectively. However, a pedestrian's perception to the wind does not depend on direction; a wind from any direction is equally as uncomfortable. Therefore, the velocity of interest is actually:

$$\bar{U} = \overline{(u^2 + v^2 + w^2)^{\frac{1}{2}}}$$

these scalar values are different because $u = \bar{u} + u'$ and $\bar{u'^2} = 0$ but $\overline{u'^2} \neq 0$, where u' is the fluctuating part of the instantaneous velocity, u . Using the fact that $k = \frac{1}{2}(\overline{u'^2} + \overline{v'^2} + \overline{w'^2})$, the velocity used of interest from the RANS equations is:

$$\bar{U}_{scalar} = (\bar{U}^2 + 2k)^{\frac{1}{2}}$$

- 3.5.5. Additionally, a 'gust' wind speed has been estimated as:

$$U_{gust} = \bar{U}_{scalar} + g \sqrt{\frac{2}{3}k}$$

Where g is a peak gust factor that was set to 3.0. This gust wind speed was divided by 1.85 to give a gust equivalent mean (GEM) value. The maximum of the GEM and the scalar mean wind speed at each sampled cell was the quantity used in the analysis.

- 3.5.6. A non-slip condition was applied to the ground and buildings. Buildings and ground within the 500m radius had a rough wall function with an assigned roughness of $z_0 = 0.02m$; the far-field (>500m

radius) ground and heavily forested areas had a rough wall function with roughness heights depending on their terrain classification (ESDU). The outlet had a zero-gradient boundary condition, side and top walls had free slip conditions. A logarithmic velocity profile was applied to the inlet whereby the velocity varies with height through:

$$U(z) = \frac{u_\tau}{\kappa} \ln \left(\frac{z + z_0}{z_0} \right)$$

where:

$$u_\tau = \frac{\kappa U_{ref}}{\ln \left(\frac{z_{ref} + z_0}{z_0} \right)}$$

and $\kappa = 0.41$ is the Von Karman constant, z is the height above the ground, $z_{ref} = 160m$, z_0 is the upstream roughness which varies by direction and $U_{ref} = 10m/s$.

- 3.5.7. The SIMPLE algorithm as implemented in OpenFOAM (Engys version HELYX Core-3.0.0) was used to iteratively solve the equations. The solution was considered to be converged when the residuals (i.e. the relative change from one iteration to the next) were 10^{-5} for momentum and 10^{-4} for pressure.
- 3.5.8. Trees and other landscaping furniture were treated as porous regions in the CFD model. For trees, the momentum loss in the transport equations is modelled through the inertial term in the Darcy-Forchheimer law for porous media which has the form $\Delta P = C U^2$, where ΔP is the pressure drop across the volume of the tree, U is the air velocity and C is the inertial term, which can be related to a drag coefficient for various tree types. Drag coefficients, obtained experimentally, were chosen from *Bitog et al (2011)*⁶.

4 RESULTS – SCENARIO 1: BASELINE

4.1 INTRODUCTION

This section analyses the results of the existing site within existing surrounds.

SAFETY CRITERIA ANALYSIS

- 4.1.1. Figure 4-1 shows that for the existing site within the context of existing surrounds ground level wind conditions are rated as safe for all users.



Figure 4-1 - Contours of safety criteria for Scenario 1.

COMFORT CRITERIA ANALYSIS

- 4.1.2. Figure 4-2 and Figure 4-3 show contours of comfort criteria on a plane 1.5m above the ground for the worst-case season (winter) and summer seasons respectively for Scenario 1.

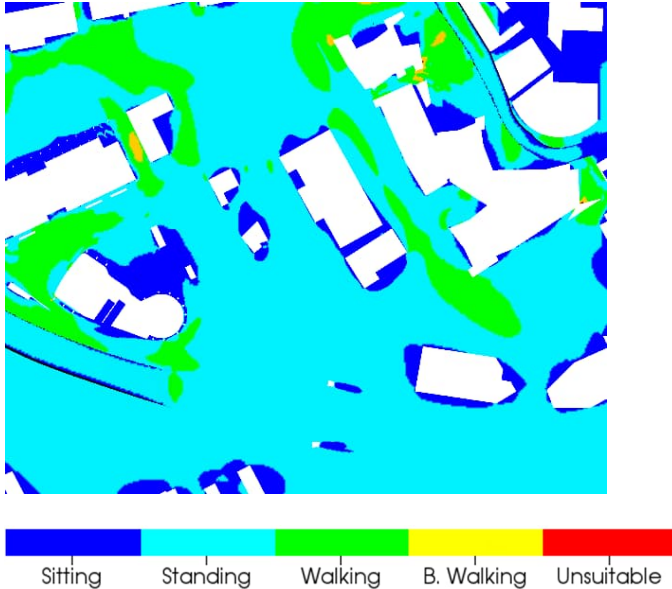


Figure 4-2 - Contours of comfort criteria for winter for Scenario 1.

- 4.1.3. Figure 4-2 shows that wind conditions within and around the existing site rate as suitable for walking, standing and sitting during winter.

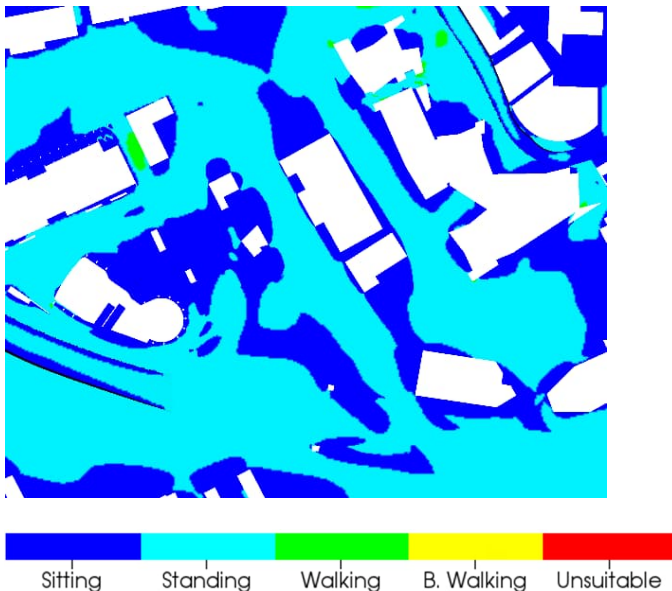


Figure 4-3 - Contours of comfort criteria for summer for Scenario 1.

- 4.1.4. Figure 4-3 shows that wind conditions within and around the existing site rate as suitable for standing and sitting during summer.

5 RESULTS – SCENARIO 5: PHASES 1-4 IN EXISTING SURROUNDS

5.1 INTRODUCTION

This section analyses the results of Phases 1-4 in existing surrounds and its associated landscaping and mitigation.

SAFETY CRITERIA ANALYSIS

- 5.1.1. Figure 5-1 shows that the introduction of the proposed development, landscaping and mitigation for Scenario 5 results in ground level wind conditions that are rated as safe for all users.

