Planning Department

Planning and Design Study on the Redevelopment of Queensway Plaza Admiralty – Feasibility Study

AVA Detailed Study
Final Report

November 2015

1 BACKGROUND

1.1 Queensway Plaza was built in 1980 as part of the development works for Admiralty Station of the Island Line. The primary purpose of the Government property was to provide elevated pedestrian connections from Admiralty Station to neighbouring developments. However, Queensway Plaza has been leased for commercial uses since 1981 and has thrived on its strategic location surrounded by various commercial and Government buildings and positioned above a major transport hub.

1.2 The current tenancy of Queensway Plaza is due to expire in January 2019, subject to the Government's right of termination two years earlier. In addition, the South Island Line (East) (SIL(E)) is due for imminent completion followed by the Shatin to Central Link (SCL) in 2020, each with a station in Admiralty. The redevelopment of Queensway Plaza with its adjoining Government land (the Study Site) would, therefore, be a timely addition to strengthen the existing business and commercial node functions and transportation hub of Admiralty. Yet redevelopment in Queensway Plaza is also constrained by various factors, such as the proximity of existing station structures, at-grade infrastructures, public transportation facilities and the large volumes of pedestrian connections across the Study Site, which would need to be resolved to meet the site's full development potential.

2 STUDY OBJECTIVES

2.1 Planning Department of the HKSAR (PlanD) commissioned Ove Arup and Partners Hong Kong Limited (Arup) on 9 January 2014 to undertake the Planning and Design Study on the Redevelopment of Queensway Plaza, Admiralty – Feasibility Study (the Study). The Assignment is to investigate the planning, architectural and engineering feasibility of redeveloping the Study Site.

2.2 Key to the redevelopment of the Study Site is to maximize commercial potential, including Grade A office and retail uses. The Study provides an opportunity to create a notable new addition to the Admiralty skyline and capitalise on the image and role of Admiralty as a strategic commercial and transportation hub in Hong Kong. The Study seeks to make recommendations to upgrade the existing public realm in its vicinity, including optimisation of the pedestrian connectivity within and through the site. The existing operation and layout of the Public Transport Interchange (PTI) will also be investigated to establish the potential for reconfiguration to increase efficiency.

2.3 In this Air Ventilation Assessment (AVA) Detailed Study, it was aimed to assess the ventilation impacts of the proposed development within the Study Site and its surrounding area of the development in accordance with the Joint Housing, Planning

and Lands Bureau and Environment, Transport and Works Bureau Technical Circular on Air Ventilation Assessment No. 1/06 (2006) (the AVA Technical Circular).

2.4 This report presents the findings of the AVA Detailed Study for the proposed development using Wind Tunnel Test. The work follows from earlier AVA Expert Evaluation and AVA Initial Study using Computational Fluid Dynamics (CFD) modelling for the initial development options for the Study Site.

2.5 The wind Velocity Ratio, Site Spatial Average Velocity Ratio and Local Spatial Average Velocity Ratio, as well as the median (50th percentile) mean wind speed, were determined for the proposed development for both annual and summer conditions.

3 STUDY AREA

3.1 The Study Site comprises the Queensway Plaza together with its adjoining Government land within the immediate vicinity of Admiralty Station, encompassing Drake Street, Tamar Street, Rodney Street and Admiralty Garden, covering an area of approximately 1.97 hectares. It is bounded by Harcourt Road, Cotton Tree Drive, Queensway and the site of the forthcoming SIL(E) Admiralty Station. The Study Site falls within the Approved Central District Outline Zoning Plan (OZP) No. S/H4/14. The Study Area covering the areas within 400 metres of the Study Site currently fall within Central District, Central District (Extension), Wan Chai, Wan Chai North, Mid-Levels West and Mid-Levels East OZPs. Figure 1 presents an aerial view of the Study Site within the wider surrounding area.

3.2 At present, the area immediately surrounding the Study Site principally comprises high-rise commercial and residential developments with mountainous terrain to the South and open water to the North. Further afield, the wider surrounding area consists of the South China Sea with urban Kowloon district and mountainous New Territories to the north.

Figure 1 Aerial view of the Study Site

4 DEVELOPMENT SCHEME

4.1 The Revised Recommended Development Scheme (RDS) for the Study Site envisages a commercial tower for Grade A office atop a retail/dining podium (including a landscape podium deck) and five levels of basement within the core development site, generating a non-domestic GFA of 93,300m^2 equivalent to a plot ratio of 15 with site coverage not exceeding 65%. Taking into account the public comments received on the RDS and the findings of the Initial Options Report (July 2015), changes have been made to the scheme including:

(i) reduction of the building height from 203mPD (at main roof level) to 200mPD (including rooftop structures);

(ii) reduction of floor-to-floor height of the landscape podium deck (from12m to 5.4m);

(iii) slight enlargement of the tower footprint (by about 5%);

(iv) removal of the terraced public open space design that allow a further building setback from Tamar Street; and

(v) conversion of the elevated plaza into an indoor atrium.

5 SITE WIND AVAILABILITY

5.1 An experimental site wind availability study was conducted for the Study Site to match with the exact extension of this AVA Detailed Study. The corresponding site wind availability data were used in conjunction with the current Detailed Study to determine the effects of topography on local wind conditions at the Project Site. A wind tunnel test of a large topographical model (1:4000) was used to generate wind profiles and turbulence intensities for the Project Site.

5.2 The Reynolds number of the test is 1.9x105 when the characteristics dimension of the dominant topographical feature (~900m) is considered, which exceed the requirement of minimum Reynolds number of 1x104 of HK Wind Loading Code (2004).

5.3 The blockage ratio of the tunnel is qualitatively assessed to be 2%, which satisfies the requirement of HK Wind Loading Code (<10%).

5.4 The vertical variation of the site wind climate has been determined from the topographic studies making use of hot-wire anemometry. Hot-wire anemometer measurements have been made for the range of full scale heights (measured in metre above local ground: 20, 50, 75, 100, 150, 200, 300, 400, 500, 600, 800, 1000 and approximately 1200m) for 16 wind directions (22.5º increments). All

measurement have been taken at a location in the approximate centre of the measurement zone such that the acquired wind properties are relevant and transferable to the small scale measurement site.

5.5 The annual prevailing wind for the site is from north-east to east (see Figure 2) while the prevailing wind during summer months is mainly from south-west (see Figure 2). There are significant numbers of tall buildings in the surroundings shielding the wind to flow directly to the site. Due to the densely built environment, the pedestrian wind environment around the site is mainly dominated by the existing tall buildings. These tall buildings bring down the high-level winds to reach the pedestrian level

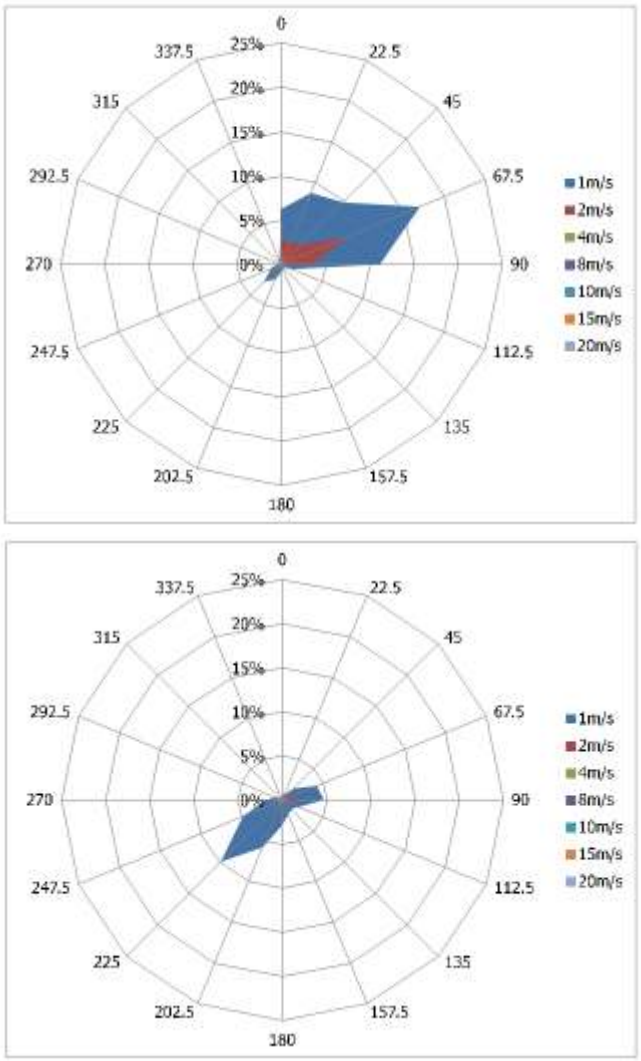

Figure 2 Wind rose for annual (top) and summer (bottom) non-typhoon winds at Queensway Plaza, corrected to 500mPD

6 METHODOLOGY

6.1 A wind tunnel model of 1:500 has been adopted in this study which included all known existing and committed developments and topographical features within a radius of approximately 750m (i.e. larger than 2H where H is height of the tallest building within the Surrounding Area) from the centre of the Project Area. The Assessment Area is defined within a radius of approximately 303m (i.e. 1H) in accordance with the AVA Technical Circular (2006). Boundaries of the Project Area, Assessment Area and Surrounding Area are shown in Figure 3. The wind tunnel model is shown in Figure 4 to Figure 7.

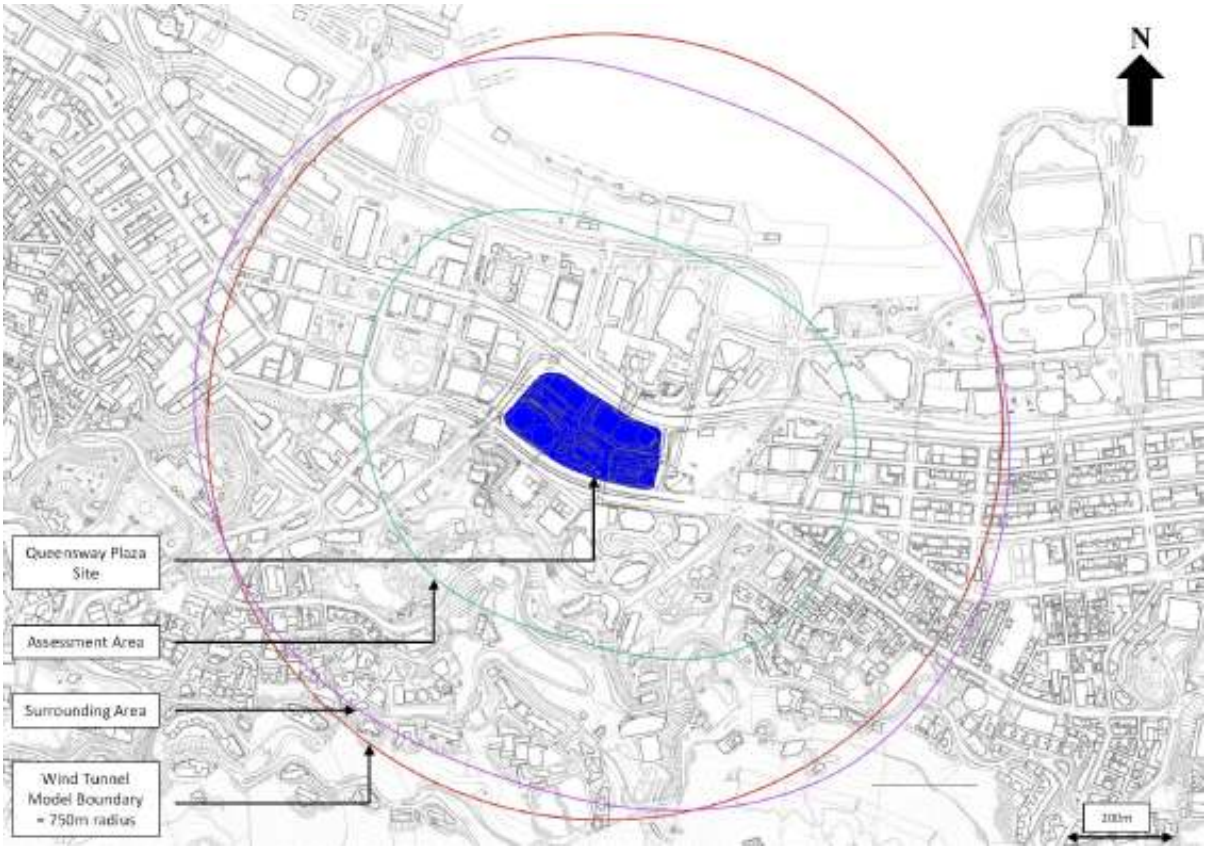

Figure 3 Boundaries of Project Area, Assessment Area and Surrounding Area

6.2 The technical standards pertaining to the execution of the current boundary layer wind tunnel studies conform with the guidelines outlined within the Hong Kong Wind Loading Code (2004) and are also in compliance with the requirements of internationally recognised guides such as the guidelines of the American Society of Civil Engineers (ASCE) Manual of Practice No.67 (1999) for Wind Tunnel Studies and the Quality Assurance Manual, AWES-QAM-1-2001 (2001) by the Australasian Wind Engineering Society (AWES).

