



Plot 9b PBSA

For

Vita Meadow Limited

Wind Microclimate Report

0510650rep1v1

22 October 2024

Architectural Aerodynamics Ltd.

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Executive Summary

Background

A study has been carried out by Architectural Aerodynamics Ltd. (ArcAero) to assess the wind microclimate for the proposed Plot 9b PBSA development in Manchester, UK.

The study has adopted wind tunnel testing to predict the strength of winds. Then using the industry standard Lawson criteria, it has established the suitability of wind conditions and the impact on the surrounding area, following the introduction of the proposed development.

Conclusions

The following conclusions have been drawn:

- Wind conditions throughout the existing site and surrounds satisfy the safety and comfort criteria for all uses.
- With the introduction of the proposed development into the existing surrounds, comfort and safety criteria are generally met, though a number of exceptions exist. The same is true with the introduction of cumulative surroundings, though this scenario is typically the windier of the two.
- With the introduction of mitigation, the safety criteria are met throughout the readily accessible parts of the study area. Conditions will broadly be acceptable for thoroughfare, and for comfortable use of the main entrance, plus the elevated terrace accessible to occupants. Some areas within Medlock Street and Hulme Street predicted to be slightly windy for strolling in winter, while some secondary entrances to the development and others within the surrounding area (that will be used infrequently) will be marginally windy during the windier seasons, primarily winter.

1 Introduction

A microclimate is defined as the distinctive climate of a small-scale area. The weather variables in a microclimate, such as wind, may be different to the conditions prevailing over the area as a whole. Wind microclimate assessments consider the wind conditions that would result upon the introduction of a new development into an existing space.

Such assessments predict the proportion of time an area will experience wind speeds in excess of threshold values associated with safe and comfortable use by pedestrians and occupants once the development is introduced. It can therefore be shown within the various parts of a new proposal and neighbouring properties whether wind conditions are suitable or unsuitable, and whether design adjustment or mitigation measures are required. It is for this purpose that wind microclimate assessments are undertaken.

This report summarises the results wind tunnel studies commissioned by Vita Meadow Limited, to assess the wind microclimate for the proposed Plot 9b PBSA development in Manchester, UK.

2 The Proposed Development

2.1 Site Location and Surrounding Area

The Plot 9b PBSA development is located entirely on 'Plot 9B', bound to the west by Medlock Street; to the north by land at Plot 9A of the FSDF area (currently being redeveloped into an office block of up to 9 storeys (pursuant to Planning Permission 132600/FO/2021); to the east by land at Plot 10A (currently being redeveloped into an office block of up to 13 storeys (pursuant to Planning Permission 136043/FO/2023)) and to the south east by Hulme Street and land at Plot 11 of the FSDF area (currently being redeveloped to deliver three co-living buildings of up to 45 storeys (pursuant to Planning Permission 125573/FO/2019)).

Further afield the terrain is typical of suburban residential areas. To the north lies Manchester City Centre, with mid-rise to high-rise office, residential developments, and buildings typical of a UK city centre. To the west lies the Great Jackson Quarter which is characterised by mid-rise to high-rise developments.

The proposed development will comprise a single building of up to 31 (+ ground) storeys, comprising purpose-built student accommodation (PBSA) (Sui Generis) and other associated works including public realm, secure cycle parking and servicing arrangements.

2.2 Drawing Information Describing the Proposed Development

Early-stage assessments were initially carried out in CFD before initial massing was substantially resolved by May 2024. At this stage, to benchmark and validate the wind-related performance of the scheme, wind tunnel testing (WTT) was carried out in July 2024, at which time key elements of mitigation were devised. This includes the soft landscaping and mitigation measures shown and described in Figure 2.1 and Figure 2.2. CFD and WTT predictions have proven to agree well.

In mid-July 2024, variations to the massing were considered by the design team, primarily comprising a reduction in height of the 'shoulder-blocks' adjoining the tower, and an increase in the height of the tower. Prior wind modelling studies had identified that the south-west facing shoulder block (along with the connected lower-levels of the tower) were responsible for the majority of increases in wind speeds upon the introduction of the proposed development. In contrast, with a form that is relatively well oriented for winds from the southwest round to the west, with the wide face oriented towards infrequent south-easterly winds and benefitting from shelter provided by the Plot 11 development; it was judged that the reduction in height of the shoulder block would broadly offset the effects of an increase to the height of the tower.

This being the case, CFD modelling has been carried out to revisit and re-examine the performance of the development scheme and to assess the sensitivity of the wind conditions with respect to the changes in height of the tower and shoulder block.

2.2.1 Wind Tunnel Testing

Assessment models have been constructed on the basis of the following 3D model received from Tim Groom Architects on 13th of May 2024:

- 9B-TGA-G000-MD-XX-00001 P02.dwg

The existing surrounding area was based upon information supplied Tim Groom Architects and supplemented by Ordnance Survey details for the area. Cumulative surrounds were based upon information contained within the Manchester City Council planning portal.

2.2.2 CFD Modelling

Assessment models have been constructed on the basis of the following 3D model received from Tim Groom Architects on 12th of August 2024:

- 9B-TGA-G000-MD-XX-00001_P04.dwg

2.3 Landscaping & Wind Mitigation Measures

Existing and consented landscaping proposals (for the cumulative scenario) were modelled where appropriate.

2.3.1 Wind Tunnel Testing

The development has been assessed, initially, in the absence of landscaping proposals or any wind mitigation measures, before landscaping and wind mitigation measures were introduced and their effectiveness verified.

Soft landscaping and wind mitigation measures are as set out in Figures 2.1 and 2.2.

2.3.2 CFD Modelling, Proposed Development

The development has been assessed with soft landscaping proposals and wind mitigation measures in place.

As with the wind tunnel modelling, soft landscaping proposals and wind mitigation measures are as set out in Figures 2.1 and 2.2.

2.4 Surrounding Contexts

The proposed development was assessed in two surrounding contexts, namely existing surrounds and cumulative surrounds.

The existing surrounding area was based upon information supplied by design team and supplemented by Ordnance Survey details for the area. Cumulative surrounds were based upon information contained within the Manchester City Council online planning register.

A number of significant developments are substantially under construction to the north and south of the proposed development. These have been included within all assessment scenarios.

Consented developments that have been additionally considered within the cumulative surrounding context are listed in Table 2-1.

Table 2-1 – Cumulative Schemes

Development Name	Planning Reference
Plot 10b, First Street (House of Social)	136170/FO/2023
Great Jackson Plot F	132199/FO/2021
Deansgate South	129406/FO/2021
Vision	111003/FO/2016/C1
Plot 10a, First Street	136043/FO/2023
One City Road	128002/FO/2020
One Medlock Street	135419/FO/2022
Park Place (Plot G, Great Jackson Street)	129273/FO/2021
Student Castle	121252/FO/2018
Great Jackson Street - Crown Street Plot D (The Lighthouse)	137227/FO/2023
Great Jackson Street Plot C and E (The Green)	137226/FO/2023
Viadux Two	139715/FO/2024
Apex Tower	133172/FO/2022
Plot 11 Block C First Street South	138831/FO/2023
Alpha Place	120113/FO/2018
Brownfield	128433/FO/2020

3 Assessment Methodology

3.1 Wind Tunnel Testing

Wind tunnel modelling was undertaken in the Imperial College 10x5 atmospheric boundary layer wind tunnel in London.

Modelling via wind tunnel testing has derived mean and gust equivalent mean wind speeds, in accordance with best industry practice. In doing so 16 wind directions were assessed, in 22.5° increments.

Full details of the wind tunnel testing conducted for the study are presented in Appendix A of this report.

3.2 CFD Modelling

CFD modelling has employed a RANS approach: full details of the CFD methodology are set out in Appendix B of this report. Salient highlights of this approach are:

- the Shear Stress Transport k- ω turbulence model has been employed.
- Architectural features of 0.5 metres or more have been captured within the geometry modelled.
- Cell sizes of as small as 0.2 metres were utilised to capture flow behaviour in critical locations.
- The region of interest closest to the ground (1.5 metres) incorporated 5 layers of cells.

Final CFD modelling of the proposed development was carried out in August 2024.

Modelling via CFD has derived mean and gust equivalent mean wind speeds, in accordance with best industry practice. All assessment scenarios have considered 16 wind directions in 22.5° increments.

Full details of the CFD modelling conducted for the study are presented in Appendix B of this report.

3.3 Wind Climate Analysis

Wind microclimate studies require that meteorological data is transposed from a nearby weather station with sufficient wind data to produce accurate wind frequency statistics. The current study uses data from Manchester Airport.

Full details of the wind climate relevant to the site, the wind properties approaching the site and the modelling of those wind properties in the wind tunnel models are provided in Appendix C of this report. All analysis of wind data and the atmospheric boundary layer has employed the methods of ESDU item 01008 (4), in accordance with best industry practice.

3.4 Assessment Scenarios

The analysis models covered a radius of 450 metres from the site. All features which are likely to impact the wind flow within the study area have been replicated. The assessment considered a full range of directions in 22.5° intervals, and considered the following configurations:

1. Existing site, existing surrounding conditions
2. Proposed development, existing surrounding conditions
3. Proposed development, cumulative surrounding conditions
4. Proposed development with mitigation, cumulative surrounding conditions

3.5 The LDDC Lawson Criteria

The industry standard criteria for wind microclimate assessments are commonly referred to in the UK as the Lawson criteria after one of their main authors. As with most other leading practitioners, ArcAero use the 'LDDC' variant of the Lawson Criteria (London Docklands Development Corporation (3)).

The LDDC variant applies a single percentage probability of exceedance of a range of wind speeds and associates different wind speeds to different types of usage. This offers a relatively simple and practical manner for the assessment of wind comfort and safety.

3.5.1 Safety

A wind speed of 15 m/s occurring once per year is rated as unsuitable, in terms of safety, with the potential to de-stabilise the less able members of the public including the elderly, cyclists and children.

3.5.2 Comfort

The LDDC variant of the Lawson criteria (3) prescribes that wind conditions are suitable for a given activity when the threshold is exceeded no more than 5% of the time. The value of 5% has been established as giving a reasonable allowance for extreme and relatively infrequent winds that are tolerable within each category.

Where certain activities are year-round, such as walking, entrance use or for waiting areas, comfort ratings are required to be met in all seasons. For more seasonal activities, such as outdoor recreation or for sitting spaces, the assessment focuses on relevant seasons where the expectation will exist for conditions to be suitable. The LDDC comfort threshold wind speed values are presented in Table 3-1.

Table 3-1 – LDDC Wind Comfort Thresholds

Threshold Wind Speed [m/s]	Comfort Rating / Activity	
4	C4	Long-term sitting
6	C3	Short-term sitting / standing

8	C2	Strolling
10	C1	Walking
> 10	C0	Uncomfortable

3.6 Pedestrian / Occupant Uses

Using the Lawson comfort criteria to consider the suitability of spaces within the site and surrounding area, the anticipated usage of each area was identified and used to confirm the level of suitability for existing and planned activities (as appropriate). For the wind tunnel study, each measurement location is assigned a pedestrian / occupant use, for each assessment scenario. This is presented in Figure D.1 to Figure D.6 within Appendix D.

4 Wind Tunnel Assessment - Results

4.1 Existing Site within Existing Surrounds

The results for the existing site conditions are presented graphically within Figure 4.1 and Figure 4.2 for worst-seasonal and summer conditions respectively.

4.1.1 Safety

Wind conditions throughout the existing site and surrounding areas satisfy the safety criteria for wind.

4.1.2 Comfort

Conditions within the existing site are largely suitable for at least strolling throughout the year and thus conditions are suitable for all existing pedestrian activities. A minor exception is to the thoroughfare northeast of the site (location 93) where the wind conditions marginally exceed comfort criteria, suitable for walking in winter and suitable for strolling for the rest of the year.

Entrances within the existing study are generally suitable for short-term standing / sitting and thus for comfortable entrance use.

4.2 Proposed Development within Existing Surrounds

The results for the proposed development within existing surrounds are presented graphically within Figure 4.3 and Figure 4.4 for worst-seasonal and Figure 4.5 and Figure 4.6 for summer conditions respectively.

4.2.1 Safety

With the introduction of the proposed development within existing surrounds, the safety criteria are substantially met throughout the study area. Exceedances occur in the following areas:

- Along Hulme Street (locations 16, 24, 34, 53 and 68)

4.2.2 Comfort

4.2.2.1 Thoroughfares

Upon the introduction of the proposed development within existing surrounds, wind conditions within the site are suitable for pedestrian use, being suitable for strolling or better throughout the year.

4.2.2.2 Entrances

Upon the introduction of the proposed development within existing surrounds, wind conditions at entrances are generally suitable for strolling. This includes entrances north of proposed development (locations 15, 42 & 51). The main entrance southeast of proposed development entrance (location 24) is suitable for walking throughout the year.

To meet the relevant comfort thresholds for entrances, wind conditions would ideally improve in these locations with the main entrance being most critical.

4.2.2.3 *Elevated levels*

The wind conditions on the terrace of the south-eastern shoulder block are suitable for short-term sitting or better in summer, thus acceptable for general recreational uses.

4.2.2.4 *Surrounding Area*

Wind conditions within the surrounding area, including the elevated spaces within Plot 11 (locations 201, 202, 301, 302, 303) are substantially acceptable following the introduction of the proposed development. Exceptions are as follows:

- Thoroughfares along Hulme Street (locations 16, 27, 34, 58, 68, 109) being suitable for at least walking throughout the year.
- The entrance to Plot 9A (locations 49) being suitable for walking or better throughout the year. These conditions would ideally be better, though being an entrance to a substation that would be accessed by workers, comfort levels at this position are less critical.
- The entrance to Plot 9A (location 107) are suitable for strolling or better throughout the year. These conditions would ideally be better, though being an entrance to a service area that would be accessed by workers, comfort levels at this position are less critical.
- The waiting area close to Plot 11 (location 100) is suitable for strolling during winter, and for short-term standing / sitting in other seasons.

4.3 Proposed Development within Cumulative Surrounds

The results for the proposed development within cumulative surrounds are presented graphically within Figure 4.7 and Figure 4.8 for worst-seasonal and Figure 4.9 and Figure 4.10 for summer conditions respectively.

4.3.1 *Safety*

With the introduction of the proposed development within cumulative surrounds, the safety criteria are substantially met throughout the study area. Exceedances occur in the following areas:

- Along Hulme and Newcastle Street (locations 21, 24, 27, 29, 53, 58, 78 and 86)
- Along Medlock Street (Location 59)
- South of Plot 9a (Location 49)

Exceedances also occur on the central reservation along Medlock Street (locations 26, 97). The central reservation is not, however, readily accessible to pedestrians or cyclists who should use the designated pavements & marked cycleways (which are one and the same) on the two sides of the road or the innermost traffic lanes of Medlock Street, all of which meet the safety criteria.

4.3.2 Comfort

4.3.2.1 *Thoroughfares*

Upon the introduction of the development into the cumulative surrounds, site thoroughfares are suitable for their intended uses.

4.3.2.2 *Entrances*

The primary entrance (location 24) to the proposed development is too windy for its intended usage throughout the year. Secondary entrances southwest and northwest of the development (locations 36, 51) is marginally too windy for short-term standing in winter. Throughout the rest of the year and at all other secondary entrances, wind conditions are suitable for short-term standing and thus for comfortable pedestrian ingress / egress.

4.3.2.3 *Elevated levels*

With the introduction of cumulative surroundings, wind conditions on the elevated terrace have improved to long-term sitting in the summer and thus are suitable for recreational use.

4.3.2.4 *Surrounding Area*

Wind conditions at measurement locations within the surrounding area and the elevated areas within Plot 11 are substantially acceptable following the introduction of the proposed development. Exceptions are as follows:

- Thoroughfares along Medlock Street (Locations 59, 64, and 96)
- Thoroughfares / cycleways within Newcastle and Hulme Street (21, 27, 29, 30, 35, 44, 53, 58, 78, and 86)
- Secondary entrances to Plot 9a and Plot 10 (Locations 16, 49, and 107)
- Waiting area nearby to Plot 11 (Location 100)

4.4 Proposed Development with Mitigation within Cumulative Surrounds

The mitigation measures introduced for this scenario are shown in Figure 2.1 and Figure 2.2. The results for the proposed development with mitigation within cumulative surrounds are presented graphically within Figure 4.11 and Figure 4.12 for worst-seasonal and Figure 4.13 and Figure 4.14 for summer conditions respectively.

4.4.1 *Safety*

With the introduction of the proposed development with mitigation within cumulative surrounds, the safety criteria are met throughout the readily accessible majority of the study area. Exceedances occur on the central reservation along Medlock Street (locations 26, 97).

The central reservation is not, however, not readily accessible to pedestrians or cyclists who should use the designated pavements & marked cycleways (which are one and the same) on the two sides of the road or the innermost traffic lanes of Medlock Street, all of which meet the safety criteria.

4.4.2 Comfort

4.4.2.1 *Thoroughfares*

All site thoroughfares are suitable for their strolling or better and thus for their intended use.

4.4.2.2 *Entrances*

With mitigation in place, wind conditions at the primary entrance (location 24) to the proposed development exceed the criteria for short-term standing throughout the year and would ideally improve. With regard to secondary entrances, those located to the northwest of the site (locations 42 and 51) are suitable for strolling year-round. Wind conditions at other entrances are suitable for short-term standing thus making them suitable for their intended usages.

4.4.2.3 *Elevated levels*

Wind conditions on the elevated terraces are suitable for long-term sitting in summer and are suitable for recreational use.

4.4.2.4 *Surrounding Area*

Wind conditions at measurement locations within the surrounding area and the elevated areas within Plot 11 are substantially acceptable following the introduction of the proposed development with mitigation. Exceptions are as follows:

- Thoroughfares along Medlock Street (locations 59, 64, and 96)
- Thoroughfares / cycleways within Newcastle and Humle Street (locations 21, 29, 30, 35, 53, and 86)
- Secondary entrances to Plot 9a and Plot 10 (locations 16, 49, and 107)
- Waiting area nearby to Plot 11 (location 100)

5 CFD Assessment - Results

5.1 Proposed Development with Mitigation within Cumulative Surrounds

As noted in Section 2.2, early wind modelling studies identified that the south-west facing shoulder block (along with the connected lower-levels of the tower) were responsible for the majority of increases in wind speeds upon the introduction of the proposed development.

In contrast, with a form that is relatively well oriented for winds from the southwest round to the west, with the wide face oriented towards infrequent south-easterly winds and benefitting from shelter provided by the Plot 11 development; the upper portions of the tower are less critical for the resulting wind microclimate. On the basis of this rationale it was judged that the reduction in height of the shoulder block would broadly offset the effects of an increase to the height of the tower.

To explore this, CFD was employed to examine the sensitivity of wind tunnel results presented within Section 4 to the revised 31-storey proposal, with the aforementioned mitigation measures embedded into the scheme. This exercise has indicated that with these changes to the proposed development, it is expected that the safety criteria within the site and readily accessible surrounding areas will continue to be met.

Worst-seasonal comfort results for the proposed development with mitigation measures, within cumulative surrounds, are presented graphically within Figure 5.1.

Wind comfort conditions are expected to remain broadly unchanged relative to those observed within the WTT results. Generally speaking, therefore, this indicates that conditions will broadly be acceptable for thoroughfare, with some exceptions along Medlock Street and Hulme Street, and some windier entrances. However, with a more deeply recessed main entrance (equivalent to location 24 from the wind tunnel results) conditions here are improved and predicted to be suitable for short-term standing or better, and therefore for comfortable ingress / egress.

Further inclusion of soft landscaping along Hulme Street may be beneficial to enhance comfort levels and maximise strolling conditions.