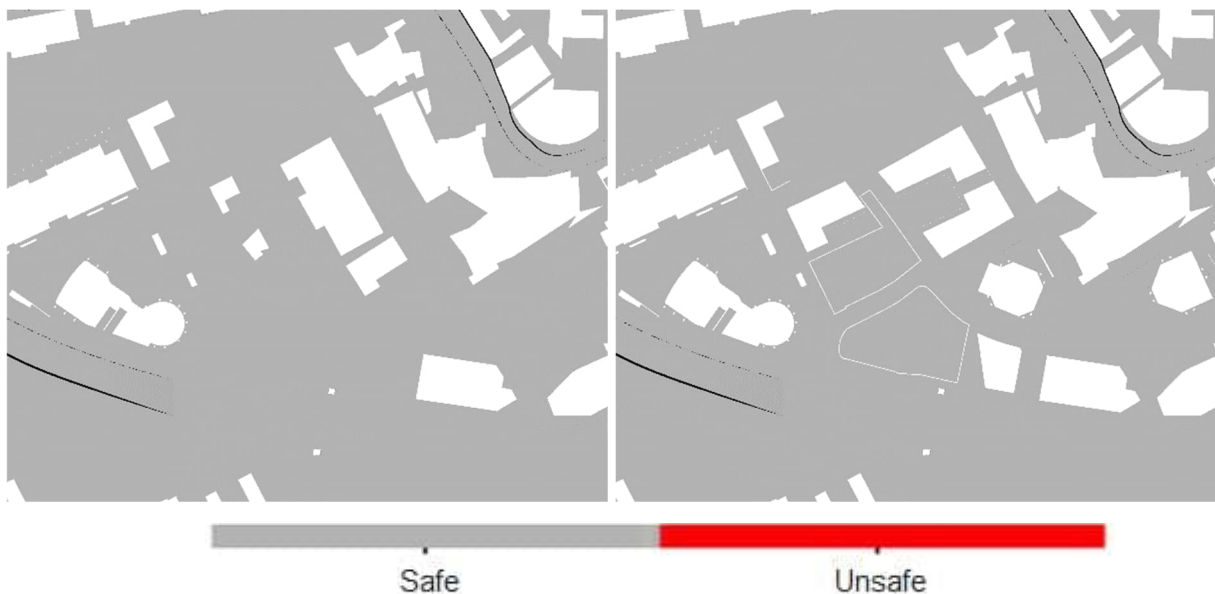


Figure 5-1 - Contours of safety criteria (left: Scenario 1, right: Scenario 5).

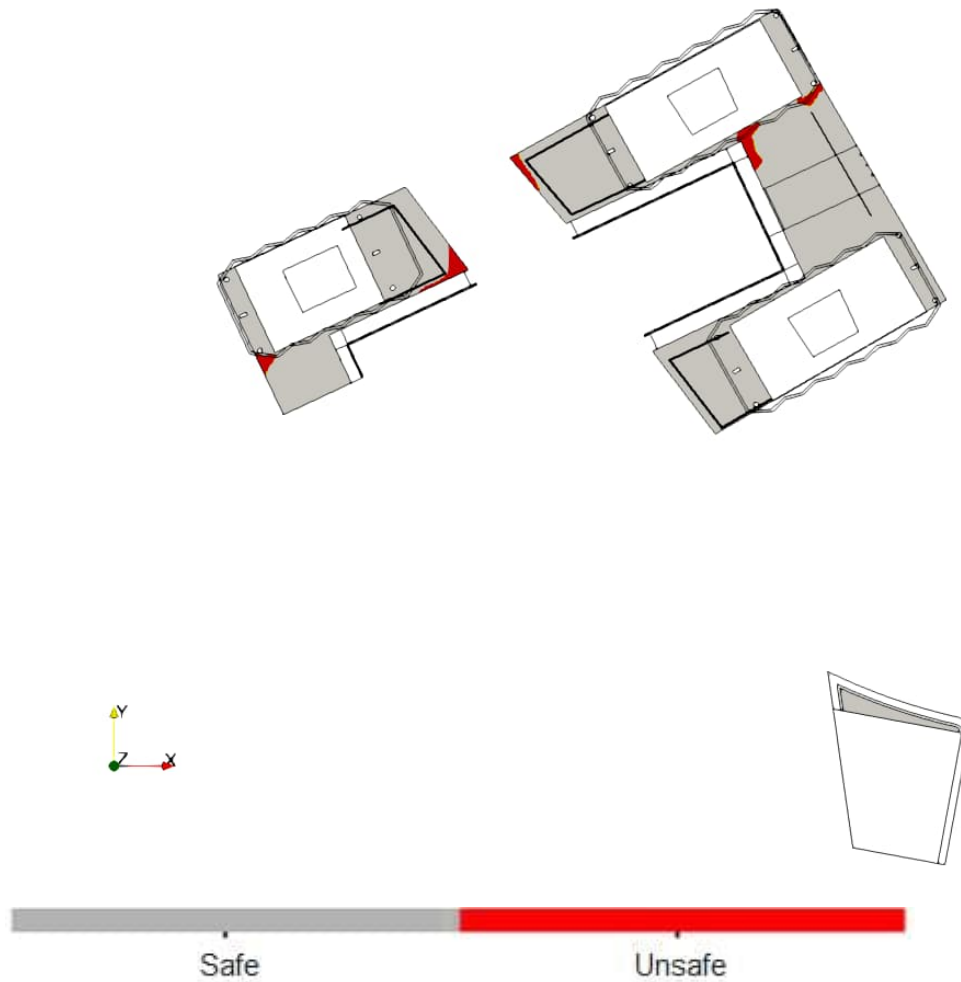


Figure 5-2 - Contours of safety criteria on elevated levels for Scenario 5.

- 5.1.2. Figure 5-2 indicates that elevated levels rate as safe for all users in accessible areas. It is understood that all areas showing unsafe conditions are not accessible. It should be noted that no proposed landscaping has been modelled on the terraces and therefore results would be expected to improve at the next stage of the design. Balustrades were modelled as 1.5m tall with 50% porosity.

COMFORT CRITERIA ANALYSIS

- 5.1.3. Figure 5-3 and Figure 5-4 show contours of comfort criteria on a plane 1.5m above the ground for the worst-case season (winter) and summer seasons respectively, directly compared against the baseline conditions (Scenario 1).

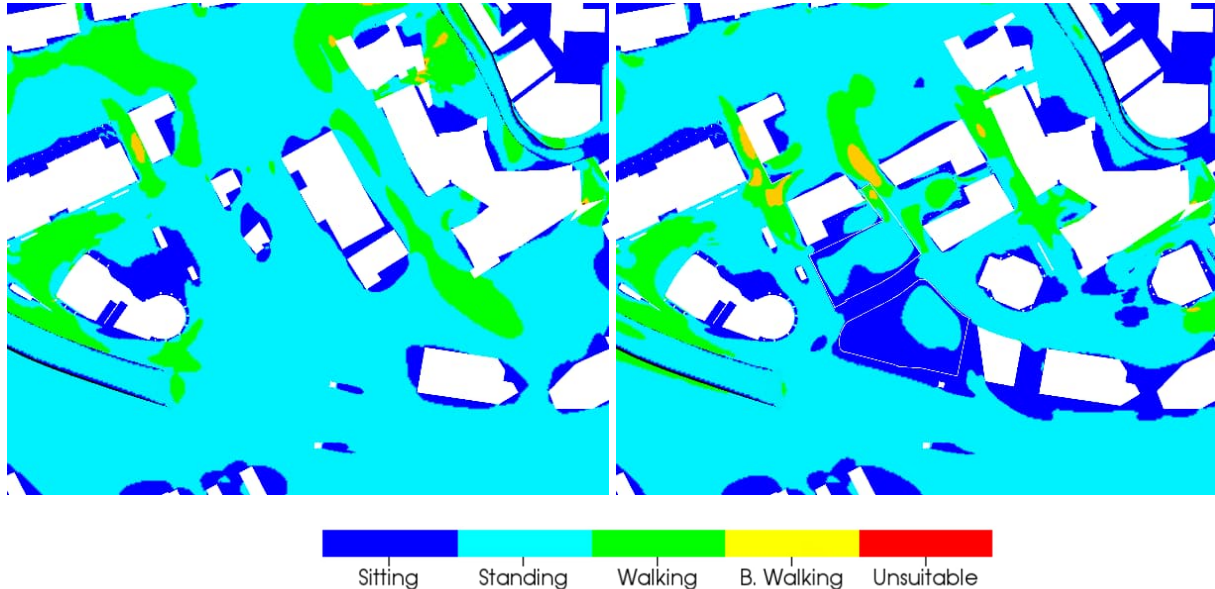


Figure 5-3 - Contours of comfort criteria for winter (left: Scenario 1, right: Scenario 5).

- 5.1.4. Figure 5-3 shows that, with the introduction of the proposed development (Scenario 5), wind conditions within the site rate as suitable for business walking, leisure walking, standing and sitting during winter.

