Central Somers Town CIP

Wind Microclimate Study

DECEMBER 2015

Somers Town Community Investment Programme

Camden

Project No. 431914

Brill Place

Wind Microclimate Study

07th October 2015

For
de Rijke Marsh Morgan
(DRMM)

Report Title	**Brill Place Wind Microclimate Study**		
Client:	**de Rijke Marsh Morgan (DRMM)**		
Document No:	**431914rep1v2**	**Release: 2**	**Copy No:**
Status	**Draft Report for Client Review**		
Report Date:	**07th October 2015**		
Holds:			

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Distribution:	**Copy no.**	**to**	**Client**
	Copy no.	**to**	**BMT Records**

Previous Release History:	**Release No:**	**Status:**	**Date:**
431914rep1v1	**1**	**Draft Report for Internal Review**	**05th October 2015**

Brill Place
Wind Microclimate Study

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EXECUTIVE SUMMARY

Background

A boundary layer wind tunnel study has been carried out by BMT Fluid Mechanics Ltd. (BMT) to assess the wind microclimate for the proposed Brill Place development in London, UK.

The boundary layer wind tunnel study has enabled the pedestrian level wind environment at the site to be quantified and classified in terms of suitability for current and planned usage, based on the industry standard Lawson criteria for pedestrian comfort and safety.

The study combines measured pedestrian level wind speeds at key areas in and around the site with long-term wind frequency statistics to determine the probability of local wind speeds exceeding comfort and safety thresholds for a range of common pedestrian activities based on the industry standard Lawson criteria. This defines the type of activities for which the wind conditions would be safe and comfortable.

Conclusions

The boundary layer wind tunnel study has assessed the wind microclimate for the proposed development. On the basis of the wind tunnel modelling, the following conclusions have been drawn:

- Wind conditions across the proposed development are considered suitable, in terms of pedestrian safety, for all users throughout the year.
- Wind conditions across the proposed development are considered suitable, in terms of comfort, for the planned pedestrian activities. Exceptions to this are the entrance located at the southwest and the balconies at the west of the proposed development. In order to enhance the local wind microclimate and to ensure the presence of amenable conditions, it might be beneficial to introduce further mitigation measures.
- With the introduction of masterplan landscaping within future surrounds, the proposed development is relatively shielded from the south-westerly winds, creating slightly calmer conditions throughout the development / site and consequently comfort criteria are met at the south entrance of proposed development.

Brill Place
Wind Microclimate Study

1. Introduction

This report summarises the results of a boundary layer wind tunnel study, commissioned by de Rijke Marsh Morgan (DRMM), to assess the wind environment for the proposed Brill Place development in London, UK.

The boundary layer wind tunnel study has enabled the pedestrian level wind environment at the site to be quantified and classified in terms of suitability for current and planned usage, based on the industry standard Lawson criteria for pedestrian comfort and safety.

The study considers the proposed development in the context of existing surrounds and approved future surrounds.

2. The Assessment of Wind Microclimate

The UK Met Office defines a microclimate 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 for safety and stability and threshold values associated with a series of typical activities such as walking, awaiting a bus or sitting within a café, restaurant or bar outlet. It can therefore be shown within the various parts of a new development proposal and the neighbouring properties, whether wind conditions are suitable or unsuitable, and whether or not design adjustment or mitigation measures are required. It is for this purpose that wind microclimate assessments are undertaken.

The industry standard criteria for such assessments are commonly referred to as the Lawson criteria and emerged during a period of substantial research by eminent wind engineers of the time, many of whom individually presented proposals for criteria within wind engineering literature, including Davenport[1] in 1972. Lawson himself presented what has become the 'University of Bristol' variant of the Lawson criteria in 1973[2], prior to a collaborative initiative that produced the London Docklands Development Corporation (LDDC) variant of the Lawson criteria[3].

The LDDC variant of the Lawson criteria 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. It is this approach that BMT adopts.

3. Study Area

3.1. Site Location & Surrounding Area

The proposed development site is located in King Cross London, UK. The site is bounded by Purchese Street to the west, London St Pancras Station to the east, Francis Crick Institute laboratory to the south, and Hampden Close street to the North.

At present the area immediately surrounding the proposed development principally comprises of mid-rise development. Further afield, the wider surrounding area largely consists of mid-rise and low-rise residential buildings.

The site location is presented within the context of the wider surrounding area in Figure 3.1. Figure 3.2 presents a site plan of the proposed development.

Three configurations of the surrounding area are considered in the current study, namely:

- Existing Site
- Proposed development within existing surrounding conditions
- Proposed development within approved future surrounding conditions

3.2. Proposed Development

The proposed development comprises of a rectangular tower approximately 78m in height.

3.3. Soft Landscaping

The wind environment has been assessed for the proposed development with existing and masterplan soft landscaping proposals as illustrated graphically within Figure 3.3a and 3.3b respectively.

4. Assessment Methodology

4.1. Boundary Layer Wind Tunnel Studies

The assessment of environmental wind flows in the built environment lies outside the scope of internationally recognised wind codes, which focus on wind loading issues. In addition, there are no handbooks or engineering methods from which reliable assessments of the complex environmental wind flows that shape the pedestrian level wind conditions can be derived and numerical / computational methods such as computational fluid dynamics do not readily apply to turbulent wind flows in the built environment.

As a result, a purposely-designed boundary layer wind tunnel study was used to provide a reliable quantification of the pedestrian level wind environment within the following key areas:

- Pedestrian access routes
- Entrances
- Recreational areas, including
    - Roof terraces
    - Balconies

The study combines wind speed-up factors at key areas in and around the site with long-term wind frequency statistics to determine the probability of local wind speeds exceeding comfort and safety thresholds for a range of common pedestrian activities. The threshold wind speeds are based on the industry standard Lawson criteria. The wind speed-ups are measured in the model-scale boundary layer wind tunnel testing for a full range of wind directions. The wind statistics are transposed from the nearest suitable weather centre to apply directly at the site.

4.2. Wind Climate Analysis

Details of the annual and seasonal climate wind analysis relevant to the site are presented in Appendix A.

4.3. Wind Tunnel and Model Details

Details of the model scale and construction, along with photos of the model and wind tunnel setup are presented in Appendix B.

The model scale of 1:300 is large enough to allow a good representation of the details that are likely to affect the local and overall wind flows at full scale. In addition, this scale enables a good simulation of the turbulence properties of the wind to be achieved.

4.4. Measurement and Analysis

The technical details relating to the instrumentation, measurements and analysis for the wind environment study along with the assessment criteria to which they are compared (Lawson criteria) are described in Appendix C.

The Lawson criteria define the type of activities for which the wind conditions would be safe and comfortable. An area that has relatively low wind speeds and would be comfortable for recreational use (involving standing or sitting) would also be suitable for uses that tolerate higher wind speeds such as walking.

The wind environment was assessed at a total of 88 locations for the proposed development, with 80 locations at ground level and 8 locations at elevated levels. Details of proposed pedestrian activities, assumed in the assessment, are also provided in Appendix C.

The measurement locations were reviewed and approved by the design team, prior to testing.

Measurements were taken for a full range of wind directions in increments of 22.5°.

4.5. Wind Direction

The 0° wind direction has been chosen to coincide with the OS Grid north (90° east, 180° south, 270° west). The wind direction denotes the direction, which the wind is blowing *from*.

5. Results

5.1. General

Results are provided for the following configurations:

- Existing Site Conditions
- Proposed Development, within the Context of Existing Surrounds
- Proposed Development, within the Context of Future Surrounds

5.2. Wind Speed-Up Factors

The measured wind speeds are converted into wind speed-up factors. These are defined as the ratio between the measured wind speeds at a height of 1.5m above the ground and the wind speed at the reference height of 78m, the highest roof height within the site relative to the wind tunnel model datum level.

5.3. Threshold Wind Speed Exceedance

Wind speed-up factors are processed in conjunction with wind statistics for the site to derive exceedances of threshold wind speeds relevant to comfort and safety criteria.

5.4. Annual and Seasonal Assessments

The results of the wind speed measurements are summarised in graphical format in electronic Appendix D (provided electronically to the design team), in terms of comfort and safety ratings derived for each pedestrian level measurement location.

6. Assessment

6.1. Approach to Assessment

6.1.1. Safety

At each area investigated, the suitability of the pedestrian level wind environment in terms of safety is assessed based on the Lawson criteria for pedestrian safety (see Appendix C). Safety is determined for the 'able-bodied' and for the 'general public'. For the general public a wind speed of 15 metres-per-second occurring once per year is rated as unsafe, with the potential to de-stabilise the less able members of the public including the elderly, cyclists and children. Able-bodied users are more likely to be capable of defending themselves against extreme pedestrian level winds and thus experience distress at a higher threshold wind speed of 20 metres-per-second, once per year.

6.1.2. Comfort

At each area investigated, the suitability of the pedestrian level wind environment in terms of comfort for various activities is assessed based on the Lawson criteria for pedestrian comfort (see Appendix C). The assessment takes full account of seasonal variations in wind conditions and pedestrian activities. For example, conditions for recreational activities focus on summer, but also consider spring and autumn, whilst conditions for pedestrian thoroughfare, access or waiting (example bus stops) consider all seasons, with winter usually being the critical season. The activities considered, and their relation to the Lawson comfort criteria, are summarised as follows:

Suitability		Lawson Comfort Criteria
Outdoor seating	For long periods of sitting such as for an outdoor café / bar, a private balcony	'Long-term sitting' in summer
Entrances, waiting areas, shop fronts	For pedestrian ingress / egress at a building entrance / shop front, window shopping, or short periods of sitting or standing such as at a bus stop, taxi rank, meeting point, etc.	'Short-term standing / sitting' in all seasons
Recreational spaces	For outdoor leisure uses such as a park, children's play area, etc.	'Short-term standing / sitting' from spring to autumn
Leisure Thoroughfare / Strolling	For access to and passage through the development and surrounding area	'Leisure Thoroughfare / Strolling' in all

Suitability		Lawson Comfort Criteria
		seasons
Pedestrian Transit / Thoroughfare (A-B)	For access to and passage through the development and surrounding area	'Pedestrian Transit / Thoroughfare (A-B)' in all seasons

6.1.3. Mitigation Requirements

The assessment considers the requirement for mitigation schemes at each location based on proposed pedestrian activities listed in Appendix C. Areas that **require** mitigation schemes in order to create a wind environment sufficiently safe and comfortable for proposed uses are highlighted.

6.2. Existing Site Conditions

The results of the assessment for existing site conditions are summarised in graphical format in Figure 6.1.

6.2.1. Safety

For the existing site conditions, wind conditions rate as suitable, in term of pedestrian safety, at all locations within the site.

6.2.2. Comfort

6.2.2.1. Thoroughfares

Wind conditions at all thoroughfares within the site are suitable for pedestrian thoroughfare and thus for pedestrian access to and passage through the site.

6.2.2.2. Surrounding Area

Wind conditions at all locations are suitable, in term of comfort, for their intended usage with the exception of generally an entrance at the south façade of the adjacent development (location 35). In order to alleviate accelerated winds at this location, a number of measures would potentially be affected. This would include trees planting along the Phoenix Road.

6.3. Proposed Development within Existing Surrounds

The proposed development is heavily sheltered from prevailing south-westerly and westerly winds. The impacts of exposure to prevailing winds and associated downdrafts, channelling of wind through narrow gaps and passages, and acceleration around exposed building corners is correspondingly minor.

The development is exposed to winds approaching from non-prevailing directions, though winds from these directions are relatively lights and rarely occurring.

The results of the assessment for existing site conditions are summarised in graphical format in Figure 6.2a (ground level) and 6.2b (elevated levels).

6.3.1. Safety

With the introduction of the proposed development within the context of existing surrounds, the wind conditions rate as suitable, in terms of pedestrian safety, at all locations throughout the site and surrounding area.

6.3.2. Comfort

6.3.2.1. Thoroughfares

Wind conditions on the thoroughfares across the proposed development site are generally suitable at least for strolling throughout the year and are thus suitable for pedestrian uses.

6.3.2.2. Entrances

With respect to pedestrian comfort, in terms of wind force, wind conditions at the entrances of proposed development are generally suitable for short periods of standing throughout the year with the exception of southwest entrance of the proposed development (location 25).

Wind condition impact at this location is largely due to subjected to the prevailing south-westerly winds. The implementation of further wind mitigation measures such as providing localised protection via soft landscaping, side screens or by recessing entrances would be expected to further enhance the wind environment to ensure the existence of more benign conditions.

6.3.2.3. Recreational Space

Wind conditions within recreational spaces across the proposed development site are generally suitable for a short period of sitting and standing throughout the year and are thus suitable for their intended uses.

6.3.2.4. Elevated Levels (Roof Terrace and Balconies)

Wind comfort at most of the elevated levels including balconies and roof terraces are generally suitable with the exception of the balcony at the west of proposed development (location 102). This location is expected to improve with the introduction of parapets/ tall side screens.

6.4. Proposed Development within Approved Future Surrounds including the Neighbouring Masterplan Development

With the introduction of masterplan landscaping within future surrounds, the proposed development is relatively shielded from the south-westerly winds, creating slightly calmer conditions throughout the development / site and consequently comfort criteria are met at location 25.

The results of the assessment for existing site conditions are summarised in graphical format in Figure 6.3a (ground level) and 6.3b (elevated levels).

7. Recommendations for Mitigation / Further Mitigation

In order to enhance the local wind microclimate and to ensure the presence of amenable conditions within the site and surrounding area, it is recommended to develop further soft landscaping proposals / mitigation measures, which might include, but would not be limited to those outlined below, and to verify the effectiveness of these via wind tunnel testing.

- Raised parapets for balconies
- Trees planting (~5m height) along Phoenix Road for surrounding area

8. Conclusions

The boundary layer wind tunnel study has assessed the wind microclimate for the proposed development. On the basis of the wind tunnel modelling, the following conclusions have been drawn:

- Wind conditions across the proposed development are considered suitable, in terms of pedestrian safety, for all users throughout the year.
- Wind conditions across the proposed development are considered suitable, in terms of comfort, for the planned pedestrian activities. Exceptions to this are the entrance located at the southwest and the balconies at the west of the proposed development. In order to enhance the local wind microclimate and to ensure the presence of amenable conditions, it might be beneficial to introduce further mitigation measures.
- With the introduction of masterplan landscaping within future surrounds, the proposed development is relatively shielded from the south-westerly winds, creating slightly calmer conditions throughout the development / site and consequently comfort criteria are met at the south entrance of proposed development.

9. References

[1] Davenport, A.G. *An Approach to Human Comfort Criteria for Environmental Wind Conditions*. Colloqium on Building Climatology, Stockholm, September 1972.

[2] Lawson, T.V. *The Wind Environment of Buildings: A Logical Approach to the Establishment of Criteria*. University of Bristol, Department of Aeronautical Engineering, TVL/7301, 1973.

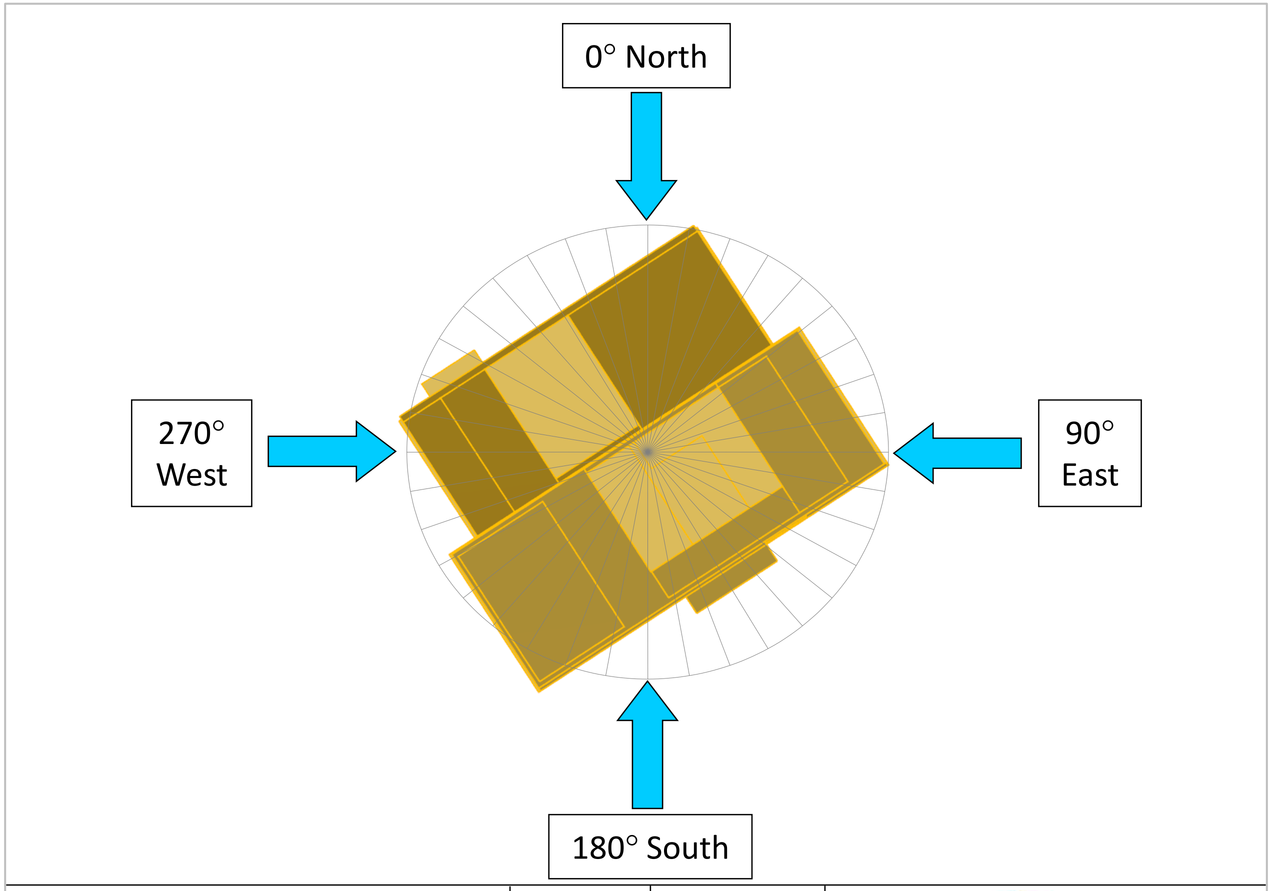
[3] Lawson, T.V. *The determination of the wind environment of a building complex before construction.* University of Bristol, Department of Aeronautical Engineering, TVL/9025, 1990.

