FINAL REPORT
FOR AN INSTRUCTED PROJECT AT EX-NORTH POINT ESTATE SITE, NORTH POINT, HONG KONG

WWTF INVESTIGATION REPORT WWTF015-2008

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Planning Department, HKSAR Government

CLP Power
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The Hong Kong University
of Science and Technology

EXECUTIVE SUMMARY

At the request of Planning Department (PlanD), HKSAR Government, a brief Expert Evaluation and wind tunnel model tests were undertaken by the CLP Power Wind/Wave Tunnel Facility (WWTF), The Hong Kong University of Science and Technology, for an instructed project at Ex-North Point Estate Site, North Point, Hong Kong under Agreement No. PLNQ37/2007 Cat. C – Term Consultancy for Air Ventilation Assessment (AVA) Services by Wind Tunnel. The study was conducted to assess the air ventilation impacts of the Initial Design Scheme on the Project Area and Assessment Area.

The wind tunnel model study was undertaken in accordance with the requirements stipulated in the Australasian Wind Engineering Society Quality Assurance Manual, AWES-QAM-1-2001 (2001) and the American Society of Civil Engineers Manual and Report on Engineering Practice No. 67 for Wind Tunnel Studies of Building and Structures (1999). The study was also conducted in accordance with the recommendations of Planning Department's Feasibility Study for Establishment of Air Ventilation Assessment System – Final Report (2005) and Technical Guide for Air Ventilation Assessment for Developments in Hong Kong (2006).

A 1:400 scale model of the Project Area, Assessment Area and the Surrounding Area, including all known existing and committed developments and topographical features within a diameter of approximately 1200 m, was fabricated to represent the state of urban areas corresponding to the existing condition in accordance with plans, drawings and information supplied by PlanD on 6 March 2008. Existing trees within the modelled area were modelled with foliage and in their mature state.

Pedestrian level wind speeds were measured at a total of 130 test points, including nine elevated test points, for 16 wind directions at increments of 22.5° using a multi-channel thermal anemometer. Wind tunnel test results were used in conjunction with the results of a 1:4000 scale wind tunnel topographical model study previously conducted by others for a proposed development at the Oil Street site, North Point (CH2M Hill Hong Kong Limited, March 2008), provided by PlanD on 10 March 2008 for use with the current project, and WWTF's statistical model of the Hong Kong non-typhoon wind climate, based on

measurements of wind speed and direction taken by Hong Kong Observatory (HKO) at Waglan Island. The wind tunnel test results were analysed to determine annual, summer and winter wind velocity ratios and mean wind speeds corresponding to a probability of exceedance of 50% at each test point, as requested by PlanD.

Test points with relatively low overall wind velocity ratios were typically located in areas to the south of the Project Area that were shielded from the prevailing winds by the extensive podia proposed for the hotel development and residential towers and/or along east-west oriented streets lined with closely spaced tall buildings. Test points with relatively higher overall wind velocity ratios were typically located close to the harbour frontage, along wider roads in the Assessment Area that are aligned approximately north-south, such as Shu Kuk Street and Kam Hong Street, and to the east of the Project Area which has relatively open spaces and tall buildings of mixed heights.

The annual, summer and winter site spatial average wind velocity ratios (SVR) for the Ex-North Point Estate Site are 0.16, 0.11 and 0.20 respectively. The annual, summer and winter local spatial average wind velocity ratios (LVR) for all pedestrian level test points are 0.16, 0.12 and 0.20 respectively. The annual, summer and winter average mean wind speeds corresponding to a probability of exceedance of 50% for the Ex-North Point Estate Site are 1.16, 0.54 and 1.58 m/s respectively.

NOMENCLATURE

F	wind speed scaling factor;
LVR	local spatial average wind velocity ratio, $LVR = \sum_{j=1}^{N} \frac{VR_{w,j}}{N}$;
M	the total number of perimeter test points;
n	the total number of test points corresponding to a nominated zone;
N	the total number of all test points, including perimeter test points but excluding special and elevated test points;
p_i	annual or summer probability of occurrence of winds approaching the study site (%);
SAVR	spatial average wind velocity ratio for a nominated zone, $SAVR = \sum_{j=1}^{n} \frac{VR_{w,j}}{n}$;
SVR	site spatial average wind velocity ratio, $SVR = \sum_{j=1}^{M} \frac{VR_{w,j}}{M}$;
$\bar{u}_{500,open}$	directional non-typhoon mean wind speed at 500 mPD above open terrain (m/s);
$\bar{u}_{ref}$	mean wind speed measured at the nominated reference height (m/s);
$\bar{u}_z$	mean wind speed measured at a height z (m/s);
$V_{p,i,j}$	wind speed at pedestrian level, i.e. at 2 m above ground at each test point and under the influence of buildings and other urban features (m/s);
$VR_{500,i,j}$	directional wind velocity ratio, with respect to the reference mean wind speed at 500 m, for a particular wind direction (i) at the j-th test point, $VR_{500,i,j} = \frac{V_{p,i,j}}{V_{500,i}}$;
V_∞	wind speed at the top of the atmospheric boundary layer, taken as the wind velocity at 500 mPD in this study, denoted as $V_{500,i}$ (m/s);
$VR_{w,j}$	overall wind velocity ratio of the j-th test point, $VR_{w,j} = \sum_{i=1}^{16} p_i \times VR_{500,i,j}$.

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1. INTRODUCTION

At the request of Planning Department (PlanD), HKSAR Government, a wind engineering study was undertaken by the CLP Power Wind/Wave Tunnel Facility (WWTF), The Hong Kong University of Science and Technology, for an instructed project at Ex-North Point Estate Site, North Point, Hong Kong under the Agreement No. PLNQ37/2007 Cat. C – Term Consultancy for Air Ventilation Assessment (AVA) Services by Wind Tunnel. The study was conducted to assess the air ventilation impacts of the Initial Design Scheme shown in Figure 1 on the prescribed Assessment Area. The location of the Project Area is shown in Figure 2 and the location and extent of the Project Area, Assessment Area and the Surrounding Area (these areas are also collectively termed as the Study Area) are shown in Figure 3.

The methodology used for the Expert Evaluation and Air Ventilation Assessment conducted for this project was previously submitted as Working Paper 1 (WWTF Investigation Report WWTF005-2008).

Based on the results of an initial Expert Evaluation and wind tunnel model study of the Initial Design Scheme, potential amelioration measures are suggested to improve the impact of the Initial Design Scheme on air ventilation within the most significantly affected parts of the Assessment Area. Details of the implementation of the adopted site wind availability data, experimental and data analysis procedures, along with the results obtained for this AVA study, are also presented in this report.

A 1:400 scale model of the Project Area, Assessment Area and the Surrounding Area, including all known existing and committed developments and topographical features within a diameter of approximately 1200 m, was fabricated to represent the state of urban areas corresponding to the existing condition in accordance with plans, drawings and information supplied by PlanD on 6 March 2008. Existing trees within the modelled area were modelled with foliage and in their mature state.

Pedestrian level wind speed measurements were taken at 22.5° increments for the full 360° azimuth (i.e. 16 wind directions), where a wind direction of 0° or 360° corresponds to an incident wind approaching the Project Area directly from the north, 90° corresponds to an incident wind approaching the Project Area from the east, etc. A multi-channel thermal anemometer was used to measure the wind speeds at 130 test points in the Project Area and Assessment Area.

Wind tunnel test results were combined with WWTF's statistical model of the Hong Kong non-typhoon wind climate based on measurements of wind speed and direction taken by Hong Kong Observatory (HKO) at Waglan Island during the period of 1953 to 2000 inclusive (Hitchcock et. al., 2003) in order to determine annual, summer and winter wind velocity ratios and mean wind speeds at each test point, as requested by PlanD. Mean wind speeds were determined based on a probability of exceedance of 50% on an annual basis, a probability of exceedance of 50% during the summer months (June, July, August) and a probability of exceedance of 50% during the winter months (December, January, February).

The wind tunnel model study was undertaken in accordance with the requirements stipulated in the Australasian Wind Engineering Society Quality Assurance Manual, AWES-QAM-1-2001 (2001) and the American Society of Civil Engineers Manual and Report on Engineering Practice No. 67 for Wind Tunnel Studies of Building and Structures (1999). The study was also conducted in accordance with the recommendations of Planning Department's Feasibility Study for Establishment of Air Ventilation Assessment System – Final Report (2005) and Technical Guide for Air Ventilation Assessment for Developments in Hong Kong (2006).

2. SITE WIND AVAILABILITY

Site wind availability at the Ex-North Point Estate Site was evaluated from a wind tunnel topographical model study previously conducted by others for a proposed development at the Oil Street site, North Point (CH2M Hill Hong Kong Limited, March 2008), provided by PlanD on 10 March 2008 for use with the current project. The Oil Street site is approximately 1 km from the Project Area and the data include direct measurements of mean wind speed, turbulence intensity and yaw angle at a number of heights and at 22.5° intervals for the full 360^{o} azimuth (i.e. 16 wind directions). In the absence of data specifically for the Project Area, these data form the most complete and relevant set of site wind availability data for the current AVA study.

In the assessment of the pedestrian level wind environment, the primary concerns are of pedestrian comfort and safety. The main objective for conducting an AVA for the ex-North Point Estate Site is to investigate and determine the likely impact of the proposed development on air flow at pedestrian level within the Assessment Area. Although the current AVA framework does not provide absolute criteria by which wind conditions may be quantitatively assessed as acceptable or unacceptable on the basis of comfort or safety, it does provide a relative indicator of potential wind conditions that are likely to occur on a relatively frequent basis. Typhoons affect Hong Kong, on average, only several times per year and typically in the warmer months of May to October inclusive. From the point of view of safety, it is expected that people would remain indoors during typhoon wind events. Hence, typhoon winds have been excluded from this study and only non-typhoon winds have been considered in the current assessment and prediction of pedestrian level wind conditions for the Study Area.

Waglan Island, located approximately 5 km southeast of Hong Kong Island, has been used by Hong Kong Observatory (HKO) for the collection of long-term wind data since December 1952. Due to its location, relative lack of development and its generally uninterrupted exposure to winds, data collected at Waglan Island is considered to be of the highest quality available for wind engineering purposes for Hong Kong and it is representative of winds approaching the Hong Kong region. The detrimental effects of nearby developments on the usefulness of wind data were clearly demonstrated by Melbourne (1984) in a comparison of wind speed measurements taken at both Waglan Island and Hong Kong Observatory in Tsim Sha Tsui. Similarly, for other HKO measurement and monitoring sites, such as at North Point, the amount and variety of nearby development that has taken place during their operational life makes them unsuitable for use for this study.

WWTF's statistical annual, summer and winter models of the Hong Kong non-typhoon wind climate, that are based on HKO data measured at Waglan Island during the period of January 1953 to May 2000 inclusive, were combined with the results of the previously undertaken 1:4000 scale site wind availability study (CH2M Hill Hong Kong Limited, March 2008) to determine wind roses for annual, summer and winter months for the Ex-North Point Estate Site, corrected to a height of 100 mPD, as presented in Figures 4, 5 and 6. Corresponding data are also presented in tabular form in Appendix A.

Some significant directional deviations were noted for certain approach wind directions in the 1:4000 scale site wind availability results that were originally determined for 22.5° sectors. For this study, those deviations, or wind shifts, were averaged over heights of 50 mPD, 100 mPD, 150 mPD and 200 mPD, i.e. the range of heights in the current study that are considered likely to influence pedestrian level wind conditions. If the average wind shift determined in the 1:4000 scale study deviated by more than ±11.25° from the approach wind direction, those winds were treated as having shifted to an adjacent sector. Therefore, the probability of occurrence was added to that of the adjacent sector and the annual, summer and winter directional probabilities of occurrence were adjusted accordingly. The average wind shifts were also applied to the wind roses presented in Figures 4, 5 and 6 and Tables A1, A2 and A3 respectively in Appendix A.

In Figures 4, 5 and 6, mean wind speeds are segregated into four categories (0 – 3.3 m/s, 3.4 – 7.9 m/s, 8.0 – 13.8 m/s and greater than 13.8 m/s) that are indicated by the thickness of the bars for the 16 cardinal wind directions. The length of the bars indicates the average probability of occurrence annually or in the summer or winter months. For example, Figure 4 illustrates that, on an annual basis at a height of 100 m, east-north-east winds occur approximately 39% of the time, Figure 5 illustrates that east-north-east winds occur approximately 19% of the time during the summer months and Figure 6 illustrates that east-north-east winds occur approximately 44% of the time during the winter months.

On an annual basis, winds approach the Project Area more than 67% of the time on average from 0° to 67.5° inclusive; during summer months, winds from 0° to 67.5° inclusive occur for approximately 25% of the time on average and winds from 180° to 270° inclusive occur approximately 51% of the time on average; during winter months, winds from 0° to 67.5° inclusive occur approximately 93% of the time on average.

3. EXPERT EVALUATION

3.1 Summary of site wind characteristics and site characteristics

As discussed in Section 2, the predominant prevailing winds for the site are expected to be easterly and north-easterly winds. The prevailing summer winds from the southerly directions are significantly blocked by the surrounding topography. Hence the Ex-North Point Estate Project Area, the Assessment Area and the Surrounding Area are not expected to benefit appreciably from the prevailing summer southerly winds.

3.2 Description of the Project Area and Assessment Area

The Ex-North Point Estate Site Project Area has an area of approximately 36,970m^2, with a harbour frontage of about 400 m, as shown in Figures 1 and 2. It is bounded by Tong Shui Road in the west, Java Road/North Point Estate Lane in the south and Tin Chiu Street in the east. The northern boundary of the Project Area is the harbour-front, which is currently occupied by a Public Transport Terminus and a sitting out area. The North Point Ferry Piers and the Island Eastern Corridor (IEC) are located to the immediate north of the Project Area. Part of the Project Area adjacent to Java Road is currently used for temporary car and lorry parking and the western part of the Project Area is currently vacant.

3.3 Site characteristics and potential air ventilation issues related to the Project Area

The Project Area is divided into two areas of interest, Site A and Site B, as shown in Figures 1 and 2. The Project Area is likely to benefit from its generally unobstructed harbour frontage and exposure to prevailing easterly and north-easterly winds. The proposed design for the Project Area retains many open spaces, notably the waterfront promenade along the northern boundary of the Project Area and public open space for Site B near Tin Chiu Street, which facilitates beneficial wind penetration into the Project Area for winds from easterly or north-easterly directions. Nevertheless, some blockage effects due to the proposed buildings for the Project Area are expected to produce some localised stagnant zones corresponding to the prevailing wind directions.

The proposed design for Site A consists of a hotel development whilst Site B comprises a combination of residential tower blocks and commercial/non-domestic buildings. For Site A, the proposed buildings' planform and configuration adopt a wide opening at the Tong Shui Road area and also a spacing of approximately 30 m between the buildings of Site A and Site B to facilitate wind penetration through the Project Area and into existing streets. However, the large podium (part at +25 mPD and part at +35 mPD) for Site B that forms part of the proposed commercial/non-domestic buildings occupies almost the entire footprint of the building site and creates a significant blockage to easterly and particularly north-easterly winds. Furthermore, the podium arrests most of the downwash at the podium roof levels and stops most of the resultant airflow from reaching the pedestrian levels. Hence, air ventilation is expected to be reduced significantly along the part of Java Road adjacent to the podium.

3.4 Site characteristics and air ventilation issues related to the Assessment Area and Surrounding Area

The Assessment Area and the Surrounding Area are mostly characterised by closely spaced tall buildings with narrow streets (for example, along both sides of Shu Kuk Street and Kam

Hong Street) leading into the Project and Assessment Areas. The pedestrian level wind climate within the Assessment Area and the Surrounding Area as it now exists is governed by these site characteristics and the site's relatively unobstructed exposure to prevailing easterly and north-easterly winds.

In general, the proposed building design for the Project Area, in terms of building height and building spacing, is similar to the existing streetscape and facilitates some wind penetrations for prevailing winds from easterly and north-easterly directions. Hence, the design for the proposed development within the Project Area is unlikely to adversely affect the overall pedestrian level wind climate within the Assessment Area and the Surrounding Area.

4. WIND TUNNEL MODELLING

4.1 Modelling the Natural Wind

In conducting wind tunnel model tests of structures on the surface of the Earth, it is necessary to adequately simulate the lowest layer of the atmosphere, known as the atmospheric boundary layer. It is within this layer that the surface of the Earth imparts drag forces on the moving air, generally resulting in mean wind speed increasing with height to a point where the effects of surface drag become negligible. In wind engineering, a convenient measure of the thickness of the atmospheric boundary layer is commonly referred to as the gradient height and its magnitude depends on the surrounding roughness over which the air must flow. Obstacles to air flow can vary from relatively large expanses of smooth, open water, to vegetation such as forests, built-up environments such as city centres, and large rugged mountain ranges. The resulting gradient heights are typically in the ranges of several hundred metres to in excess of 1000 m.

Site wind availability at the Ex-North Point Estate Site was evaluated from a 1:4000 scale experimental study that was previously conducted for the proposed development at the Oil Street site, North Point (CH2M Hill Hong Kong Limited, March 2008), provided by PlanD on 10 March 2008 for use in the current AVA study. The Oil Street site is located approximately 1 km from the Project Area and in that study measurements of mean wind speed, turbulence intensity and yaw angle were taken at a number of heights, and at 22.5° intervals for the full 360° azimuth (i.e. 16 wind directions).

Due to the similarities between both mean wind speed and turbulence intensity profiles for certain wind directions, three representative approach profiles (denoted here as approach conditions A, B and C) are considered to be adequate to represent the range of wind conditions affected by the surrounding terrain for the full 360° azimuth. The approach conditions corresponding to each of the 16 wind directions tested are presented in Table 1. Mean wind speed profiles, turbulence intensity profiles and longitudinal velocity spectra for the approach conditions A, B and C are presented in graphical form in the Figures 7, 8, and 9, respectively.

For all tests, reference wind speeds were measured at a height of 300 mPD. Wind speed scaling factors were applied to relate the non-typhoon wind speed at 500 mPD above open terrain to wind speeds at the reference height, as shown in Equation (1).

$$\overline{u}_{ref} = F\overline{u}_{500,open} \qquad (1)$$

where:

F = wind speed scaling factor;

$\overline{u}_{ref}$ = the mean wind speed measured at the reference height (equivalent to 300 mPD in this 1:400 scale study); and

$\overline{u}_{500,open}$ = directional non-typhoon mean wind speed at 500 mPD above open terrain.

The wind speed scaling factors (F) are calculated from the ratios of mean wind speeds measured in the 1:4000 scale topographical model and the 1:400 scale model as shown in Equation (2).

$$F = \left[\frac{\overline{u}_z}{\overline{u}_{500,open}}\right]_{1:4000} \left[\frac{\overline{u}_{ref}}{\overline{u}_z}\right]_{1:400} \qquad (2)$$

where:

$\bar{u}_z$ = mean wind speed measured at a height z (i.e. where z is equivalent to 50 mPD, 100 mPD and 150 mPD respectively at prototype scale);

$\bar{u}_{ref}$ = the mean wind speed measured at the reference height (z_{ref}) in the 1:400 scale tests, taken as 300 mPD for this study; and

$\bar{u}_{500,open}$ = directional mean wind speed at 500 mPD above open terrain.

The wind speed scaling factors presented in Table 2 for each of the 16 measured wind directions were determined as an average from the wind speeds measured in the 1:4000 and 1:400 scale tests at 50 mPD, 100 mPD and 150 mPD.

4.2 Physical Model of the Project Area and Assessment Area

A 1:400 scale model of the Ex-North Point Estate Site was tested in the WWTF's high speed test section, as shown for the various illustrative views in Figures 10a to 10d. The test model included all known existing and proposed buildings, structures and topographical features within a radius of approximately 600 m from the centre of the Project Area, and was fabricated to represent the state of the urban areas corresponding to the information supplied by PlanD at the commencement of this AVA study. All existing trees on site were modelled with foliage and in a mature growth state in accordance with information supplied by PlanD on 6 March 2008.

The model was installed with a total of 130 sensors at a height equivalent to approximately 2 m above the local ground level to measure pedestrian level mean wind speeds at various locations within the Project Area and Assessment Area only, no test points are placed within the Surrounding Area. As shown in Figure 11, the locations of the sensors in the 1:400 scale model were positioned at test points within and along the boundary of the Project Area, at the junctions of all roads leading to the Project Area, at main entrances and at corners of the Project Area. Test points were also located in open spaces, on the streets and in areas of expected frequent pedestrian access.