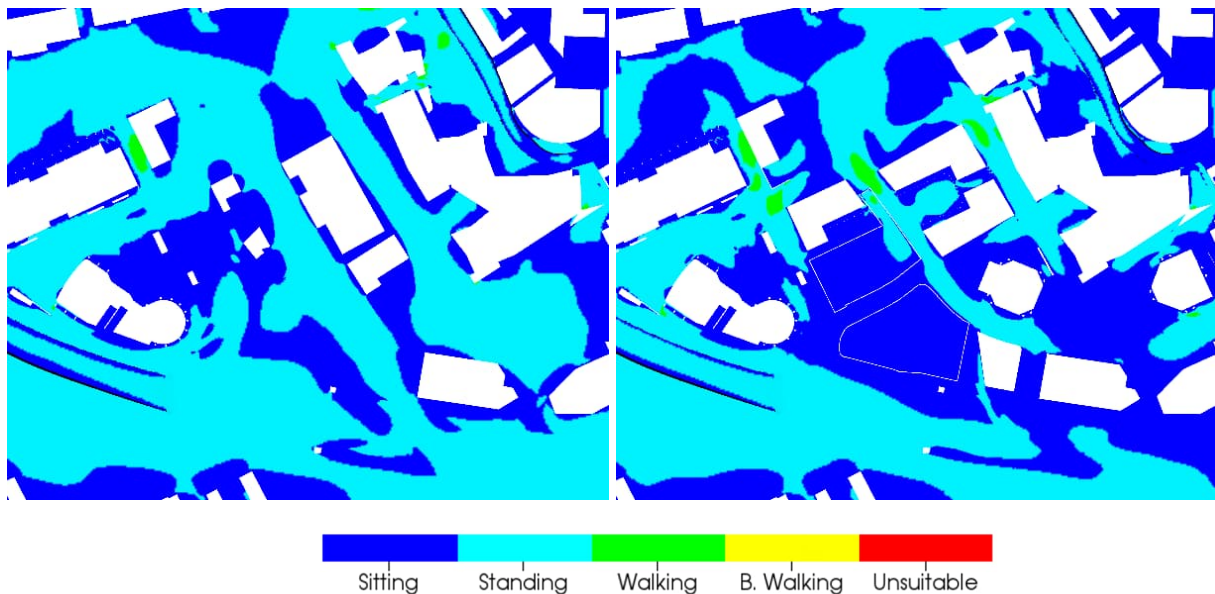


Figure 5-4 - Contours of comfort criteria for summer (left: Scenario 1, right: Scenario 5).

- 5.1.5. Figure 5-4 shows that, with the introduction of the proposed development (Scenario 5), wind conditions within the site rate as suitable for walking, standing and sitting during summer.

- 5.1.6. Figure 5-5 and Figure 5-6 show contours of comfort criteria on a plane 1.5m above the elevated levels for the summer and winter seasons for Scenario 5.

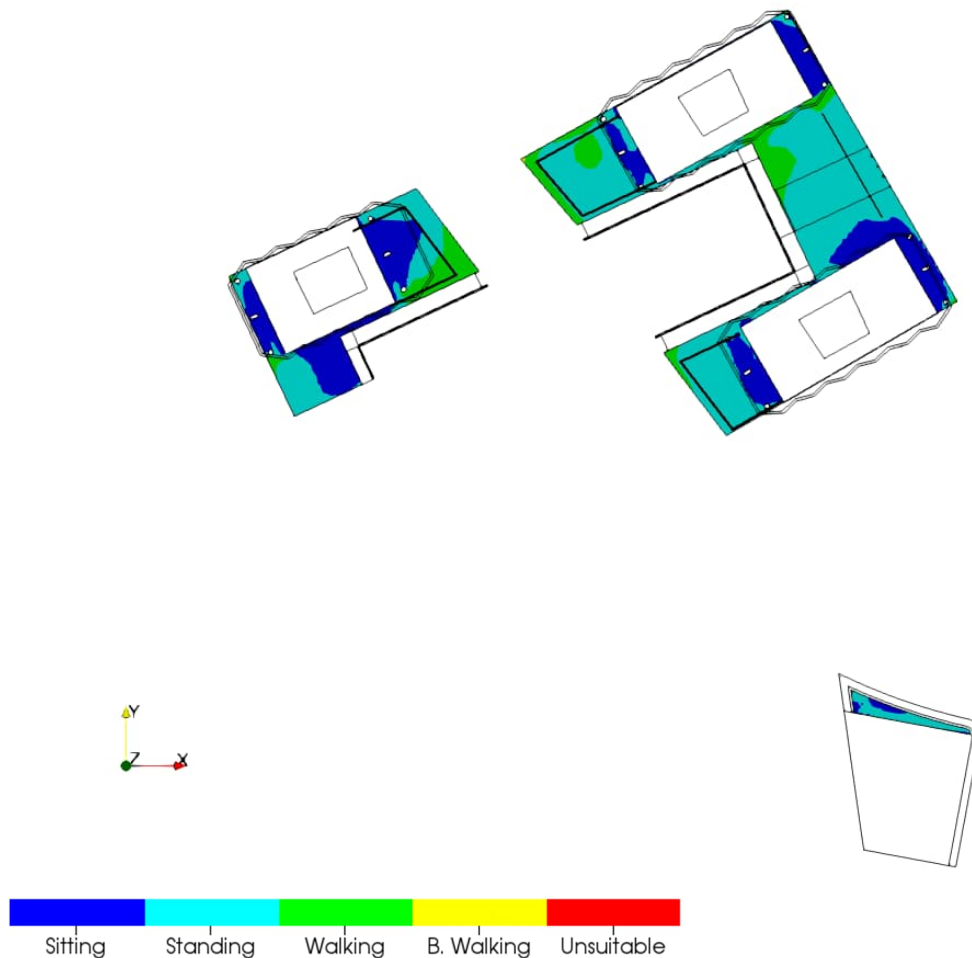


Figure 5-5 - Contours of comfort criteria on elevated levels in summer.

- 5.1.7. Figure 5-5 indicates that during summer, most areas underneath the towers rate as suitable for sitting. Generally, other areas rate as suitable for standing. It should be noted that no proposed landscaping has been modelled on the terraces and therefore results would be expected to improve at the next stage of the design.

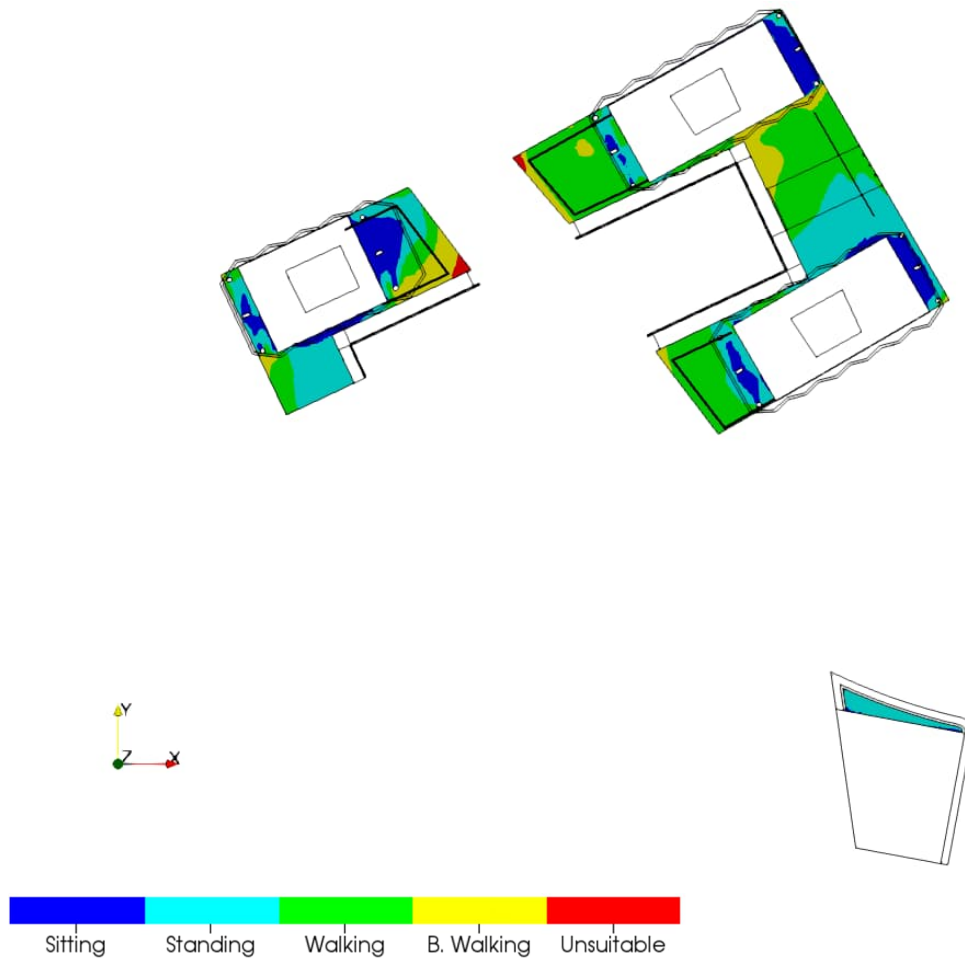


Figure 5-6 - Contours of comfort criteria on elevated levels in winter.