6 Conclusions

The following conclusions have been drawn:

- Wind conditions throughout the existing site and surrounds satisfy the safety and comfort criteria for all uses.
- With the introduction of the proposed development into the existing surrounds, comfort and safety criteria are generally met, though a number of exceptions exist. The same is true with the introduction of cumulative surroundings, though this scenario is typically the windier of the two.
- With the introduction of mitigation, the safety criteria are met throughout the readily accessible parts of the study area. Conditions will broadly be acceptable for thoroughfare, and for comfortable use of the main entrance, plus the elevated terrace accessible to occupants. Some areas within Medlock Street and Hulme Street predicted to be slightly windy for strolling in winter, while some secondary entrances to the development and others within the surrounding area (that will be used infrequently) will be marginally windy during the windier seasons, primarily winter.

7 References

1. Quality Assurance Manual - Wind Engineering Studies of Buildings. 2001. AWES-QAM-1-2001.
2. The American Society of Civil Engineers (ASCE) Manual of Practice No.67 for Wind Tunnel Studies. ASCE SEI 49/12.
3. Lawson, T.V. *The determination of the wind environment of a building complex before construction*. Bristol : University of Bristol, Department of Aeronautical Engineering, 1990.
4. ESDU (Engineering Science Data Unit). *Item 01008. Computer Program for wind speeds and turbulence properties: flat or hilly sites in terrain with roughness*. 2001.
5. F, Menter. *Zonal Two Equation $k-\omega$ Turbulence Models for Aerodynamic Flows*. 1993. AIAA Paper 93-2906.
6. F, Menter. *Turbulence Modelling for Engineering Flows*. s.l. : ANSYS Inc., 2011.
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8 Figures

Figure 2.1 - Mitigation measures, 1 of 2

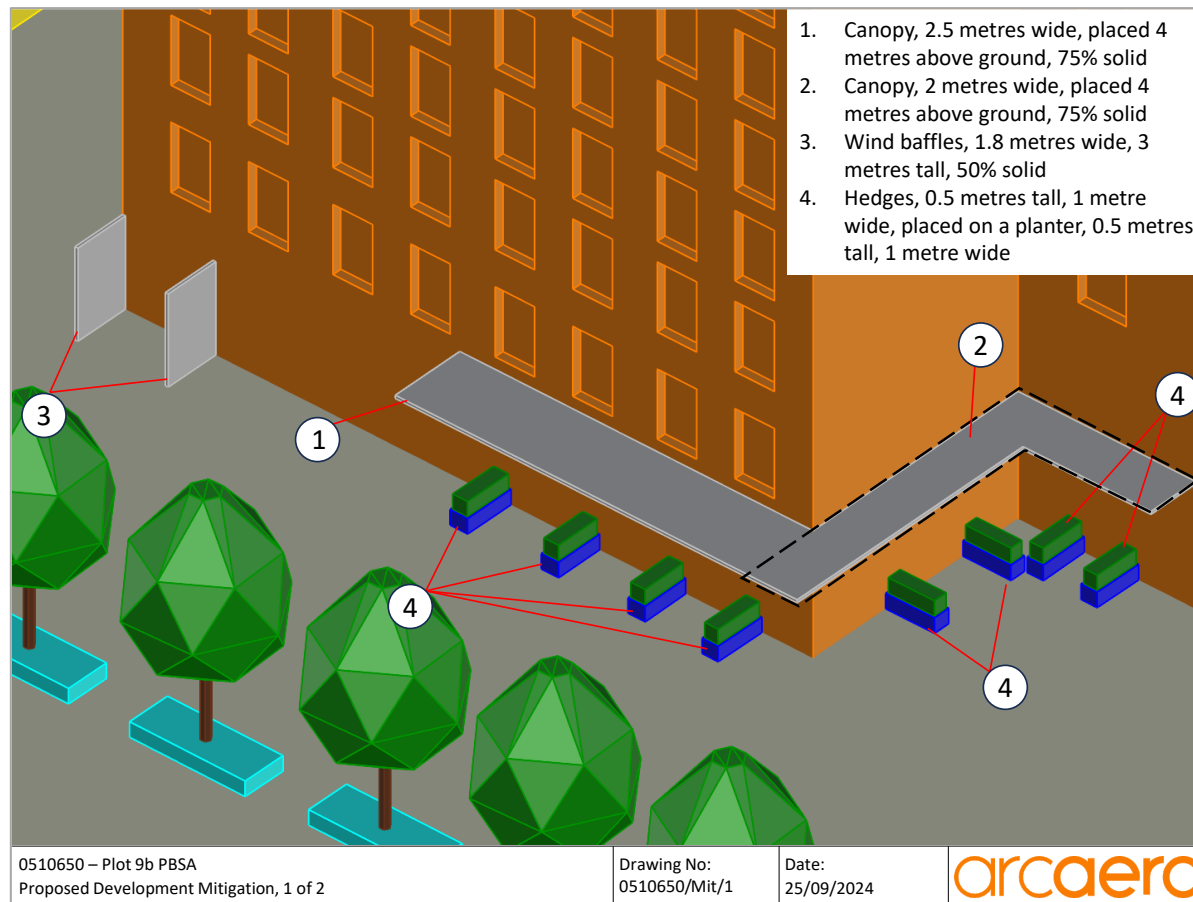


Figure 2.2 - Mitigation measures, 2 of 2

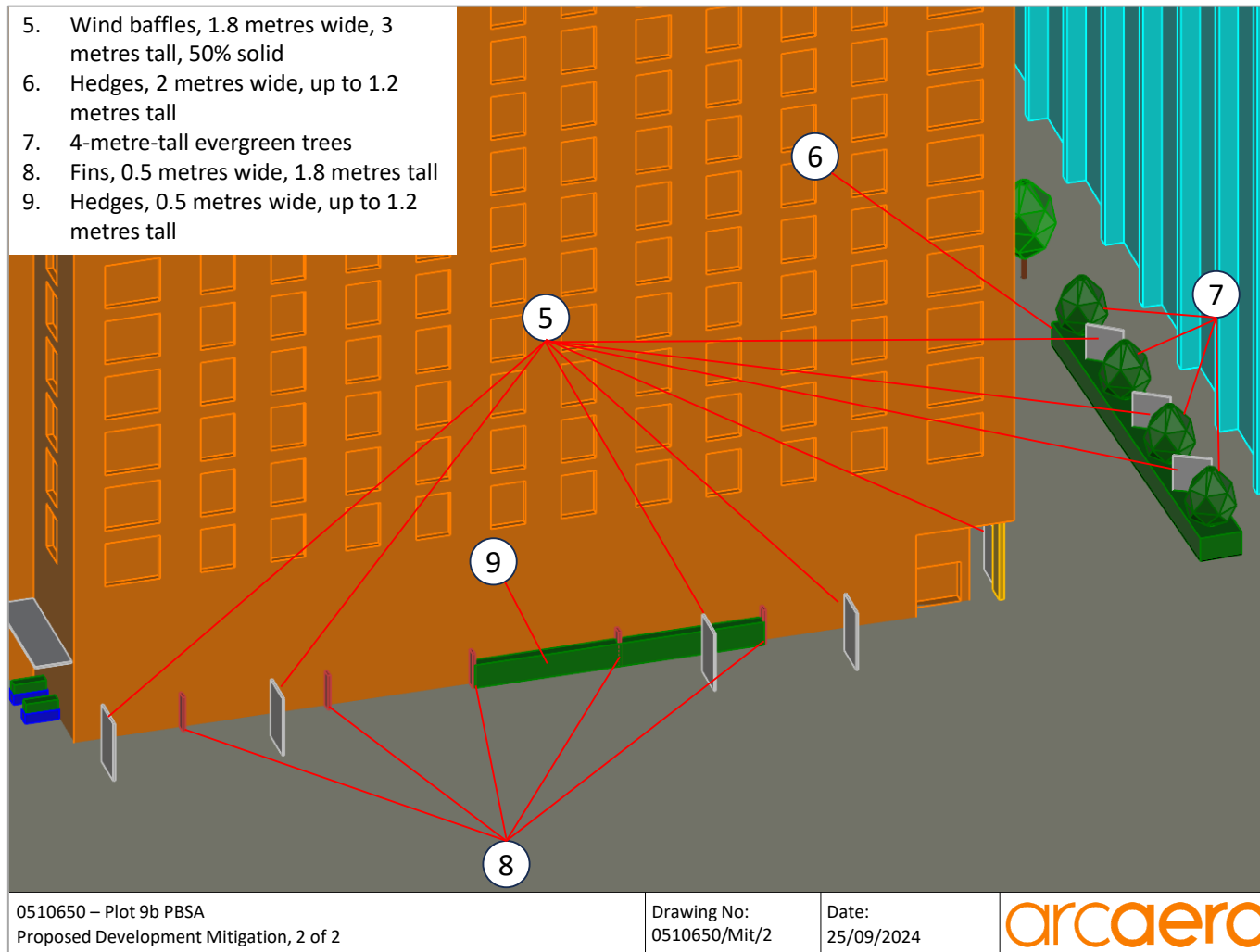


Figure 4.1 - Pedestrian wind conditions, existing site within existing surrounds, 'worst' season

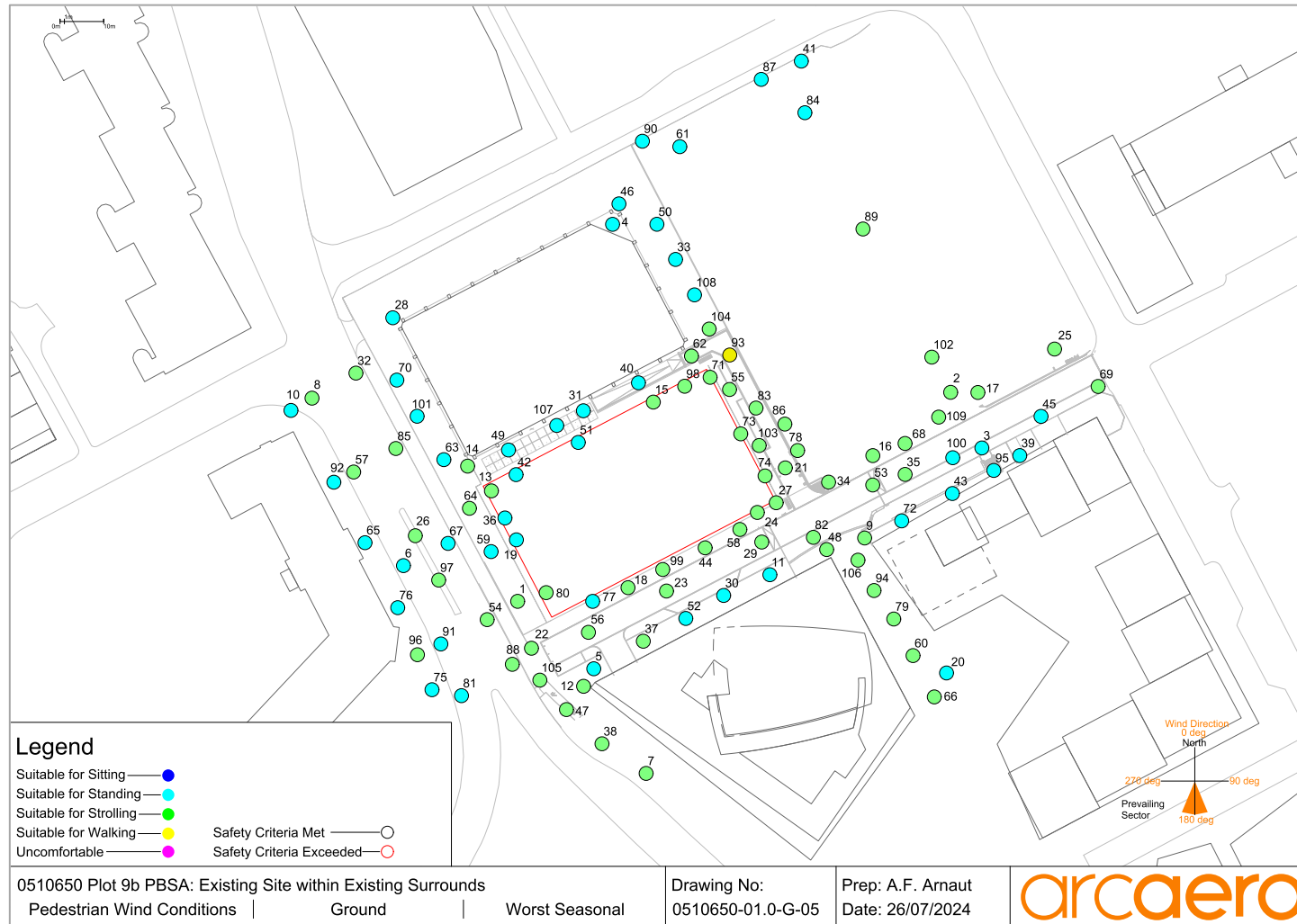


Figure 4.2 - Pedestrian wind conditions, existing site within existing surrounds, summer

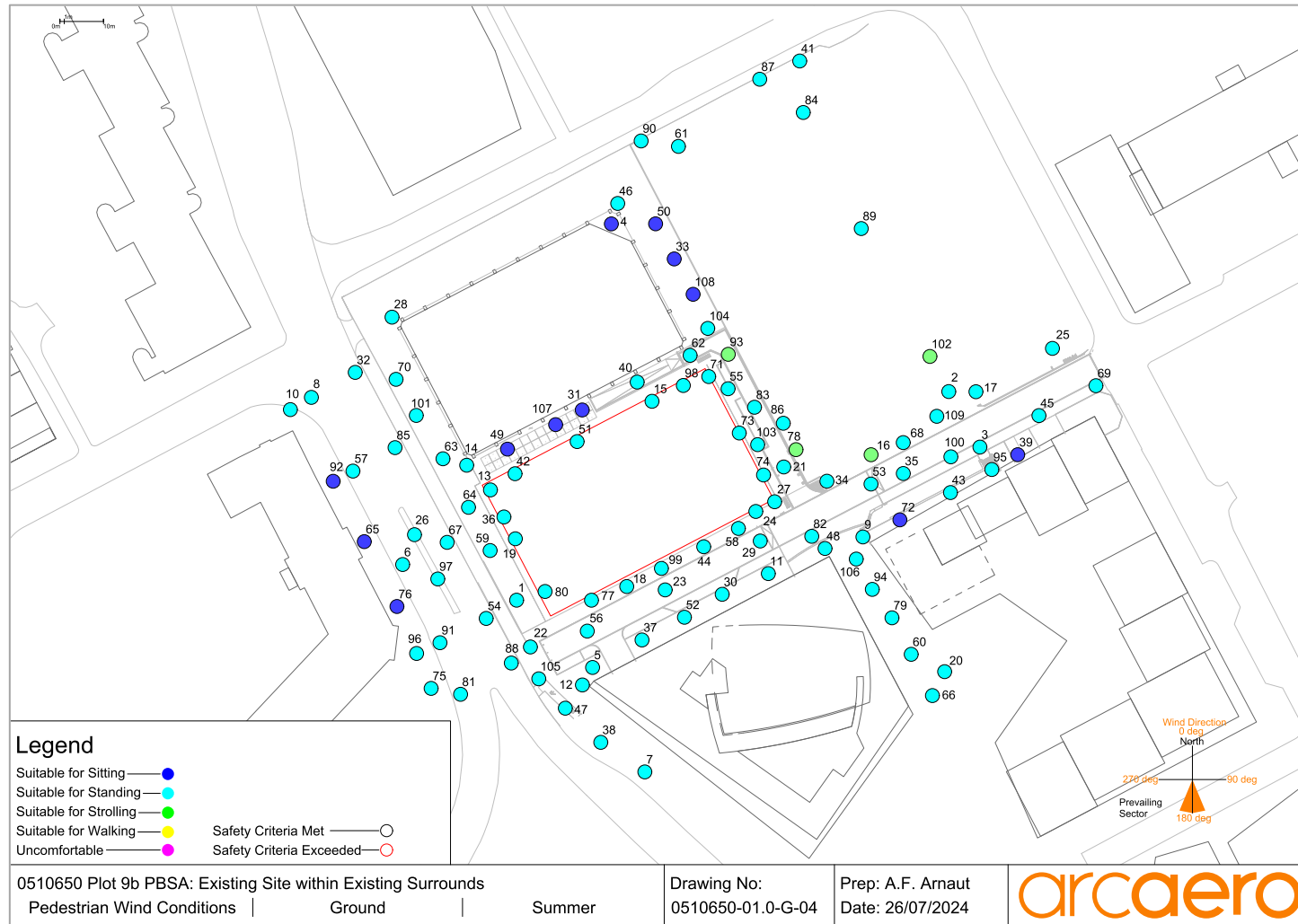


Figure 4.3 - Pedestrian wind conditions, proposed development within existing surrounds, 'worst' season – ground level

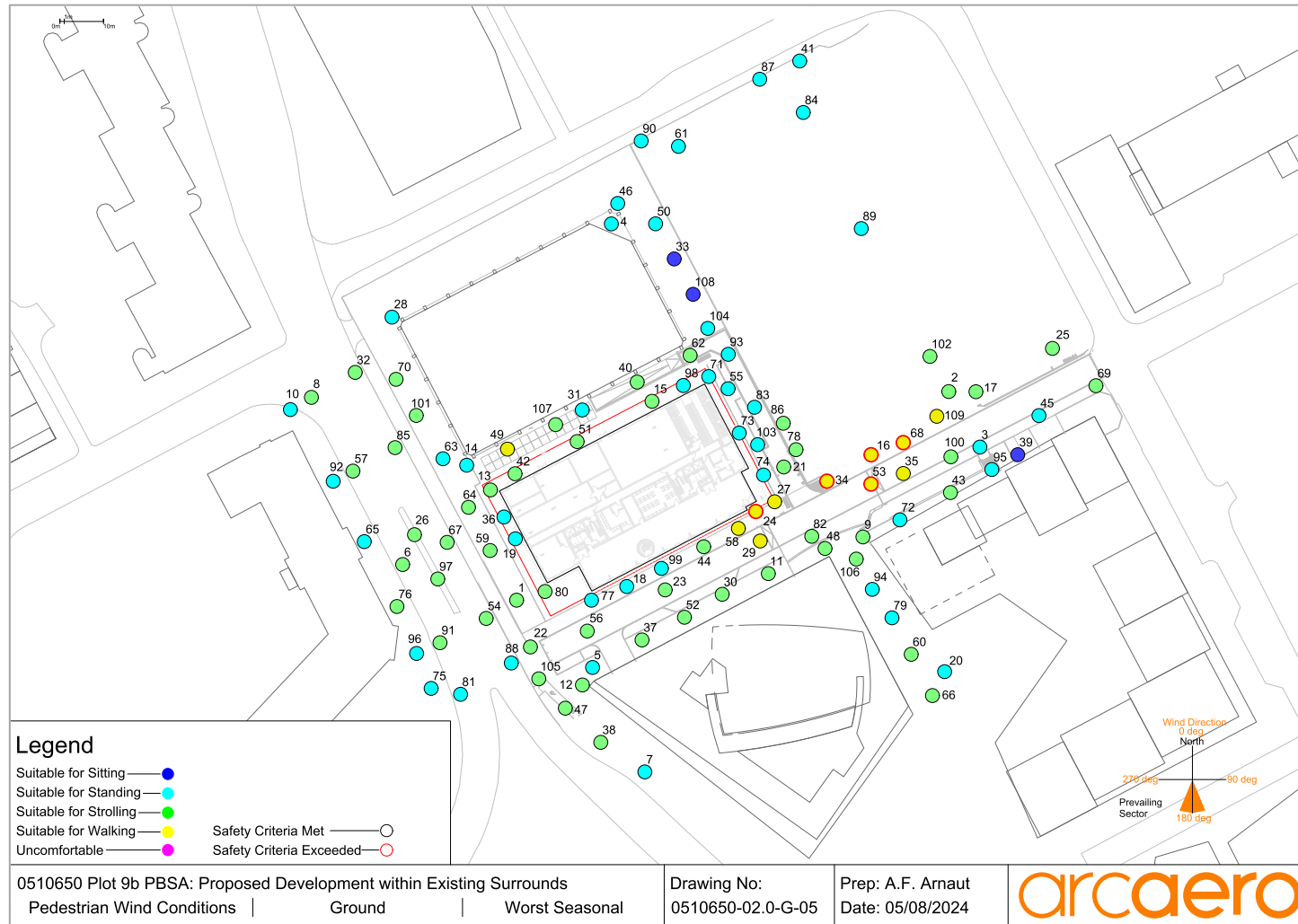


Figure 4.4 – Pedestrian wind conditions, proposed development within existing surrounds, 'worst' season – elevated levels

