VOLUME 1: GENERAL INFORMATION

1.5.8 WIND STUDIES REPORT

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FLUID MECHANICS

Kent Street
Birmingham, UK

Wind Microclimate Study

29th April 2022

Kent Street Birmingham, UK

Wind Microclimate Study

For: Winvic Construction Limited

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Executive Summary

Background

A boundary layer wind tunnel study has been carried out by NOVA Fluid Mechanics Ltd to assess the wind microclimate for the proposed Kent Street development in Birmingham, UK.

The boundary layer wind tunnel study has enabled the pedestrian level wind microclimate at the site to be quantified and classified in terms of suitability for 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

On the basis of the wind tunnel modelling, the following conclusions have been drawn:

- Wind conditions in and around the proposed development in existing surrounds, both with and without the proposed soft landscaping, are suitable, in terms of pedestrian safety and comfort, for intended uses.
- With the introduction of the cumulative schemes, wind conditions remain suitable, both in terms of pedestrian safety and comfort, for the intended uses.

Kent Street – Wind Microclimate Study

1. Introduction

This report summarises the results of a boundary layer wind tunnel study, commissioned by Winvic Construction Limited, to assess the wind microclimate for the proposed Kent Street development in Birmingham, UK.

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

The study considers the proposed development in the context of both the existing surrounding conditions and with the introduction of cumulative schemes.

2. The Assessment of Wind Microclimate

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.

3. Study Area

3.1. Site Location & Surrounding Area

The proposed development is located in Birmingham, UK. The site is bounded by the Bromsgrove Street to the north-west, Gooch Street to the north-east, Kent Street to the south-east and Henstead Street to the south-west. Plot 2 of the development is located to the south-west of the site, and has been considered as part of the cumulative scenario.

At present the area immediately surrounding the proposed development principally comprises a mixture of low and mid-rise buildings with Birmingham city centre to the north. Further afield, the wider surrounding area largely consists of typical suburban terrain giving way to open country.

The site location is presented within the context of the wider surrounding area in Figure 3.1.

Two configurations of the surrounding area were considered in the current study, namely the existing surrounding conditions and the cumulative surrounding conditions, which comprise ‘Plot 2’ and ‘Oasis’.

3.2. Proposed Development

The proposed development comprises four blocks, nominally rectangular in plan, surrounding a central courtyard with a circular pavilion. The tallest block is to the north-west of the site and is approximately 62 m tall.

Figure 3.2 presents a site plan of the proposed development.

3.3. Soft Landscaping

The wind microclimate has been assessed for the proposed development in existing surrounds both with and without current soft landscaping proposals. As illustrated graphically within Figure 3.3, the modelled soft landscaping comprised of the following:

- 27 multi-stem deciduous trees, ~2.4 m tall, within the central courtyard;
- 22 pleached deciduous trees, ~3.2 m tall, within the courtyard areas and along the pedestrian route between Henstead Street and Kent Street; and
- Six deciduous trees, ~ 6 m tall, along the pedestrian route between Henstead Street and Kent Street and in the courtyard on Kent Street.

In addition to the soft landscaping, each of the passages between Blocks A & B, C & D and A & D are closed off by 50% solid gates, which were retained for all test configurations.

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.

A detailed quantification of the local wind microclimate requires a purposely designed boundary layer wind tunnel study, such that wind conditions can classified in terms of suitability for planned usage, based on the industry standard Lawson criteria, and wind mitigation measures developed and validated as required.

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[2]. 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

The wind tunnel model was built at a scale of 1:400, which 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.

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

4.4. Measurement and Analysis

The technical details relating to the instrumentation, measurements and analysis for the wind microclimate 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 microclimate was assessed at a total of 81 locations, which were reviewed and approved by the design team prior to testing. Details of proposed pedestrian activities, assumed in the assessment, are also provided in Appendix C.

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 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:

- Proposed development in existing surrounds;
- Proposed development in cumulative surrounds.

The proposed development in existing surrounds was assessed both with and without the current soft landscaping proposals.

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 1.5 m above the ground and the wind speed at the reference height of 60 m.

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 Appendix D, 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 microclimate 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 microclimate in terms of comfort for various activities is assessed based on the Lawson criteria[3] 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:

Activity	Comfort Rating	Season	Examples
"Thoroughfare (A-B)"	Pedestrian Transit	All seasons	Local areas around tall buildings where people are not likely to linger. For access to and passage through the development and surrounding area.
"Leisure thoroughfare"	Strolling	All seasons	General areas of walking and sightseeing. For recreational passage through the development and surrounding area.
"Viewing Balcony"	Short Periods of Standing / Sitting	Summer	For short periods of sitting and standing on balconies.
"Recreational space"		Spring through autumn	For leisure uses including parks, gardens, children's play areas, terraces, bench seating, etc.
"Entrance / shop front / waiting area"		All seasons	For pedestrian ingress/egress at a building entrance, or short periods of sitting or standing such as at a bus stop, taxi rank, meeting point, etc.
"Outdoor seating" / "Seating Balcony"	Long-term Sitting	Summer	For long periods of sitting such as for an outdoor café/bar/restaurant, event seating, etc.

6.2. Proposed Development in Existing Surrounds

The proposed development is generally similar in height to the immediate surrounding buildings. However, Block A (to the north-west of the site) protrudes significantly above, and is thus exposed to prevailing south westerly winds. This has the potential to create downdraughts that redirect fast moving upper-level winds toward ground level where they could be further accelerated through the passage between Blocks A and D. However, the strength of downdraughts is limited by the narrow façade, and the strength of subsequent acceleration at ground level is mitigated by the inclusion of 50% solid gates across the passage, see Figure 3.3.

The results of the assessment for the proposed development in existing surrounds with and without soft landscaping are summarised in Figures 6.1 and 6.2, respectively.

6.2.1. Safety

Wind conditions in and around the proposed development in existing surrounds are suitable, in terms of pedestrian safety, for all users.

6.2.2. Comfort

Wind conditions in and around the proposed development in existing surrounds are suitable, in terms of pedestrian comfort, for the intended uses being a mixture of leisurely thoroughfare, entrances and recreational spaces.

Whilst wind conditions deteriorate slightly in the absence of the current soft landscaping proposals they remain suitable for the intended uses.

6.3. Proposed Development in Cumulative Surrounds

Whilst the cumulative developments are within the immediate vicinity of the site and represent an increase in the massing of the surrounding buildings, their principal impact is to provide additional sheltering from the corresponding wind directions. Consequently, wind conditions remain similar to those for the proposed development in existing surrounds, being suitable, both in terms of pedestrian safety and comfort, for the intended uses.

7. 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 in and around the proposed development in existing surrounds, both with and without the proposed soft landscaping, are suitable, in terms of pedestrian safety and comfort, for intended uses.
- With the introduction of the cumulative schemes, wind conditions remain suitable, both in terms of pedestrian safety and comfort, for the intended uses.

8. References

[1] Davenport, A.G. An Approach to Human Comfort Criteria for Environmental Wind Conditions. Colloquium 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.

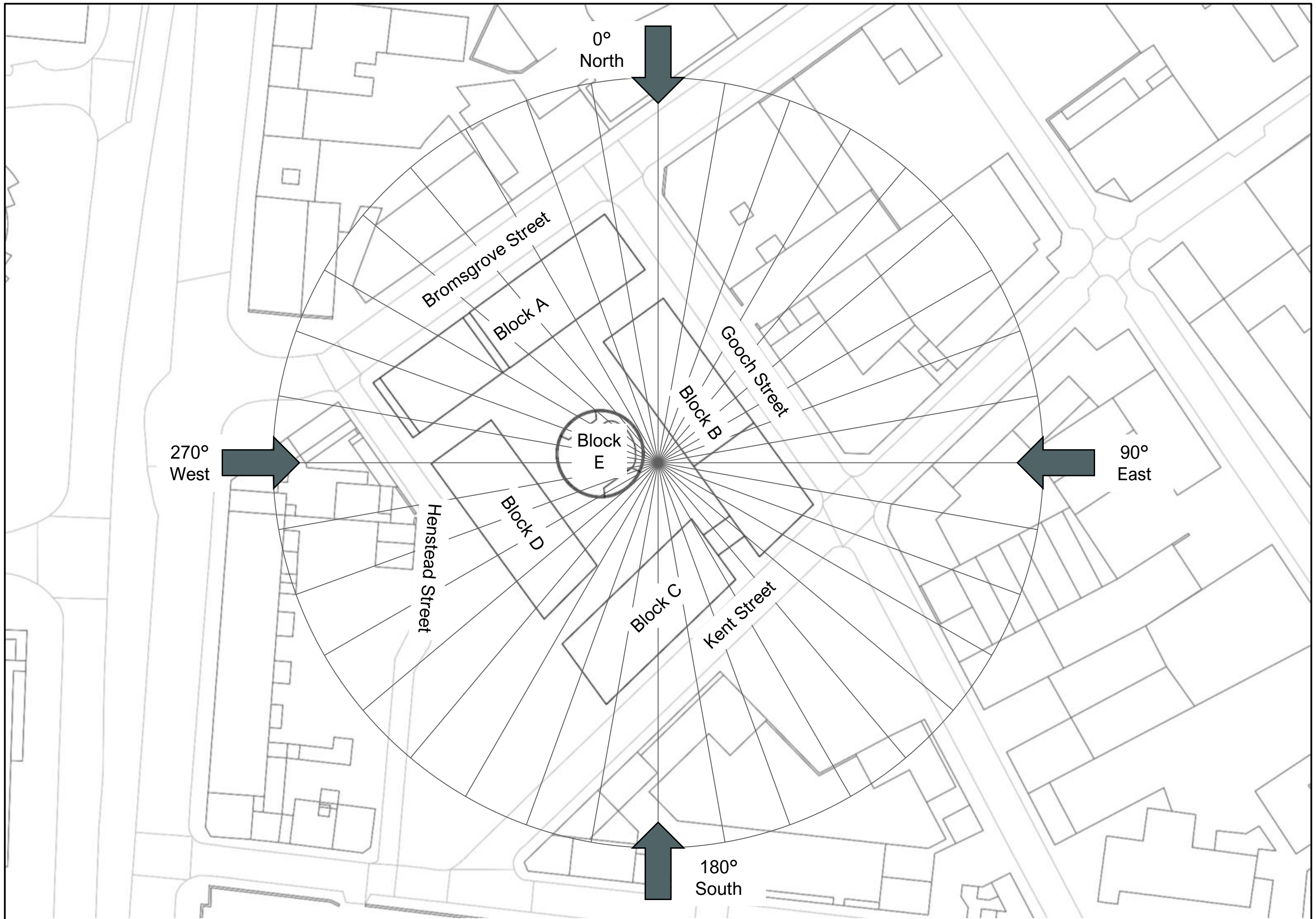
[3] Lawson, T.V. The Determination of The Wind Environment of A Building Complex Before Construction. University of Bristol, Department of Aeronautical Engineering, TVL/9025, 1990.