- 5.1.8. Figure 5-6 indicates that during winter, most areas underneath the towers rate as suitable for sitting and standing. Generally, other areas rate as suitable for standing or walking. It should be noted that no proposed landscaping has been modelled on the terraces and therefore results would be expected to improve at the next stage of the design.

6 RESULTS – SCENARIO 7: PHASES 1-6 IN EXISTING SURROUNDS

6.1 INTRODUCTION

This section analyses the results of Phases 1-6 in existing surrounds and its associated landscaping and mitigation.

SAFETY CRITERIA ANALYSIS

- 6.1.1. Figure 6-1 shows that the introduction of the proposed development, landscaping and mitigation for Scenario 7 results in ground level wind conditions that are rated as safe for all users.

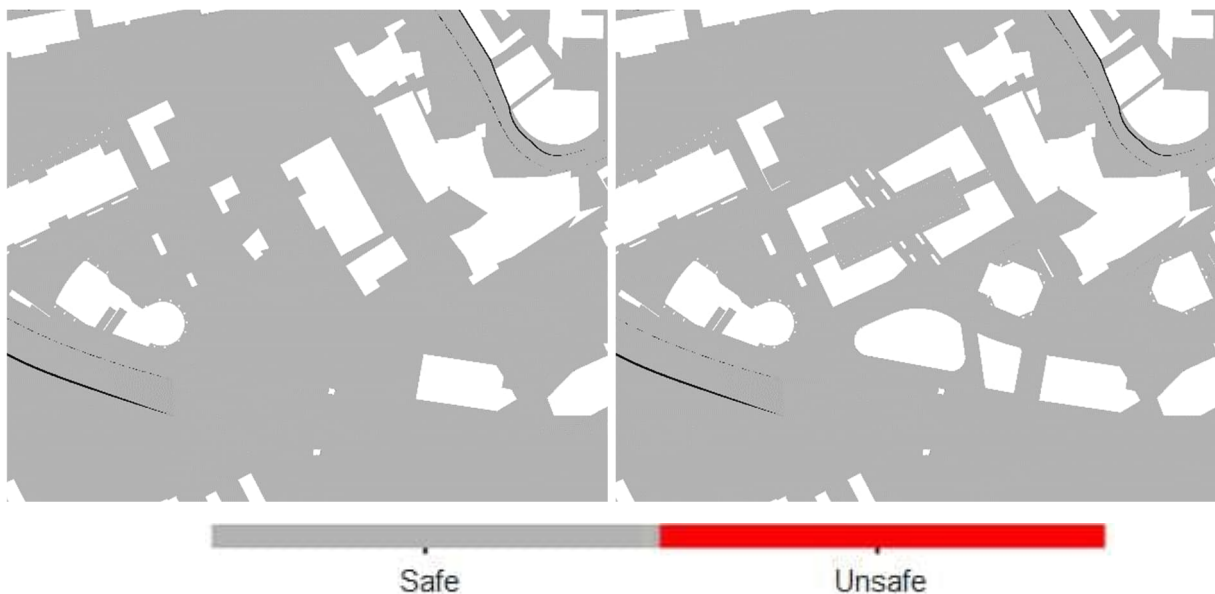


Figure 6-1 - Contours of safety criteria (left: Scenario 1, right: Scenario 7).

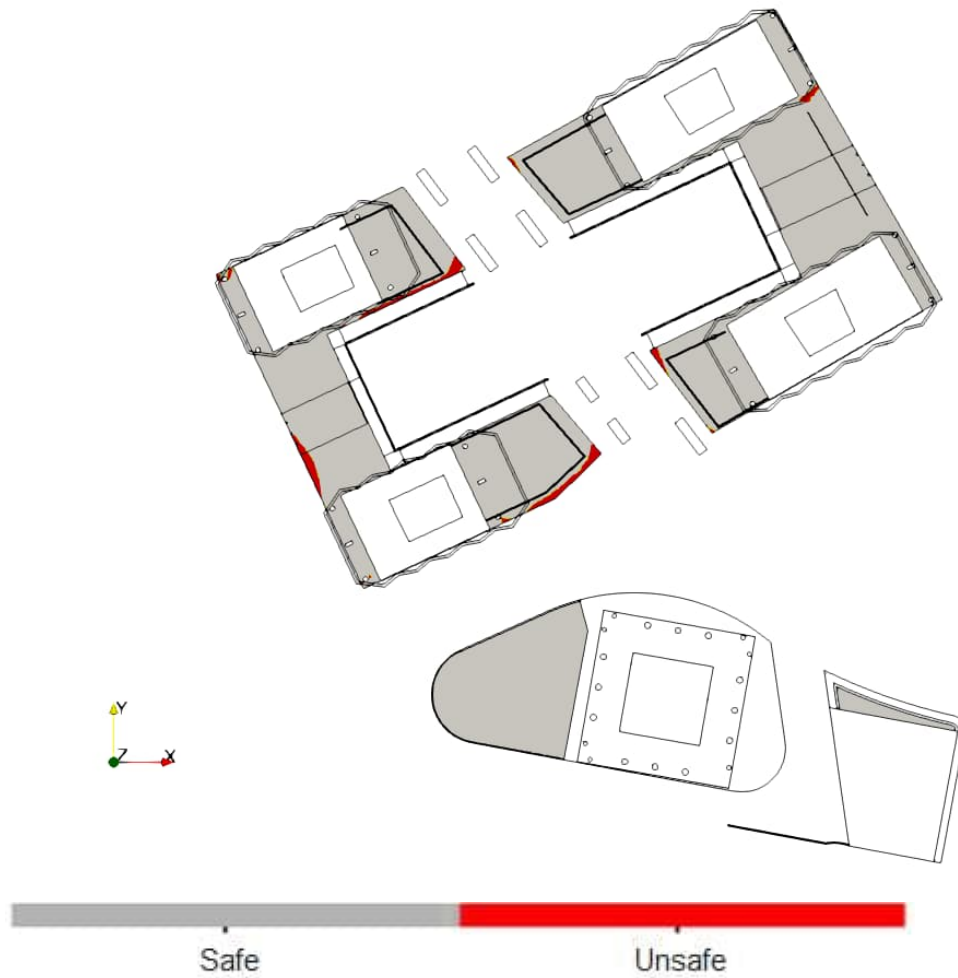


Figure 6-2 - Contours of safety criteria on elevated levels for Scenario 7.

- 6.1.2. Figure 6-2 indicates that elevated levels rate as safe for all users in accessible areas. It is understood that all areas showing unsafe conditions are not accessible. It should be noted that no proposed landscaping has been modelled on the terraces and therefore results would be expected to improve at the next stage of the design. Balustrades were modelled as 1.5m tall with 50% porosity.

COMFORT CRITERIA ANALYSIS

- 6.1.3. Figure 6-3 and Figure 6-4 show contours of comfort criteria on a plane 1.5m above the ground for the worst-case season (winter) and summer seasons respectively, directly compared against the baseline scenario (Scenario 1).