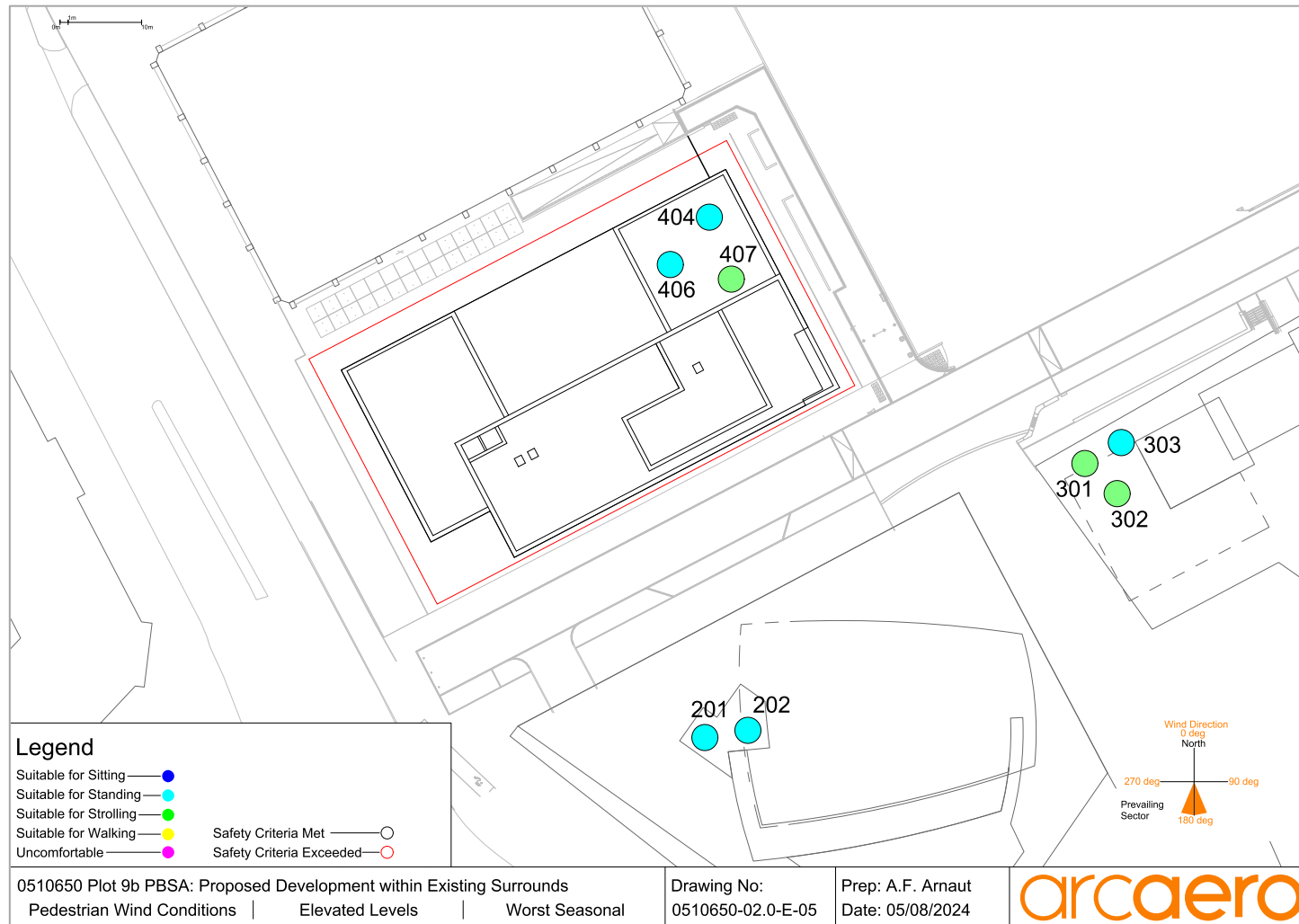


Figure 4.5 - Pedestrian wind conditions, proposed development within existing surrounds, summer – ground level

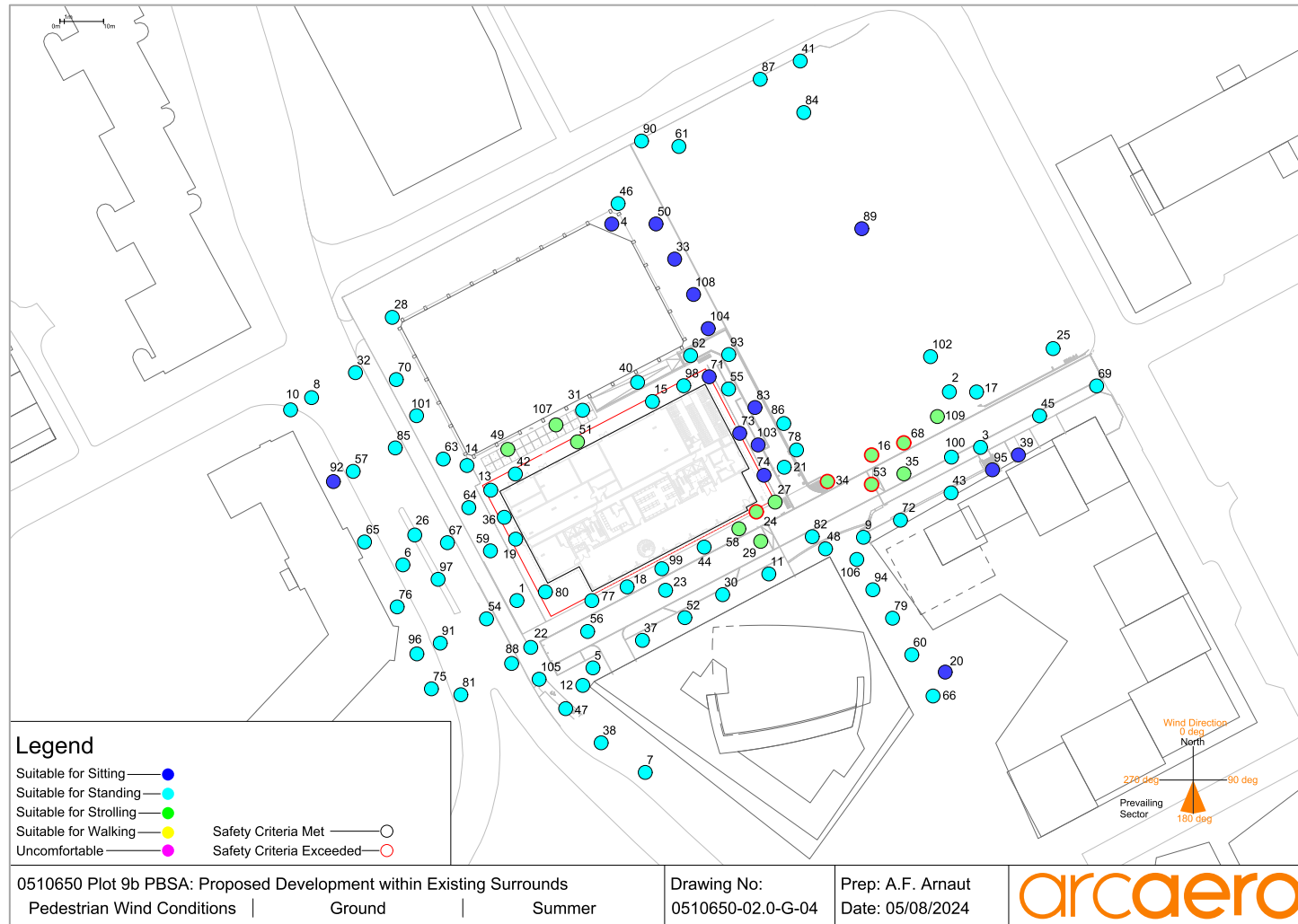


Figure 4.6 – Pedestrian wind conditions, proposed development within existing surrounds, summer – elevated levels

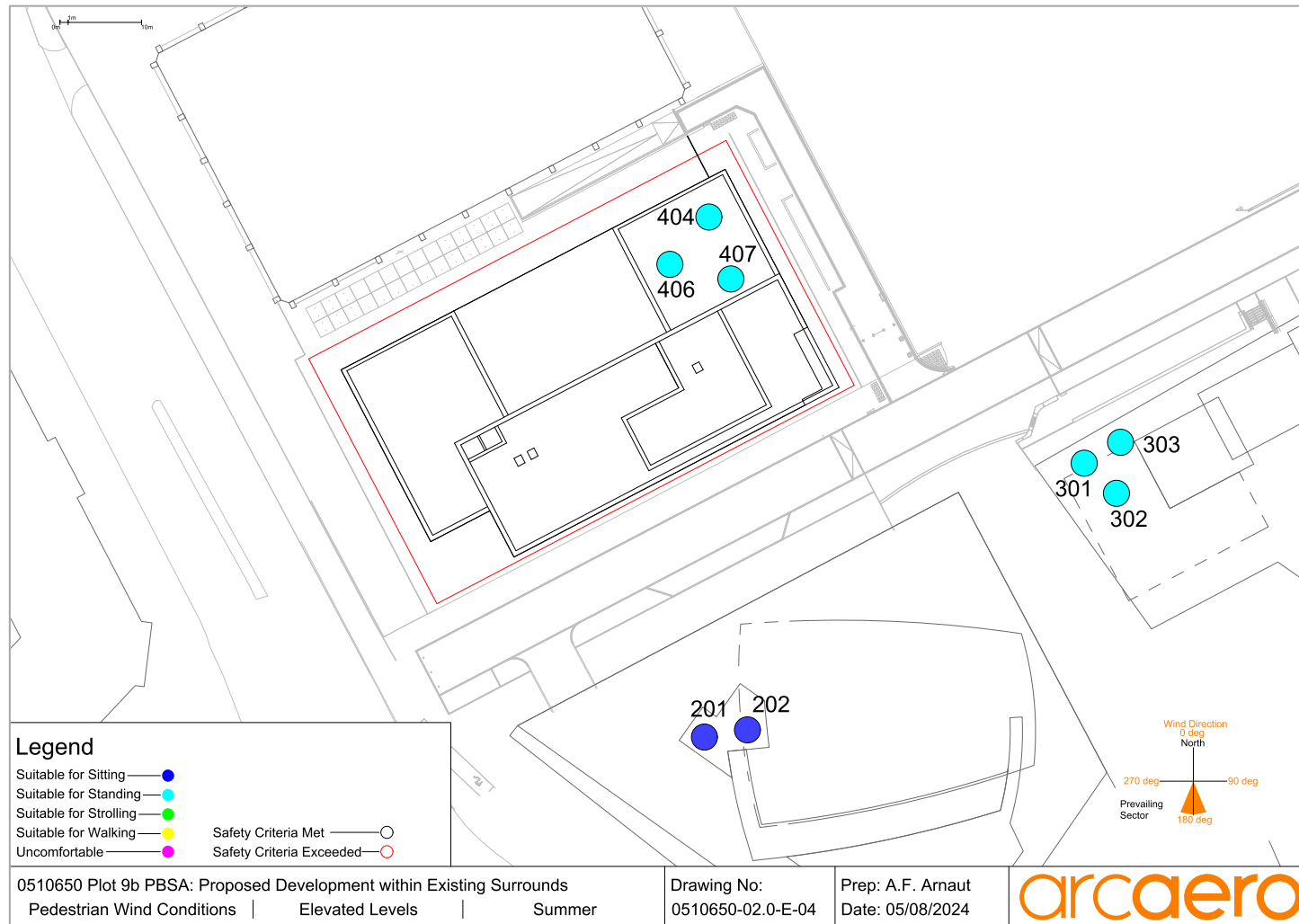


Figure 4.7 - Pedestrian wind conditions, proposed development within cumulative surrounds, 'worst' season – ground level

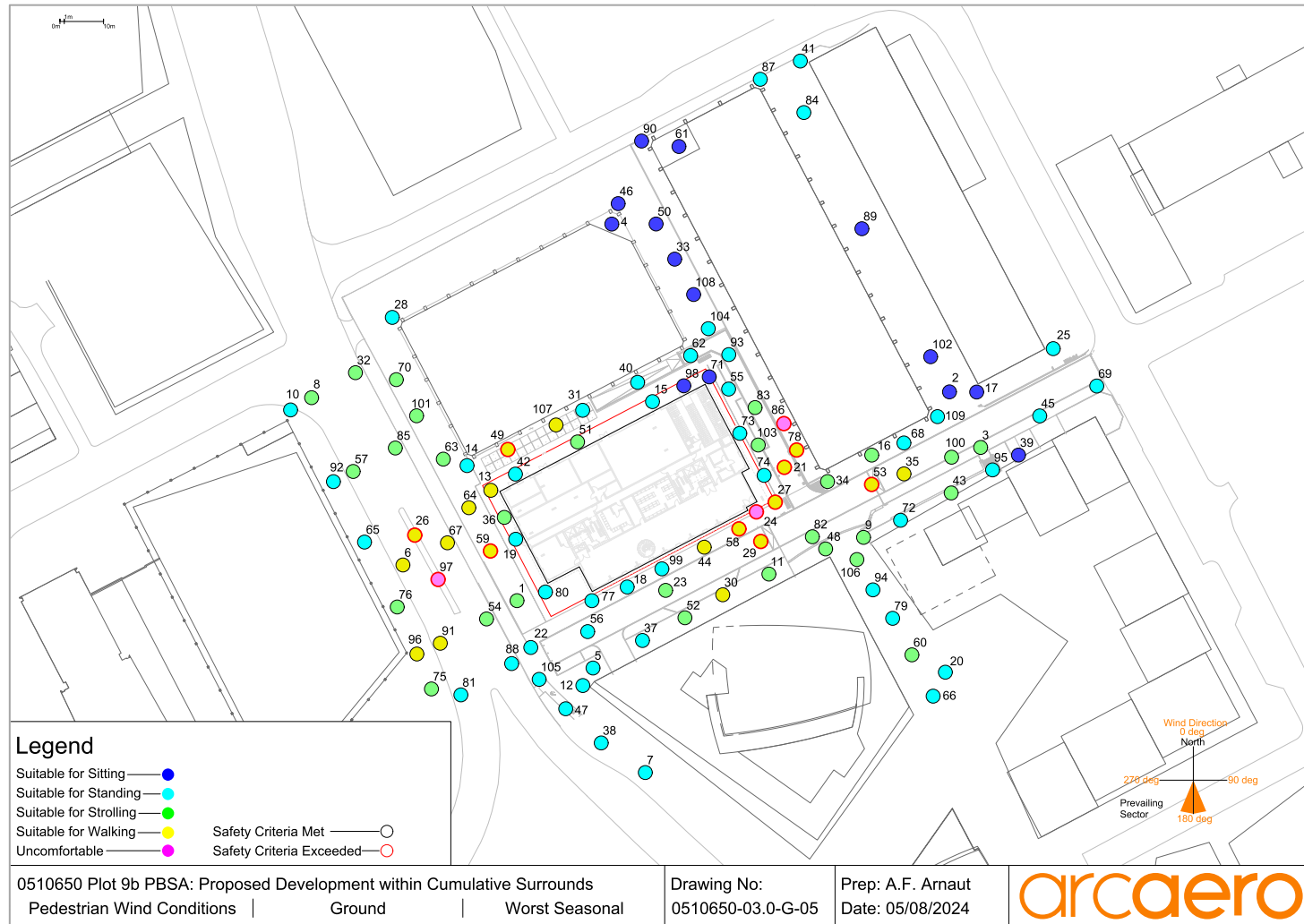


Figure 4.8 – Pedestrian wind conditions, proposed development within cumulative surrounds, 'worst' season – elevated levels

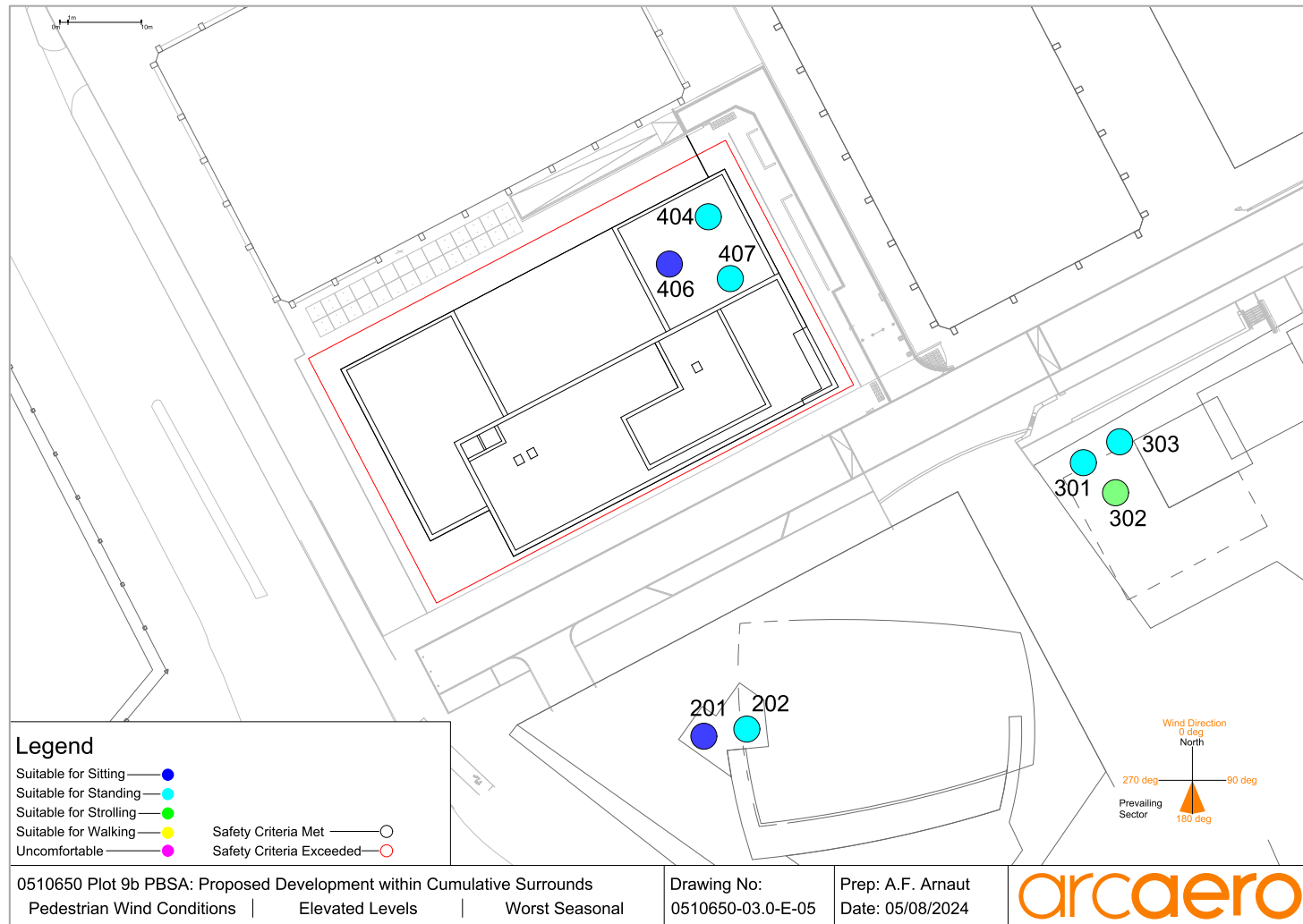


Figure 4.9 - Pedestrian wind conditions, proposed development within cumulative surrounds, summer – ground level

