



Green Room

For

Vita Living T2 Ltd

Wind Microclimate Report

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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 Green Room development, UK.

The study has adopted wind tunnel testing, with supporting CFD modelling, 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:

- With the introduction of the mitigation measures, wind conditions within the site and surrounding areas are substantially suitable for planned and existing uses.
- While marginal exceedances of comfort thresholds can be observed, conditions are considered to be broadly acceptable for use.
- The exceedances within the recreational area to the south of T2, the sitting areas on the L1 terrace to the north of T2 and to the northwest and south of T1 and the lobby entrance to the south of T2 would be expected to become suitable for their intended uses upon the introduction of the mitigation measures. The feasibility of mitigation measures has been demonstrated via wind tunnel testing.

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 Living T2 Ltd, to assess the wind microclimate for the proposed Green Room development.

2 The Proposed Development

2.1 Site Location and Proposed Development

The site is located within the St. John's Masterplan, forming part of Enterprise City. It is bounded by Water Street to the east, the under-construction Factory to the south, the Victoria and Albert Hotel located to the north, and the River Irwell to the west.

The 'T2' development is for a 36-storey, mixed use building, comprising one basement level, ground floor plus mezzanine, and first floor of associated amenity spaces, three floors of co-working space, with a mix of co-living apartments above in the form of studio, 'trio' and 'quad' apartments.

In addition to this, a single storey extension, referred to as the "Green Room", which wraps around the west elevation of the tower is proposed.

The area immediately surrounding the proposed development principally comprises medium-rise buildings with some high-rise developments, especially moving further afield. There are a number of additional committed developments, the majority of which are high-rise and in close proximity to the proposed development.

2.2 Information Describing the Proposed Development and Existing Surroundings

Assessment models have been constructed on the basis of the following drawings received from Denton Corker Marshall in July and October 2022:

- 6568-G200-3-ALL.dwg
- T2-EXA-G710-PL-XX-00100.dwg

The existing surrounding area was based upon information supplied by the design team and supplemented by Ordinance Survey details for the area. Cumulative surrounds were based upon information contained within the Manchester planning portal.

2.3 Soft Landscaping

The wind microclimate has been assessed for the proposed development with current soft landscaping proposals (shown in Figure 2.1) and surrounding landscaping.

2.4 Wind Alleviation / Mitigation Measures

The proposed development within existing surrounds, has been tested with and without wind alleviation / mitigation measures, explored via CFD and wind tunnel testing, and ultimately validated via wind tunnel testing as part of an interactive workshop with the design team.

In addition to the soft landscaping proposals for Green Room, the following measures were implemented as part of this wind mitigation scheme:

- Removal of 3 deciduous trees immediately to the south of Green Room, replaced with 1.0m tall hedges on top of ~0.7m tall planters, 1.2m wide x 17m long

- A 5.0m tall and 0.8m wide solid totem signage running towards the river and a 5.0m tall and 1.5m wide 50% perforated screen at the southeast corner of T2
- A ~1.2m tall planter (5.5m x 1.25m) at the southeast corner of T2
- Two 2.0m tall and 2.0m wide 50% porous screens on the southwestern corner of Level 1 of T2
- Addition of eight 4.5m tall evergreen trees along Water Street
- 2 rows of 1.0m tall hedges on top of ~0.7m tall planters, 1.2m wide x 12m long. Positioning of the hedges is between the fifth and seventh trees (from River Irwell) and near locations 211 and 128.

The position and key dimensions of all alleviation measures are summarised within Figure 2.2.

2.5 Surrounding Contexts

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

Under construction (inclusive of T1) and recently completed schemes which have been included within the existing surrounds context are displayed in Figure 2.3.

Consented developments that have been additionally considered within the cumulative surrounds scenario are listed in Table 2.1, and are displayed in Figure 2.4.

Table 2.1 – Cumulative Schemes

Development Name	Planning Reference
Middlewood Locks Plots A, B, C, D & P	21/78212/OUTEIA
St John's Place 1, 3 & 4	109660/FO/2015/C1
Salford Central	16/68325/OUT
Trinity Islands	132429/FO/2021
No 1 Grape Street	121511/FO/2018

3 Assessment Methodology

3.1 Overview

With studies commencing in 2022, both CFD and wind tunnel studies have been conducted.

CFD modelling has employed a RANS approach: full details of the CFD methodology are set out in Appendix A 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.

Wind tunnel modelling was undertaken in the Imperial College 10x5 atmospheric boundary layer wind tunnel in London. Full details of the wind tunnel testing conducted for the study are presented in Appendix B of this report.

Modelling via both CFD and wind tunnel testing 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.

The industry standard criteria for wind microclimate assessments, the LDDC variant of the Lawson criteria ⁽¹⁾, has been employed for the study.

3.2 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 employs wind climate statistics 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 CFD and 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 ⁽²⁾, in accordance with best industry practice.

3.3 Detailed Design Modelling & Assessment Scenarios

Results presented within this report are those for the assessment of the detailed design of the proposed development.

Having completed a number of early-stage CFD predictions, final CFD assessments were undertaken prior to wind tunnel testing taking place to explore the performance of preferred design options. This additionally informed the placement of measurement probes on the wind tunnel model to ensure capture of critical areas. The CFD assessments principally considered the proposed development in existing surrounds.

The results upon which the findings for this study are based are those captured via wind tunnel testing.

The wind tunnel model 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 model was reviewed and approved by the design team prior to the study. The assessment considered a full range of directions in 22.5° intervals.

The following scenarios have been assessed via wind tunnel testing and are presented within Section 4 of this report.

1. Proposed development (T1 + T2 and Green Room) in existing surrounds
2. Proposed development (T1 + T2 and Green Room) in cumulative surrounds
3. Proposed development (T1 + T2 and Green Room) in existing surrounds with mitigation
4. Proposed development (T1 + T2 and Green Room) in cumulative surrounds with mitigation

3.4 The 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, Architectural Aerodynamics use the 'LDDC' variant of the Lawson Criteria (London Docklands Development Corporation ⁽¹⁾).

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.

3.4.1 Comfort

The LDDC ⁽¹⁾ 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	Standing / short-term sitting
8	C2	Strolling
10	C1	Walking
> 10	C0	Uncomfortable

The LDDC variant of the Lawson criteria prescribe 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 acceptable 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.

3.4.2 Safety

A wind speed of 15 m/s occurring once per year (equivalent to 0.022% of the time per annum) is classified 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 Pedestrian / Occupant Uses

In using the Lawson criteria to consider the suitability of spaces, in terms of comfort, it is necessary to identify the anticipated usage of the various areas and assign that usage to an assessment receptor. Each measurement location is assigned a pedestrian / occupant use. This is presented in Figure D.1 in Appendix D.

4 Results

The following scenarios have been assessed via wind tunnel testing and are presented herein.

1. Proposed development (T1 + T2 and Green Room) in existing surrounds
2. Proposed development (T1 + T2 and Green Room) in cumulative surrounds
3. Proposed development (T1 + T2 and Green Room) in existing surrounds with mitigation
4. Proposed development (T1 + T2 and Green Room) in cumulative surrounds with mitigation

4.1 Existing Site within Existing Surrounds

The conditions for the existing site scenario have not been directly assessed by the wind tunnel tests. Instead, professional judgement has been used to assess conditions in existing site in addition to the wind conditions from the original 2021 assessment.

4.1.1 Safety

All areas within the site and immediate existing surrounds are expected to satisfy the safety criteria for wind.

4.1.2 Comfort

Wind conditions in and around the site are generally expected to be suitable for standing / short-term sitting or better, throughout the year.

Within the immediate surrounding area, wind conditions are similar and are also expected to be suitable for standing / short-term sitting throughout the year, with exceptions near the north-western and south-eastern corners of the neighbouring T1 development, and near the Salford Central Plots C1 and C2, which are generally expected to be suitable for strolling.

4.2 Proposed Development in Existing Surrounds

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

4.2.1 Safety

With the introduction of the Proposed Development (in tandem with T1 & T2), the wind conditions within the site and surrounding area generally meet the safety criteria for all users.

Localised exceptions occur at the following areas:

- to the northeast of T2 (location 50)
- to the south-eastern corner of T2 (location 58)

4.2.2 Comfort

4.2.2.1 *Thoroughfares*

Wind conditions within the site are generally suitable for strolling or better throughout the year, and thus for pedestrian access to and passage through the area. Fast walking conditions can be observed in winter to the east (locations 50, 58, 113, 158, 159,) and southwest of T2 (locations 54, 123, 124, 165 and 223). Where so, conditions are generally suitable for strolling in excess of ~90% of the time in winter.

4.2.2.2 *Entrances*

Within T1, wind conditions to the entrances are generally suitable for at least standing and thus for comfortable pedestrian ingress / egress. Exceptions to this occur to the service entrances to the west of T1 (locations 213 and 221) where conditions would still be considered suitable for secondary entrances with conditions in winter suitable for short-term standing in excess of ~92% of the time.

Conditions to the southwestern entrances of T2 (locations 55 and 57) are found to be suitable for standing throughout the year and hence for comfortable ingress / egress. Further, the entrance to the bin store to the north of T2 (location 114) and the main entrance to the south of T2 (location 166) would still be considered suitable for the intended use with suitability of more than ~93% of the time in winter.

4.2.2.3 *Recreational Spaces*

Wind conditions to the general recreational spaces located to the south of T2 are generally too windy for short periods of standing / sitting from spring to autumn in the absence of mitigation.

To the north of T2, the wind conditions to the recreational spaces along the Canal Basin are generally suitable for short periods of standing / sitting from spring to autumn and thus for comfortable general recreation. Exceptions are observed across the Canal Basin (locations 24 and 117) but being predominantly for access to the canal path, strolling conditions recorded would be sufficient.

4.2.2.4 *Outdoor Seating*

The wind conditions to the outdoor seating areas to the south of T2 (location 204) are suitable for long-term sitting in summer and thus comfortable for their intended uses.

The outdoor seating areas to the north of T2 (locations 52 and 122) are suitable for long-term sitting approximately 82% of the time during summer, rather than the 95% criteria, in the absence of the wind mitigation.

The wind conditions to the outdoor seating areas at the northwest and south of T1 (locations 401 & 402 and location 67 respectively) are suitable for long-term sitting in excess of ~89% of the time in summer. To improve conditions here further, to become suitable, the introduction of 600mm tall planter and 900mm tall shrubs, would be effective, and could be employed at the discretion of the tenant.

4.2.2.5 Surrounding Area

Following the introduction of the proposed development, conditions remain generally suitable for at least strolling and are thus comfortable for thoroughfare use.

Fast walking conditions can be observed along Water Street to the east of T2 (locations 59, 60, 62 and 225), as well as across the River Irwell on Salford Plot C2 (location 140).

Wind conditions are suitable for short-term standing or better at surrounding entrances and are hence suitable for comfortable ingress / egress, with the exceptions of the western entrances to the Manchester Goods Yard (locations 215 and 216). The exceedances are marginal and only during the winter season, and wind conditions in all other seasons remain suitable for use of an entrance.

Wind conditions at recreational spaces off-site are generally suitable for standing or short-term sitting during the spring to autumn months, with the terrace space on Salford Central Plot C1 (location 141) and as an exception. Conditions here are still suitable for general recreation in the summer months.

The outdoor seating area at the southeast corner of the Victoria and Albert Hotel (location 161) remains suitable for long-term sitting all year long, hence is suitable for outdoor seating. The outdoor seating areas at the southwest corner of the Victoria and Albert Hotel (location 21) would be suitable for short periods of standing / sitting in summer. Within the context of wind tunnel testing however, this space was modelled without any nearby walls or immediate landscaping, all of which would be likely to improve conditions to the extent that this space would be suitable for outdoor seating during at least summer.

4.3 Proposed Development in Cumulative Surrounds

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

4.3.1 Safety

The following improvements or deterioration to the safety criteria are as follows:

- To the northeast of T2, location 50 now meets the safety criteria.
- To the southwest of T2, locations 165 and 123, exceed the safety criteria
- Locations 9, 11, 12 and 14 around St John's Place exceed the safety criteria.

Exceedances of safety criteria are still observed to the southeast of T2 (location 58).

The safety exceedances around St John's Place are caused by localised corner accelerations and downdraughts due to the introduction of St John's Place, and hence unrelated to the introduction of the proposed development, and will need to be mitigated via the measures set forth within its associated planning application.

4.3.2 Comfort

In general, conditions remain similar to the existing scenario with the exceptions of the following areas:

- Thoroughfares along Water Street are now mostly comfortable for strolling throughout the year – exceptions still persist around northeast and southeast of T2 (locations 50, 58, 60, 113 and 158).
- Thoroughfares along the River Irwell are now substantially comfortable for strolling throughout the year – exceptions still persist around southwest of T2 (locations 123, 124 and 165).
- The entrances to the north and south of T2 (locations 120 and 166) are now suitable for standing and thus for comfortable ingress / egress.
- The entrances within T1 (locations 213 and 221) are now suitable for standing and thus for comfortable ingress / egress.
- The recreational space immediately to the south of T2 (location 126) is now suitable for short-term sitting from spring to autumn and thus for comfortable general recreation.
- The outdoor seating area to the south of T1 (location 67) has become suitable for long-term sitting in summer and thus for seating areas.
- The western entrance to the Manchester Goods Yard (location 215) is now suitable for standing and thus for comfortable ingress / egress.
- Thoroughfares around St John's Place (locations 9, 11 and 12) are suitable for fast walking throughout the year – west of St John's Place (location 14) is an exception and is uncomfortable in winter but suitable for fast walking the rest of the year.

Elsewhere, conditions within the site and surrounding areas remain similar to those in the existing configuration.

4.4 Proposed Development in Existing Surrounds with Mitigation

The results for the proposed development within existing surrounds, with wind mitigation / alleviation schemes as described within Section 2.4 and displayed within Figure 2.2 are presented graphically within Figure 4.5 and Figure 4.6 for worst-seasonal and summer conditions respectively.

4.4.1 Safety

With the introduction of the mitigation scheme, wind conditions within the site and surrounding area have improved, and now meet the safety criteria for all users.

4.4.2 Comfort

4.4.2.1 Thoroughfares

With the introduction of the mitigation measures, wind conditions within the site are generally suitable for strolling or better throughout the year, and thus for pedestrian access to and

passage through the area. While minor exceedances are still observed to the southeast of T2 (location 58) and to the southwest of T2 (locations 124 and 223), these isolated locations remain acceptable for walking throughout the year with conditions suitable for walking in excess of 93% of the time in winter, and thus for use as a general thoroughfare.