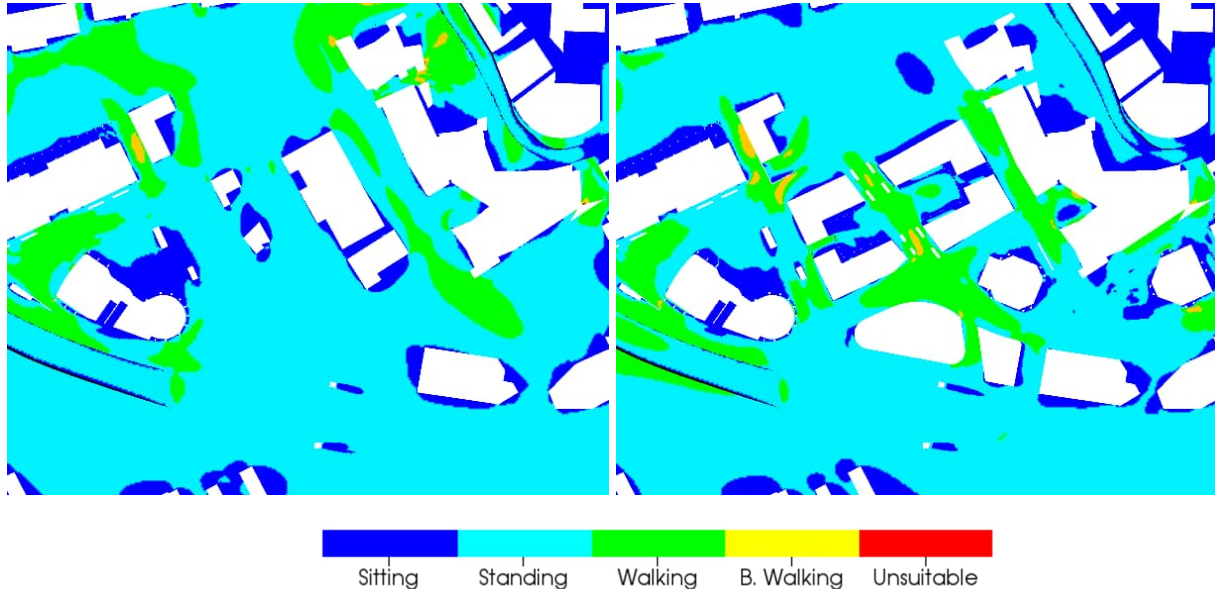


Figure 6-3 - Contours of comfort criteria for winter (left: Scenario 1, right: Scenario 7).

- 6.1.4. Figure 6-3 shows that, with the introduction of the proposed development (Scenario 7), wind conditions within the site rate as suitable for business walking, leisure walking, standing and sitting during winter.

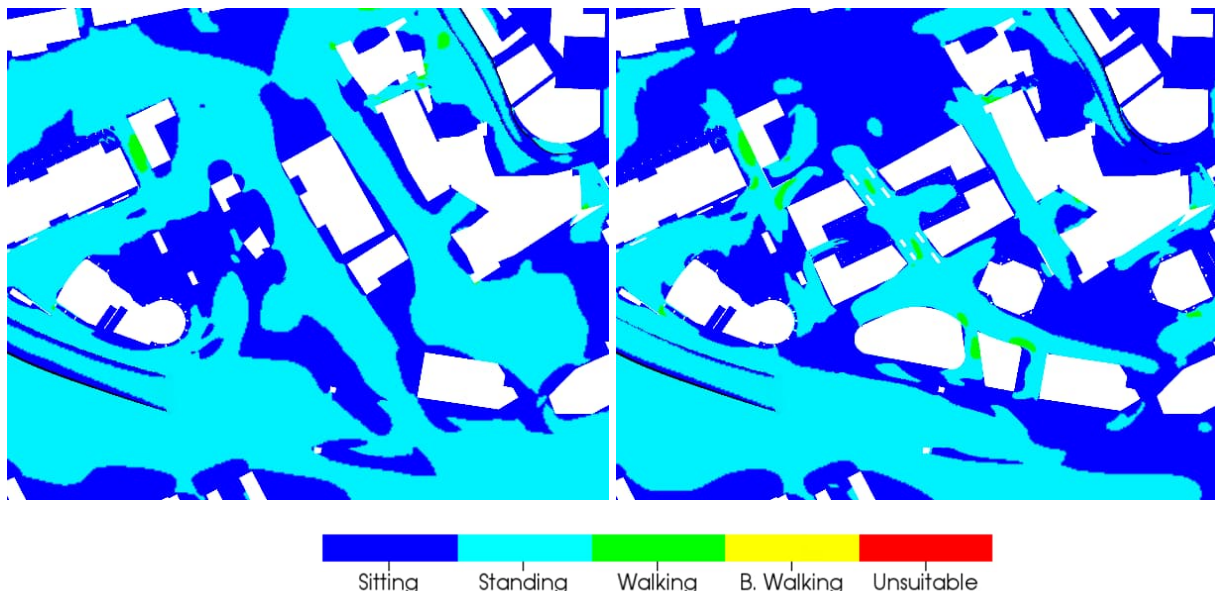


Figure 6-4 - Contours of comfort criteria for summer (left: Scenario 1, right: Scenario 7).

- 6.1.5. Figure 6-4 shows that, with the introduction of the proposed development (Scenario 7), wind conditions within the site rate as suitable for walking, standing and sitting during summer.

6.1.6. Figure 6-5 and Figure 6-6 show contours of comfort criteria on a plane 1.5m above the elevated levels for the summer and winter seasons for Scenario 7.

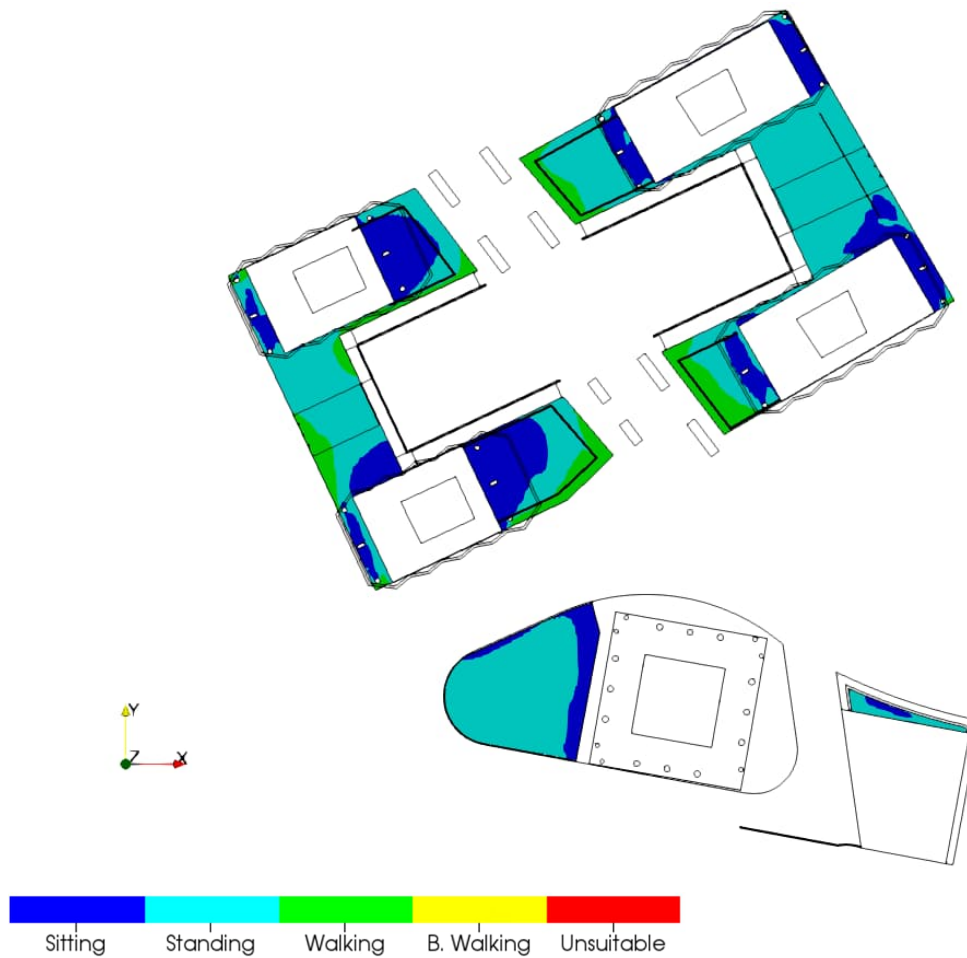


Figure 6-5 - Contours of comfort criteria on elevated levels in summer.