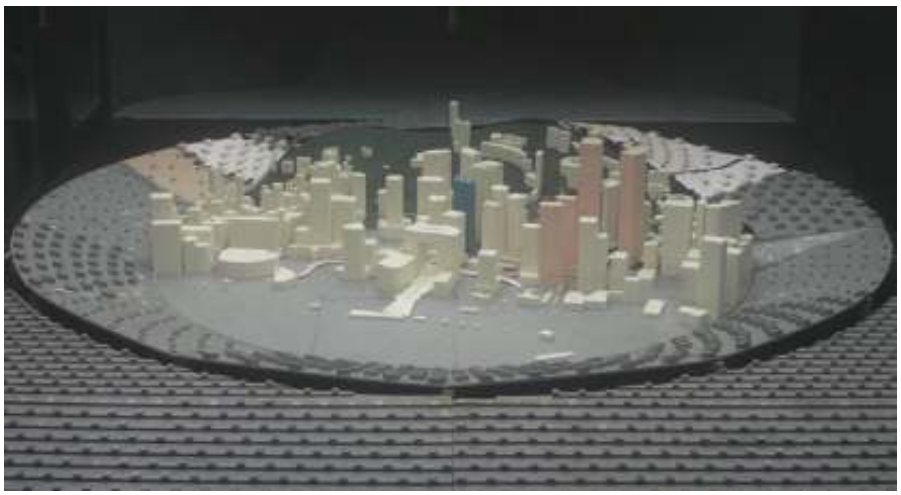

Figure 4 Wind tunnel model, viewed from North

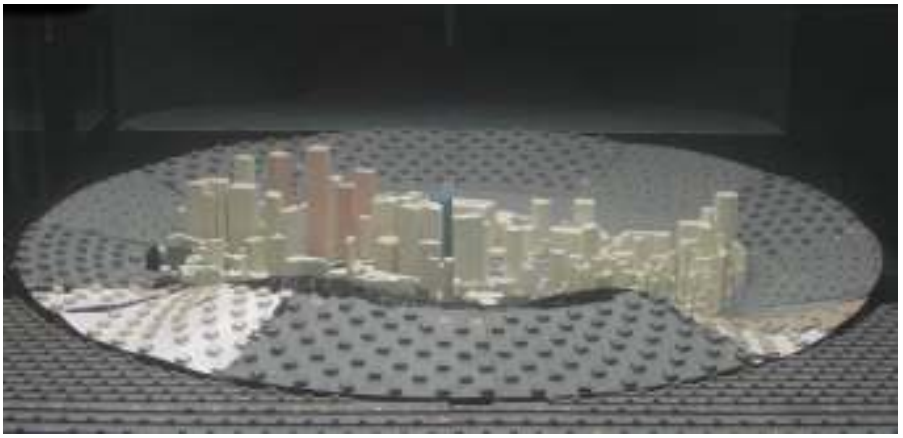

Figure 5 Wind tunnel model, viewed from South

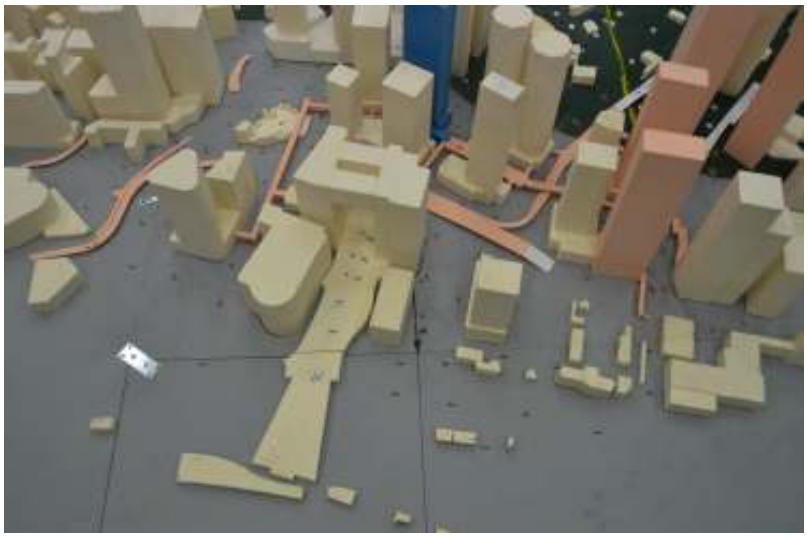

Figure 6 Wind tunnel model and setup, close-up view

Figure 7 Wind tunnel model and setup, viewed from Northwest

6.3 The wind Velocity Ratio (VR) is defined as:

$$VR = \frac{V_p}{V_\infty}$$

where V_p is the wind speed at pedestrian height (i.e. 2m above ground) and V_∞ is the velocity at the top of the boundary layer.

6.4 Both VR and median mean wind speed were measured at a total of 231 test points in the 1:500 scale mode for 16 wind directions ranging from 22.5° to 360°(north) at increments of 22.5°. For ease of assessment, 16 focus areas (see Figure 9) have been defined within the whole Assessment Area.

6.5 Test point locations and demarcation of the focus areas are shown in Figure 9.

6.6 For each focus area, the spatial average velocity ratio, VRw has been derived from an examination of the velocity ratio for each of the points within the corresponding focus area. This is defined as:

$$VR_w = \frac{\sum_{j-1}^{m} VR}{m}$$

where *VR* is the wind velocity ratio for each point within the zone and *m* is the number of test points within that zone.

6.7 The overall velocity ratio, VRw was calculated for each test point and focus area. This is defined as the average of the directional velocity ratio, weighted by the probability of occurrence of each wind direction ($\mathbf{p_i}$).

$$VR_w = \Sigma_{i=1}^{16} VR \times p_i$$

This was calculated for both annual and summer probabilities. These values will be referred to as the *overall annual velocity ratio* and the *overall summer velocity ratio*.

6.8 Details of the measurement locations and corresponding focus area definitions are provided in Table 1~~Table 1~~ in Appendix A.

6.9 Measurements were taken at the following areas within and around the site:

- Along the Project Area boundary (defined as “Perimeter” test points), such that the Site Spatial Average Velocity Ratio (SVR), an average of 39 perimeter test points (i.e. Test Point 1 to 39), could be defined.
- Throughout the Assessment Area (defined as “Overall” test points), such that the Local Spatial Average Velocity Ratio (LVR), an average of 169 overall test points (i.e. Test Point 63 to 231) and 39 perimeter test points (i.e. Test Point 1 to 39), can be defined.
- There are 23 special test points (i.e. Test Point 40 to 62) placed at key areas within the Project Area.

6.10 Test point locations are shown in Figure 8.

Figure 8 Locations of perimeter test points (red), overall test points (blue) and special test points (orange and green)

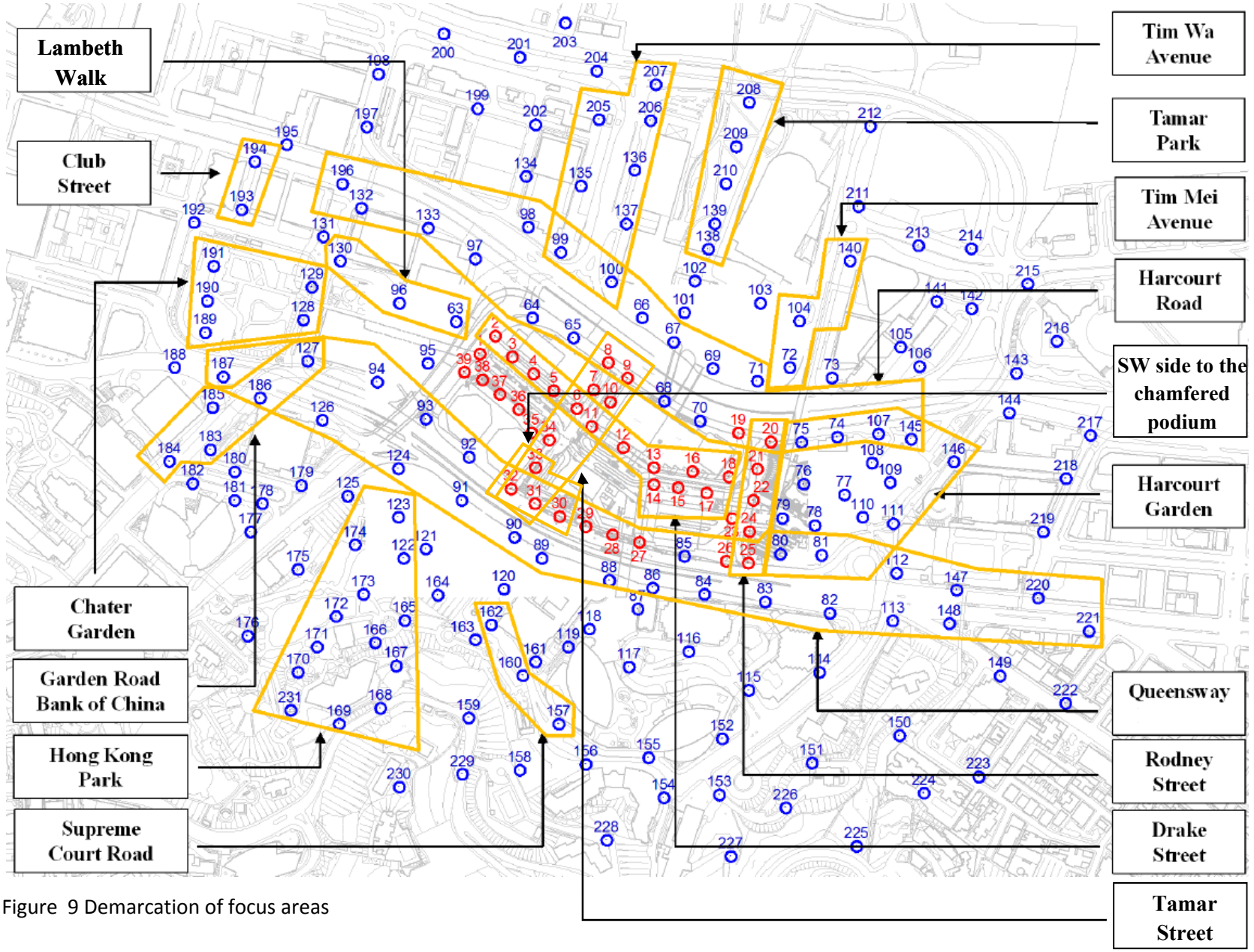

Figure 9 Demarcation of focus areas

7 RESULTS AND DISCUSSION

Topographic Effects

7.1 The Project Area is located along the northern coast of Hong Kong Island, within the Admiralty area.

7.2 In terms of significant topography or built environment, the Project Area is surrounded by high-rise building in the immediate vicinity and, farther away, flanked by mountains to the eastern, southern and western sides, with Victoria Harbour to the north.

7.3 The previously undertaken site wind availability study demonstrated a low level of turbulence coming from the north-west and north-east due to the relatively low upstream terrain roughness, characterised primarily by water.

7.4 Higher level of turbulence characterises winds coming from the western and eastern sectors, where mountains and city terrain characterise the upstream conditions.

Site Spatial Average Velocity Ratio (SVR)

7.5 In order to assess the wind availability within the immediate area surrounding the Project Area following the introduction of the proposed development, test points were placed along the border of the Project Area (defined as “Perimeter Test Point”) and the site spatial average velocity ratio (SVR), an average of the perimeter test points, was derived.

7.6 The annual SVR for the RDS of the proposed development has been derived as 0.19. As the location of the SVR points are on the perimeter of the Project Area, this gives a hint of how the proposed development impacts the wind environment of its immediate vicinity. Although not significant, the annual VRw of test points along the south-western perimeter of the Project Area and along Tamar Street are slightly higher than those test points along north-eastern perimeter because the former benefits from north-easterly prevailing winds channelling along Tamar Street and the 15m setback area. Conversely, the area between Admiralty Centre and the proposed development shows marginally decreased VRw, due to the shielding from prevailing north-easterly winds by Admiralty Centre. However, in either case these areas have reasonable ventilation and do not indicate any areas of stagnation.

7.7 Similarly, the summer SVR for the RDS of the proposed development has been derived as 0.17. Whilst there is a reduction in VR when compared to annual condition, this is largely a consequence of the shift in prevailing winds from the northeast to the southwest and the winds are mostly blocked by the existing developments limiting them from reaching the Project Area.

Local Spatial Average Velocity Ratio (LVR)

7.8 In order to assess how the proposed development impacts on the wind availability of the local area in the surroundings, including areas along the perimeter of the Project Area, the local spatial average velocity ratio (LVR), an average of the overall and perimeter test points, was determined.

7.9 The annual LVR for the RDS of the proposed development has been derived as 0.22. The annual VRw of test points around the Queensway Government Offices [Test Points 120 & 160-162] and at the southern base of AIG tower [Test Points 131 & 193] as well as at Test Points 63, 89, 181, are significantly higher than the LVR (increased by between 0.1-0.18) as a result of localised accelerations of the prevailing northwest winds. In particular, around the Queensway Government Offices, this is a consequence of prevailing winds from the northeast moving through Tamar Street and the 15m setback area.

7.10 Furthermore, as a consequence of the localised shielding from the surrounding buildings (in particular Admiralty Centre) in and around the proposed development, the annual VRw of Locations 16 and 53 is significantly lower than the LVR (reduced by 0.11).

7.11 Similarly, the summer LVR for the RDS of the proposed development has been derived as 0.19. The summer VRw of test points around the Queensway Government Offices [Test Points 161 & 162] and along Garden Road [Test Point 184], Cotton Tree Drive [Test Point 179] and Queen's Road [Test Point 188] are significantly higher than the LVR. In all cases, this is indicative of channelling of the prevailing south-westerly winds between neighbouring buildings, possibly combined with winds being drawn down the façades.

7.12 The LVR is slightly higher than the SVR under both annual and summer conditions, although the difference is relatively minor. This is indicative of the situation of the proposed development located within the more built-up region within the Assessment Area.

Spatial Average Velocity Ratio (SAVR)

7.13 The spatial average velocity ratios (SAVR) for each focus area are tabulated in Table 1.

Table 1 Summary of SVR, LVR and SAVR for each focus area

SVR/ LVR / Focus Area	Annual	Summer
SVR	**0.19**	**0.17**
LVR	**0.22**	**0.19**
Tamar Street	0.21	0.18
Drake Street	0.17	0.16
SW side to the Chamfered Podium	0.22	0.20
Queensway	0.21	0.19
Harcourt Road	0.21	0.18
Rodney Street	0.18	0.16
Tim Mei Avenue	0.21	0.17
Harcourt Garden	0.21	0.17
Supreme Court Road	0.30	0.26
Lambeth Walk	0.28	0.22
Hong Kong Park	0.19	0.19
Tamar Park	0.22	0.19
Chater Garden	0.22	0.21
Garden Road and Bank of China	0.23	0.24
Tim Wa Avenue	0.22	0.19
Club Street	0.33	0.24

7.14 As aforementioned, the pedestrian wind environment around the site is mainly dominated by the existing tall buildings due to the densely built environment. It has been confirmed in the previously conducted AVA Initial Study that the proposed redevelopment would create some localised influence to the pedestrian wind environment. Three focus areas, i.e. Tamar Street, Drake Street and SW side to the chamfered podium which are located close to the project site, should be concentrated on in evaluating the potential air ventilation impact to the localised pedestrian wind environment.

Tamar Street

7.15 It is running across the western part of the Project Area. Based on the experimental results (see Table 1), the SAVR of Tamar Street (i.e. annual: 0.21 and summer: 0.18) are higher than SVR (i.e. annual: 0.19 and summer: 0.17) and comparable to the LVR (i.e. annual: 0.22 and summer: 0.19) under both annual and summer conditions. It is demonstrated that the proposed building setback of 15m from Tamar Street

would facilitate wind penetration through the site and bring about localised improvements to the pedestrian areas.

Drake Street

7.16 It is running along the Northern perimeter of the Project Area. For Drake Street, it is relatively shielded by the existing high-rise developments for most wind directions. The SAVR of Drake Street (i.e. annual: 0.17 and summer: 0.16) is relatively lower when compared to other focus areas. Test Points 2 (i.e. VR = 0.25) and 6 (i.e. VR = 0.22), located at either corner of the Far East Finance Centre, show more comparable annual VRw (i.e. VR = 0.25) as they are exposed to the prevailing winds. In the latter case, this is a consequence of the 15m setback along Tamar Street. The summer SAVR is derived as 0.16, which is slightly lower than the LVR value of 0.19 due to the significant blockage by the Lippo Centre, the United Centre and the proposed development, which dominate the south-western boundary of the Drake Street area.

7.17 While a proposed building setback of 5.5m from Drake Street would widen the building gap along this street to facilitate wind flow, additional mitigation measures could be provided for further improvement at the detailed design stage.