A small number of exceptions still persist to the east of the site within the turning circle area (locations 59 and 159), however wind conditions are suitable for strolling in excess of ~94% and ~90% of the time respectively in winter and fully suitable for strolling for the rest of the year. This marginal exceedance of fast walking would be acceptable.

Furthermore, the minor exceedances that are observed to the northeast corner of T2 (locations 113 & 212) would be considered acceptable since this area is understood to be limited for bin store access only and not for public access, suitable for strolling in excess of ~92.5% of the time in winter.

4.4.2.2 Entrances

Entrances to T2 are found to be generally suitable for at least standing and thus for comfortable pedestrian ingress / egress.

Exceptions still persist at the north and south of T2 (location 114 and 166). However, conditions still remain suitable for standing from spring to autumn, and in excess of 93% of the time in winter, and are thus tolerable for entrance use. The introduction of 1.5m depth side screens would be expected to improve the wind conditions to become comfortable for use throughout the year.

Within T1, wind conditions to the entrances remain generally suitable for at least standing and thus for comfortable pedestrian ingress / egress. Minor exceptions to this still persist to the service entrances to the west of T1 (locations 213 and 221) where conditions would still be considered to be suitable for secondary entrances with conditions in winter suitable for standing in excess of ~92% of the time.

4.4.2.3 Recreational Spaces

With the introduction of the mitigation measures, wind conditions within the recreational spaces to the south of T2 are largely suitable for short periods of sitting from spring to autumn and thus for general recreation.

Exceedances still persist at some areas (locations 95, 96, 129, 209 and 210) but the majority of these locations are still suitable for short-term sitting in summer months. The introduction of hedges as implemented around locations 211 and 128 would be expected to result in conditions suitable for the intended use.

Minor exceedances of conditions for general recreational use are still observed across the Canal Basin (locations 24 and 117), but being predominantly for access to the canal path, the strolling conditions recorded would be acceptable.

4.4.2.4 Outdoor Seating

With the implementation of mitigation measures, wind conditions at the outdoor seating area to the north of T2 (location 52) would still be considered suitable for long-term sitting and thus for sitting area.

On the Level 1 terrace (location 122), wind conditions here are only suitable for ~85% of the time in summer for long-term sitting and thus too windy for comfortable use. The introduction of ~1.0m planting across the terrace would be expected to result in conditions suitable for the intended use.

The wind conditions to the outdoor seating areas at the to the northwest and south of T1 (locations 401 & 402 and location 67 respectively) remain suitable for long-term sitting in excess of ~89% of the time in summer. To improve conditions here further, to become suitable, the introduction of 600mm tall planter and 900mm tall shrubs, would be effective, and could be employed at the discretion of the tenant

4.4.2.5 Surrounding Area

With the introduction of wind mitigation measures, wind conditions at the surrounding areas remain similar to those for the proposed development in existing surroundings.

Wind conditions along Water Street are now substantially suitable for strolling throughout the year and thus for pedestrian access to and passage through the area. A couple of exceptions still persist (locations 49 and 62), however wind conditions are suitable for strolling in excess of ~93% of the time in winter and fully suitable for strolling for the rest of the year. This marginal exceedance of fast walking would be acceptable.

Wind conditions are also suitable for short-term standing or better at the surrounding entrances and hence suitable for comfortable ingress / egress, with the exception of the minor exceedance of criteria at western entrance to Manchester Goods Yard (location 216). Wind conditions to the main entrance of the Victoria and Albert Hotel (location 20) are suitable for standing from spring to autumn, and only marginally windy in winter. However, conditions still remain suitable for standing in excess of 94% of the time and thus still tolerable for entrance use.

The outdoor seating area to the southeast corner of the Victoria and Albert Hotel (location 161) remains suitable for long-term sitting all year long, hence is suitable for outdoor seating. The outdoor seating areas to the southwest corner of the Victoria and Albert Hotel (location 21) remain suitable for short periods of standing / sitting in summer. Similar to the unmitigated existing surrounds scenario, this space was modelled without any nearby walls or immediate landscaping, all of which would be likely to improve conditions to the extent that this space would be suitable for outdoor seating during at least summer.

4.5 Proposed Development in Cumulative Surrounds with Mitigation

The results for the proposed development within cumulative surrounds with wind mitigation / alleviation schemes as described within Section 2.4 and displayed within Figure 2.2 are presented graphically within Figure 4.7 and Figure 4.8 for worst-seasonal and summer conditions respectively.

4.5.1 Safety

With the introduction of the mitigation scheme, wind conditions within the site and surrounding area have improved, and now satisfy the safety criteria for all users.

4.5.2 Comfort

With the introduction of the mitigation measures, wind conditions are substantially suitable for planned and existing usages.

4.5.2.1 Thoroughfares

All thoroughfares within the site are substantially suitable for strolling throughout the year, with one localised exception to the southwest corner of T2 (location 124). Conditions here however are still considered suitable for strolling with suitability of more than ~93% of the time in winter.

4.5.2.2 Entrances

Entrances within the site remain largely suitable for standing and thus for comfortable ingress / egress. Marginal exceedances in winter are still observed to the bin store entrance to the north of T2 (location 114). However wind conditions here are still tolerable for comfortable use.

4.5.2.3 Recreational Spaces

With the introduction of the mitigation measures, wind conditions within the recreational spaces to the south of T2 are largely suitable for short periods of sitting from spring to autumn and thus for general recreation.

Exceedances still persist at some areas (locations 95, 96, 209 and 210) but the majority of these locations are still suitable for short-term sitting in summer months. The introduction of hedges as implemented around locations 128 and 211 would be expected to result in conditions suitable for the intended use.

Exceedances of conditions for general recreational use are still observed across the Canal Basin (locations 24 and 117), but being predominantly for access to the canal path, the strolling conditions recorded would be acceptable.

4.5.2.4 Outdoor Seating

With the implementation of mitigation measures, wind conditions at the outdoor seating area to the north of T2 (location 52) are suitable for long-term sitting in summer and thus for seating areas.

On the terrace Level 1 (location 122), wind conditions here are only suitable for ~83% of the time in summer for long-term sitting and thus too windy for comfortable use. The introduction of ~1.0m planting across the terrace would be expected to result in conditions suitable for the intended use.

Wind conditions to the outdoor seating area to the northwest of T1 (locations 401 & 402) remain suitable for short periods of sitting in summer, suitable for 90% of the time in summer for long periods of sitting. The introduction of ~600mm tall planter and ~900mm tall shrubs would be expected to result in conditions suitable for the intended use.

Wind conditions to the outdoor seating areas to the south of T1 (location 67) remain suitable for long period of sitting in summer and thus for their intended use.

4.5.2.5 *Surrounding Area*

With the introduction of wind mitigation measures, wind conditions at the surrounding areas remain similar to those for the proposed development in cumulative scenario.

Thoroughfares along Water Street are now fully suitable for strolling throughout the year and thus for comfortable pedestrian access to and passage through the site.

Thoroughfares around St John's Place (locations 9, 11 and 12) remain suitable for fast walking throughout the year, with the area to the west of St John's Place (location 14) an exception and is uncomfortable in winter but suitable for fast walking the rest of the year. Similar to the unmitigated scenario, these exceedances are caused by localised corner accelerations and downdraughts due to the introduction of St John's Place, and hence unrelated to the introduction of the proposed development, and will need to be mitigated via the measures set forth within its associated planning application.

The surrounding entrances remain generally suitable for their intended use with the sole exception of the western entrance to the Manchester Goods Yard (location 216). The exceedances here are considered marginal and during the winter and spring seasons, and wind conditions in all other seasons remain suitable for use of an entrance.

Elsewhere, conditions within the site and surrounding areas remain similar to those in unmitigated cumulative configuration.

5 Mitigation Recommendations

Exceedances of the comfort criteria across the study area are not excessive but they may benefit from the introduction of mitigation measures in some form. Examples of mitigation that may be effective would include, but would not be limited to, the following:

- Introduction of hedges as implemented between the fifth and seventh trees (from River Irwell) (near locations 211 and 128) to the remaining recreational areas that do not meet the comfort criteria (locations 95, 96, 129, 209 and 210).
- ~1.0m planting across the L1 north terrace of T2 (location 122).
- ~600mm tall planter and ~900mm tall shrubs to the outdoor seating areas to the northwest of T1 (locations 401 & 402) and south of T1 (location 67).
- ~1.5m depth side screens to the entrance lobby to the south of T1 (location 166)

6 Summary and Conclusions

The following conclusions have been drawn:

- With the introduction of the mitigation measures, wind conditions within the site and surrounding areas are substantially suitable for planned and existing uses.
- While marginal exceedances of comfort thresholds can be observed, conditions are considered to be broadly acceptable for use.
- The exceedances within the recreational area to the south of T2, the sitting areas on the L1 terrace to the north of T2 and to the northwest and south of T1 and the lobby entrance to the south of T2 would be expected to become suitable for their intended uses upon the introduction of the mitigation measures. The feasibility of mitigation measures has been demonstrated via wind tunnel testing.

7 References

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2. **ESDU (Engineering Science Data Unit)**. *Item 01008. Computer Program for wind speeds and turbulence properties: flat or hilly sites in terrain with roughness*. 2001.
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8 Figures

Figure 2.1 – Soft landscaping scheme

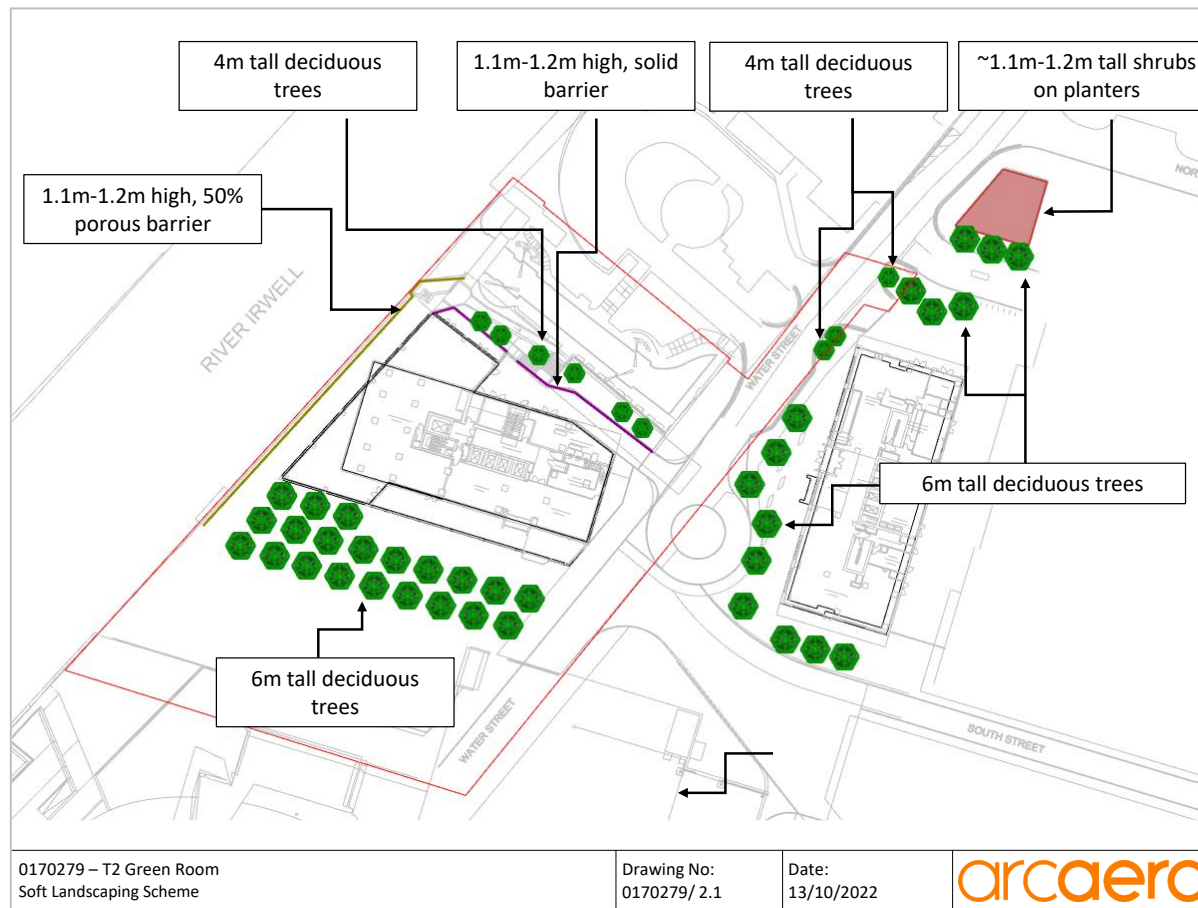


Figure 2.2 – Wind alleviation / mitigation measures

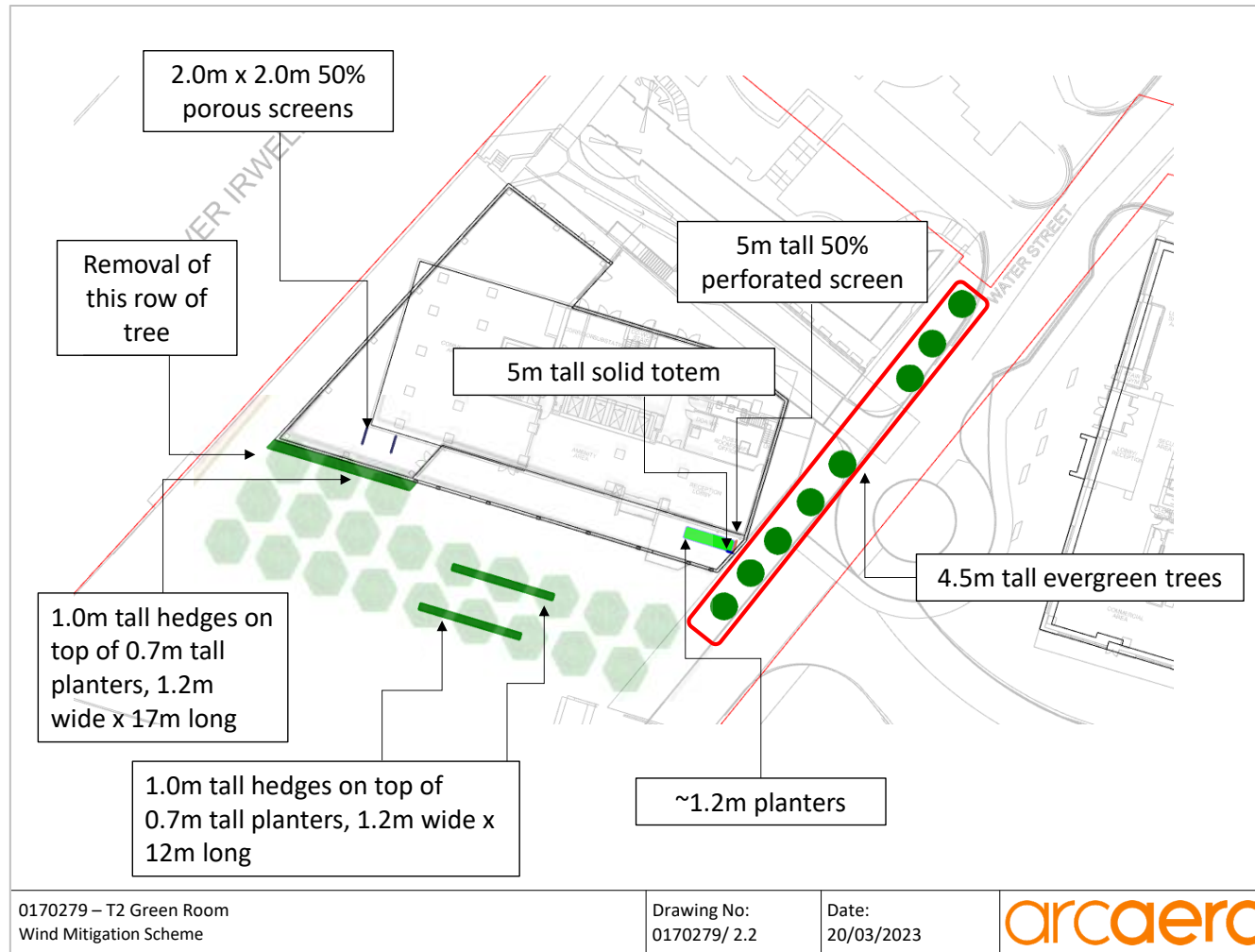


Figure 2.3 – Under construction and recently completed schemes included within the existing surrounds context