5. EXPERIMENTAL AND ANALYSIS PROCEDURES

5.1 Wind Tunnel Model Testing

Detailed wind tunnel model tests were conducted in the WWTF's high speed test section using a 1:400 scale model of the Ex-North Point Estate Site and surrounds. Wind speeds were measured at a total of 130 test points, as shown in Figure 11, for 16 wind directions ranging from 22.5° to 360° (i.e. north) at increments of 22.5° using a multi-channel thermal anemometer. In general, measurements were taken at a height of approximately 2 m above ground level at prototype scale, i.e. 5 mm at model scale.

The 130 test points used for this study were categorised as one of three types: perimeter test points, overall test points and elevated test points. Perimeter test points are positioned along the boundary of the Ex-North Point Estate Site to assess the "immediate" effect of the proposed development on the Assessment Area. A total of 25 perimeter test points were tested. The locations of the perimeter test points were selected based on the layout of the Project Area, taking into account the need to locate test points at the junctions of all roads leading to the site, at main entrances to, and at corners of, the Project Area. This group of perimeter test points were used to calculate the site spatial average velocity ratio (SVR).

Overall test points were evenly distributed and positioned in open spaces, on the streets and public places within the building site and the Assessment Area that are likely to be frequented by pedestrians. A total of 96 overall test points were tested. Measurements taken at the overall test points and perimeter test points were grouped and used to calculate the spatial average velocity ratio (SAVR) for each of the nominated zones discussed below.

Elevated test points were located on the two podia inside the Ex-North Point Estate Site and in relatively exposed positions above the North Point Ferry Piers to serve as reference points. The elevated test points are not included in the determination of spatial average velocity ratios. A total of 9 elevated test points were used in the current study.

For the convenience of data analysis and the discussion of results, the Project Area, designated as Zone A for this study, was subdivided into three zones: a western part that is located between Tong Shui Road and Shu Kuk Street, a central part that is located between Shu Kuk Street and Kam Hong Street, and an eastern part that is located between Kam Hong Street and Tin Chiu Street.

At the request of PlanD, the Assessment Area was divided into a further five zones, that are designated as Zones B, C, D, E and F in Figure 11, and the four main north-south roads in the Assessment Area, namely Tong Shui Road, Shu Kuk Street, Kam Hong Street and Tin Chiu Street were also considered separately. Zone B covers the part of the Assessment Area west of Tong Shui Road, extending from the harbour-front to King's Road in the south. Zone C covers the area to the south of the western part of the Project Area and is bounded by North Point Estate Lane in the north, King's Road in the south, Tong Shui Road in the west and Shu Kuk Street in the east. Zone D covers the area to the south of the central part of the Project Area and is bounded by Java Road in the north, King's Road in the south, Shu Kuk Street in the west and Kam Hong Street in the east. Zone E covers the area to the south of the eastern part of the Project Area and is bounded by Java Road in the north, King's Road in the south, Kam Hong Street in the west and Tin Chiu Street in the east. Zone F covers the part of the Assessment Area east of Tin Chiu Street, extending from the harbour-front to King's Road in the south and which includes the North Point Vehicular Ferry toll gate and nearby playgrounds.

5.2 Wind Speed Measurements and Analysis Procedures

5.2.1 Determining Directional and Overall Wind Velocity Ratios

Wind speeds at each test point were measured using a multi-channel thermal anemometer whose signals were sampled using a dedicated computer for a period corresponding to approximately one hour at prototype scale. The measurements were used to determine the mean wind speed at each test point and subsequently related to approaching upper level wind speeds as a directional wind velocity ratio ($VR_{500,i,j}$).

At a particular wind direction (i), the directional wind velocity ratio of the j-th test point is defined as:

$$VR_{500,i,j} = \frac{V_{p,i,j}}{V_{500,i}} \qquad (3)$$

where $V_{p,i,j}$ is the wind velocity at pedestrian level (i.e. measured at 2 m above ground at each test point and under the influence of buildings and other urban features) and $V_{500,i}$ is the wind velocity at an elevation of 500 mPD above the study site for the wind direction (i). Directional wind velocity ratios were measured at 22.5° intervals for the full 360° azimuth (i.e. 16 wind directions) for each test point and are used as an indicator of the wind characteristics in each of the ten studied zones.

The overall wind velocity ratio of the j-th test point ($VR_{w,j}$) is defined in Equation (4), which accounts for the probability of occurrence (p_i) of winds approaching the Ex-North Point Estate Site study area from each of the 16 measured wind directions.

$$VR_{w,j} = \sum_{i=1}^{16} p_i \times VR_{500,i,j} \qquad (4)$$

5.2.2 Definition of Site Spatial Average Velocity Ratio

Site spatial average velocity ratio (SVR), defined as the spatial average of the $VR_{w,j}$ of all perimeter test points, as expressed in Equation (5), was determined for Zone A, i.e. the Project Area. The SVR accounts for the air ventilation effects of the Project Area on the immediate surrounding area.

$$SVR = \sum_{j=1}^{M} \frac{VR_{w,j}}{M} \qquad (5)$$

Where M is the total number of perimeter test points, of which there are 25 in the Project Area in this study.

5.2.3 Definition of Local Spatial Average Velocity Ratio

The local spatial average velocity ratio (LVR), defined as the spatial average of the $VR_{w,j}$ of all perimeter test points and overall test points, but excluding elevated and special test points, is defined in Equation (6).

$$LVR = \sum_{j=1}^{N} \frac{VR_{w,j}}{N} \qquad (6)$$

Where N is the total number of test points within the Project Area and Assessment Area, including perimeter test points but excluding elevated and special test points.

5.2.4 Definition of Spatial Average Velocity Ratio for the Nominated Zones

The spatial average velocity ratio (SAVR) for a nominated zone, defined as the spatial average of the $VR_{w,j}$ of all perimeter test points and overall test points relevant to that zone, is defined in Equation (7).

$$SAVR = \sum_{j=1}^{n} \frac{VR_{w,j}}{n} \quad (7)$$

Where n is the total number of test points relevant to a particular zone, including perimeter test points but excluding elevated test points.

5.2.5 Calculating the Mean Wind Speed

Thermal anemometer signals were sampled using a dedicated computer for a period corresponding to approximately one hour at prototype scale at each test point. In the test, two wind speed quantities were measured, one being $V_{p,i,j}$, which is the measured pedestrian level mean wind speed in m/s for the 130 test points, and the other being $V_{300,i}$, which is the reference mean wind speed at a height equivalent to 300 mPD at prototype scale.

The measured local mean wind speeds were then transformed into wind speeds for the site by using appropriate wind speed scaling factors with the cumulative probability distribution based on the measurements of mean wind speed and direction taken by the Hong Kong Observatory at Waglan Island. These wind speeds were then subsequently integrated with annual, summer or winter months wind roses determined for the Ex-North Point Estate Site, corrected to a height of 300 mPD, in order to determine the mean wind speed at pedestrian level ($V_{p,i,j}$) corresponding to a probability of exceedance of 50% on an annual basis or a probability of exceedance of 50% in the summer months (June, July, August) or the winter months (December, January, February) only.

6. EXPERIMENTAL RESULTS AND DISCUSSION

6.1 Site Spatial Average Velocity Ratio Results

Site spatial average velocity ratios (SVR) were determined for the Project Area (Zone A) in order to quantify the air ventilation effects of the proposed development at Ex-North Point Estate Site on its immediate surrounding areas. The annual, summer and winter site wind velocity ratios for the Ex-North Point Estate Site are 0.16, 0.11 and 0.20 respectively.

6.2 Local Spatial Average Velocity Ratio Results

The annual, summer and winter local spatial average velocity ratios (LVR) for the Ex-North Point Estate Site, excluding elevated test points, are 0.16, 0.12 and 0.20 respectively.

6.3 Spatial Average Velocity Ratio Results for the Nominated Zones

Spatial average velocity ratios (SAVR) were determined for each of the nominated zones and streets. The annual SAVR for Zones A, B, C, D, E and F in the Ex-North Point Estate Site study area are 0.17, 0.17, 0.14, 0.11, 0.17 and 0.17 respectively. The summer SAVR for Zones A, B, C, D, E and F in the Ex-North Point Estate Site study area are 0.11, 0.12, 0.10, 0.09, 0.11 and 0.12 respectively. The winter SAVR for Zones A, B, C, D, E and F in the Ex-North Point Estate Site are 0.21, 0.21, 0.18, 0.13, 0.22 and 0.21 respectively.

The annual SAVR for Tong Shui Road, Shu Kuk Street, Kam Hong Street and Tin Chiu Street are 0.17, 0.17, 0.16 and 0.20 respectively. The summer SAVR for Tong Shui Road, Shu Kuk Street, Kam Hong Street and Tin Chiu Street are 0.13, 0.13, 0.13 and 0.13 respectively. The winter SAVR for Tong Shui Road, Shu Kuk Street, Kam Hong Street and Tin Chiu Street are 0.22, 0.22, 0.20 and 0.25 respectively.

The annual SAVR for the western part, central part and eastern part of the Project Area (Zone A) are 0.18, 0.14 and 0.18 respectively. The summer SAVR for the western part, central part and eastern part of the Project Area are 0.11, 0.09 and 0.12 respectively. The winter SAVR for the western part, central part and eastern part of the Project Area are 0.22, 0.18 and 0.23 respectively.

The annual, summer and winter SAVR for all pedestrian level test points in the Assessment Area are 0.16, 0.11 and 0.20, respectively.

6.4 Overall Wind Velocity Ratio Results

The annual, summer and winter overall wind velocity ratios of each individual test point are presented graphically in Figures 12, 13 and 14, respectively. Directional wind velocity ratios ($VR_{500i,j}$) are presented in Tables B1 to B6 of Appendix B for all test points located in Zones A, B, C, D, E and F respectively and Table B7 for the elevated test points. Directional wind velocity ratios are presented in Tables B8, B9, B10 and B11 for Tong Shui Road, Shu Kuk Street, Kam Hong Street and Tin Chiu Street respectively. Directional wind velocity ratios are presented in Tables B12, B13 and B14 for the western part, central part and eastern part of the Project Area (Zone A).

6.4.1 Perimeter Test Points

The annual, summer and winter overall wind velocity ratios ($VR_{w,j}$) of the perimeter test points for the Project Area are presented in Table 3.

Among the perimeter test points, the largest annual $VR_{w,j}$ was measured at test point S13 (0.25_{annual} / 0.18_{summer} / 0.30_{winter}) that is located at the ingress/egress of the hotel development. Relatively large directional wind velocity ratios at test point S13 were determined for winds from 0° to 67.5° inclusive. Similar $VR_{w,j}$ were also measured at test point S39 (0.20_{annual} / 0.15_{summer} / 0.30_{winter}), which is also attributed to the large directional wind velocity ratios for winds from 0° to 67.5° inclusive due to the exposure of test point S39 to winds from those directions. The lowest annual, summer and winter $VR_{w,j}$ was recorded at test point S20 (0.06_{annual} / 0.05_{summer} / 0.07_{winter}), which is located immediately behind the 35 mPD podium structure alongside Java Road. Other test points with relatively low $VR_{w,j}$ include S03 (0.12_{annual} / 0.07_{summer} / 0.16_{winter}), S21 (0.08_{annual} / 0.07_{summer} / 0.10_{winter}) and S30 (0.11_{annual} / 0.09_{summer} / 0.13_{winter}), each of which are located on the southern boundary of the Project Area and each of which are shielded from the prevailing wind directions by buildings and podia in the Project Area.

6.4.2 Overall Test Points

Annual, summer and winter overall velocity ratios ($VR_{w,j}$) are presented in Tables 4, 5 and 6 for the western part, central part and eastern part of the Project Area (Zone A). For the Assessment Area, annual, summer and winter overall velocity ratios for the overall test points in the Ex-North Point Estate Site are presented in Tables 7, 8, 9, 10, 11and 12 for Zones A, B, C, D, E and F respectively. Similarly, annual, summer and winter overall velocity ratios are presented in Tables 13, 14, 15 and 16 for Tong Shui Road, Shu Kuk Street, Kam Hong Street and Tin Chiu Street respectively.

6.4.2.1 Zone A – Project Area

SAVR for Zone A, i.e. the Project Area, (0.17_{annual} / 0.11_{summer} / 0.21_{winter}) are of similar magnitude to the LVR. A comparison of SAVR for the western part (0.18_{annual} / 0.11_{summer} / 0.22_{winter}), central part (0.14_{annual} / 0.09_{summer} / 0.18_{winter}) and eastern part (0.18_{annual} / 0.12_{summer} / 0.23_{winter}) in Zone A highlights that the large podium in the central part presents a significant obstacle to winds at test points nearby.

For Zone A, relatively high annual $VR_{w,j}$ were measured at test point S40 (0.25_{annual} / 0.17_{summer} / 0.31_{winter}), located in the public open space of the eastern part between the 36 mPD non-domestic block and the eastern 73 mPD residential tower, which is due to the exposure of that location to winds from 0° to 67.5° inclusive and the interaction of those winds with the adjacent buildings. Test point S40 is likely to experience windy conditions in the winter months. The diminishing penetration of winds from 0° to 67.5° inclusive into the Project Area is reflected by the declining $VR_{w,j}$ magnitudes as one moves west from test point S40 to test points S36 (0.18_{annual} / 0.10_{summer} / 0.23_{winter}) and S33 (0.17_{annual} / 0.10_{summer} / 0.22_{winter}), which is likely to be due to the effects of both the non-domestic block and the residential towers. However, test points S36 and S33 have annual $VR_{w,j}$ that are typical of Zone A indicating that wind conditions at those locations are likely to be similar to those throughout the zone. Relatively low $VR_{w,j}$ were recorded at test point S18 (0.11_{annual} / 0.06_{summer} / 0.14_{winter}), which is located to the west of the 80 mPD residential towers and podium in the central part of the Project Area and hence is shielded from the prevailing winds.

6.4.2.2 Zone B

The highest annual, summer and winter $VR_{w,j}$ were recorded in Zone B, i.e. the area located to the west of the Project Area. Test points A04 (0.32_{annual} / 0.18_{summer} / 0.43_{winter}) and A05 (0.24_{annual} / 0.17_{summer} / 0.29_{winter}) are located in Wharf Road and wind conditions at those locations are evidently enhanced by the surrounding tall buildings, with large directional wind velocity ratios measured for winds from the north-east quadrant. This contributed to the corresponding SAVR for Zone B (0.17_{annual} / 0.12_{summer} / 0.21_{winter}) being greater than the LVR (0.16_{annual} / 0.11_{summer} / 0.20_{winter}). Both locations are likely to experience windy conditions during periods of strong north-easterly monsoon winds during the winter months.

Relatively low $VR_{w,j}$ were measured at test points A15 (0.09_{annual} / 0.07_{summer} / 0.10_{winter}) and A16 (0.11_{annual} / 0.07_{summer} / 0.14_{winter}). These test points are located in Chun Yeung Street behind a row of four proposed buildings and podia that evidently inhibit the penetration of the prevailing winds into this area.

By comparing the $VR_{w,j}$ at test points A01 (0.20_{annual} / 0.11_{summer} / 0.26_{winter}), A04 (0.32_{annual} / 0.18_{summer} / 0.43_{winter}), A05 (0.24_{annual} / 0.17_{summer} / 0.29_{winter}) and A06 (0.21_{annual} / 0.13_{summer} / 0.26_{winter}) in the north of Zone B with those in the south of Zone B, such as A21 (0.12_{annual} / 0.16_{summer} / 0.10_{winter}), A22 (0.13_{annual} / 0.16_{summer} / 0.13_{winter}) and A23 (0.09_{annual} / 0.13_{summer} / 0.07_{winter}), it is apparent that the penetration of winds diminishes as one moves away from the harbour-front. This is mainly attributed to the cumulative shielding effects of buildings located on east-west oriented streets, such as Wharf Road, Java Road and Chun Yeung Street.

6.4.2.3 Zone C

The SAVR for Zone C (0.14_{annual} / 0.10_{summer} / 0.18_{winter}), i.e. the area located to the south of the western part of the Project Area, are noticeably lower than the LVR (0.16_{annual} / 0.11_{summer} / 0.20_{winter}).

The lowest annual and winter $VR_{w,j}$ in Zone C were measured at test point A28 (0.09_{annual} / 0.12_{summer} / 0.09_{winter}), located on King’s Road, due to the shielding of this location from the prevailing north-east winds by nearby buildings. The lowest summer $VR_{w,j}$ in Zone C were measured at test points A35 (0.12_{annual} / 0.05_{summer} / 0.18_{winter}), A37 (0.13_{annual} / 0.06_{summer} / 0.19_{winter}) and A39 (0.12_{annual} / 0.06_{summer} / 0.16_{winter}). The directional wind velocity ratios for these test points indicated that winds from the north-east quadrant were moderated by the surrounding buildings, which for test point A39 includes the proposed hotel buildings in the Project Area, while winds from southerly directions were moderated by the surrounding topography and built environment.

Relatively high $VR_{w,j}$ in Zone C were measured at test points located along Marble Road (test points A32, A33 and A34). These effects are attributed to the effects of northerly winds being accelerated between the proposed towers on Java Road and Marble Road that are outside of the Project Area.

6.4.2.4 Zone D

The SAVR for Zone D (0.11_{annual} / 0.09_{summer} / 0.13_{winter}), i.e. the area located to the south of the central part of the Project Area, are the lowest of the functional areas considered for this study. This is attributed to the effects of the large obstruction presented by the proposed 25 mPD and 30 mPD podia in the Project Area to the prevailing north-east winds and other existing buildings in the streets in the south of Zone D.

The lowest annual and winter $VR_{w,j}$ in Zone D were measured at test points A52 (0.08_{annual} / 0.06_{summer} / 0.10_{winter}), located on Java Road immediately to the south of the proposed podium in the Project Area; A42 (0.08_{annual} / 0.09_{summer} / 0.07_{winter}) and A50 (0.08_{annual} / 0.05_{summer} / 0.14_{winter}), located in Marble Road; and A45 (0.08_{annual} / 0.09_{summer} / 0.07_{winter}), located in King's Road. In general, low summer $VR_{w,j}$ were measured in Zone D, and in particular at test points A40 (0.10_{annual} / 0.04_{summer} / 0.14_{winter}) and A53 (0.12_{annual} / 0.07_{summer} / 0.15_{winter}), located on Java Road; and test points A50 (0.08_{annual} / 0.05_{summer} / 0.09_{winter}) and A51 (0.11_{annual} / 0.07_{summer} / 0.14_{winter}), located on Marble Road.

The highest annual, summer and winter $VR_{w,j}$ in Zone D were measured at test point A48 (0.18_{annual} / 0.15_{summer} / 0.21_{winter}), located on King's Road.

6.4.2.5 Zone E

The SAVR for Zone E (0.17_{annual} / 0.11_{summer} / 0.22_{winter}), i.e. the area located to the south of the eastern part of the Project Area, are similar to the LVR and relatively consistent across the Zone.

The lowest annual, summer and winter $VR_{w,j}$ in Zone E were measured at test point A60 (0.11_{annual} / 0.07_{summer} / 0.13_{winter}), located on King's Road. Wind conditions at that location are mainly attributed to localised shielding effects, caused by nearby buildings on King's Road, for the majority of the measured wind directions.

The highest annual, summer and winter $VR_{w,j}$ in Zone E were measured at test point A66 (0.21_{annual} / 0.15_{summer} / 0.26_{winter}), located in the open space of a playground between Java Road and Marble Road.

6.4.2.6 Zone F

The SAVR for Zone F (0.17_{annual} / 0.12_{summer} / 0.21_{winter}), i.e. the area located to the south of the eastern part of the Project Area, are similar to the LVR. The variation of $VR_{w,j}$ of the test points in Zone F highlights the localised effects of the various structures and open spaces within this area. Evidently, the proposed development has no significant influence on wind conditions in Zone F.

The lowest annual, summer and winter $VR_{w,j}$ in Zone F were measured at test point A74 (0.13_{annual} / 0.09_{summer} / 0.15_{winter}), located on Java Road to the north of a relatively isolated proposed highrise development that quite clearly dominates wind conditions at that location. In contrast, the highest annual and winter $VR_{w,j}$ in Zone F were measured at test point A75 (0.21_{annual} / 0.15_{summer} / 0.27_{winter}), located in relatively open space to the east of the proposed highrise development.

6.4.2.7 Tong Shui Road

The SAVR for Tong Shui Road (0.17_{annual} / 0.13_{summer} / 0.22_{winter}) are similar to the LVR for the Assessment Area.