SW side to the chamfered podium

7.18 For “SW side to the chamfered podium”, its SAVR (i.e. annual: 0.22 and summer: 0.20) are higher than both SVR and LVR under annual and summer conditions. This proves that the chamfered podium design in the south-western corner of the project site could minimise the wind stagnant area and a reduced podium footprint with site coverage of not more than 65% would help facilitating wind flow to adjoining streets.

Queensway

7.19 Located immediately south of the proposed development, and running east to west across the Assessment Area, Queensway is largely shielded by high-rise developments on either side of the street with the exception of where it borders the Harcourt Garden and Hong Kong Park zones.

7.20 The annual SAVR is derived as 0.21 and the summer SAVR is derived as 0.19. In both cases, the SAVR is comparable to the LVR, which is reasonable given that this focus area represents a section that runs through the Assessment Area.

7.21 The area to the immediate southwest of the proposed development [Test Point 89] has an annual VRw of 0.36. This is largely driven by the prevailing winds from the northeast, which is able to flow relatively unimpeded down Tamar Street and the 15m setback area. This observation is further supported by the generally higher VRw of locations in this area, which would also indicate that the chamfered southwestern

corner of the proposed development allows for increased ventilation within the immediate area as a result of the aforementioned prevailing winds.

Harcourt Road

7.22 Located to the north of the Project Area, Harcourt Road runs east to west between the Central Government offices and Admiralty Centre. It is a relatively wide passage between developments on either side of the road.

7.23 The annual SAVR is derived as 0.21 and the summer SAVR is derived as 0.18. In both cases the SAVR are comparable to LVR. Whilst exposed to annual prevailing winds from the northeast, the upstream area is relatively permeable and allows wind penetrating through the existing developments such as Central Government Offices to reach Harcourt Road. Although the overall pedestrian wind environment under summer condition is relatively calmer when compared to the annual condition due to different topographical features, it was revealed that the proposed development would not create significantly blockage to Harcourt Road.

Rodney Street

7.24 Rodney Street is located along the eastern perimeter of the proposed development and the western edge of Harcourt Garden. It is relatively open to the north and east, but sheltered by the surrounding high-rise developments to the south and west.

7.25 The annual SAVR is derived as 0.18 and the summer SAVR is derived as 0.16. Both the SAVR are slightly lower than the LVR, but are comparable to the SVR.

Tim Mei Avenue

7.26 Tim Mei Avenue is running from north to south between CITIC Tower and the Central Government Offices. The area to the north is relatively open, but there are developments along the road in all other directions.

7.27 The annual SAVR is derived as 0.21 and the summer SAVR is derived as 0.17. Whilst exposed to annual prevailing winds from the northeast, the zone is shielded from the prevailing southwesterly summer winds. As the gap between the developments on either side is not particularly constricted, there are no localised accelerations and wind conditions are comparable to the overall Assessment Area.

Harcourt Garden

7.28 Located to the east of the proposed development site between Harcourt Road and Queensway, Harcourt Garden is relatively open.

7.29 The annual SAVR is derived as 0.21 and the summer SAVR is derived as 0.17. In both cases the difference between the SAVRs and LVRs is negligible. Whilst exposed to annual prevailing winds from the northeast, the area is relatively open. Consequently, the flow is dominated by the incoming wind rather than localised

accelerations and annual conditions are comparable to the overall Assessment Area. Conversely, the area is significantly shielded from the prevailing southwesterly summer winds, which contributes to the slight reduction in summer SAVR.

Supreme Court Road

7.30 Supreme Court Road is located to the south of the Project Area, around the base of Queensway Government Offices. It is situated between the high-rise developments to the North and mountains to the south.

7.31 The annual SAVR is derived as 0.30 and the summer SAVR is derived as 0.26. It indicates the channelling and localised acceleration of northeast annual prevailing winds along Tamar Street and around Queensway Government Offices and its exposure to the summer prevailing southwesterly winds, which would be drawn down the façade of the Queensway Government Offices.

Lambeth Walk

7.32 Lambeth Walk is located to the south of Hutchinson House. It isexposed at either end to the northeast prevailing winds, but is otherwise largely sheltered.

7.33 The annual SAVR is derived as 0.28 and the summer SAVR is derived as 0.22. It is found that the locations at either end are exposed to the annual prevailing winds from the northeast which are further accelerated via channelling between the neighbouring developments leading to the increase in the annual SAVR over the LVR.

Hong Kong Park

7.34 Hong Kong Park is located to the southwest of the Assessment Area. It is subject to significant shielding from the annual prevailing winds, but is otherwise relatively open and exposed.

7.35 The annual SAVR is derived as 0.19 and the summer SAVR is derived as 0.19. The reduction in annual SAVR comparing with the annual LVR (i.e. 0.22) is a result of the shielding from the built up area to the north.

Tamar Park

7.36 Tamar Park extends south from the waterfront to the Central Government Offices. It is relatively open and unshielded.

7.37 The annual SAVR is derived as 0.22 and the summer SAVR is derived as 0.19. Whilst exposed to prevailing winds, the park area is relatively open. Consequently, the flow is dominated by the incoming wind rather than localised accelerations, and hence conditions are comparable to the overall Assessment Area.

Chater Garden

7.38 Located to the west of the Assessment Area, Chater Garden represents an open area that is shielded from most directions by high-rise developments.

7.39 The annual SAVR is derived as 0.22 and the summer SAVR is derived as 0.21. The slight increase in summer SAVR comparing with LVR (i.e. 0.19) is due to funnelling of the prevailing southwest winds, which subsequently disperse into the open area.

Garden Road and Bank of China

7.40 This focus area is located to the west of the Assessment Area. Garden Road running from northeast to southwest aligns with both the annual and summer prevailing winds.

7.41 The annual SAVR is derived as 0.23 and the summer SAVR is derived as 0.24. The higher summer SAVR comparing with the LVR is a consequence of funnelling of the prevailing southwest winds along Garden Road.

Tim Wa Avenue

7.42 Tim Wa Avenue runs from north to south along the western edge of Tamar Park. It is relatively open and unshielded.

7.43 The annual SAVR is derived as 0.22 and the summer SAVR is derived as 0.19. Whilst exposed to prevailing winds, the wide spacing between developments alleviates funnelling of the wind. Consequently conditions in this area are comparable to the overall Assessment Area.

Club Street

7.44 This focus area is located to the northwest of the Assessment Area. Club Street is relatively exposed to annual prevailing winds from the northeast, but shielded from the southwest prevailing winds in summer.

7.45 Consequently, whilst the annual SAVR is derived as 0.33, which is significantly higher than the annual LVR; the summer SAVR is 0.24, which is also higher than the summer LVR. This is a result of funnelling of the prevailing winds between the two developments on either side of the street, particularly evident to the southern end [Test Point 193].

Special Test Points within the Project Site

7.46 A number of locations have been assessed within the project site, both at ground and podium level (defined as “Special Test Point”). The annual and summer spatial average velocity ratios (SAVRs) are 0.18.

7.47 Whilst there is no significant deviation in either the annual or summer VRw of these special test points from the SAVR for this focus area, closer examination of the

individual VRw indicates some increased ventilation due to various features of the proposed development. The 15m setback along Tamar Street permits the summer prevailing winds to enter in to the Project Area where they are subsequently dispersed along Drake Street. In addition, due to the 7.5m setback distance between the development and the United centre, it allows the prevailing winds to travel through the building gap.

Median Mean Wind Speed

7.48 The annual and summer median (50^{th} percentile) hourly mean wind speed of each test point are shown graphically in Figure 10 to Figure 13.

7.49 Evidently, the proposed redevelopment and its surroundings enjoy a better pedestrian wind environment under the annual condition when compared to that of the summer condition. This is because the annual prevailing winds are mainly coming from northeast quadrant which is relatively open in nature, while the summer prevailing winds are mainly coming from southwest quadrant which is largely built-up areas lessening to a certain extent the amount of incoming wind.

7.50 The results show that the median mean wind speeds of over 97% of the test points are greater than 0.6 metre/second (m/s) which is considered sufficient safeguard against a stagnant wind environment under annual condition. Given that there is no significant reduction in median mean wind speeds in the downstream areas under annual condition, it demonstrates that the proposed redevelopment would not create adverse air ventilation impact to the surroundings.

7.51 For summer condition, due to the relatively weak incoming wind flow in general, the median mean wind speeds of only about 40% of the test points are greater than 0.6m/s. Similar to the annual condition, there is no significant reduction in median mean wind speeds in the downstream areas under summer condition. Thus, it also demonstrates that the proposed redevelopment would not create adverse air ventilation impact to the surroundings.

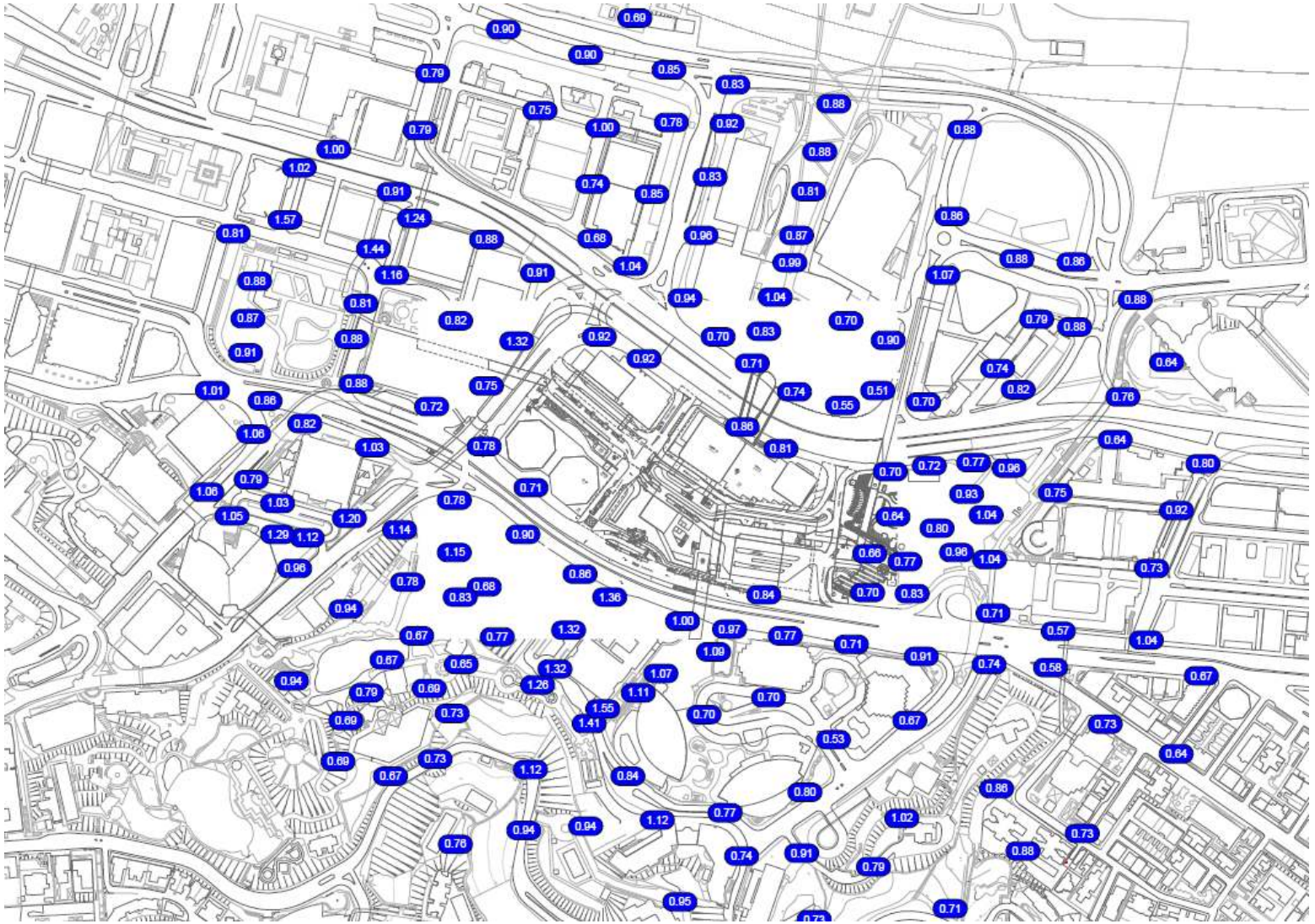

Figure 10 Annual median hourly mean wind speed, overall test points

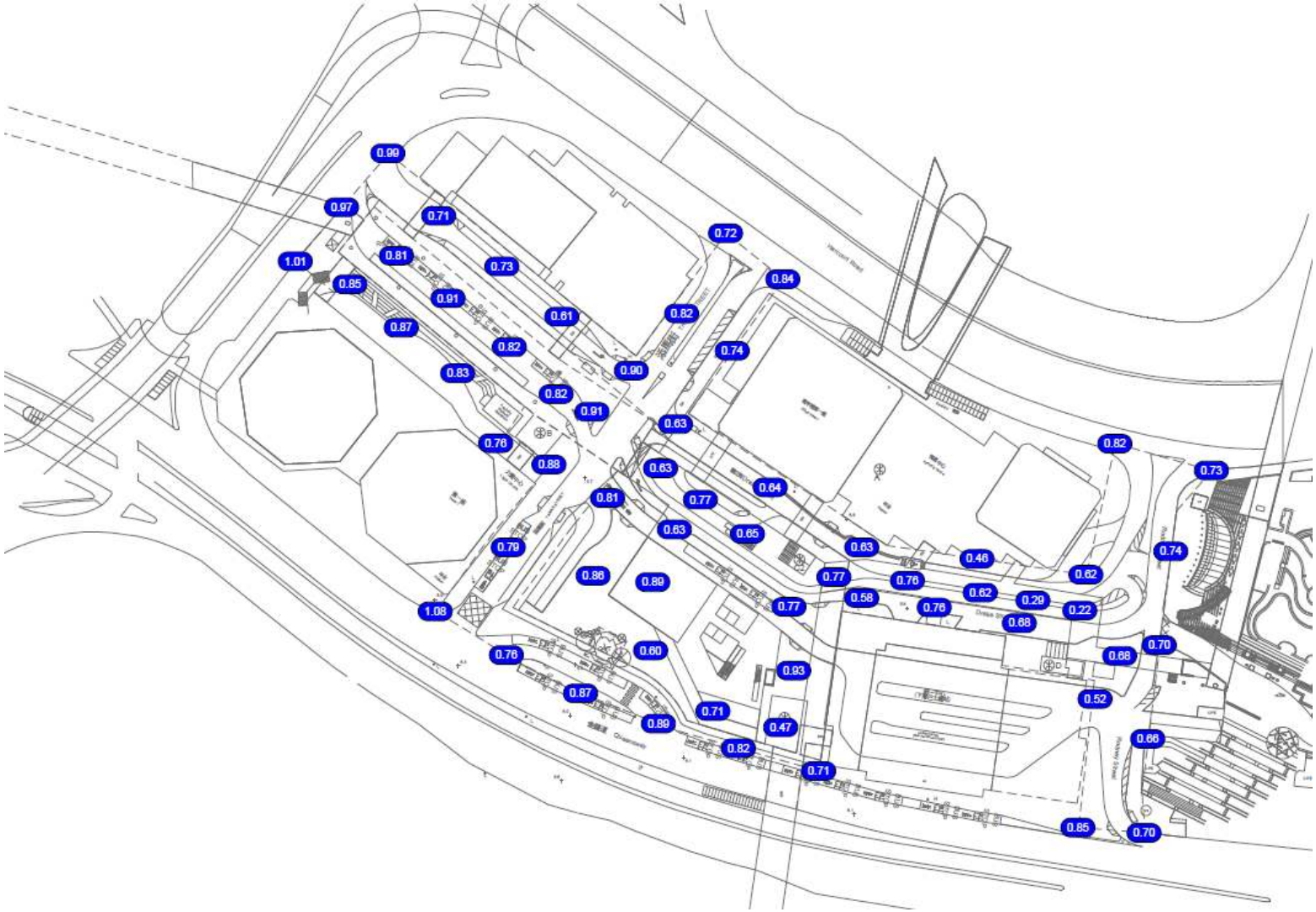

Figure 11 Annual median hourly mean wind speed, perimeter and special test points