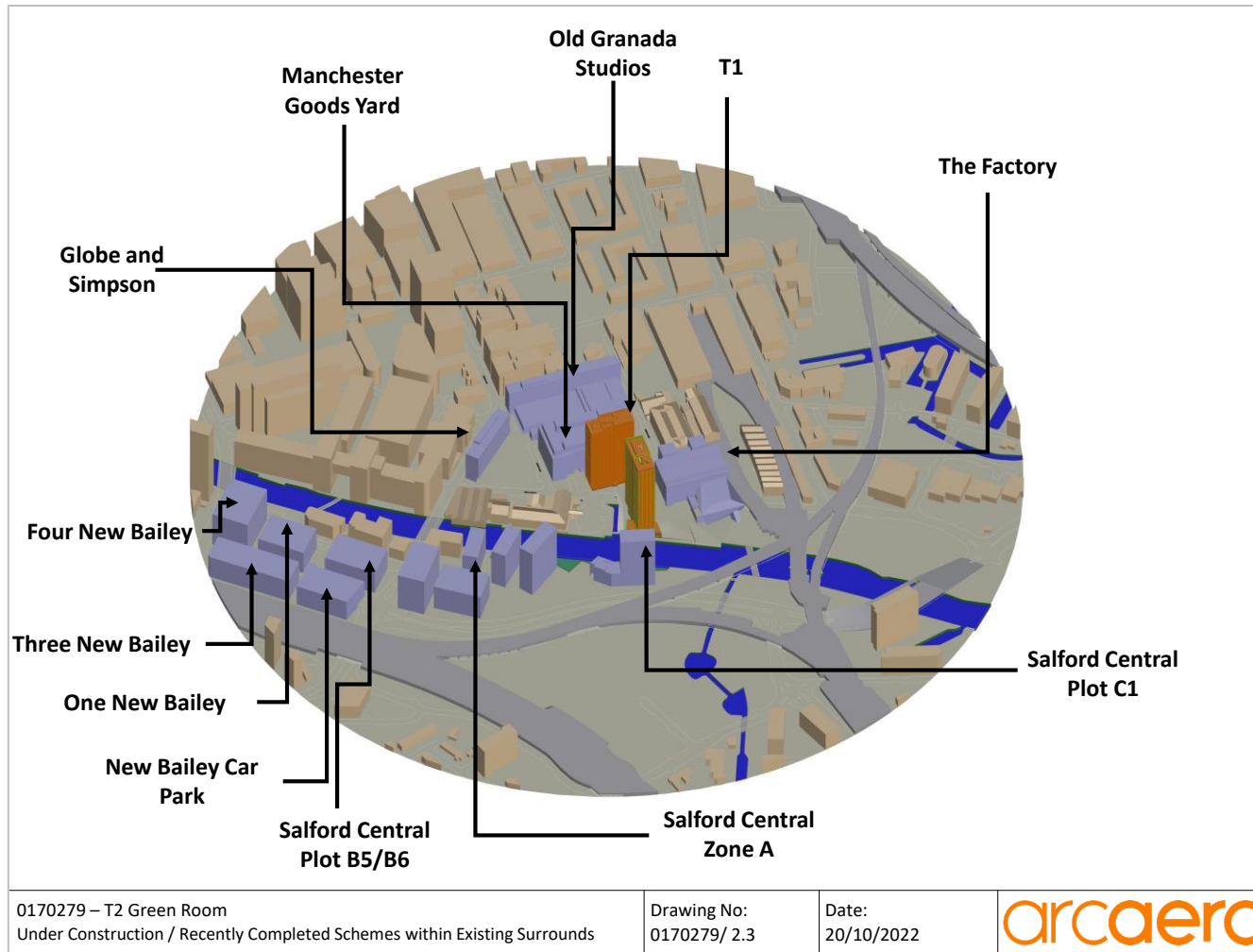


Figure 2.4 – Cumulative schemes

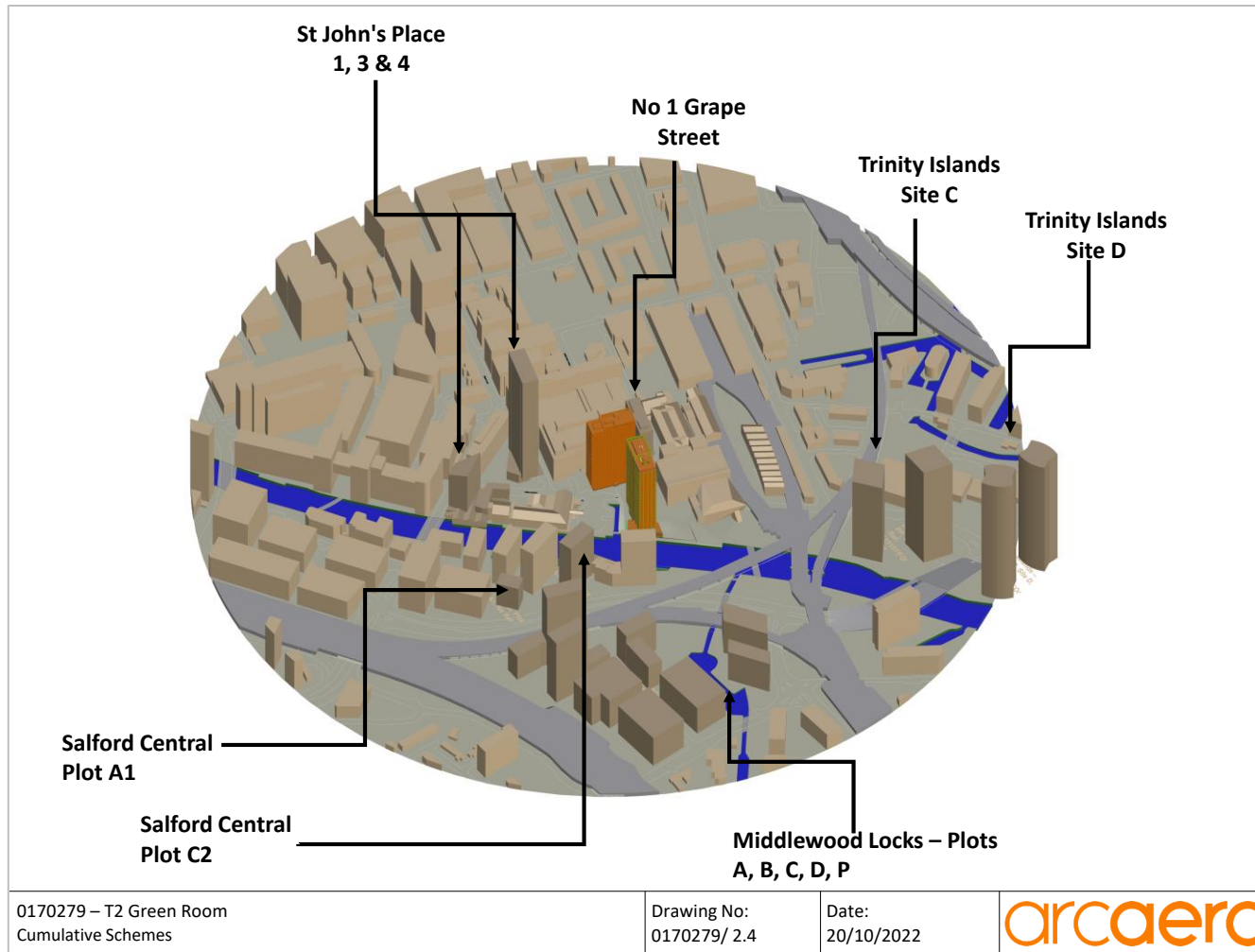


Figure 4.1 - Pedestrian wind conditions, proposed development within existing surrounds, 'worst' season.

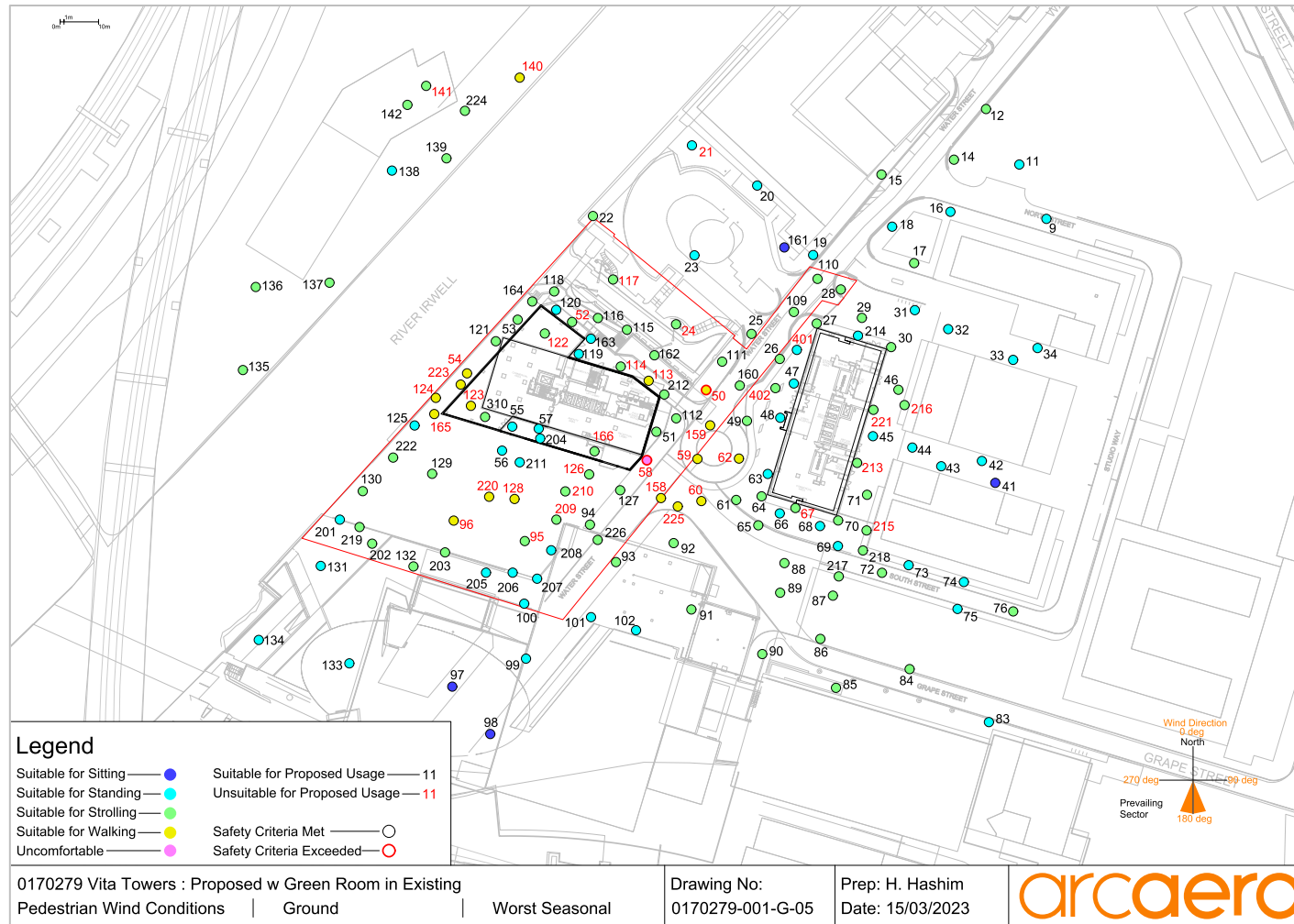


Figure 4.2 - Pedestrian wind conditions, proposed development within existing surrounds, summer.