[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

NOVA FLUID MECHANICS	75090 Kent Street Site location	Drawing no.: 75090-FIG-3.1	By: D. Hankin Date: 28-APR-22

Figure 3.2: Site plan of the proposed development



NOVA FLUID MECHANICS	75090 Kent Street Site plan of the proposed development	Drawing no.: 75090-FIG-3.2	By: D. Hankin Date: 28-APR-22

Figure 3.3: Proposed soft landscaping

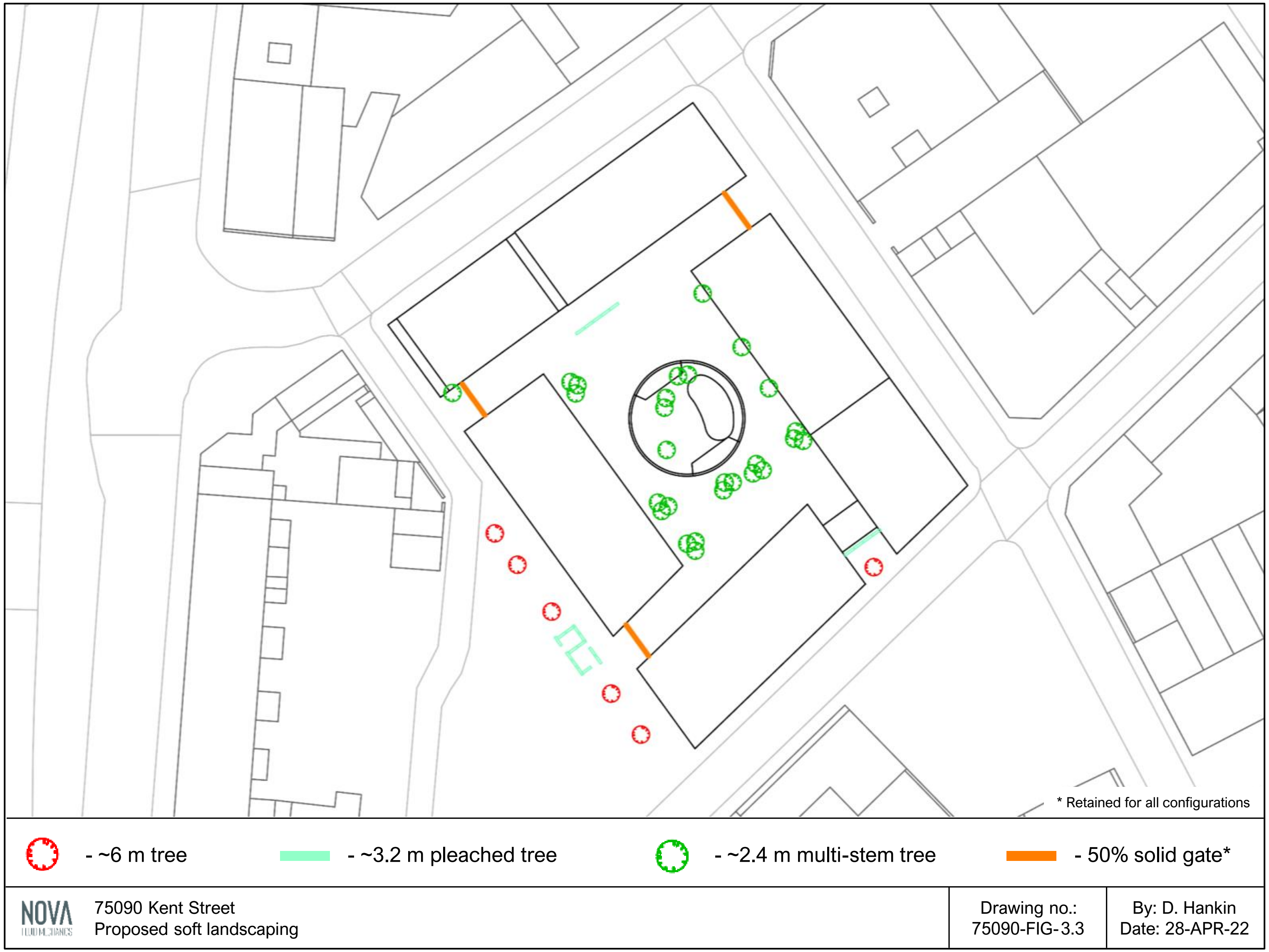


Figure 6.1: Wind microclimate summary, proposed in existing with landscaping

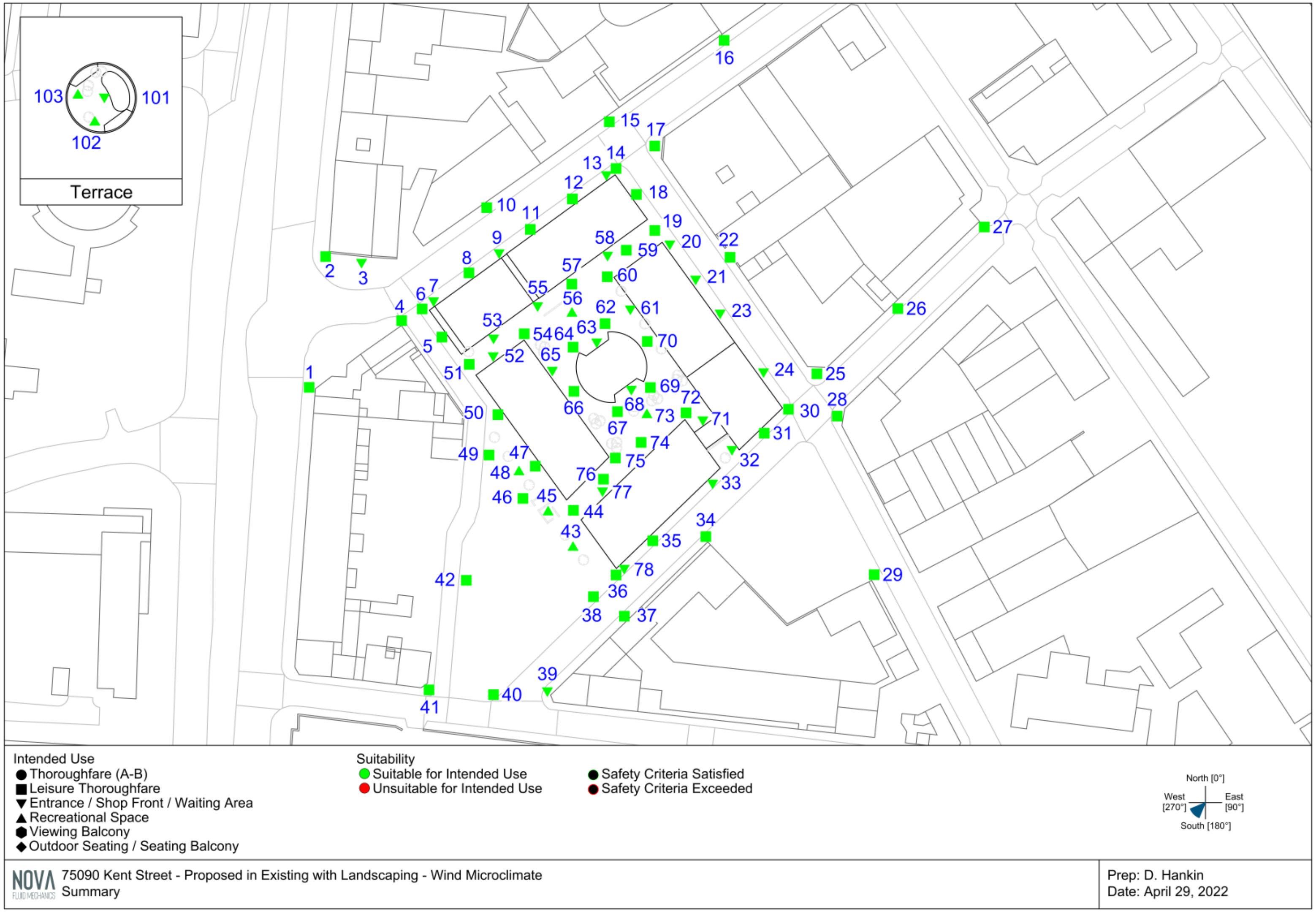


Figure 6.2: Wind microclimate summary, proposed in existing without landscaping

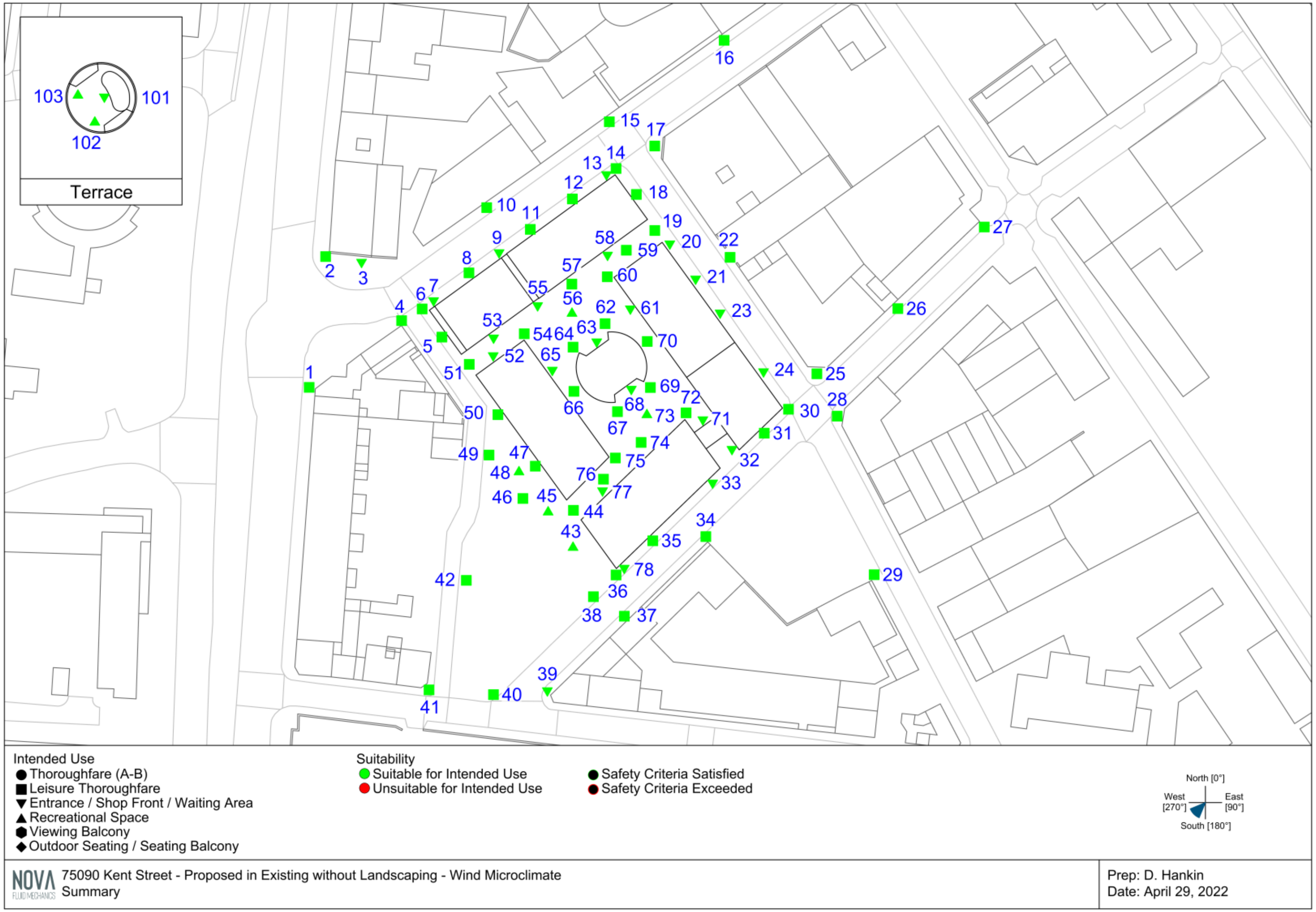
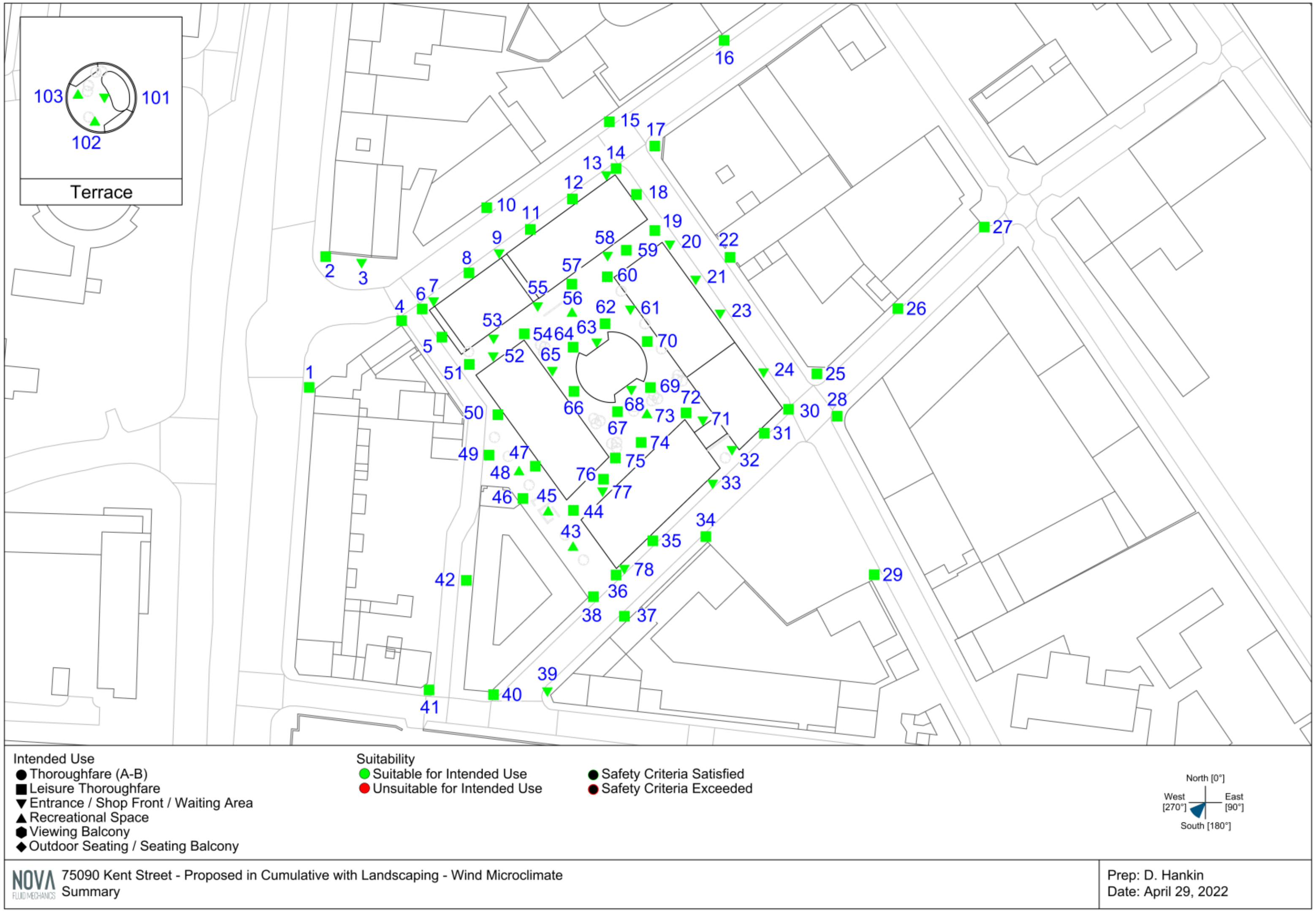


Figure 6.3: Wind microclimate summary, proposed in cumulative with landscaping



APPENDIX A. WIND CLIMATE ANALYSIS

A.1. ESDU Wind Analysis

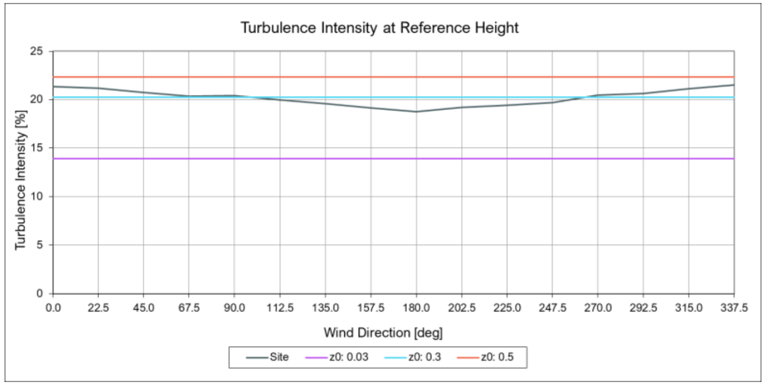
A detailed analysis was carried out to determine the wind properties at the site. The wind analysis is based on the widely accepted Deaves and Harris model of the atmospheric boundary layer (ABL), as defined in ESDU Item 01008[4], and has provided wind profiles describing the variation of wind speed 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.