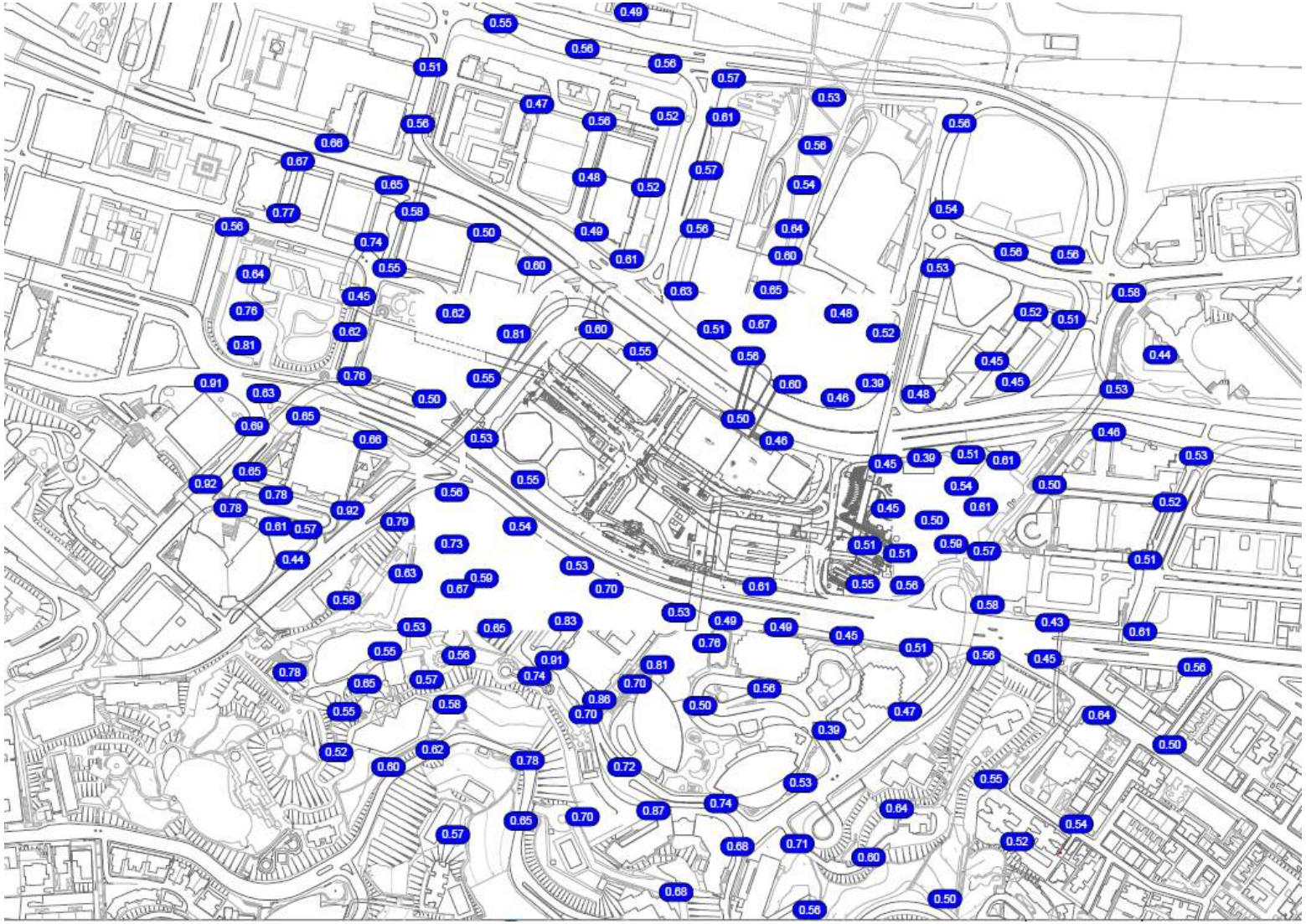

Figure 12 Summer median hourly mean wind speed, overall test points

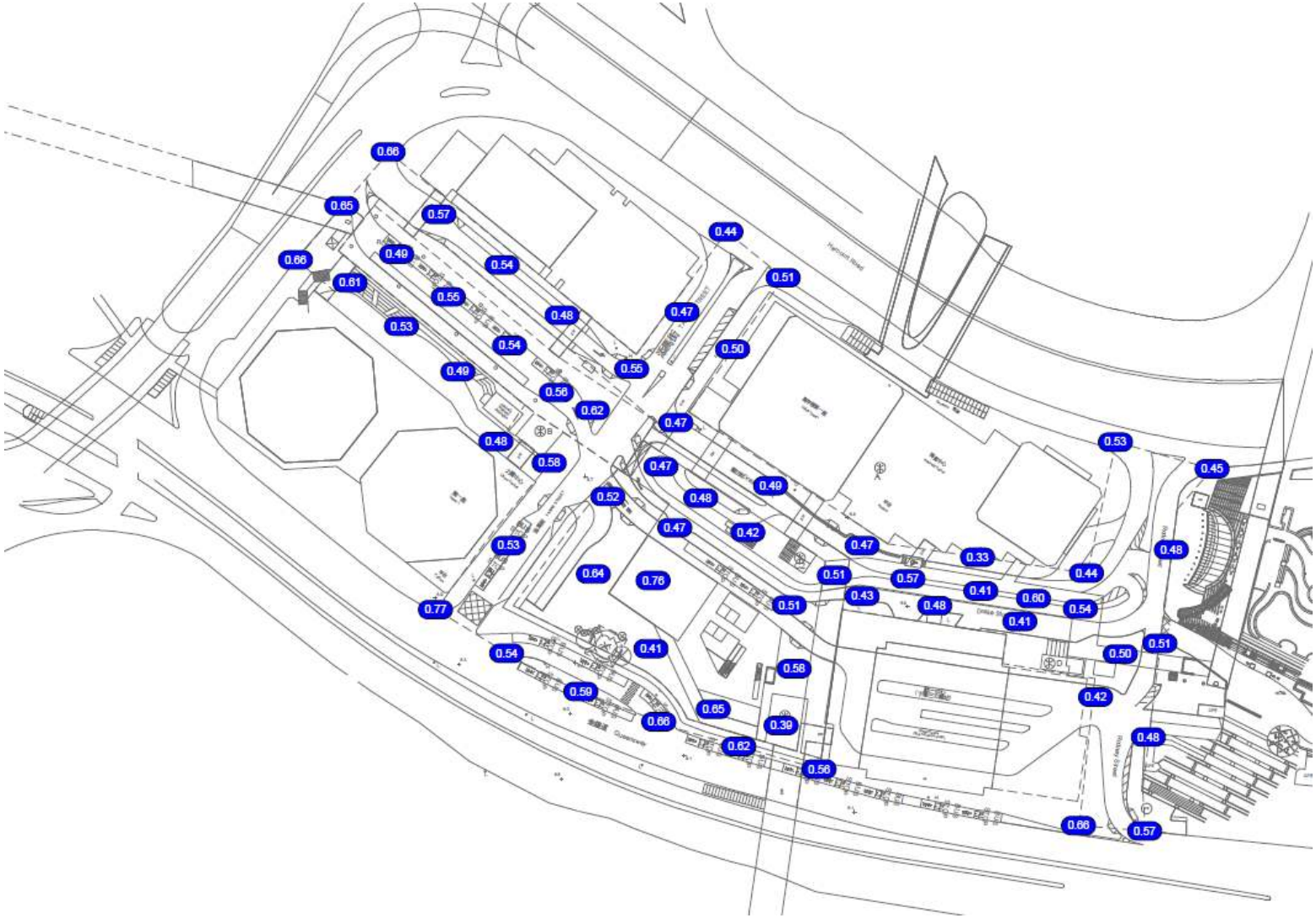

Figure 13 Summer median hourly mean wind speed, perimeter and special test points

8 CONCLUSION

8.1 In view of the above, it is concluded that the proposed redevelopment with the provision of building setbacks of 5.5m from Drake Street, 7.5m from United Centre and 15m from Tamar Street as well as the reduced podium footprint with site coverage of not more than 65% plus the chamfered podium design in the south-western corner of the project site could help minimise the wind stagnant area and facilitate wind penetration through the site in particular along Tamar Street and area near the south-western corner of the project site. It is also concluded that the proposed redevelopment would not create significant adverse air ventilation impact to the Project Area and its surroundings.

8.2 The governing wind effect with regard to the ventilation of the majority of the Assessment Area is largely exposed to prevailing winds although some areas do experience localised acceleration/blockage, often as a result of channelling of the wind or shielding by the surrounding buildings. and the results do not indicate any areas of significant stagnation or extreme winds.

9 REFERENCES

[1] Planning and Design Study on the Redevelopment of Queensway Plaza, Admiralty - Feasibility Study. Air Ventilation Assessment, Expert Evaluation, 5th February 2014

[2] Planning and Design Study on the Redevelopment of Queensway Plaza, Admiralty - Feasibility Study. Air Ventilation Assessment, Initial Study, 28th July 2015

[3] Technical Guide for Air Ventilation Assessment for Developments in Hong Kong, Hong Kong Planning Department (HPLB and ETWB Technical Circular No 1/06 Air Ventilation Assessment')

[4] Code of Practice on Wind Effects in Hong Kong, 2004

[5] American Society of Civil Engineers (ASCE) Manual of Practice No.67 for Wind Tunnel Studies

[6] Australasian Wind Engineering Society, AWES-QAM-1-2001, Quality Assurance Manual - Wind Engineering Studies of Buildings

[7] BEAM Plus for New Buildings, Version 1.2, 2012.07

Appendix A

Wind Velocity Ratio (VR) of each Test Point

Table 2 **Measurement locations used in each zone, perimeter, overall and special test points**

Zone	Test Locations																									
Queensway	25	26	27	28	29	30	31	32	80	81	82	83	84	85	86	88	89	90	91	92						
	93	94	112	113	124	126	127	147	148	186	187	220	221													
Drake Street	2	3	4	5	6	11	12	13	14	15	16	17	18													
Harcourt Road	8	9	19	20	64	65	66	67	68	69	70	71	74	75	97	98	99	100	107	132	133	145	196			
Rodney Street	20	21	22	24	25																					
Tim Mei Avenue	72	104	140																							
Harcourt Garden	74	75	76	77	78	79	80	81	107	108	109	110	111	145	146											
Supreme Court Road	157	160	162																							
Lambeth Walk	63	96	130																							
Hong Kong Park	122	123	165	166	167	168	169	170	171	172	173	174	231													
Tamar Park	138	139	208	209	210																					
Chater Garden	128	129	189	190	191																					
Garden Road Bank of China	127	183	184	185	186																					
Tim Wa Avenue	99	100	135	136	137	205	206	207																		
Club Street	193	194																								
SVR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20						
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39							
LVR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20						
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	63						
	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83						
	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103						
	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123						
	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143						
	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163						
	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183						
	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203						
	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	224						
	224	225	226	227	228	229	230	231																		
Special	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	40	41	42
Overall	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82						
	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102						
	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122						
	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142						
	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162						
	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182						
	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202						
	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222						
	224	224	225	226	227	228	229	230	231	224																

Table 3 **Directional velocity ratio (VR) for each zone**

Zone	0.0°	22.5°	45.0°	67.5°	90.0°	112.5°	135.0°	157.5°	180.0°	202.5°	225.0°	247.5°	270.0°	292.5°	315.0°	337.5°
Queensway	0.23	0.23	0.23	0.22	0.20	0.15	0.18	0.17	0.18	0.18	0.18	0.18	0.20	0.19	0.23	0.24
Drake Street	0.21	0.18	0.17	0.18	0.18	0.13	0.15	0.15	0.15	0.15	0.15	0.14	0.16	0.19	0.20	0.22
Harcourt Road	0.25	0.23	0.22	0.23	0.22	0.15	0.14	0.17	0.18	0.16	0.15	0.15	0.16	0.20	0.25	0.29
Rodney Street	0.23	0.19	0.17	0.18	0.18	0.12	0.16	0.16	0.18	0.16	0.15	0.15	0.15	0.15	0.21	0.25
Tim Mei Avenue	0.24	0.24	0.22	0.24	0.23	0.17	0.15	0.17	0.19	0.14	0.12	0.12	0.12	0.18	0.24	0.25
Harcourt Garden	0.27	0.24	0.24	0.22	0.20	0.15	0.14	0.17	0.19	0.16	0.16	0.14	0.14	0.15	0.25	0.29
Supreme Court Road	0.27	0.31	0.35	0.35	0.30	0.22	0.29	0.22	0.24	0.24	0.24	0.25	0.31	0.26	0.22	0.26
Lambeth Walk	0.33	0.33	0.35	0.31	0.26	0.14	0.18	0.20	0.20	0.21	0.20	0.20	0.26	0.25	0.21	0.31
Hong Kong Park	0.20	0.17	0.17	0.19	0.20	0.18	0.20	0.18	0.19	0.19	0.18	0.18	0.24	0.28	0.25	0.23
Tamar Park	0.24	0.23	0.24	0.26	0.24	0.20	0.17	0.19	0.17	0.16	0.16	0.16	0.20	0.28	0.33	0.28
Chater Garden	0.20	0.23	0.24	0.24	0.20	0.11	0.22	0.22	0.25	0.22	0.22	0.20	0.23	0.17	0.20	0.23
Garden Road, Bank of China	0.30	0.26	0.23	0.22	0.19	0.14	0.28	0.26	0.24	0.24	0.24	0.25	0.32	0.29	0.24	0.31
Tim Wa Avenue	0.23	0.24	0.23	0.26	0.25	0.18	0.13	0.17	0.17	0.18	0.17	0.16	0.18	0.21	0.25	0.24
Club Street	0.37	0.44	0.44	0.37	0.30	0.16	0.19	0.22	0.25	0.23	0.21	0.19	0.21	0.22	0.19	0.33
SVR	0.23	0.21	0.20	0.20	0.19	0.14	0.15	0.16	0.17	0.17	0.17	0.16	0.17	0.18	0.22	0.24
LVR	0.25	0.24	0.23	0.23	0.22	0.16	0.18	0.18	0.19	0.18	0.18	0.17	0.20	0.22	0.24	0.26
Special	0.23	0.19	0.18	0.19	0.18	0.13	0.14	0.15	0.17	0.17	0.19	0.18	0.21	0.22	0.24	0.26
Overall	0.25	0.24	0.24	0.24	0.22	0.17	0.19	0.18	0.20	0.18	0.18	0.18	0.21	0.22	0.25	0.27