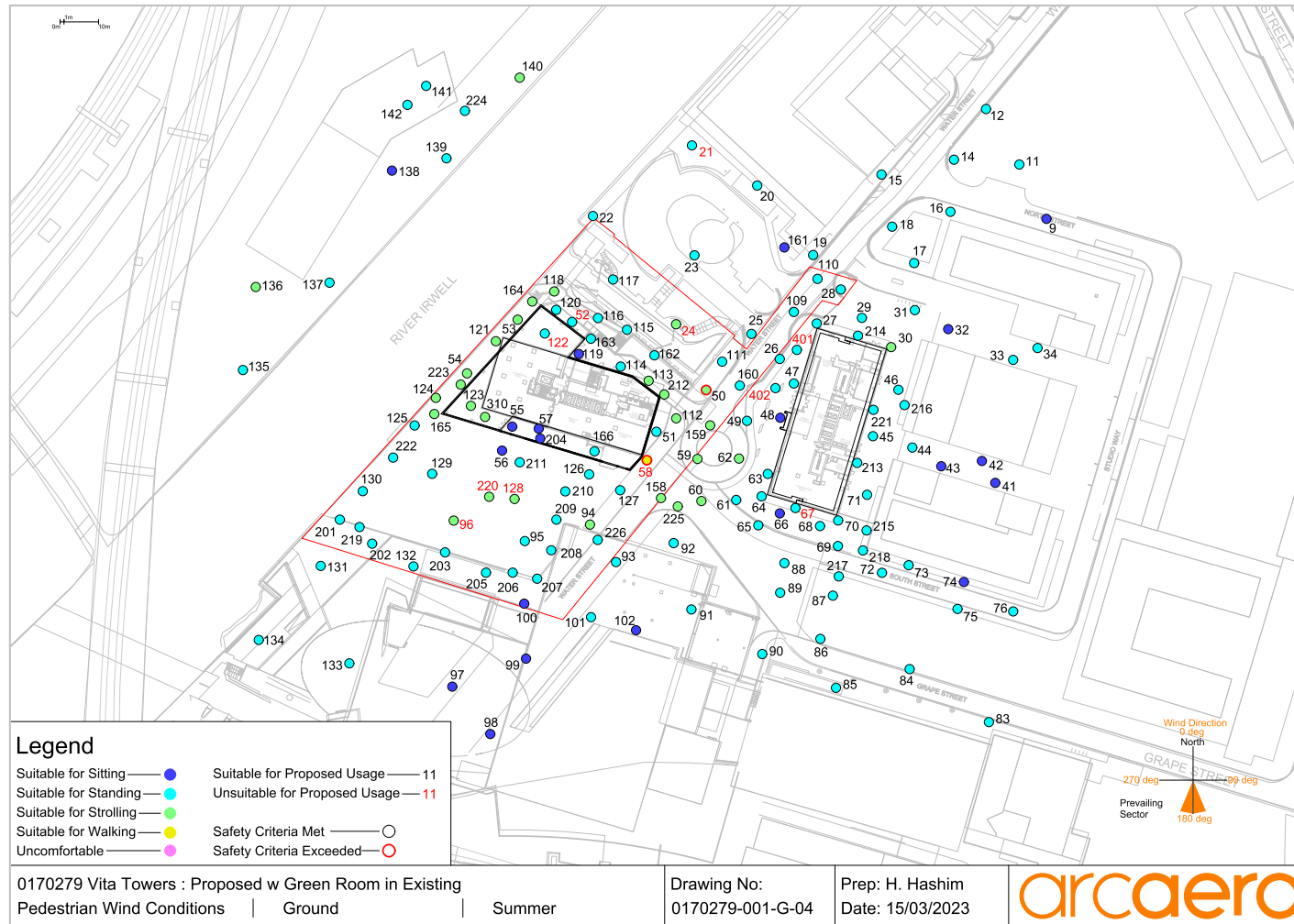


Figure 4.3 - Pedestrian wind conditions, proposed development within cumulative surrounds, 'worst' season.

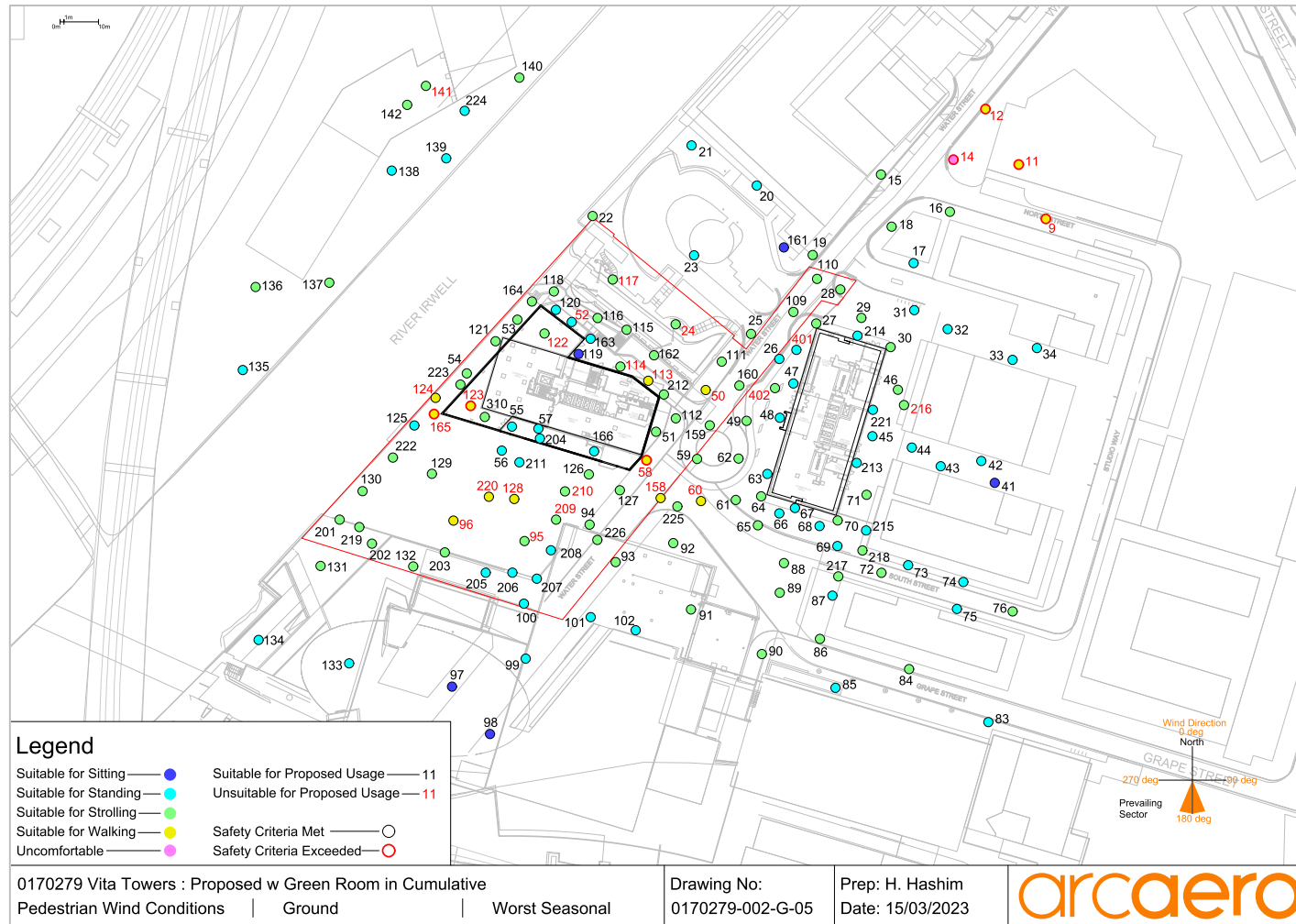


Figure 4.4 - Pedestrian wind conditions, proposed development within cumulative surrounds, summer.

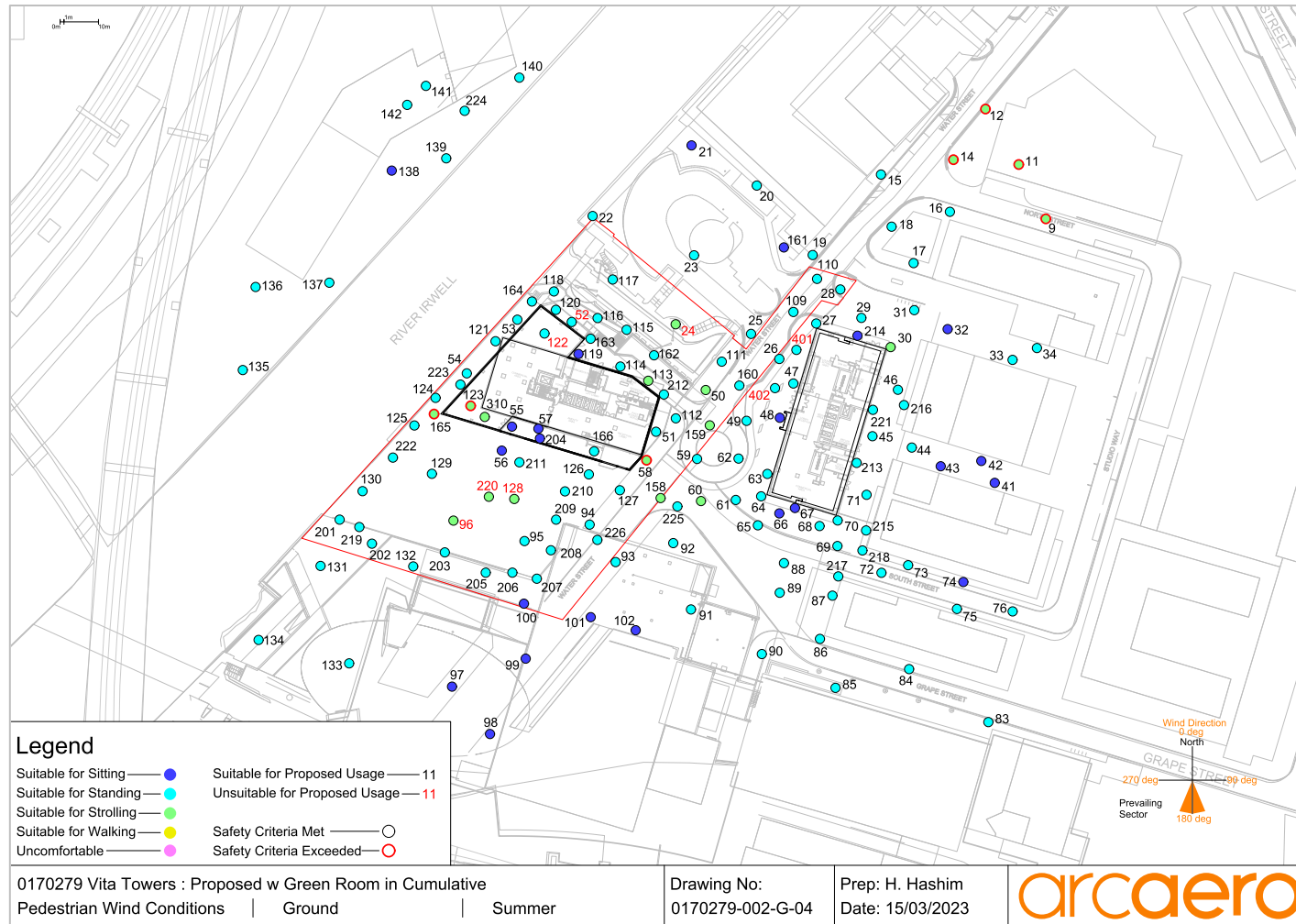


Figure 4.5 - Pedestrian wind conditions, proposed development within existing surrounds with mitigation, 'worst' season.

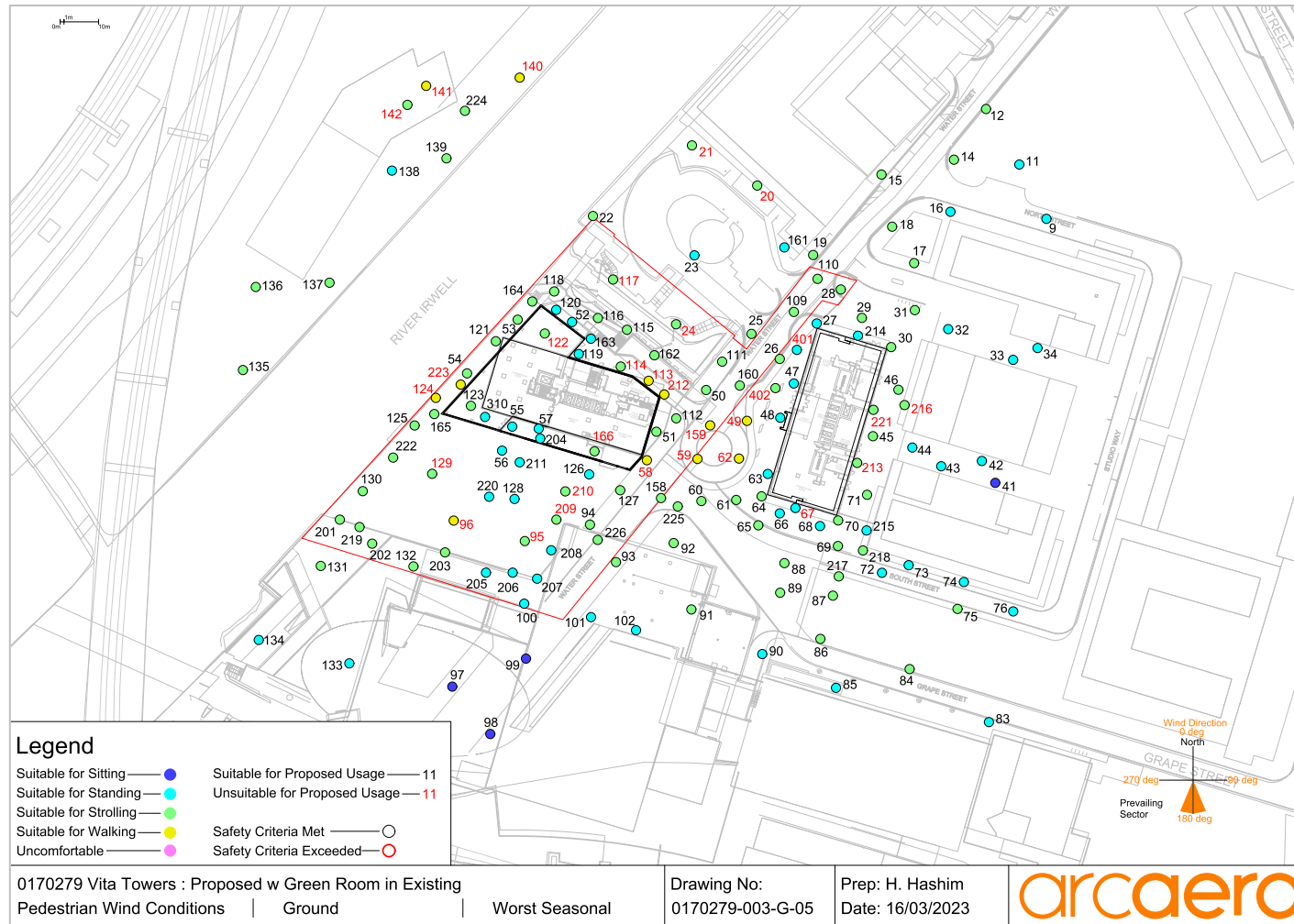


Figure 4.6 - Pedestrian wind conditions, proposed development within existing surrounds with mitigation, summer.