[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.

Figure 3.1: Site location

431914 – Brill Place Ariel View of Proposed Site	Status: Preliminary	Drawing No: 431914/FIG. 3.1	Prep: T. Syafizan Date: 5-Oct-15

Figure 3.2: Plan view of the proposed development



431914 – Brill Place Tower Plan and Wind Directions	Status: Preliminary	Drawing No: 431914/FIG. 3.2	Prep: T. Syafizan Date: 5-Oct-15

Figure 3.3a: Proposed Development within Existing Soft Landscaping

431914 – Brill Place Proposed Development within Existing Landscaping	Status: Preliminary	Drawing No: 431914/FIG. 3.3a	Prep: T. Syafizan Date: 6-Oct-15 BMT Fluid Mechanics

Figure 3.3b: Proposed Development within Masterplan Soft Landscaping

Landscaping Key

- Tree - ~5m

431914 – Brill Place Proposed Development within Masterplan Landscaping	Status: Preliminary	Drawing No: 431914/FIG. 3.3b	Prep: T. Syafizan Date: 6-Oct-15

Figure 6.1: Existing site conditions wind microclimate summary

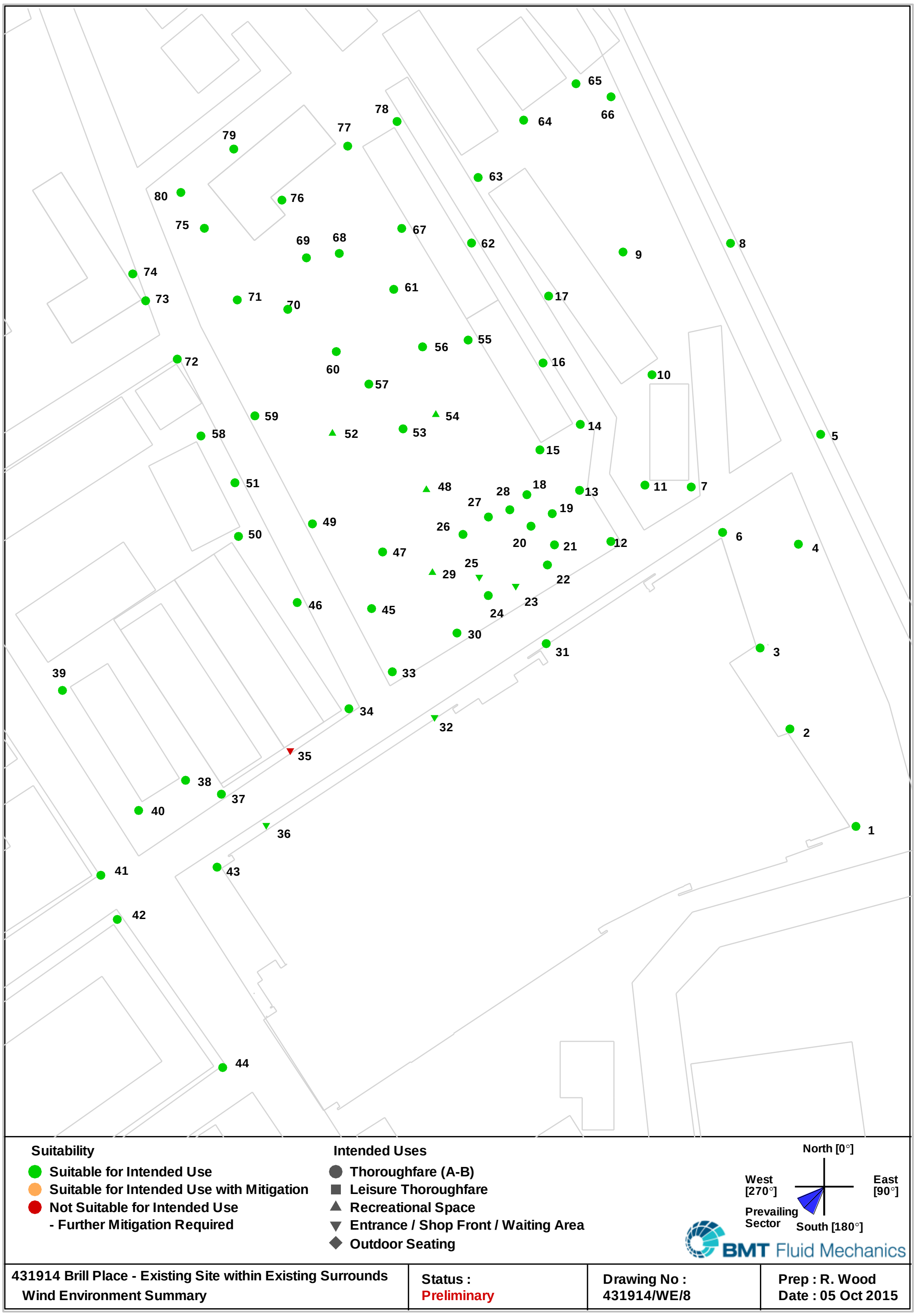


Figure 6.2a: Wind microclimate summary, proposed development within existing surrounds – Ground Level

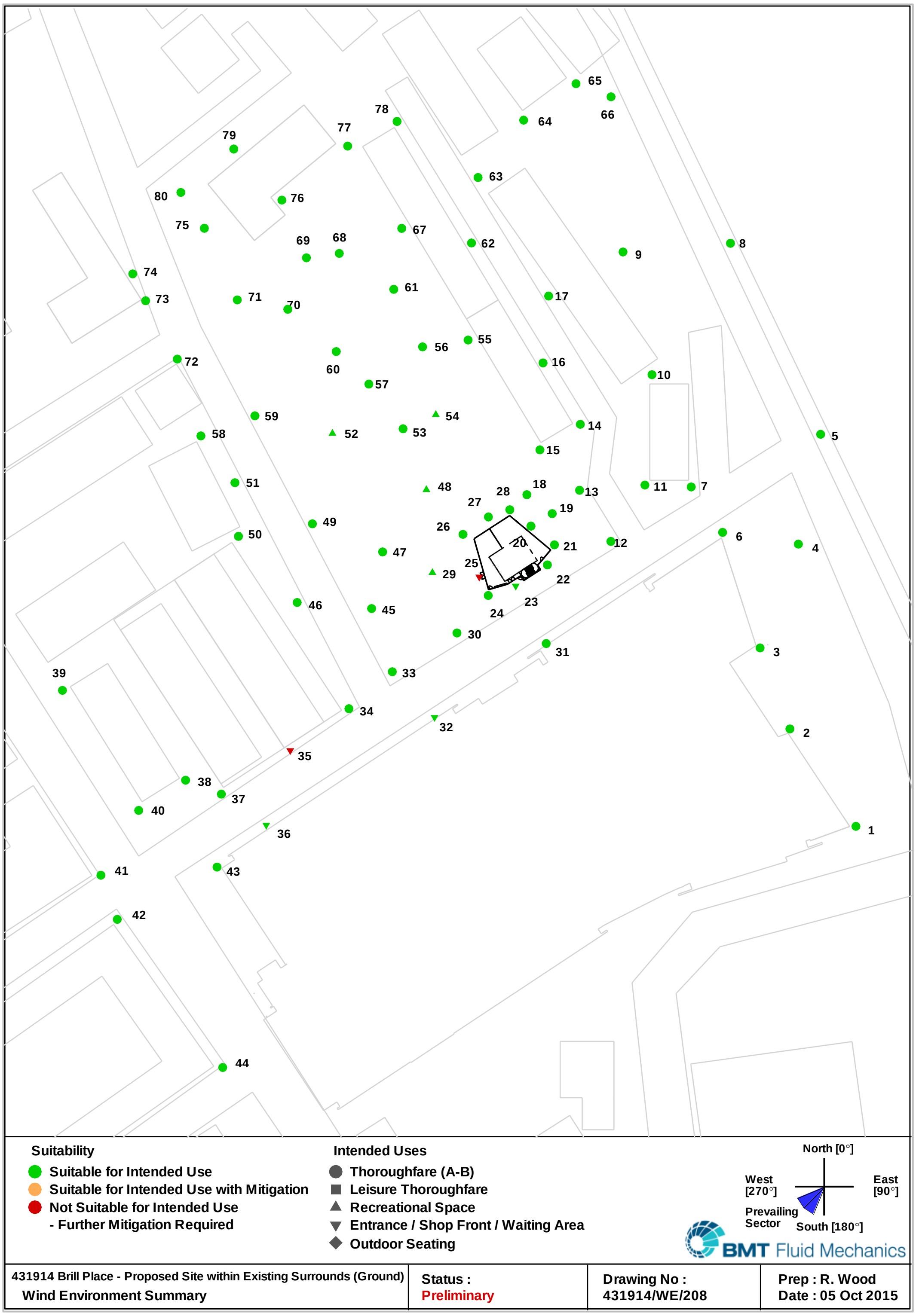


Figure 6.2b: Wind microclimate summary, proposed development within existing surrounds – Elevated Levels

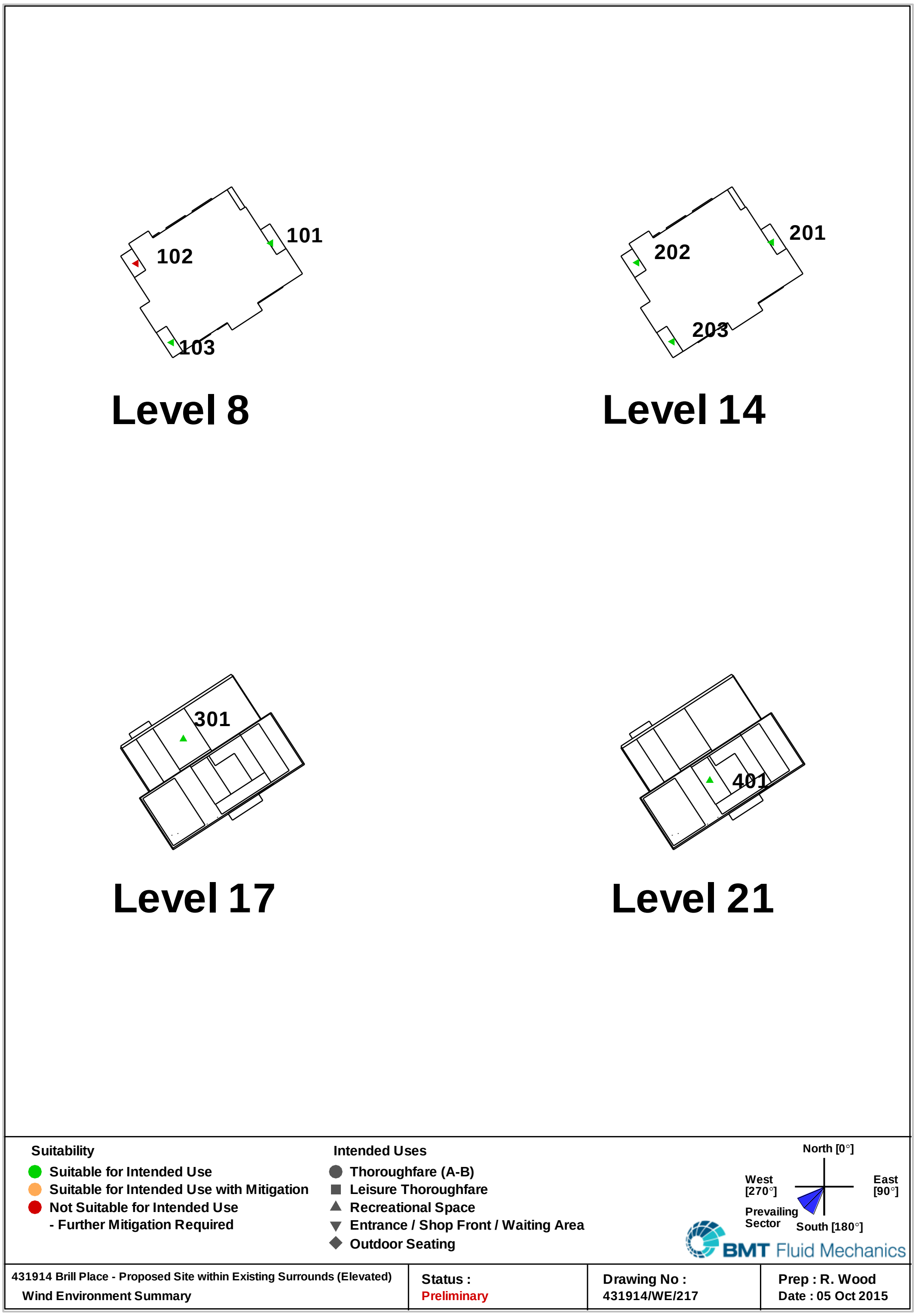


Figure 6.3a: Wind microclimate summary, proposed development within future surrounds including the neighbouring masterplan development – Ground Level

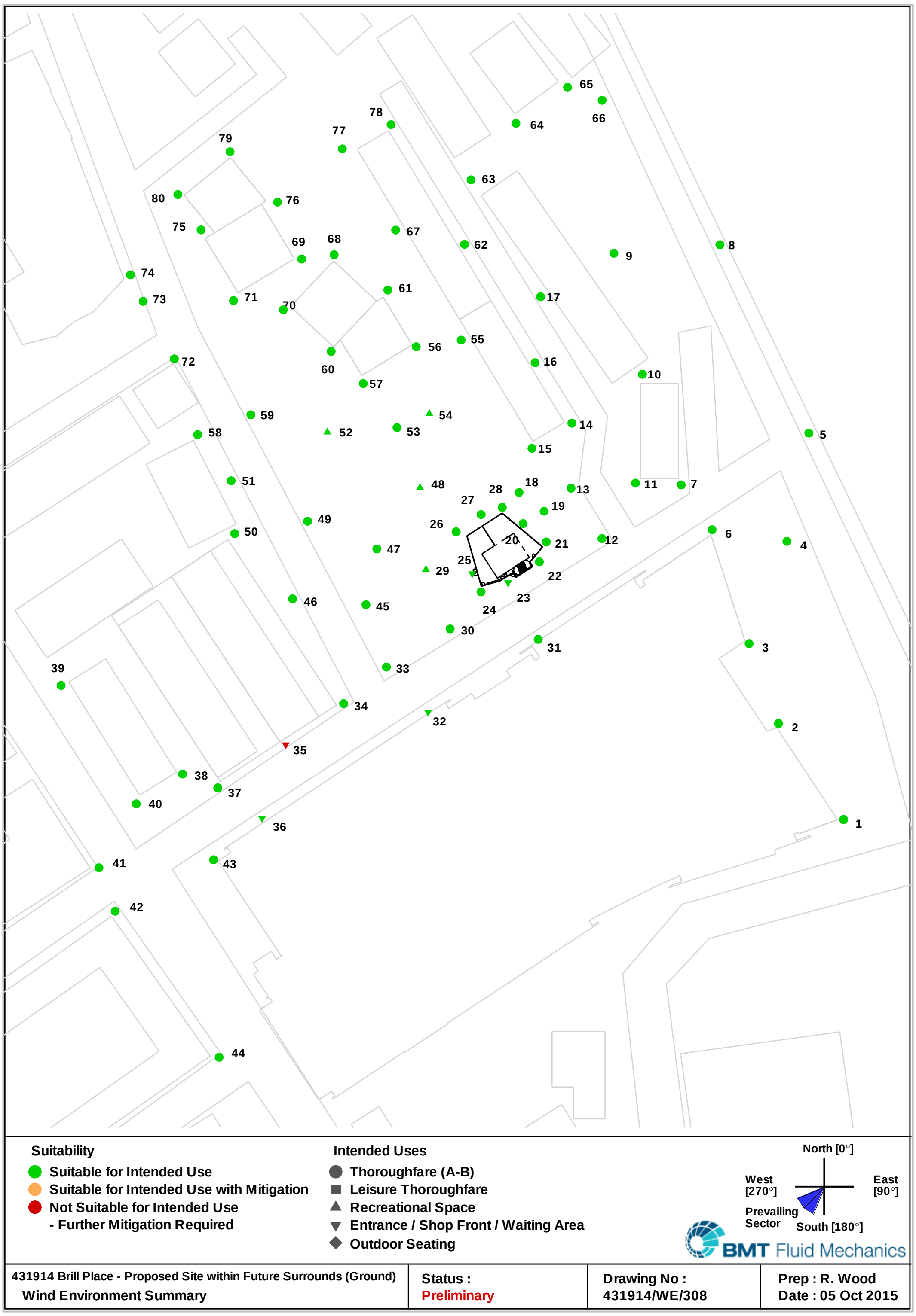
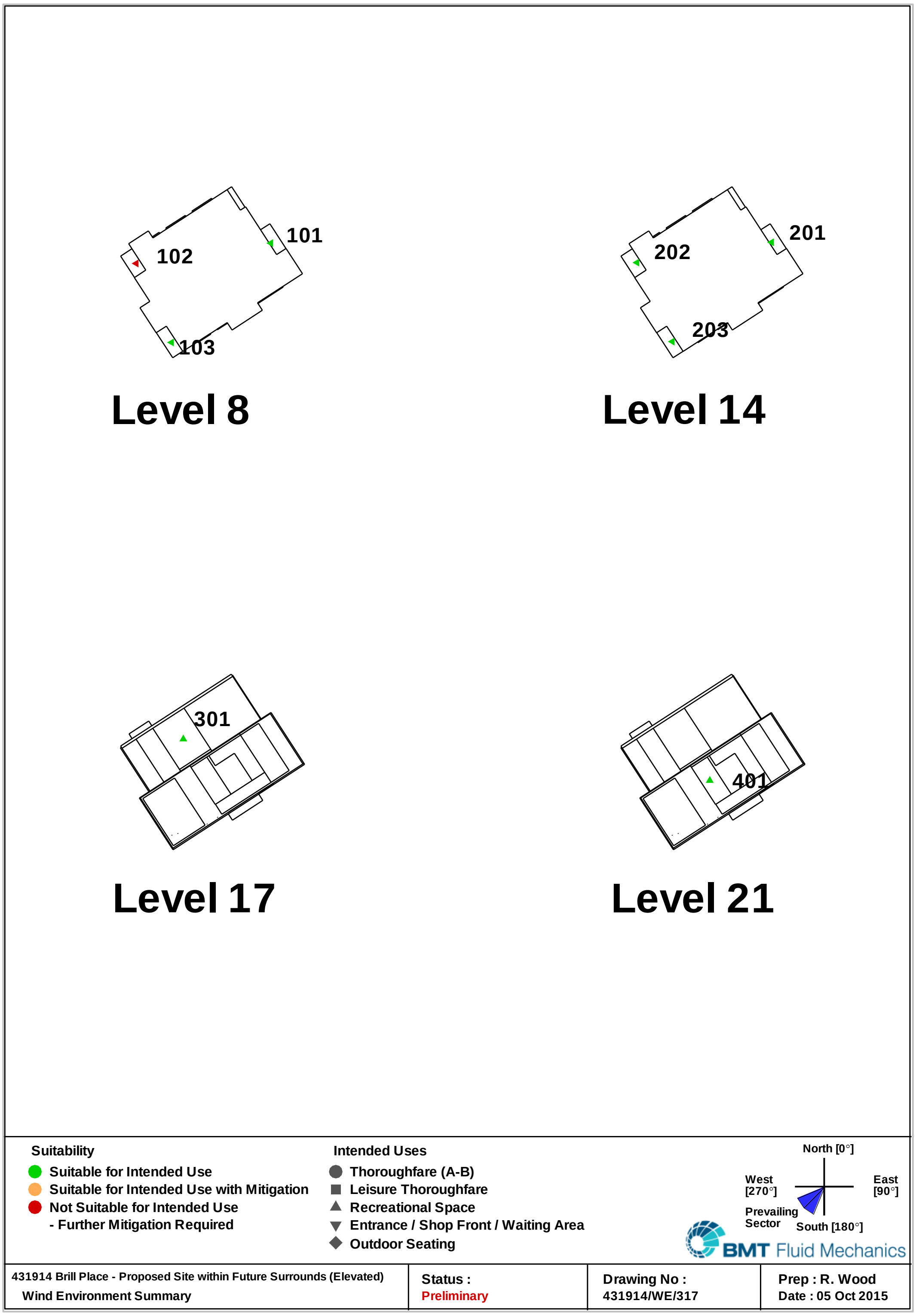