The lowest annual and winter $VR_{w,j}$ on Tong Shui Road were measured at test point A26 (0.13_{annual} / 0.13_{summer} / 0.15_{winter}), that is located in the vicinity of the junction of Tong Shui Road and King's Road and which is sheltered from winds from the north-east quadrant by an adjacent building. The lowest summer $VR_{w,j}$ were measured at test point A03 (0.15_{annual} / 0.09_{summer} / 0.19_{winter}), located adjacent to the elevated roadway at the northern end of Tong Shui Road.

The highest annual and winter $VR_{w,j}$ on Tong Shui Road were measured at test point A07 (0.20_{annual} / 0.11_{summer} / 0.26_{winter}), located adjacent to the western part of the Project Area, and the highest summer $VR_{w,j}$ were measured at test point A25 (0.19_{annual} / 0.19_{summer} / 0.21_{winter}), located at the junction of Tong Shui Road and King's Road.

Evidently, the elevated roadway, footbridge and buildings create localised wind effects at the various test locations. Nevertheless, the relatively consistent magnitudes of $VR_{w,j}$ at a number of locations along Tong Shui Road, such as A12 (0.17_{annual} / 0.10_{summer} / 0.23_{winter}), A18 (0.17_{annual} / 0.13_{summer} / 0.21_{winter}) and A24 (0.17_{annual} / 0.16_{summer} / 0.28_{winter}) demonstrates the ability of Tong Shui Road to allow winds to penetrate into the built environment.

6.4.2.8 Shu Kuk Street

The SAVR for Shu Kuk Street (0.17_{annual} / 0.13_{summer} / 0.22_{winter}) are similar to the LVR for the Assessment Area.

The consistency of $VR_{w,j}$ measured at test points A41 (0.19_{annual} / 0.13_{summer} / 0.25_{winter}), A43 (0.19_{annual} / 0.13_{summer} / 0.24_{winter}) and A44 (0.18_{annual} / 0.14_{summer} / 0.23_{winter}) demonstrates the ability of Shu Kuk Street to serve as a breezeway by which the prevailing winds, particularly those from the north-east quadrant, may be conveyed into the Assessment Area. In contrast, $VR_{w,j}$ measured at test point A30 (0.12_{annual} / 0.11_{summer} / 0.15_{winter}), located at the southern end of Shu Kuk Street, were significantly lower in magnitude than those measured at test points A41, A43 and A44. The magnitude of $VR_{w,j}$ measured at test point A30 are similar to those measured at nearby test points A45, A46 and A47 on King's Road in Zone D and those wind conditions are mainly attributed to the effects of the large buildings lining King's Road to the west and east of the junction with Shu Kuk Street.

6.4.2.9 Kam Hong Street

Although the SAVR for Kam Hong Street (0.16_{annual} / 0.13_{summer} / 0.20_{winter}) are similar to the LVR, $VR_{w,j}$ at the northern end of the street, i.e. at test points A54 (0.19_{annual} / 0.15_{summer} / 0.24_{winter}) and A55 (0.21_{annual} / 0.15_{summer} / 0.26_{winter}), are significantly larger than those for the three test points, i.e. A56 (0.14_{annual} / 0.10_{summer} / 0.18_{winter}), A57 (0.13_{annual} / 0.11_{summer} / 0.16_{winter})and A58 (0.13_{annual} / 0.12_{summer} / 0.15_{winter}), located to the south of Marble Road. The diminished $VR_{w,j}$ at the southern end of Kam Hong Street are likely to be caused by adjacent existing and proposed buildings rather than the proposed ex-North Point Estate development.

6.4.2.10 Tin Chiu Street

Relatively high $VR_{w,j}$ were measured at test points A73 (0.21_{annual} / 0.14_{summer} / 0.27_{winter}), A76 (0.22_{annual} / 0.14_{summer} / 0.30_{winter}), A77 (0.21_{annual} / 0.15_{summer} / 0.27_{winter}) and A78 (0.25_{annual} / 0.18_{summer} / 0.31_{winter}) highlighting the ability of Tin Chiu Street to serve as an air path by which the prevailing winds may be conveyed to the built environment beyond. The relatively high winter $VR_{w,j}$ at test points A76 (0.30) and A78 (0.31) also indicate that windy conditions are likely along Tin Chiu Street during periods of strong winter monsoon winds.

6.4.3 Elevated Test Points

The overall wind velocity ratios ($VR_{w,j}$) of the elevated test points are presented in Table 17. Seven of the elevated test points (S09, S10, S22, S23, S27, S29 and S42) are located on top of podia or buildings within the Project Area. Two further elevated test points (A87 and A88) were located above the North Point Ferry Piers.

Due to their exposed locations, annual, summer and winter $VR_{w,j}$ at test points A87 (0.32_{annual} / 0.26_{summer} / 0.36_{winter}) and A88 (0.30_{annual} / 0.24_{summer} / 0.33_{winter}) provide a useful reference against which the $VR_{w,j}$ at other test points can be assessed. It is clear that $VR_{w,j}$ for the majority of perimeter and overall test points are significantly less than those for test points A87 and A88. However, the winter $VR_{w,j}$ at test point A04 is comparatively high, although this is not attributed to the proposed development at the Ex-North Point Estate Site. Other test points at which windy winter conditions are indicated include S39, S40, A05, A09, A76 and A78.

In general, relatively low summer $VR_{w,j}$ were recorded at each of the test points at the elevated locations within the Project Area. High annual and winter $VR_{w,j}$ were recorded at test point S29 (0.24_{annual} / 0.11_{summer} / 0.34_{winter}) indicating that windy conditions can be expected at that location during periods of strong winter monsoons. In contrast, winter monsoonal winds are likely to cause windy conditions at most of the elevated locations tested in the current study, and in particular between the two proposed hotel buildings (test points S09 and S10) due to channelling effects.

6.5 Annual, Summer and Winter Mean Wind Speeds

The annual, summer and winter average mean wind speeds corresponding to a probability of exceedance of 50% for the Ex-North Point Estate Site are 1.16, 0.54 and 1.58 m/s respectively. Annual, summer and winter mean wind speeds corresponding to a probability of exceedance of 50% at each test point are presented in Appendix C.

7. RECOMMENDED AMELIORATION MEASURES

The results of the detailed AVA study support the assessment of the Expert Evaluation that the large podia proposed for the hotel development and the residential towers at the Ex-North Point Estate Site present a significant obstacle to the prevailing winds penetrating nearby areas, resulting in low wind velocity ratios at locations in Java Road and North Point Estate Lane to the south of the podia. Although the effects of those structures are quite localised, the magnitudes of the wind velocity ratios in these affected areas are approximately half of that for similar locations to the east of the podia in Java Road and are likely to create undesirable regions of low wind flow. To address these effects, it is recommended to reduce the size, height and solidity of the large podium structure which accommodates the Public Transport Terminus.

While the towers of the proposed development did not have a significant impact on wind conditions in the Assessment Area, it is evident that their height, shape, location and orientation are not particularly effective in enhancing wind conditions in the Project Area and its immediate surrounds. Further benefits to pedestrian level wind conditions may be realised through the appropriate utilisation of increased building height to capture and convey upper level winds to pedestrian level and/or through the modification of the shapes of the buildings and podia in the Project Area. However, it is noted that further studies would be required to optimise these building parameters and their effects and, furthermore, that the suitability of various building forms may ultimately depend on other factors that are beyond the scope of this AVA study.

Relatively high wind velocity ratios were measured towards the eastern part of the Project Area, and the magnitude of the measured wind velocity ratios generally decreased towards the central and western parts of the Project Area. As the strong wind effects in the eastern part are relatively local, the inclusion of trees in this region may provide some shelter from strong north-easterly winds that typically occur in the winter months.

High wind velocity ratios corresponding to winter winds were also measured at elevated locations on the podium between the hotel towers in the western part of the Project Area and on the podium to the east of the residential towers in the central part of the Project Area. If these areas are eventually able to be accessed by pedestrians, it is recommended that some forms of porous windbreak, such as mature trees, or demountable wind breaks, be implemented to provide shelter from strong winter winds without significantly diminishing desirable winds at other times of the year.

A region of high wind velocity ratios was identified along Wharf Road to the west of the Project Area that was attributed to the effects of nearby tall buildings and not the proposed development. Relatively high wind velocity ratios were also measured at several locations along Tin Chiu Street adjacent to a playground and a proposed tall building, approximately 140 m high, between Java Road and Marble Road. The characteristics of Tin Chiu Street in this region, i.e. a mixture of relatively open spaces and buildings with mixed heights, allows it to act as an effective air path in the study area by which the prevailing winds may be conveyed to the Assessment Area. Therefore, it is recommended that spacings between the proposed buildings in the Project Area are retained or enhanced, particularly for roads with north-south orientations, to provide effective air paths by which the prevailing winds have the potential to penetrate the built environment beyond the Project Area.

Relatively low wind velocity ratios were commonly measured in east-west oriented roads, such as Java Road, Marble Road and King's Road. These conditions are mainly attributed to existing or other proposed buildings outside of the Project Area and demonstrate the detrimental effects that a large number of closely spaced tall buildings of similar height may have on the pedestrian level wind environment.

8. CONCLUSIONS

A brief Expert Evaluation and a 1:400 scale model study of an instructed project at the Ex-North Point Estate Site was undertaken by the CLP Wind Wave Tunnel Facility at The Hong Kong University of Science and Technology. The wind tunnel study was conducted to assess the air ventilation impacts of the Initial Design Scheme on a prescribed Assessment Area.

Wind speeds were measured at a total of 130 test points, including nine elevated test points, for 16 wind directions ranging from 22.5° to 360° (north) at increments of 22.5° using a multi-channel thermal anemometer. Wind tunnel test results were used in conjunction with the results of a wind tunnel topographical model study previously conducted by others for a proposed development at the Oil Street site, North Point (CH2M Hill Hong Kong Limited, March 2008), as provided by PlanD, and WWTF's statistical model of the Hong Kong non-typhoon wind climate, based on measurements of wind speed and direction taken by Hong Kong Observatory (HKO) at Waglan Island.

The annual, summer and winter site spatial average velocity ratios (SVR) for the Ex-North Point Estate Site are 0.16, 0.11 and 0.20 respectively. The annual, summer and winter local spatial average wind velocity ratios (LVR) for all pedestrian level test points are 0.16, 0.12 and 0.20 respectively. The annual, summer and winter average mean wind speeds corresponding to a probability of exceedance of 50% for the Ex-North Point Estate Site study area are 1.16, 0.54 and 1.58 m/s respectively.

The large podia proposed for the hotel development and the residential towers at the Ex-North Point Estate Site present a significant obstacle to the prevailing winds penetrating nearby areas, resulting in low wind velocity ratios at locations in the Project Area and on Java Road and North Point Estate Lane to the south of the podia, where undesirable regions of low wind flow are likely. Relatively high wind velocity ratios were measured towards the eastern end of the Project Area, and the magnitude of the measured wind velocity ratios generally decreased towards the central and western parts of the Project Area.

Major north-south oriented streets may provide effective air paths by which the prevailing winds can penetrate the built environment beyond the Project Area, and it is recommended that spacings between the proposed buildings in the Project Area are retained or enhanced to facilitate this. Relatively low wind velocity ratios were commonly measured in east-west oriented roads that were mainly attributed to existing or other proposed buildings outside of the Project Area. These low wind conditions demonstrated the detrimental effects that a large number of closely spaced tall buildings of similar height may have on the pedestrian level wind environment.

9. REFERENCES

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Table 1: Directional approach wind conditions

Wind Angle (°)	Approach Condition	Wind Angle (°)	Approach Condition
22.5	A	202.5	C
45	B	225	C
67.5	A	247.5	C
90	C	270	A
112.5	B	292.5	A
135	B	315	B
157.5	B	337.5	A
180	C	0, 360	A

Table 2: Wind speed scaling factors for the Ex-North Point Estate Site study area

Wind Direction	Wind Angle (°)	Scaling Factor (F)
North	0 or 360	0.87
North-north-east	22.5	0.68
North-east	45	0.65
East-north-east	67.5	0.64
East	90	0.61
East-south-east	112.5	0.60
South-east	135	0.67
South-south-east	157.5	0.78
South	180	0.67
South-south-west	202.5	0.45
South-west	225	0.56
West-south-west	247.5	0.82
West	270	0.76
West-north-west	292.5	0.65
North-west	315	0.74
North-north-west	337.5	0.69

The wind speed scaling factors (F) are site specific, including effects of local topography, and were determined from Equation (2).

Table 3: Overall wind velocity ratios ($VR_{w,j}$) for the perimeter test points

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
S01	0.17	0.10	0.22
S02	0.19	0.10	0.26
S03	0.12	0.07	0.16
S04	0.17	0.09	0.23
S06	0.21	0.15	0.25
S07	0.16	0.10	0.18
S11	0.16	0.11	0.18
S12	0.20	0.16	0.25
S13	0.25	0.18	0.30
S14	0.15	0.11	0.17
S15	0.15	0.10	0.18
S19	0.17	0.10	0.22
S20	0.06	0.05	0.07
S21	0.08	0.07	0.10
S25	0.17	0.12	0.19
S26	0.19	0.12	0.22
S30	0.11	0.09	0.13
S31	0.18	0.10	0.24
S32	0.16	0.09	0.20
S34	0.15	0.10	0.19
S35	0.15	0.11	0.17
S37	0.18	0.11	0.23
S38	0.19	0.14	0.24
S39	0.20	0.15	0.30
S41	0.17	0.13	0.25
Mean	0.16	0.11	0.20

Table 4: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points
– Zone A, Western Part

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
S01	0.17	0.10	0.22
S02	0.19	0.10	0.26
S03	0.12	0.07	0.16
S04	0.17	0.09	0.23
S05	0.20	0.10	0.26
S06	0.21	0.15	0.25
S07	0.16	0.10	0.18
S08	0.15	0.08	0.19
S11	0.16	0.11	0.18
S12	0.20	0.16	0.25
S13	0.25	0.18	0.30
S14	0.15	0.11	0.17
Mean	0.18	0.11	0.22

Table 5: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points
– Zone A, Central Part

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
S15	0.15	0.10	0.18
S16	0.15	0.10	0.19
S17	0.20	0.10	0.27
S18	0.11	0.06	0.14
S19	0.17	0.10	0.22
S20	0.06	0.05	0.07
S21	0.08	0.07	0.10
S25	0.17	0.12	0.19
S26	0.19	0.12	0.22
S28	0.17	0.09	0.23
S30	0.11	0.09	0.13
S31	0.18	0.10	0.24
Mean	0.14	0.09	0.18

Table 6: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points
– Zone A, Eastern Part

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
S24	0.14	0.08	0.19
S32	0.16	0.09	0.20
S33	0.17	0.10	0.22
S34	0.15	0.10	0.19
S35	0.15	0.11	0.17
S36	0.18	0.10	0.23
S37	0.18	0.11	0.23
S38	0.19	0.14	0.24
S39	0.20	0.15	0.30
S40	0.25	0.17	0.31
S41	0.17	0.13	0.25
Mean	0.18	0.12	0.23

Table 7: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points – Zone A

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
S01	0.17	0.10	0.22
S02	0.19	0.10	0.26
S03	0.12	0.07	0.16
S04	0.17	0.09	0.23
S05	0.20	0.10	0.26
S06	0.21	0.15	0.25
S07	0.16	0.10	0.18
S08	0.15	0.08	0.19
S11	0.16	0.11	0.18
S12	0.20	0.16	0.25
S13	0.25	0.18	0.30
S14	0.15	0.11	0.17
S15	0.15	0.10	0.18
S16	0.15	0.10	0.19
S17	0.20	0.10	0.27
S18	0.11	0.06	0.14
S19	0.17	0.10	0.22
S20	0.06	0.05	0.07
S21	0.08	0.07	0.10
S24	0.14	0.08	0.19
S25	0.17	0.12	0.19
S26	0.19	0.12	0.22
S28	0.17	0.09	0.23
S30	0.11	0.09	0.13
S31	0.18	0.10	0.24
S32	0.16	0.09	0.20
S33	0.17	0.10	0.22
S34	0.15	0.10	0.19
S35	0.15	0.11	0.17
S36	0.18	0.10	0.23
S37	0.18	0.11	0.23
S38	0.19	0.14	0.24
S39	0.20	0.15	0.30
S40	0.25	0.17	0.31
S41	0.17	0.13	0.25
Mean	0.17	0.11	0.21

Table 8: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points – Zone B

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
A1	0.20	0.11	0.26
A2	0.11	0.07	0.14
A4	0.32	0.18	0.43
A5	0.24	0.17	0.29
A6	0.21	0.13	0.26
A8	0.19	0.13	0.25
A9	0.22	0.13	0.29
A15	0.09	0.07	0.10
A16	0.11	0.07	0.14
A21	0.12	0.16	0.10
A22	0.13	0.16	0.13
A23	0.09	0.13	0.07
Mean	0.17	0.12	0.21

Table 9: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points – Zone C

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
A27	0.11	0.11	0.12
A28	0.09	0.12	0.09
A29	0.15	0.13	0.18
A31	0.12	0.08	0.16
A32	0.18	0.10	0.25
A33	0.21	0.14	0.27
A34	0.18	0.10	0.24
A35	0.12	0.05	0.18
A36	0.11	0.07	0.14
A37	0.13	0.06	0.19
A38	0.19	0.17	0.21
A39	0.12	0.06	0.16
Mean	0.14	0.10	0.18

Table 10: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points – Zone D

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
A40	0.10	0.04	0.14
A42	0.08	0.09	0.07
A45	0.08	0.09	0.07
A46	0.11	0.10	0.12
A47	0.13	0.13	0.14
A48	0.18	0.15	0.21
A49	0.14	0.12	0.16
A50	0.08	0.05	0.09
A51	0.11	0.07	0.14
A52	0.08	0.06	0.10
A53	0.12	0.07	0.15
Mean	0.11	0.09	0.13

Table 11: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points – Zone E

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
A59	0.17	0.11	0.22
A60	0.11	0.07	0.13
A61	0.19	0.12	0.23
A62	0.18	0.11	0.24
A63	0.19	0.13	0.25
A64	0.18	0.09	0.24
A65	0.18	0.11	0.22
A66	0.21	0.15	0.26
A86	0.16	0.09	0.22
Mean	0.17	0.11	0.22

Table 12: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points – Zone F

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
A68	0.16	0.11	0.19
A69	0.14	0.10	0.16
A70	0.20	0.14	0.24
A72	0.15	0.11	0.19
A74	0.13	0.09	0.15
A75	0.21	0.15	0.27
A82	0.19	0.12	0.25
A83	0.16	0.09	0.20
A84	0.19	0.16	0.22
A85	0.16	0.11	0.19
Mean	0.17	0.12	0.21

Table 13: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points – Tong Shui Road

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
A3	0.15	0.09	0.19
A7	0.20	0.11	0.26
A10	0.19	0.12	0.25
A11	0.18	0.13	0.22
A12	0.17	0.10	0.23
A13	0.20	0.15	0.24
A14	0.16	0.11	0.21
A17	0.17	0.10	0.23
A18	0.17	0.13	0.21
A19	0.18	0.12	0.24
A20	0.15	0.12	0.19
A24	0.17	0.16	0.18
A25	0.19	0.19	0.21
A26	0.13	0.13	0.15
Mean	0.17	0.13	0.22

Table 14: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points – Shu Kuk Street

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
A30	0.12	0.11	0.15
A41	0.19	0.13	0.25
A43	0.19	0.13	0.24
A44	0.18	0.14	0.23
Mean	0.17	0.13	0.22

Table 15: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points – Kam Hong Street

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
A54	0.19	0.15	0.24
A55	0.21	0.15	0.26
A56	0.14	0.10	0.18
A57	0.13	0.11	0.16
A58	0.13	0.12	0.15
Mean	0.16	0.13	0.20

Table 16: Overall wind velocity ratios ($VR_{w,j}$) for all pedestrian level test points – Tin Chiu Street

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
A67	0.15	0.10	0.18
A71	0.15	0.11	0.18
A73	0.21	0.14	0.27
A76	0.22	0.14	0.30
A77	0.21	0.15	0.27
A78	0.25	0.18	0.31
A79	0.18	0.11	0.24
A80	0.21	0.14	0.26
A81	0.19	0.13	0.25
Mean	0.20	0.13	0.25