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 Figure A.1.

A.2. Wind Properties at the Site

Figure A.2 shows the variation of longitudinal turbulence intensity with wind direction at the reference height of 60 m.

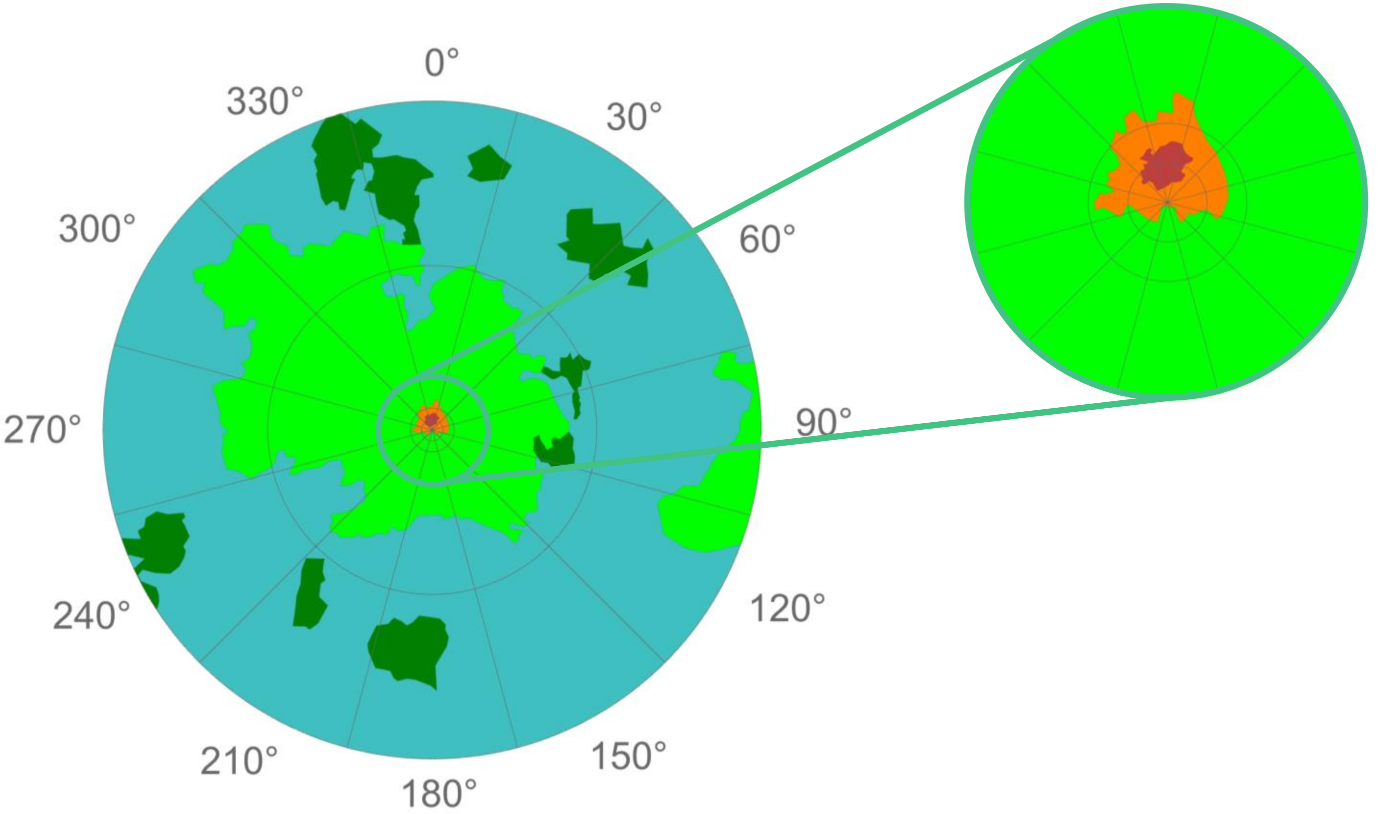
Figure A.2: Variation of turbulence intensity with wind direction at 60 m height, including reference turbulence levels



Due to the low variation of wind properties with wind direction, one target profile has been selected for the boundary layer simulation, being that for 240°.

Figures A.3 and A.4 show the variation of mean wind-speed (normalised by the mean wind speed at the reference height of 60 m) and turbulence intensity with height for winds approaching the site from the four primary quarters.

Figure A.1: Terrain roughness changes from the site



z_0 = 0.03 m (Open Country)
z_0 = 0.1 m (Parks)
z_0 = 0.3 m (Suburbs)
z_0 = 0.5 m (Centre of Town)
z_0 = 0.7 m (City Centre)

NOVA FLUID MECHANICS 75090 Kent Street Terrain roughness changes from the site	Drawing no.: 75090-FIG-A.1	By: D. Hankin Date: 28-APR-22

Figure A.3: Variation of mean wind speed normalised by mean wind speed at the reference height of 60 m