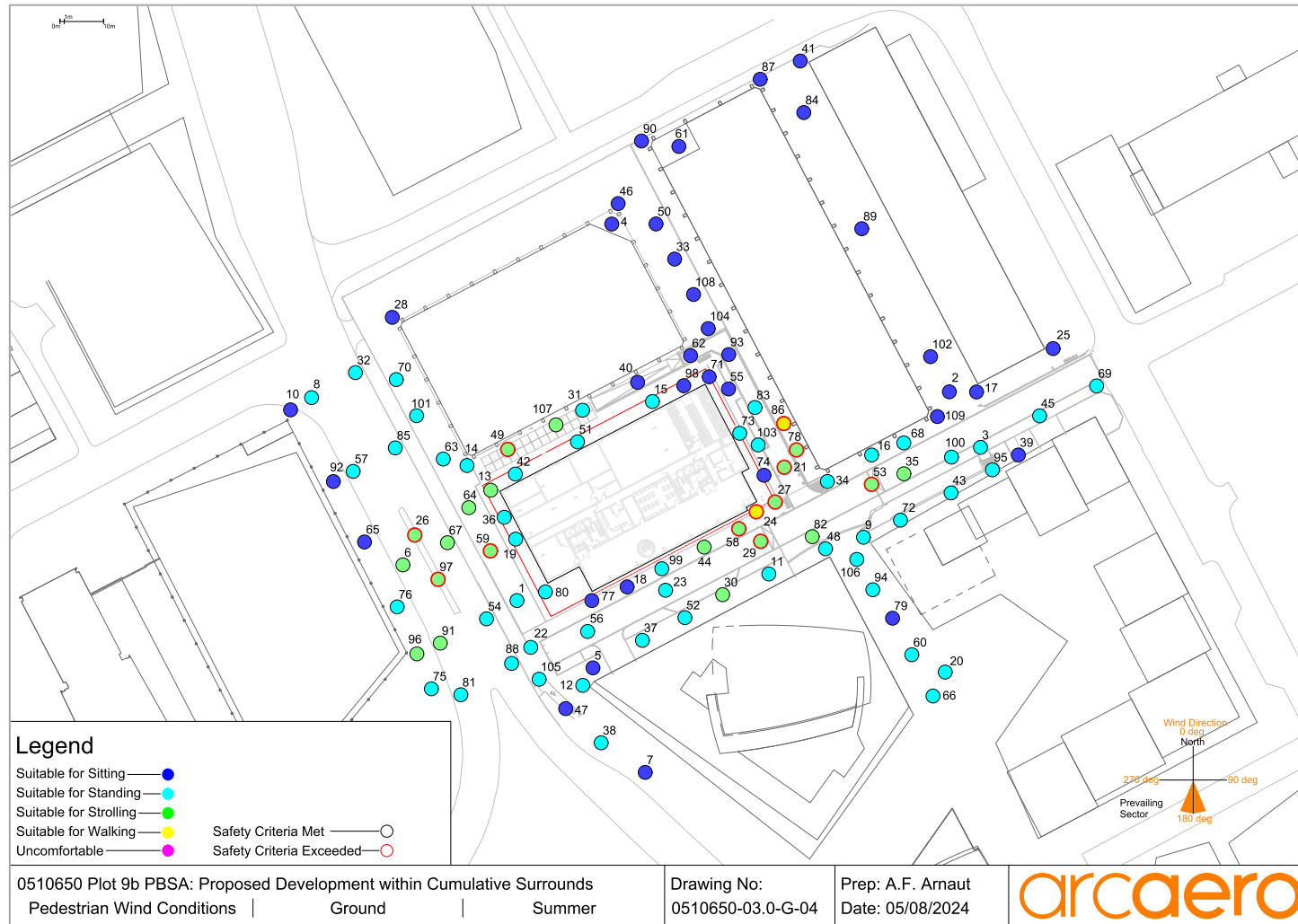


Figure 4.10 – Pedestrian wind conditions, proposed development within cumulative surrounds, summer – elevated levels

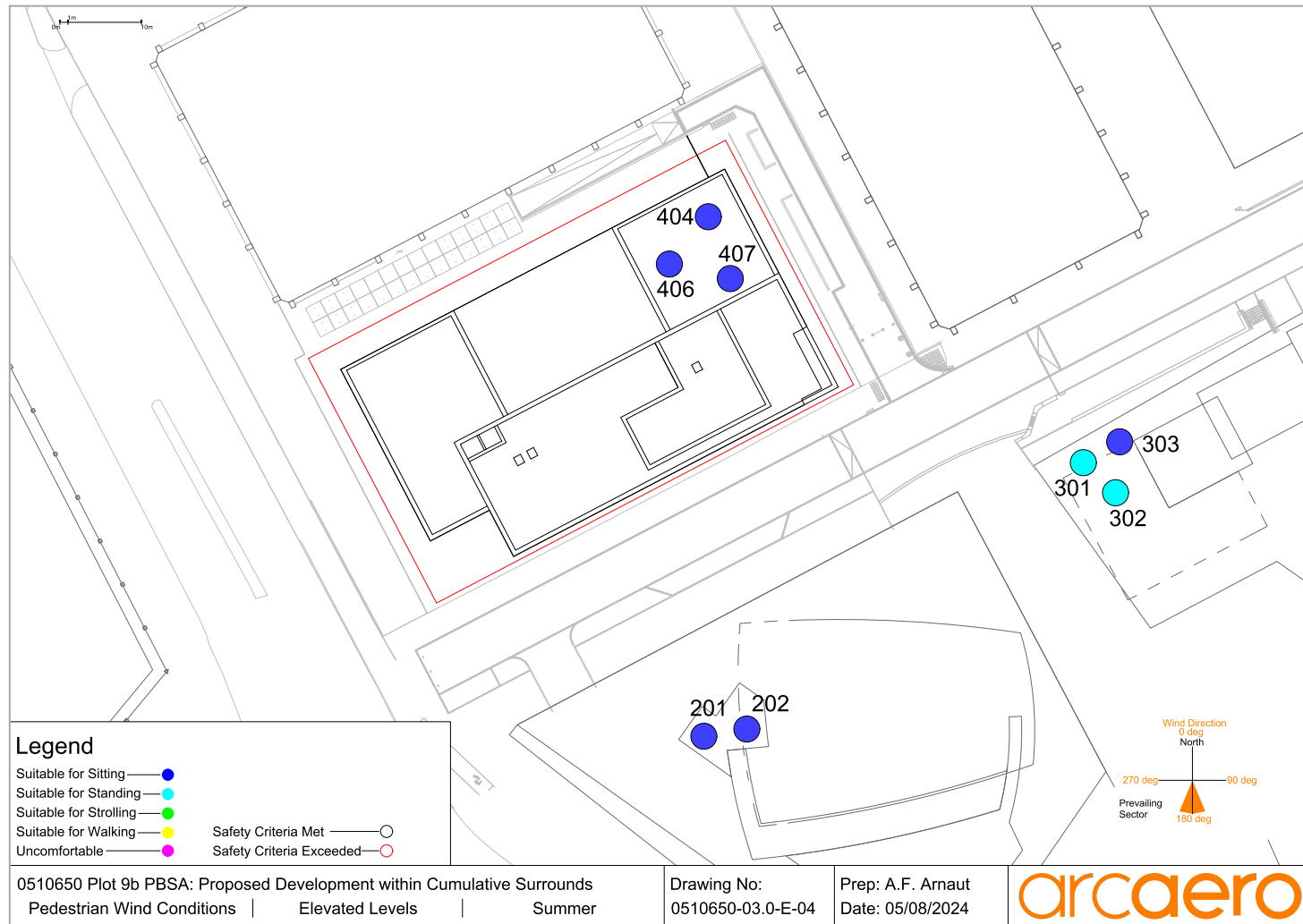


Figure 4.11 - Pedestrian wind conditions, proposed development with mitigation within cumulative surrounds, 'worst' season – ground level

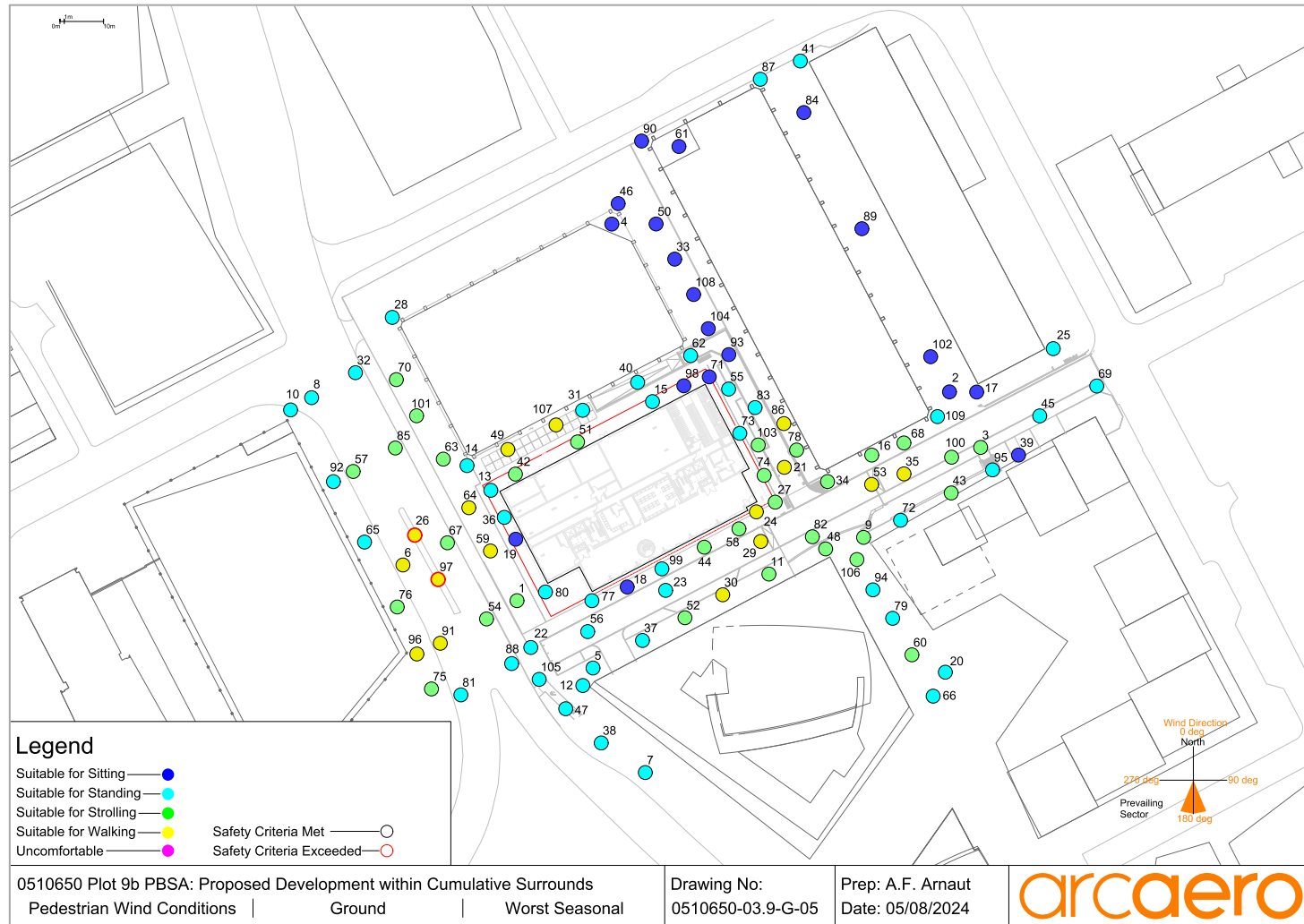


Figure 4.12 – Pedestrian wind conditions, proposed development with mitigation within cumulative surrounds, 'worst' season – elevated levels

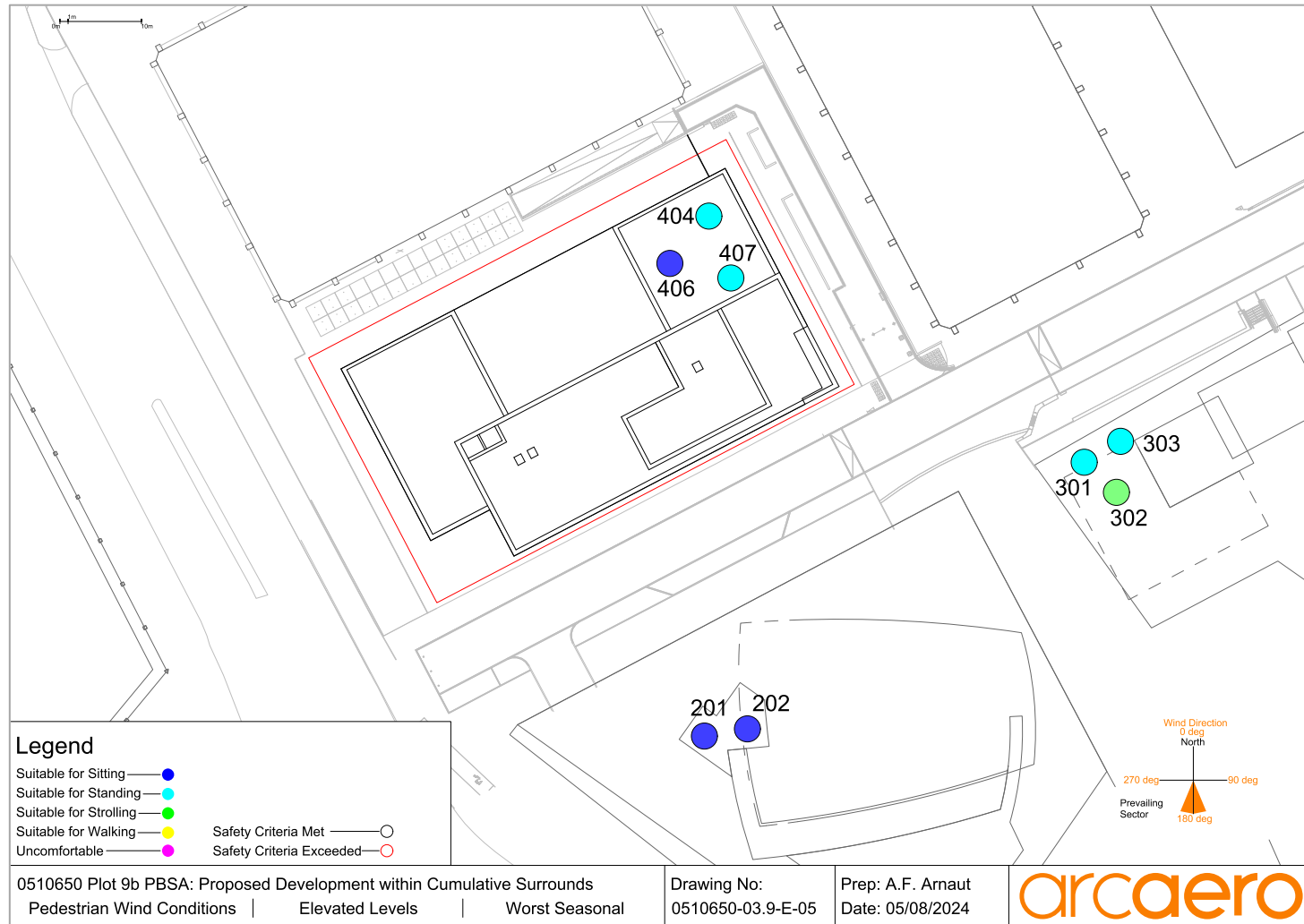


Figure 4.13 - Pedestrian wind conditions, proposed development with mitigation within cumulative surrounds, summer – ground level

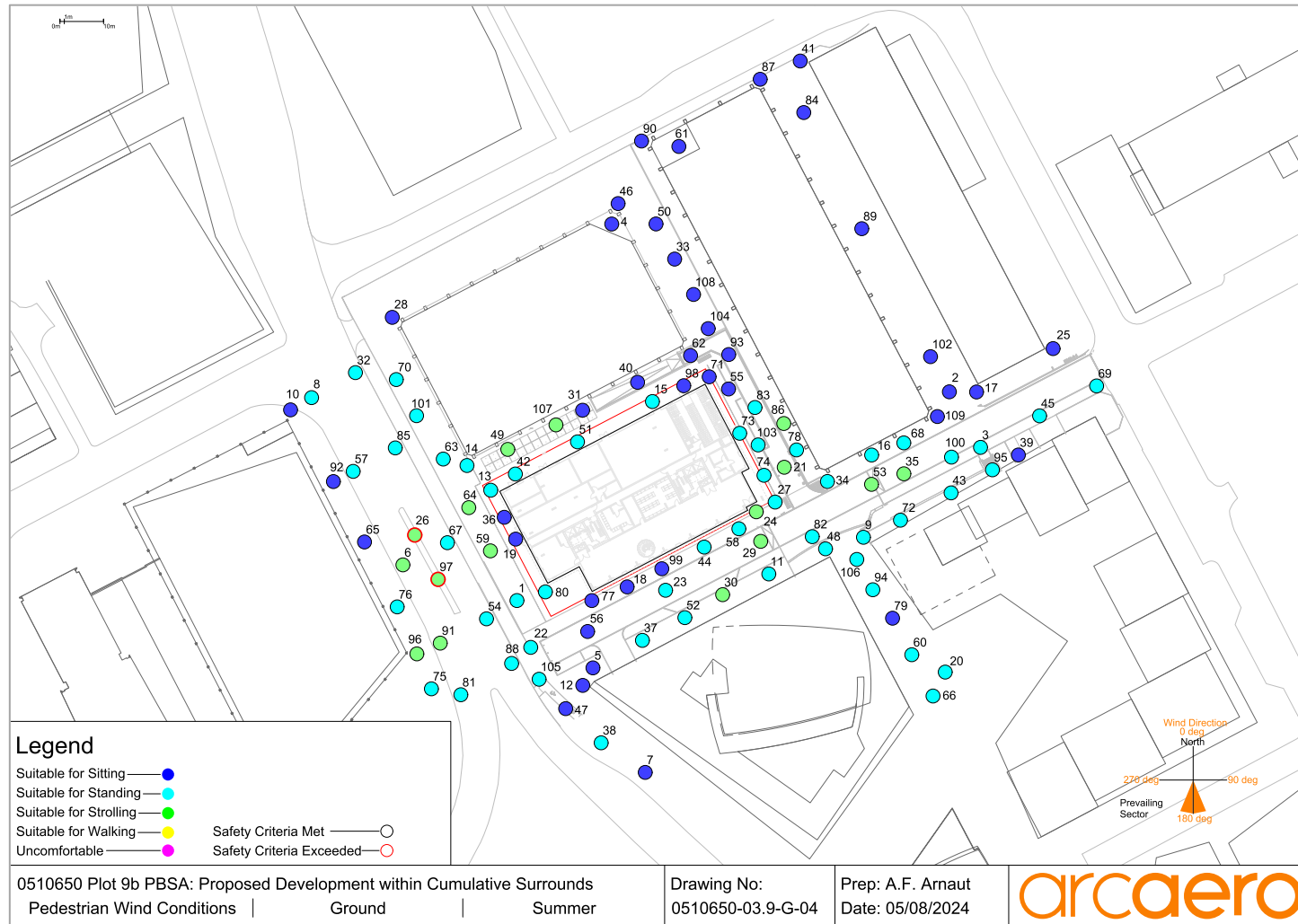


Figure 4.14 – Pedestrian wind conditions, proposed development with mitigation within cumulative surrounds, summer – elevated levels