Table 17: Overall wind velocity ratios ($VR_{w,j}$) for all elevated test points

Test Point	$VR_{w,j}$ – annual	$VR_{w,j}$ – summer	$VR_{w,j}$ – winter
S09	0.16	0.09	0.23
S10	0.19	0.09	0.27
S22	0.17	0.08	0.24
S23	0.14	0.07	0.18
S27	0.17	0.10	0.22
S29	0.24	0.11	0.34
S42	0.23	0.14	0.27
A87	0.32	0.26	0.36
A88	0.30	0.24	0.33
Mean	0.21	0.13	0.27

Figure 1: Schematic drawing of the Initial Design Scheme for the Project Area of the Ex-North Point Estate Site

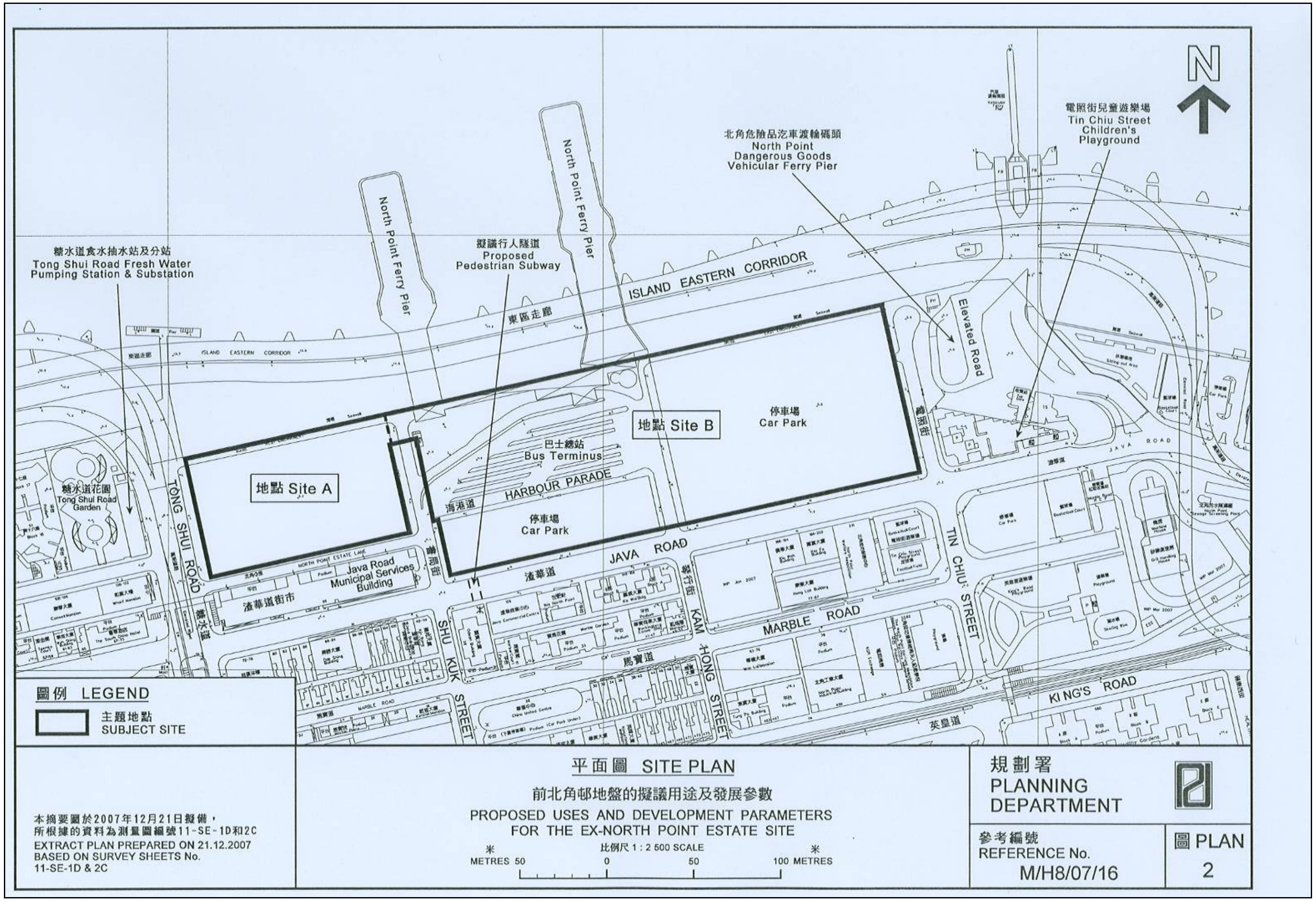


Figure 2: Site Plan for the Project Area of the Ex-North Point Estate Site

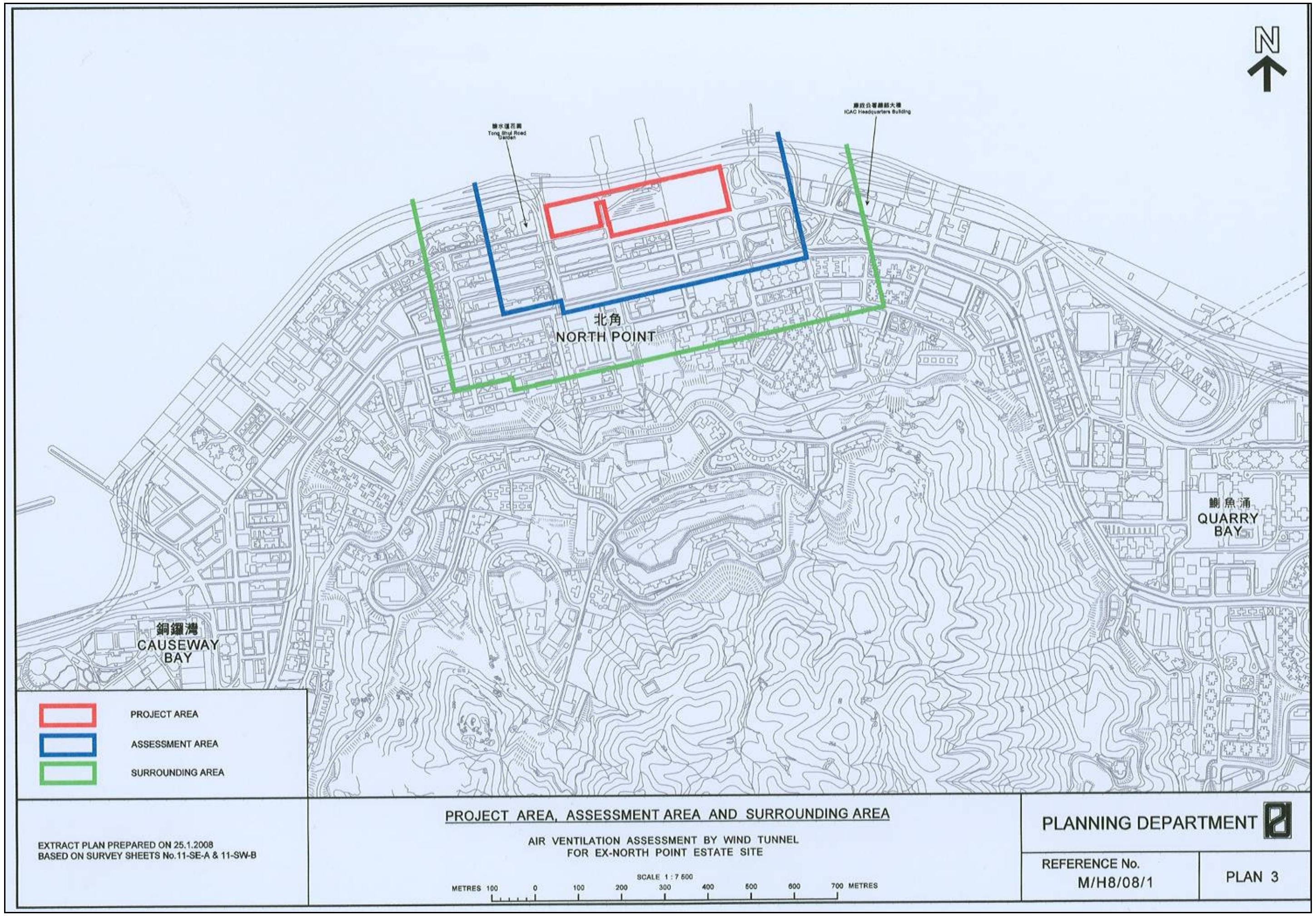


Figure 3: Locations and boundaries of the Project, Assessment and Surrounding Areas of the Ex-North Point Estate Site

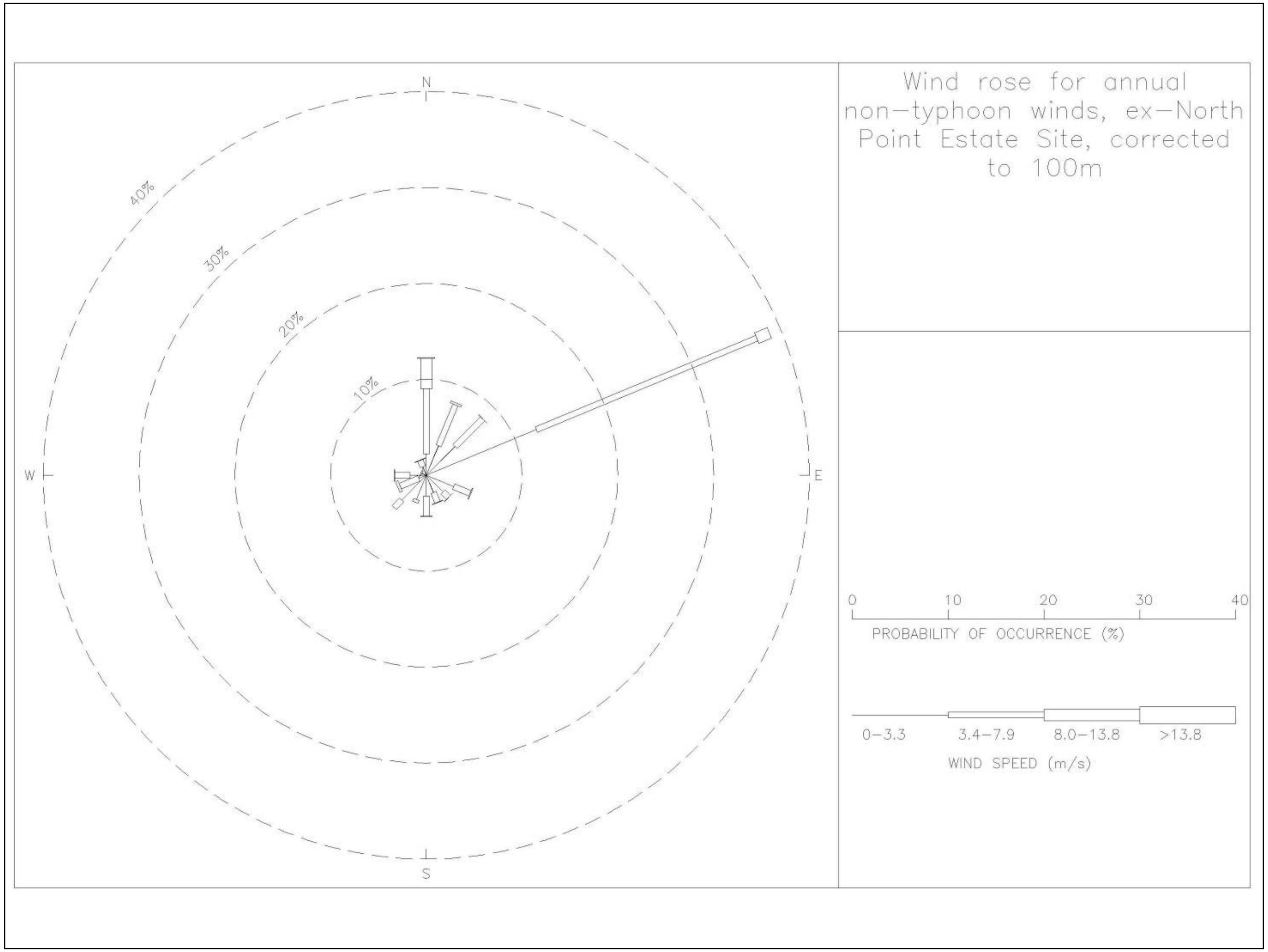


Figure 4: Wind rose for annual non-typhoon winds at the Ex-North Point Estate Site corrected to 100 m

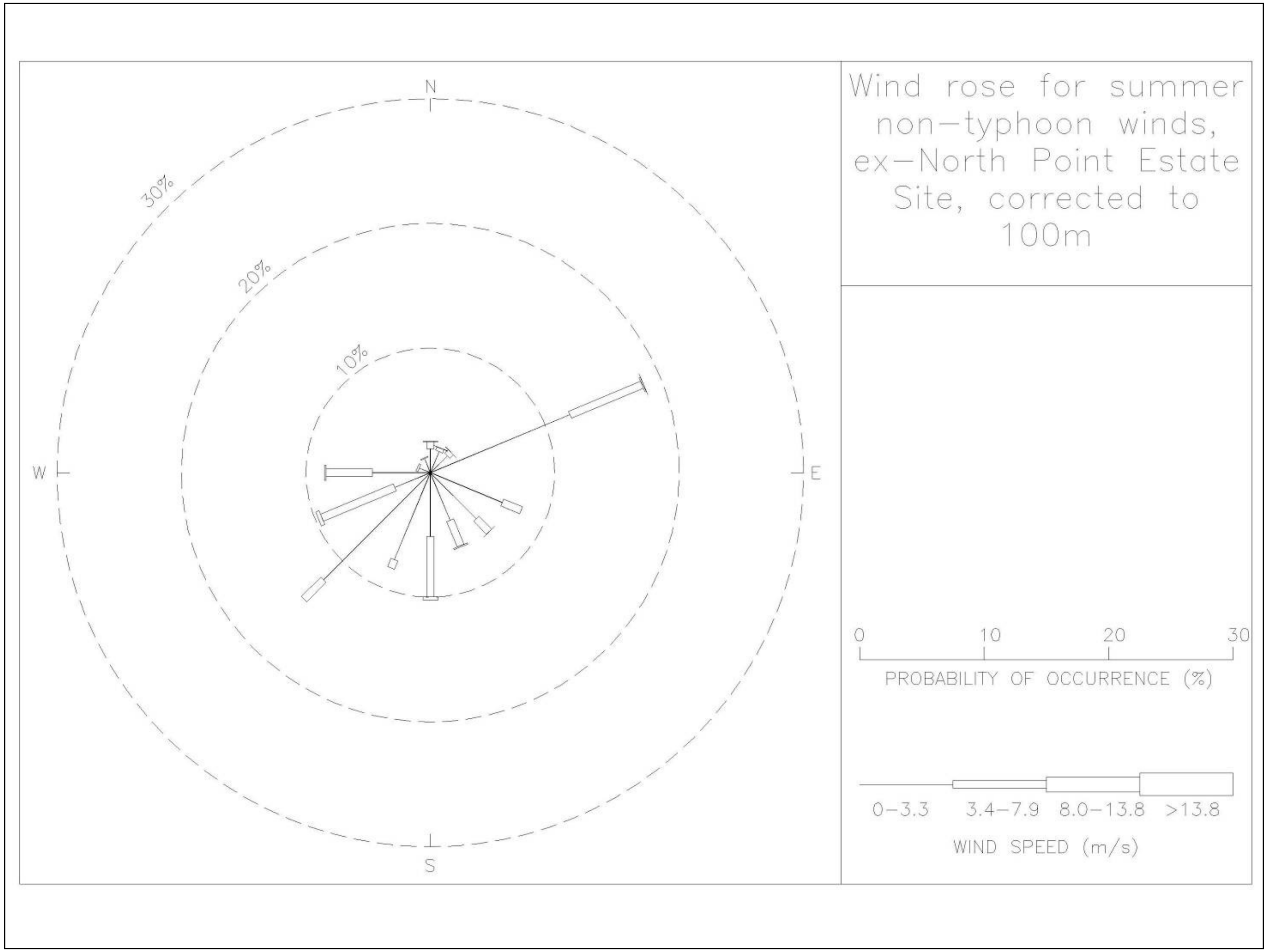


Figure 5: Wind rose for summer (June, July, August) non-typhoon winds at the Ex-North Point Estate Site corrected to 100 m

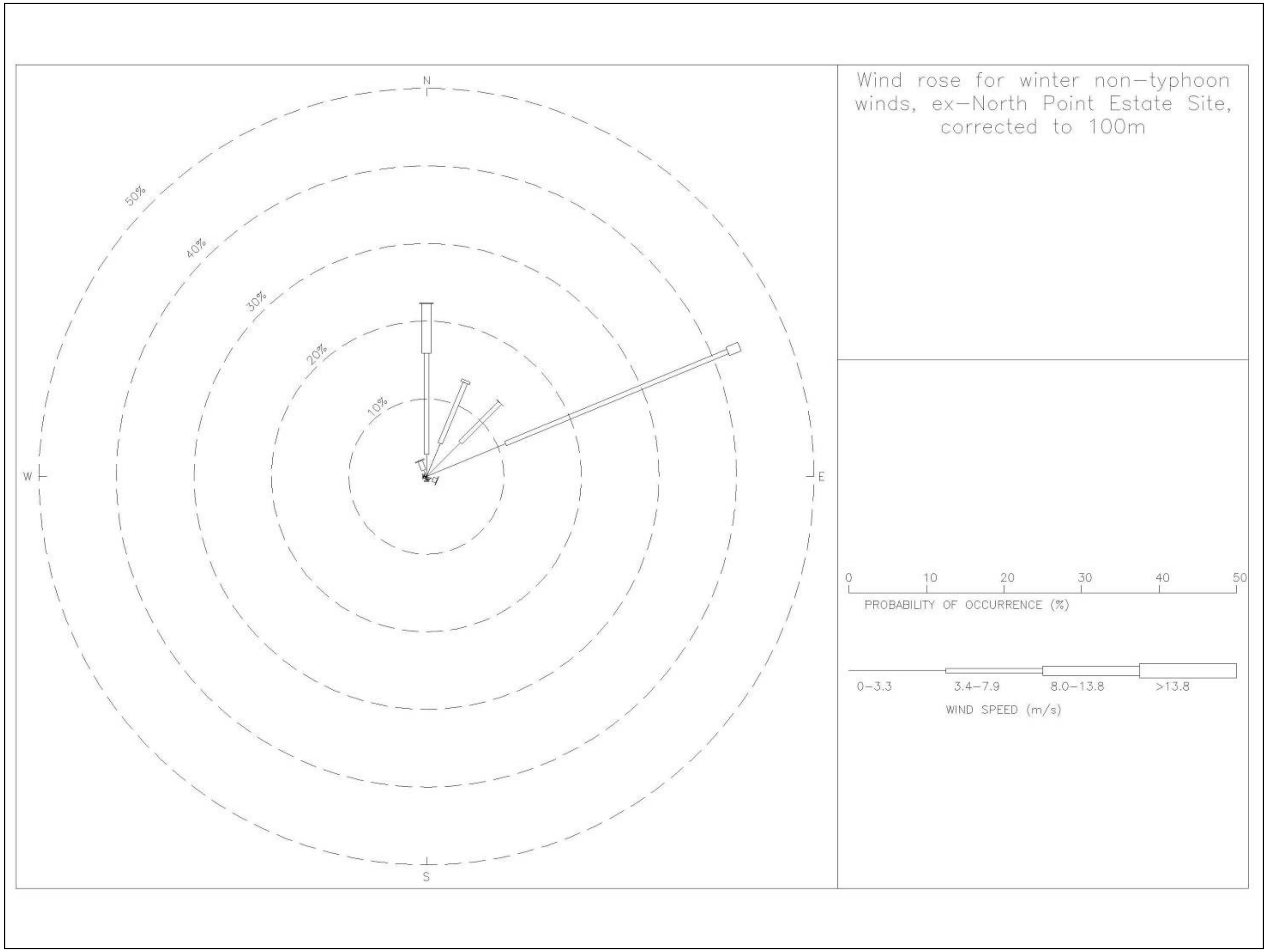


Figure 6: Wind rose for winter (December, January, February) non-typhoon winds at the Ex-North Point Estate Site corrected to 100 m