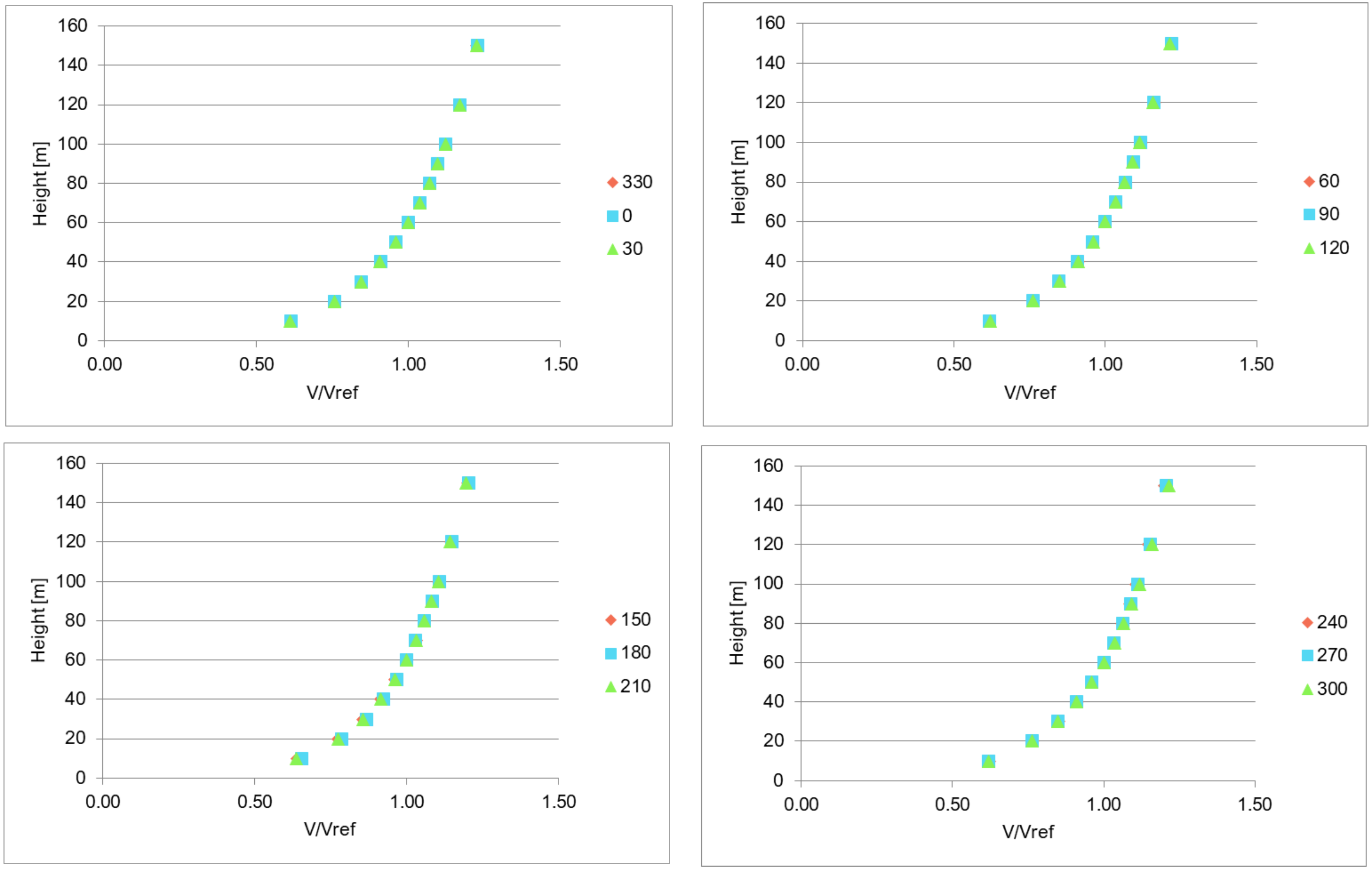


Figure A.4: Variation of longitudinal turbulence intensity with wind direction the reference height of 60 m.

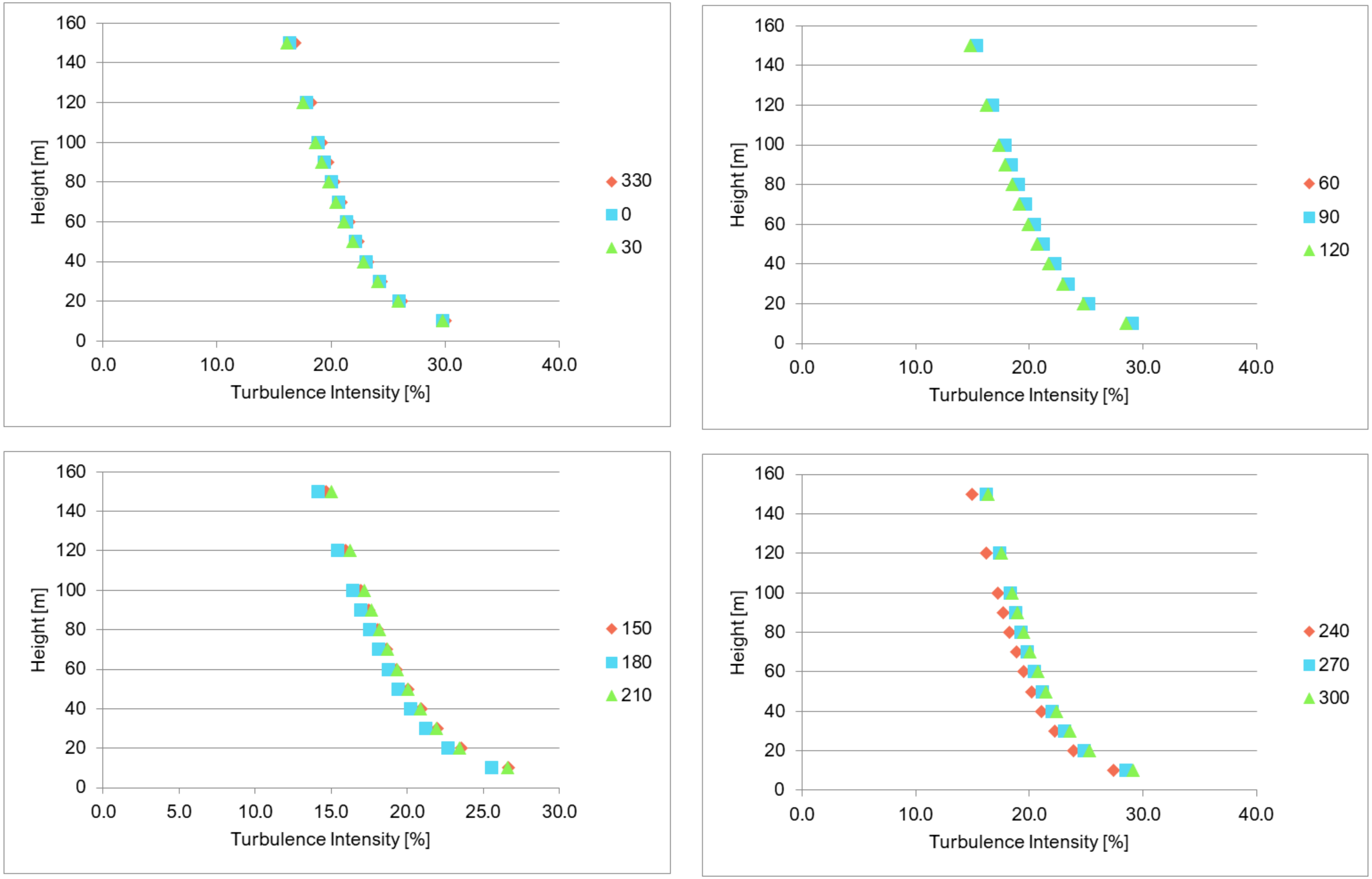
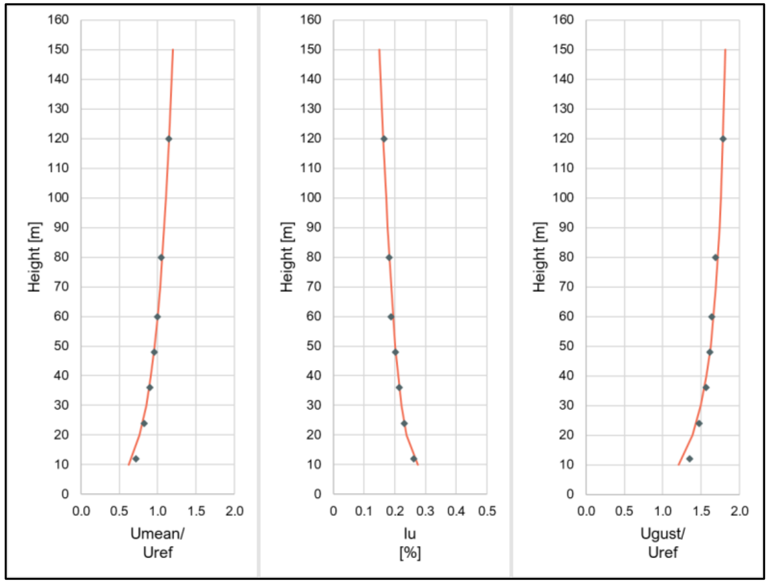


Figure A.5 presents the variation of mean wind speed, longitudinal turbulence intensity and gust wind speed used in the tests. The wind speed profiles are normalised by the mean wind speed at the reference height of 60 m.

Figure A.5: 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



It can be seen that, over the range of heights of interest, the boundary layer simulations used in the tests were a good representation of the profiles expected for the site at full scale.

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:

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

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. The resulting annual and seasonal directional and wind speed probability distributions at the reference height of 60 m, at the proposed site, are given in Figures A.6a to A.6e, respectively.

Values of *p*, *c* and *k* for the Birmingham weather centre transposed to open-country terrain at 10 m height above sea-level altitude are given in Table A.1.

Figure A.6a: Directional wind speed probability distribution at site: annual (at 60 m height)

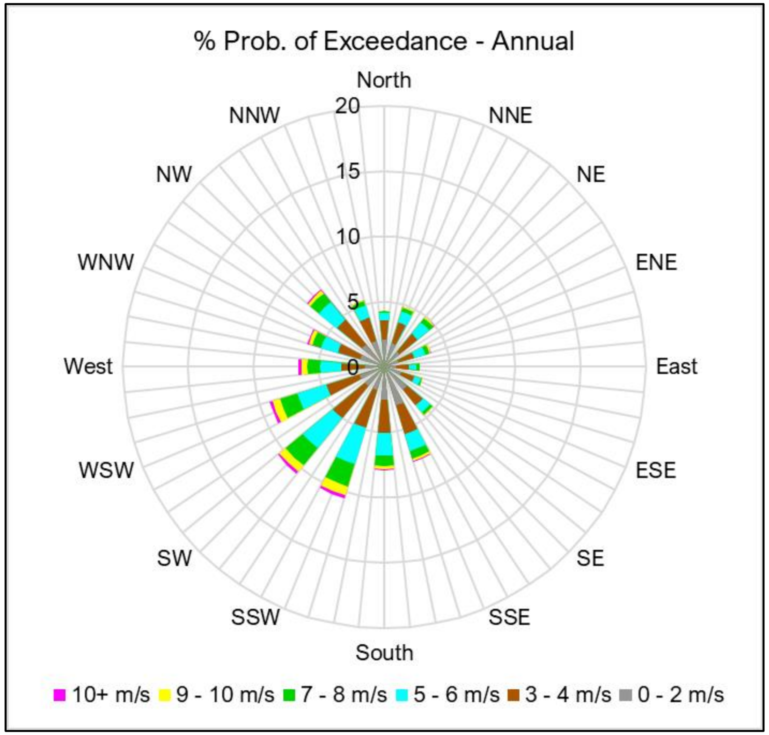


Figure A.6b: Directional wind speed probability distribution at site: spring (at 60 m height)