Table 4 **Directional velocity ratio (VR) for each test point**

Test Point	0.0°	22.5°	45.0°	67.5°	90.0°	112.5°	135.0°	157.5°	180.0°	202.5°	225.0°	247.5°	270.0°	292.5°	315.0°	337.5°
1	0.36	0.33	0.29	0.23	0.20	0.12	0.20	0.21	0.22	0.23	0.23	0.18	0.17	0.15	0.23	0.32
2	0.34	0.32	0.28	0.24	0.22	0.13	0.20	0.20	0.21	0.22	0.22	0.19	0.20	0.20	0.24	0.33
3	0.22	0.16	0.15	0.18	0.18	0.14	0.16	0.18	0.19	0.20	0.19	0.16	0.18	0.24	0.21	0.23
4	0.24	0.18	0.16	0.19	0.19	0.14	0.15	0.18	0.19	0.19	0.17	0.13	0.15	0.20	0.19	0.23
5	0.16	0.15	0.14	0.16	0.16	0.12	0.14	0.15	0.16	0.17	0.15	0.14	0.15	0.21	0.16	0.16
6	0.27	0.29	0.27	0.23	0.21	0.13	0.13	0.15	0.16	0.17	0.18	0.16	0.19	0.22	0.22	0.32
7	0.19	0.21	0.24	0.26	0.26	0.16	0.13	0.12	0.12	0.12	0.14	0.14	0.16	0.16	0.17	0.21
8	0.24	0.24	0.21	0.18	0.17	0.11	0.11	0.11	0.13	0.12	0.13	0.14	0.15	0.17	0.21	0.28
9	0.19	0.22	0.25	0.27	0.24	0.15	0.10	0.14	0.15	0.14	0.14	0.15	0.21	0.29	0.19	0.24
10	0.25	0.19	0.18	0.19	0.19	0.14	0.14	0.16	0.16	0.16	0.15	0.13	0.16	0.23	0.24	0.31
11	0.27	0.18	0.14	0.14	0.14	0.12	0.14	0.13	0.14	0.14	0.15	0.15	0.17	0.24	0.28	0.34
12	0.13	0.14	0.16	0.19	0.19	0.15	0.15	0.13	0.14	0.14	0.16	0.15	0.19	0.16	0.17	0.16
13	0.14	0.15	0.16	0.17	0.16	0.13	0.14	0.13	0.13	0.14	0.15	0.15	0.19	0.18	0.16	0.15
14	0.15	0.16	0.15	0.15	0.14	0.11	0.12	0.12	0.12	0.13	0.14	0.14	0.16	0.13	0.14	0.15
15	0.21	0.20	0.20	0.22	0.21	0.15	0.15	0.13	0.13	0.13	0.14	0.13	0.17	0.21	0.21	0.23
16	0.15	0.13	0.10	0.11	0.12	0.10	0.11	0.10	0.11	0.10	0.10	0.09	0.11	0.13	0.18	0.19
17	0.23	0.18	0.17	0.19	0.19	0.14	0.13	0.13	0.14	0.12	0.11	0.10	0.12	0.16	0.24	0.27
18	0.16	0.16	0.16	0.17	0.17	0.15	0.17	0.15	0.18	0.13	0.12	0.11	0.12	0.14	0.16	0.17
19	0.30	0.24	0.21	0.21	0.20	0.16	0.24	0.19	0.23	0.15	0.13	0.14	0.13	0.19	0.30	0.33
20	0.22	0.21	0.19	0.20	0.20	0.14	0.18	0.15	0.16	0.12	0.12	0.13	0.12	0.14	0.23	0.25
21	0.33	0.24	0.18	0.19	0.17	0.12	0.17	0.16	0.17	0.14	0.13	0.14	0.12	0.16	0.32	0.38
22	0.20	0.17	0.16	0.19	0.19	0.11	0.15	0.18	0.21	0.16	0.16	0.14	0.12	0.14	0.18	0.22
23	0.13	0.12	0.12	0.13	0.13	0.11	0.15	0.15	0.16	0.14	0.13	0.12	0.13	0.15	0.15	0.15
24	0.19	0.16	0.16	0.17	0.17	0.13	0.16	0.17	0.18	0.16	0.15	0.13	0.14	0.15	0.18	0.21
25	0.20	0.17	0.16	0.17	0.16	0.11	0.15	0.16	0.18	0.20	0.21	0.23	0.25	0.13	0.15	0.19
26	0.19	0.22	0.22	0.22	0.20	0.15	0.19	0.19	0.21	0.22	0.23	0.22	0.26	0.16	0.17	0.18
27	0.14	0.18	0.18	0.19	0.18	0.15	0.16	0.15	0.15	0.17	0.19	0.20	0.26	0.23	0.20	0.15
28	0.16	0.20	0.23	0.23	0.21	0.15	0.13	0.14	0.16	0.19	0.21	0.23	0.31	0.28	0.25	0.16
29	0.18	0.21	0.22	0.25	0.26	0.19	0.15	0.16	0.17	0.19	0.23	0.24	0.29	0.24	0.31	0.24
30	0.22	0.20	0.23	0.25	0.26	0.18	0.15	0.15	0.18	0.18	0.18	0.17	0.19	0.19	0.32	0.31
31	0.26	0.19	0.17	0.20	0.20	0.14	0.14	0.15	0.18	0.19	0.17	0.15	0.16	0.18	0.28	0.25
32	0.21	0.32	0.33	0.30	0.25	0.14	0.17	0.20	0.25	0.28	0.29	0.24	0.26	0.22	0.23	0.17
33	0.20	0.22	0.21	0.22	0.20	0.14	0.13	0.14	0.15	0.17	0.19	0.16	0.16	0.14	0.18	0.19
34	0.44	0.31	0.22	0.20	0.19	0.13	0.13	0.14	0.16	0.17	0.21	0.21	0.21	0.19	0.22	0.33
35	0.31	0.24	0.19	0.19	0.18	0.14	0.13	0.15	0.16	0.16	0.16	0.12	0.12	0.15	0.19	0.23
36	0.39	0.31	0.22	0.21	0.19	0.13	0.13	0.15	0.16	0.15	0.15	0.13	0.13	0.16	0.22	0.29
37	0.35	0.30	0.23	0.22	0.20	0.15	0.15	0.17	0.18	0.18	0.16	0.12	0.13	0.17	0.23	0.29
38	0.28	0.24	0.20	0.22	0.19	0.14	0.17	0.21	0.22	0.23	0.21	0.15	0.16	0.21	0.26	0.22
39	0.31	0.30	0.30	0.27	0.23	0.14	0.19	0.21	0.22	0.23	0.22	0.18	0.17	0.17	0.23	0.26
40	0.31	0.24	0.22	0.21	0.20	0.14	0.14	0.15	0.16	0.16	0.15	0.12	0.12	0.15	0.25	0.34
41	0.33	0.25	0.20	0.22	0.20	0.13	0.13	0.16	0.17	0.18	0.17	0.14	0.16	0.22	0.20	0.24
42	0.24	0.26	0.27	0.23	0.21	0.15	0.14	0.15	0.16	0.19	0.22	0.22	0.23	0.18	0.21	0.31
43	0.27	0.18	0.14	0.14	0.14	0.12	0.14	0.13	0.14	0.14	0.15	0.15	0.17	0.24	0.28	0.34
44	0.22	0.23	0.24	0.22	0.20	0.13	0.13	0.12	0.14	0.16	0.18	0.16	0.18	0.16	0.17	0.18
45	0.30	0.22	0.20	0.22	0.19	0.13	0.13	0.14	0.21	0.22	0.23	0.25	0.27	0.21	0.25	0.30
46	0.20	0.16	0.16	0.15	0.14	0.11	0.11	0.11	0.11	0.15	0.17	0.17	0.27	0.31	0.32	0.28
47	0.13	0.15	0.17	0.18	0.16	0.11	0.11	0.11	0.12	0.13	0.13	0.12	0.15	0.14	0.20	0.17
48	0.15	0.17	0.18	0.20	0.19	0.14	0.13	0.12	0.12	0.12	0.12	0.10	0.15	0.21	0.21	0.19
49	0.17	0.20	0.23	0.23	0.21	0.16	0.17	0.14	0.17	0.13	0.15	0.14	0.18	0.21	0.18	0.16
50	0.17	0.20	0.23	0.23	0.21	0.16	0.17	0.14	0.17	0.13	0.15	0.14	0.18	0.21	0.18	0.16
51	0.11	0.11	0.11	0.12	0.12	0.10	0.11	0.11	0.13	0.13	0.13	0.13	0.15	0.11	0.12	0.11
52	0.16	0.15	0.16	0.18	0.18	0.14	0.14	0.12	0.12	0.11	0.12	0.11	0.15	0.17	0.18	0.18
53	0.22	0.08	0.02	0.02	0.04	0.09	0.12	0.17	0.26	0.24	0.28	0.29	0.31	0.28	0.34	0.35
54	0.18	0.17	0.17	0.17	0.17	0.14	0.22	0.20	0.22	0.16	0.15	0.12	0.12	0.14	0.18	0.19
55	0.43	0.28	0.21	0.24	0.24	0.16	0.14	0.15	0.17	0.18	0.16	0.13	0.15	0.24	0.29	0.42
56	0.26	0.24	0.20	0.21	0.20	0.16	0.16	0.17	0.17	0.18	0.18	0.15	0.17	0.25	0.23	0.26
57	0.31	0.19	0.18	0.22	0.21	0.14	0.13	0.13	0.13	0.14	0.14	0.13	0.18	0.30	0.32	0.38
58	0.44	0.28	0.18	0.18	0.17	0.13	0.13	0.16	0.21	0.26	0.36	0.40	0.46	0.24	0.28	0.43
59	0.13	0.15	0.17	0.18	0.16	0.11	0.14	0.15	0.16	0.22	0.31	0.35	0.44	0.31	0.31	0.16
60	0.19	0.24	0.30	0.30	0.25	0.18	0.17	0.18	0.20	0.17	0.17	0.14	0.17	0.18	0.19	0.17
61	0.19	0.19	0.19	0.20	0.19	0.16	0.18	0.17	0.15	0.16	0.19	0.18	0.22	0.23	0.20	0.20
62	0.23	0.09	0.03	0.03	0.06	0.11	0.13	0.18	0.31	0.26	0.30	0.31	0.34	0.39	0.39	0.38
63	0.32	0.39	0.42	0.38	0.33	0.15	0.20	0.23	0.26	0.27	0.26	0.25	0.29	0.22	0.18	0.22