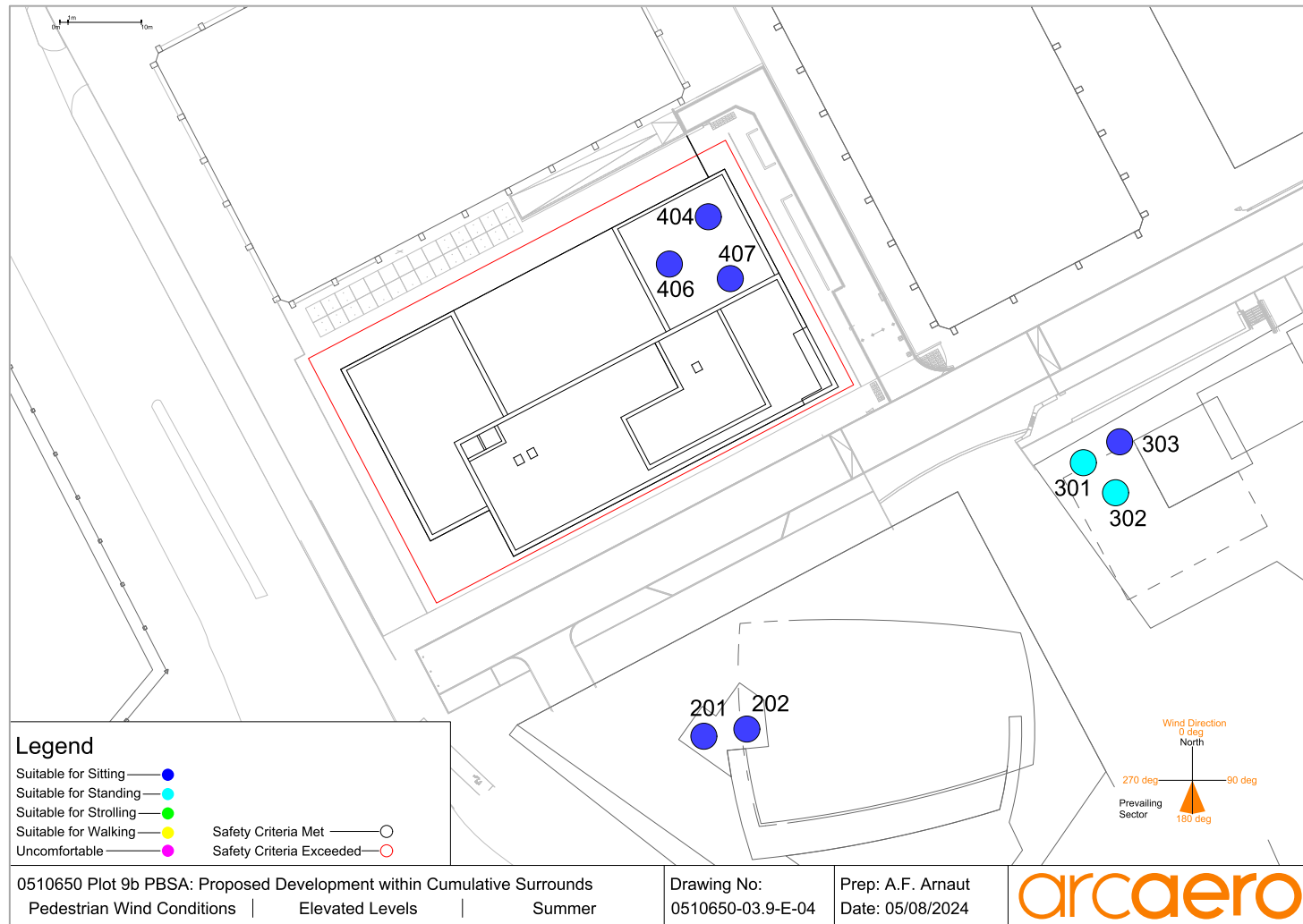
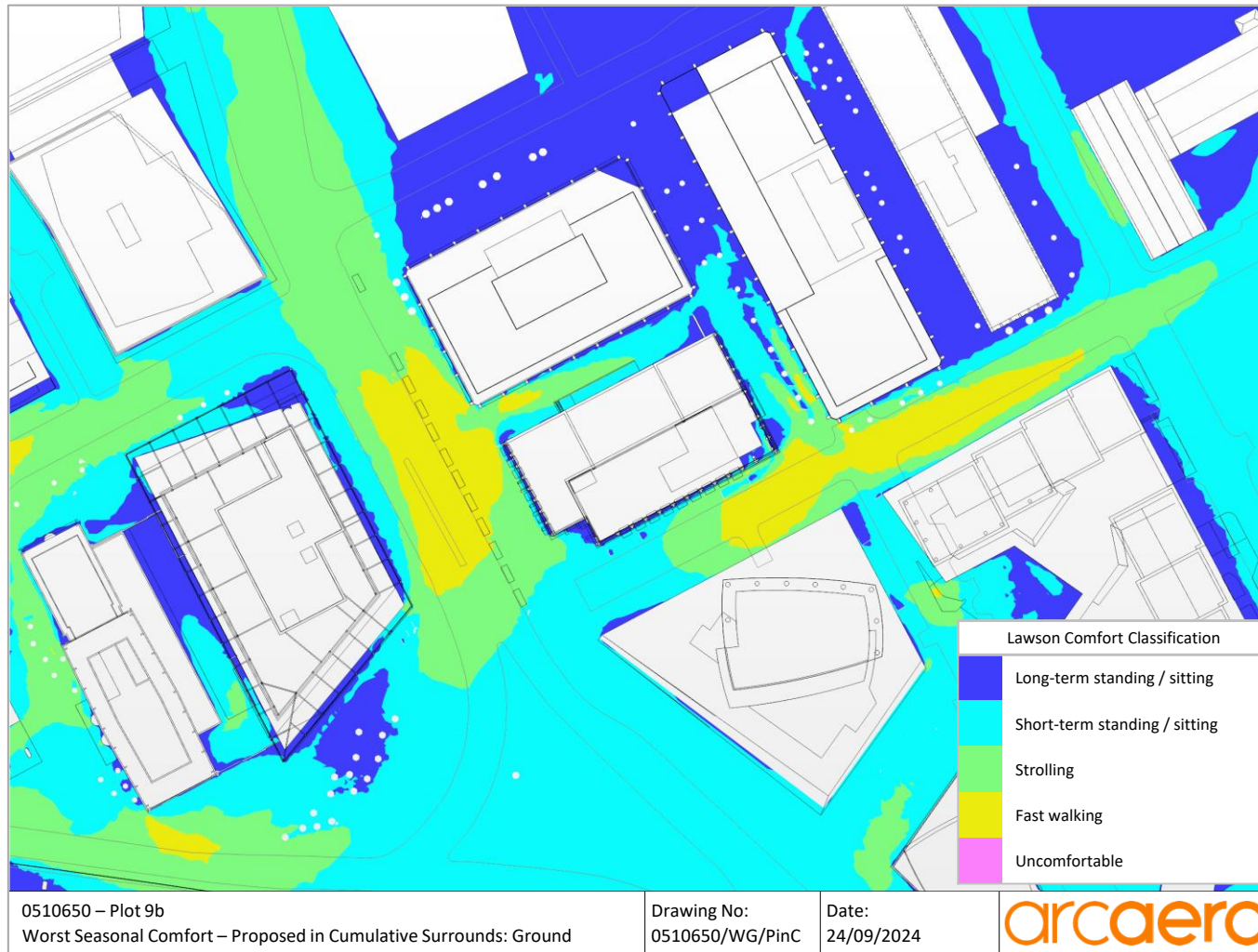


Figure 5.1 - CFD Results, proposed development (31 storeys) in cumulative surrounds, worst-seasonal, ground



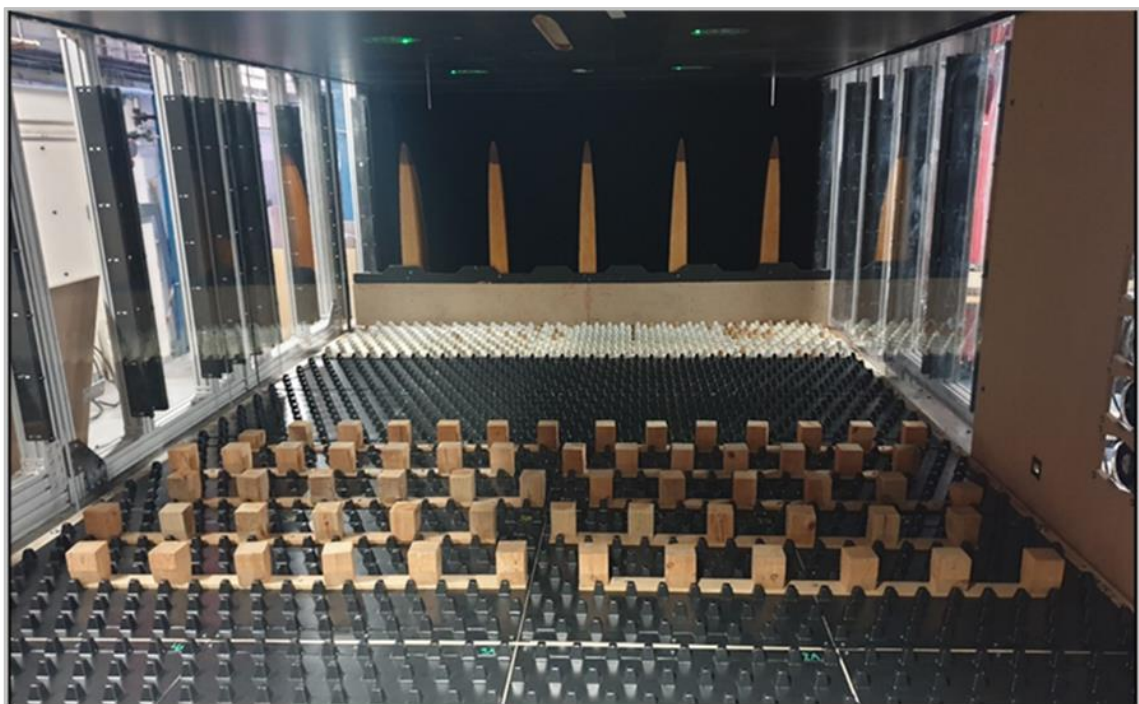
Appendix A Wind Tunnel and Model

A.1 Atmospheric Boundary Layer Modelling

The study was conducted at the Imperial College wind tunnel in London. This closed-loop facility provides a 20-metre-long boundary layer test section and a 3.0 metre x 1.5 metre test section. The wind speed operating range is 0-40 m/s.

'Roughness blocks', a 2D fence and 3D posts were used to replicate the boundary layer. These elements are presented Figure A.1.

Figure A.1 - Boundary layer creation, Imperial College, London.



A.2 Wind Tunnel Models

A 1:300 scale wind tunnel was constructed from materials such as dense foam, wood and plastic. The wind microclimate was assessed at a total of 123 locations for the proposed development.

Photos of the wind tunnel model are presented as follows:

- Figure A.2 and Figure A.3: existing site conditions
- Figure A.4 and Figure A.5: proposed development within existing surrounds
- Figure A.6 and Figure A.7: proposed development within cumulative surrounds
- Figure A.8 and Figure A.9: proposed development with mitigation within cumulative surrounds