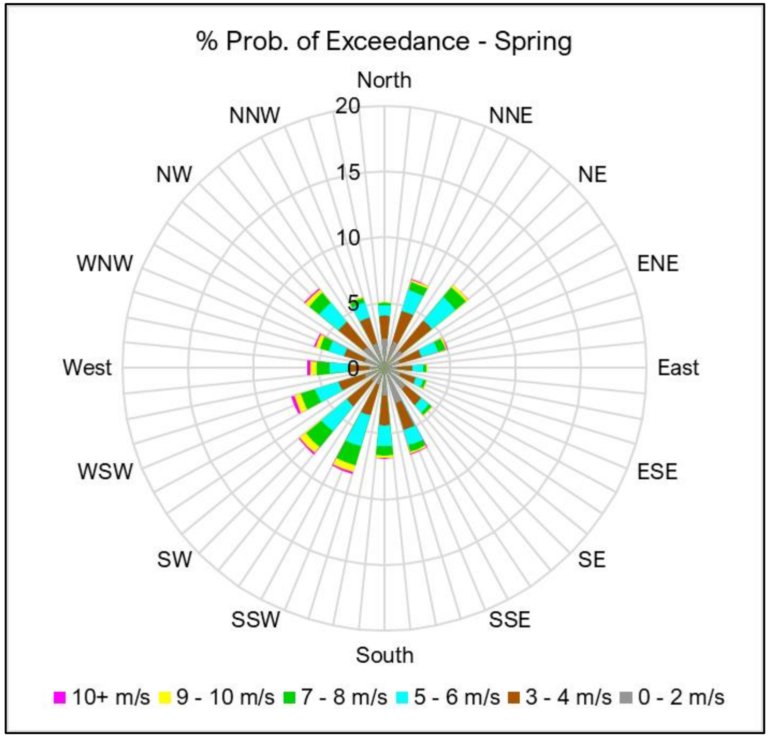


Figure A.6c: Directional wind speed probability distribution at site: summer (at 60 m height)

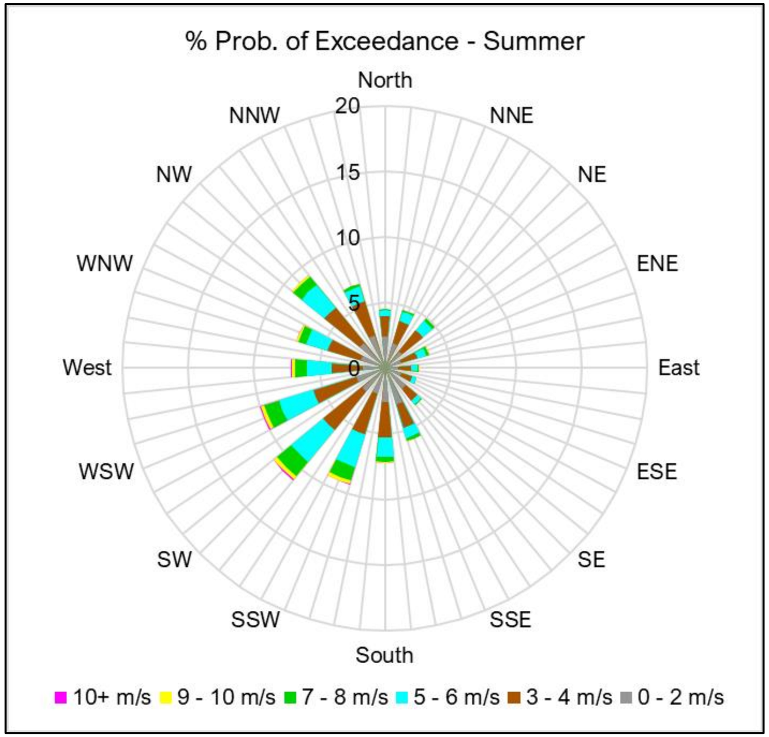


Figure A.6d: Directional wind speed probability distribution at site: autumn (at 60 m height)

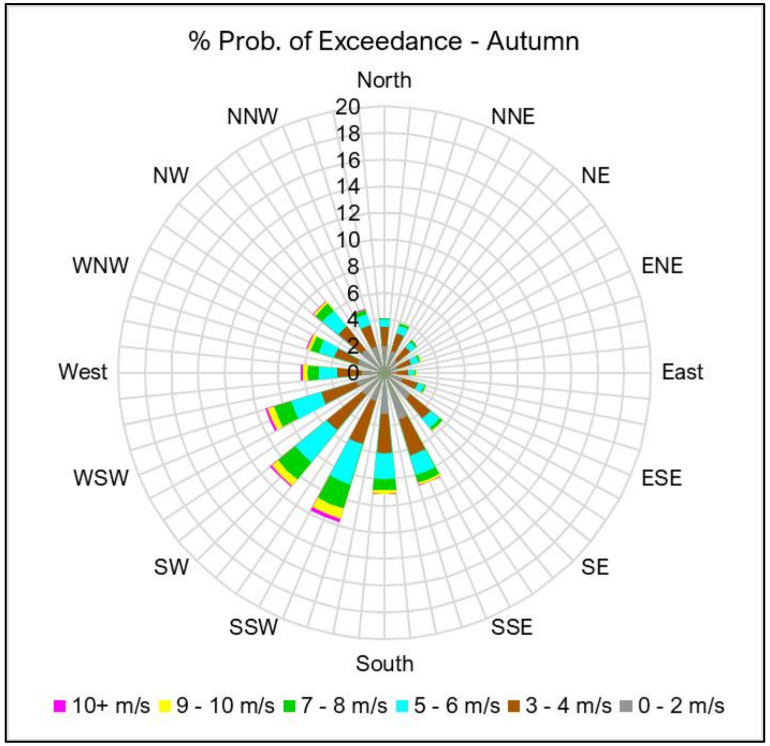


Figure A.6e: Directional wind speed probability distribution at site: winter (at 60 m height)

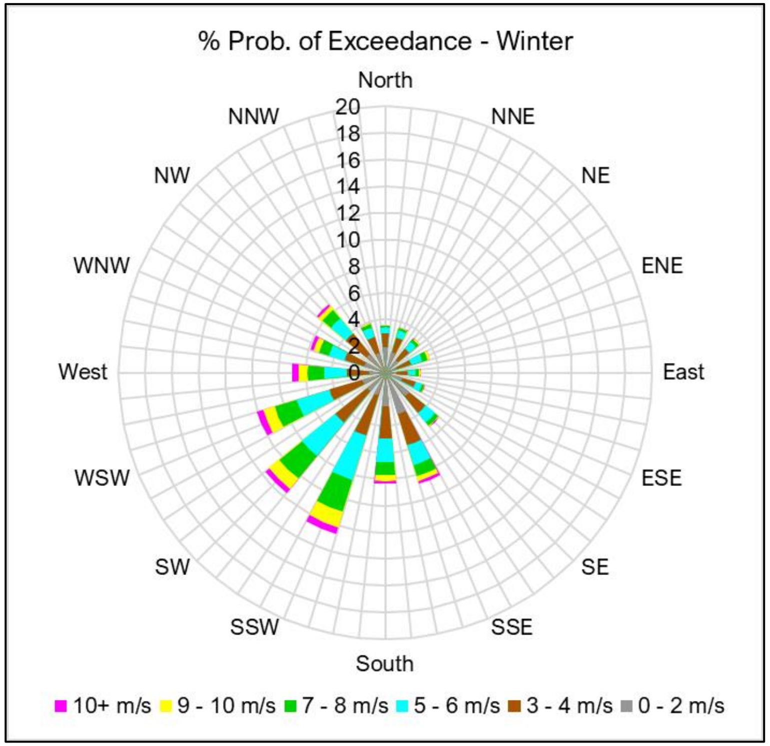


Table A.1: Wind frequency statistics: corrected Birmingham weather station data transformed to z_0=0.03m

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	4.31	4.83	4.94	3.74	2.74	3.06	4.81	7.56	7.91	10.51	10.57	9.20	6.61	6.18	7.68	5.35
c	3.38	3.91	4.31	4.39	4.14	3.55	3.43	3.79	4.24	5.35	5.27	5.24	5.41	4.70	4.73	3.93
k	1.87	1.91	2.15	2.12	2.07	1.91	1.77	1.69	1.93	2.28	2.33	2.08	1.95	1.78	2.00	1.95

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	5.04	7.10	8.25	5.02	3.25	3.33	4.68	6.85	6.91	8.45	8.50	7.43	5.91	5.62	7.93	5.72
c	3.61	4.46	4.84	4.71	4.30	3.81	3.55	3.76	4.28	5.40	5.47	5.34	5.68	4.91	4.95	4.15
k	1.93	2.10	2.44	2.27	2.30	2.01	1.86	1.76	2.00	2.44	2.45	2.07	2.05	1.86	2.01	2.06

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	4.51	4.68	4.95	3.55	2.62	2.55	3.66	5.84	7.22	9.26	11.02	9.95	7.18	7.05	9.20	6.75
c	3.16	3.57	3.92	3.95	3.72	3.15	2.94	3.21	3.74	4.67	4.80	4.73	4.88	4.43	4.51	3.75
k	1.96	2.12	2.36	2.07	2.17	1.90	1.79	1.77	2.14	2.43	2.47	2.34	2.26	2.27	2.31	2.29

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	4.11	3.90	3.16	2.84	2.40	3.24	5.66	8.86	9.17	11.75	11.11	9.37	6.33	6.15	6.95	4.99
c	3.38	3.64	3.72	3.90	3.92	3.49	3.48	3.68	4.10	5.28	5.12	5.04	5.01	4.45	4.49	3.86
k	2.03	1.96	2.10	2.15	2.08	2.00	1.89	1.79	1.91	2.21	2.29	2.06	1.85	1.72	1.94	1.82

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	3.57	3.58	3.35	3.52	2.68	3.13	5.25	8.72	8.36	12.64	11.68	10.06	7.01	5.90	6.63	3.91
c	3.26	3.65	4.10	4.79	4.48	3.65	3.65	4.17	4.52	5.85	5.71	5.76	6.12	5.19	5.00	4.03
k	1.66	1.77	1.84	2.17	1.96	1.81	1.72	1.61	1.78	2.36	2.33	2.11	2.03	1.72	1.92	1.77

APPENDIX B. WIND TUNNEL & MODEL DETAILS

B.1. Wind Tunnel Specifications

All the tests were conducted in University of Genoa's Wind Tunnel which has a working section of 1.7 m wide, 1.35 m high and 8.8 m long. The operating wind speed range is 0 – 32m/s.

A turbulent boundary layer, representative of the conditions at the site, is set up using turbulence inducing elements at the entrance to the test section and an arrangement of roughness elements distributed over the floor of the wind tunnel.

B.2. Model

B.2.1. Information for Model Construction

The model of the proposed development was constructed based on the 3D models "2325-GHA-XX-ZZ-M3-A-9002_BULDG-P15.rvt", "2325-GHA-XX-ZZ-M3-A-9003_ENVLP-P12.rvt" and "2325-GHA-XX-ZZ-M3-A-9004_APRTM-P11.rvt" in conjunction with the corresponding plans and elevations downloaded from Winvic CDE system on 21st February 2022.

The model of the surrounding area was based on a site survey using publicly available information.

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

B.2.2. Scale

A model scale of 1:400 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 320 m from the centre of the site. The surrounding buildings were represented to a sufficient level of detail to reproduce the wind flows at the location of the proposed development.

Trees were represented in winter, or bare, format in order to obtain conservative results, but it is presumed that trees planted as part of the development will be a species which is robust, and offers a worthwhile degree of alleviation of accelerated winds, i.e. the trees retain a substantial level of solidity during winter (lots of twigs and branches).

B.2.4. Model Photos

Images of the wind tunnel model are presented as follows:

- Figure B.1: Proposed development in existing surrounds
- Figure B.2: Proposed development in cumulative surrounds
- Figures B.3 & B.4: Close-ups of proposed development

Figure B.1: Proposed development in existing surrounds viewed from the south-west.

Figure B.2: Proposed development in cumulative surrounds viewed from the south-west.

Figure B.3: Close-up of proposed development viewed from the north-east.

Figure B.4: Close-up of proposed development viewed from the north-west.