Test Point	0.0°	22.5°	45.0°	67.5°	90.0°	112.5°	135.0°	157.5°	180.0°	202.5°	225.0°	247.5°	270.0°	292.5°	315.0°	337.5°
64	0.24	0.23	0.23	0.25	0.27	0.17	0.15	0.18	0.17	0.19	0.18	0.15	0.21	0.25	0.22	0.28
65	0.29	0.25	0.25	0.26	0.26	0.16	0.14	0.16	0.16	0.16	0.16	0.16	0.16	0.20	0.25	0.34
66	0.17	0.17	0.16	0.20	0.20	0.11	0.13	0.17	0.20	0.16	0.15	0.15	0.16	0.21	0.28	0.24
67	0.16	0.15	0.16	0.20	0.19	0.12	0.16	0.18	0.22	0.16	0.18	0.19	0.19	0.22	0.28	0.23
68	0.28	0.23	0.21	0.25	0.24	0.18	0.12	0.15	0.18	0.14	0.13	0.14	0.14	0.19	0.27	0.32
69	0.30	0.21	0.13	0.17	0.19	0.14	0.18	0.18	0.23	0.15	0.19	0.23	0.25	0.29	0.38	0.39
70	0.30	0.26	0.21	0.22	0.20	0.15	0.11	0.14	0.16	0.13	0.13	0.13	0.13	0.17	0.25	0.31
71	0.14	0.15	0.08	0.16	0.16	0.11	0.10	0.14	0.17	0.16	0.16	0.17	0.14	0.16	0.21	0.20
72	0.11	0.12	0.11	0.16	0.16	0.10	0.14	0.14	0.15	0.13	0.11	0.11	0.10	0.12	0.14	0.14
73	0.22	0.19	0.15	0.19	0.19	0.14	0.12	0.17	0.20	0.15	0.14	0.13	0.12	0.14	0.21	0.25
74	0.22	0.21	0.24	0.21	0.17	0.14	0.10	0.13	0.14	0.10	0.10	0.10	0.10	0.11	0.19	0.23
75	0.18	0.18	0.18	0.21	0.20	0.15	0.12	0.15	0.16	0.14	0.12	0.12	0.11	0.14	0.20	0.22
76	0.16	0.16	0.16	0.18	0.17	0.12	0.12	0.15	0.17	0.14	0.14	0.13	0.12	0.12	0.17	0.19
77	0.31	0.27	0.26	0.20	0.17	0.13	0.14	0.16	0.18	0.15	0.15	0.13	0.14	0.15	0.26	0.33
78	0.31	0.24	0.22	0.18	0.17	0.12	0.14	0.16	0.18	0.17	0.16	0.15	0.14	0.14	0.27	0.34
79	0.16	0.15	0.15	0.18	0.18	0.12	0.16	0.18	0.20	0.17	0.16	0.15	0.13	0.13	0.17	0.20
80	0.23	0.18	0.16	0.17	0.16	0.12	0.14	0.16	0.18	0.19	0.18	0.20	0.21	0.12	0.22	0.28
81	0.32	0.26	0.24	0.20	0.18	0.13	0.15	0.17	0.19	0.18	0.17	0.17	0.18	0.16	0.30	0.37
82	0.29	0.34	0.35	0.27	0.18	0.13	0.15	0.15	0.16	0.14	0.14	0.14	0.18	0.23	0.23	0.26
83	0.26	0.25	0.21	0.18	0.15	0.10	0.11	0.13	0.14	0.15	0.13	0.15	0.17	0.12	0.17	0.22
84	0.29	0.26	0.23	0.19	0.16	0.12	0.12	0.13	0.15	0.15	0.14	0.16	0.18	0.17	0.20	0.25
85	0.16	0.23	0.26	0.25	0.21	0.13	0.19	0.17	0.20	0.19	0.20	0.19	0.22	0.17	0.16	0.15
86	0.27	0.32	0.37	0.31	0.22	0.12	0.11	0.11	0.13	0.14	0.14	0.16	0.18	0.20	0.17	0.16
87	0.23	0.32	0.34	0.30	0.25	0.15	0.26	0.20	0.22	0.22	0.24	0.28	0.34	0.24	0.22	0.22
88	0.24	0.31	0.37	0.32	0.24	0.16	0.26	0.17	0.16	0.13	0.13	0.15	0.16	0.14	0.17	0.17
89	0.24	0.36	0.53	0.50	0.41	0.31	0.18	0.16	0.17	0.19	0.22	0.19	0.21	0.20	0.19	0.21
90	0.22	0.24	0.25	0.24	0.23	0.15	0.17	0.15	0.17	0.16	0.15	0.13	0.18	0.15	0.28	0.29
91	0.22	0.26	0.27	0.25	0.25	0.17	0.14	0.15	0.16	0.16	0.16	0.14	0.15	0.28	0.32	0.21
92	0.17	0.17	0.17	0.19	0.17	0.12	0.20	0.19	0.21	0.19	0.18	0.16	0.17	0.16	0.22	0.17
93	0.24	0.22	0.22	0.19	0.18	0.15	0.14	0.15	0.17	0.14	0.18	0.19	0.20	0.12	0.12	0.19
94	0.26	0.18	0.18	0.20	0.18	0.13	0.19	0.16	0.17	0.16	0.15	0.13	0.14	0.18	0.19	0.24
95	0.23	0.18	0.18	0.20	0.19	0.13	0.17	0.19	0.19	0.21	0.19	0.15	0.13	0.13	0.17	0.24
96	0.22	0.19	0.21	0.22	0.20	0.13	0.18	0.18	0.18	0.18	0.18	0.22	0.35	0.36	0.20	0.24
97	0.27	0.26	0.25	0.23	0.23	0.15	0.16	0.19	0.19	0.19	0.18	0.15	0.19	0.22	0.27	0.28
98	0.18	0.15	0.17	0.19	0.18	0.13	0.14	0.16	0.16	0.16	0.15	0.13	0.14	0.15	0.19	0.22
99	0.21	0.27	0.31	0.36	0.33	0.24	0.15	0.18	0.18	0.19	0.17	0.15	0.17	0.20	0.25	0.26
100	0.29	0.26	0.21	0.25	0.27	0.15	0.15	0.19	0.19	0.18	0.20	0.23	0.18	0.22	0.26	0.26
101	0.20	0.22	0.21	0.20	0.19	0.17	0.22	0.18	0.24	0.18	0.24	0.25	0.26	0.20	0.21	0.18
102	0.35	0.35	0.32	0.27	0.22	0.15	0.17	0.20	0.18	0.18	0.20	0.21	0.24	0.26	0.35	0.34
103	0.19	0.18	0.15	0.21	0.21	0.14	0.12	0.17	0.18	0.15	0.14	0.14	0.13	0.17	0.21	0.22
104	0.23	0.25	0.24	0.26	0.27	0.20	0.14	0.20	0.20	0.15	0.13	0.13	0.12	0.19	0.25	0.24
105	0.19	0.20	0.20	0.22	0.21	0.17	0.11	0.15	0.20	0.13	0.12	0.11	0.11	0.13	0.19	0.21
106	0.24	0.25	0.23	0.22	0.20	0.18	0.14	0.16	0.24	0.13	0.11	0.10	0.11	0.14	0.22	0.23
107	0.23	0.19	0.21	0.21	0.21	0.17	0.13	0.16	0.18	0.14	0.15	0.14	0.13	0.16	0.26	0.29
108	0.23	0.25	0.28	0.29	0.25	0.18	0.14	0.17	0.20	0.16	0.16	0.14	0.12	0.13	0.18	0.21
109	0.32	0.30	0.32	0.29	0.25	0.19	0.16	0.19	0.21	0.18	0.18	0.15	0.14	0.17	0.29	0.33
110	0.38	0.33	0.32	0.25	0.19	0.15	0.16	0.18	0.20	0.18	0.19	0.16	0.15	0.17	0.35	0.41
111	0.46	0.43	0.37	0.27	0.20	0.14	0.14	0.17	0.19	0.17	0.18	0.15	0.16	0.18	0.31	0.44
112	0.21	0.18	0.14	0.17	0.17	0.16	0.25	0.20	0.21	0.18	0.20	0.16	0.13	0.19	0.36	0.31
113	0.22	0.23	0.19	0.17	0.15	0.15	0.22	0.19	0.22	0.18	0.19	0.15	0.14	0.15	0.19	0.22
114	0.20	0.21	0.19	0.16	0.15	0.12	0.18	0.17	0.19	0.15	0.14	0.11	0.13	0.14	0.15	0.17
115	0.13	0.14	0.13	0.14	0.14	0.11	0.13	0.12	0.14	0.12	0.11	0.11	0.12	0.13	0.22	0.16
116	0.14	0.15	0.16	0.20	0.20	0.14	0.28	0.24	0.28	0.17	0.16	0.15	0.18	0.14	0.14	0.13
117	0.15	0.19	0.20	0.19	0.18	0.11	0.15	0.14	0.15	0.14	0.16	0.17	0.21	0.19	0.17	0.16
118	0.25	0.28	0.31	0.28	0.23	0.15	0.22	0.19	0.24	0.26	0.29	0.31	0.40	0.35	0.19	0.25
119	0.25	0.31	0.33	0.32	0.29	0.24	0.40	0.20	0.16	0.17	0.20	0.22	0.28	0.26	0.19	0.22
120	0.30	0.34	0.41	0.40	0.35	0.21	0.16	0.18	0.24	0.25	0.28	0.27	0.35	0.20	0.25	0.29
121	0.18	0.14	0.14	0.17	0.18	0.15	0.15	0.19	0.22	0.20	0.19	0.17	0.23	0.24	0.47	0.35
122	0.25	0.21	0.18	0.19	0.19	0.14	0.16	0.18	0.19	0.21	0.26	0.25	0.33	0.26	0.41	0.31
123	0.34	0.36	0.33	0.30	0.28	0.20	0.18	0.22	0.22	0.22	0.21	0.22	0.25	0.30	0.33	0.37
124	0.20	0.21	0.20	0.23	0.18	0.14	0.19	0.19	0.17	0.16	0.17	0.18	0.21	0.15	0.20	0.20
125	0.32	0.36	0.33	0.28	0.25	0.19	0.21	0.21	0.24	0.25	0.25	0.25	0.32	0.27	0.23	0.35
126	0.51	0.37	0.29	0.22	0.23	0.24	0.24	0.23	0.18	0.18	0.18	0.17	0.20	0.26	0.49	0.57
127	0.30	0.24	0.19	0.19	0.18	0.11	0.32	0.34	0.26	0.31	0.24	0.22	0.27	0.29	0.30	0.31
128	0.18	0.24	0.26	0.26	0.22	0.11	0.20	0.22	0.21	0.19	0.19	0.20	0.20	0.15	0.18	0.16

Test Point	0.0°	22.5°	45.0°	67.5°	90.0°	112.5°	135.0°	157.5°	180.0°	202.5°	225.0°	247.5°	270.0°	292.5°	315.0°	337.5°
129	0.22	0.25	0.25	0.24	0.21	0.11	0.11	0.15	0.14	0.14	0.13	0.12	0.12	0.12	0.13	0.21
130	0.44	0.42	0.42	0.34	0.24	0.14	0.17	0.18	0.17	0.17	0.15	0.12	0.15	0.18	0.23	0.48
131	0.47	0.50	0.52	0.42	0.32	0.17	0.16	0.18	0.24	0.22	0.23	0.21	0.24	0.25	0.22	0.34
132	0.40	0.44	0.44	0.35	0.29	0.16	0.16	0.17	0.16	0.16	0.15	0.15	0.26	0.24	0.21	0.32
133	0.33	0.24	0.24	0.24	0.24	0.15	0.15	0.16	0.16	0.15	0.14	0.11	0.15	0.17	0.29	0.48
134	0.18	0.20	0.22	0.22	0.19	0.13	0.13	0.16	0.15	0.15	0.14	0.12	0.17	0.19	0.21	0.20
135	0.20	0.24	0.25	0.24	0.23	0.21	0.12	0.16	0.16	0.16	0.16	0.14	0.14	0.16	0.21	0.18
136	0.21	0.20	0.20	0.24	0.23	0.17	0.15	0.17	0.16	0.19	0.18	0.15	0.19	0.24	0.31	0.26
137	0.31	0.31	0.29	0.26	0.24	0.14	0.12	0.17	0.16	0.18	0.17	0.16	0.18	0.21	0.27	0.29
138	0.33	0.33	0.30	0.26	0.22	0.15	0.15	0.19	0.17	0.16	0.17	0.17	0.21	0.31	0.38	0.33
139	0.26	0.23	0.21	0.22	0.21	0.17	0.18	0.24	0.22	0.18	0.19	0.19	0.24	0.33	0.38	0.30
140	0.37	0.36	0.31	0.29	0.26	0.20	0.15	0.18	0.22	0.14	0.12	0.13	0.15	0.24	0.31	0.36
141	0.22	0.23	0.19	0.22	0.22	0.16	0.15	0.17	0.22	0.16	0.14	0.14	0.13	0.16	0.18	0.21
142	0.35	0.31	0.24	0.22	0.21	0.16	0.14	0.16	0.21	0.14	0.13	0.12	0.18	0.27	0.34	0.38
143	0.21	0.19	0.19	0.21	0.20	0.18	0.21	0.17	0.19	0.15	0.14	0.14	0.17	0.20	0.21	0.21
144	0.13	0.15	0.18	0.17	0.17	0.19	0.19	0.15	0.16	0.13	0.13	0.12	0.14	0.14	0.15	0.14
145	0.29	0.26	0.26	0.26	0.25	0.21	0.17	0.20	0.23	0.18	0.18	0.15	0.15	0.20	0.32	0.34
146	0.21	0.21	0.19	0.20	0.19	0.16	0.16	0.17	0.19	0.16	0.15	0.11	0.13	0.17	0.22	0.22
147	0.17	0.15	0.12	0.14	0.15	0.15	0.15	0.14	0.15	0.13	0.13	0.11	0.12	0.13	0.19	0.19
148	0.24	0.18	0.13	0.12	0.12	0.11	0.11	0.14	0.16	0.16	0.17	0.13	0.12	0.14	0.22	0.27
149	0.19	0.14	0.13	0.16	0.26	0.35	0.31	0.20	0.16	0.17	0.23	0.19	0.18	0.24	0.32	0.28
150	0.27	0.28	0.21	0.21	0.22	0.19	0.15	0.15	0.19	0.17	0.17	0.15	0.15	0.14	0.22	0.25
151	0.34	0.32	0.30	0.27	0.24	0.16	0.23	0.18	0.20	0.17	0.18	0.21	0.24	0.17	0.19	0.26
152	0.23	0.22	0.23	0.22	0.19	0.17	0.25	0.19	0.20	0.15	0.14	0.14	0.16	0.15	0.20	0.21
153	0.25	0.24	0.25	0.22	0.19	0.18	0.26	0.20	0.27	0.19	0.21	0.26	0.36	0.30	0.19	0.19
154	0.15	0.16	0.17	0.17	0.17	0.19	0.26	0.21	0.33	0.21	0.19	0.21	0.35	0.39	0.20	0.15
155	0.17	0.21	0.17	0.17	0.15	0.18	0.31	0.22	0.26	0.21	0.25	0.31	0.37	0.33	0.28	0.29
156	0.22	0.27	0.29	0.31	0.28	0.31	0.44	0.27	0.25	0.24	0.26	0.27	0.32	0.31	0.16	0.18
157	0.14	0.18	0.22	0.23	0.21	0.20	0.29	0.18	0.16	0.20	0.25	0.30	0.39	0.36	0.17	0.17
158	0.17	0.22	0.26	0.27	0.26	0.26	0.38	0.21	0.18	0.19	0.20	0.21	0.26	0.30	0.21	0.25
159	0.25	0.26	0.29	0.32	0.32	0.33	0.43	0.26	0.20	0.21	0.21	0.20	0.30	0.36	0.30	0.30
160	0.32	0.41	0.49	0.45	0.38	0.27	0.40	0.20	0.17	0.18	0.18	0.18	0.22	0.20	0.22	0.26
161	0.34	0.44	0.52	0.49	0.42	0.26	0.38	0.21	0.18	0.21	0.24	0.29	0.40	0.34	0.25	0.24
162	0.36	0.35	0.35	0.36	0.32	0.18	0.17	0.27	0.39	0.34	0.28	0.26	0.31	0.21	0.27	0.36
163	0.36	0.37	0.37	0.36	0.31	0.19	0.18	0.22	0.25	0.26	0.23	0.19	0.19	0.24	0.37	0.34
164	0.20	0.16	0.16	0.19	0.20	0.15	0.15	0.18	0.21	0.22	0.23	0.20	0.24	0.26	0.38	0.32
165	0.15	0.13	0.14	0.17	0.18	0.15	0.16	0.18	0.19	0.19	0.18	0.16	0.22	0.22	0.18	0.19
166	0.16	0.14	0.15	0.18	0.20	0.17	0.22	0.18	0.17	0.18	0.18	0.16	0.22	0.22	0.19	0.21
167	0.19	0.15	0.16	0.20	0.21	0.17	0.21	0.18	0.18	0.19	0.18	0.15	0.22	0.22	0.21	0.27
168	0.21	0.16	0.14	0.17	0.18	0.24	0.31	0.19	0.18	0.17	0.18	0.19	0.32	0.36	0.24	0.22
169	0.18	0.14	0.13	0.15	0.17	0.25	0.29	0.17	0.15	0.16	0.18	0.20	0.35	0.41	0.35	0.18
170	0.18	0.17	0.15	0.18	0.18	0.14	0.19	0.17	0.20	0.17	0.16	0.16	0.21	0.27	0.22	0.20
171	0.19	0.18	0.17	0.20	0.22	0.18	0.22	0.19	0.24	0.21	0.20	0.18	0.29	0.29	0.24	0.25
172	0.16	0.15	0.15	0.17	0.18	0.14	0.16	0.17	0.19	0.19	0.18	0.15	0.21	0.22	0.18	0.19
173	0.17	0.15	0.15	0.17	0.20	0.15	0.16	0.16	0.19	0.18	0.16	0.14	0.17	0.21	0.18	0.20
174	0.20	0.18	0.17	0.18	0.22	0.21	0.19	0.18	0.22	0.19	0.17	0.19	0.27	0.37	0.21	0.23
175	0.22	0.25	0.26	0.29	0.29	0.18	0.16	0.16	0.19	0.16	0.16	0.17	0.19	0.21	0.20	0.23
176	0.25	0.21	0.19	0.24	0.26	0.20	0.23	0.27	0.38	0.27	0.24	0.21	0.24	0.25	0.23	0.29
177	0.33	0.33	0.34	0.28	0.19	0.11	0.08	0.08	0.09	0.09	0.15	0.22	0.24	0.35	0.22	0.29
178	0.38	0.31	0.32	0.38	0.27	0.16	0.09	0.12	0.17	0.14	0.15	0.19	0.24	0.35	0.53	0.55
179	0.30	0.27	0.30	0.34	0.28	0.21	0.23	0.23	0.32	0.30	0.30	0.31	0.38	0.38	0.36	0.39
180	0.44	0.32	0.29	0.23	0.20	0.20	0.36	0.32	0.27	0.27	0.21	0.20	0.25	0.30	0.51	0.46
181	0.54	0.43	0.41	0.40	0.26	0.17	0.14	0.12	0.14	0.14	0.18	0.24	0.26	0.37	0.54	0.65
182	0.38	0.34	0.30	0.23	0.21	0.21	0.35	0.28	0.20	0.22	0.22	0.26	0.36	0.37	0.26	0.35
183	0.27	0.21	0.18	0.18	0.17	0.15	0.23	0.22	0.24	0.23	0.20	0.19	0.25	0.25	0.27	0.31
184	0.38	0.30	0.26	0.22	0.20	0.17	0.29	0.24	0.27	0.26	0.38	0.43	0.54	0.41	0.21	0.38
185	0.34	0.31	0.31	0.30	0.23	0.15	0.34	0.30	0.23	0.21	0.19	0.18	0.20	0.20	0.21	0.34
186	0.21	0.23	0.20	0.21	0.18	0.12	0.26	0.21	0.19	0.18	0.21	0.25	0.35	0.30	0.21	0.20
187	0.23	0.25	0.23	0.22	0.19	0.12	0.25	0.24	0.20	0.20	0.19	0.19	0.26	0.23	0.18	0.23
188	0.21	0.23	0.24	0.26	0.21	0.14	0.28	0.23	0.43	0.28	0.35	0.35	0.41	0.32	0.23	0.23
189	0.19	0.23	0.23	0.22	0.18	0.12	0.30	0.27	0.34	0.26	0.29	0.28	0.33	0.24	0.25	0.26
190	0.19	0.21	0.21	0.22	0.19	0.11	0.27	0.26	0.31	0.27	0.27	0.23	0.34	0.18	0.24	0.24
191	0.21	0.22	0.25	0.26	0.20	0.11	0.22	0.22	0.24	0.24	0.21	0.18	0.17	0.17	0.19	0.27
192	0.35	0.28	0.22	0.19	0.17	0.11	0.18	0.19	0.19	0.19	0.16	0.15	0.18	0.23	0.19	0.38
193	0.46	0.55	0.58	0.47	0.36	0.17	0.18	0.21	0.26	0.24	0.23	0.20	0.23	0.22	0.18	0.40