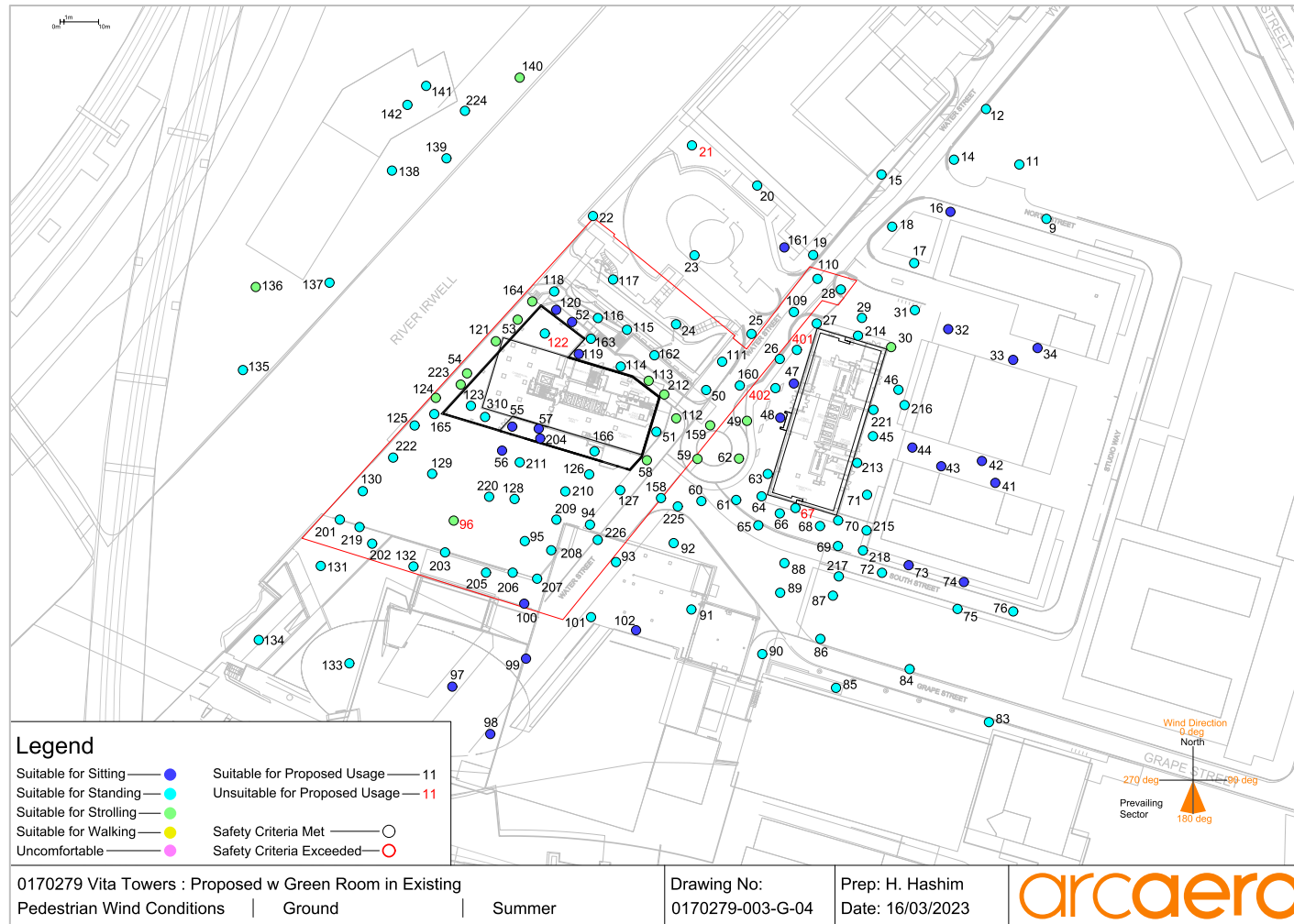


Figure 4.7 - Pedestrian wind conditions, proposed development within cumulative surrounds with mitigation, 'worst' season.

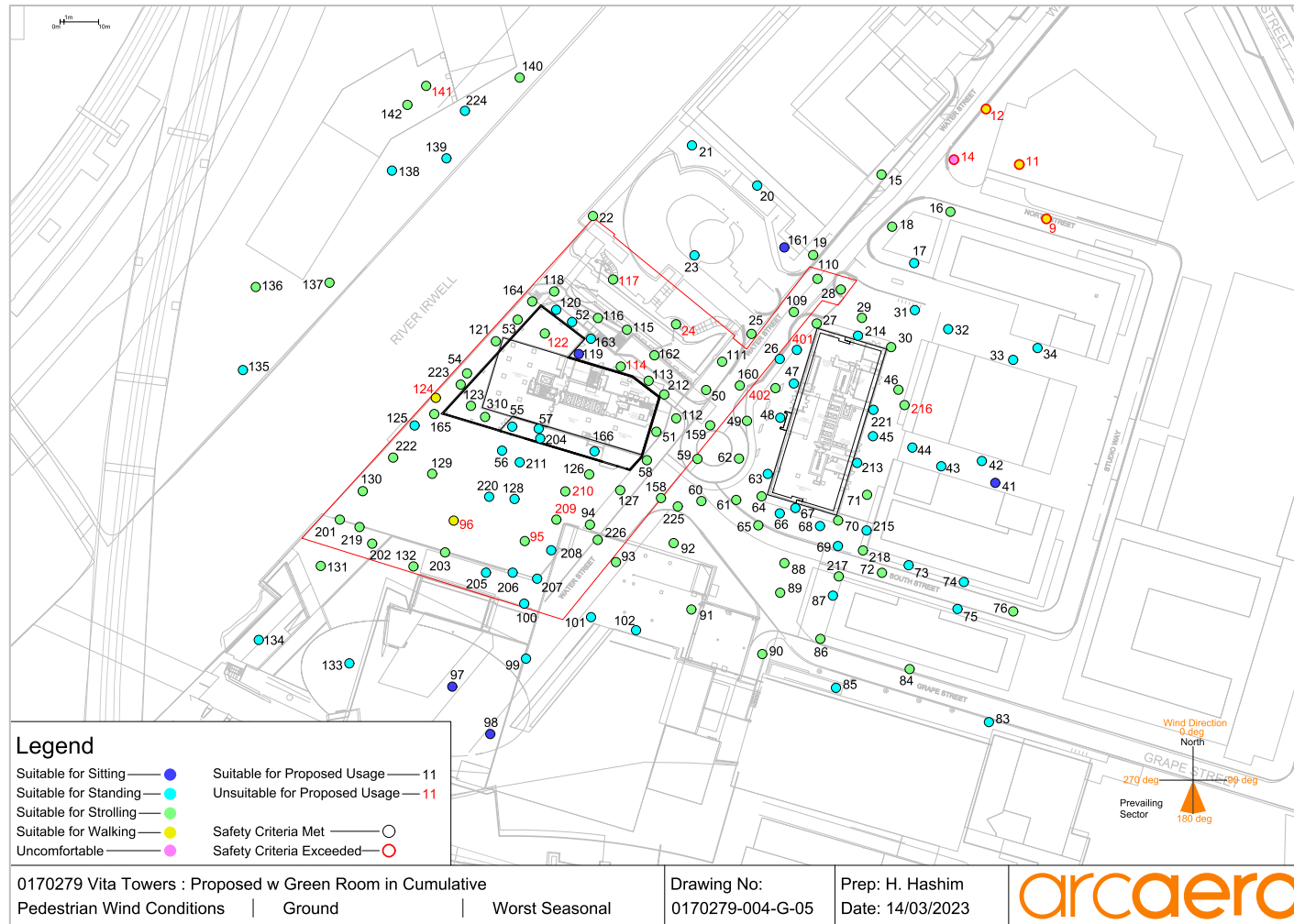
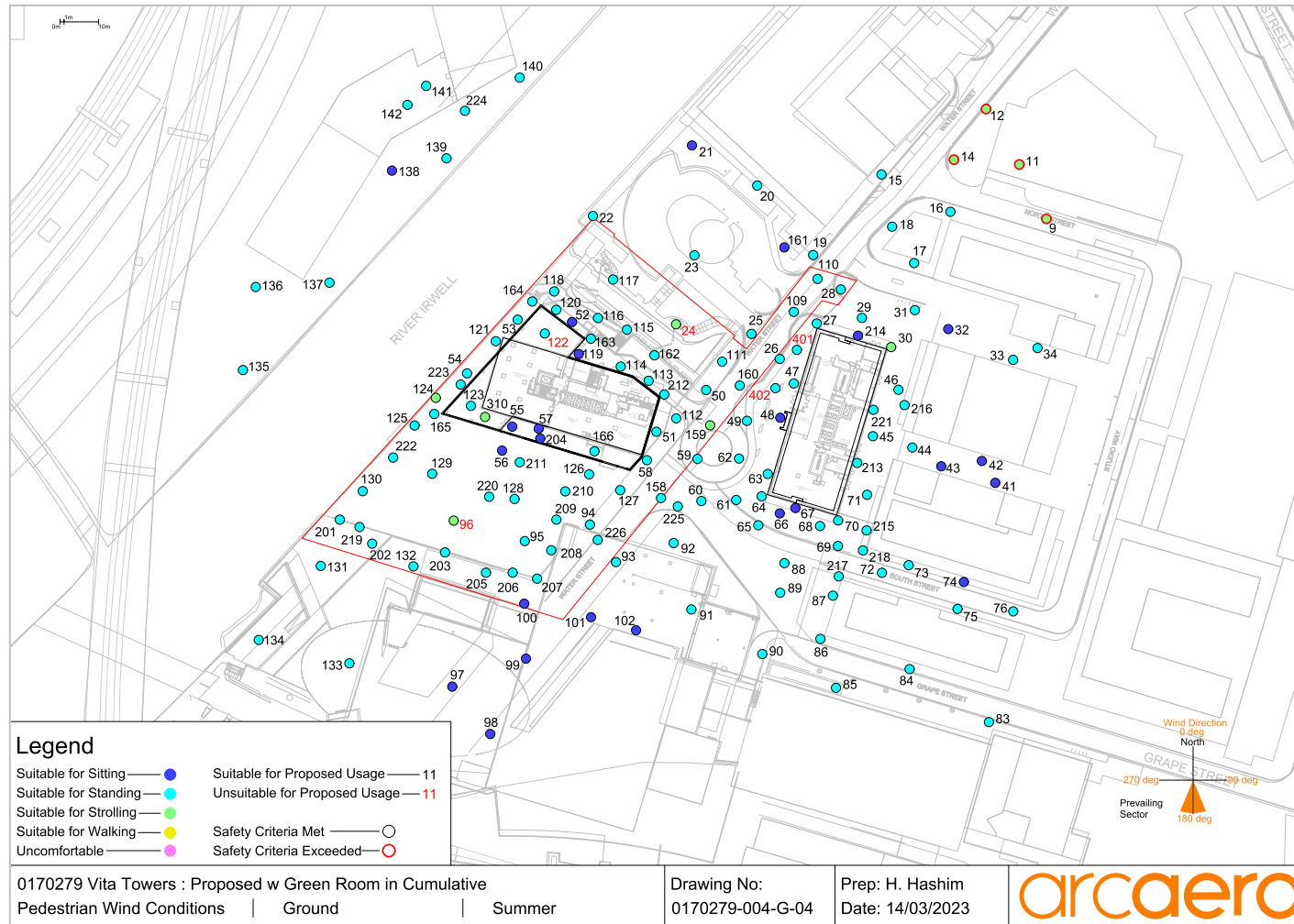


Figure 4.8 - Pedestrian wind conditions, proposed development within cumulative surrounds with mitigation, summer.



Appendix A CFD Modelling

A.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.

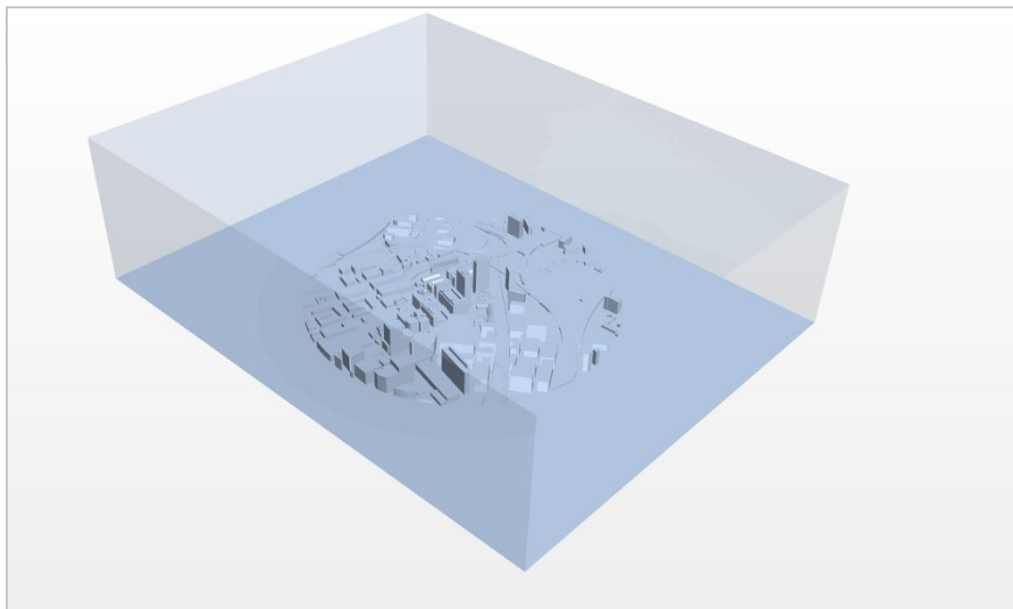
The computational domain includes the proposed development site, with surrounding buildings and topographical features within a 450m radius represented explicitly. The full computational domain extends to 1450m in the along-wind direction, 1300m in the across-wind direction, and 450m vertically.

The height of the domain has been selected to replicate the scaled dimensions of the Imperial College 10x5 wind tunnel, where the wind tunnel testing has been conducted. As Section A.5 shows, the validity of this choice is exhibited by the agreement between wind tunnel and CFD results.