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 81 locations at a height corresponding to 1.5 m 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. NOVA 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		Examples
4 m/s	C4	Long-term standing / sitting	Reading a newspaper and eating and drinking
6 m/s	C3	Short-term standing / sitting	Appropriate for bus stops, window shopping and building entrances
8 m/s	C2	Leisure thoroughfare / strolling	General areas of walking and sightseeing
10 m/s	C1	Pedestrian transit / thoroughfare (A-B)	Local areas around tall buildings where people are not likely to linger
> 10 m/s	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 the 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 the general public	Less able and cyclists find conditions physically difficult
> 20 m/s	S1	Unsuitable for the able-bodied	Physically impossible for able-bodied to remain standing during gusts.

C.3. Pedestrian Activities

Table C.3 presents the pedestrian uses assumed for each of the corresponding measurement locations presented in Figures 6.1 to 6.3, for the proposed development in both existing and cumulative surrounds.

Table C.3: Pedestrian uses – proposed development

Loc'n	Usage	Loc'n	Usage	Loc'n	Usage
1	Leisure thoroughfare	28	Leisure thoroughfare	55	Entrance
2	Leisure thoroughfare	29	Leisure thoroughfare	56	Recreational space
3	Entrance	30	Leisure thoroughfare	57	Leisure thoroughfare
4	Leisure thoroughfare	31	Leisure thoroughfare	58	Entrance
5	Leisure thoroughfare	32	Entrance	59	Leisure thoroughfare
6	Leisure thoroughfare	33	Entrance	60	Leisure thoroughfare
7	Entrance	34	Leisure thoroughfare	61	Entrance
8	Leisure thoroughfare	35	Leisure thoroughfare	62	Leisure thoroughfare
9	Entrance	36	Leisure thoroughfare	63	Entrance
10	Leisure thoroughfare	37	Leisure thoroughfare	64	Leisure thoroughfare
11	Leisure thoroughfare	38	Leisure thoroughfare	65	Entrance
12	Leisure thoroughfare	39	Entrance	66	Leisure thoroughfare
13	Entrance	40	Leisure thoroughfare	67	Leisure thoroughfare
14	Leisure thoroughfare	41	Leisure thoroughfare	68	Entrance
15	Leisure thoroughfare	42	Leisure thoroughfare	69	Leisure thoroughfare
16	Leisure thoroughfare	43	Recreational space	70	Leisure thoroughfare
17	Leisure thoroughfare	44	Leisure thoroughfare	71	Entrance
18	Leisure thoroughfare	45	Recreational space	72	Leisure thoroughfare
19	Leisure thoroughfare	46	Leisure thoroughfare	73	Recreational space
20	Entrance	47	Leisure thoroughfare	74	Leisure thoroughfare
21	Entrance	48	Recreational space	75	Leisure thoroughfare
22	Leisure thoroughfare	49	Leisure thoroughfare	76	Leisure thoroughfare
23	Entrance	50	Leisure thoroughfare	77	Entrance
24	Entrance	51	Leisure thoroughfare	78	Entrance
25	Leisure thoroughfare	52	Entrance	101	Entrance
26	Leisure thoroughfare	53	Entrance	102	Recreational space
27	Leisure thoroughfare	54	Leisure thoroughfare	103	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.1c present **annual safety** ratings for each configuration
- Figures D.2a to D.2c present **summer comfort** ratings for each configuration
- Figures D.3a to D.3c present **worst seasonal comfort** ratings for each configuration

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).