- Figure A.10 and Figure A.11: close-ups of proposed development

Figure A.2 – Existing site conditions, viewed from north

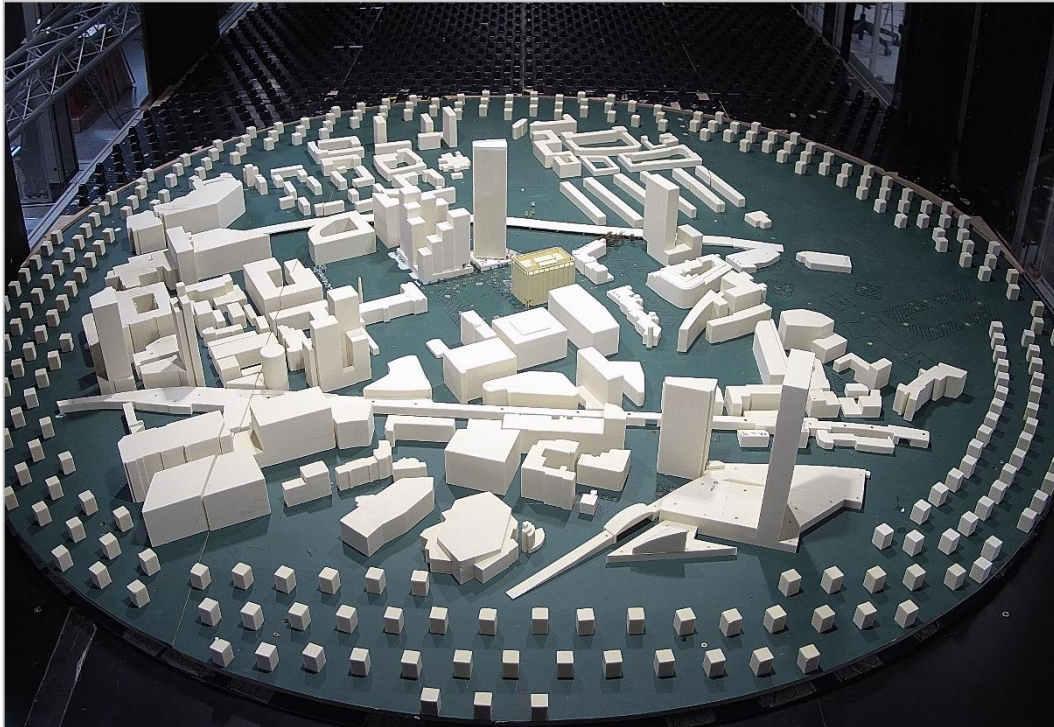


Figure A.3 - Existing site conditions, viewed from south

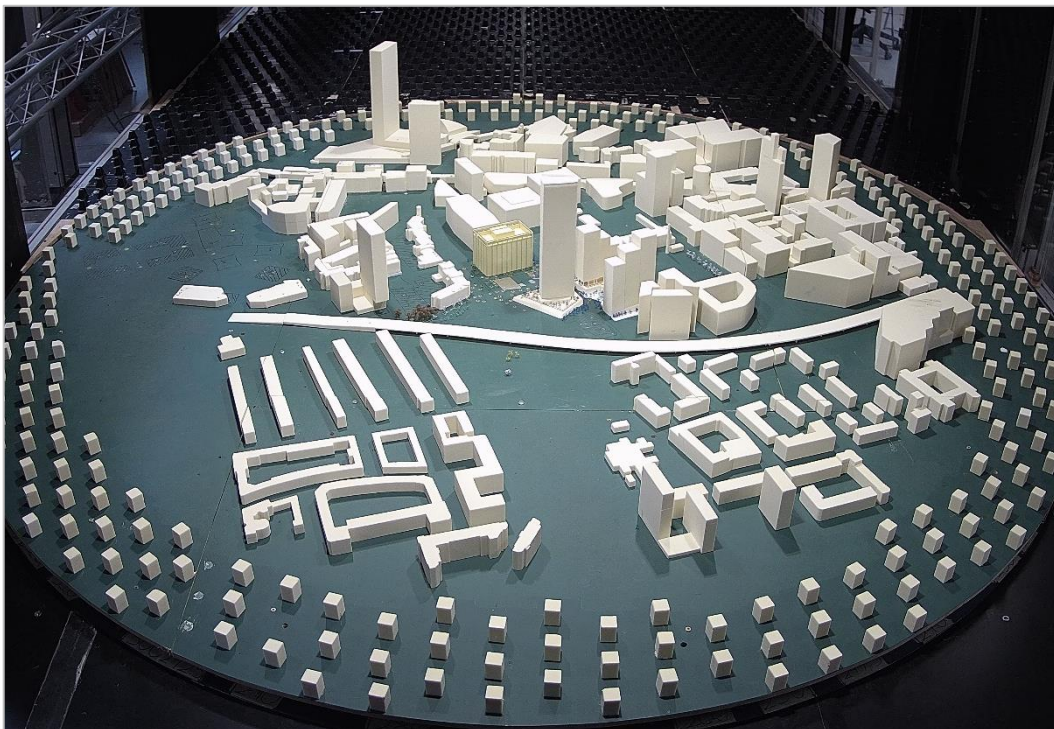


Figure A.4 - Proposed development within existing surrounds, viewed from north

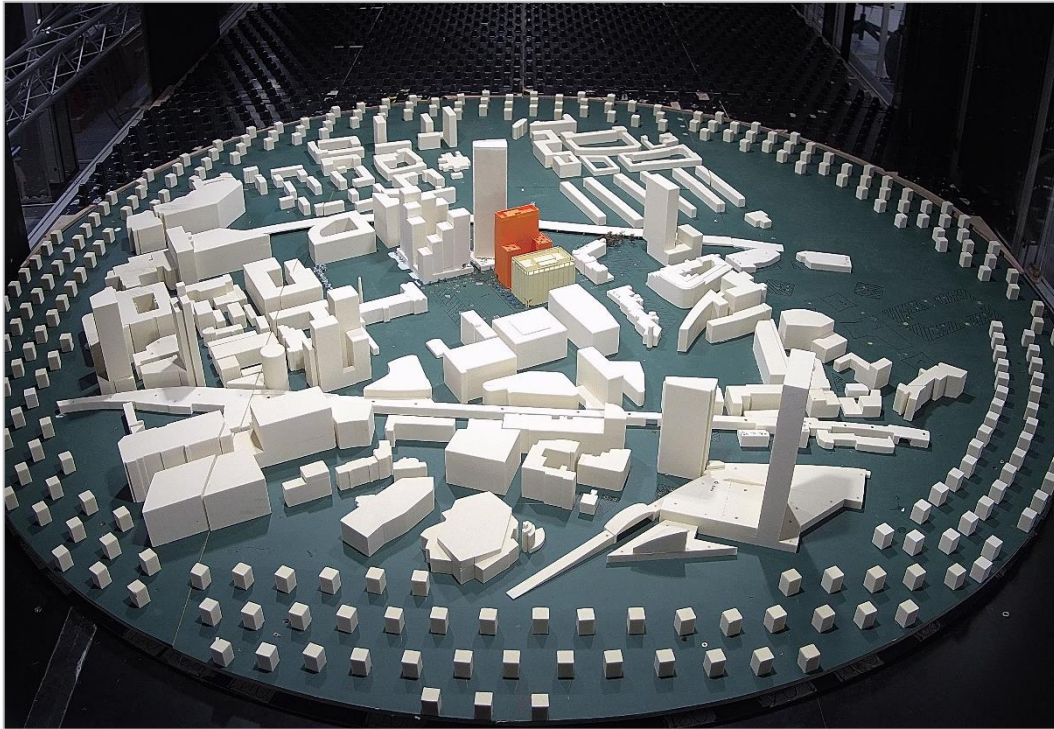


Figure A.5 - Proposed development within existing surrounds, viewed from south

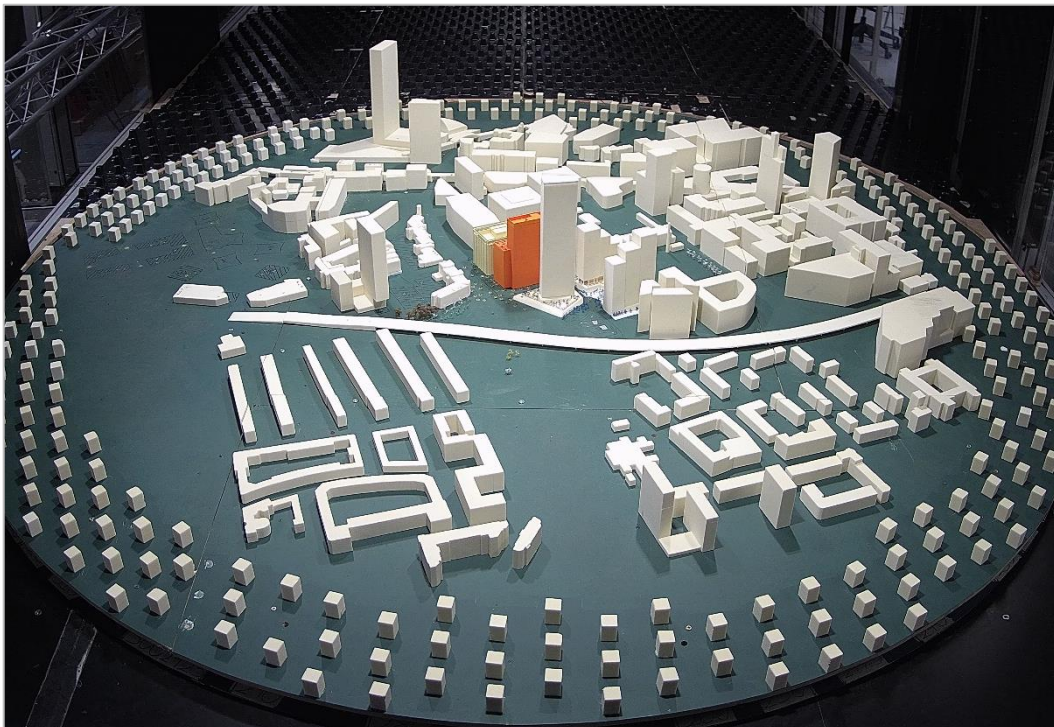


Figure A.6 – Proposed development within cumulative surrounds, viewed from north

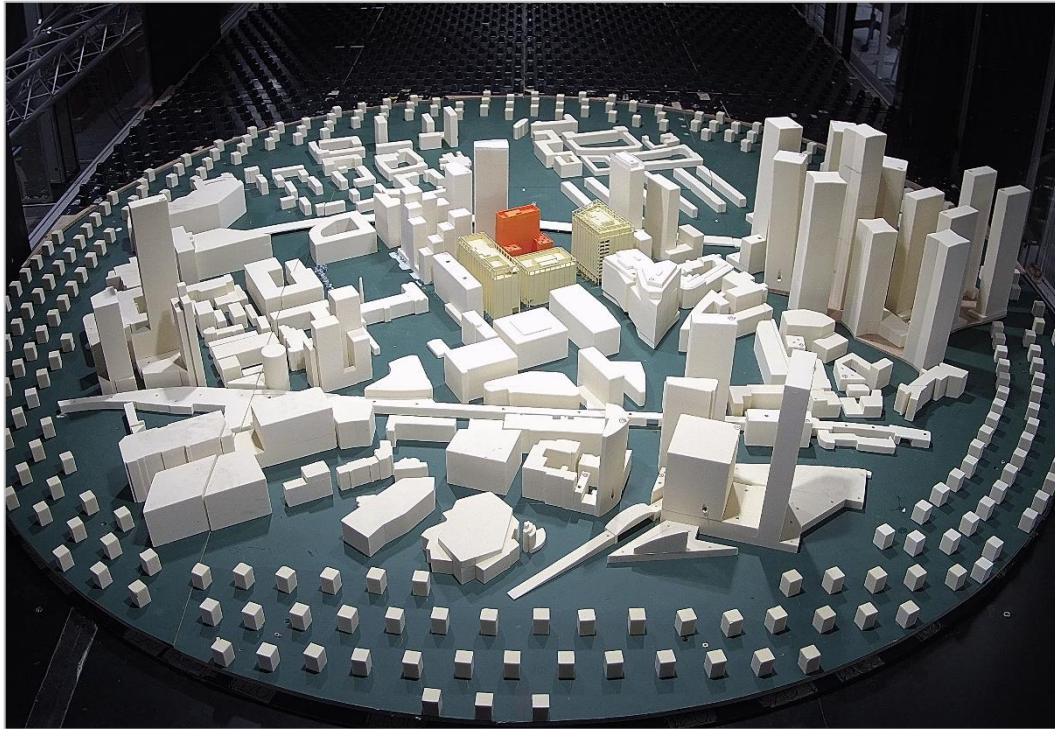


Figure A.7 – Proposed development within cumulative surrounds, viewed from south

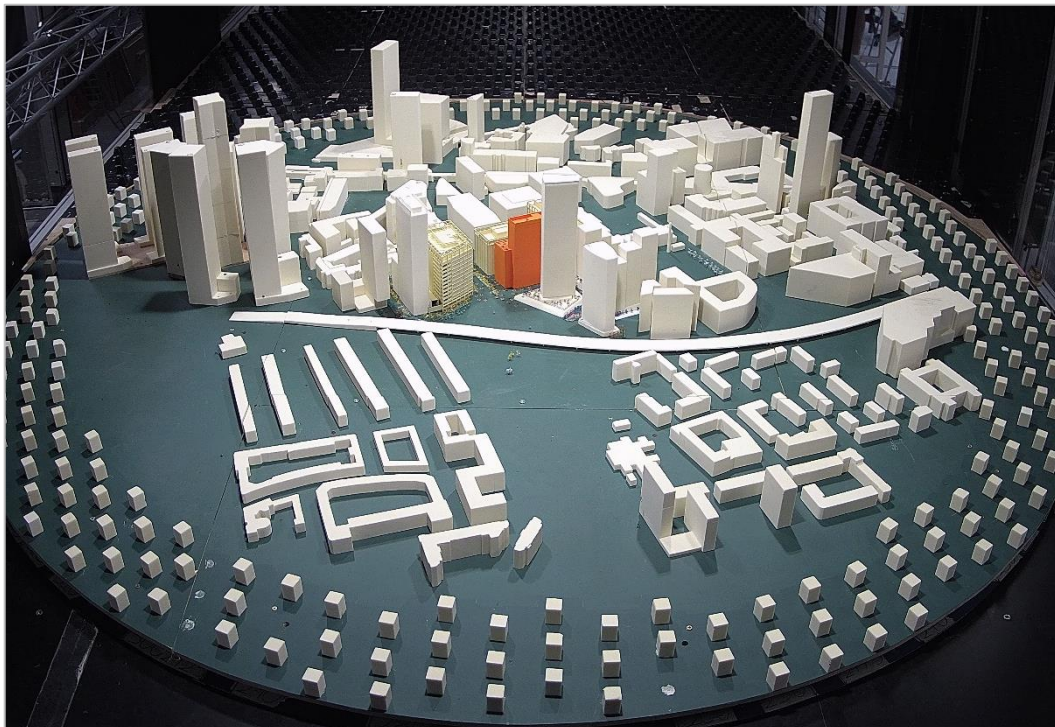


Figure A.8 – Proposed development with mitigation within cumulative surrounds, viewed from north

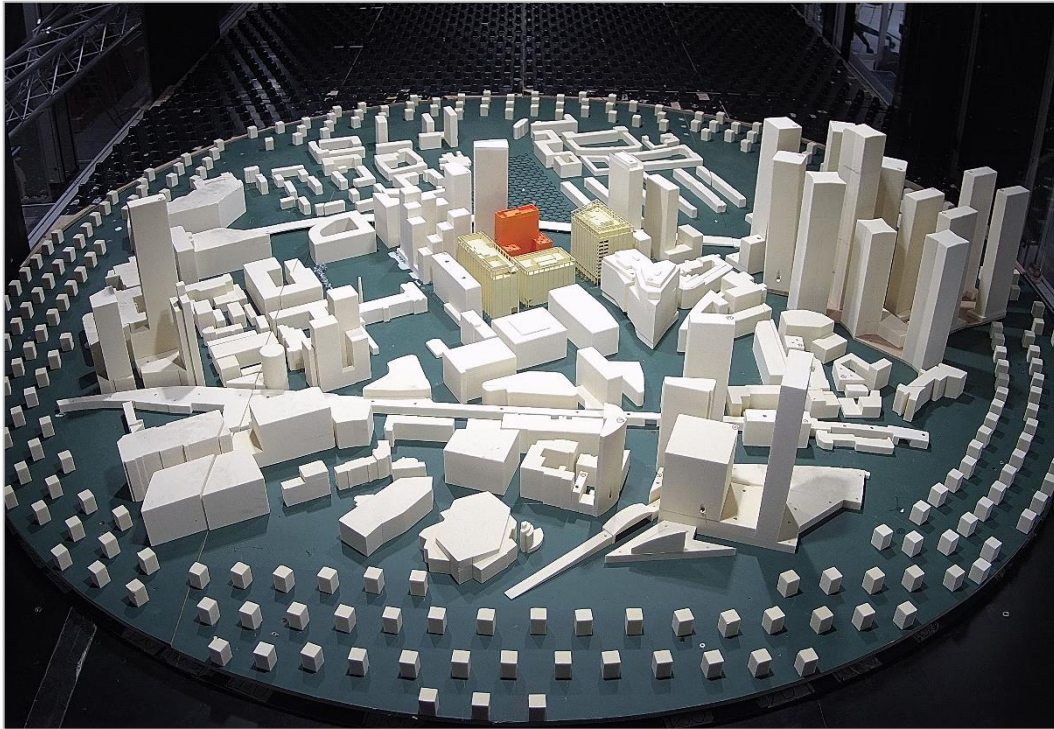


Figure A.9 – Proposed development with mitigation within cumulative surrounds, viewed from east

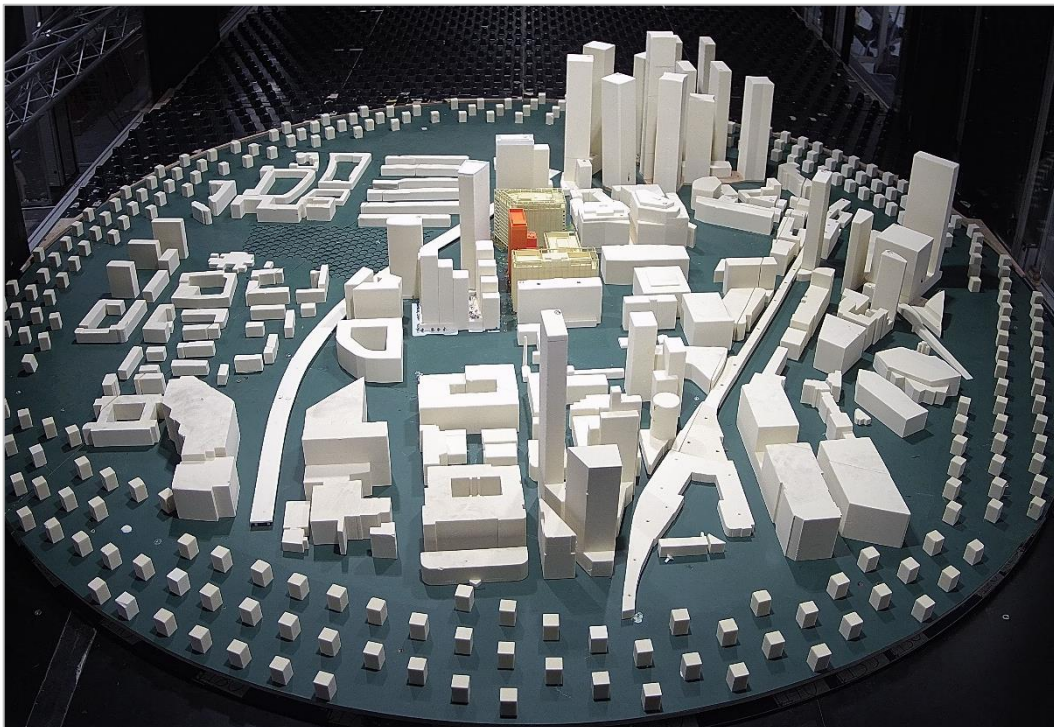


Figure A.10 – Close-up of the proposed development within cumulative surrounds, viewed from northeast

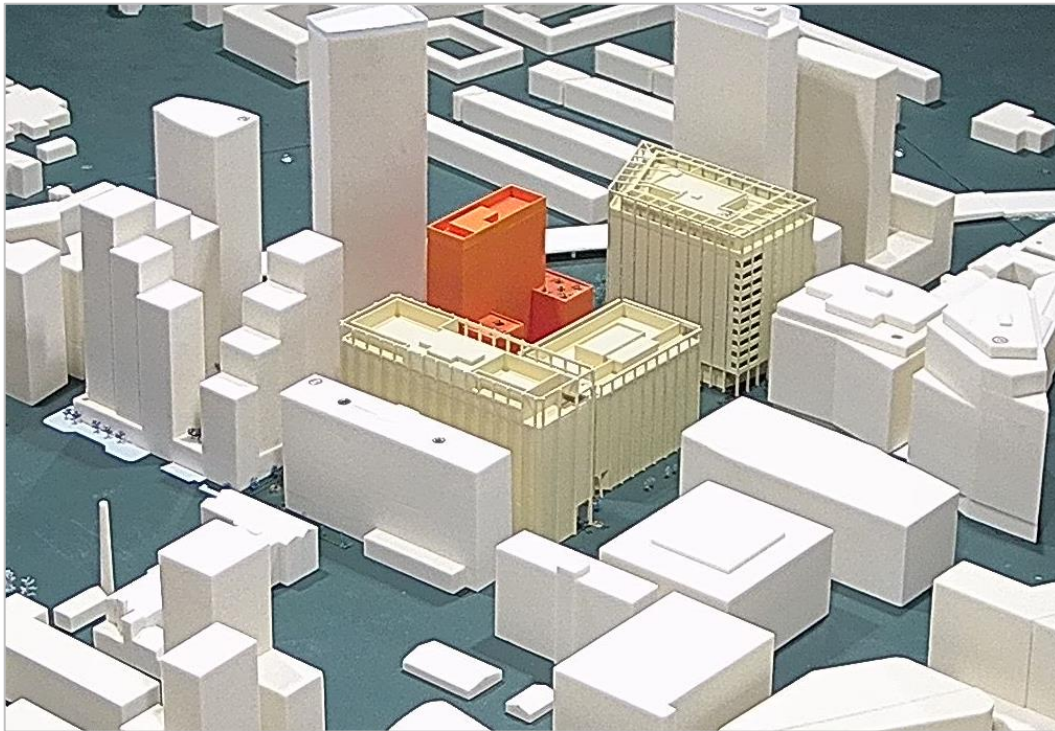
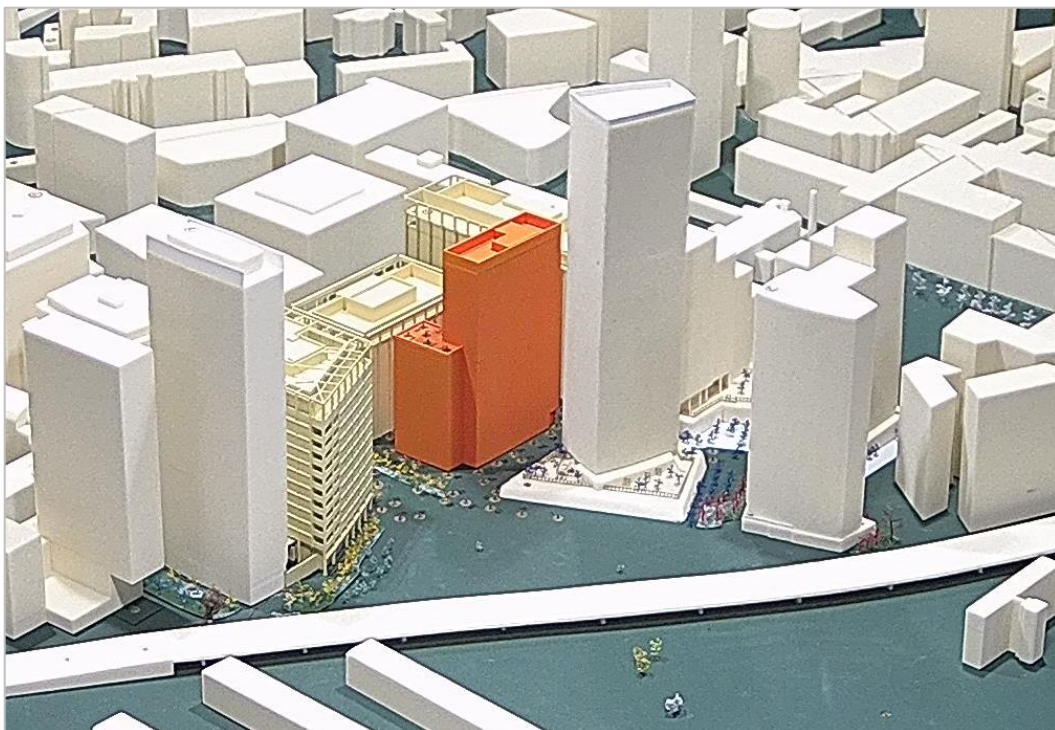


Figure A.11 – Close-up of the proposed development within cumulative surrounds, viewed from southwest



A.3 Data Acquisition

Wind speed measurements were made using 'Irwin probes', capable of measuring fluctuating pressure differences that are calibrated against wind speed. A system of probes running simultaneously was used to obtain results from approximately 123 locations at a height corresponding to 1.5m at full scale.

Data was recorded for a sufficient length of time to determine the mean and 3-second gust wind speeds.

The gust wind speed is translated to an equivalent mean wind speed, the Gust Equivalent Mean or GEM, according to the following equation:

$$U_{GEM} = \frac{U_{GUST}}{1.85}$$

The results at each location were combined with wind statistics transposed to the site to assess the exceedance of threshold wind speeds that relate to comfort and safety in accordance with the Lawson criteria.

Appendix B CFD Modelling

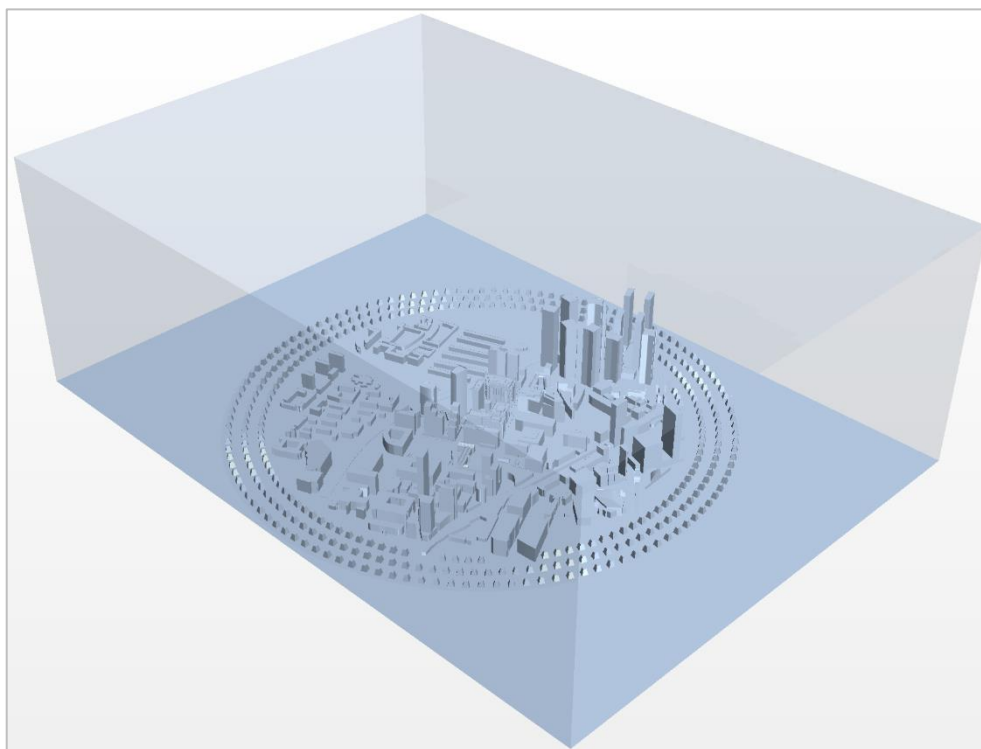
B.1 Spatial discretization

The computational domain was discretised using polyhedral cells for the core mesh, and low aspect-ratio prism cells adjacent to walls and the ground. Computational meshes were constructed for each of the three different study configurations.

The computational domain includes the proposed development site, with surrounding buildings and topographical features within a 450m radius represented explicitly. The full computational domain extends to 1500m in the along-wind direction, 1100m in the across-wind direction, and 450m vertically.

The proposed development and immediate vicinity were meshed down to a cell size of 0.2m in order to capture the detailed geometric features and resulting flow artefacts. The pedestrian ground level surfaces were meshed with a prism layer mesh of 5 layers, which, in the vicinity of the building rise up to a total height of 1.5m above the ground.