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. The final mesh comprises ~8 million polyhedral cells.

An image of the computational domain is presented in Figure A.1.

Figure A.1 – Computational domain



A.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- ω turbulence model. This model was suggested by Menter⁽³⁾ and is based on a two-equation eddy-viscosity approach, where the SST model formulation combines the use of a k- ω in the inner parts of the boundary layer, but also switches to a k- ϵ behaviour in the free-stream regions of the solutions. Further details for the selected turbulence model are provided in the work of Menter^{(3), (4)}.

A.3 Initial and Boundary Conditions

The atmospheric boundary layer flow was simulated by implementing a logarithmic velocity profile model presented by Richards and Hoxey⁽⁵⁾, 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 constant shear stress with height, maintained by the turbulent kinetic energy k equation below:

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

where:

- $C_\mu = 0.09$ - is a k-ε 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.

A.4 Gust Equivalent Mean Calculation

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

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

The Gust Equivalent Mean is then calculated as:

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

where gust factor, $k_g = 1.85$

The final wind speed ratio (speed-up) used in the Lawson criteria is the worst case derived from U_{Mean} and U_{GEM} .

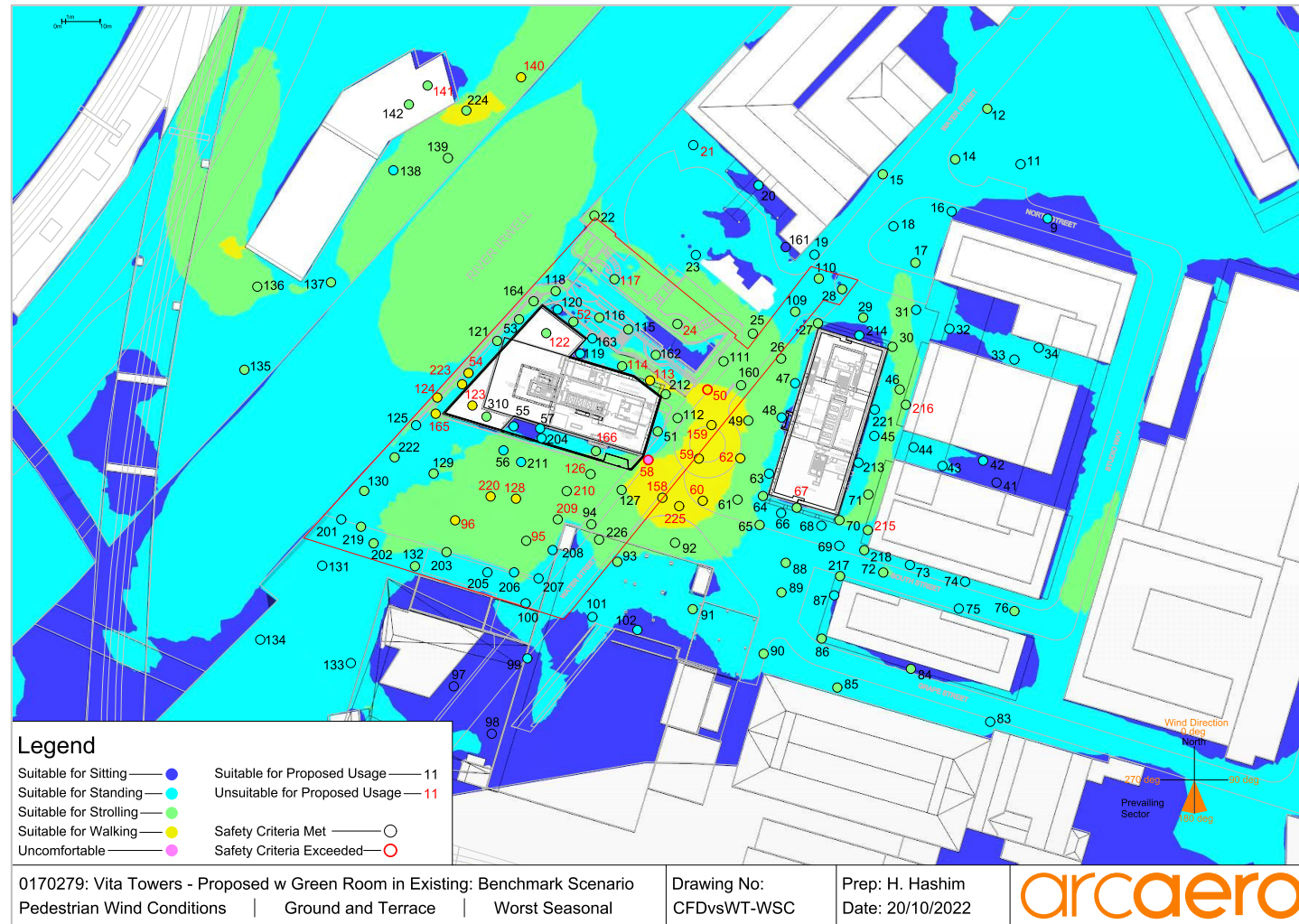
A.5 CFD Predictions: Benchmarking Against Wind Tunnel

Findings of an exercise to benchmark CFD and wind tunnel predictions against one another are presented in Figure A.2, showing regions where the two methodologies predict exceedances of the (worst-seasonal) comfort criteria.

As the figure demonstrates, an acceptable level of agreement has been achieved between the two techniques.

Where discrepancies exist, these are typically minor, with the wind tunnel predictions generally slightly windier in the majority of places where those differences do exist.

Figure A.2 – CFD-WT overlay: worst seasonal comfort predictions: benchmark scenario



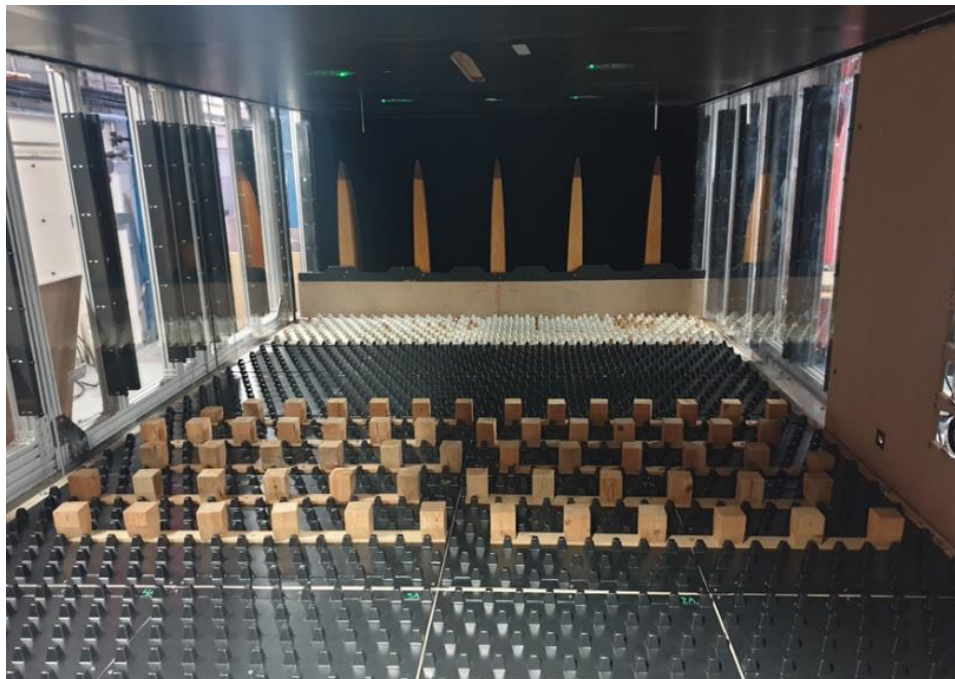
Appendix B Wind Tunnel and Model

B.1 Atmospheric Boundary Layer Modelling

The study was conducted at the Imperial College 10' x 5' wind tunnel in London. This closed-loop facility provides a 20m long boundary layer test section and a 3.0 m x 1.5 m 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 B.1.

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



B.2 Wind Tunnel Model

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 150 locations for the proposed development.

Photos of the wind tunnel model are presented as follows:

- Figure B.2 – B.3: Proposed Development within existing surrounds
- Figure B.4 – B.5: Proposed Development within cumulative surrounds
- Figure B.6: Close up of proposed development
- Figure B.7 – B.8: Close ups of wind mitigation measures

Figure B.2 – Proposed development within existing surrounds, viewed from northwest

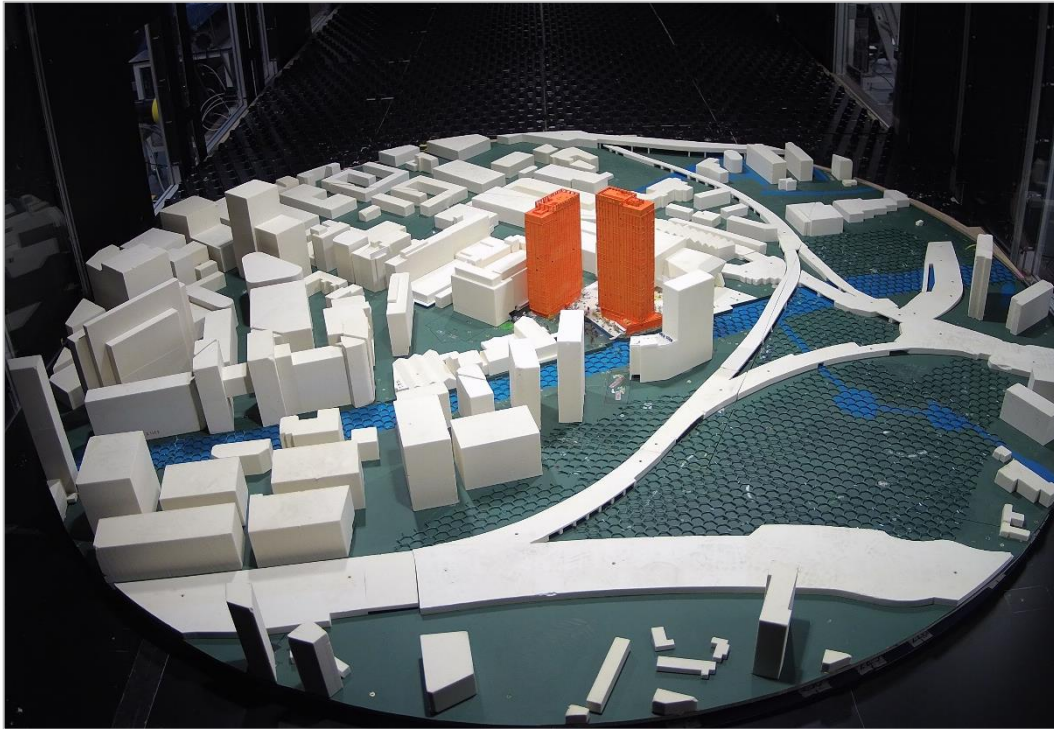


Figure B.3 – Proposed development within existing surrounds, viewed from northeast

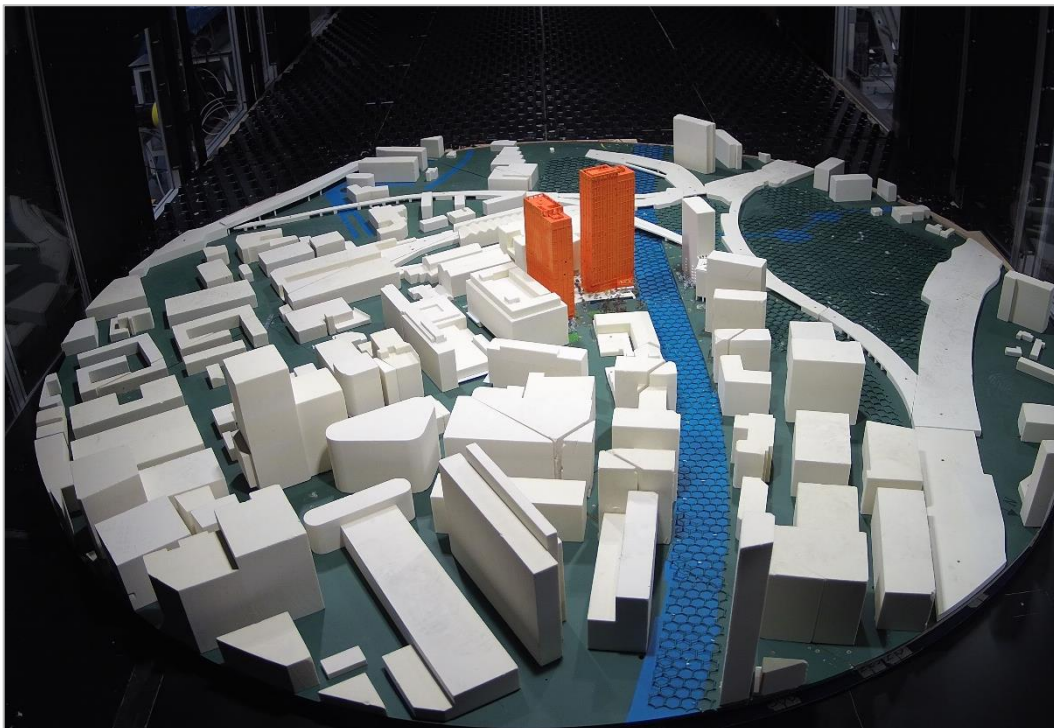


Figure B.4 – Proposed development within cumulative surrounds, viewed from northwest