Figure 6.3b: Wind microclimate summary, proposed development within future surrounds including the neighbouring masterplan development – Elevated Levels



APPENDIX A. WIND CLIMATE ANALYSIS

A.1. ESDU Wind Analysis

A detailed analysis was carried out to determine the wind properties at the site. The wind analysis is based on the widely accepted Deaves and Harris model of the atmospheric boundary layer (ABL), as defined in ESDU Item 01008[4], and has provided wind profiles describing the variation of wind speed and turbulence intensity with height and wind direction. From this analysis representative profiles were defined as targets for the ABL simulation in the wind tunnel.

A.1.1. Terrain Roughness Changes for ESDU Wind Analysis

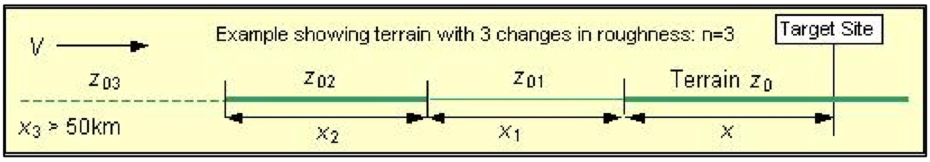
The wind analysis takes detailed account of the variation of the upwind terrain on each wind sector. The roughness changes used in the analysis for the current study are given in Table A.1 below.

Table A.1: Terrain roughness changes from the site

Wind Dir	z_0 [m]	x_0 [m]	z_{01} [m]	x_{01} [m]	z_{02} [m]	x_{02} [m]	z_{03} [m]	x_{03} [m]	z_{04} [m]
0°	0.5	1194	0.3	14359	0.03				
30°	0.5	1505	0.3	17890	0.03				
60°	0.5	3530	0.3	17226	0.03				
90°	0.5	6724	0.3	17449	0.03				
120°	0.5	418	0.7	4940	0.5	3916	0.3	17653	0.03
150°	0.5	354	0.7	3717	0.5	608	0.3	16093	0.03
180°	0.5	390	0.7	3407	0.5	1624	0.3	20330	0.03
210°	0.5	591	0.7	2238	0.5	3552	0.3	19437	0.03
240°	0.5	5784	0.3	23886	0.03				
270°	0.5	3563	0.3	20886	0.03				
300°	0.5	1881	0.3	25300	0.03				
330°	0.5	1268	0.3	14663	0.03				

Where
x_0 = upwind fetch
z_0 = roughness length

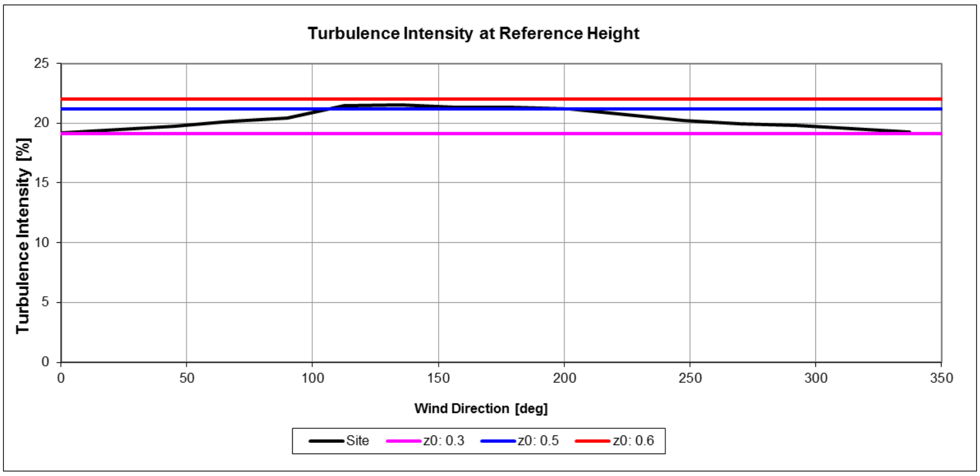
z0		
water	=	sea, lakes, estuaries
0.03	=	open country
0.1	=	sparse suburban
0.3	=	suburban
0.5	=	urban
0.7 / 1.0	=	city centre



A.2. Wind Properties at the Site

Figure A.1 shows the variation of longitudinal turbulence intensity with wind direction at a reference height of 78m.

Figure A.1: Variation of turbulence intensity with wind direction at 78m height, including reference turbulence levels



One target profile has been selected for the boundary layer simulation.

The target profile selected for the boundary layer simulation is that for 180°.

Figures A.2 and A.3 show the variation of mean wind-speed (normalised by the mean wind speed at the reference height of 78m) and turbulence intensity with height for winds approaching the site from the four primary quarters.

Figure A.2: Variation of mean wind speed normalised by mean wind speed at a reference height of 78m

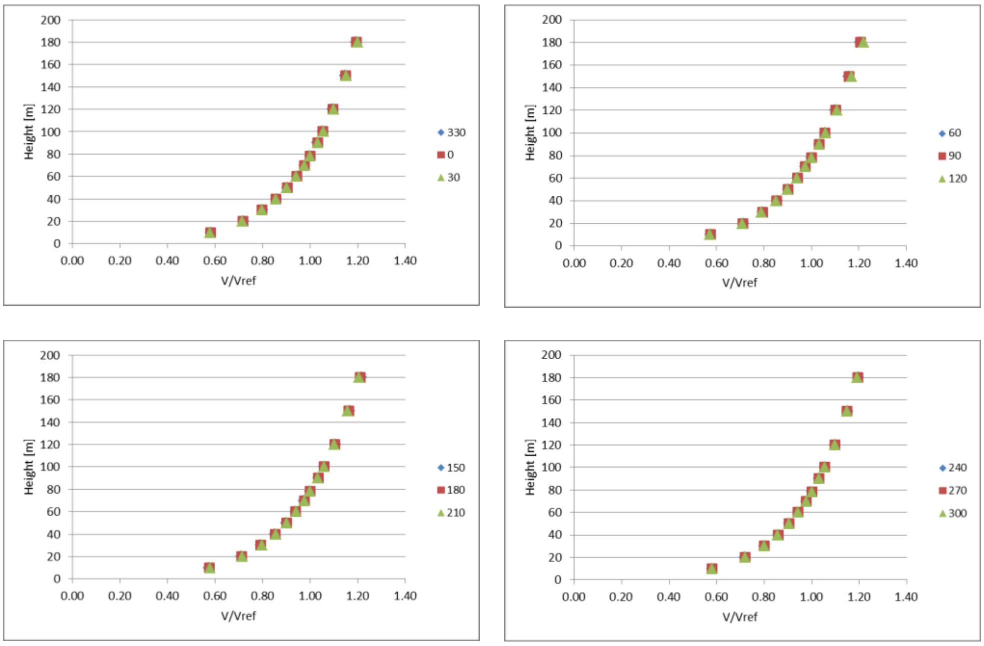


Figure A.3: Variation of longitudinal turbulence intensity with wind direction a reference height of 78m

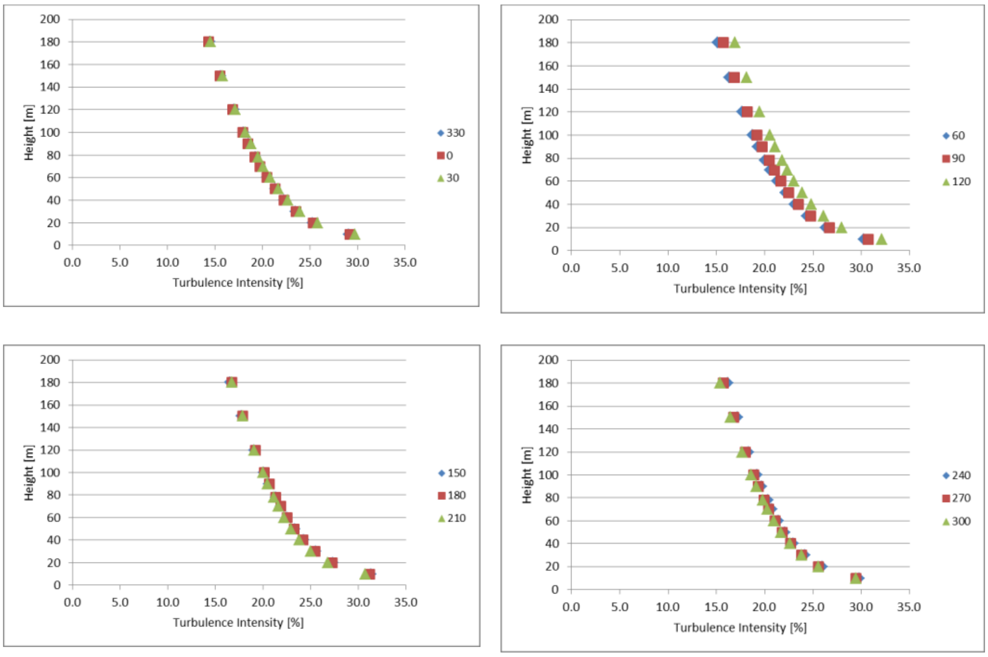
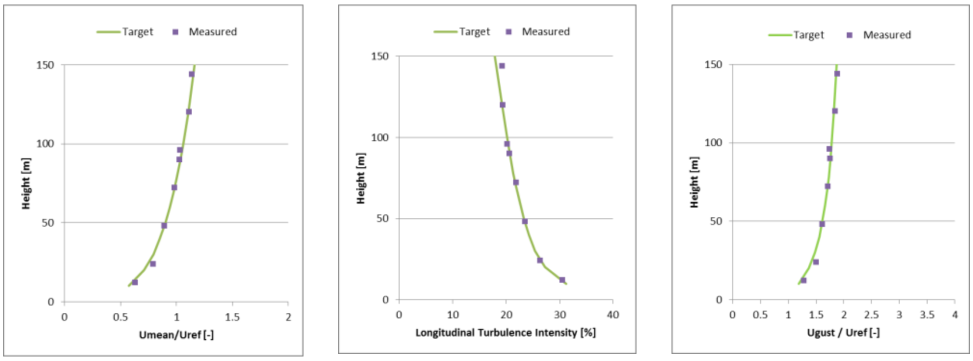


Figure A.4 presents the variation of mean wind speed, longitudinal turbulence intensity and gust wind speed used in the tests. The wind speed profiles are normalised by the mean wind speed at a reference height of 78m.

Figure A.4: Mean wind speed ($U_{mean}/U_{mean}(ref)$), longitudinal turbulence intensity profiles (I_u) and gust wind speed ($U_{gust}/U_{mean}(ref)$) modelled in the study



A.3. Wind Frequency Data

Wind microclimate studies require that wind speed data obtained from a measurement station be transposed to the site of interest.

The wind speed history, provided by weather centres such as the UK Met Office or the National Oceanic & Atmospheric Administration, is 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:

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

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 reference height at the site of the proposed development, accounting for upwind terrain, topography and altitude for the target site. The resulting annual and seasonal directional and wind speed probability distributions at a reference height of 78m, at the proposed site, are given in Figures A.5a to A.5e, respectively.

Values of *p*, *c* and *k* for the London Heathrow Weather Centre, transposed to open-country terrain at 10m height above sea-level altitude are given in Table A.2.

Figure A.5a: Directional Windspeed Probability Distribution at Site: Annual (at 78m height)

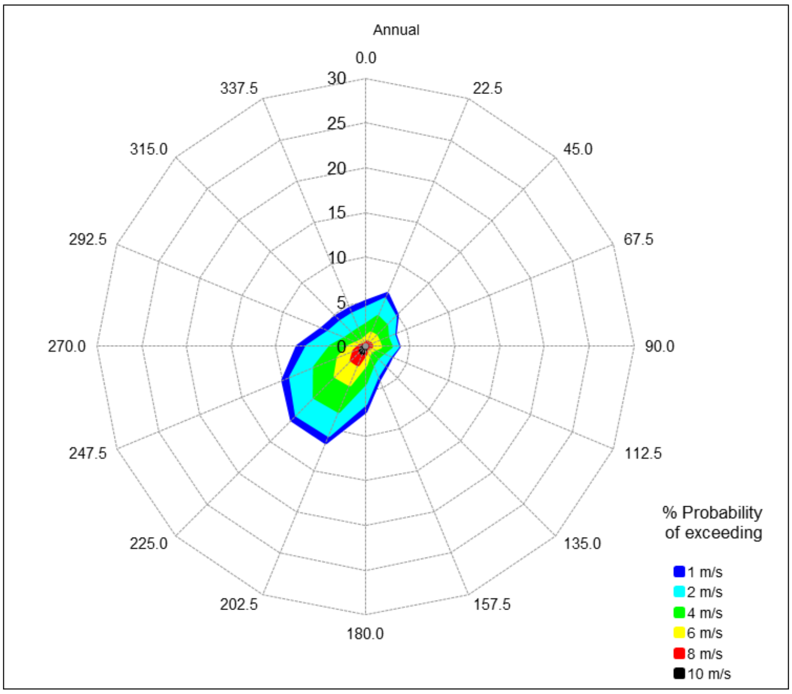


Figure A.5b: Directional Windspeed Probability Distribution at Site: Spring (at 78m height)

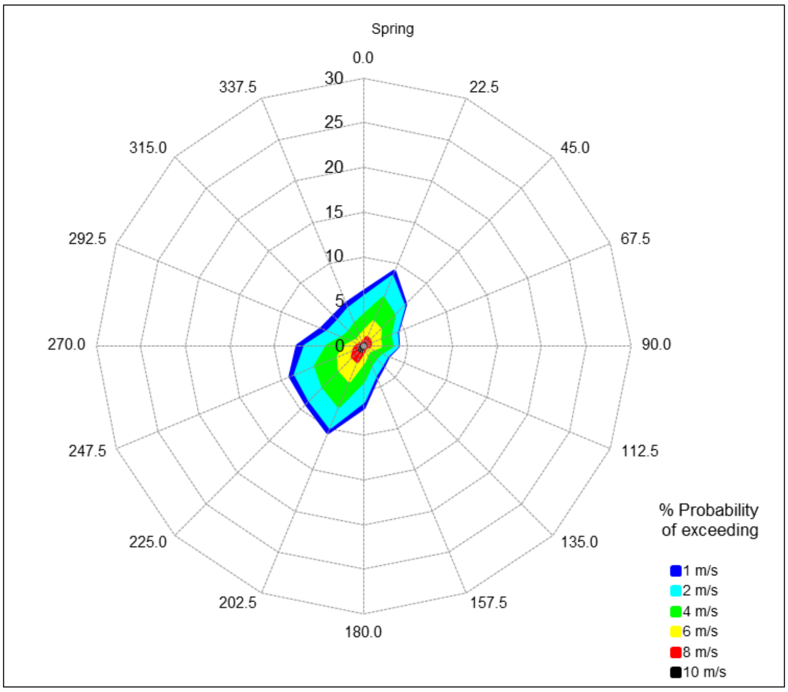


Figure A.5c: Directional Windspeed Probability Distribution at Site: Summer (at 78m height)