Figure D.1a: Annual safety ratings, proposed in existing with landscaping

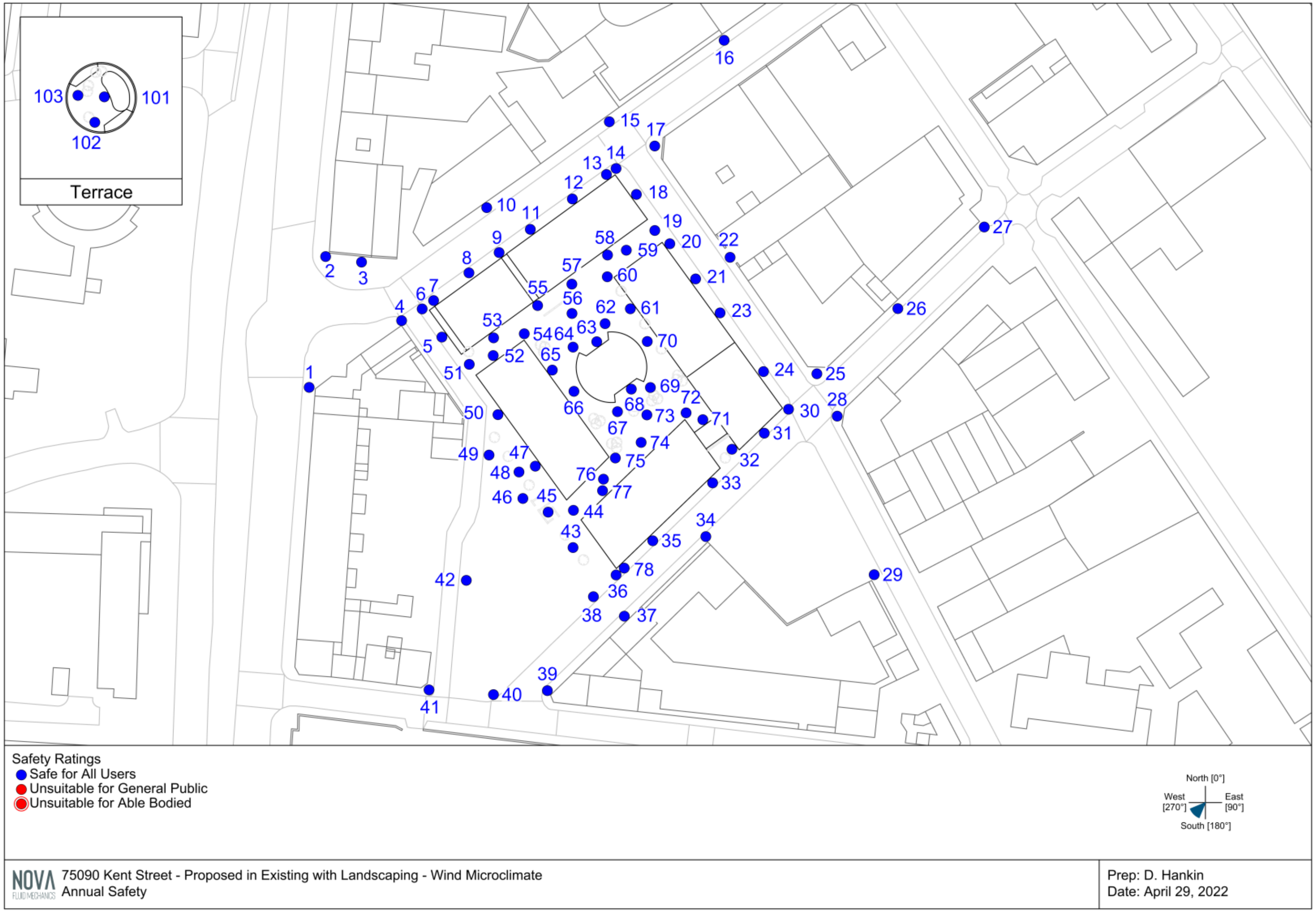


Figure D.1b: Annual safety ratings, proposed in existing without landscaping

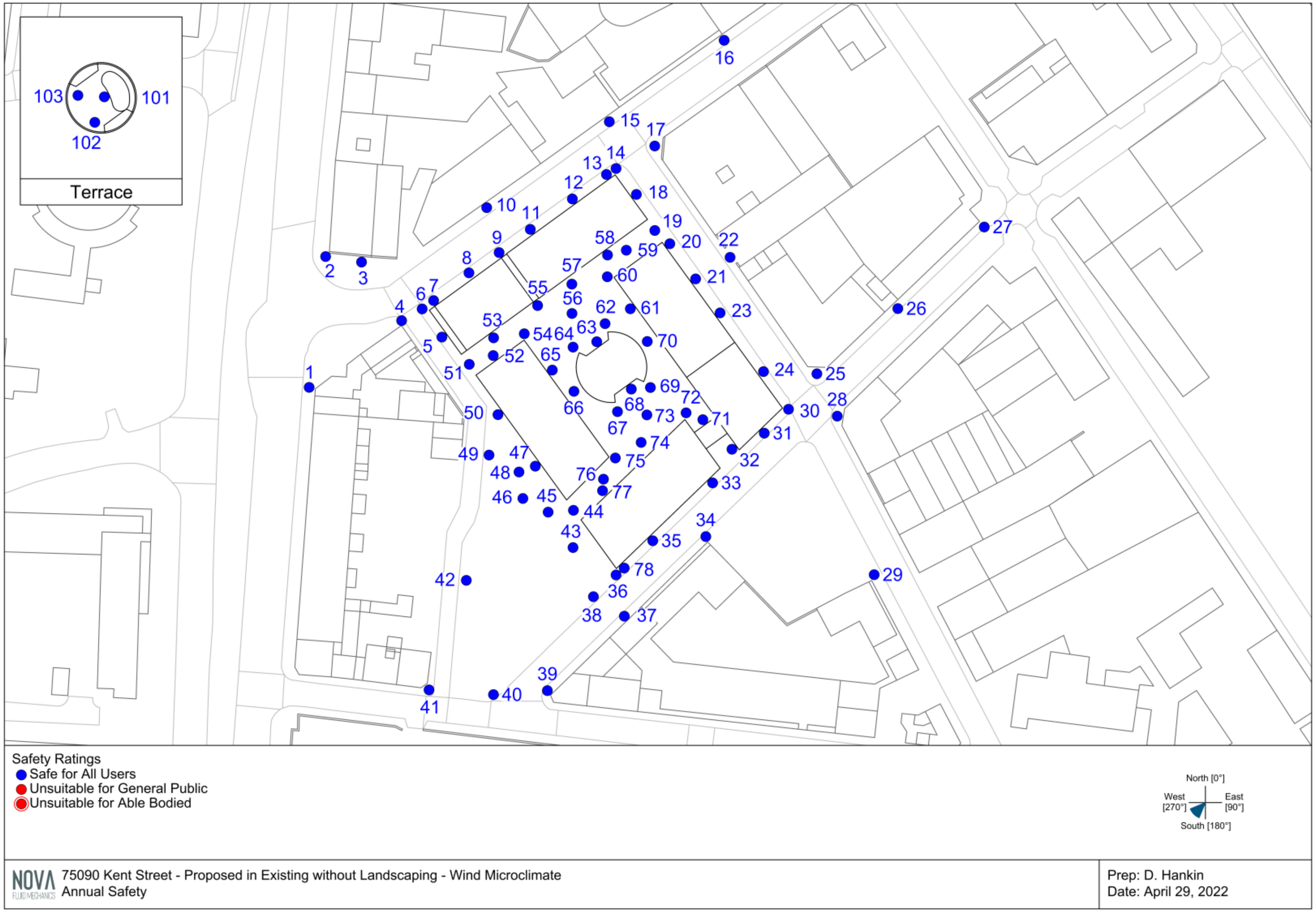


Figure D.1c: Annual safety ratings, proposed in cumulative with landscaping

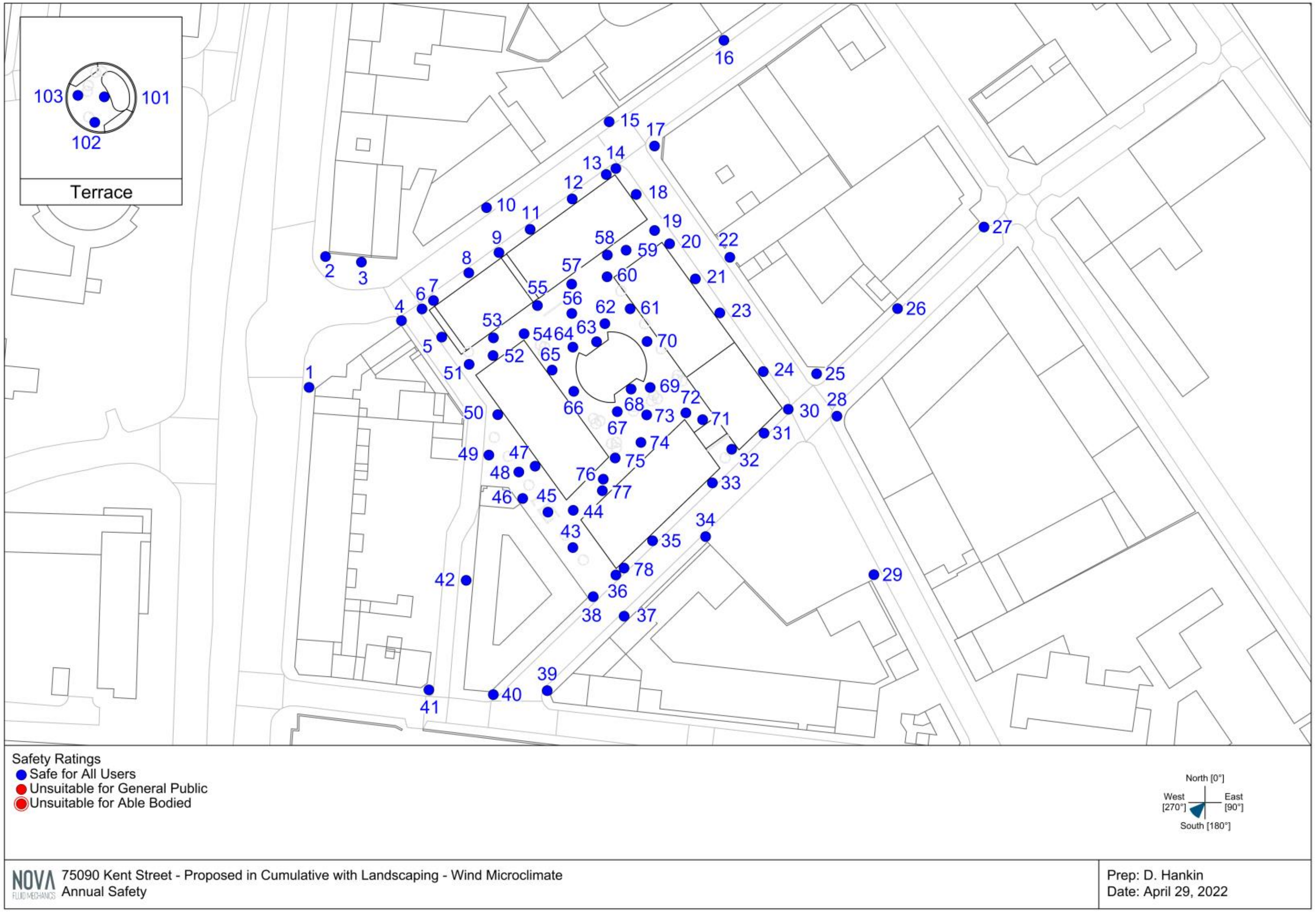


Figure D.2a: Summer comfort ratings, proposed in existing with landscaping

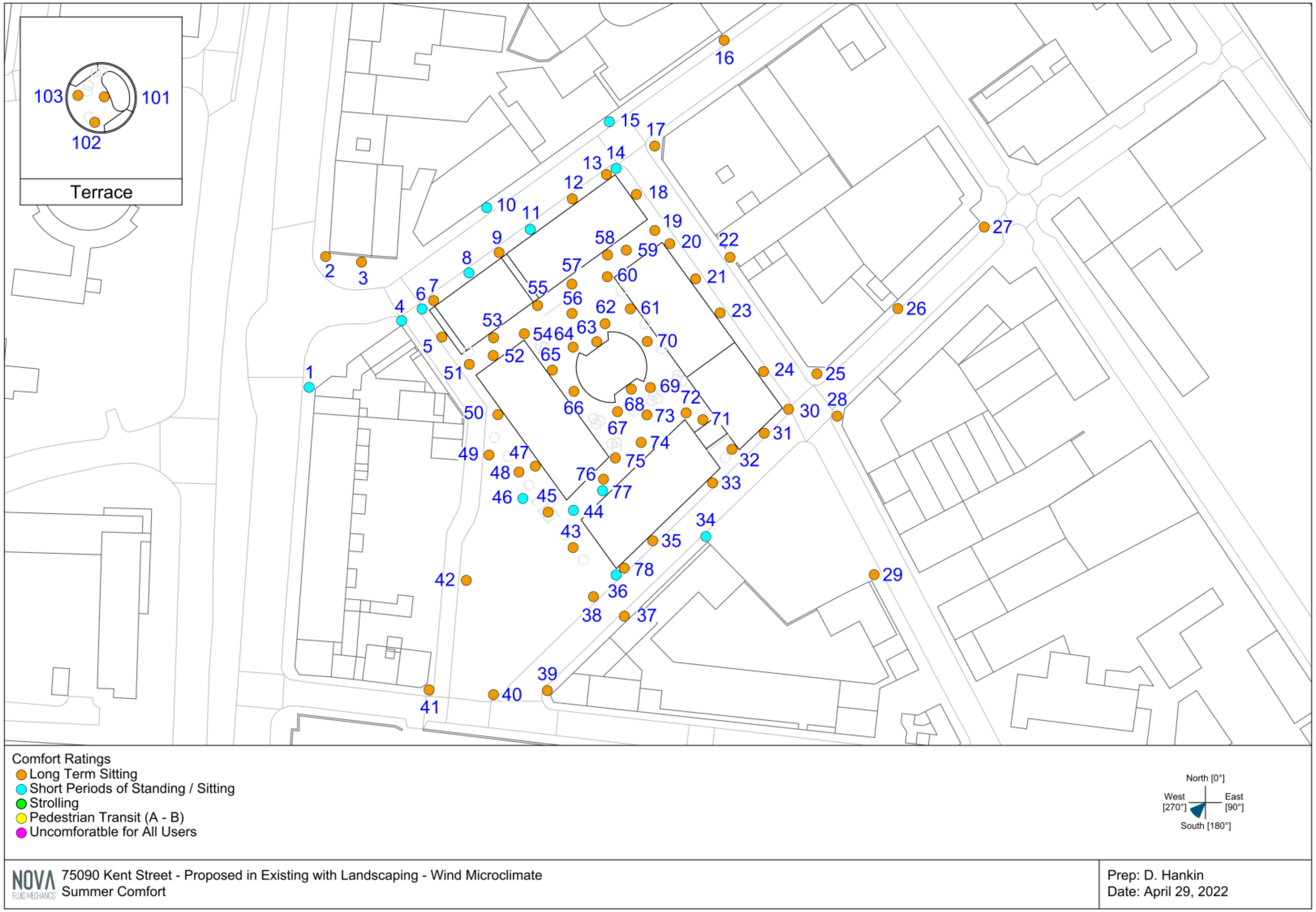


Figure D.2b: Summer comfort ratings, proposed in existing without landscaping