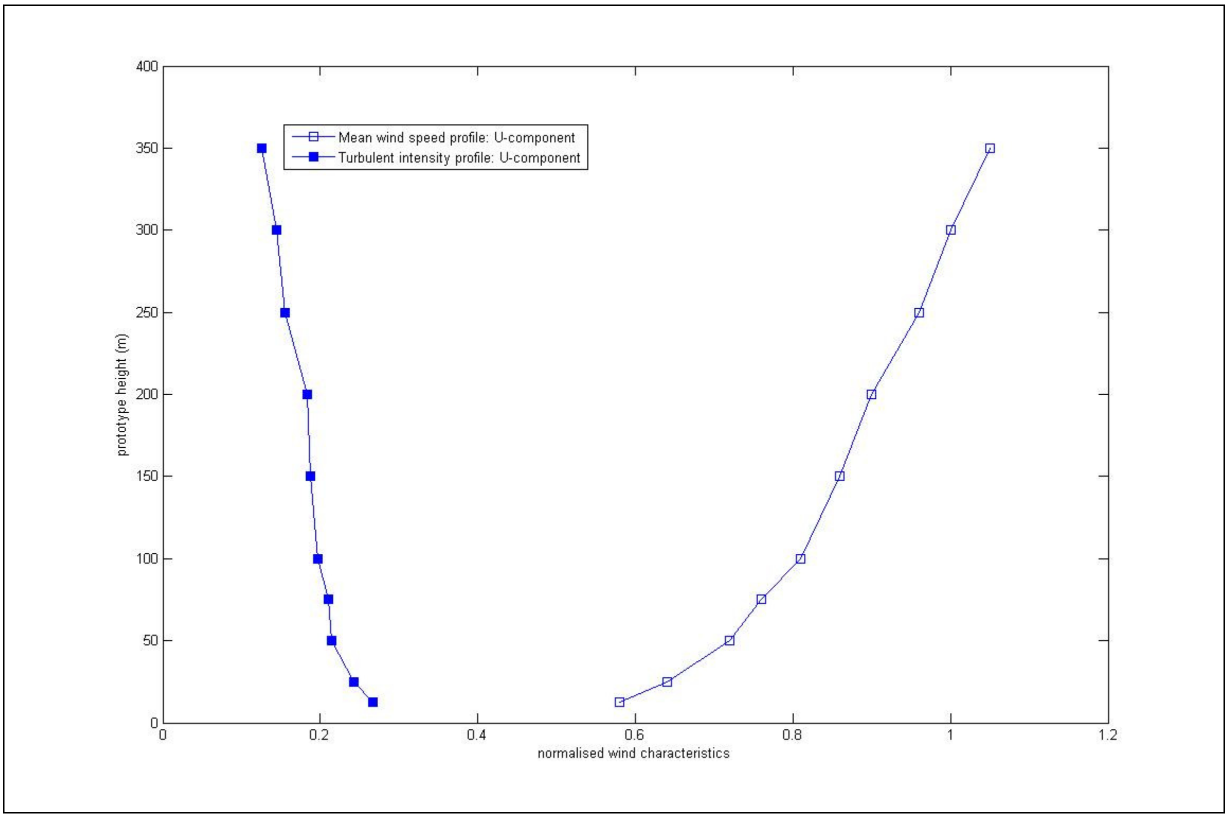


Figure 7a: 1:400 scale wind characteristics, approach condition A

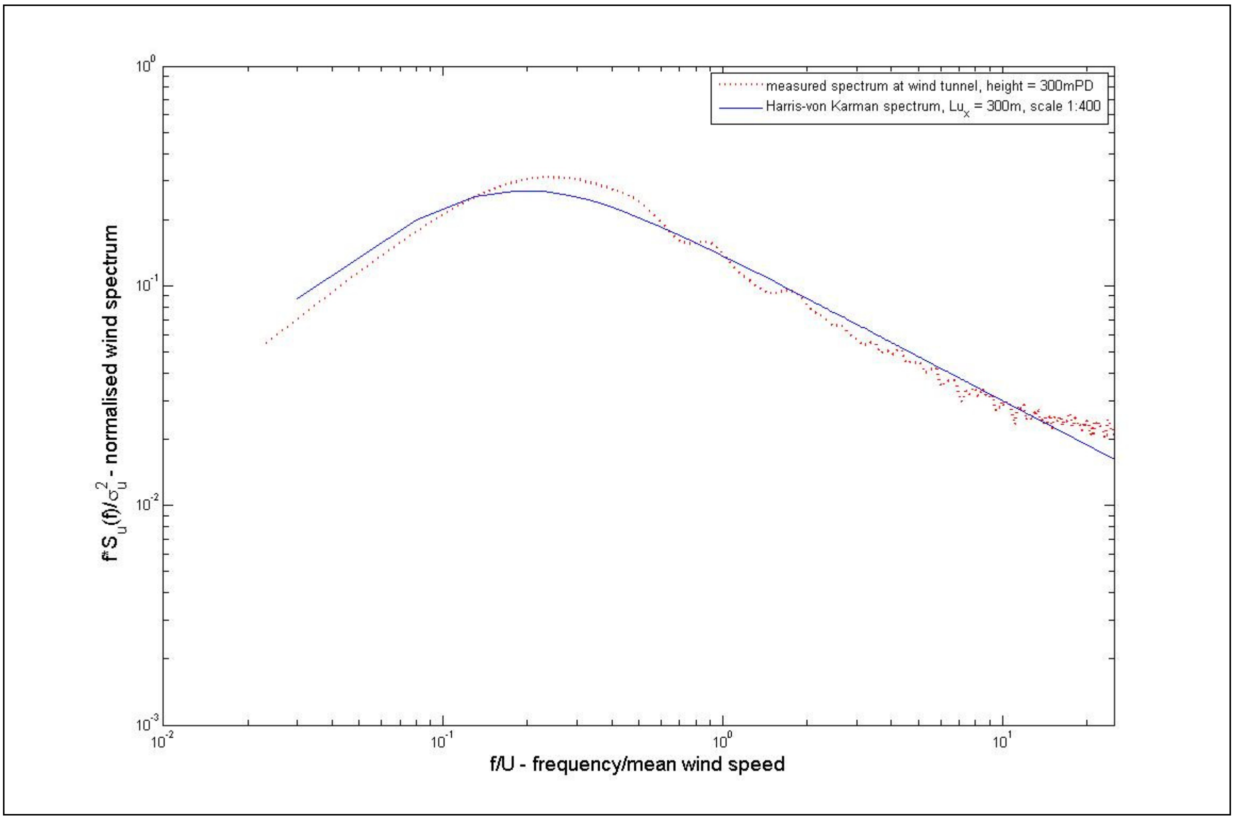


Figure 7b: Longitudinal velocity spectrum of 1:400 scale wind, approach condition A

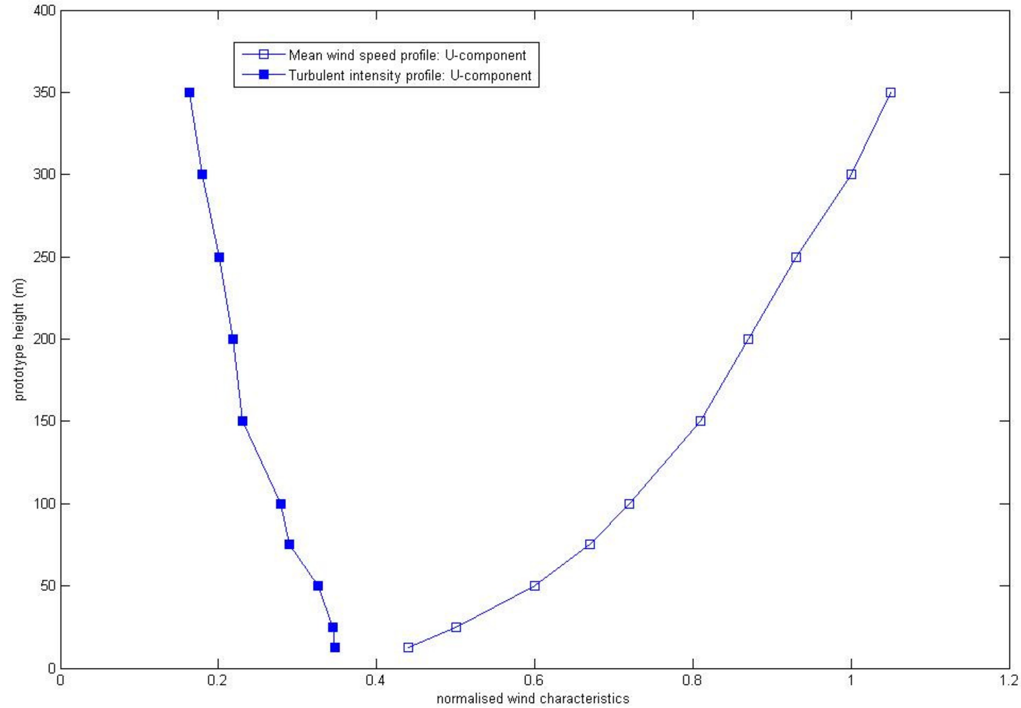


Figure 8a: 1:400 scale wind characteristics, approach condition B

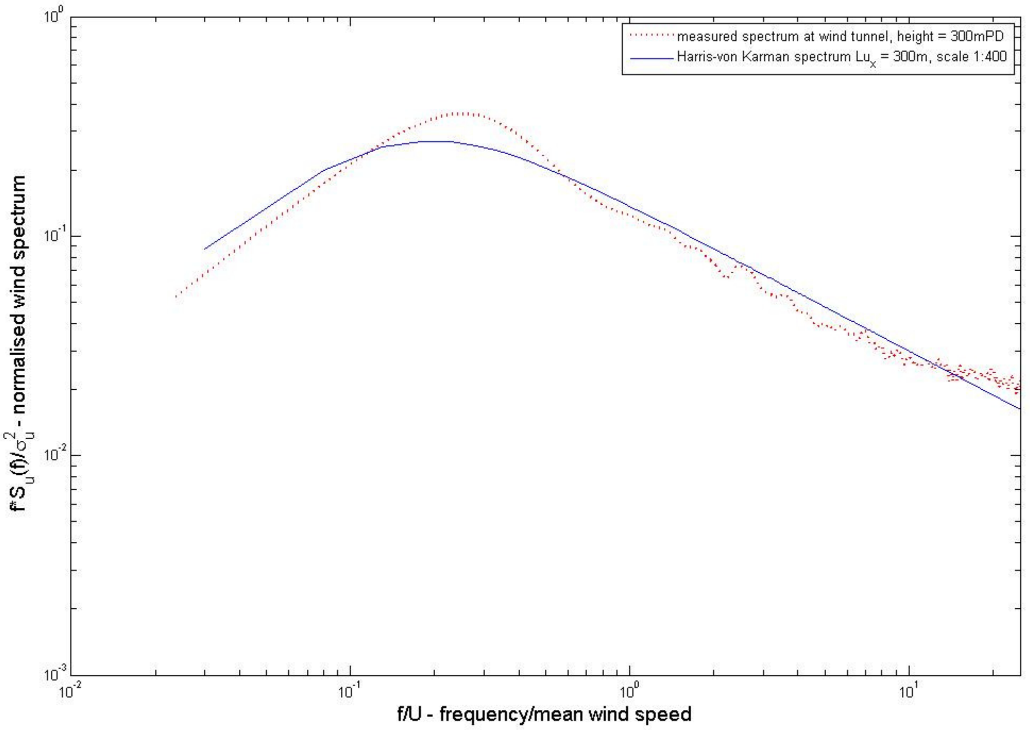


Figure 8b: Longitudinal velocity spectrum of 1:400 scale wind, approach condition B

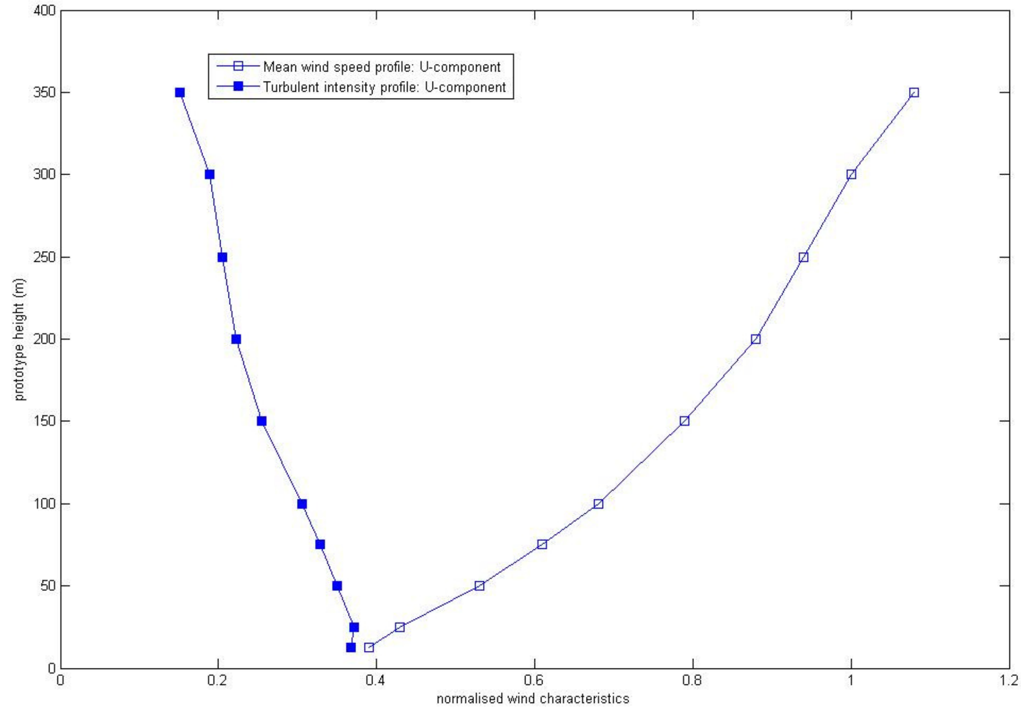


Figure 9a: 1:400 scale wind characteristics, approach condition C

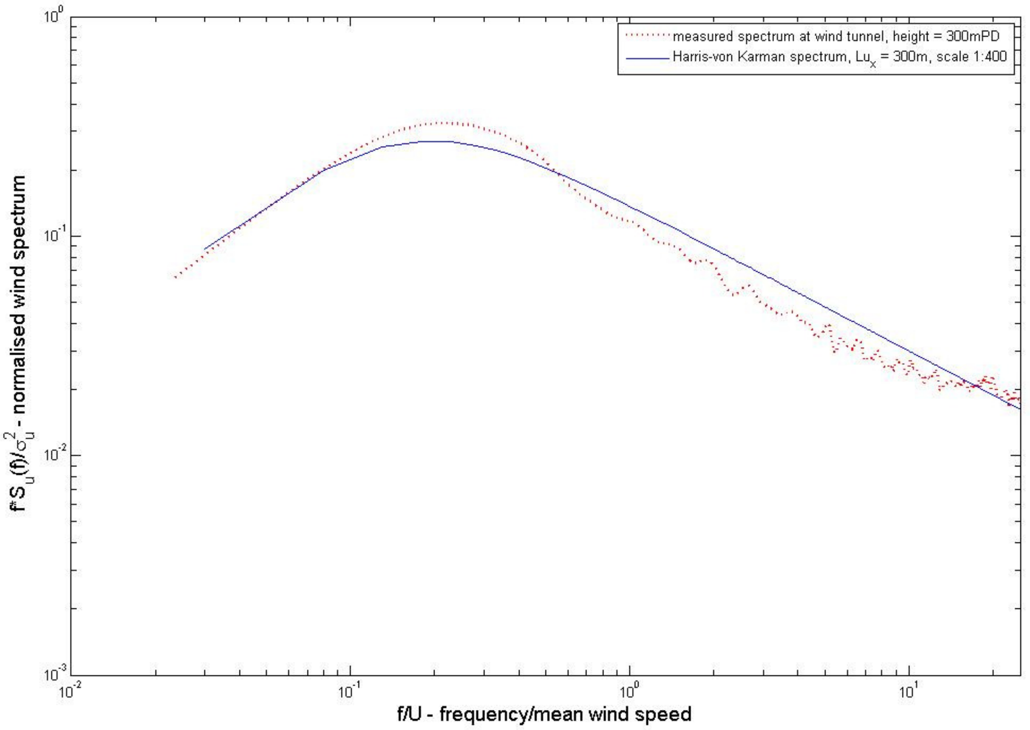
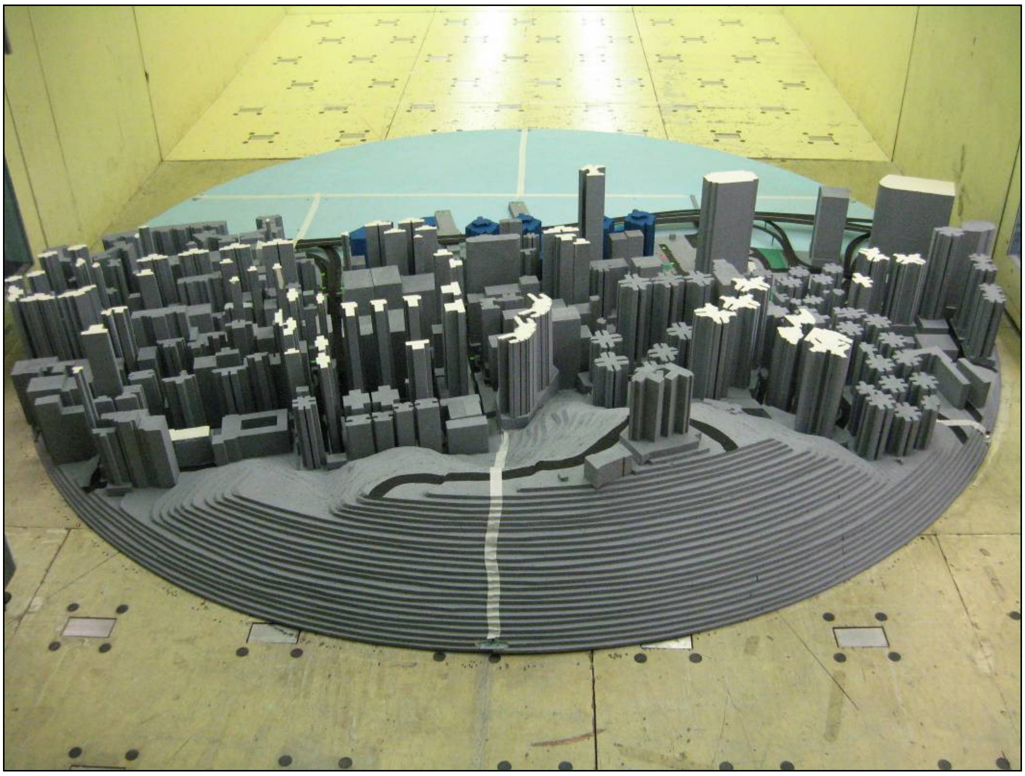
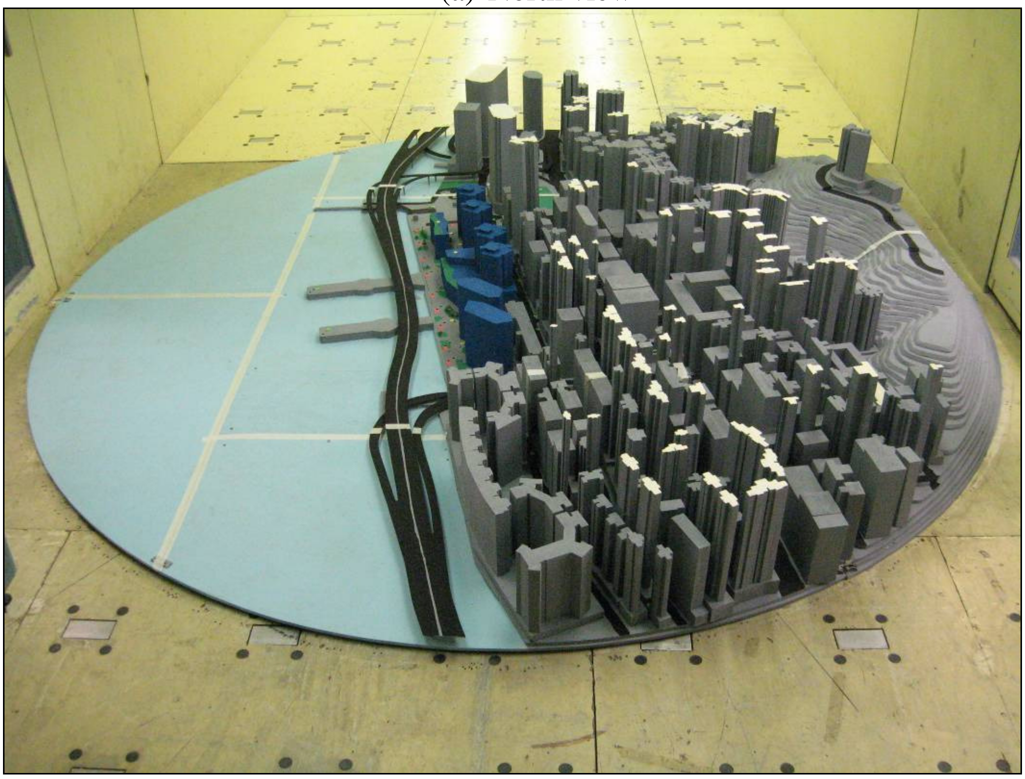