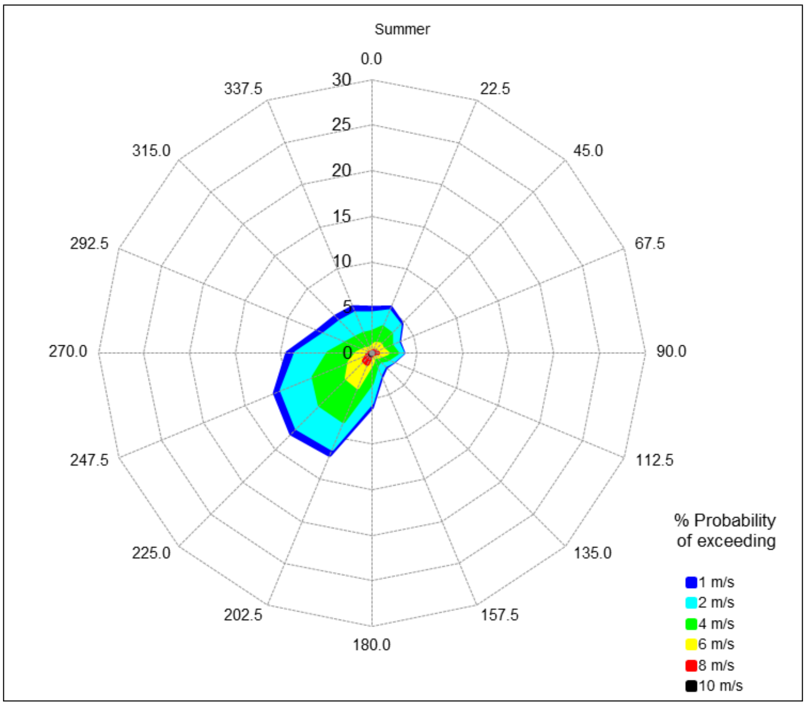


Figure A.5d: Directional Windspeed Probability Distribution at Site: Autumn (at 78m height)

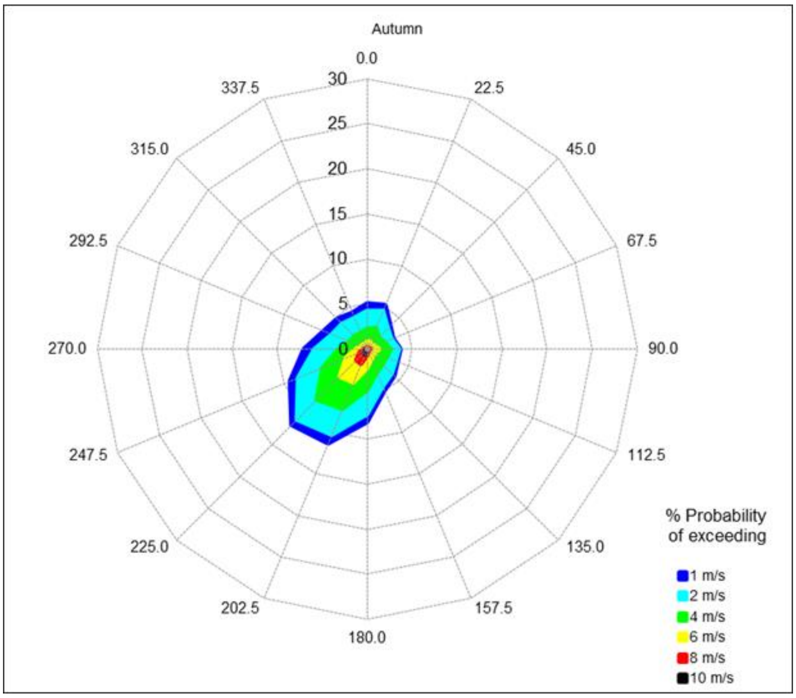


Figure A.5e: Directional Windspeed Probability Distribution at Site: Winter (at 78m height)

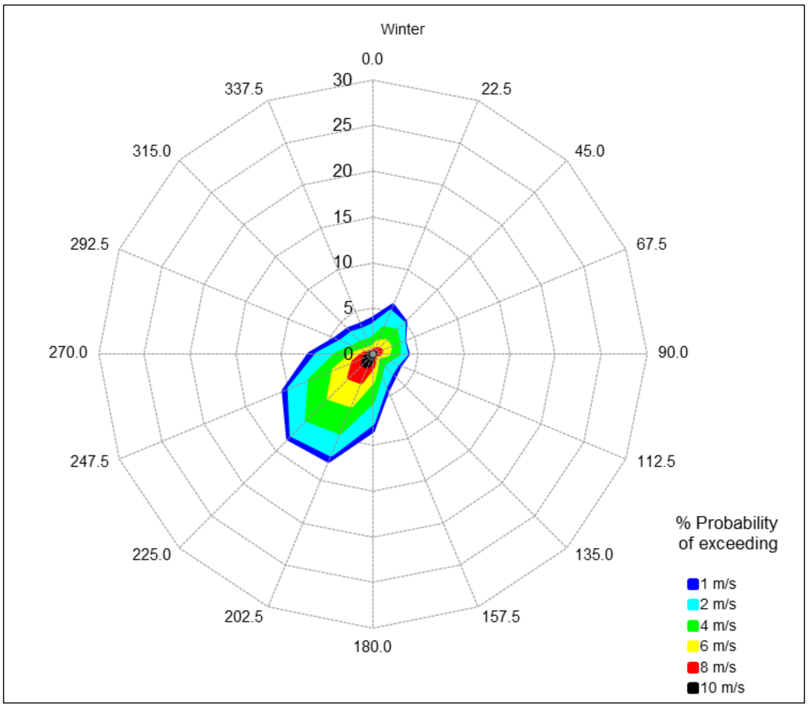


Table A.2: Wind frequency statistics: corrected London Heathrow weather centre data transformed to z0=0.03m Weibull Coefficients

Annual	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
P	5.28	6.57	5.05	3.56	3.73	3.14	3.35	4.14	7.58	11.87	11.82	10.28	8.08	5.67	5.03	4.85
C	3.77	4.26	4.84	5.52	5.59	4.92	4.44	4.43	4.56	5.42	5.43	4.79	4.06	3.70	3.58	3.62
K	1.88	2.06	2.38	2.46	2.68	2.48	2.18	1.94	1.84	2.01	2.13	1.97	1.74	1.69	1.79	1.91

Autumn	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
P	5.44	5.53	3.78	3.17	3.74	3.71	4.37	5.19	8.42	11.76	12.16	9.66	7.66	5.75	5.08	4.59
C	3.60	3.82	3.90	4.81	5.11	4.82	4.52	4.49	4.54	5.11	5.16	4.51	3.70	3.42	3.55	3.63
K	1.86	2.09	2.31	2.48	2.70	2.55	2.24	2.11	2.01	1.92	2.19	1.99	1.72	1.74	1.89	2.09

Winter	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
P	4.27	6.06	5.06	3.71	3.87	3.29	3.57	4.52	8.74	12.86	13.22	10.77	7.37	4.79	4.10	3.79
C	3.56	4.12	5.25	6.22	5.59	4.51	4.00	4.54	5.10	6.10	6.25	5.58	4.59	3.96	3.82	3.59
K	1.60	1.85	2.47	2.74	2.42	2.19	1.96	1.76	1.82	2.06	2.29	2.06	1.65	1.60	1.76	1.70

Spring	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
P	6.26	9.20	6.67	4.10	3.87	3.01	3.23	4.01	7.13	10.63	9.24	9.04	7.77	5.49	5.03	5.35
C	4.21	4.72	5.19	5.66	5.76	5.09	4.67	4.48	4.52	5.45	5.49	4.94	4.29	3.92	3.76	3.95
K	2.06	2.24	2.61	2.65	3.01	2.60	2.31	2.08	2.05	2.20	2.20	2.22	1.85	1.64	1.79	1.97

Summer	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
P	5.12	5.49	4.66	3.25	3.45	2.56	2.24	2.88	6.07	12.26	12.72	11.67	9.52	6.64	5.85	5.62
C	3.69	4.17	4.65	5.20	5.84	5.27	4.50	4.17	4.33	5.07	4.87	4.43	4.01	3.76	3.57	3.51
K	2.27	2.49	2.55	2.45	2.87	2.78	2.15	2.15	2.40	2.43	2.35	2.57	2.34	2.19	2.27	2.35

APPENDIX B. WIND TUNNEL & MODEL DETAILS

B.1. Wind Tunnel Specifications

All the tests were conducted in BMT's Boundary Layer Wind Tunnel which has a working section 4.8m wide, 2.4m high and 15m long with a 4.4m diameter multiple plate turntable and a remotely controlled 3-dimensional traversing system. The operating wind speed range is 0.2 – 45 m/s.

A turbulent boundary layer, representative of the conditions at the site, is set up using an arrangement of roughness elements distributed over the floor of the wind tunnel and a 2-dimensional barrier with square posts or spires at the entrance to the test section.

B.2. Model

B.2.1. Information For Model Construction

The model of the proposed development was constructed based on drawing information supplied by DRMM, the architects for the scheme, as follows:

Drawing	Date	Drawing	Date
150828_ Wind Brill Place Building.dwg	28/08/2015	372-ELE-402.dwg	28/08/2015
372-TYP-290.dwg	28/08/2015	372-ELE-401.dwg	28/08/2015
372-TYP-273.dwg	28/08/2015	372-ELE-400.dwg	28/08/2015
372-TYP-272.dwg	28/08/2015	150915_Brill Place Building.dwg	16/09/2015
372-TYP-271.dwg	28/08/2015	DMA_150903_Massing for D&S and RoL Assessment.dwg	16/09/2015
372-TYP-270.dwg	28/08/2015	A228-Massing.skp	16/09/2015
372-TYP-269.dwg	28/08/2015	DMA_150903_Massing for D&S and RoL Assessment.pdf	16/09/2015
372-TYP-268.dwg	28/08/2015	176 ENPS section.pdf	16/09/2015
372-TYP-267.dwg	28/08/2015	176 ENPS roof.pdf	16/09/2015
372-TYP-266.dwg	28/08/2015	176 150907 EPNS School SketchUp V8.skp	16/09/2015
372-TYP-256.dwg	28/08/2015	057_3110h.pdf	16/09/2015
372-TYP-255.dwg	28/08/2015	057_3120e.pdf	16/09/2015
372-TYP-252.dwg	28/08/2015	057_Lot 3 3D Draft Model.dwg	16/09/2015
372-TYP-251.dwg	28/08/2015	176 ENPS roof.pdf	16/09/2015
372-TYP-250.dwg	28/08/2015	CST-SitePlanTrees_Existing.dwg	18/09/2015
372-TYP-249.dwg	28/08/2015	CST-SitePlanTrees_Proposed.dwg	18/09/2015
372-TYP-248.dwg	28/08/2015	246-A-P-00-SitePlanContours with Context 150921.dwg	21/09/2015
372-SITE-1XX_WIP 150828.dwg	28/08/2015	246-Exsiting OS Map.dwg	21/09/2015
372-ELE-403.dwg	28/08/2015		

The model of the existing surrounding area was based on OS superplan data supplemented by a site survey conducted by BMT using publically available information.

The models of the consented future surrounding development were based on the data supplied by the design team.

The models were reviewed and approved by the design team, prior to testing.

B.2.2. Scale

A model scale of 1:300 has been adopted. At this scale the model is large enough to allow a good representation of the details that are likely to affect the local and overall wind flows at full scale. In addition, this scale enables a good simulation of the turbulence properties of the wind to be achieved.

B.2.3. Construction

The model was constructed from a combination of materials such as hard foam and wood. The model incorporated all of the features that are likely to significantly affect the local wind flow around the development at full scale. The surrounding area was modelled to a radius of 450m from the centre of the site. The surrounding buildings and topography were represented to a sufficient level of detail to reproduce the wind flows at the location of the proposed development.

The model was mounted on a 3.0m diameter baseboard and installed on the 4.4m diameter turntable of BMT's Boundary Layer Wind Tunnel.

B.2.4. Model Photos

Images of the wind tunnel model are presented as follows

- Figure B.1 - close-up : existing site conditions
- Figure B.2 - close-up : proposed development
- Figure B.3 - existing surrounding conditions
- Figure B.4 - proposed development within existing surrounding conditions
- Figure B.5 - proposed development within future surrounding conditions including the neighbouring masterplan development
- Figure B.6 - wind tunnel set-up, viewed from downstream