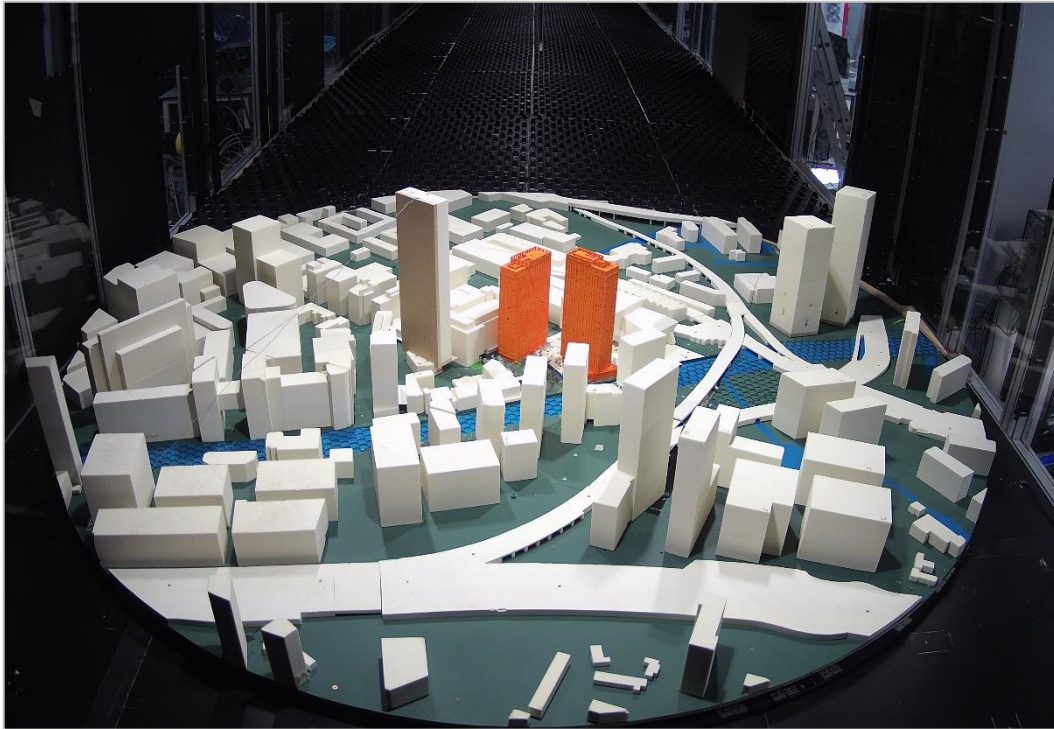


Figure B.5 – Proposed development within cumulative surrounds, viewed from northeast

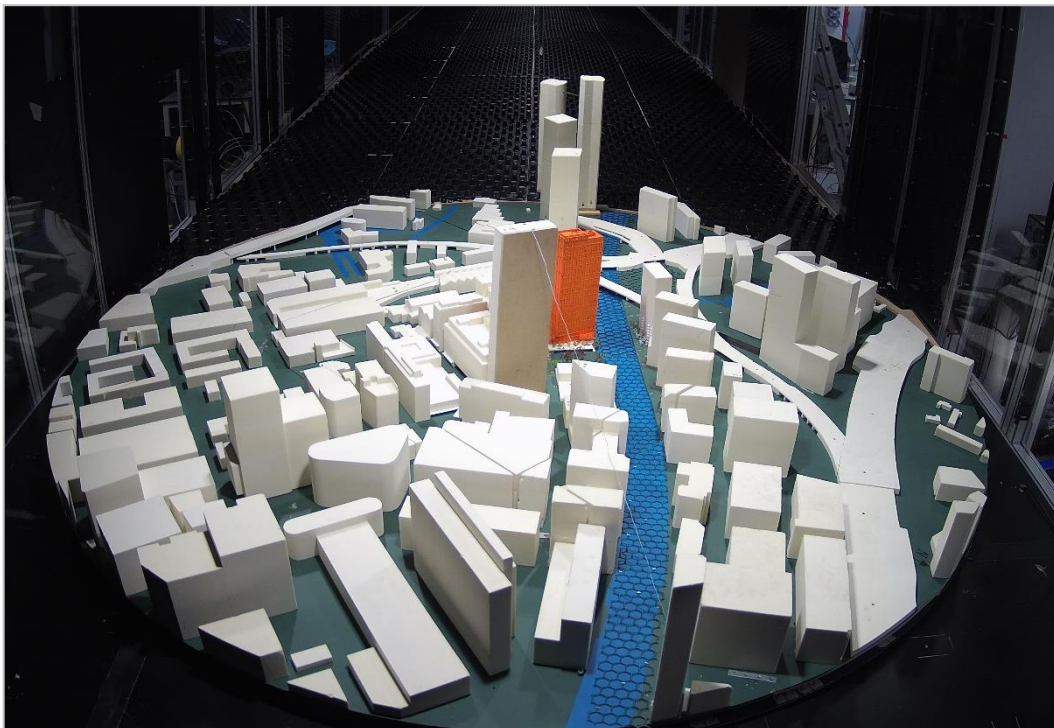


Figure B.6 – Close up of proposed development

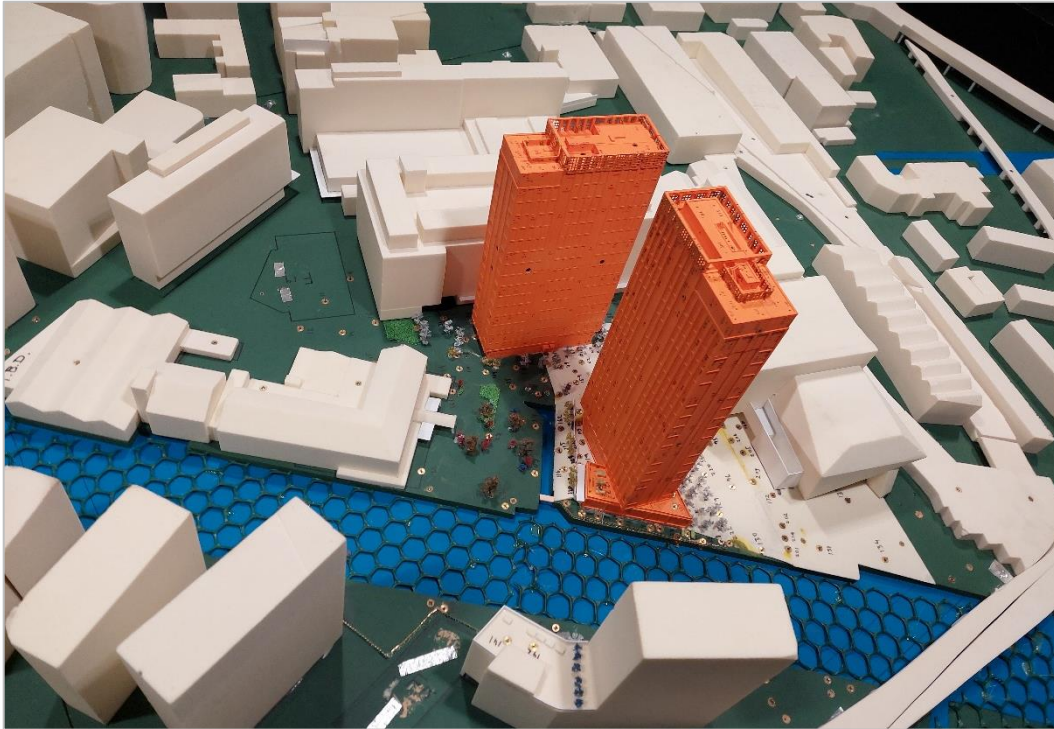


Figure B.7 – Close up of soft landscaping & wind mitigation measures

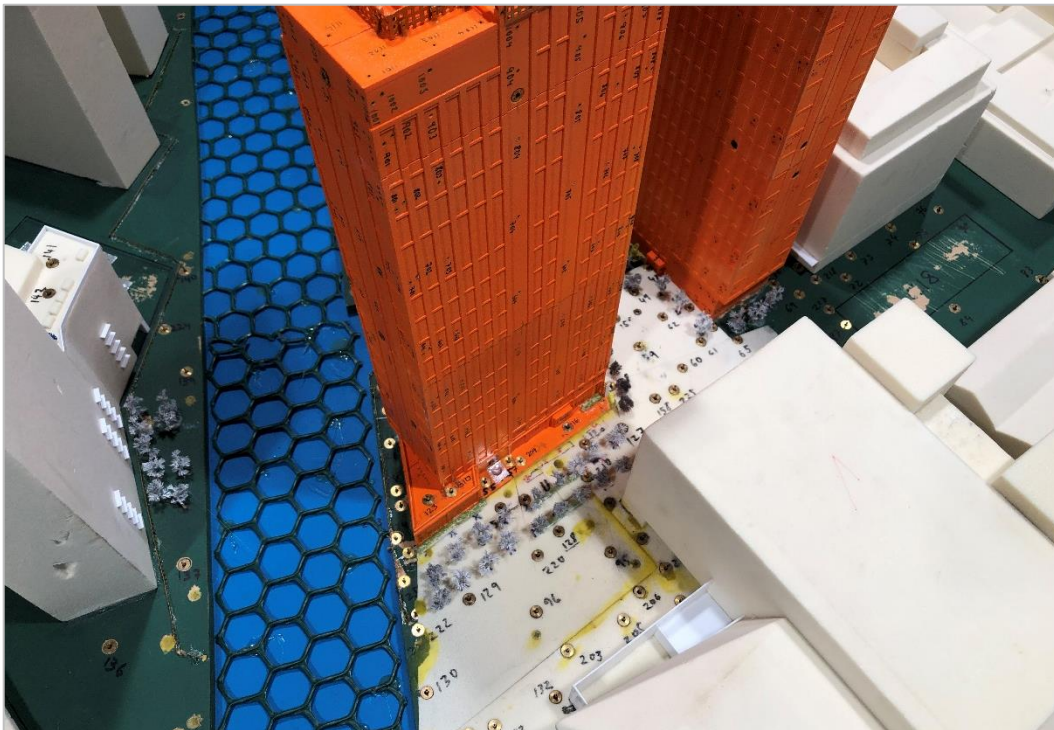
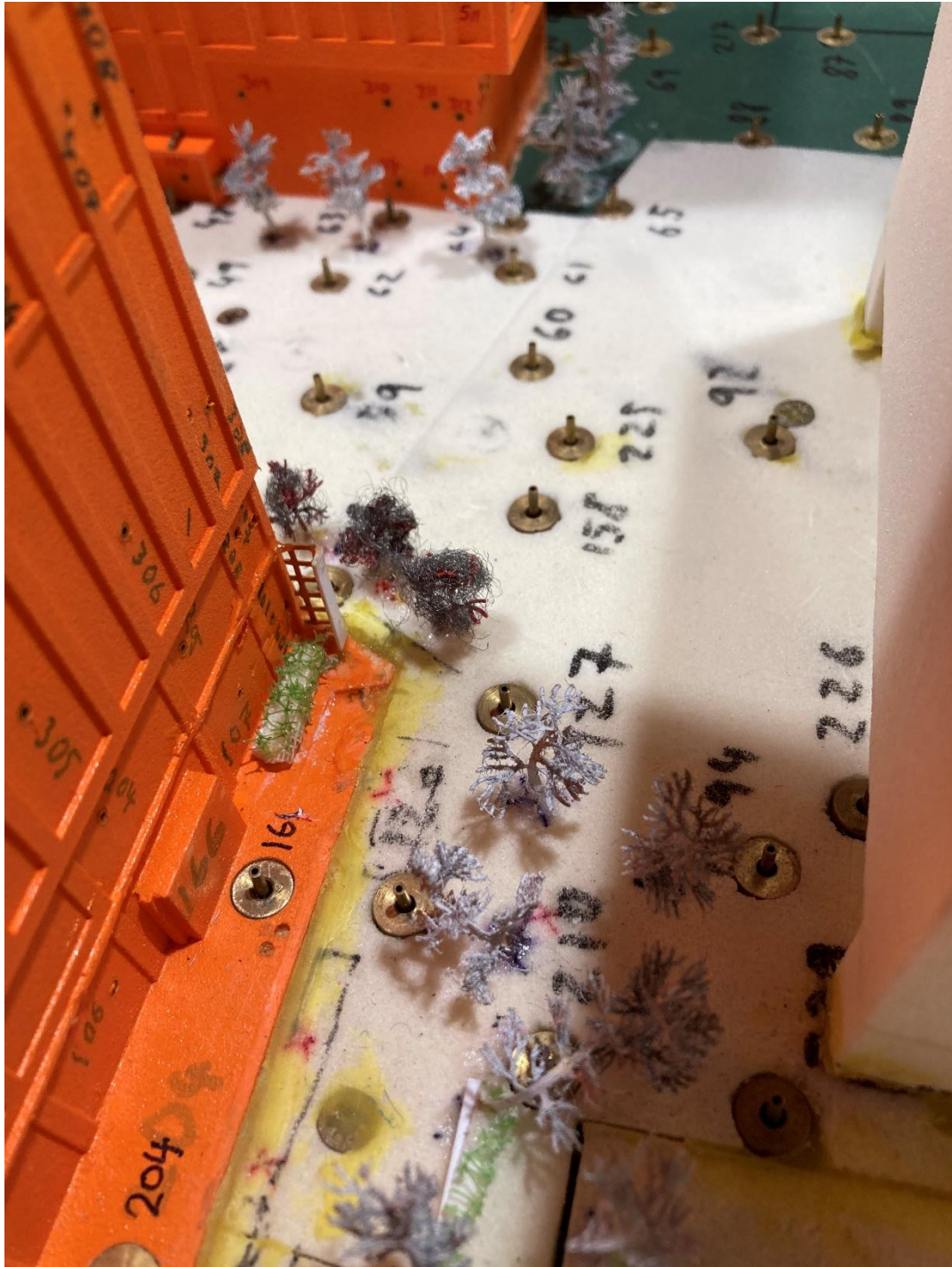


Figure B.8 – Close up of soft landscaping & wind mitigation measures



B.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 150 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 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 ⁽²⁾ (the industry standard) have been employed.

The resulting annual and seasonal directional and wind speed probability distributions at the reference height of 90m, at the proposed site, are given in Figures C.2 to C.6, respectively.