Figure 9b: Longitudinal velocity spectrum of 1:400 scale wind, approach condition C

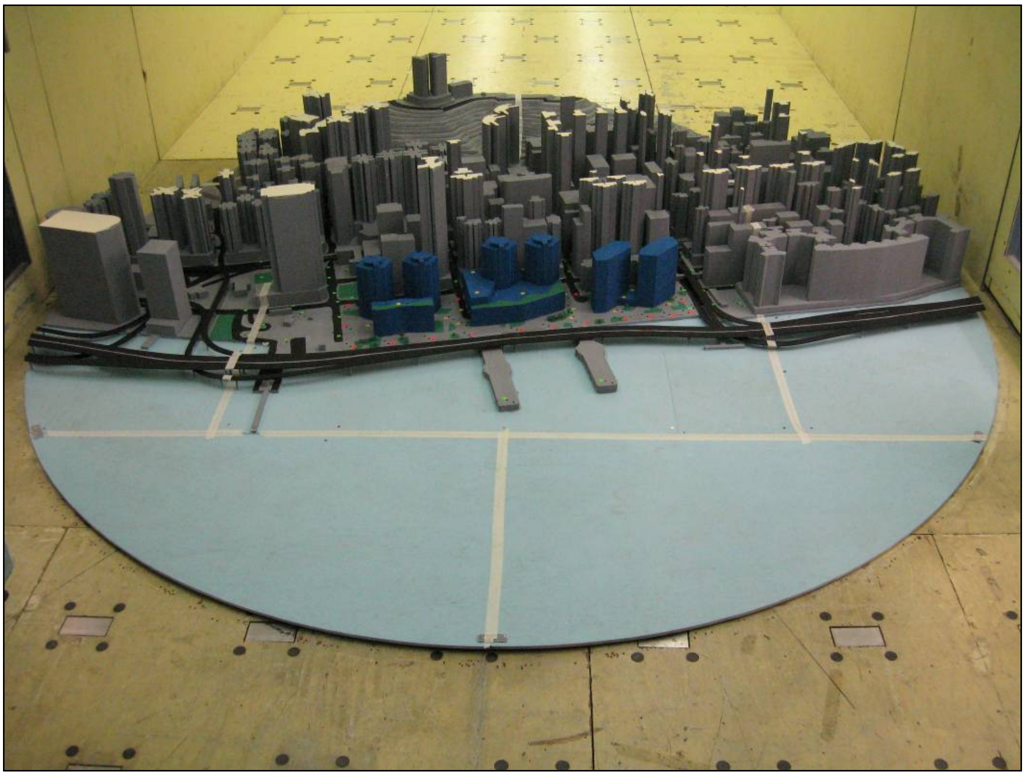


(a) North view

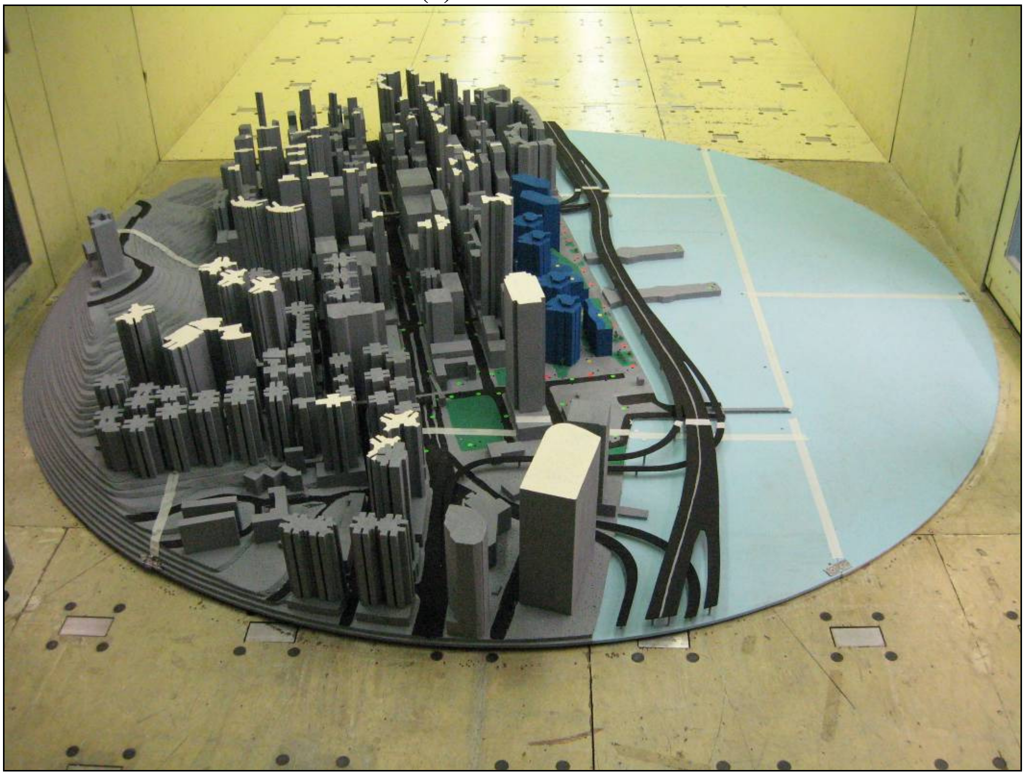


(b) East view

Figure 10(a) to (b): A 1:400 scale model of the Ex-north Point Estate Site, North Point, Hong Kong in the high speed test section of the CLP Power Wind/Wave Tunnel Facility (North and East view)



(c) South view



(d) West view

Figure 10(c) to (d): A 1:400 scale model of the Ex-North Point Estate Site, North Point, Hong Kong in the high speed test section of the CLP Power Wind/Wave Tunnel Facility (South and West view)

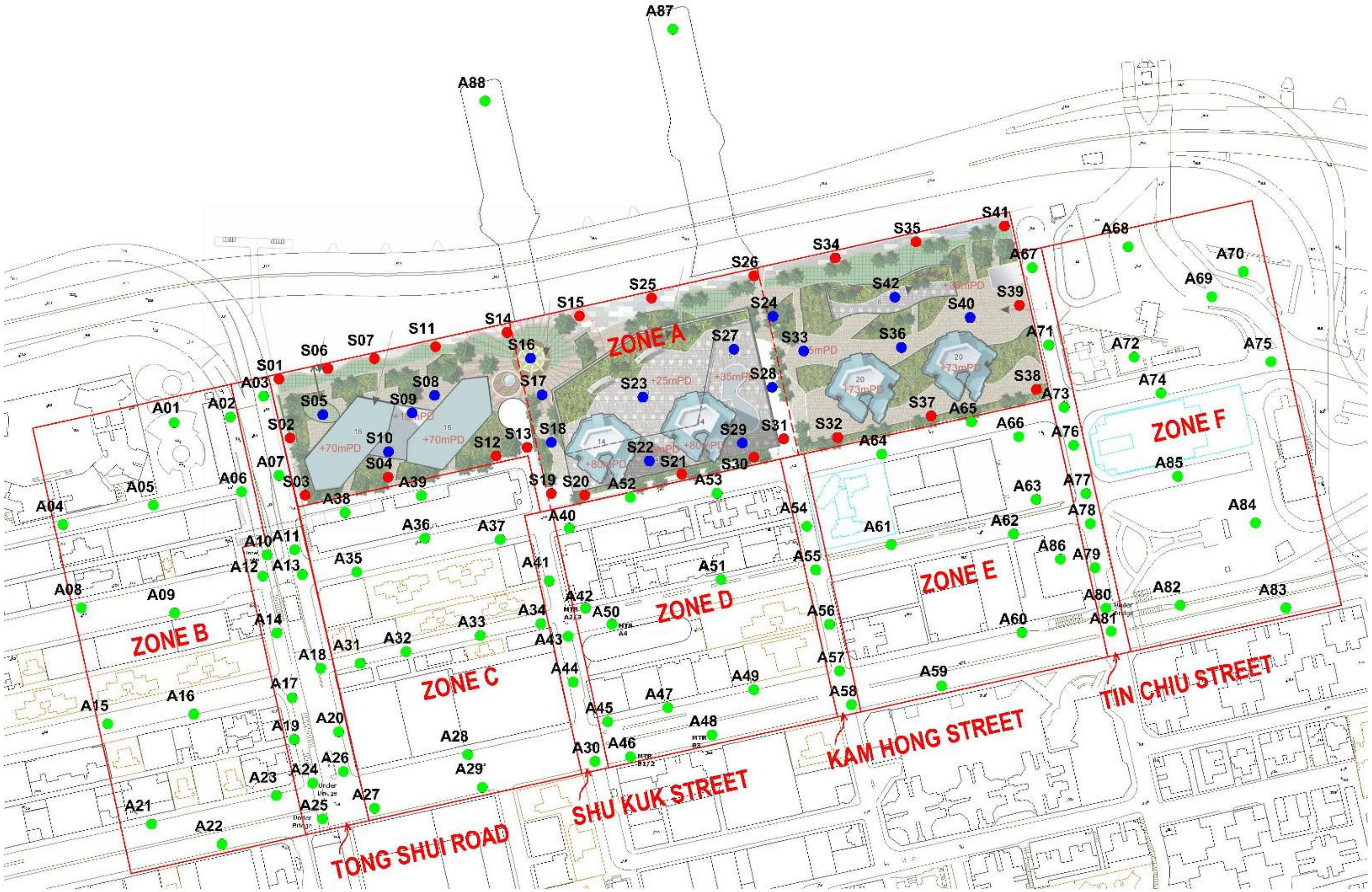


Figure 11: Location of test points and the defined zones

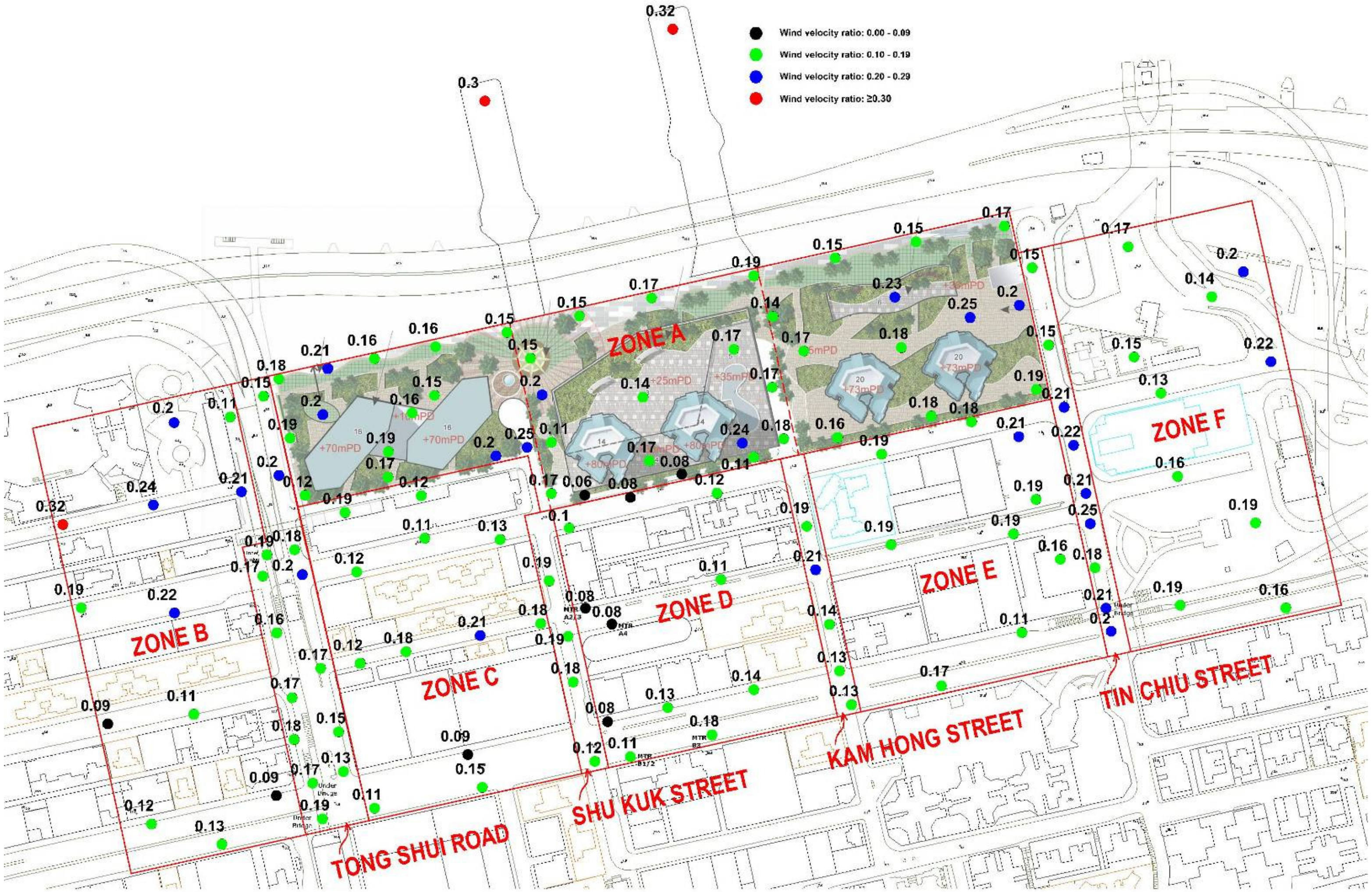


Figure 12: Overall wind velocity ratios – annual

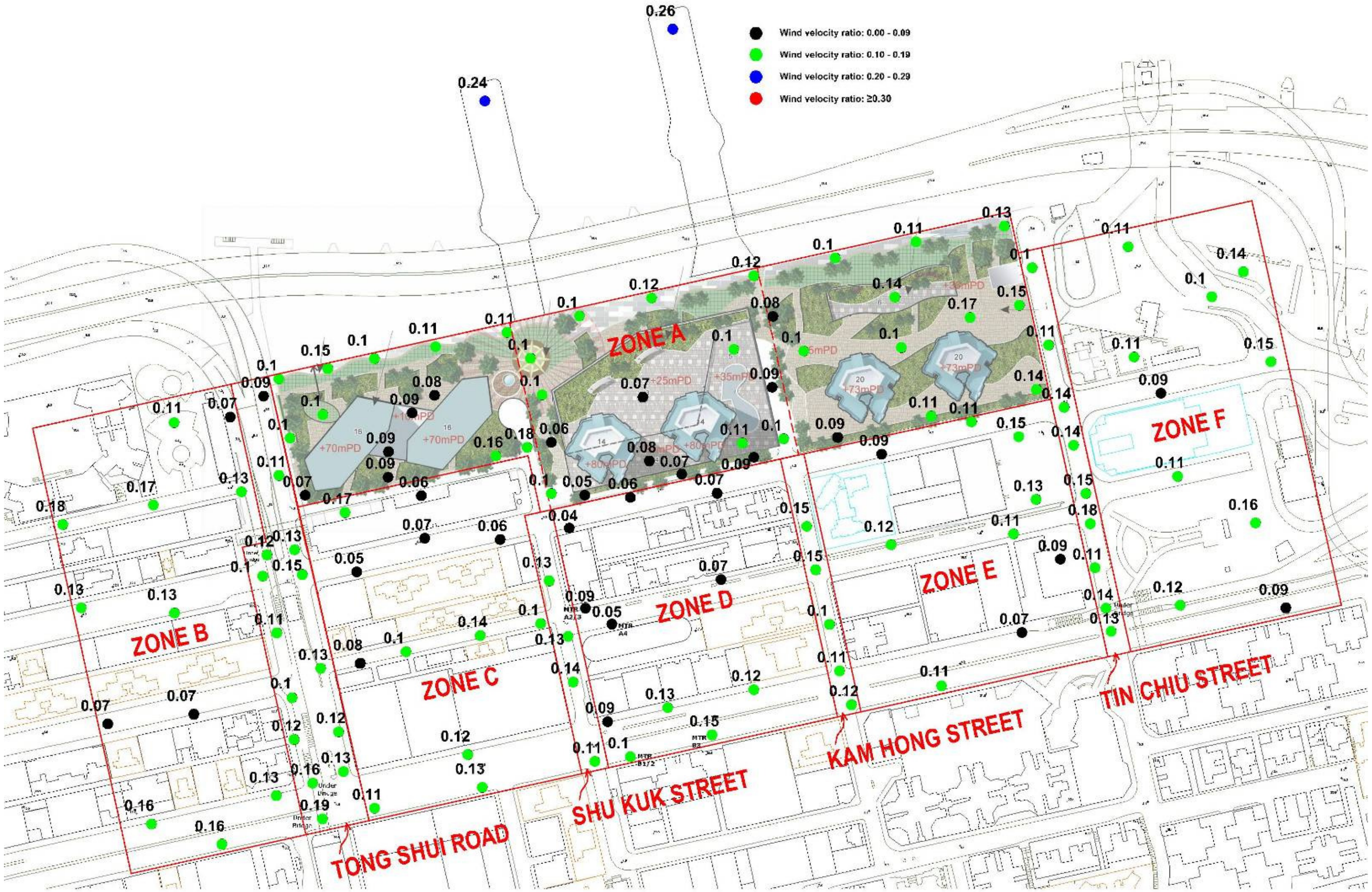


Figure 13: Overall wind velocity ratios – summer months

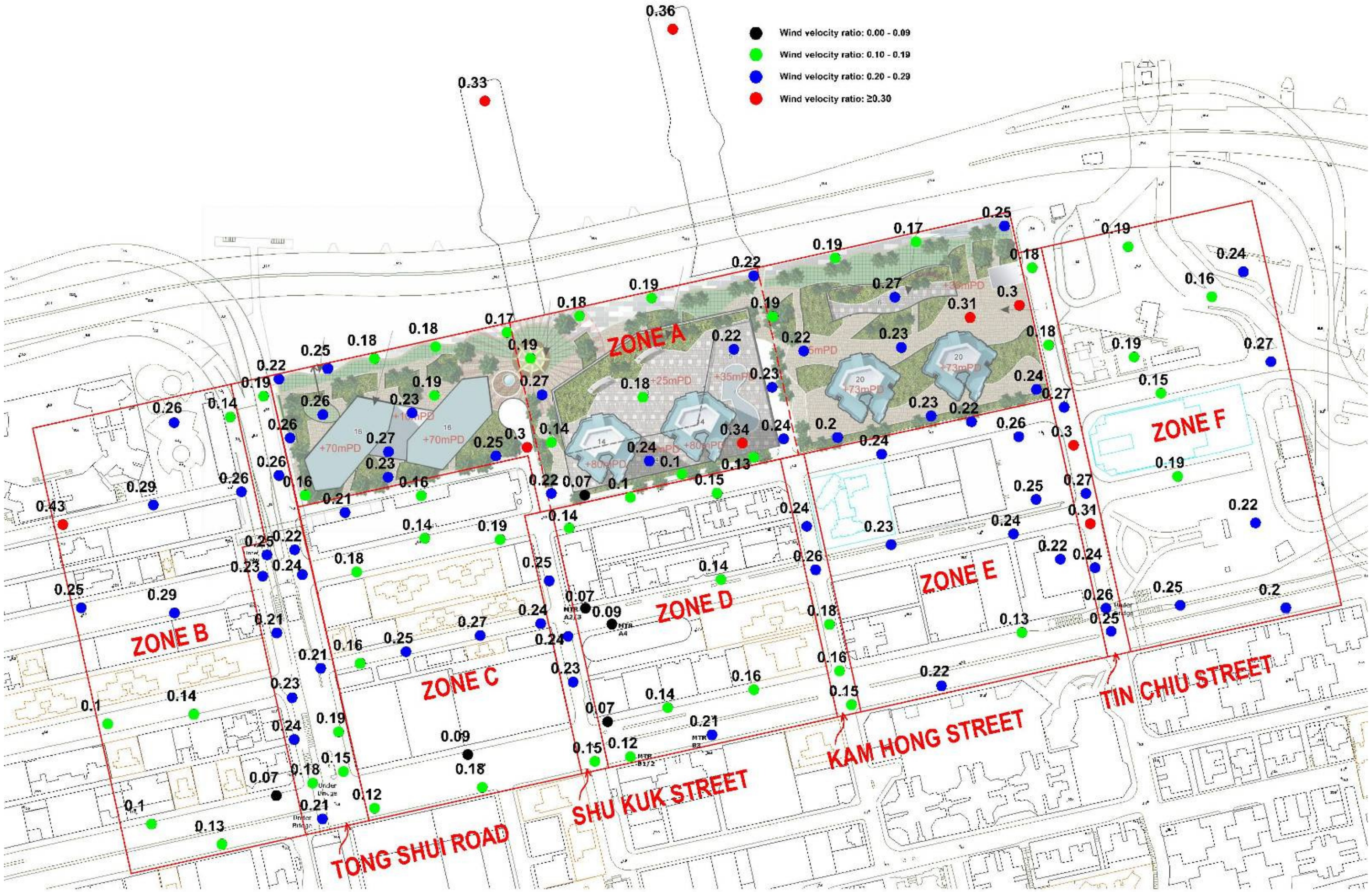


Figure 14: Overall wind velocity ratios – winter months

Appendix A

Tabulated Wind Rose Data

Table A1: Percentage occurrence of annual non-typhoon winds for the Ex-North Point Estate Site, corrected to 100 m