Figure B.1: Close-up of existing site conditions, viewed from northwest

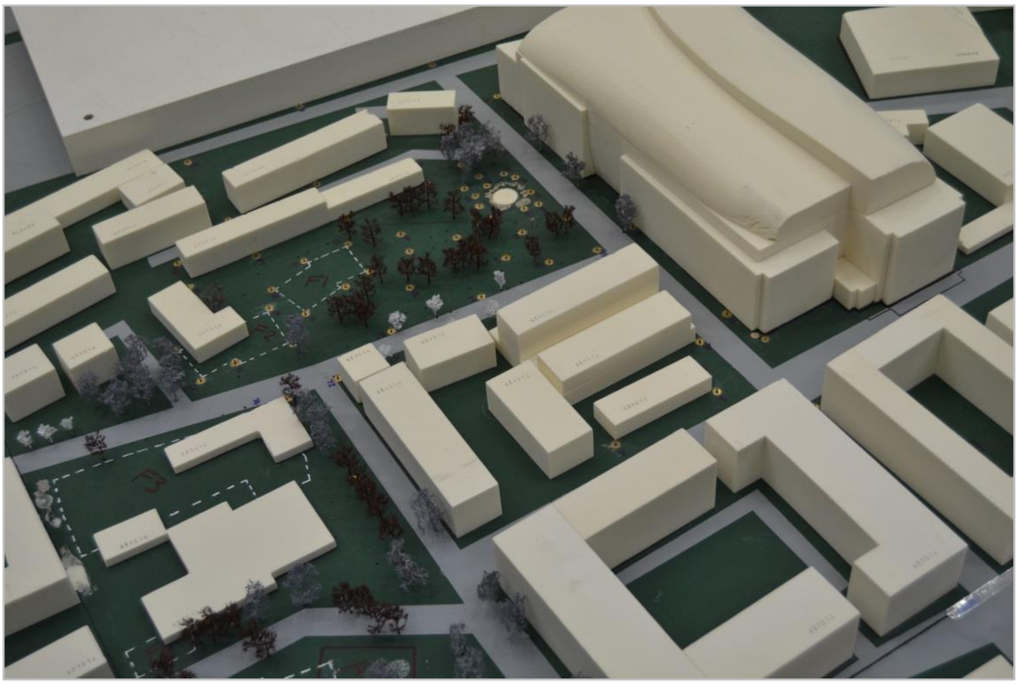


Figure B.2: Close-up of the proposed development, viewed from west

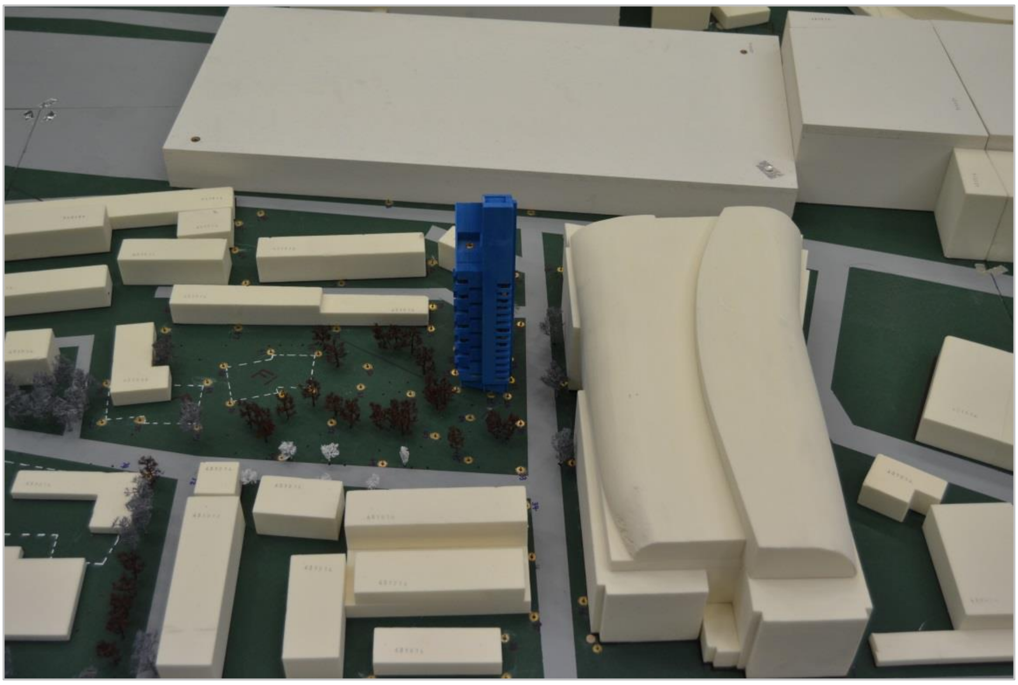


Figure B.3: Existing surrounding conditions

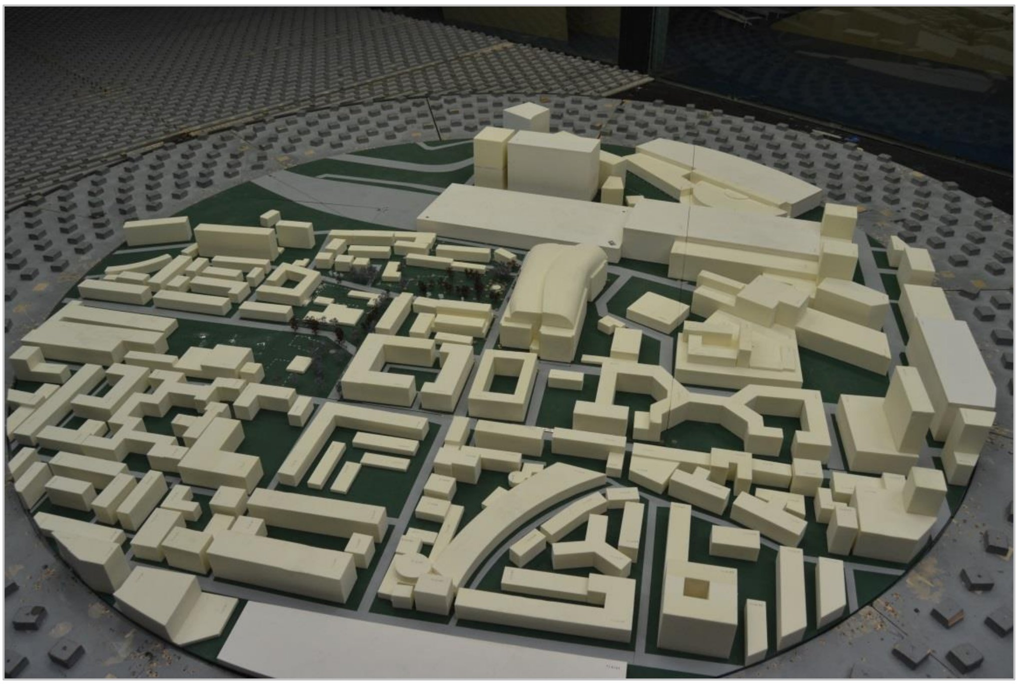


Figure B.4: Proposed development within existing surrounding conditions

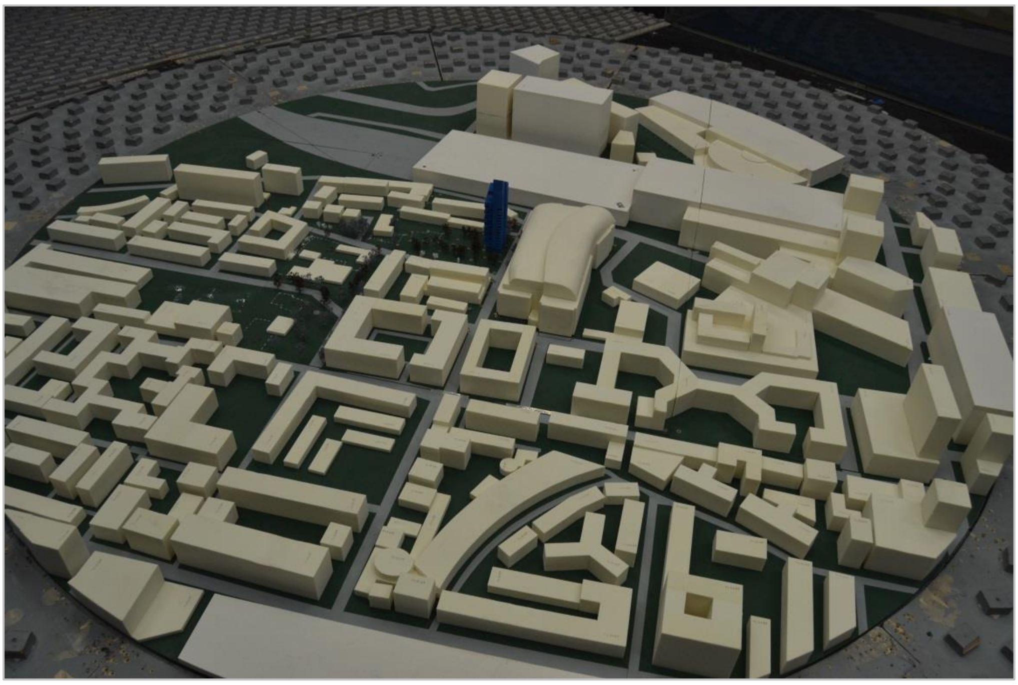
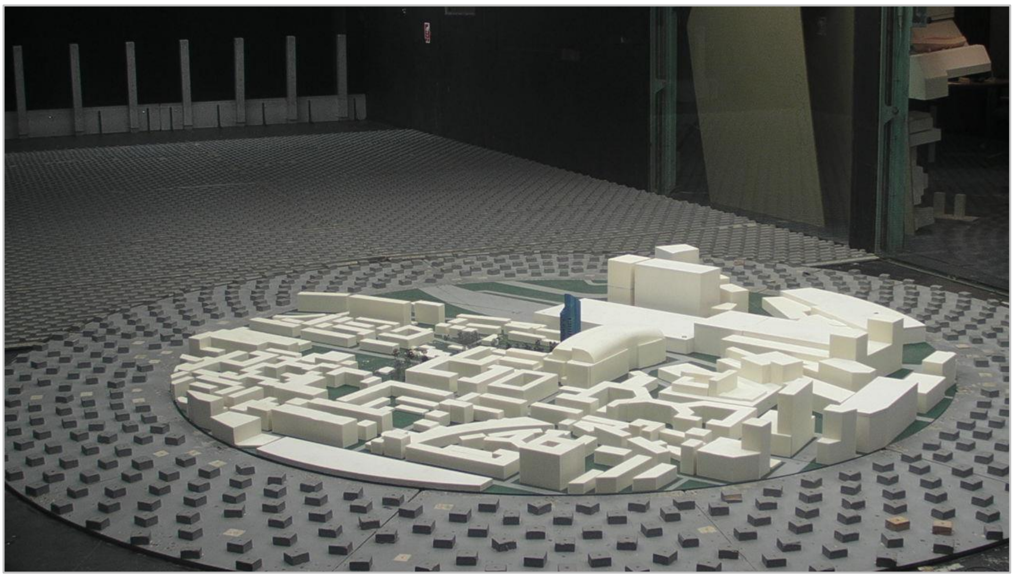


Figure B.5: Proposed development within future surrounding conditions including the neighbouring masterplan development

Figure B.6: Wind tunnel set-up, viewed from downstream



APPENDIX C. MEASUREMENTS AND ANALYSIS

C.1. Wind Speed Measurements

Wind speed measurements were made using so-called '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 up to 88 locations at a height corresponding to 1.5m at full scale. Measurements were taken for a full range of wind directions in increments of 22.5°.

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

Gusts in the wind flow may lead to additional discomfort beyond that caused by the mean wind speed. In order to assess this discomfort the gust wind speed is translated to an equivalent mean wind speed, the Gust Equivalent Mean or GEM, according to the following equation:

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

For each location the results were combined with local wind statistics to assess the wind microclimate in terms of the exceedance of threshold wind speeds that relate to comfort levels perceived during standard pedestrian activities.

C.2. Assessment Criteria

The accepted, UK industry standard, Lawson criteria for pedestrian comfort and safety are applied in the study. BMT adhere to the LDDC variant of the Lawson criteria[3].

Details of the comfort criteria are presented in Table C.1 and are based on the exceedance of the threshold wind speeds, based on the mean hourly value and on the gust equivalent mean value, occurring less 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.

Table C.1: Lawson comfort criteria – LDDC variant[3]

Threshold Wind Speed	Comfort Rating / Activity		Examples
4 ms^{-1}	C4	Long-term standing / sitting	Reading a newspaper and eating and drinking
6 ms^{-1}	C3	Short-term standing / sitting	Appropriate for bus stops, window shopping and building entrances
8 ms^{-1}	C2	Leisure thoroughfare / strolling	General areas of walking and sightseeing
10 ms^{-1}	C1	Pedestrian transit / thoroughfare (A-B)	Local areas around tall buildings where people are not likely to linger
> 10 ms^{-1}	C0	Uncomfortable for all uses	Uncomfortable for all pedestrian activities

Details of the safety criteria are presented in Table C.2 and are based on the exceedance of threshold wind speeds, again both the mean-hourly value and on the gust equivalent mean value, occurring once per annum.

- A wind speed greater than 15 metres-per-second occurring once a year is classified as unsuitable for general public and represents a wind speed with the potential to destabilise the less able members of the public such as the elderly, cyclists and children.
- Able-bodied users are those determined to experience distress when the wind speed exceeds 20 metres-per-second once per year.

Table C.2: Lawson safety criteria – LDDC variant[3]

Threshold Wind Speed	Safety Rating		Qualifying Comments
> 15 m/s	S2	Unsuitable for general public	Less able and cyclists find conditions physically difficult
> 20 m/s	S1	Unsuitable for able-bodied	Able-bodied persons find conditions difficult. Physically impossible to remain standing during gusts.

C.3. Pedestrian Activities

Tables C.3a and C.3b present the pedestrian uses assumed for each of the corresponding measurement locations presented in Figures 6.1 to 6.3b.

- Table C.3a presents the pedestrian uses for the existing site conditions
- Table C.3b presents the potential uses at each measurement location for the proposed development within the context of
    - existing surrounds
    - future surrounds

Table C.3a: Pedestrian uses – existing site conditions

Location	Intended Use	Location	Intended Use
1	Thoroughfare (A-to-B)	41	Thoroughfare (A-to-B)
2	Thoroughfare (A-to-B)	42	Thoroughfare (A-to-B)
3	Thoroughfare (A-to-B)	43	Thoroughfare (A-to-B)
4	Thoroughfare (A-to-B)	44	Thoroughfare (A-to-B)
5	Thoroughfare (A-to-B)	45	Thoroughfare (A-to-B)
6	Thoroughfare (A-to-B)	46	Thoroughfare (A-to-B)
7	Thoroughfare (A-to-B)	47	Thoroughfare (A-to-B)
8	Thoroughfare (A-to-B)	48	Recreational Space
9	Thoroughfare (A-to-B)	49	Thoroughfare (A-to-B)
10	Thoroughfare (A-to-B)	50	Thoroughfare (A-to-B)
11	Thoroughfare (A-to-B)	51	Thoroughfare (A-to-B)
12	Thoroughfare (A-to-B)	52	Recreational Space
13	Thoroughfare (A-to-B)	53	Thoroughfare (A-to-B)
14	Thoroughfare (A-to-B)	54	Recreational Space
15	Thoroughfare (A-to-B)	55	Thoroughfare (A-to-B)
16	Thoroughfare (A-to-B)	56	Thoroughfare (A-to-B)
17	Thoroughfare (A-to-B)	57	Thoroughfare (A-to-B)
18	Thoroughfare (A-to-B)	58	Thoroughfare (A-to-B)
19	Thoroughfare (A-to-B)	59	Thoroughfare (A-to-B)
20	Thoroughfare (A-to-B)	60	Thoroughfare (A-to-B)
21	Thoroughfare (A-to-B)	61	Thoroughfare (A-to-B)
22	Thoroughfare (A-to-B)	62	Thoroughfare (A-to-B)
23	Entrance / Shop Front / Waiting Area	63	Thoroughfare (A-to-B)
24	Thoroughfare (A-to-B)	64	Thoroughfare (A-to-B)
25	Entrance / Shop Front / Waiting Area	65	Thoroughfare (A-to-B)
26	Thoroughfare (A-to-B)	66	Thoroughfare (A-to-B)
27	Thoroughfare (A-to-B)	67	Thoroughfare (A-to-B)
28	Thoroughfare (A-to-B)	68	Thoroughfare (A-to-B)

29	Recreational Space	69	Thoroughfare (A-to-B)
30	Thoroughfare (A-to-B)	70	Thoroughfare (A-to-B)
31	Thoroughfare (A-to-B)	71	Thoroughfare (A-to-B)
32	Entrance / Shop Front / Waiting Area	72	Thoroughfare (A-to-B)
33	Thoroughfare (A-to-B)	73	Thoroughfare (A-to-B)
34	Thoroughfare (A-to-B)	74	Thoroughfare (A-to-B)
35	Entrance / Shop Front / Waiting Area	75	Thoroughfare (A-to-B)
36	Entrance / Shop Front / Waiting Area	76	Thoroughfare (A-to-B)
37	Thoroughfare (A-to-B)	77	Thoroughfare (A-to-B)
38	Thoroughfare (A-to-B)	78	Thoroughfare (A-to-B)
39	Thoroughfare (A-to-B)	79	Thoroughfare (A-to-B)
40	Thoroughfare (A-to-B)	80	Thoroughfare (A-to-B)

Table C.3b: Pedestrian Uses – proposed development, existing surrounds and future surrounds

Location	Intended Use	Location	Intended Use
1	Thoroughfare (A-to-B)	45	Thoroughfare (A-to-B)
2	Thoroughfare (A-to-B)	46	Thoroughfare (A-to-B)
3	Thoroughfare (A-to-B)	47	Thoroughfare (A-to-B)
4	Thoroughfare (A-to-B)	48	Recreational Space
5	Thoroughfare (A-to-B)	49	Thoroughfare (A-to-B)
6	Thoroughfare (A-to-B)	50	Thoroughfare (A-to-B)
7	Thoroughfare (A-to-B)	51	Thoroughfare (A-to-B)
8	Thoroughfare (A-to-B)	52	Recreational Space
9	Thoroughfare (A-to-B)	53	Thoroughfare (A-to-B)
10	Thoroughfare (A-to-B)	54	Recreational Space
11	Thoroughfare (A-to-B)	55	Thoroughfare (A-to-B)
12	Thoroughfare (A-to-B)	56	Thoroughfare (A-to-B)
13	Thoroughfare (A-to-B)	57	Thoroughfare (A-to-B)
14	Thoroughfare (A-to-B)	58	Thoroughfare (A-to-B)
15	Thoroughfare (A-to-B)	59	Thoroughfare (A-to-B)
16	Thoroughfare (A-to-B)	60	Thoroughfare (A-to-B)
17	Thoroughfare (A-to-B)	61	Thoroughfare (A-to-B)
18	Thoroughfare (A-to-B)	62	Thoroughfare (A-to-B)
19	Thoroughfare (A-to-B)	63	Thoroughfare (A-to-B)
20	Thoroughfare (A-to-B)	64	Thoroughfare (A-to-B)
21	Thoroughfare (A-to-B)	65	Thoroughfare (A-to-B)
22	Thoroughfare (A-to-B)	66	Thoroughfare (A-to-B)
23	Entrance / Shop Front / Waiting Area	67	Thoroughfare (A-to-B)
24	Thoroughfare (A-to-B)	68	Thoroughfare (A-to-B)
25	Entrance / Shop Front / Waiting Area	69	Thoroughfare (A-to-B)
26	Thoroughfare (A-to-B)	70	Thoroughfare (A-to-B)
27	Thoroughfare (A-to-B)	71	Thoroughfare (A-to-B)
28	Thoroughfare (A-to-B)	72	Thoroughfare (A-to-B)
29	Recreational Space	73	Thoroughfare (A-to-B)
30	Thoroughfare (A-to-B)	74	Thoroughfare (A-to-B)
31	Thoroughfare (A-to-B)	75	Thoroughfare (A-to-B)
32	Entrance / Shop Front / Waiting Area	76	Thoroughfare (A-to-B)
33	Thoroughfare (A-to-B)	77	Thoroughfare (A-to-B)
34	Thoroughfare (A-to-B)	78	Thoroughfare (A-to-B)
35	Entrance / Shop Front / Waiting Area	79	Thoroughfare (A-to-B)
36	Entrance / Shop Front / Waiting Area	80	Thoroughfare (A-to-B)
37	Thoroughfare (A-to-B)	101	Viewing Balcony

38	Thoroughfare (A-to-B)	102	Viewing Balcony
39	Thoroughfare (A-to-B)	103	Viewing Balcony
40	Thoroughfare (A-to-B)	201	Viewing Balcony
41	Thoroughfare (A-to-B)	202	Viewing Balcony
42	Thoroughfare (A-to-B)	203	Viewing Balcony
43	Thoroughfare (A-to-B)	301	Recreational Space
44	Thoroughfare (A-to-B)	401	Recreational Space

APPENDIX D. COMFORT AND SAFETY RATINGS

The results of the wind speed measurements are summarised in graphical format in terms of comfort and safety ratings derived for each measurement location, as follows:

- Figures D.1a to D.1e presents **annual safety** ratings for each configuration, for ground, balcony and rooftop terrace levels
- Figures D.2a to D.2e presents **summer season comfort** ratings for each configuration, for ground, balcony and rooftop terrace levels
- Figures D.3a to D.3e presents **worst seasonal comfort** ratings for each configuration, for ground, balcony and rooftop terrace levels

The presentations listed above show the worst case between the results derived using wind speed-up factors based on the mean and gust equivalent mean (GEM) wind speeds (see Appendix C).

Equivalent comfort summaries pertaining to autumn, winter, spring and summer for ground, rooftop terrace and balcony levels, for each configuration, are supplied electronically to the design team.