6.1.7. Figure 6-5 indicates that during summer, most areas underneath the towers on Crown Street Phase 3 rate as suitable for sitting. Generally, other areas rate as suitable for standing / walking. It should be noted that no proposed landscaping has been modelled on the terraces and therefore results would be expected to improve at the next stage of the design.

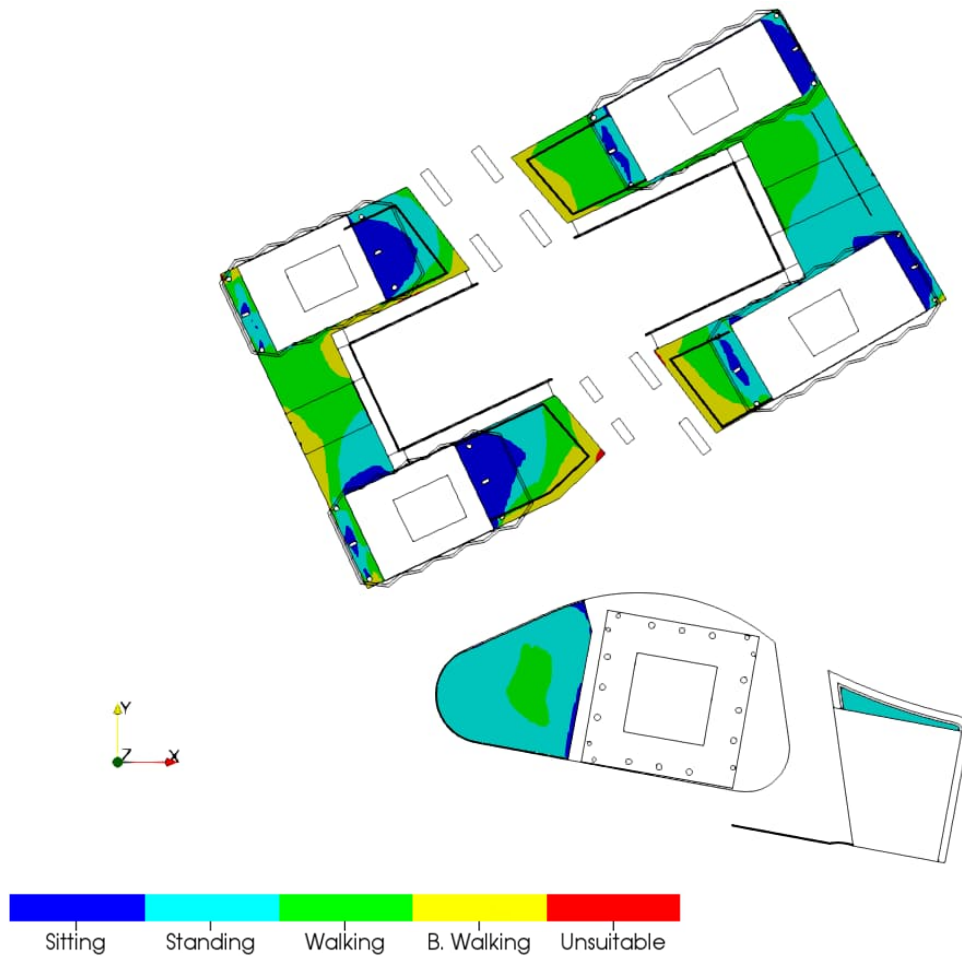


Figure 6-6 - Contours of comfort criteria on elevated levels in winter.

- 6.1.8. Figure 6-6 indicates that during winter, most areas underneath the towers on Crown Street Phase 3 rate as suitable for sitting or standing. Generally, other areas rate as suitable for standing / walking, with some areas of business walking identified. It should be noted that no proposed landscaping has been modelled on the terraces and therefore results would be expected to improve at the next stage of the design. Local shelter around the entrance to C8 in the form of side screens is expected to improve wind conditions at this particular location.

7 RESULTS – SCENARIO 13: PHASES 1-6 IN CUMULATIVE SURROUNDS

7.1 INTRODUCTION

This section analyses the results of Phases 1-6 in cumulative surrounds and its associated landscaping and mitigation.

SAFETY CRITERIA ANALYSIS

- 7.1.1. Figure 7-1 shows that the introduction of the proposed development, landscaping and mitigation for Scenario 13 results in ground level wind conditions that are rated as safe for all users.

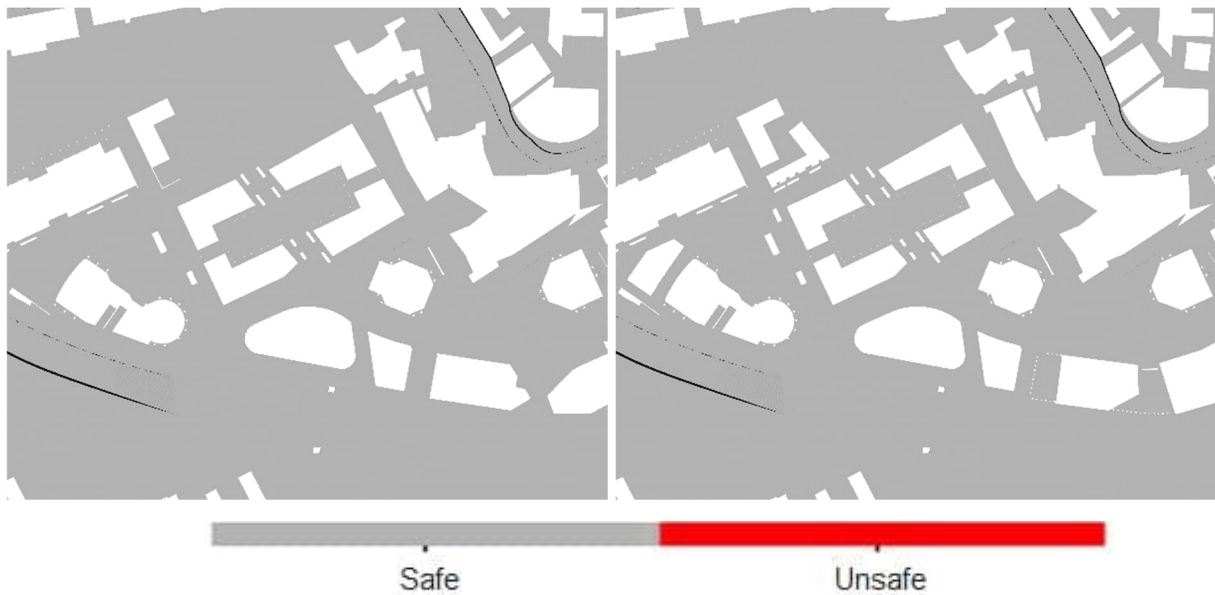


Figure 7-1 - Contours of safety criteria (left: Scenario 7, right: Scenario 13).