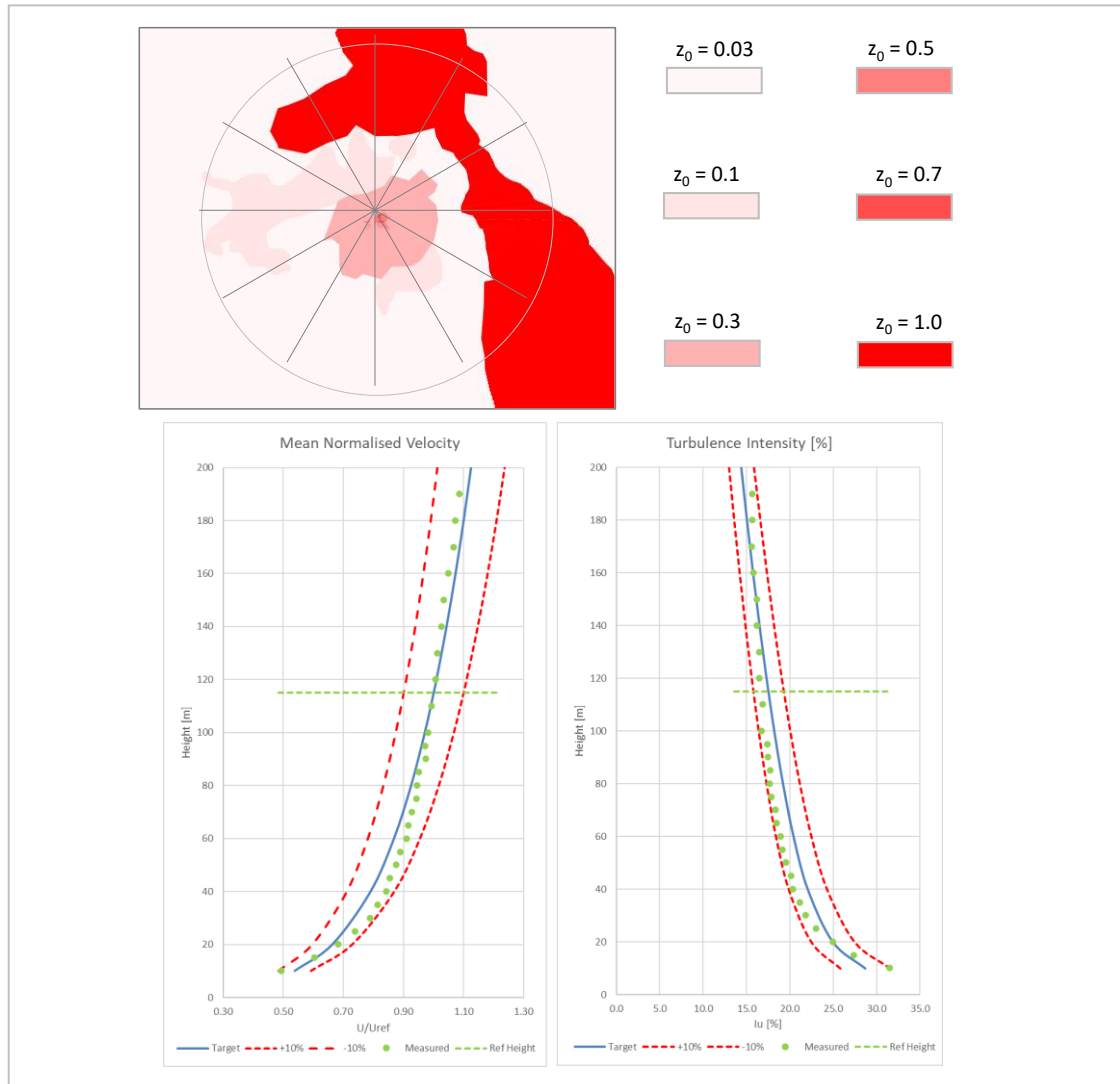
C.2 Wind Properties at the Site

A detailed analysis, based on the widely accepted Deaves and Harris model of the atmospheric boundary layer (ABL), as defined in ESDU Item 01008 ⁽²⁾, 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 CFD model and wind tunnel.

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

Architectural Aerodynamic'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, CFD and wind tunnel profiles.



The CFD simulation replicates the wind speed and turbulence 'target' profile directly, while the green markers represent measurements of the wind tunnel profile, showing a good match against the specified target.

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 (%)

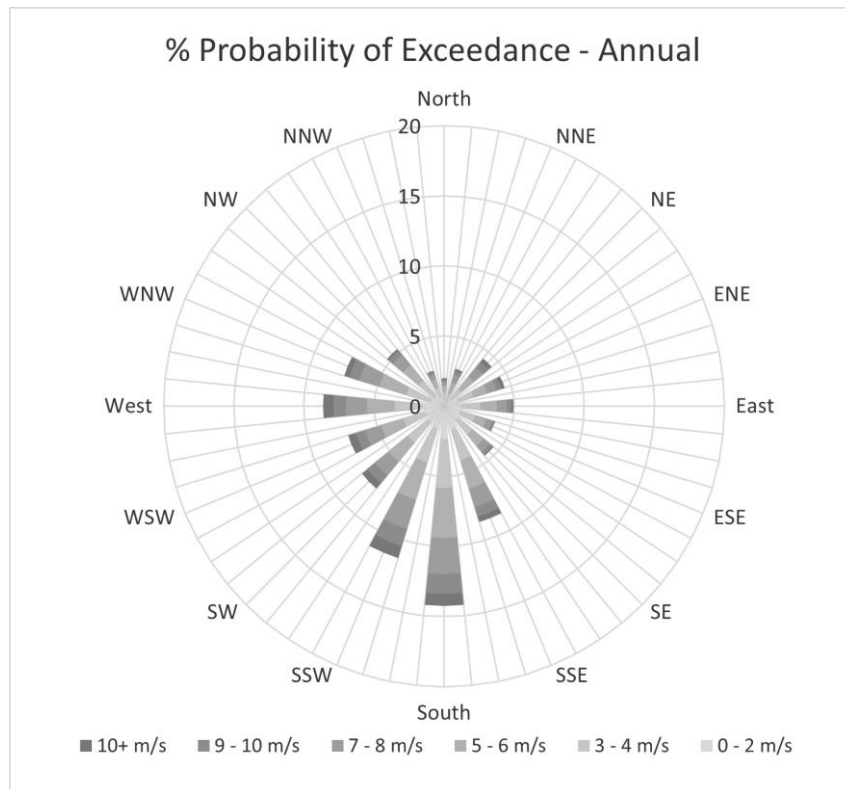


Figure C.3 – Cumulative wind speed probability distribution at site, spring (%)

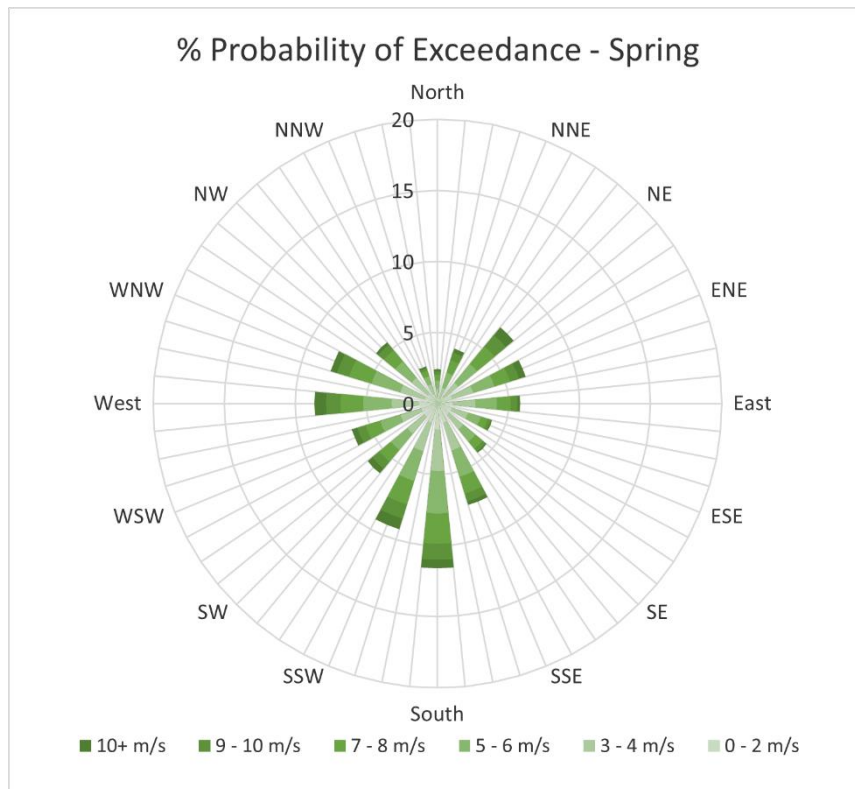


Figure C.4 – Cumulative wind speed probability distribution at site, summer (%)

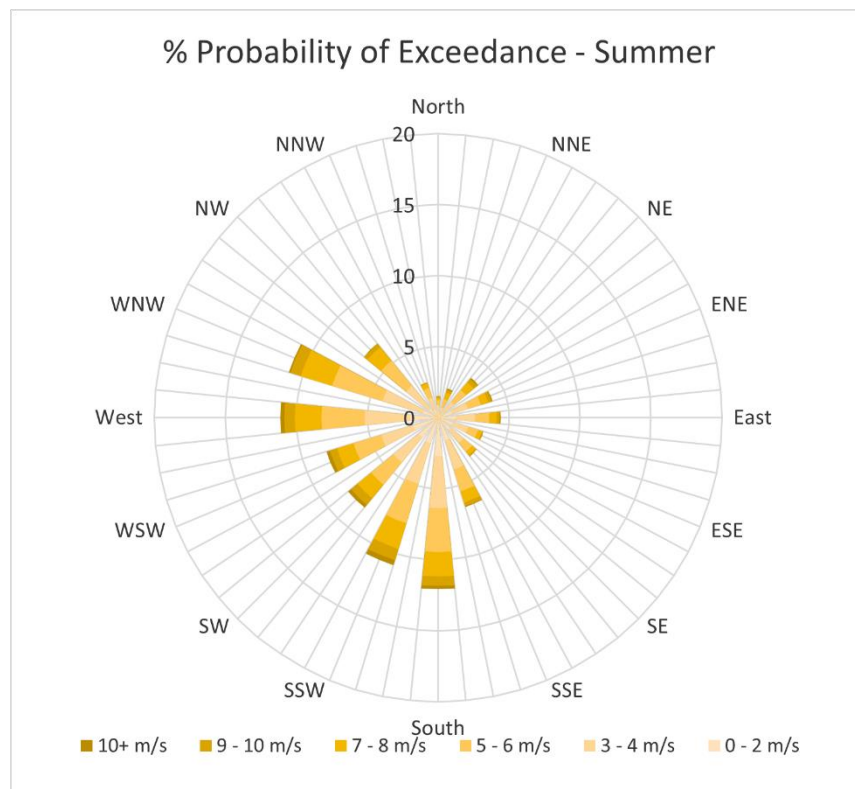


Figure C.5 – Cumulative wind speed probability distribution at site, autumn (%)

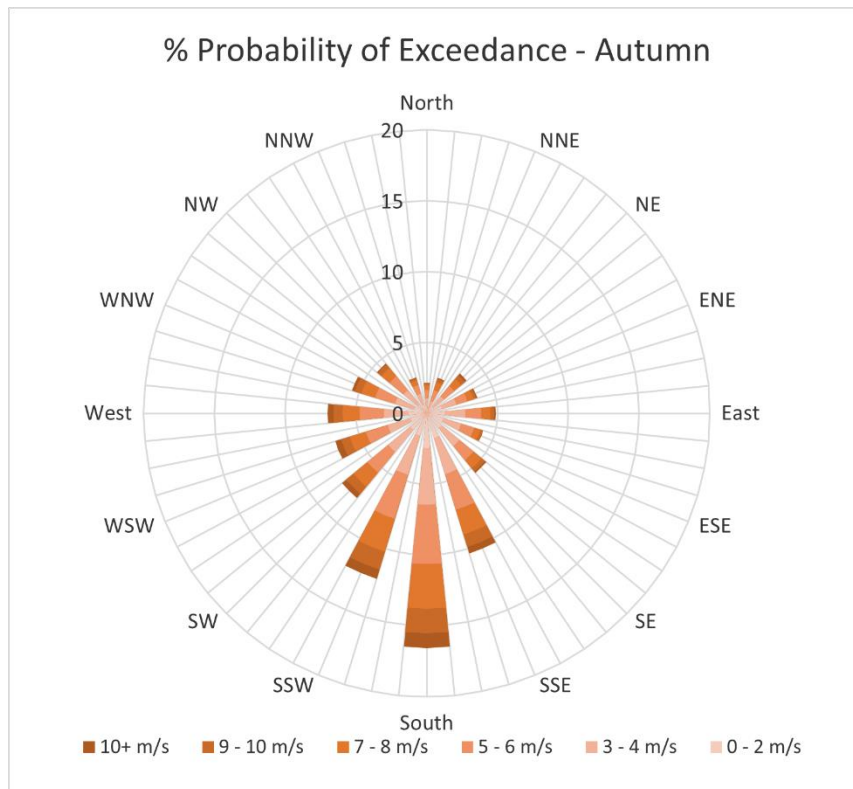
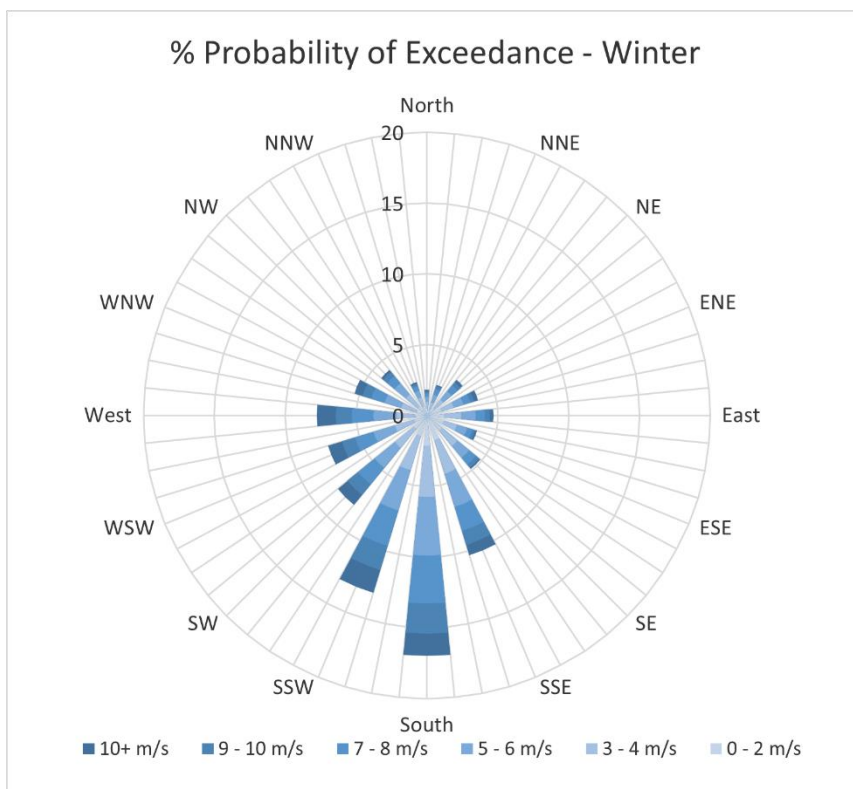


Figure C.6 – Cumulative wind speed probability distribution at site, winter (%)



Appendix D Pedestrian / Occupant Uses

Figure D.1 – Assumed pedestrian uses, proposed development.