Figure D.1a: Annual safety ratings, existing site conditions

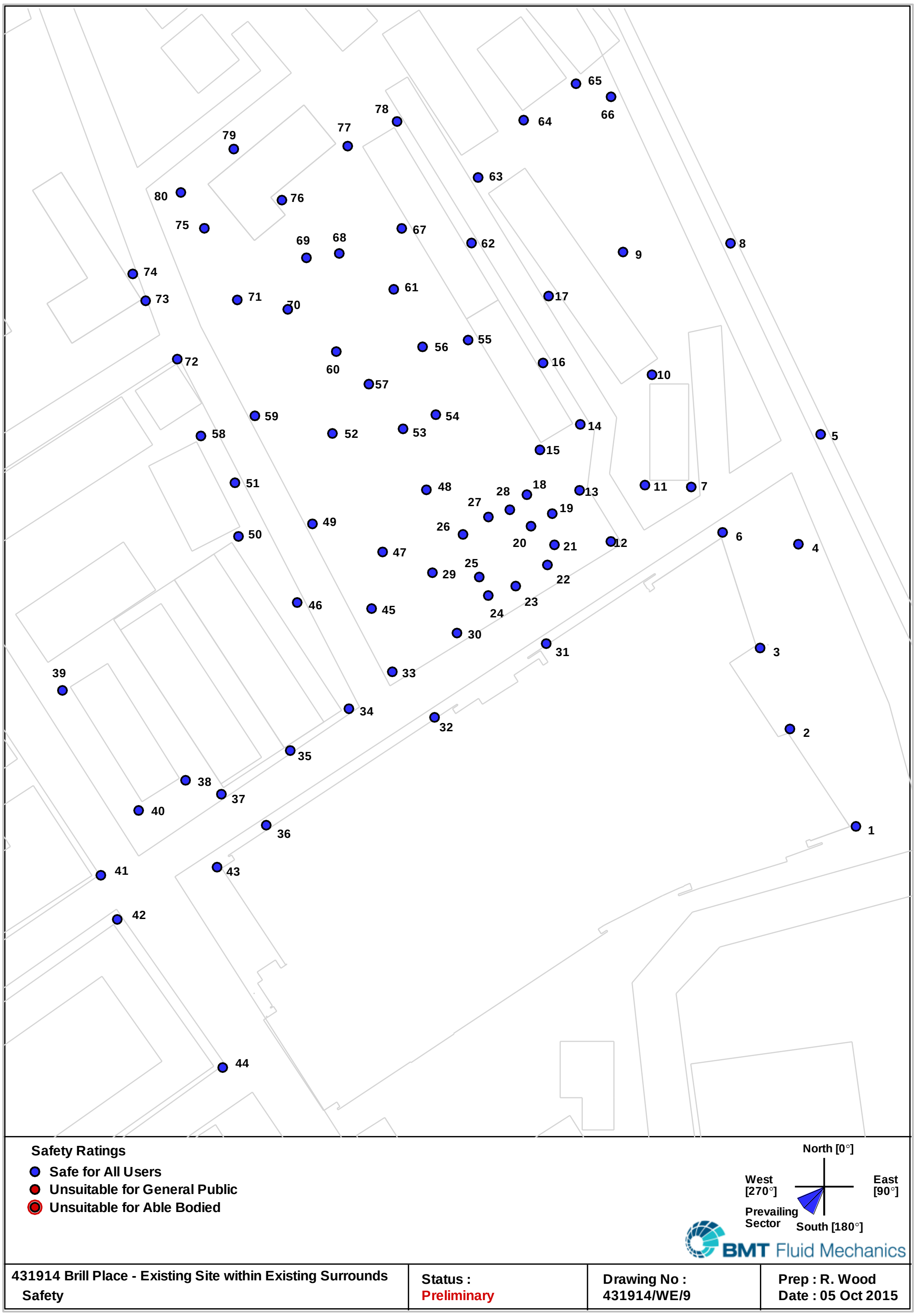
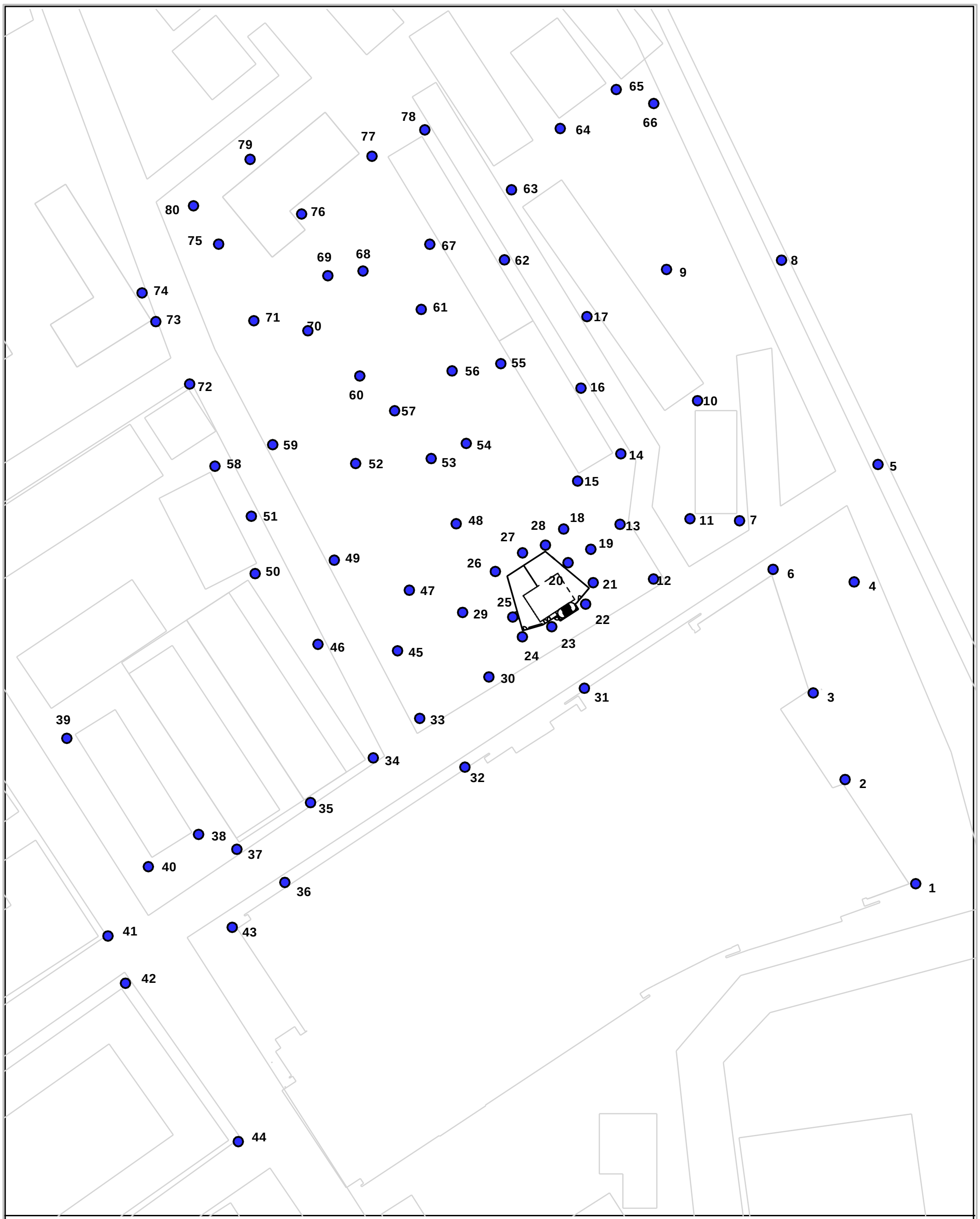


Figure D.1b: Annual safety ratings, proposed development within existing surrounds – ground level



Safety Ratings

- Safe for All Users
- Unsuitable for General Public
- Unsuitable for Able Bodied

North [0°]
West [270°]
East [90°]
Prevailing Sector
South [180°]

BMT Fluid Mechanics

431914 Brill Place - Proposed Site within Existing Surrounds (Ground) Safety	Status : Preliminary	Drawing No : 431914/WE/209	Prep : R. Wood Date : 05 Oct 2015

Figure D.1c: Annotated safety ratings, proposed development within existing surrounds – elevated level

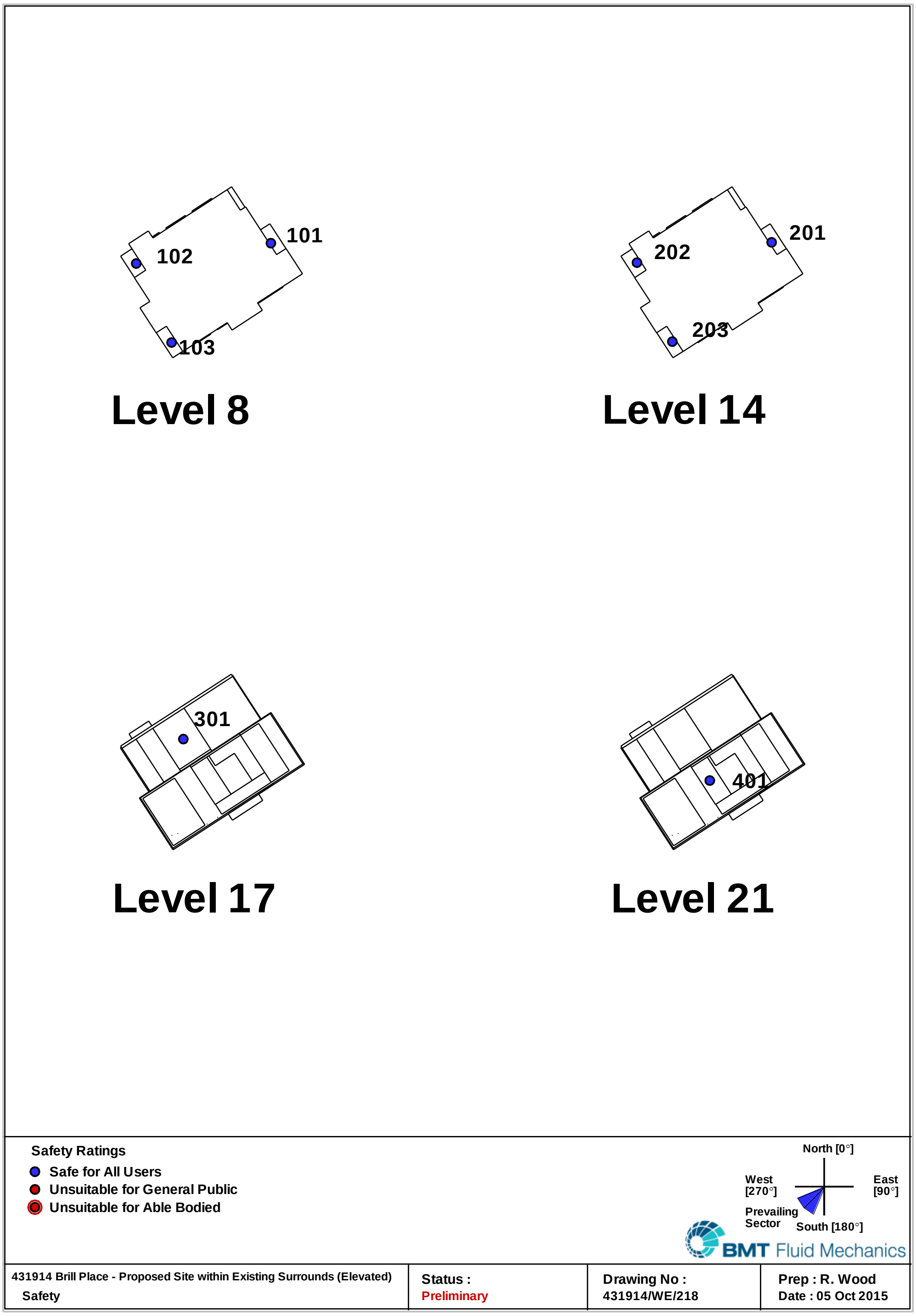
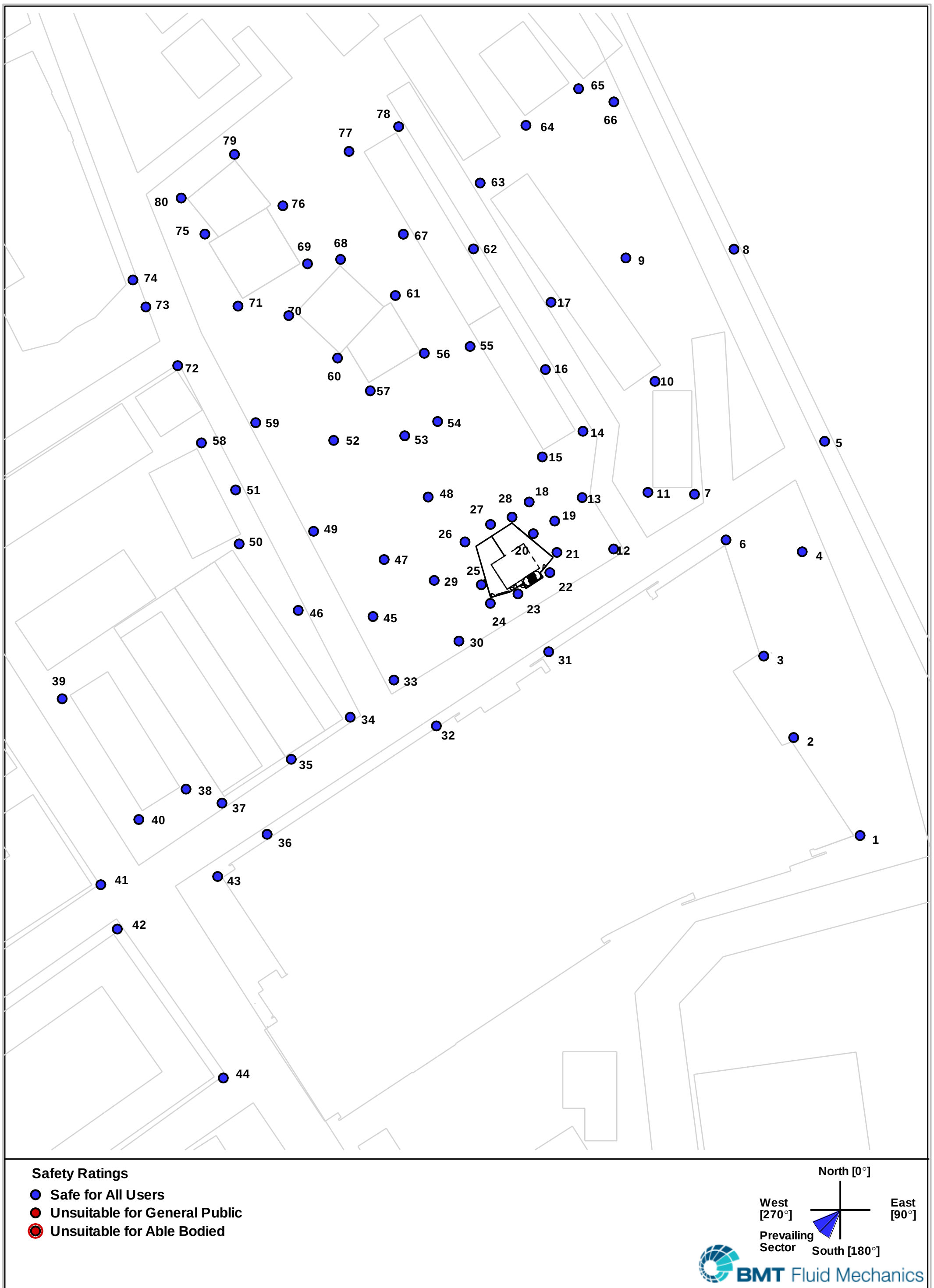


Figure D.1d: Annual safety ratings, proposed development within future surrounds including the neighbouring masterplan development – ground level



431914 Brill Place - Proposed Site within Future Surrounds (Ground) Safety	Status : Preliminary	Drawing No : 431914/WE/309	Prep : R. Wood Date : 05 Oct 2015

Figure D.1e: **Summer comfort ratings, proposed development within future surrounds including the neighbouring masterplan development – elevated level**