Figure B.1 – Computational Domain



B.2 Solution Method

The modelling of an incompressible fluid flow was completed with combinations of semi-implicit method for pressure-linked equations (SIMPLE) algorithms. The resulting flow turbulent features were modelled with introduction of the Shear Stress Transport (SST) $k-\omega$ turbulence model. This model was suggested by Menter (5) and is based on a two-equation eddy-viscosity

approach, where the SST model formulation combines the use of a $k-\omega$ in the inner parts of the boundary layer, but also switches to a $k-\epsilon$ behaviour in the free-stream regions of the solutions. Further details for the selected turbulence model are provided in the work of Menter (6).

B.3 Initial and Boundary Conditions

The atmospheric boundary layer flow was simulated by implementing a logarithmic velocity profile model presented by Richards and Hoxey (7), with the following main assumptions:

- The vertical velocity component at the domain boundary is negligible
- The pressure gradient and shear stress are constant

The model implies the following equation for the mean inlet velocity at the CFD domain:

$$U(z) = \frac{U^*}{\kappa} \cdot \ln\left(\frac{z + z_0}{z_0}\right)$$

where:

- κ - is the von Karman's constant
- z - is the distance from the ground surface in vertical direction
- z_0 - is the ground surface roughness length in meters

The friction velocity U^* is calculated by the following equations:

$$U^* = \kappa \cdot \frac{U_{ref}}{\ln\left(\frac{z_{ref} + z_0}{z_0}\right)}$$

where:

- z_{ref} – is the reference height in metres
- U_{ref} - is the reference velocity in m/s measured at z_{ref}

The turbulent velocity fluctuations at the domain inlet are induced by the constant shear stress with height, maintained by the turbulent kinetic energy k equation below:

$$k(z) = \frac{(U^*)^2}{\sqrt{C_\mu}}$$

where:

- $C_\mu = 0.03$ - is a $k-\epsilon$ turbulence model constant

All surface boundary conditions were modelled as smooth walls with a no-slip condition. A no-slip wall boundary condition with a varying roughness length height based on the terrain

analysis for the site was applied on the ground surface outside the explicit surrounds area of the domain.

B.4 Gust Equivalent Mean Calculation

The gusts in the wind flow is a major component that may lead to additional danger and discomfort to that caused by the mean wind flow. Thus, the gust wind speed is accounted by a calculation of the equivalent mean wind speed, considering the standard deviation of the mean wind speed, in particular the turbulent kinetic energy, k :

$$\sigma = \sqrt{(k * 2/3)}$$

The GEM is then calculated as:

$$U_{GEM} = \frac{U_{Mean} + 3.5\sigma}{k_g}$$

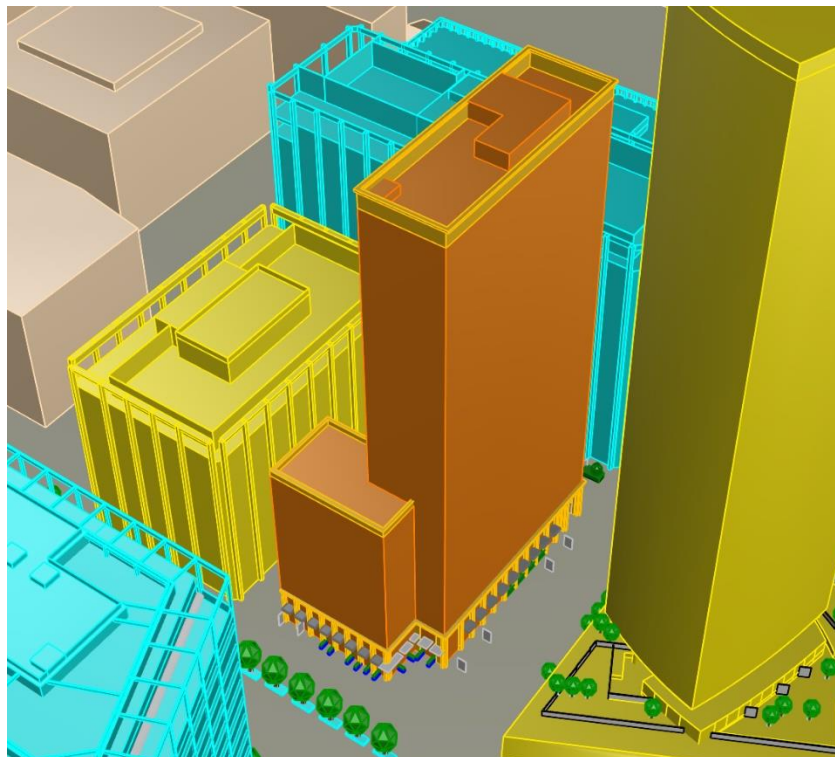
Where gust factor, $k_g = 1.85$

The final speedup used in the Lawson criteria is the worst case from U_{GEM} and U_{Mean} .

B.5 Digital Model

The digital model prepared for CFD analysis are presented within Figure B.2.

Figure B.2 – Digital model for CFD analysis.



Appendix C Wind Climate Analysis

C.1 Wind Frequency Data, Manchester Airport

Wind microclimate studies require that wind speed data obtained from a measurement station be transposed to the site of interest. The current study employs wind data from Manchester airport.

The wind speed history has been reformatted into the number of observations of mean-hourly wind speeds within each of several wind speed ranges, for each wind direction and for each month of the year. To facilitate the transposition of the wind data, the months are grouped into the seasons and a Weibull distribution is fitted to the wind speed distribution for each wind direction, for each season.

From the Weibull cumulative distribution, the probability that, for a given wind direction, a wind speed, V , will be exceeded is given by:

$$P(>V) = e^{-\left(\frac{V}{c}\right)^k}$$

where c is the dispersion parameter and k is the shape parameter.

To these parameters is further added the probability, p , of each wind direction occurring. Thus, for each month of the year the probability that a specified wind speed is exceeded for a specified wind direction may be calculated.

The resulting weather centre wind data is transposed to a standard reference terrain category, 'open country terrain', at sea-level, accounting for upwind terrain, topography and altitude for the weather centre. The open country wind data is then transposed to the reference height at the site of the proposed development, accounting for upwind terrain, topography and altitude for the target site.

For the transposition of wind speed data from the weather station to open country, and from open country to the site, the methods set out in ESDU item 01008 (4) (the industry standard) have been employed.

The resulting annual and seasonal directional and wind speed probability distributions at the reference height of 140m, at the proposed site, are given in Figures B.2 to B.6, respectively.

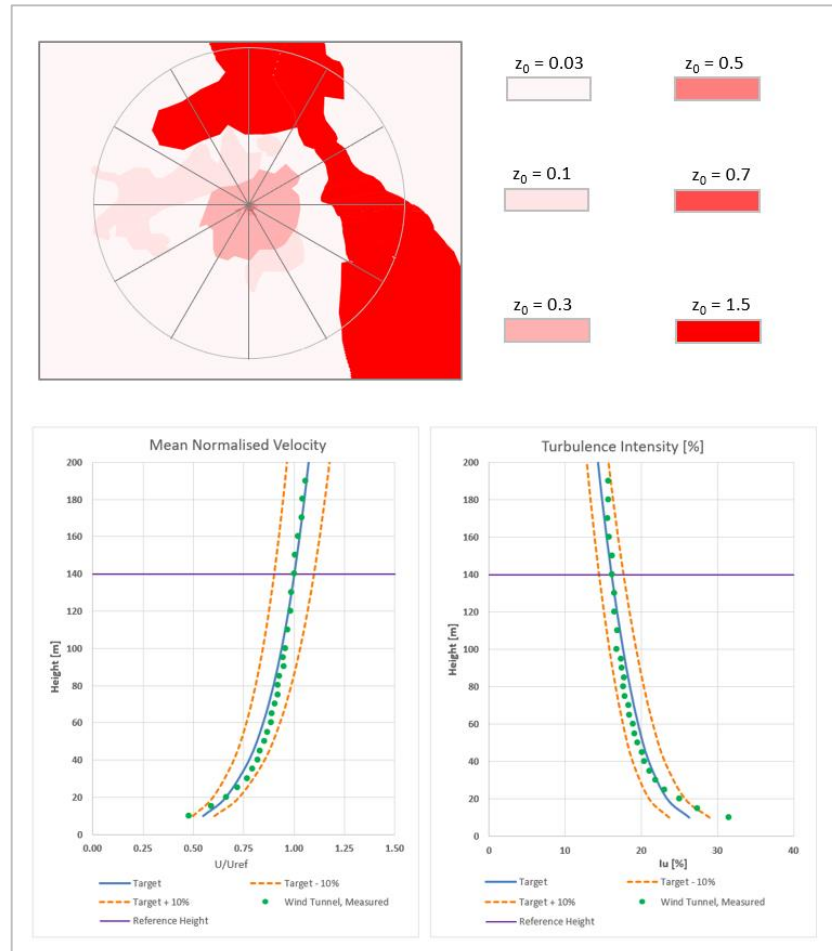
C.2 Wind Properties at the Site

A detailed analysis, based on the widely accepted Deaves and Harris model of the atmospheric boundary layer (ABL), as defined in ESDU Item 01008 (4), has been carried out to determine the wind properties at the site. From this analysis a representative profile was defined as a target for the ABL simulation in the wind tunnel.

Upon conducting the ESDU analysis, one wind profile was replicated in the wind tunnel to adequately account for wind blowing from all angles.

ArcAero's terrain analysis and resulting mean wind speed and turbulence intensity profiles are presented within Figure C.1

Figure C.1 – Target mean wind speed and turbulence intensity profiles and wind tunnel profile



C.3 Wind Frequency Data

Wind microclimate studies require that meteorological data is transposed from a nearby weather station with sufficient wind data to produce accurate wind frequency statistics. The current study uses data from Manchester Airport. The cumulative wind speed probability distributions, transposed to building height at site are provided in Figure C.2 to Figure C.6.