Wind Direction	Wind Angle (°)	Percentage occurrence of mean wind speed (%)				
		0 - 3.3 m/s	3.4 - 7.9 m/s	8 - 13.8 m/s	>13.8 m/s	Total
north	0	2.2%	6.8%	3.2%	0.07%	12.3%
north-north-east	22.5	3.3%	4.6%	0.2%	0.0%	8.2%
north-east	45	4.2%	4.1%	0.02%	0.0%	8.3%
east-north-east	67.5	12.4%	24.9%	1.4%	0.0%	38.8%
east	90	0.0%	0.0%	0.0%	0.0%	0.0%
east-south-east	112.5	3.1%	1.8%	0.1%	0.0%	5.0%
south-east	135	2.5%	0.8%	0.01%	0.0%	3.3%
south-south-east	157.5	1.9%	1.1%	0.05%	0.0%	3.1%
south	180	2.2%	2.1%	0.08%	0.0%	4.3%
south-south-west	202.5	2.7%	0.3%	0.0%	0.0%	3.0%
south-west	225	3.6%	1.1%	0.0%	0.0%	4.8%
west-south-west	247.5	0.9%	2.1%	0.3%	0.0%	3.2%
west	270	1.7%	1.6%	0.1%	0.0%	3.4%
west-north-west	292.5	0.5%	0.1%	0.01%	0.0%	0.6%
north-west	315	0.0%	0.0%	0.0%	0.0%	0.0%
north-north-west	337.5	1.0%	0.7%	0.06%	0.0%	1.7%

Table A2: Percentage occurrence of summer non-typhoon winds for the Ex-North Point Estate Site, corrected to 100 m

Wind Direction	Wind Angle (°)	Percentage occurrence of mean wind speed (%)				
		0 - 3.3 m/s	3.4 - 7.9 m/s	8 - 13.8 m/s	>13.8 m/s	Total
north	0	1.9%	0.6%	0.04%	0.0%	2.5%
north-north-east	22.5	1.8%	0.3%	0.02%	0.0%	2.1%
north-east	45	1.9%	0.4%	0.01%	0.0%	2.3%
east-north-east	67.5	12.1%	6.3%	0.1%	0.01%	18.5%
east	90	0.0%	0.0%	0.0%	0.0%	0.0%
east-south-east	112.5	6.3%	1.6%	0.0%	0.0%	7.9%
south-east	135	5.2%	1.5%	0.01%	0.0%	6.7%
south-south-east	157.5	4.1%	2.2%	0.1%	0.0%	6.4%
south	180	5.1%	4.9%	0.2%	0.0%	10.2%
south-south-west	202.5	7.5%	0.7%	0.0%	0.0%	8.3%
south-west	225	12.1%	2.2%	0.0%	0.0%	14.4%
west-south-west	247.5	3.1%	6.3%	0.3%	0.0%	9.7%
west	270	4.7%	3.7%	0.1%	0.0%	8.5%
west-north-west	292.5	1.0%	0.1%	0.0%	0.0%	1.1%
north-west	315	0.0%	0.0%	0.0%	0.0%	0.0%
north-north-west	337.5	1.2%	0.06%	0.0%	0.0%	1.3%

Table A3: Percentage occurrence of winter non-typhoon winds for the Ex-North Point Estate Site, corrected to 100 m

Wind Direction	Wind Angle (°)	Percentage occurrence of mean wind speed (%)				
		0 - 3.3 m/s	3.4 - 7.9 m/s	8 - 13.8 m/s	>13.8 m/s	Total
north	0	2.8%	13.0%	6.4%	0.09%	22.4%
north-north-east	22.5	4.6%	8.4%	0.3%	0.0%	13.4%
north-east	45	6.2%	7.2%	0.01%	0.0%	13.4%
east-north-east	67.5	11.1%	31.0%	1.6%	0.0%	43.7%
east	90	0.0%	0.0%	0.0%	0.0%	0.0%
east-south-east	112.5	0.9%	0.5%	0.06%	0.0%	1.5%
south-east	135	0.5%	0.02%	0.0%	0.0%	0.5%
south-south-east	157.5	0.4%	0.04%	0.0%	0.0%	0.5%
south	180	0.5%	0.2%	0.0%	0.0%	0.7%
south-south-west	202.5	0.3%	0.01%	0.0%	0.0%	0.3%
south-west	225	0.3%	0.02%	0.0%	0.0%	0.3%
west-south-west	247.5	0.2%	0.05%	0.0%	0.0%	0.2%
west	270	0.4%	0.09%	0.0%	0.0%	0.5%
west-north-west	292.5	0.3%	0.06%	0.0%	0.0%	0.4%
north-west	315	0.0%	0.0%	0.0%	0.0%	0.0%
north-north-west	337.5	0.9%	1.3%	0.1%	0.0%	2.3%

Appendix B

Directional Wind Velocity Ratios of the Test Points

Table B1: Directional wind velocity ratios ($VR_{500,i,j}$) – Zone A

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
S01	0.29	0.24	0.21	0.20	0.15	0.09	0.04	0.05	0.03	0.04	0.05	0.11	0.18	0.16	0.20	0.20
S02	0.40	0.28	0.23	0.20	0.09	0.03	0.03	0.03	0.04	0.03	0.05	0.07	0.09	0.26	0.39	0.34
S03	0.25	0.16	0.13	0.13	0.05	0.03	0.05	0.05	0.04	0.03	0.04	0.06	0.06	0.13	0.28	0.23
S04	0.26	0.23	0.24	0.22	0.09	0.04	0.05	0.06	0.05	0.03	0.03	0.04	0.08	0.15	0.29	0.18
S05	0.34	0.28	0.29	0.24	0.07	0.04	0.03	0.04	0.04	0.02	0.03	0.06	0.09	0.18	0.21	0.22
S06	0.27	0.24	0.26	0.25	0.15	0.10	0.09	0.12	0.10	0.06	0.10	0.18	0.24	0.22	0.28	0.17
S07	0.16	0.16	0.19	0.22	0.14	0.08	0.04	0.06	0.05	0.03	0.06	0.13	0.23	0.23	0.26	0.12
S08	0.19	0.15	0.19	0.22	0.10	0.05	0.02	0.03	0.03	0.02	0.03	0.06	0.14	0.26	0.25	0.18
S11	0.13	0.13	0.18	0.23	0.14	0.08	0.04	0.06	0.05	0.04	0.07	0.14	0.23	0.24	0.25	0.13
S12	0.42	0.26	0.22	0.17	0.12	0.12	0.12	0.16	0.15	0.11	0.13	0.17	0.16	0.14	0.22	0.32
S13	0.43	0.29	0.29	0.25	0.14	0.11	0.15	0.21	0.18	0.10	0.14	0.18	0.20	0.18	0.33	0.33
S14	0.15	0.13	0.17	0.19	0.14	0.08	0.05	0.07	0.06	0.03	0.07	0.18	0.34	0.29	0.25	0.14
S15	0.17	0.17	0.19	0.19	0.14	0.09	0.06	0.07	0.06	0.05	0.06	0.12	0.20	0.21	0.18	0.12
S16	0.29	0.20	0.17	0.15	0.12	0.07	0.04	0.06	0.04	0.02	0.06	0.15	0.24	0.29	0.31	0.24
S17	0.49	0.32	0.26	0.17	0.08	0.05	0.05	0.05	0.04	0.02	0.04	0.09	0.17	0.29	0.40	0.41
S18	0.18	0.14	0.14	0.11	0.04	0.03	0.06	0.05	0.03	0.01	0.03	0.06	0.10	0.26	0.34	0.26
S19	0.31	0.24	0.23	0.18	0.10	0.06	0.10	0.09	0.07	0.05	0.05	0.08	0.10	0.16	0.28	0.29
S20	0.11	0.08	0.09	0.05	0.02	0.03	0.06	0.03	0.05	0.04	0.03	0.03	0.05	0.08	0.12	0.10
S21	0.19	0.10	0.09	0.06	0.03	0.02	0.03	0.09	0.10	0.08	0.07	0.07	0.07	0.08	0.09	0.11
S24	0.35	0.17	0.14	0.13	0.08	0.07	0.06	0.04	0.03	0.02	0.03	0.06	0.09	0.12	0.26	0.30
S25	0.15	0.18	0.21	0.22	0.15	0.11	0.07	0.08	0.07	0.05	0.08	0.15	0.23	0.24	0.20	0.10
S26	0.19	0.19	0.25	0.26	0.18	0.16	0.04	0.05	0.05	0.03	0.05	0.16	0.30	0.26	0.24	0.18
S28	0.37	0.25	0.20	0.18	0.11	0.07	0.07	0.05	0.06	0.03	0.03	0.06	0.12	0.17	0.19	0.21
S30	0.24	0.17	0.12	0.08	0.08	0.10	0.08	0.11	0.12	0.07	0.06	0.12	0.04	0.07	0.07	0.09
S31	0.41	0.26	0.23	0.16	0.08	0.07	0.05	0.06	0.12	0.05	0.03	0.08	0.07	0.15	0.30	0.30
S32	0.25	0.16	0.21	0.18	0.13	0.14	0.11	0.08	0.04	0.02	0.02	0.07	0.11	0.16	0.28	0.27
S33	0.36	0.26	0.19	0.16	0.11	0.09	0.08	0.06	0.04	0.03	0.05	0.09	0.17	0.22	0.33	0.32

Table B1 (cont.): Directional wind velocity ratios ($VR_{500,i,j}$) – Zone A

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
S34	0.22	0.21	0.21	0.18	0.11	0.11	0.03	0.05	0.05	0.03	0.04	0.16	0.27	0.19	0.16	0.12
S35	0.19	0.10	0.15	0.18	0.16	0.14	0.03	0.05	0.06	0.03	0.05	0.19	0.30	0.25	0.28	0.21
S36	0.26	0.21	0.26	0.23	0.13	0.13	0.08	0.08	0.03	0.01	0.02	0.08	0.16	0.21	0.31	0.24
S37	0.30	0.19	0.25	0.22	0.15	0.15	0.11	0.10	0.07	0.03	0.03	0.06	0.13	0.17	0.27	0.26
S38	0.41	0.32	0.23	0.14	0.11	0.14	0.21	0.27	0.14	0.09	0.09	0.09	0.12	0.17	0.27	0.28
S39	0.37	0.20	0.16	0.19	0.19	0.19	0.20	0.22	0.14	0.08	0.10	0.12	0.19	0.30	0.39	0.36
S40	0.37	0.27	0.33	0.30	0.20	0.19	0.12	0.15	0.11	0.07	0.09	0.12	0.25	0.32	0.42	0.34
S41	0.29	0.14	0.12	0.19	0.20	0.17	0.12	0.13	0.08	0.05	0.06	0.18	0.28	0.26	0.32	0.29

Table B2: Directional wind velocity ratios ($VR_{500,i,j}$) – Zone B

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
A1	0.34	0.24	0.23	0.25	0.16	0.08	0.05	0.08	0.03	0.03	0.06	0.07	0.09	0.11	0.23	0.32
A2	0.18	0.12	0.13	0.13	0.09	0.03	0.02	0.03	0.05	0.07	0.04	0.07	0.09	0.13	0.28	0.18
A4	0.64	0.53	0.46	0.33	0.19	0.03	0.03	0.03	0.07	0.10	0.11	0.19	0.26	0.24	0.14	0.37
A5	0.53	0.38	0.31	0.15	0.16	0.23	0.28	0.22	0.09	0.10	0.12	0.23	0.31	0.25	0.24	0.42
A6	0.30	0.24	0.26	0.27	0.14	0.07	0.08	0.06	0.08	0.08	0.07	0.08	0.06	0.16	0.35	0.27
A8	0.46	0.36	0.27	0.13	0.03	0.05	0.04	0.03	0.07	0.08	0.11	0.20	0.27	0.18	0.09	0.26
A9	0.51	0.41	0.30	0.16	0.04	0.08	0.05	0.05	0.07	0.06	0.09	0.15	0.22	0.14	0.24	0.35
A15	0.13	0.10	0.10	0.10	0.05	0.02	0.05	0.06	0.09	0.05	0.05	0.03	0.02	0.02	0.05	0.08
A16	0.16	0.15	0.15	0.13	0.06	0.02	0.05	0.04	0.06	0.04	0.03	0.03	0.01	0.05	0.13	0.10
A21	0.11	0.10	0.08	0.09	0.06	0.06	0.09	0.12	0.18	0.17	0.23	0.32	0.32	0.27	0.26	0.06
A22	0.18	0.15	0.12	0.09	0.06	0.03	0.05	0.04	0.18	0.16	0.21	0.30	0.31	0.27	0.25	0.08
A23	0.08	0.06	0.04	0.07	0.05	0.06	0.06	0.11	0.10	0.13	0.20	0.30	0.31	0.23	0.10	0.10

Table B3: Directional wind velocity ratios ($VR_{500,i,j}$) – Zone C

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
A27	0.19	0.11	0.08	0.10	0.08	0.00	0.02	0.07	0.04	0.08	0.17	0.29	0.28	0.24	0.24	0.23
A28	0.16	0.12	0.06	0.06	0.05	0.03	0.04	0.09	0.08	0.10	0.19	0.28	0.29	0.09	0.12	0.10
A29	0.24	0.29	0.21	0.12	0.06	0.01	0.03	0.06	0.04	0.05	0.17	0.30	0.31	0.25	0.37	0.21
A31	0.27	0.20	0.17	0.11	0.07	0.01	0.05	0.11	0.09	0.03	0.05	0.07	0.02	0.09	0.10	0.20
A32	0.42	0.31	0.27	0.16	0.08	0.03	0.04	0.07	0.07	0.04	0.06	0.08	0.03	0.06	0.12	0.30
A33	0.48	0.33	0.27	0.16	0.09	0.10	0.12	0.14	0.12	0.08	0.11	0.14	0.14	0.11	0.19	0.35
A34	0.42	0.29	0.26	0.15	0.09	0.06	0.09	0.08	0.05	0.04	0.05	0.08	0.05	0.09	0.19	0.33
A35	0.39	0.24	0.16	0.07	0.01	0.02	0.02	0.03	0.03	0.01	0.03	0.02	0.03	0.05	0.16	0.23
A36	0.31	0.18	0.12	0.06	0.01	0.03	0.06	0.08	0.08	0.07	0.06	0.04	0.07	0.09	0.15	0.19
A37	0.40	0.27	0.21	0.07	0.04	0.01	0.02	0.05	0.04	0.02	0.02	0.02	0.03	0.07	0.18	0.32
A38	0.30	0.23	0.20	0.17	0.17	0.15	0.16	0.21	0.19	0.12	0.16	0.22	0.21	0.19	0.28	0.25
A39	0.16	0.24	0.20	0.15	0.07	0.02	0.02	0.05	0.04	0.02	0.01	0.02	0.05	0.07	0.17	0.13

Table B4: Directional wind velocity ratios ($VR_{500,i,j}$) – Zone D

A40	0.23	0.14	0.13	0.11	0.03	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.03	0.12	0.19	0.21
A42	0.09	0.04	0.04	0.07	0.09	0.05	0.17	0.18	0.13	0.07	0.08	0.08	0.09	0.06	0.11	0.13
A45	0.06	0.07	0.06	0.07	0.04	0.05	0.06	0.08	0.10	0.07	0.11	0.15	0.15	0.12	0.16	0.05
A46	0.15	0.11	0.13	0.11	0.03	0.03	0.06	0.07	0.09	0.04	0.12	0.19	0.20	0.16	0.28	0.11
A47	0.10	0.19	0.18	0.14	0.05	0.04	0.06	0.08	0.10	0.08	0.15	0.24	0.28	0.10	0.11	0.04
A48	0.32	0.24	0.21	0.15	0.13	0.12	0.13	0.17	0.13	0.09	0.13	0.26	0.29	0.17	0.24	0.23
A49	0.22	0.22	0.17	0.12	0.08	0.08	0.10	0.13	0.10	0.07	0.11	0.16	0.20	0.09	0.12	0.11
A50	0.09	0.08	0.07	0.10	0.09	0.05	0.12	0.10	0.04	0.03	0.02	0.03	0.03	0.05	0.11	0.12
A51	0.15	0.14	0.16	0.14	0.11	0.07	0.07	0.13	0.06	0.02	0.02	0.02	0.05	0.04	0.13	0.16
A52	0.16	0.10	0.12	0.07	0.04	0.04	0.04	0.05	0.06	0.05	0.04	0.05	0.05	0.09	0.13	0.14
A53	0.28	0.14	0.13	0.11	0.07	0.05	0.03	0.04	0.04	0.05	0.05	0.05	0.07	0.10	0.17	0.30

Table B5: Directional wind velocity ratios ($VR_{500,i,j}$) – Zone E

A59	0.31	0.29	0.23	0.16	0.11	0.05	0.09	0.12	0.11	0.05	0.05	0.16	0.21	0.16	0.12	0.14
A60	0.20	0.14	0.12	0.11	0.09	0.04	0.03	0.03	0.04	0.06	0.05	0.10	0.12	0.05	0.06	0.14
A61	0.30	0.24	0.24	0.20	0.21	0.18	0.13	0.06	0.09	0.05	0.04	0.08	0.15	0.20	0.28	0.34
A62	0.42	0.33	0.28	0.14	0.14	0.15	0.18	0.23	0.06	0.05	0.04	0.04	0.14	0.15	0.20	0.24
A63	0.47	0.33	0.27	0.12	0.11	0.13	0.19	0.32	0.13	0.07	0.08	0.07	0.07	0.17	0.32	0.34
A64	0.34	0.25	0.27	0.20	0.16	0.14	0.09	0.08	0.03	0.01	0.01	0.04	0.07	0.12	0.25	0.36
A65	0.24	0.20	0.26	0.21	0.17	0.16	0.10	0.13	0.08	0.03	0.04	0.04	0.15	0.21	0.29	0.27
A66	0.47	0.34	0.25	0.15	0.14	0.16	0.23	0.30	0.16	0.10	0.10	0.08	0.14	0.22	0.32	0.35
A86	0.49	0.28	0.15	0.09	0.07	0.06	0.12	0.28	0.08	0.05	0.06	0.05	0.04	0.10	0.27	0.32

Table B6: Directional wind velocity ratios ($VR_{500,i,j}$) – Zone F

A68	0.22	0.16	0.14	0.21	0.17	0.15	0.09	0.10	0.06	0.07	0.05	0.14	0.23	0.22	0.26	0.21
A69	0.22	0.12	0.15	0.16	0.11	0.15	0.13	0.12	0.08	0.06	0.06	0.07	0.09	0.12	0.24	0.23
A70	0.32	0.23	0.22	0.23	0.12	0.12	0.13	0.17	0.13	0.08	0.06	0.10	0.14	0.17	0.27	0.25
A72	0.32	0.20	0.16	0.12	0.16	0.19	0.13	0.18	0.09	0.08	0.05	0.06	0.11	0.24	0.33	0.30
A74	0.24	0.15	0.16	0.10	0.17	0.23	0.11	0.10	0.06	0.05	0.04	0.05	0.10	0.21	0.31	0.25
A75	0.50	0.30	0.23	0.16	0.12	0.17	0.19	0.22	0.15	0.08	0.10	0.07	0.15	0.25	0.40	0.42
A82	0.49	0.31	0.17	0.15	0.12	0.09	0.12	0.29	0.11	0.07	0.08	0.11	0.11	0.11	0.18	0.25
A83	0.35	0.16	0.21	0.14	0.09	0.09	0.09	0.11	0.06	0.04	0.05	0.07	0.08	0.12	0.18	0.36
A84	0.41	0.23	0.13	0.15	0.14	0.19	0.20	0.27	0.15	0.12	0.14	0.13	0.09	0.11	0.22	0.30
A85	0.30	0.31	0.23	0.10	0.15	0.17	0.14	0.23	0.10	0.09	0.08	0.05	0.04	0.09	0.30	0.22