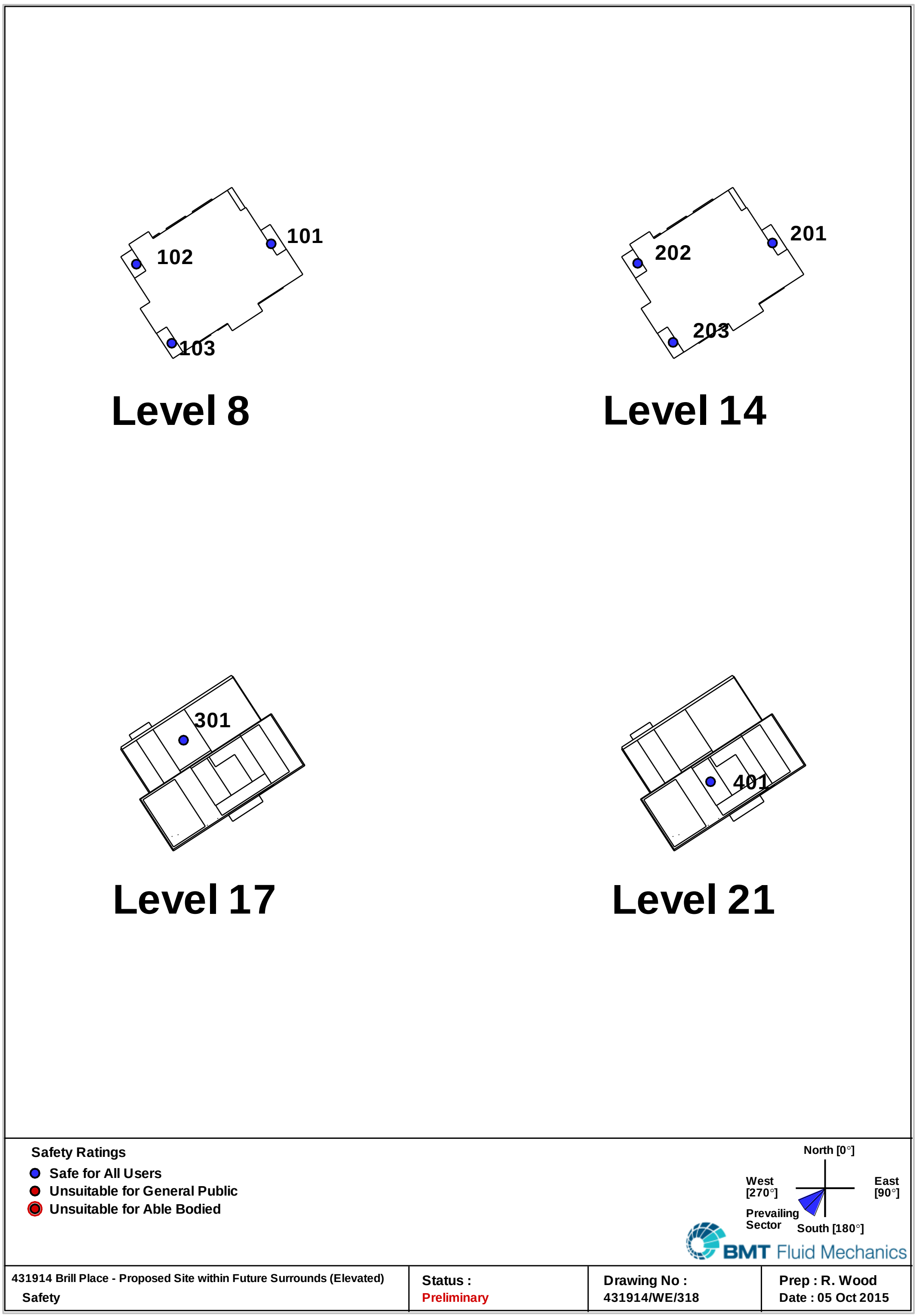
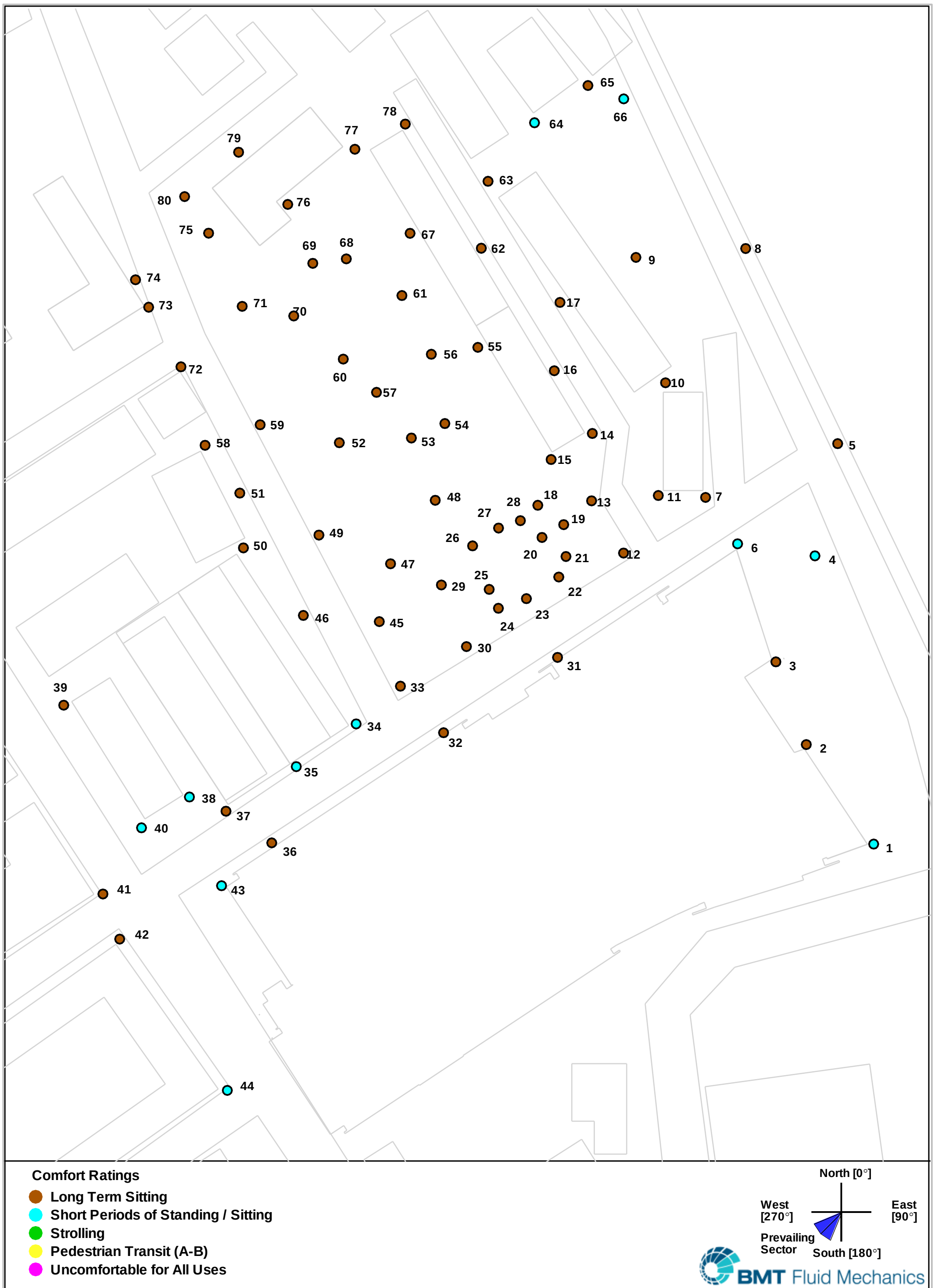
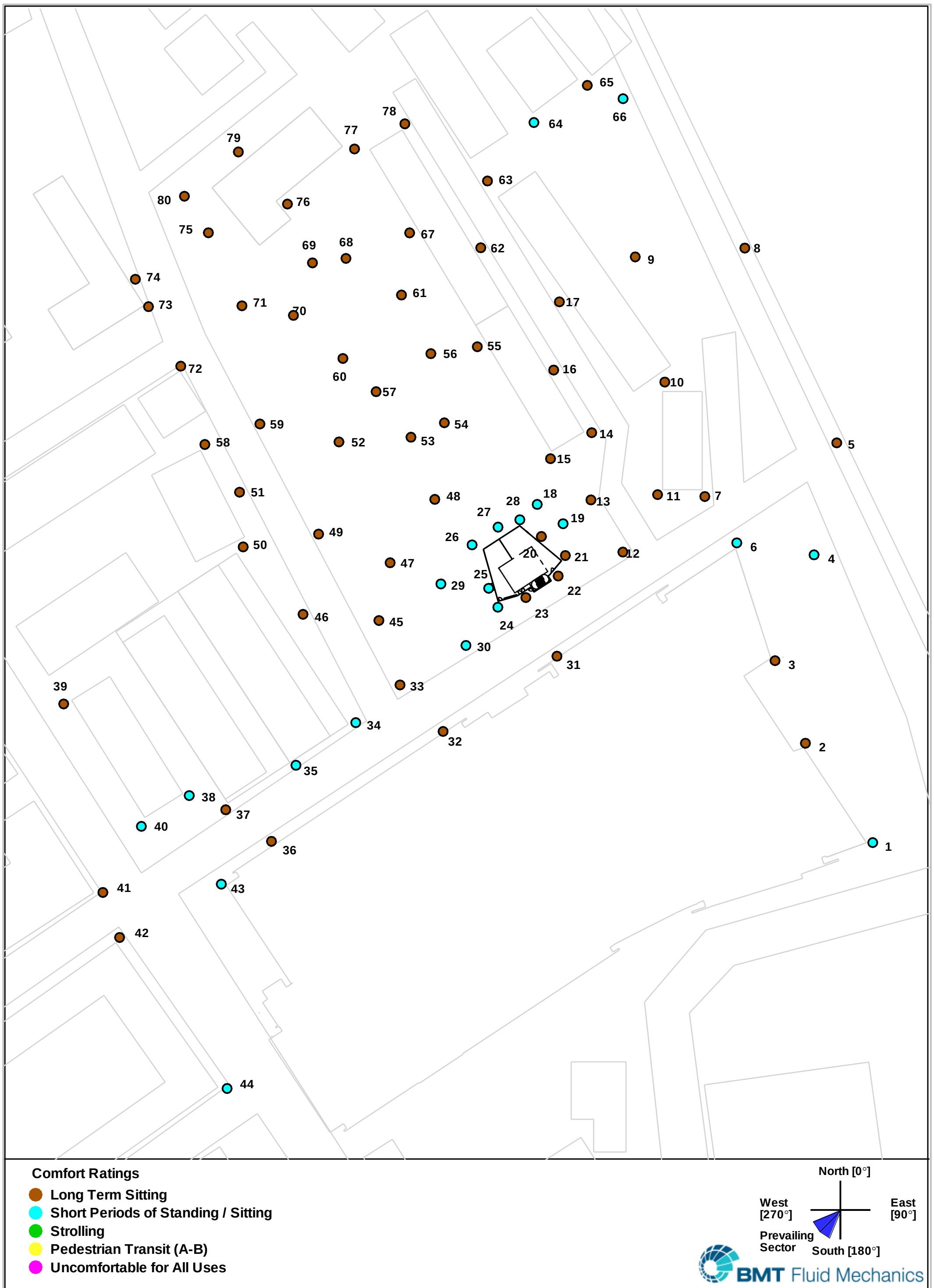


Figure D.2a: Summer comfort ratings, existing site conditions



431914 Brill Place - Existing Site within Existing Surrounds Summer Comfort	Status : Preliminary	Drawing No : 431914/WE/5	Prep : R. Wood Date : 05 Oct 2015

Figure D.2b: Summer comfort ratings, proposed development within existing surrounds – ground level



431914 Brill Place - Proposed Site within Existing Surrounds (Ground) Summer Comfort	Status : Preliminary	Drawing No : 431914/WE/205	Prep : R. Wood Date : 05 Oct 2015

Figure D.2c: **Summer comfort ratings, proposed development within existing surrounds – elevated level**

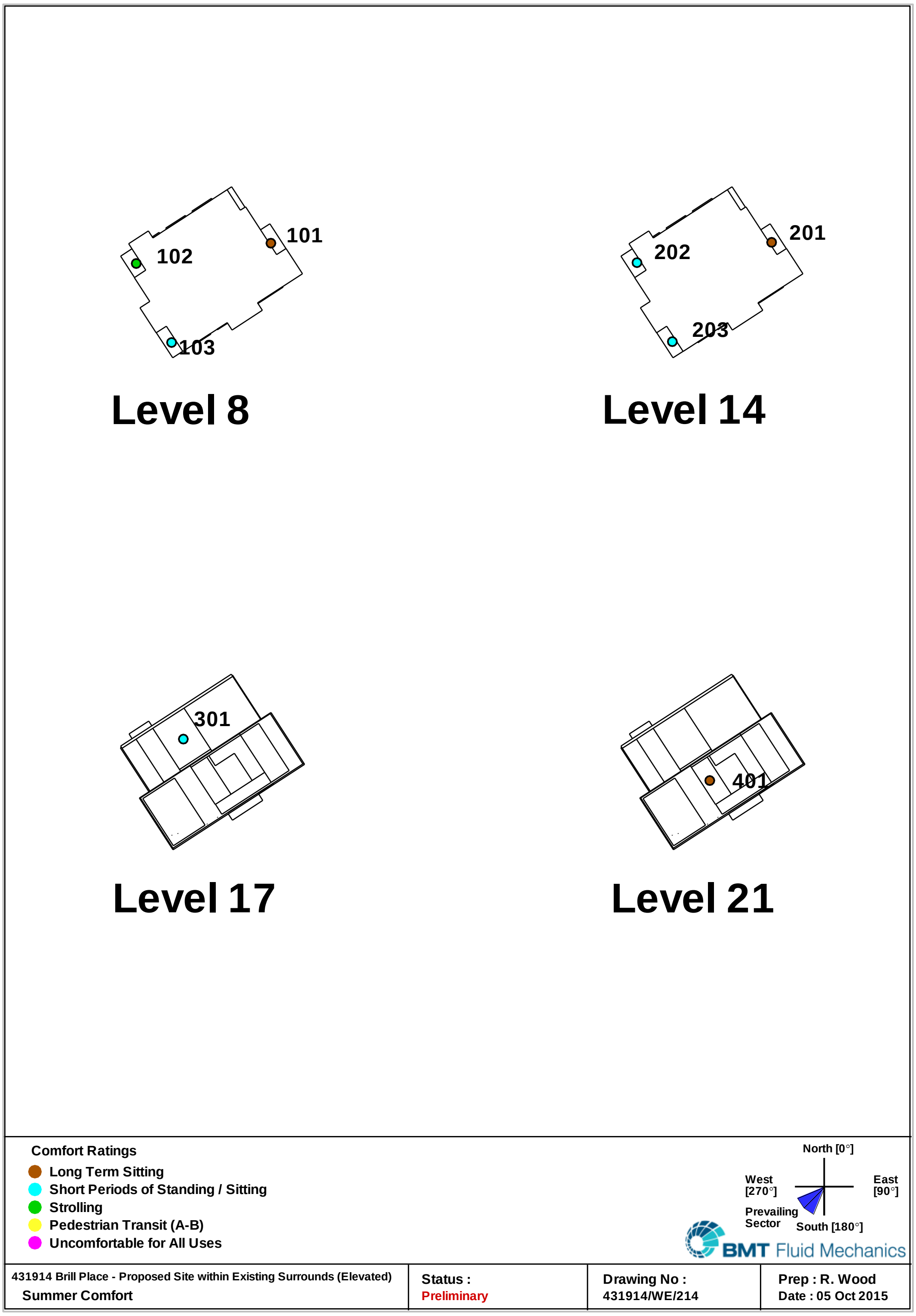
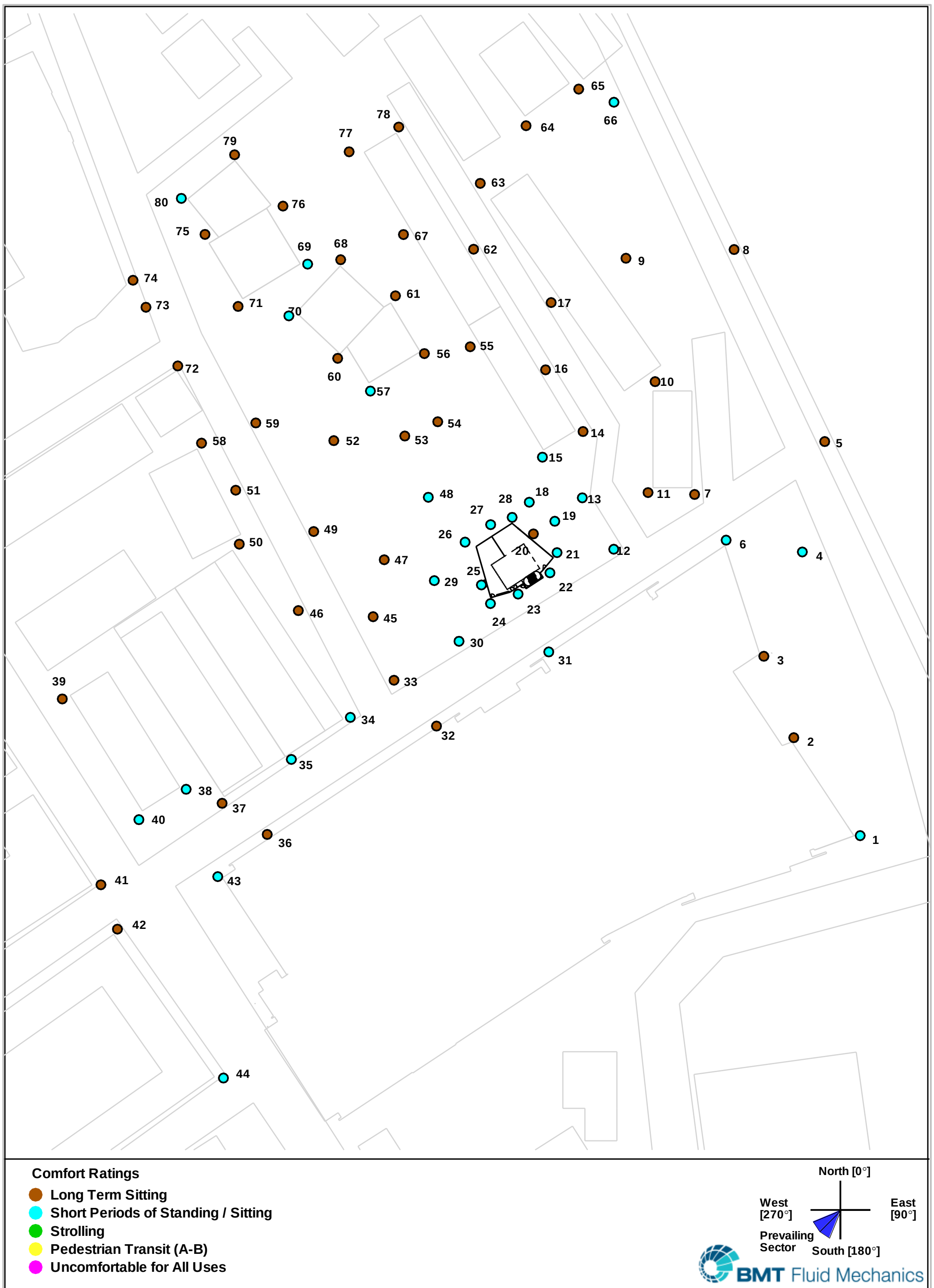


Figure D.2d: **Worst-seasonal comfort ratings, proposed development within future surrounds including the neighbouring masterplan development – ground level**



431914 Brill Place - Proposed Site within Future Surrounds (Ground) Summer Comfort	Status : Preliminary	Drawing No : 431914/WE/305	Prep : R. Wood Date : 05 Oct 2015

Figure D.2e: **Worst-seasonal comfort ratings, proposed development within future surrounds including the neighbouring masterplan development – elevated level**