Test Point	0.0°	22.5°	45.0°	67.5°	90.0°	112.5°	135.0°	157.5°	180.0°	202.5°	225.0°	247.5°	270.0°	292.5°	315.0°	337.5°
194	0.27	0.32	0.31	0.27	0.24	0.15	0.20	0.22	0.24	0.21	0.20	0.19	0.20	0.22	0.19	0.27
195	0.30	0.30	0.28	0.25	0.23	0.18	0.17	0.18	0.19	0.18	0.20	0.22	0.29	0.28	0.20	0.33
196	0.31	0.25	0.24	0.23	0.21	0.16	0.18	0.21	0.22	0.20	0.20	0.18	0.22	0.24	0.22	0.38
197	0.16	0.19	0.21	0.23	0.23	0.22	0.13	0.17	0.18	0.16	0.16	0.17	0.18	0.21	0.18	0.23
198	0.15	0.19	0.21	0.26	0.27	0.20	0.12	0.16	0.17	0.15	0.14	0.14	0.15	0.16	0.18	0.18
199	0.14	0.19	0.21	0.24	0.25	0.18	0.11	0.14	0.14	0.14	0.13	0.13	0.17	0.15	0.17	0.17
200	0.20	0.21	0.24	0.27	0.28	0.27	0.14	0.15	0.14	0.14	0.14	0.18	0.26	0.24	0.21	0.22
201	0.20	0.22	0.23	0.28	0.29	0.28	0.15	0.16	0.15	0.15	0.14	0.17	0.25	0.23	0.21	0.21
202	0.22	0.27	0.28	0.31	0.32	0.22	0.11	0.17	0.16	0.17	0.14	0.15	0.19	0.26	0.30	0.30
203	0.18	0.18	0.16	0.19	0.19	0.14	0.12	0.16	0.16	0.15	0.13	0.15	0.20	0.21	0.23	0.22
204	0.20	0.20	0.20	0.27	0.27	0.25	0.16	0.16	0.15	0.15	0.14	0.16	0.25	0.26	0.22	0.21
205	0.19	0.19	0.18	0.24	0.24	0.15	0.12	0.17	0.17	0.17	0.16	0.15	0.14	0.16	0.19	0.19
206	0.23	0.23	0.24	0.27	0.26	0.19	0.13	0.17	0.17	0.20	0.18	0.17	0.20	0.22	0.27	0.25
207	0.21	0.21	0.20	0.24	0.23	0.19	0.13	0.16	0.16	0.18	0.16	0.16	0.25	0.28	0.27	0.24
208	0.20	0.20	0.22	0.30	0.29	0.25	0.19	0.15	0.14	0.15	0.13	0.13	0.21	0.27	0.29	0.24
209	0.20	0.20	0.23	0.27	0.28	0.25	0.18	0.18	0.17	0.17	0.15	0.13	0.17	0.22	0.25	0.24
210	0.22	0.21	0.21	0.23	0.21	0.16	0.15	0.19	0.16	0.15	0.15	0.15	0.19	0.27	0.32	0.27
211	0.30	0.25	0.22	0.23	0.22	0.16	0.15	0.17	0.20	0.15	0.14	0.14	0.18	0.30	0.34	0.30
212	0.25	0.20	0.22	0.26	0.27	0.25	0.23	0.16	0.16	0.15	0.13	0.14	0.23	0.28	0.30	0.28
213	0.27	0.24	0.22	0.24	0.24	0.22	0.18	0.17	0.21	0.17	0.15	0.14	0.16	0.21	0.26	0.29
214	0.29	0.26	0.21	0.22	0.23	0.17	0.17	0.17	0.22	0.16	0.14	0.14	0.21	0.26	0.32	0.31
215	0.28	0.25	0.24	0.24	0.21	0.15	0.15	0.18	0.22	0.17	0.16	0.15	0.23	0.32	0.36	0.33
216	0.20	0.19	0.14	0.17	0.16	0.13	0.14	0.14	0.16	0.13	0.12	0.11	0.14	0.18	0.22	0.21
217	0.25	0.26	0.23	0.19	0.19	0.17	0.19	0.19	0.23	0.16	0.13	0.13	0.16	0.22	0.20	0.23
218	0.39	0.37	0.31	0.22	0.19	0.16	0.16	0.16	0.21	0.15	0.14	0.13	0.14	0.22	0.33	0.40
219	0.27	0.21	0.16	0.16	0.20	0.17	0.14	0.14	0.17	0.16	0.17	0.14	0.11	0.17	0.28	0.33
220	0.30	0.31	0.32	0.25	0.29	0.24	0.18	0.17	0.22	0.16	0.19	0.15	0.13	0.20	0.26	0.28
221	0.14	0.14	0.13	0.19	0.21	0.16	0.14	0.17	0.22	0.18	0.21	0.17	0.14	0.16	0.19	0.18
222	0.16	0.14	0.15	0.17	0.17	0.13	0.14	0.16	0.17	0.15	0.17	0.15	0.13	0.16	0.26	0.25
223	0.23	0.19	0.16	0.18	0.19	0.20	0.20	0.14	0.16	0.15	0.18	0.16	0.16	0.19	0.27	0.30
224	0.40	0.30	0.23	0.23	0.20	0.14	0.12	0.13	0.17	0.15	0.15	0.15	0.19	0.18	0.29	0.45
225	0.18	0.18	0.19	0.19	0.18	0.15	0.14	0.14	0.16	0.15	0.14	0.15	0.22	0.26	0.14	0.16
226	0.20	0.21	0.18	0.20	0.20	0.17	0.24	0.17	0.21	0.17	0.16	0.20	0.29	0.25	0.18	0.17
227	0.18	0.19	0.18	0.18	0.18	0.15	0.24	0.17	0.20	0.15	0.16	0.18	0.25	0.27	0.15	0.16
228	0.17	0.23	0.25	0.27	0.28	0.25	0.30	0.20	0.17	0.17	0.18	0.21	0.31	0.44	0.29	0.33
229	0.24	0.21	0.23	0.26	0.26	0.31	0.37	0.23	0.18	0.18	0.16	0.16	0.22	0.25	0.23	0.26
230	0.20	0.18	0.20	0.20	0.19	0.14	0.15	0.15	0.17	0.18	0.17	0.18	0.28	0.35	0.30	0.23
231	0.18	0.16	0.15	0.19	0.20	0.14	0.16	0.16	0.20	0.18	0.16	0.16	0.10	0.25	0.24	0.20

Table 5 **Overall velocity ratio (VR_w) for each test point, annual and summer conditions**

Location	Annual	Summer	Location	Annual	Summer	Location	Annual	Summer	Location	Annual	Summer	Location	Annual	Summer	Location	Annual	Summer
1	0.25	0.21	40	0.20	0.16	79	0.16	0.16	118	0.26	0.26	157	0.21	0.23	196	0.23	0.21
2	0.25	0.21	41	0.21	0.18	80	0.17	0.17	119	0.28	0.24	158	0.24	0.23	197	0.20	0.18
3	0.18	0.18	42	0.22	0.20	81	0.21	0.18	120	0.33	0.27	159	0.29	0.27	198	0.20	0.17
4	0.18	0.17	43	0.16	0.15	82	0.24	0.18	121	0.17	0.19	160	0.36	0.26	199	0.19	0.16
5	0.15	0.15	44	0.20	0.17	83	0.18	0.15	122	0.21	0.22	161	0.39	0.30	200	0.23	0.19
6	0.22	0.18	45	0.21	0.21	84	0.20	0.16	123	0.29	0.24	162	0.32	0.29	201	0.23	0.19
7	0.21	0.16	46	0.16	0.16	85	0.21	0.19	124	0.20	0.18	163	0.31	0.25	202	0.25	0.20
8	0.18	0.14	47	0.15	0.13	86	0.25	0.17	125	0.28	0.25	164	0.19	0.20	203	0.17	0.16
9	0.21	0.17	48	0.16	0.14	87	0.27	0.25	126	0.27	0.22	165	0.16	0.18	204	0.22	0.19
10	0.18	0.16	49	0.19	0.17	88	0.26	0.19	127	0.22	0.24	166	0.17	0.18	205	0.20	0.17
11	0.16	0.15	50	0.19	0.17	89	0.36	0.26	128	0.22	0.20	167	0.18	0.19	206	0.23	0.20
12	0.16	0.16	51	0.12	0.12	90	0.21	0.18	129	0.20	0.15	168	0.19	0.20	207	0.21	0.19
13	0.16	0.15	52	0.15	0.14	91	0.22	0.18	130	0.30	0.20	169	0.17	0.20	208	0.23	0.19
14	0.14	0.14	53	0.11	0.19	92	0.18	0.18	131	0.36	0.26	170	0.17	0.17	209	0.22	0.19
15	0.19	0.16	54	0.17	0.16	93	0.19	0.17	132	0.31	0.21	171	0.20	0.21	210	0.20	0.18
16	0.11	0.11	55	0.23	0.19	94	0.18	0.16	133	0.22	0.17	172	0.17	0.17	211	0.22	0.18
17	0.17	0.14	56	0.20	0.18	95	0.19	0.18	134	0.18	0.16	173	0.17	0.17	212	0.22	0.19
18	0.16	0.14	57	0.20	0.16	96	0.20	0.20	135	0.21	0.17	174	0.19	0.20	213	0.22	0.19
19	0.21	0.18	58	0.24	0.26	97	0.22	0.19	136	0.21	0.19	175	0.24	0.20	214	0.22	0.18
20	0.18	0.15	59	0.18	0.23	98	0.17	0.16	137	0.24	0.19	176	0.24	0.25	215	0.22	0.19
21	0.19	0.16	60	0.24	0.19	99	0.27	0.21	138	0.25	0.20	177	0.24	0.17	216	0.16	0.14
22	0.17	0.16	61	0.19	0.18	100	0.23	0.21	139	0.22	0.21	178	0.28	0.21	217	0.20	0.18
23	0.13	0.13	62	0.13	0.22	101	0.21	0.21	140	0.27	0.19	179	0.30	0.29	218	0.24	0.18
24	0.16	0.16	63	0.33	0.27	102	0.26	0.21	141	0.20	0.17	180	0.27	0.26	219	0.18	0.17
25	0.17	0.18	64	0.23	0.20	103	0.18	0.16	142	0.22	0.18	181	0.33	0.23	220	0.26	0.21
26	0.21	0.21	65	0.23	0.18	104	0.23	0.18	143	0.19	0.17	182	0.27	0.26	221	0.17	0.18
27	0.18	0.18	66	0.18	0.17	105	0.19	0.15	144	0.16	0.15	183	0.20	0.21	222	0.16	0.16
28	0.20	0.20	67	0.18	0.18	106	0.20	0.16	145	0.24	0.20	184	0.27	0.31	223	0.18	0.18
29	0.22	0.22	68	0.21	0.17	107	0.19	0.17	146	0.19	0.16	185	0.27	0.23	224	0.23	0.18
30	0.22	0.19	69	0.19	0.19	108	0.23	0.18	147	0.14	0.14	186	0.20	0.21	225	0.18	0.16
31	0.19	0.17	70	0.20	0.16	109	0.26	0.20	148	0.15	0.14	187	0.21	0.20	226	0.20	0.19
32	0.27	0.25	71	0.14	0.15	110	0.25	0.20	149	0.20	0.22	188	0.25	0.29	227	0.18	0.18
33	0.19	0.17	72	0.13	0.13	111	0.28	0.20	150	0.21	0.18	189	0.23	0.26	228	0.24	0.23
34	0.23	0.19	73	0.18	0.16	112	0.18	0.19	151	0.25	0.21	190	0.22	0.24	229	0.24	0.22
35	0.19	0.16	74	0.18	0.13	113	0.18	0.18	152	0.20	0.18	191	0.22	0.21	230	0.19	0.18
36	0.22	0.17	75	0.18	0.15	114	0.17	0.15	153	0.23	0.23	192	0.21	0.18	231	0.17	0.17
37	0.22	0.18	76	0.16	0.15	115	0.13	0.12	154	0.19	0.22	193	0.40	0.27			
38	0.21	0.20	77	0.21	0.17	116	0.18	0.18	155	0.20	0.24	194	0.26	0.22			
39	0.25	0.22	78	0.19	0.17	117	0.17	0.16	156	0.28	0.28	195	0.25	0.22			

Table 6 **Median (50th percentile) hourly mean wind speeds [m/s] for each test point, annual and summer conditions**