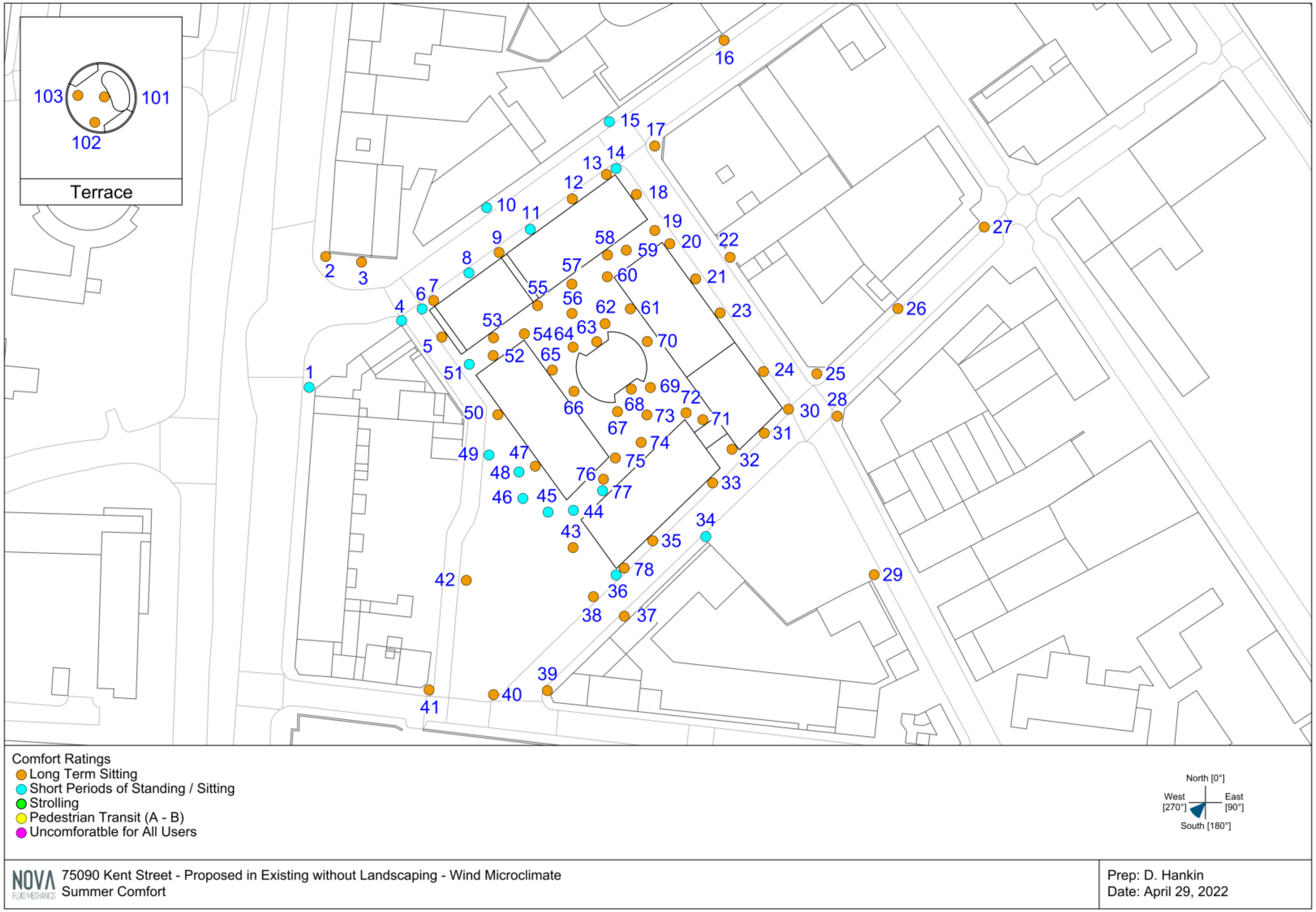


Figure D.2c: Summer comfort ratings, proposed in cumulative with landscaping

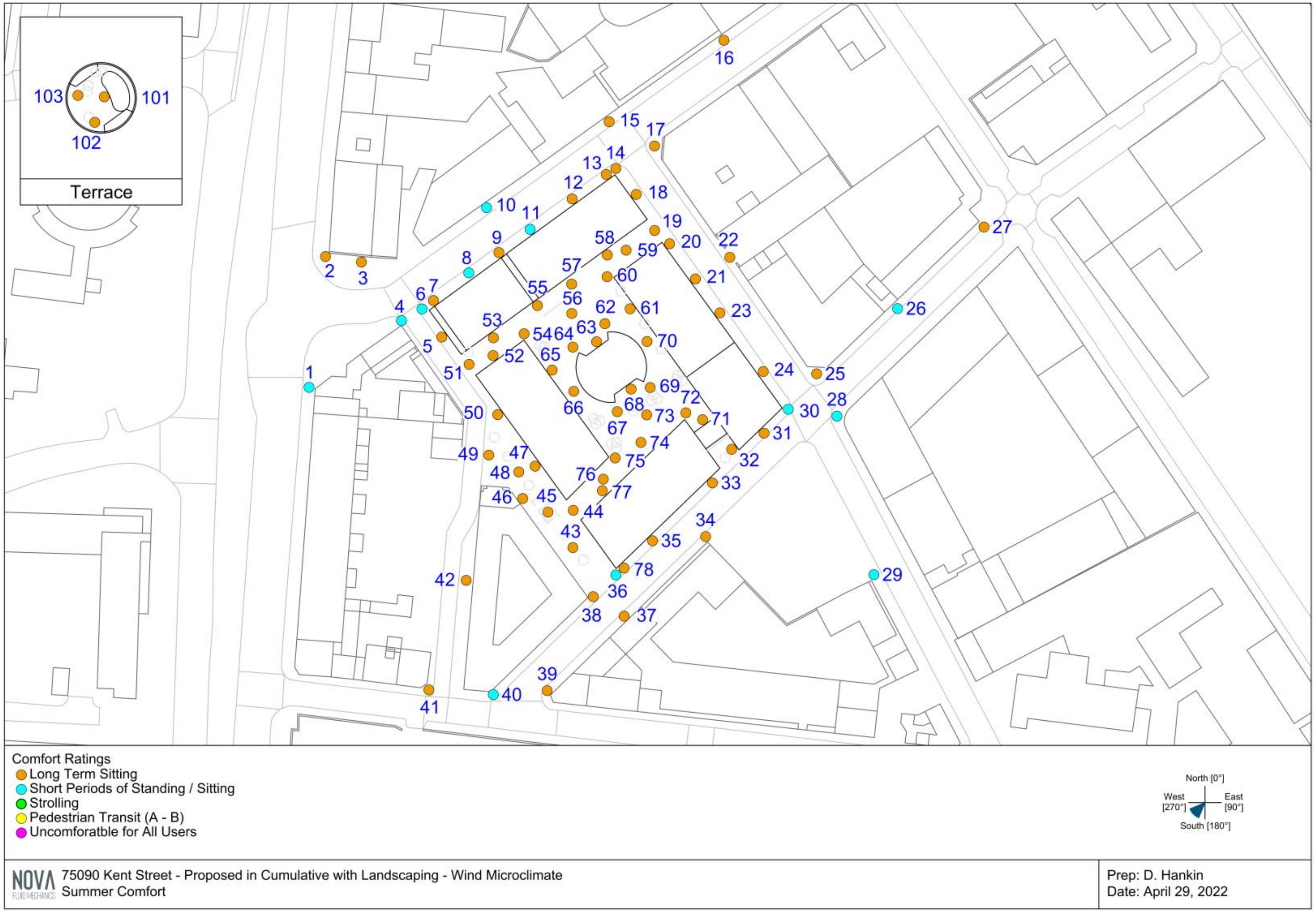


Figure D.3a: Worst seasonal comfort ratings, proposed in existing with landscaping

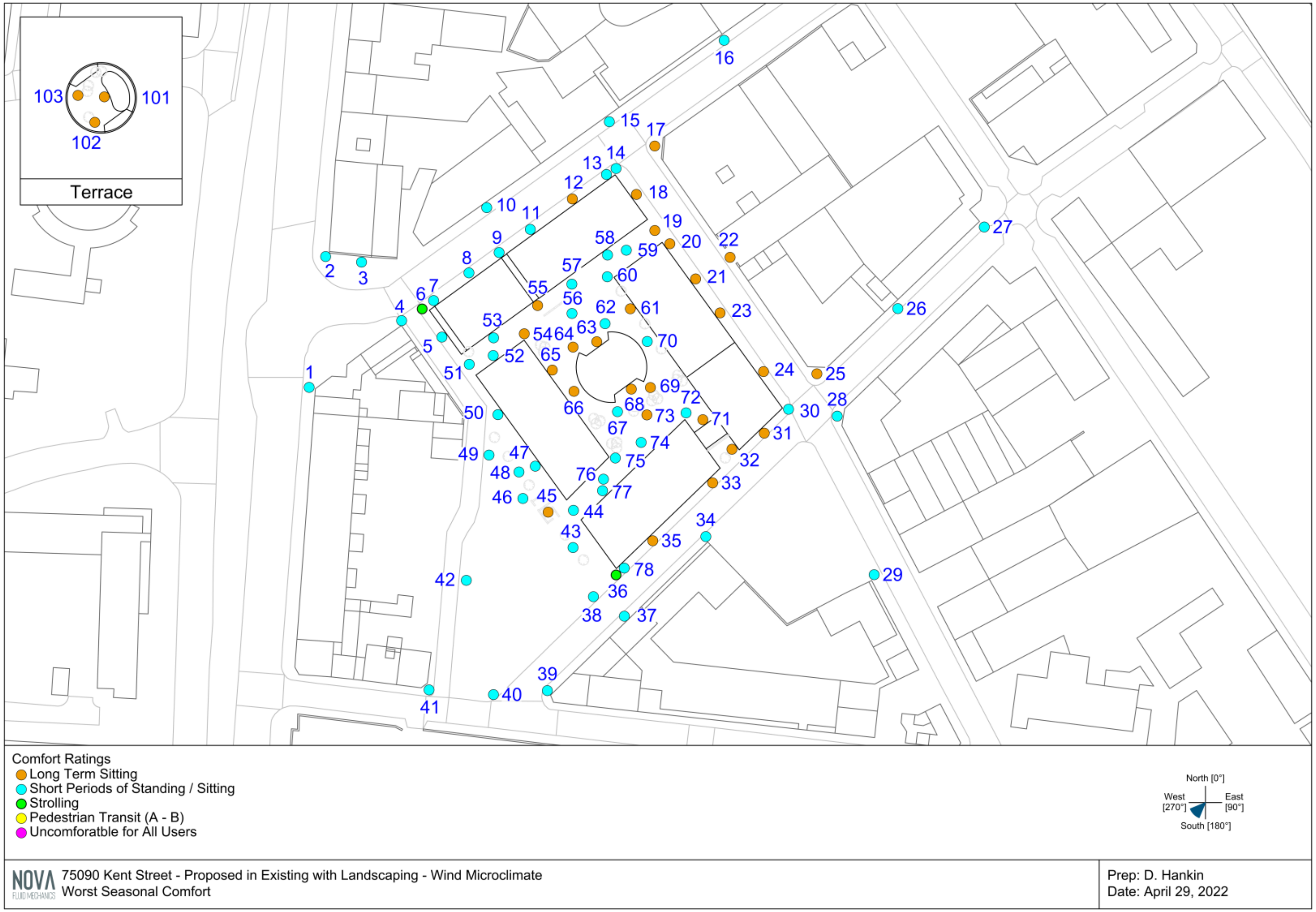


Figure D.3b: Worst seasonal comfort ratings, proposed in existing without landscaping

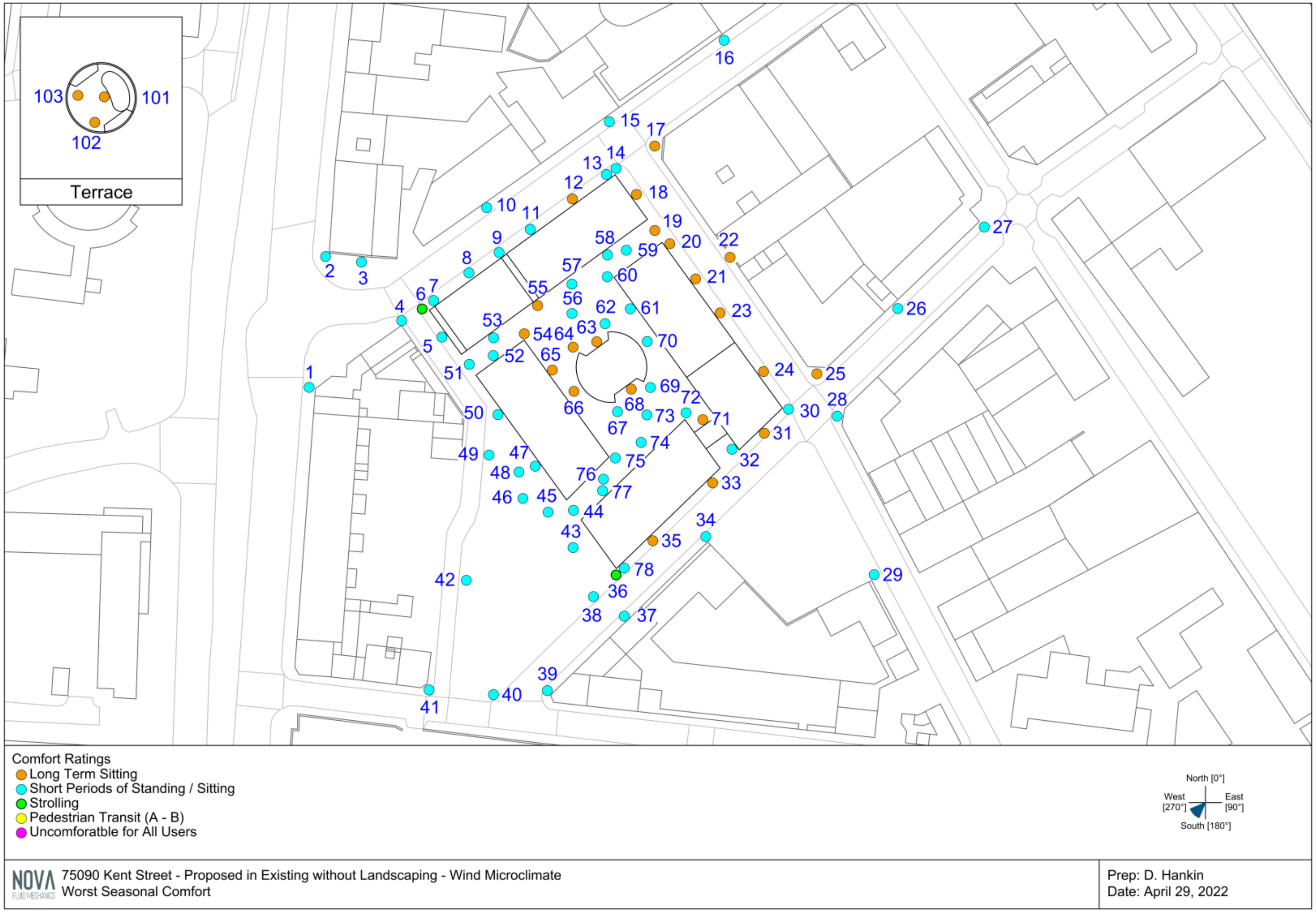


Figure D.3c: Worst seasonal comfort ratings, proposed in cumulative with landscaping