Figure C.2 – Cumulative wind speed probability distribution at site, annual

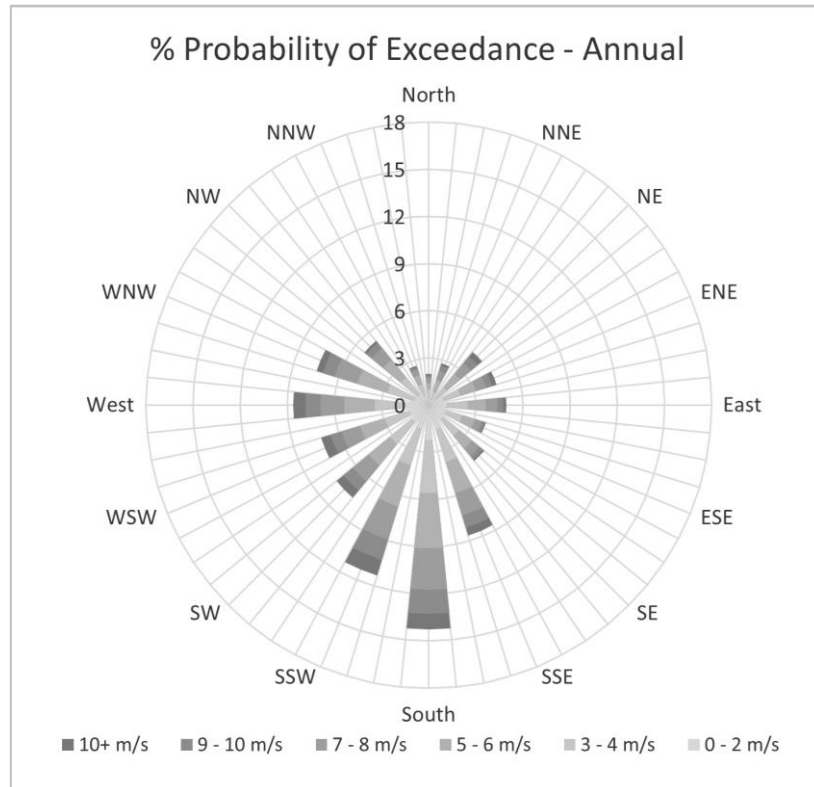


Figure C.3 – Cumulative wind speed probability distribution at site, spring

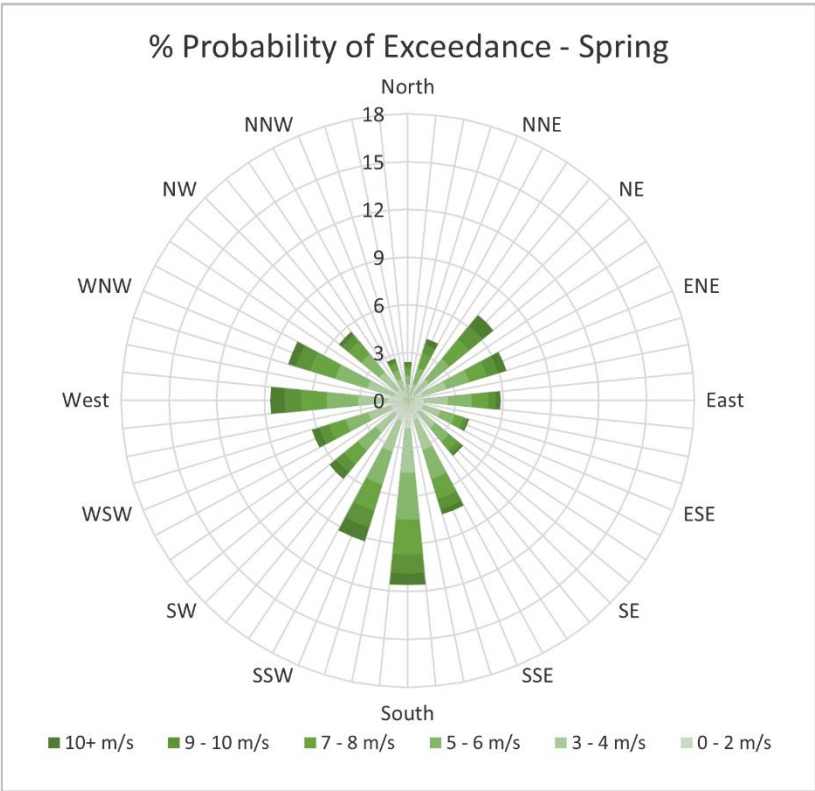


Figure C.4 – Cumulative wind speed probability distribution at site, summer

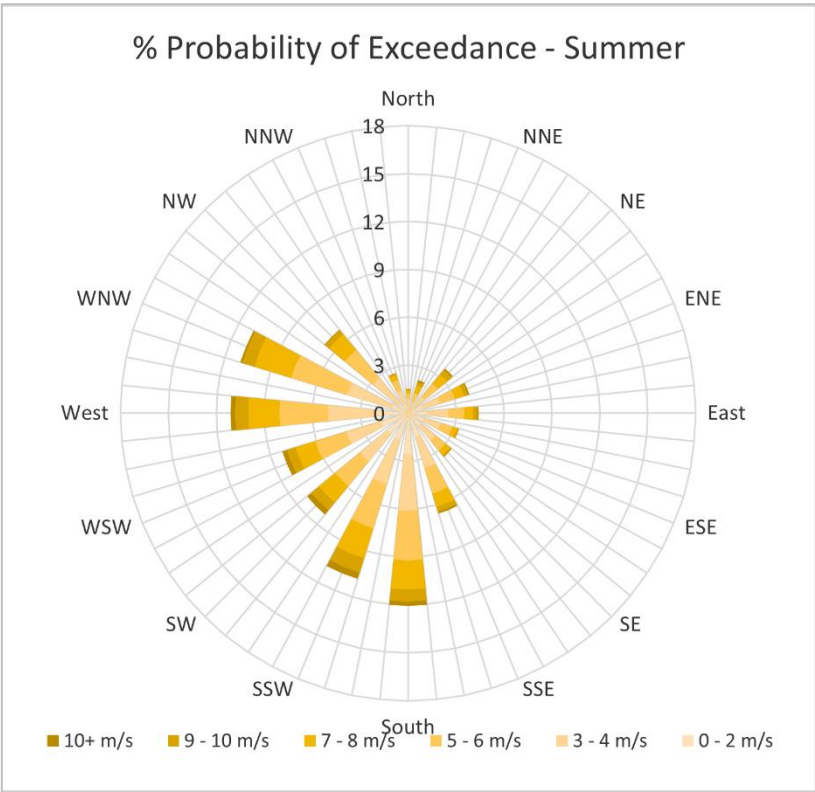


Figure C.5 – Cumulative wind speed probability distribution at site, autumn

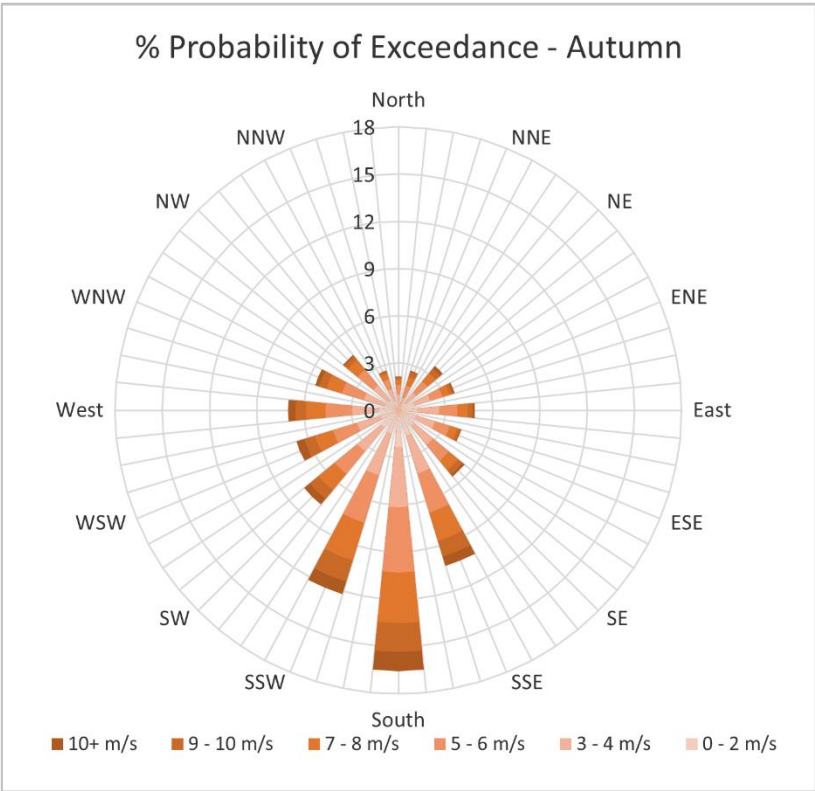
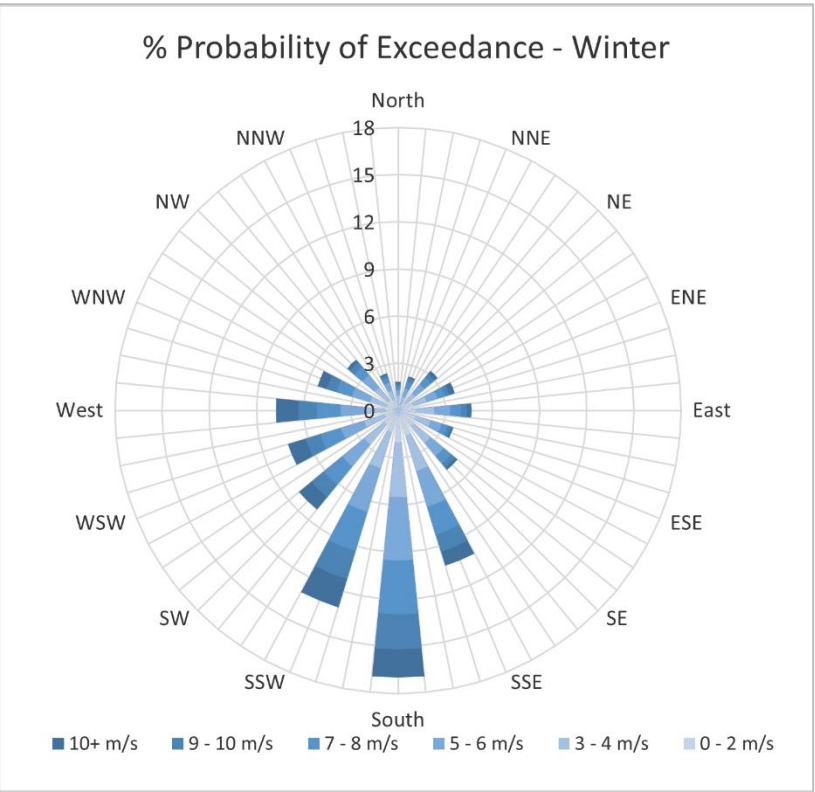
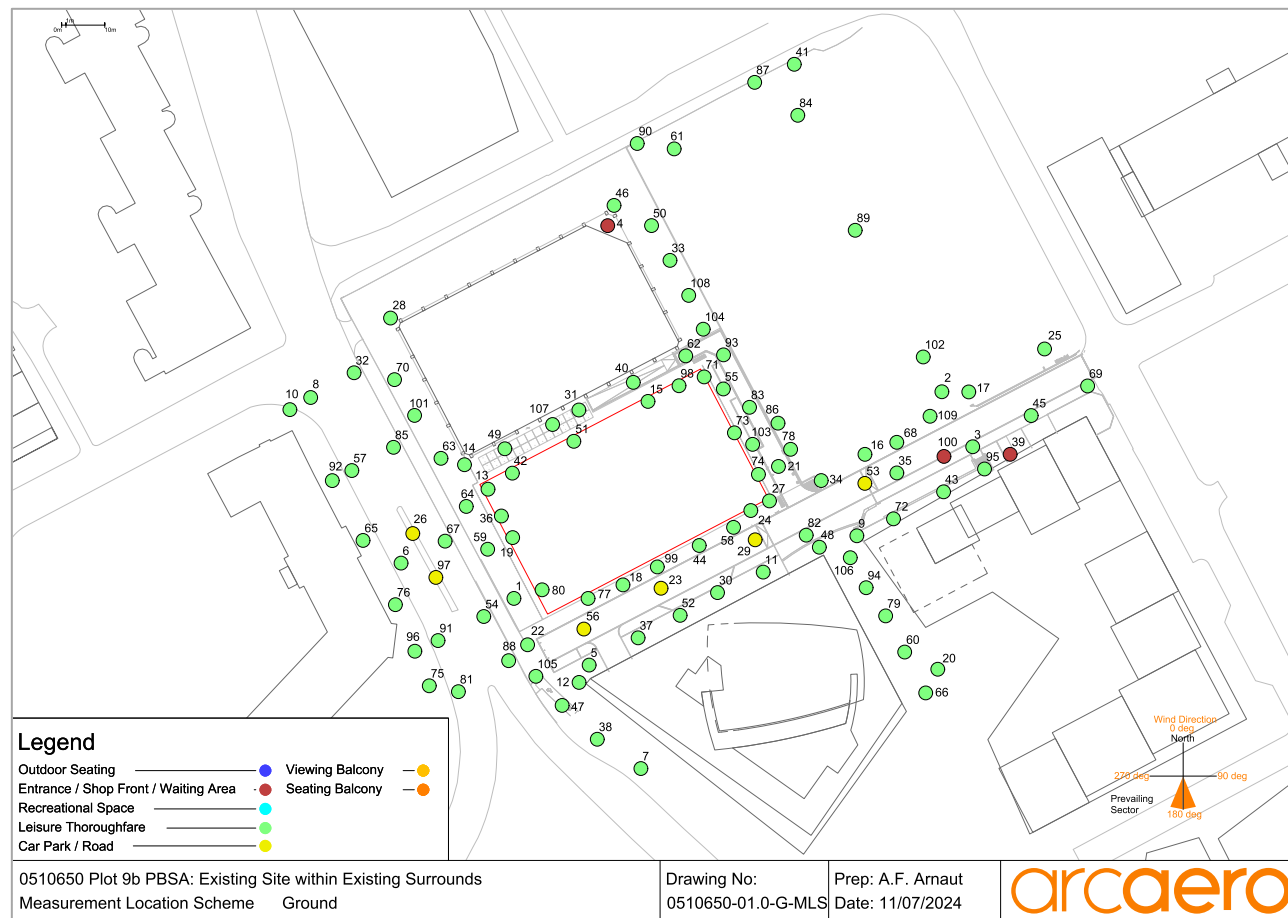


Figure C.6 – Cumulative wind speed probability distribution at site, winter



Appendix D Pedestrian / Occupant Uses

Figure D.1 - Existing site uses, ground



Plot 9b PBSA
Vita Meadow Limited
0510650rep1v1

Architectural Aerodynamics
22 October 2024

Figure D.2 - Existing site uses, elevated levels

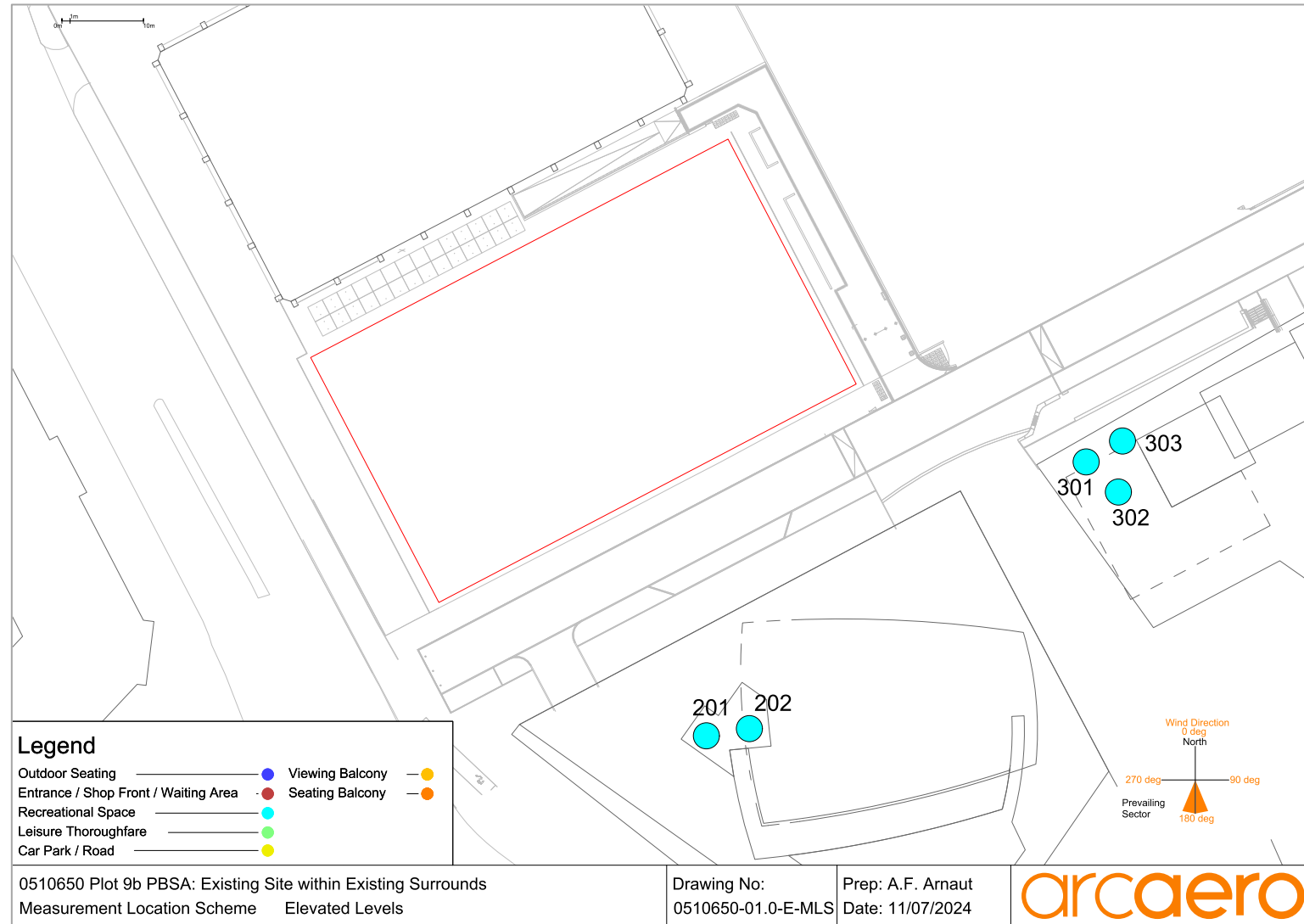
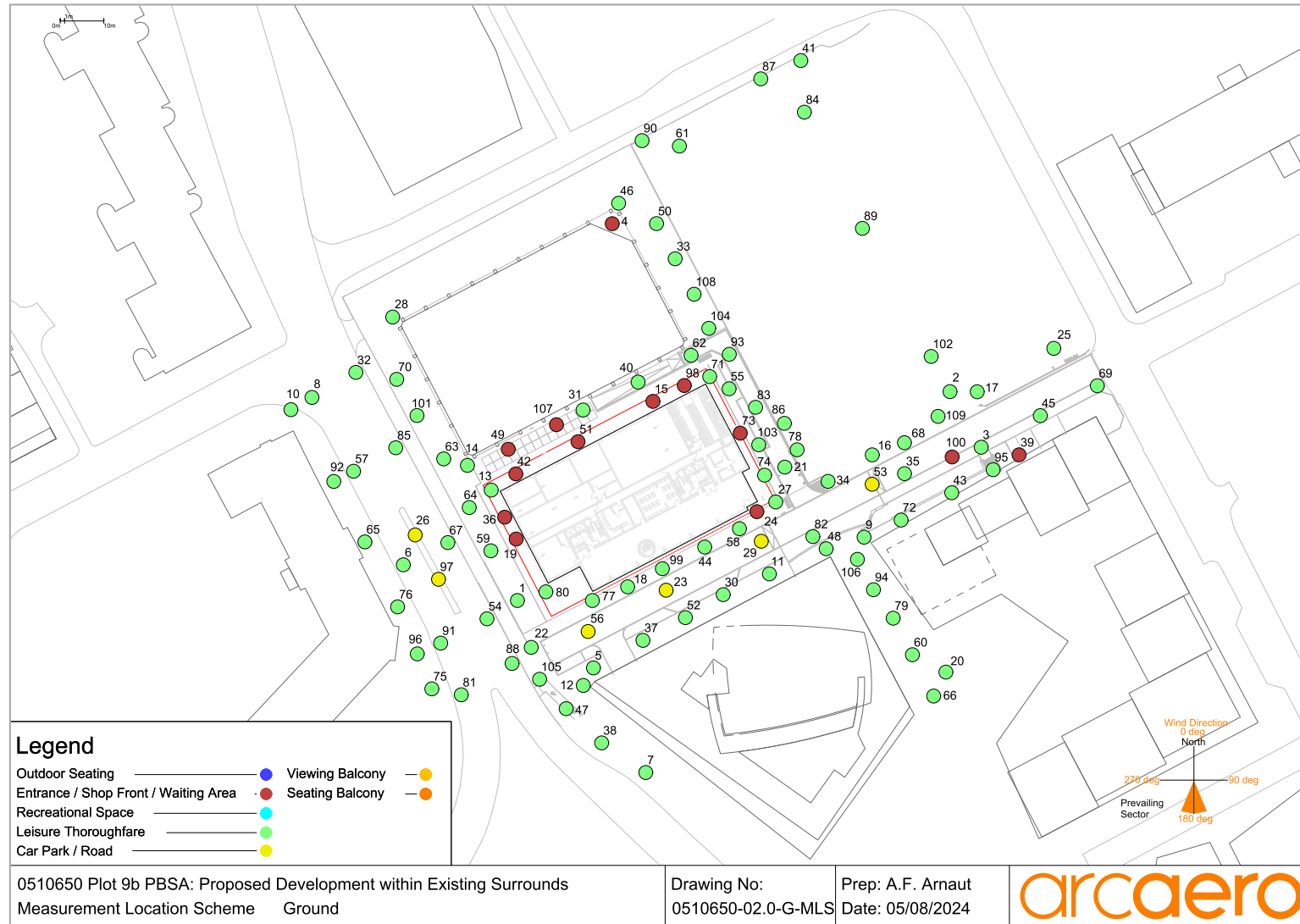


Figure D.3 - Proposed development within existing surrounds uses, ground



Plot 9b PBSA
Vita Meadow Limited
0510650rep1v1

Architectural Aerodynamics
22 October 2024

Figure D.4 - Proposed development within existing surrounds uses, elevated levels

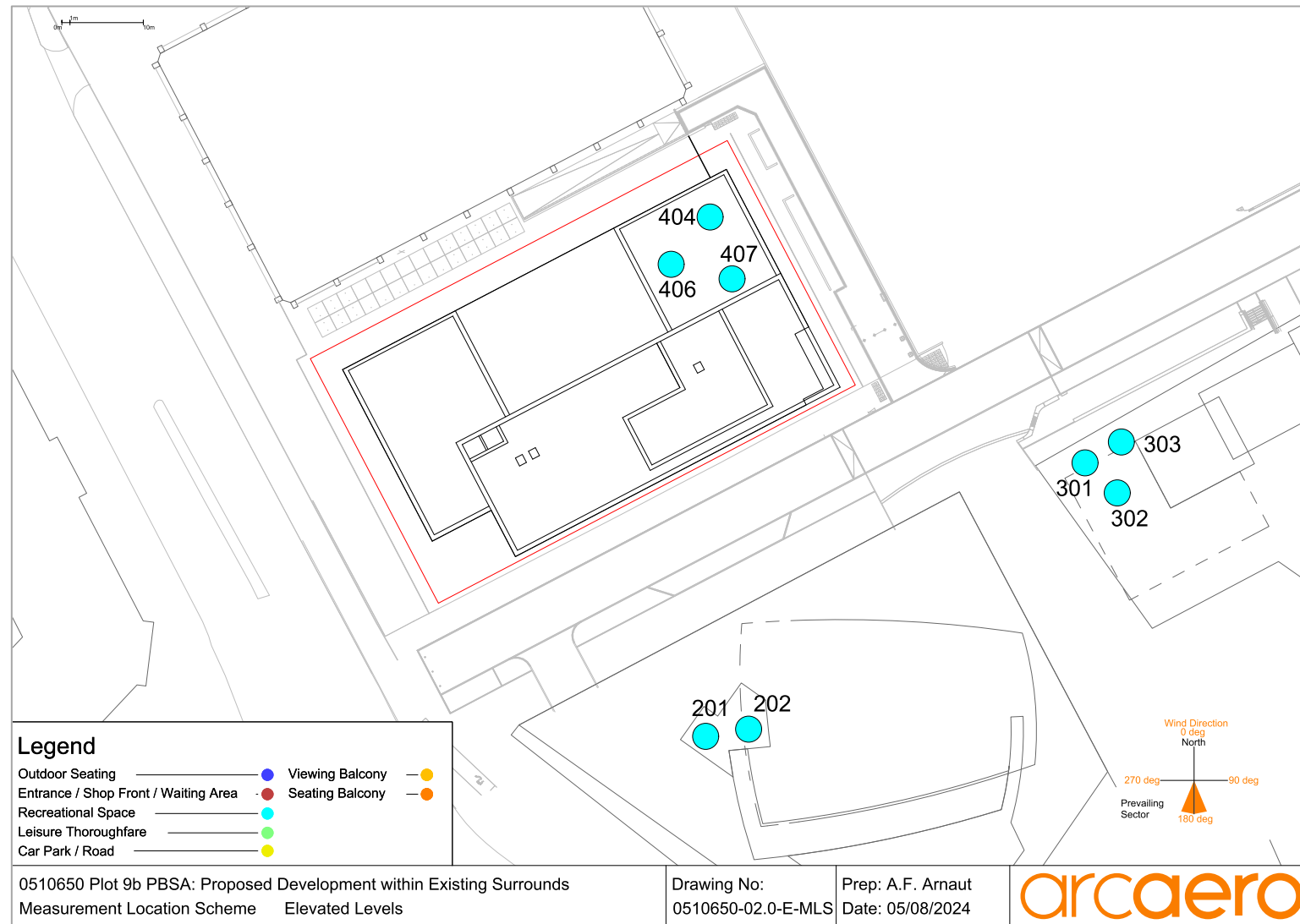


Figure D.5 - Proposed development within cumulative surrounds uses, ground

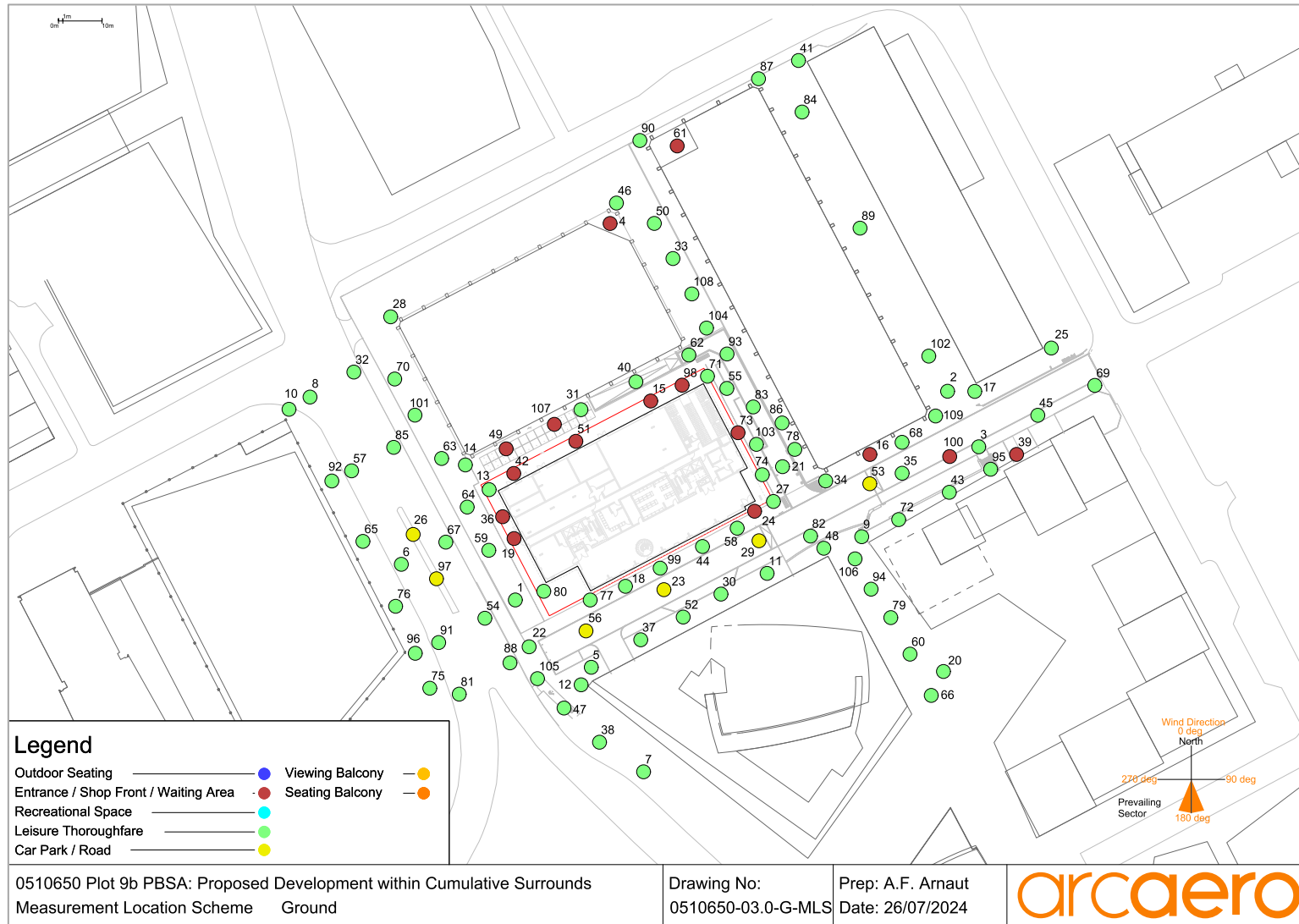


Figure D.6 - Proposed development within cumulative surrounds uses, elevated levels