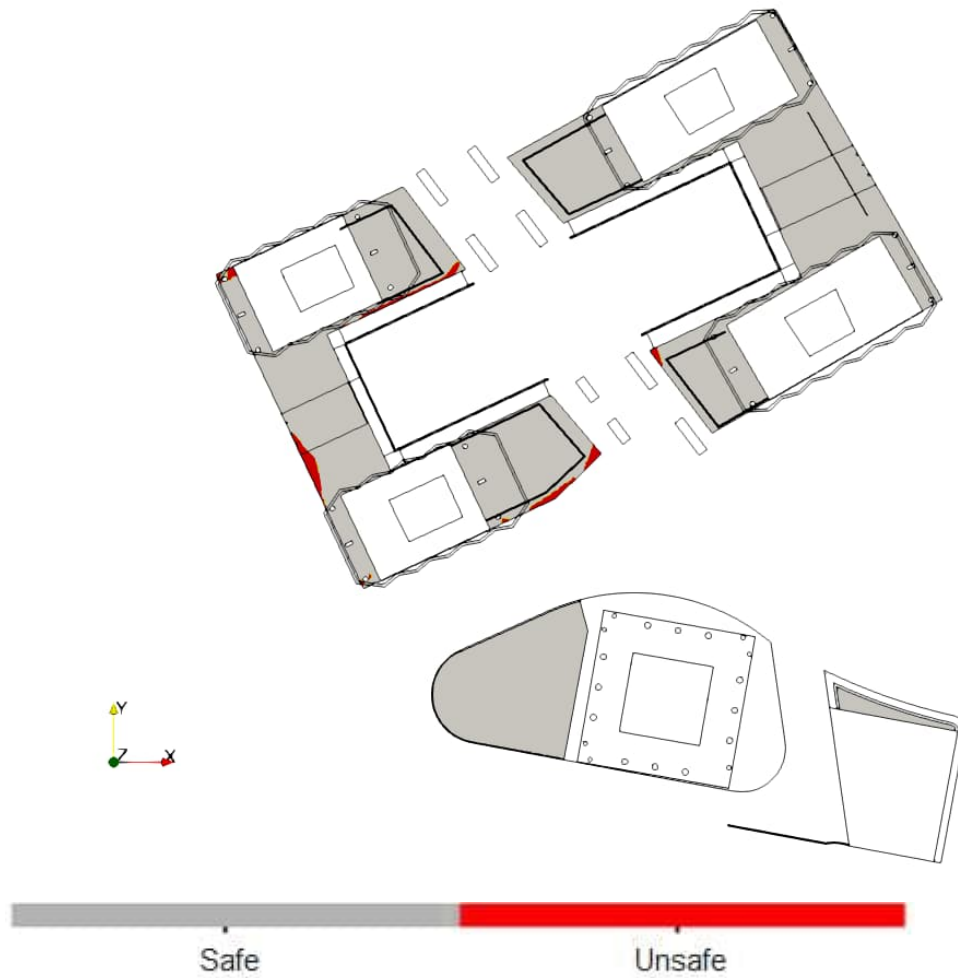


Figure 7-2 - Contours of safety criteria on elevated levels for Scenario 13.

- 7.1.2. Figure 7-2 indicates that elevated levels rate as safe for all users in accessible areas. It is understood that all areas showing unsafe conditions are not accessible. It should be noted that no proposed landscaping has been modelled on the terraces and therefore results would be expected to improve at the next stage of the design. Balustrades were modelled as 1.5m tall with 50% porosity.

COMFORT CRITERIA ANALYSIS

- 7.1.3. Figure 7-3 and Figure 7-4 show contours of comfort criteria on a plane 1.5m above the ground for the worst-case season (winter) and summer seasons respectively, directly compared against Scenario 7.

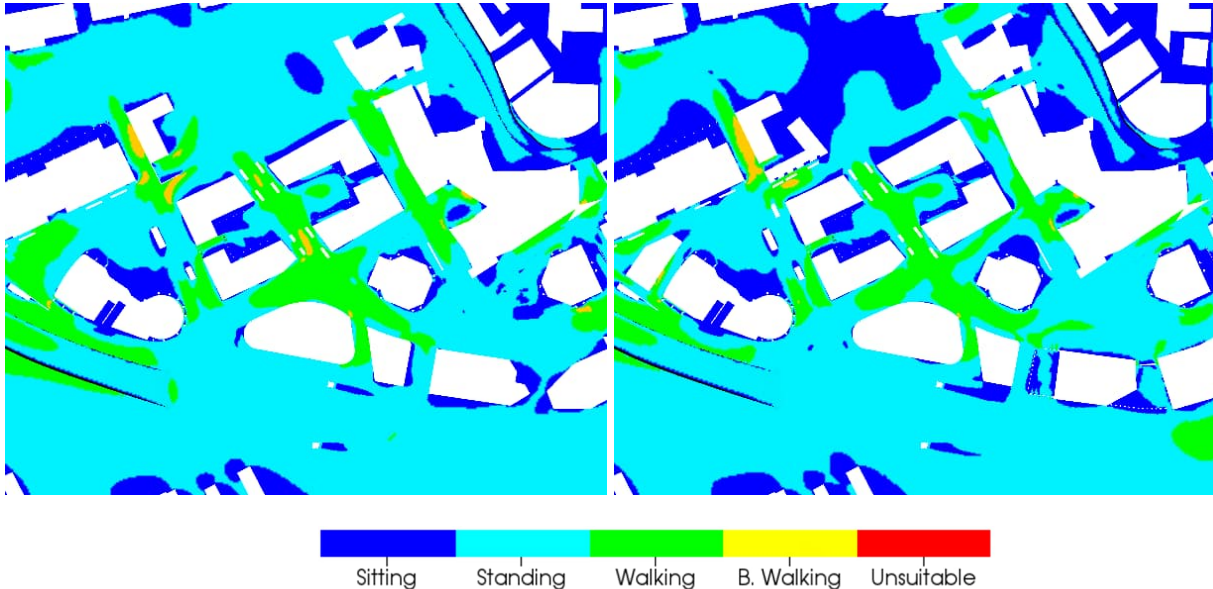


Figure 7-3 - Contours of comfort criteria for winter (left: Scenario 7, right: Scenario 13).

- 7.1.4. Figure 7-3 shows that, with the introduction of the proposed development (Scenario 13), wind conditions within the site rate as suitable for walking, standing and sitting during winter.

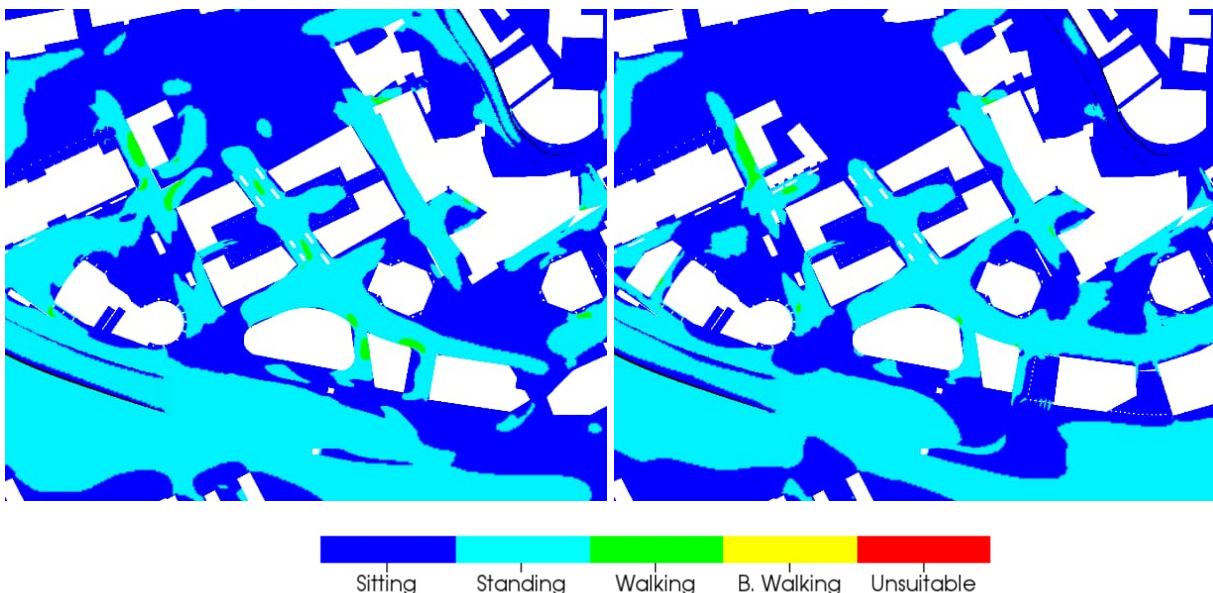


Figure 7-4 - Contours of comfort criteria for summer (left: Scenario 7, right: Scenario 13).

- 7.1.5. Figure 7-4 shows that, with the introduction of the proposed development (Scenario 13), wind conditions within the site rate as suitable for standing and sitting during summer. Off-site, some areas suitable for walking are identified.

- 7.1.6. Figure 7-5 and Figure 7-6 show contours of comfort criteria on a plane 1.5m above the elevated levels for the summer and winter seasons for Scenario 13.