Location	Annual	Summer	Location	Annual	Summer	Location	Annual	Summer	Location	Annual	Summer	Location	Annual	Summer	Location	Annual	Summer
1	0.97	0.65	40	0.81	0.49	79	0.66	0.51	118	1.07	0.81	157	0.84	0.72	196	0.91	0.65
2	0.99	0.66	41	0.82	0.54	80	0.70	0.55	119	1.11	0.70	158	0.94	0.70	197	0.79	0.56
3	0.71	0.57	42	0.91	0.62	81	0.83	0.56	120	1.32	0.83	159	1.12	0.78	198	0.79	0.51
4	0.73	0.54	43	0.63	0.47	82	0.91	0.51	121	0.68	0.59	160	1.41	0.70	199	0.75	0.47
5	0.61	0.48	44	0.81	0.52	83	0.71	0.45	122	0.83	0.67	161	1.55	0.86	200	0.90	0.55
6	0.90	0.55	45	0.86	0.64	84	0.77	0.49	123	1.15	0.73	162	1.32	0.91	201	0.90	0.56
7	0.82	0.47	46	0.63	0.47	85	0.84	0.61	124	0.78	0.56	163	1.26	0.74	202	1.00	0.56
8	0.72	0.44	47	0.60	0.41	86	0.97	0.49	125	1.14	0.79	164	0.77	0.65	203	0.69	0.49
9	0.84	0.51	48	0.65	0.42	87	1.09	0.76	126	1.03	0.66	165	0.65	0.56	204	0.85	0.56
10	0.74	0.50	49	0.77	0.51	88	1.00	0.53	127	0.88	0.76	166	0.69	0.57	205	0.78	0.52
11	0.63	0.47	50	0.77	0.51	89	1.36	0.70	128	0.88	0.62	167	0.73	0.58	206	0.92	0.61
12	0.64	0.49	51	0.47	0.39	90	0.86	0.53	129	0.81	0.45	168	0.73	0.62	207	0.83	0.57
13	0.63	0.47	52	0.62	0.41	91	0.90	0.54	130	1.16	0.55	169	0.67	0.60	208	0.88	0.53
14	0.58	0.43	53	0.22	0.54	92	0.71	0.55	131	1.44	0.74	170	0.69	0.55	209	0.88	0.56
15	0.76	0.48	54	0.68	0.50	93	0.78	0.53	132	1.24	0.58	171	0.79	0.65	210	0.81	0.54
16	0.46	0.33	55	0.91	0.55	94	0.72	0.50	133	0.88	0.50	172	0.67	0.55	211	0.86	0.54
17	0.68	0.41	56	0.82	0.56	95	0.75	0.55	134	0.74	0.48	173	0.67	0.53	212	0.88	0.56
18	0.62	0.44	57	0.77	0.48	96	0.82	0.62	135	0.85	0.52	174	0.78	0.63	213	0.88	0.56
19	0.82	0.53	58	0.89	0.76	97	0.91	0.60	136	0.83	0.57	175	0.94	0.58	214	0.86	0.56
20	0.73	0.45	59	0.71	0.65	98	0.68	0.49	137	0.96	0.56	176	0.94	0.78	215	0.88	0.58
21	0.74	0.48	60	0.93	0.58	99	1.04	0.61	138	0.99	0.60	177	0.96	0.44	216	0.64	0.44
22	0.70	0.51	61	0.76	0.57	100	0.94	0.63	139	0.87	0.64	178	1.12	0.57	217	0.80	0.53
23	0.52	0.42	62	0.29	0.60	101	0.83	0.67	140	1.07	0.53	179	1.20	0.92	218	0.92	0.52
24	0.66	0.48	63	1.32	0.81	102	1.04	0.65	141	0.79	0.52	180	1.03	0.78	219	0.73	0.51
25	0.70	0.57	64	0.92	0.60	103	0.70	0.48	142	0.88	0.51	181	1.29	0.61	220	1.04	0.61
26	0.85	0.66	65	0.92	0.55	104	0.90	0.52	143	0.76	0.53	182	1.05	0.78	221	0.67	0.56
27	0.71	0.56	66	0.70	0.51	105	0.74	0.45	144	0.64	0.46	183	0.79	0.65	222	0.64	0.50
28	0.82	0.62	67	0.71	0.56	106	0.82	0.45	145	0.96	0.61	184	1.06	0.92	223	0.73	0.54
29	0.89	0.66	68	0.86	0.50	107	0.77	0.51	146	0.75	0.50	185	1.06	0.69	224	0.88	0.52
30	0.87	0.59	69	0.74	0.60	108	0.93	0.54	147	0.57	0.43	186	0.82	0.65	225	0.71	0.50
31	0.76	0.54	70	0.81	0.46	109	1.04	0.61	148	0.58	0.45	187	0.86	0.63	226	0.79	0.60
32	1.08	0.77	71	0.55	0.46	110	0.96	0.59	149	0.73	0.64	188	1.01	0.91	227	0.73	0.56
33	0.79	0.53	72	0.51	0.39	111	1.04	0.57	150	0.86	0.55	189	0.91	0.81	228	0.95	0.68
34	0.88	0.58	73	0.70	0.48	112	0.71	0.58	151	1.02	0.64	190	0.87	0.76	229	0.94	0.65
35	0.76	0.48	74	0.72	0.39	113	0.74	0.56	152	0.80	0.53	191	0.88	0.64	230	0.76	0.57
36	0.83	0.49	75	0.70	0.45	114	0.67	0.47	153	0.91	0.71	192	0.81	0.56	231	0.69	0.52
37	0.87	0.53	76	0.64	0.45	115	0.53	0.39	154	0.74	0.68	193	1.57	0.77			
38	0.85	0.61	77	0.80	0.50	116	0.70	0.56	155	0.77	0.74	194	1.02	0.67			
39	1.01	0.66	78	0.77	0.51	117	0.70	0.50	156	1.12	0.87	195	1.00	0.66			

Appendix B

Wind Climate Analysis

Wind Tunnel Simulation

When modelling the interaction of wind with structures on the surface of the Earth, it is necessary to correctly simulate the lower level of the atmosphere, known as the atmospheric boundary layer. More specifically, two quantities are of key interest, namely the variation of mean (average) wind speed with height, and longitudinal turbulence intensity with height.

During the course of the Wind Availability Study[2] a series of wind tunnel tests were conducted to determine the variation of mean wind speed and longitudinal turbulence intensity with height.

As noted within this study, there are some significant changes in the upstream flow characteristics for the wind directions considered due the effect of the surrounding topographic features, with each of these required to be simulated in the present series of 1:500 scale wind tunnel studies for the detailed AVA studies.

As a result, six groups of wind profiles have been formed, each group containing wind angles with similar mean wind speed, turbulence and longitudinal gust characteristics.

One angle was chosen from each group/fetch, and is representative of the wind characteristics of that group. Details on the target angle selection and grouping is shown in Table B.1 below. The corresponding profiles are presented graphically in Figure B.1.

Table B.1: Wind angle ranges and target angles

Profile	Wind Angle Range	Target Angle
Exp 1	292.5°, 337.5°	337.5°
Exp 2	315°	315°
Exp 2	22.5°, 67.5° to 90°, 270°	90°
Exp 4	0°, 45°, 112.5° to 135°	0°
Exp 5	157.5°, 202.5°	202.5°
Exp 6	225° to 247.5°	247.5°

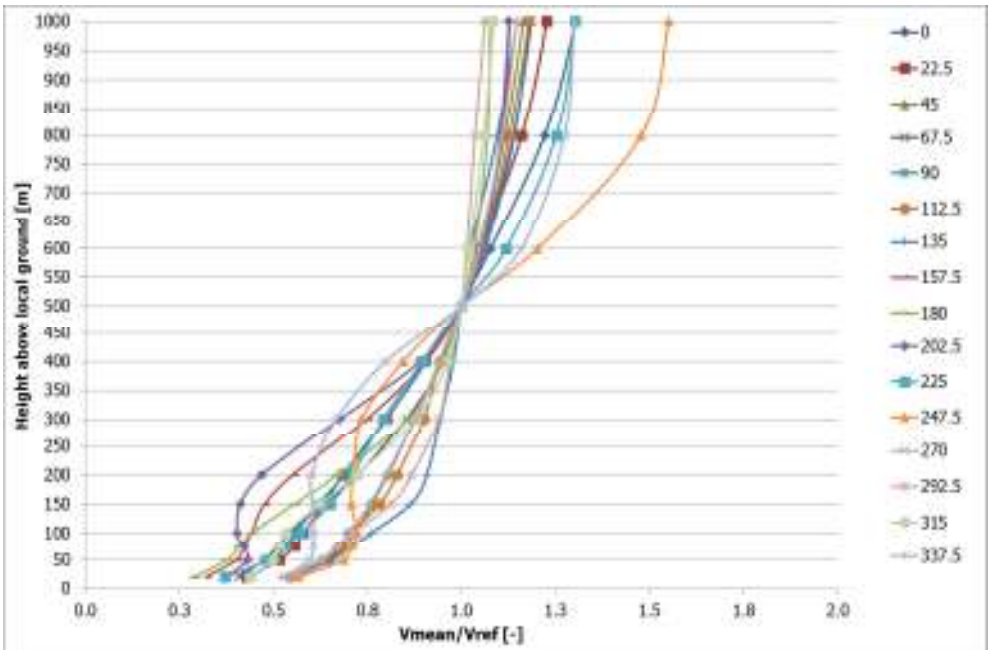

Figure B.1: Measured wind profiles from wind availability study[2] normalised by the velocity at a reference height of 500m

Wind Frequency Data

Environmental 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 Hong Kong Met Office, 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. Further to this, records of Typhoon storm systems that are known to have occurred during these records are removed from the data set, such that the data set represents a statistical model of the non-typhoon wind climate.

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 open country terrain at 10m height above sea-level, accounting for upwind terrain, topography and altitude for the weather centre. Values of *p*, *c* and *k* for *Waglan Island Weather Station*, transposed to open-country terrain at 10m height above sea-level are given in the Table B.2, whilst Table B.3 presents the same values at the site. The corresponding wind rose at a reference height of 500m is presented graphically in figures B.2 and B.3 for annual and summer conditions, respectively.

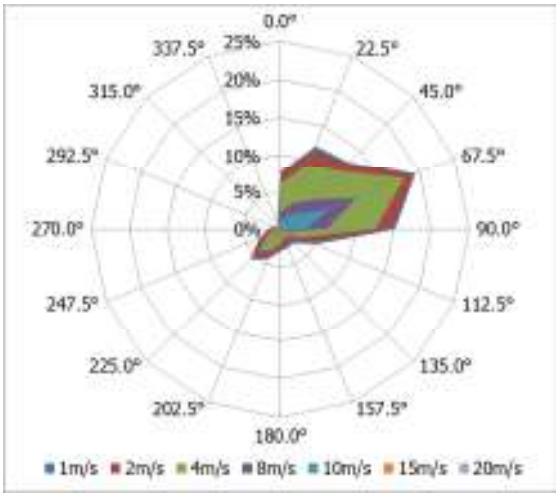

Figure B.2: Annual wind rose at a reference height of 500m

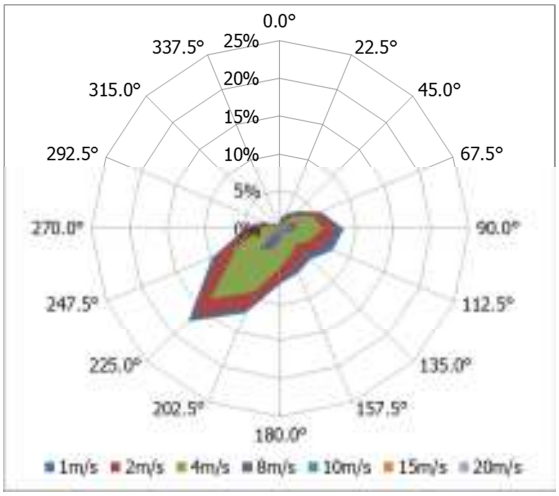

Figure B.3: Summer wind rose at a reference height of 500m

Table B2: Wind frequency statistics (*Weibull coefficients*) for non-typhoon winds, *Waglan Island Weather Station (1989-2008)* Data transposed to z_0= 0.03m, 10m height

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	7.79	12.37	12.91	19.44	15.33	5.54	2.99	2.86	2.96	4.37	5.72	3.12	1.72	1.10	0.62	1.15
C	5.10	4.86	5.43	6.38	5.26	3.31	2.43	2.69	3.15	3.61	4.19	4.12	3.13	2.50	1.46	3.00
K	2.34	2.11	2.45	2.69	2.26	1.54	1.37	1.66	1.98	2.11	2.23	2.26	1.99	1.80	1.09	1.46

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	1.74	2.48	3.57	5.98	8.85	8.11	6.23	6.58	7.40	12.18	17.45	9.91	4.83	2.53	1.19	0.97
C	2.42	2.55	4.33	5.35	4.18	3.29	2.94	3.15	3.50	3.92	4.53	4.47	3.43	2.83	1.69	1.45
K	1.56	1.52	1.35	1.84	1.65	1.51	1.53	1.87	2.14	2.24	2.39	2.48	2.20	2.01	1.19	1.16

Table B.3: Wind frequency statistics (*Weibull coefficients*) for non-typhoon winds, *Project Site*

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	7.79	12.37	12.91	19.44	15.33	5.54	2.99	2.86	2.96	4.37	5.72	3.12	1.72	1.10	0.62	1.15
C	10.45	9.95	11.12	13.06	10.76	6.77	4.99	5.52	6.45	7.40	8.58	8.44	6.41	5.12	2.99	6.15
K	2.34	2.11	2.45	2.69	2.26	1.54	1.37	1.66	1.98	2.11	2.23	2.26	1.99	1.80	1.09	1.46

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	1.74	2.48	3.57	5.98	8.85	8.11	6.23	6.58	7.40	12.18	17.45	9.91	4.83	2.53	1.19	0.97
C	4.96	5.23	8.87	10.97	8.55	6.73	6.03	6.44	7.16	8.02	9.27	9.15	7.03	5.81	3.47	2.96
K	1.56	1.52	1.35	1.84	1.65	1.51	1.53	1.87	2.14	2.24	2.39	2.48	2.20	2.01	1.19	1.16

Appendix C

Wind Tunnel & Model Details

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.

Model

Information for Model Construction

The model of the proposed development was constructed based on drawing information, as follows:

Drawing	Date
bldpoly_Output_2.shp	22/07/2015
podpoly_Output_2.shp	22/07/2015
20150721-WP3 Massing for Wind-tunnel_MG.skp	22/07/2015
20150722 - QWP - plans for AVA.dwg	22/07/2015
20150826 - Selection of drawings SCL.pdf	26/08/2015
M_UD_15_56_01 20150924 Layout.pdf	10/07/2015
Hutchison Site.pdf	10/07/2015
20140127 - B1000 - Full drawing.dwg	20/10/2015

The wind tunnel models representative of the surrounding building morphology were constructed based on drawing information and information sourced and from the public domain.

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

Scale

A model scale of 1:500 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.

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 area was modelled to a radius of 1,100m from the centre of the site.

Topography was 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 4.4m diameter baseboard and installed on the 4.4m diameter turntable of BMT's Boundary Layer Wind Tunnel.

Appendix D

Wind Speed Measurements

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 222 locations at a height corresponding to 2m 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 standard deviation wind speeds.