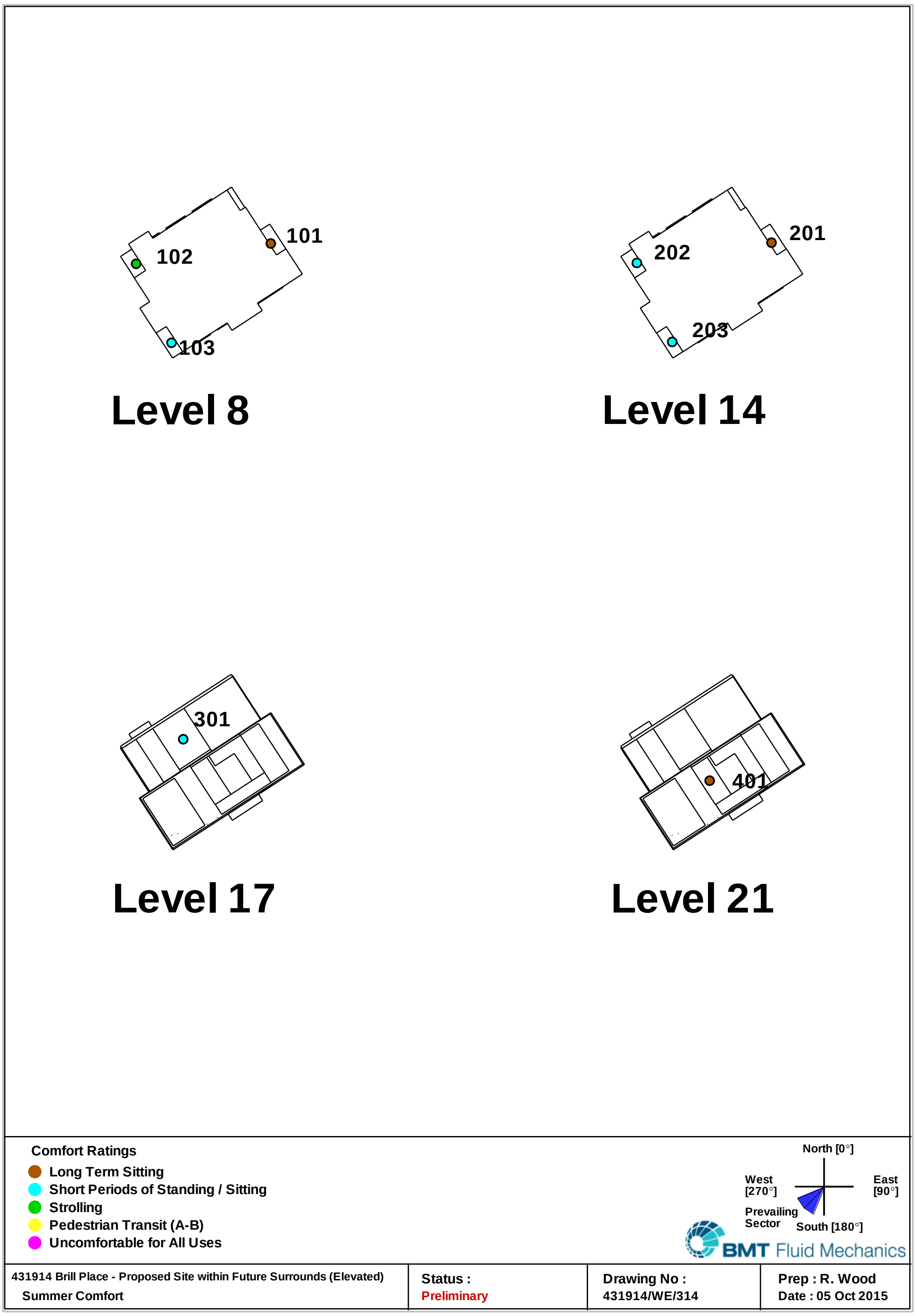
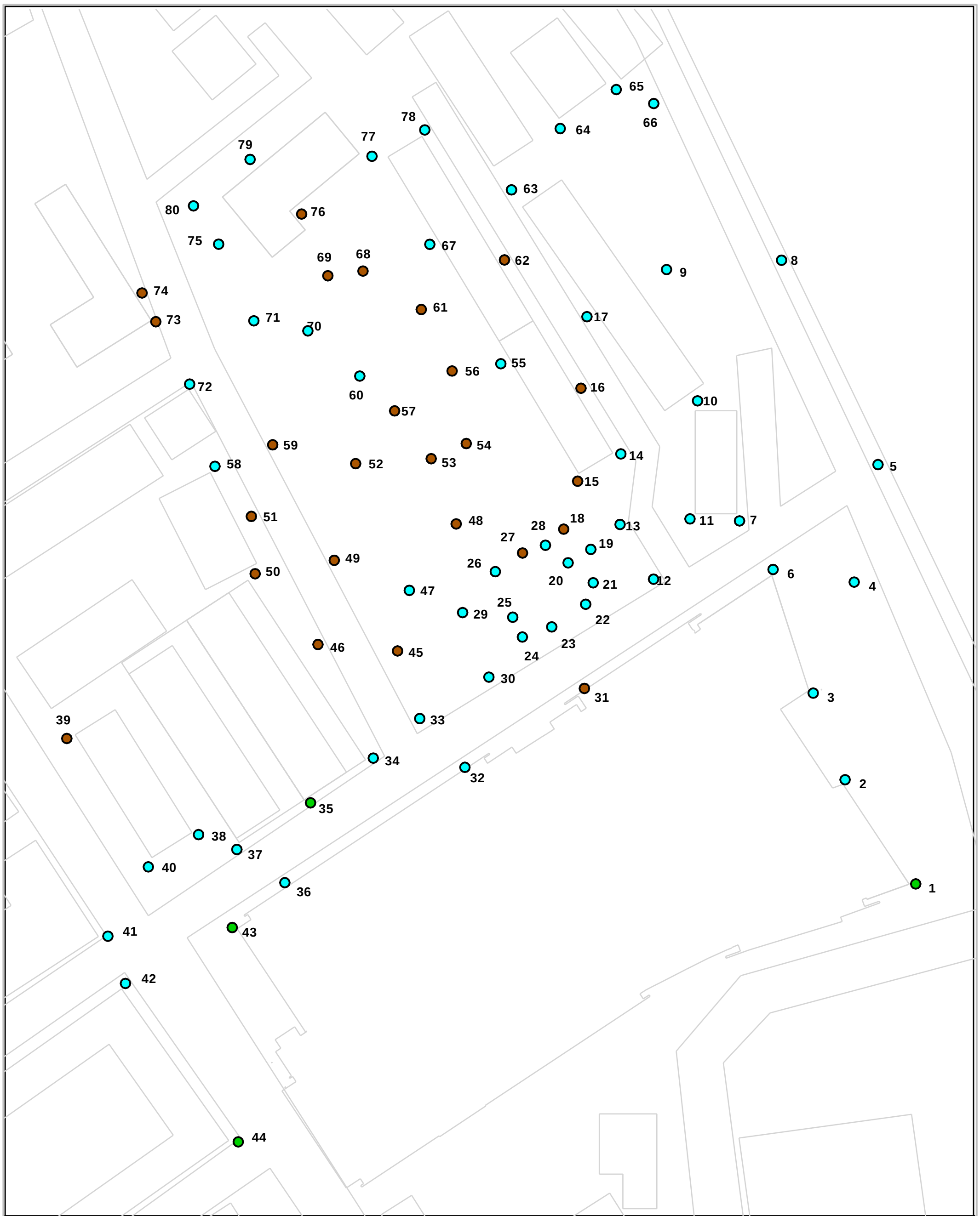
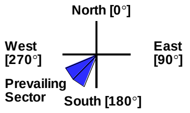


Figure D.3a: Worst-seasonal comfort ratings, existing site conditions



Comfort Ratings
- Long Term Sitting
- Short Periods of Standing / Sitting
- Strolling
- Pedestrian Transit (A-B)
- Uncomfortable for All Uses



BMT Fluid Mechanics

431914 Brill Place - Existing Site within Existing Surrounds Worst Seasonal Comfort	Status : Preliminary	Drawing No : 431914/WE/6	Prep : R. Wood Date : 05 Oct 2015

Figure D.3b: Worst-seasonal comfort ratings, proposed development within existing surrounds – ground level

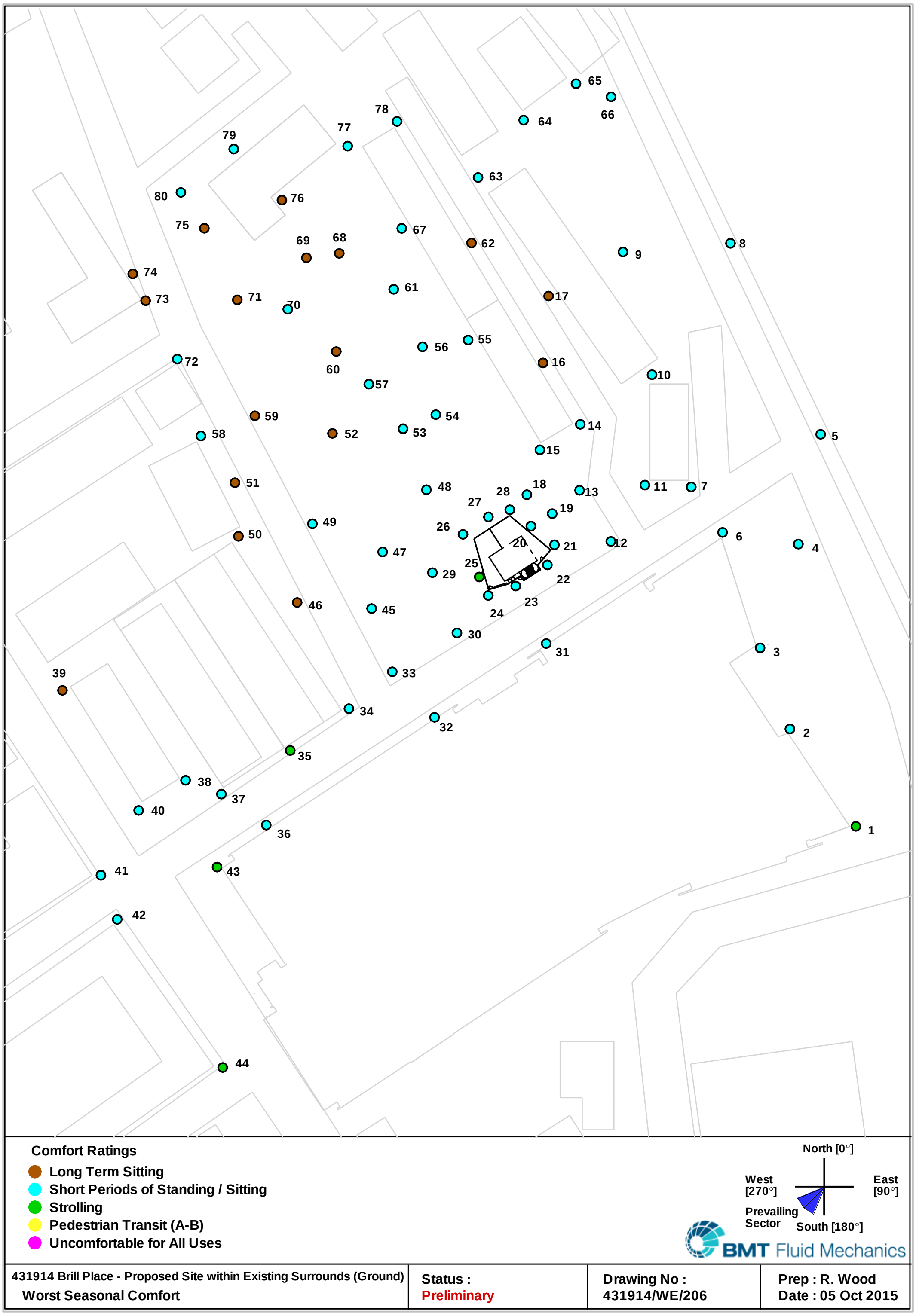


Figure D.3c: Worst-seasonal comfort ratings, proposed development within existing surrounds – elevated level

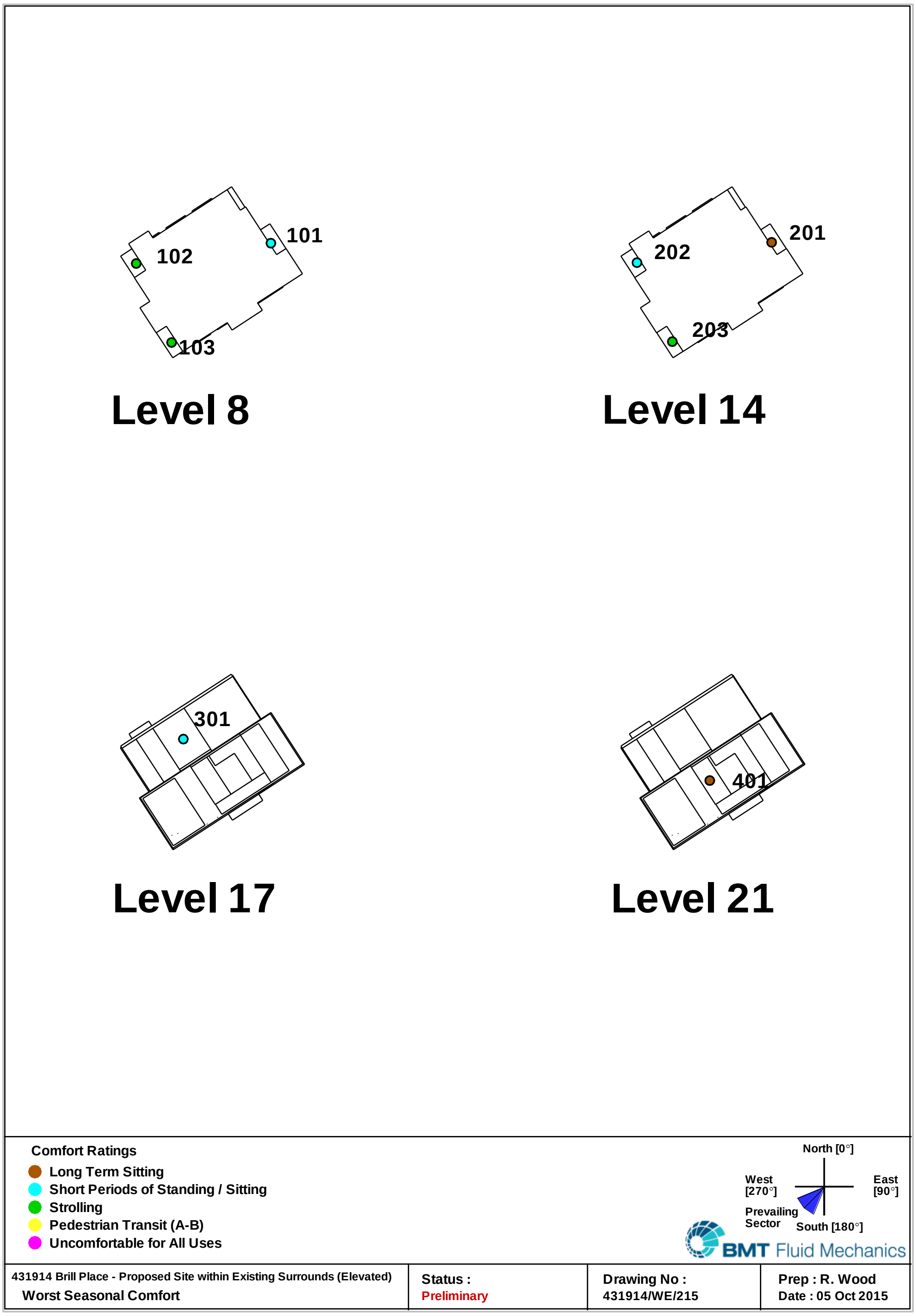
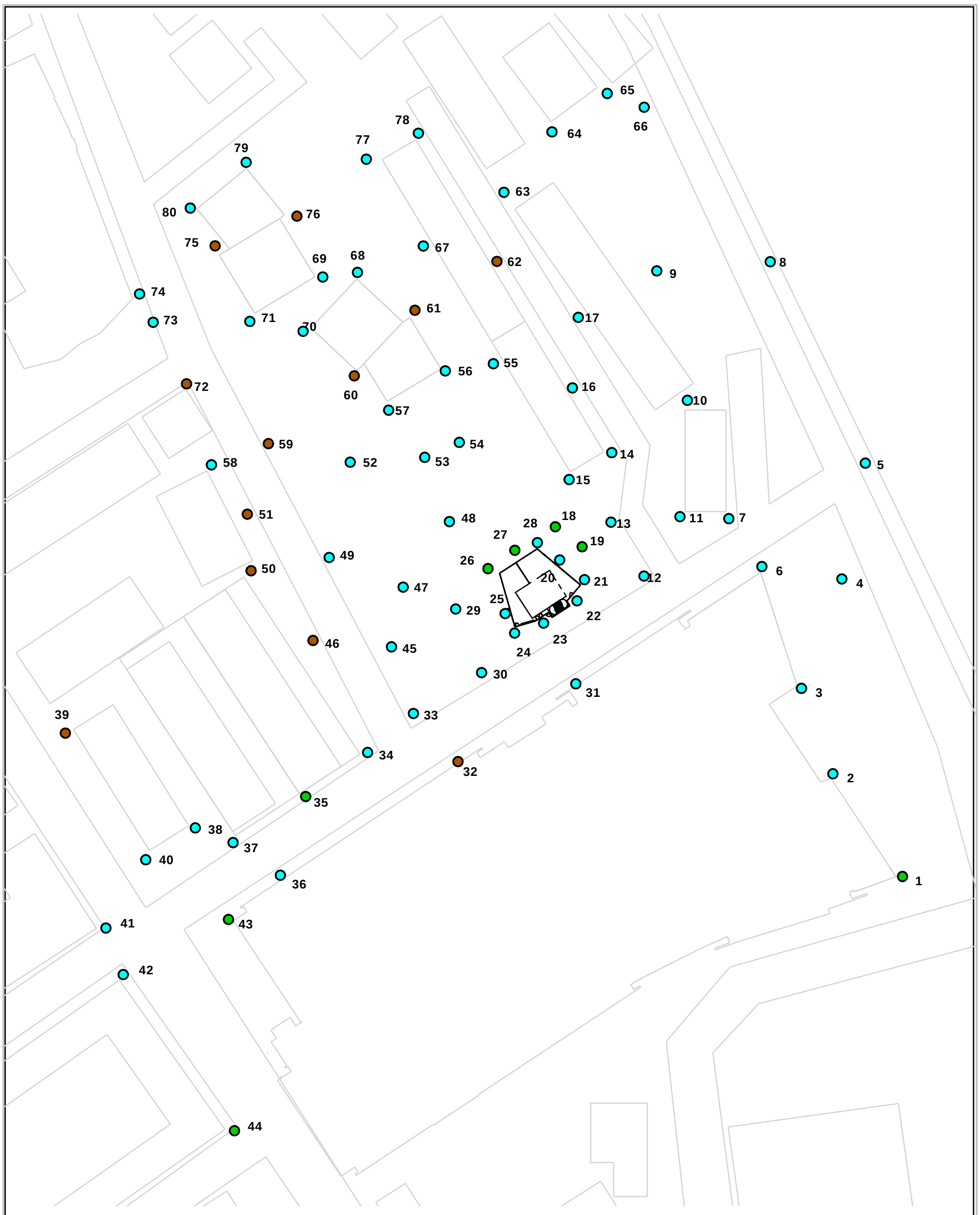


Figure D.3d: Worst-seasonal comfort ratings, proposed development within future surrounds including the neighbouring masterplan development – ground level



Comfort Ratings
- Long Term Sitting
- Short Periods of Standing / Sitting
- Strolling
- Pedestrian Transit (A-B)
- Uncomfortable for All Uses

North [0°] West [270°] East [90°] South [180°] Prevailing Sector

BMT Fluid Mechanics

431914 Brill Place - Proposed Site within Future Surrounds (Ground) Worst Seasonal Comfort	Status : Preliminary	Drawing No : 431914/WE/306	Prep : R. Wood Date : 05 Oct 2015

Figure D.3e: Worst-seasonal comfort ratings, proposed development within future surrounds including the neighbouring masterplan development – elevated level