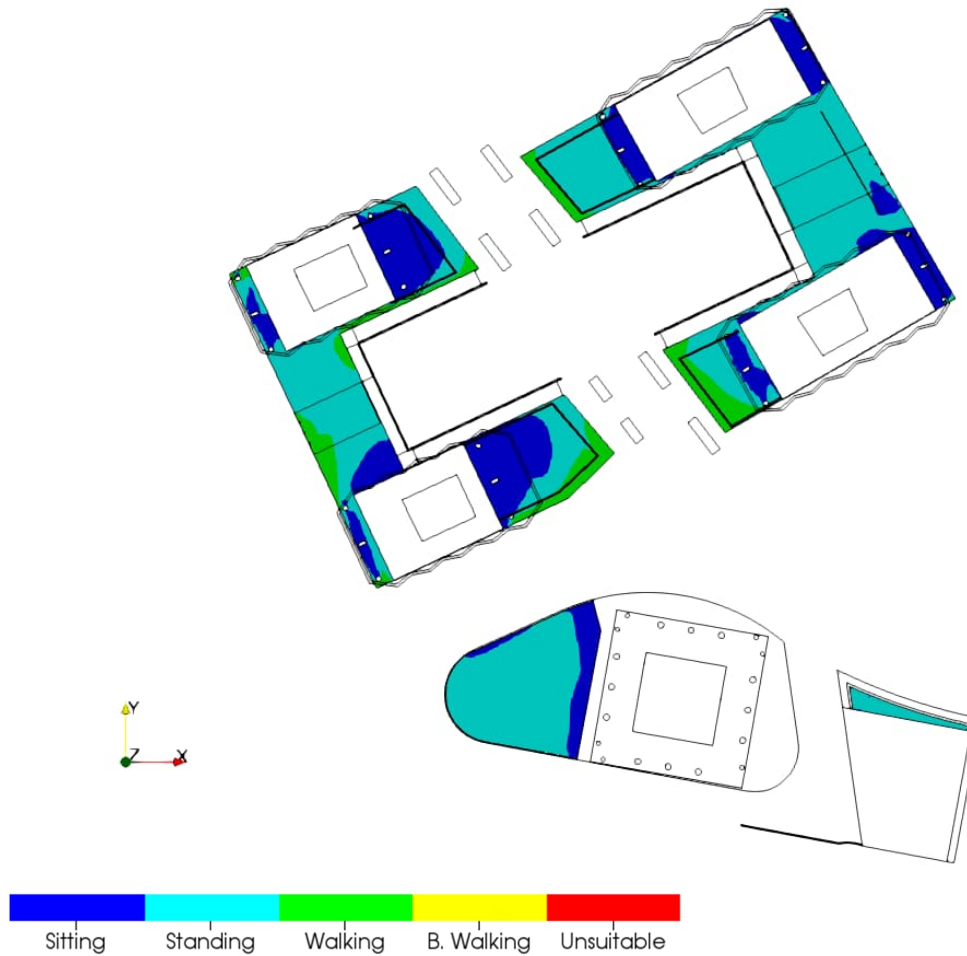


Figure 7-5 - Contours of comfort criteria on elevated levels in summer.

- 7.1.7. Figure 7-5 indicates that during summer, most areas underneath the towers on Crown Street Phase 3 rate as suitable for sitting. Generally, other areas rate as suitable for standing / walking. It should be noted that no proposed landscaping has been modelled on the terraces and therefore results would be expected to improve at the next stage of the design.

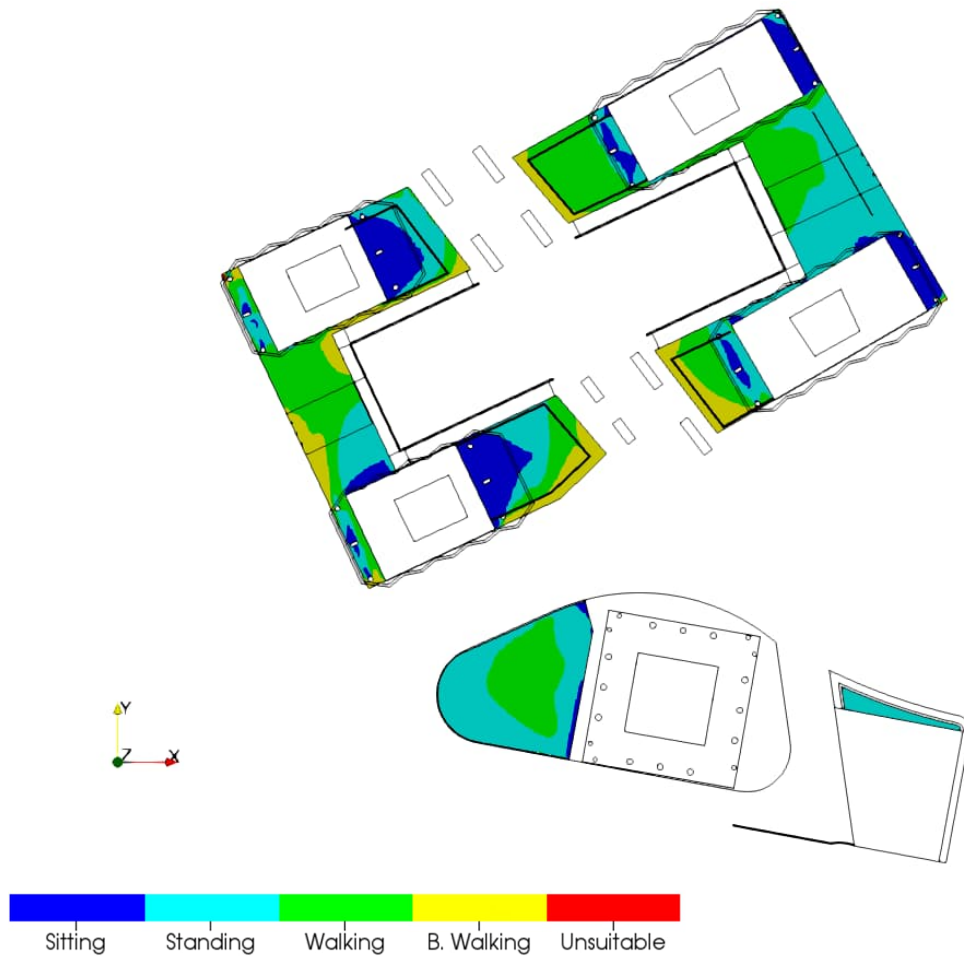


Figure 7-6 - Contours of comfort criteria on elevated levels in winter.

- 7.1.8. Figure 7-6 indicates that during winter, most areas underneath the towers on Crown Street Phase 3 rate as suitable for sitting or standing. Generally, other areas rate as suitable for standing / walking, with some areas of business walking identified. It should be noted that no proposed landscaping has been modelled on the terraces and therefore results would be expected to improve at the next stage of the design. Local shelter around the entrance to C8 in the form of side screens is expected to improve wind conditions at this particular location.

8 CONCLUSIONS

An analysis of the wind conditions around the proposed Crown Street Phase 3 & Great Jackson Street Plot D developments in Manchester has been performed. The study consisted of CFD simulations over a range of wind directions which were combined with long-term wind statistics to provide a statistical representation of the expected wind conditions. A total of four surrounds configurations (baseline included) were studied. Specialist wind engineering advice was provided right from the start of the design process: this allowed the wider design team to consider and take on board 'wind microclimate' input whilst the design was evolving. This process also allowed wind mitigation measures to become an integral part of the architectural and landscaping design of the proposed development: for this reason, the wind microclimate conditions within and in the vicinity of the proposed development have been presented with its fully integrated wind mitigation strategy and proposed landscaping in place. The following conclusions can be drawn:

- With the implementation of the proposed landscaping and mitigation scheme, all ground-level areas around the proposed development rate as safe for pedestrians in all scenarios.
- At the elevated levels, some terraces show some small areas which rate as unsafe for pedestrians across all scenarios and / or fall short of meeting the required level of wind comfort. However, all areas showing unsafe conditions are not accessible to residents. The amenity areas are rated as safe in terms of the pedestrian safety criteria, without the need for further mitigation measures.
- Further studies relating to pedestrian comfort on the terraces will be carried out prior to construction to allow mitigation measures to be incorporated. At present, no landscaping is modelled on these terraces, which is deemed to be conservative. Local shelter around the terrace entrance to C8 in the form of side screens is expected to improve wind conditions at this particular location. The balustrades on the terraces are modelled as 1.5m tall with 50% porosity.

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Appendix A

FULL RESULTS





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