Table B7: Directional wind velocity ratios ($VR_{500,i,j}$) – elevated test points

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
S09	0.44	0.27	0.21	0.12	0.05	0.03	0.03	0.07	0.06	0.02	0.03	0.08	0.19	0.34	0.40	0.35
S10	0.56	0.34	0.26	0.13	0.05	0.03	0.03	0.06	0.06	0.02	0.03	0.07	0.17	0.40	0.50	0.46
S22	0.47	0.26	0.24	0.13	0.08	0.03	0.04	0.03	0.03	0.02	0.02	0.06	0.13	0.24	0.32	0.44
S23	0.24	0.21	0.21	0.15	0.05	0.03	0.04	0.03	0.02	0.02	0.02	0.09	0.13	0.17	0.20	0.19
S27	0.30	0.25	0.22	0.19	0.11	0.05	0.03	0.05	0.06	0.03	0.03	0.10	0.17	0.23	0.29	0.29
S29	0.61	0.47	0.33	0.20	0.12	0.07	0.03	0.07	0.08	0.03	0.02	0.03	0.07	0.09	0.14	0.26
S42	0.17	0.31	0.34	0.31	0.21	0.16	0.06	0.07	0.05	0.03	0.04	0.19	0.34	0.36	0.40	0.18
A87	0.38	0.35	0.37	0.37	0.26	0.26	0.12	0.12	0.10	0.10	0.27	0.46	0.47	0.41	0.41	0.32
A88	0.34	0.34	0.36	0.34	0.26	0.23	0.13	0.13	0.08	0.10	0.24	0.38	0.39	0.38	0.37	0.28

Table B8: Directional wind velocity ratios ($VR_{500,i,j}$) – Tong Shui Road

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
A3	0.27	0.20	0.16	0.17	0.13	0.07	0.03	0.05	0.05	0.05	0.05	0.08	0.11	0.14	0.22	0.21
A7	0.40	0.28	0.21	0.22	0.09	0.03	0.04	0.04	0.05	0.05	0.06	0.08	0.07	0.23	0.40	0.35
A10	0.49	0.35	0.24	0.12	0.06	0.03	0.05	0.06	0.12	0.10	0.10	0.15	0.10	0.13	0.38	0.40
A11	0.31	0.22	0.19	0.19	0.10	0.02	0.04	0.05	0.13	0.12	0.12	0.16	0.08	0.10	0.31	0.28
A12	0.45	0.31	0.20	0.11	0.04	0.02	0.07	0.09	0.09	0.07	0.08	0.11	0.14	0.09	0.32	0.35
A13	0.38	0.29	0.23	0.16	0.06	0.05	0.11	0.09	0.17	0.14	0.14	0.19	0.11	0.07	0.21	0.26
A14	0.41	0.29	0.20	0.09	0.03	0.03	0.07	0.11	0.11	0.08	0.10	0.13	0.07	0.07	0.22	0.29
A17	0.45	0.32	0.21	0.11	0.06	0.03	0.06	0.08	0.07	0.04	0.07	0.19	0.16	0.09	0.23	0.33
A18	0.37	0.28	0.18	0.11	0.09	0.05	0.08	0.12	0.16	0.12	0.11	0.16	0.16	0.12	0.18	0.26
A19	0.45	0.33	0.23	0.12	0.07	0.04	0.05	0.08	0.09	0.10	0.12	0.11	0.09	0.06	0.23	0.32
A20	0.39	0.29	0.19	0.07	0.03	0.04	0.03	0.08	0.16	0.11	0.11	0.18	0.22	0.09	0.21	0.30
A24	0.32	0.24	0.16	0.11	0.07	0.06	0.05	0.10	0.17	0.14	0.18	0.27	0.30	0.16	0.15	0.21
A25	0.35	0.27	0.20	0.14	0.11	0.03	0.04	0.06	0.13	0.19	0.26	0.39	0.38	0.28	0.14	0.16
A26	0.34	0.23	0.11	0.05	0.04	0.07	0.07	0.16	0.13	0.11	0.17	0.24	0.26	0.16	0.27	0.29

Table B9: Directional wind velocity ratios ($VR_{500,i,j}$) – Shu Kuk Street

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
A30	0.24	0.22	0.15	0.08	0.05	0.05	0.07	0.07	0.08	0.07	0.11	0.22	0.21	0.16	0.24	0.24
A41	0.48	0.33	0.27	0.11	0.04	0.08	0.14	0.18	0.14	0.09	0.10	0.08	0.04	0.11	0.29	0.36
A43	0.49	0.32	0.25	0.10	0.06	0.05	0.16	0.20	0.18	0.10	0.09	0.08	0.11	0.12	0.30	0.33
A44	0.43	0.29	0.24	0.11	0.06	0.04	0.13	0.14	0.13	0.10	0.14	0.16	0.18	0.08	0.24	0.29

Table B10: Directional wind velocity ratios ($VR_{500,i,j}$) – Kam Hong Street

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
A54	0.42	0.29	0.25	0.12	0.12	0.11	0.11	0.11	0.14	0.10	0.10	0.30	0.22	0.17	0.31	0.35
A55	0.40	0.24	0.23	0.21	0.19	0.14	0.09	0.11	0.15	0.09	0.09	0.18	0.14	0.16	0.30	0.36
A56	0.35	0.22	0.18	0.08	0.06	0.05	0.11	0.13	0.15	0.07	0.06	0.06	0.11	0.16	0.25	0.32
A57	0.32	0.16	0.13	0.08	0.06	0.03	0.10	0.11	0.13	0.06	0.10	0.18	0.20	0.17	0.26	0.34
A58	0.18	0.21	0.17	0.11	0.07	0.04	0.10	0.11	0.10	0.09	0.11	0.21	0.24	0.13	0.22	0.23

Table B11: Directional wind velocity ratios ($VR_{500,i,j}$) – Tin Chiu Street

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
A67	0.30	0.13	0.09	0.16	0.15	0.15	0.13	0.14	0.07	0.05	0.04	0.08	0.14	0.20	0.29	0.28
A71	0.32	0.20	0.12	0.13	0.11	0.12	0.16	0.19	0.10	0.07	0.06	0.07	0.13	0.24	0.30	0.25
A73	0.54	0.38	0.28	0.10	0.11	0.13	0.20	0.30	0.15	0.11	0.09	0.09	0.10	0.23	0.32	0.40
A76	0.69	0.45	0.26	0.08	0.10	0.11	0.21	0.33	0.17	0.10	0.07	0.07	0.12	0.26	0.44	0.53
A77	0.61	0.32	0.19	0.11	0.16	0.21	0.25	0.33	0.14	0.09	0.09	0.10	0.12	0.27	0.44	0.52
A78	0.67	0.36	0.23	0.14	0.18	0.21	0.26	0.40	0.19	0.11	0.12	0.13	0.13	0.27	0.46	0.56
A79	0.51	0.26	0.17	0.12	0.10	0.10	0.15	0.33	0.10	0.06	0.07	0.05	0.05	0.14	0.32	0.41
A80	0.43	0.29	0.20	0.20	0.17	0.14	0.12	0.22	0.08	0.08	0.11	0.14	0.12	0.08	0.23	0.31
A81	0.46	0.33	0.19	0.15	0.10	0.06	0.08	0.14	0.11	0.08	0.12	0.13	0.12	0.07	0.20	0.30

Table B12: Directional wind velocity ratios ($VR_{500,i,j}$) – Zone A, Western Part

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
S01	0.29	0.24	0.21	0.20	0.15	0.09	0.04	0.05	0.03	0.04	0.05	0.11	0.18	0.16	0.20	0.20
S02	0.40	0.28	0.23	0.20	0.09	0.03	0.03	0.03	0.04	0.03	0.05	0.07	0.09	0.26	0.39	0.34
S03	0.25	0.16	0.13	0.13	0.05	0.03	0.05	0.05	0.04	0.03	0.04	0.06	0.06	0.13	0.28	0.23
S04	0.26	0.23	0.24	0.22	0.09	0.04	0.05	0.06	0.05	0.03	0.03	0.04	0.08	0.15	0.29	0.18
S05	0.34	0.28	0.29	0.24	0.07	0.04	0.03	0.04	0.04	0.02	0.03	0.06	0.09	0.18	0.21	0.22
S06	0.27	0.24	0.26	0.25	0.15	0.10	0.09	0.12	0.10	0.06	0.10	0.18	0.24	0.22	0.28	0.17
S07	0.16	0.16	0.19	0.22	0.14	0.08	0.04	0.06	0.05	0.03	0.06	0.13	0.23	0.23	0.26	0.12
S08	0.19	0.15	0.19	0.22	0.10	0.05	0.02	0.03	0.03	0.02	0.03	0.06	0.14	0.26	0.25	0.18
S11	0.13	0.13	0.18	0.23	0.14	0.08	0.04	0.06	0.05	0.04	0.07	0.14	0.23	0.24	0.25	0.13
S12	0.42	0.26	0.22	0.17	0.12	0.12	0.12	0.16	0.15	0.11	0.13	0.17	0.16	0.14	0.22	0.32
S13	0.43	0.29	0.29	0.25	0.14	0.11	0.15	0.21	0.18	0.10	0.14	0.18	0.20	0.18	0.33	0.33
S14	0.15	0.13	0.17	0.19	0.14	0.08	0.05	0.07	0.06	0.03	0.07	0.18	0.34	0.29	0.25	0.14

Table B13: Directional wind velocity ratios ($VR_{500,i,j}$) – Zone A, Central Part

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
S15	0.17	0.17	0.19	0.19	0.14	0.09	0.06	0.07	0.06	0.05	0.06	0.12	0.20	0.21	0.18	0.12
S16	0.29	0.20	0.17	0.15	0.12	0.07	0.04	0.06	0.04	0.02	0.06	0.15	0.24	0.29	0.31	0.24
S17	0.49	0.32	0.26	0.17	0.08	0.05	0.05	0.05	0.04	0.02	0.04	0.09	0.17	0.29	0.40	0.41
S18	0.18	0.14	0.14	0.11	0.04	0.03	0.06	0.05	0.03	0.01	0.03	0.06	0.10	0.26	0.34	0.26
S19	0.31	0.24	0.23	0.18	0.10	0.06	0.10	0.09	0.07	0.05	0.05	0.08	0.10	0.16	0.28	0.29
S20	0.11	0.08	0.09	0.05	0.02	0.03	0.06	0.03	0.05	0.04	0.03	0.03	0.05	0.08	0.12	0.10
S21	0.19	0.10	0.09	0.06	0.03	0.02	0.03	0.09	0.10	0.08	0.07	0.07	0.07	0.08	0.09	0.11
S25	0.15	0.18	0.21	0.22	0.15	0.11	0.07	0.08	0.07	0.05	0.08	0.15	0.23	0.24	0.20	0.10
S26	0.19	0.19	0.25	0.26	0.18	0.16	0.04	0.05	0.05	0.03	0.05	0.16	0.30	0.26	0.24	0.18
S28	0.37	0.25	0.20	0.18	0.11	0.07	0.07	0.05	0.06	0.03	0.03	0.06	0.12	0.17	0.19	0.21
S30	0.24	0.17	0.12	0.08	0.08	0.10	0.08	0.11	0.12	0.07	0.06	0.12	0.04	0.07	0.07	0.09
S31	0.41	0.26	0.23	0.16	0.08	0.07	0.05	0.06	0.12	0.05	0.03	0.08	0.07	0.15	0.30	0.30

Table B14: Directional wind velocity ratios ($VR_{500,i,j}$) – Zone A, Eastern Part

Test Point	0°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°
S24	0.35	0.17	0.14	0.13	0.08	0.07	0.06	0.04	0.03	0.02	0.03	0.06	0.09	0.12	0.26	0.30
S32	0.25	0.16	0.21	0.18	0.13	0.14	0.11	0.08	0.04	0.02	0.02	0.07	0.11	0.16	0.28	0.27
S33	0.36	0.26	0.19	0.16	0.11	0.09	0.08	0.06	0.04	0.03	0.05	0.09	0.17	0.22	0.33	0.32
S34	0.22	0.21	0.21	0.18	0.11	0.11	0.03	0.05	0.05	0.03	0.04	0.16	0.27	0.19	0.16	0.12
S35	0.19	0.10	0.15	0.18	0.16	0.14	0.03	0.05	0.06	0.03	0.05	0.19	0.30	0.25	0.28	0.21
S36	0.26	0.21	0.26	0.23	0.13	0.13	0.08	0.08	0.03	0.01	0.02	0.08	0.16	0.21	0.31	0.24
S37	0.30	0.19	0.25	0.22	0.15	0.15	0.11	0.10	0.07	0.03	0.03	0.06	0.13	0.17	0.27	0.26
S38	0.41	0.32	0.23	0.14	0.11	0.14	0.21	0.27	0.14	0.09	0.09	0.09	0.12	0.17	0.27	0.28
S39	0.37	0.20	0.16	0.19	0.19	0.19	0.20	0.22	0.14	0.08	0.10	0.12	0.19	0.30	0.39	0.36
S40	0.37	0.27	0.33	0.30	0.20	0.19	0.12	0.15	0.11	0.07	0.09	0.12	0.25	0.32	0.42	0.34
S41	0.29	0.14	0.12	0.19	0.20	0.17	0.12	0.13	0.08	0.05	0.06	0.18	0.28	0.26	0.32	0.29

Appendix C

50% Probability of Exceedance Mean Wind Speeds for all Pedestrian Level Test Points

Table C1: Mean wind speeds (50% probability of exceedance) for all pedestrian level test points in Zone A (Project Area)

Test Point	$V_{p,i,,j}$ – annual	$V_{p,i,,j}$ – summer	$V_{p,i,,j}$ – winter
S01	1.41	0.37	2.02
S02	1.52	0.32	2.22
S03	0.90	0.29	1.32
S04	1.45	0.28	2.09
S05	1.66	0.27	2.42
S06	1.64	0.70	2.25
S07	1.20	0.41	1.63
S08	1.20	0.24	1.71
S11	1.13	0.43	1.51
S12	1.50	0.86	1.99
S13	1.92	0.97	2.60
S14	1.12	0.48	1.46
S15	1.16	0.45	1.59
S16	1.14	0.40	1.59
S17	1.39	0.33	2.13
S18	0.83	0.25	1.19
S19	1.35	0.45	1.96
S20	0.46	0.25	0.63
S21	0.58	0.38	0.72
S24	0.97	0.29	1.41
S25	1.27	0.57	1.68
S26	1.49	0.40	1.98
S28	1.31	0.32	1.92
S30	0.81	0.49	1.04
S31	1.28	0.40	1.89
S32	1.27	0.28	1.77
S33	1.25	0.41	1.81
S34	1.28	0.35	1.75
S35	1.13	0.42	1.50
S36	1.51	0.25	2.12
S37	1.47	0.38	2.08
S38	1.33	0.73	1.83
S39	1.46	0.79	1.90
S40	2.01	0.75	2.80
S41	1.21	0.58	1.68
Mean	1.27	0.44	1.78

Table C2: Mean wind speeds (50% probability of exceedance) for all pedestrian level test points in Zone B

Test Point	$V_{p,i,,j}$ – annual	$V_{p,i,,j}$ – summer	$V_{p,i,,j}$ – winter
A1	1.60	0.36	2.35
A2	0.88	0.32	1.26
A4	2.57	0.67	3.81
A5	1.59	0.85	2.16
A6	1.68	0.53	2.42
A8	1.28	0.60	1.86
A9	1.46	0.57	2.23
A15	0.70	0.34	0.92
A16	0.90	0.26	1.29
A21	0.85	0.83	0.84
A22	0.98	0.82	1.06
A23	0.62	0.60	0.61
Mean	1.26	0.56	1.73

Table C3: Mean wind speeds (50% probability of exceedance) for all pedestrian level test points in Zone C

Test Point	$V_{p,i,,j}$ – annual	$V_{p,i,,j}$ – summer	$V_{p,i,,j}$ – winter
A27	0.87	0.51	1.02
A28	0.61	0.50	0.67
A29	1.20	0.50	1.55
A31	0.91	0.37	1.34
A32	1.33	0.41	2.05
A33	1.44	0.73	2.09
A34	1.24	0.40	1.91
A35	0.64	0.17	1.06
A36	0.65	0.37	0.91
A37	0.67	0.14	1.14
A38	1.54	1.00	1.84
A39	1.04	0.14	1.49
Mean	1.01	0.44	1.42

Table C4: Mean wind speeds (50% probability of exceedance) for all pedestrian level test points in Zone D

Test Point	$V_{p,i,,j}$ – annual	$V_{p,i,,j}$ – summer	$V_{p,i,,j}$ – winter
A40	0.80	0.06	1.18
A42	0.58	0.47	0.59
A45	0.60	0.50	0.60
A46	0.91	0.54	1.09
A47	1.07	0.67	1.26
A48	1.37	0.82	1.76
A49	1.08	0.64	1.39
A50	0.60	0.21	0.80
A51	0.93	0.22	1.30
A52	0.62	0.32	0.86
A53	0.83	0.32	1.21
Mean	0.85	0.43	1.10

Table C5: Mean wind speeds (50% probability of exceedance) for all pedestrian level test points in Zone E

Test Point	$V_{p,i,,j}$ – annual	$V_{p,i,,j}$ – summer	$V_{p,i,,j}$ – winter
A59	1.29	0.48	1.87
A60	0.83	0.35	1.17
A61	1.52	0.48	2.11
A62	1.28	0.43	1.88
A63	1.19	0.64	1.71
A64	1.53	0.19	2.19
A65	1.45	0.40	2.01
A66	1.43	0.78	1.97
A86	0.85	0.43	1.25
Mean	1.27	0.46	1.79

Table C6: Mean wind speeds (50% probability of exceedance) for all pedestrian level test points in Zone F

Test Point	$V_{p,i,,j}$ – annual	$V_{p,i,,j}$ – summer	$V_{p,i,,j}$ – winter
A68	1.25	0.47	1.72
A69	1.06	0.50	1.45
A70	1.57	0.63	2.21
A72	1.10	0.51	1.48
A74	0.91	0.38	1.23
A75	1.47	0.77	2.01
A82	1.28	0.61	1.84
A83	1.12	0.41	1.64
A84	1.34	0.87	1.64
A85	1.04	0.59	1.44
Mean	1.21	0.57	1.66

Table C7: Mean wind speeds (50% probability of exceedance) for all pedestrian level test points on Tong Shui Road

Test Point	$V_{p,i,,j}$ – annual	$V_{p,i,,j}$ – summer	$V_{p,i,,j}$ – winter
A3	1.17	0.38	1.70
A7	1.56	0.40	2.29
A10	1.22	0.65	1.76
A11	1.44	0.75	1.91
A12	1.03	0.52	1.52
A13	1.49	0.86	1.96
A14	0.93	0.56	1.30
A17	1.07	0.47	1.61
A18	1.17	0.71	1.53
A19	1.21	0.62	1.72
A20	0.90	0.62	1.14
A24	1.20	0.85	1.42
A25	1.44	0.97	1.72
A26	0.68	0.62	0.75
Mean	1.18	0.64	1.60

Table C8: Mean wind speeds (50% probability of exceedance) for all pedestrian level test points on Shu Kuk Street

Test Point	$V_{p,i,,j}$ – annual	$V_{p,i,,j}$ – summer	$V_{p,i,,j}$ – winter
A30	0.85	0.54	1.10
A41	1.13	0.65	1.62
A43	1.09	0.63	1.52
A44	1.17	0.74	1.57
Mean	1.06	0.64	1.45

Table C9: Mean wind speeds (50% probability of exceedance) for all pedestrian level test points on Kam Hong Street

Test Point	$V_{p,i,,j}$ – annual	$V_{p,i,,j}$ – summer	$V_{p,i,,j}$ – winter
A54	1.27	0.75	1.72
A55	1.61	0.77	2.21
A56	0.87	0.49	1.20
A57	0.87	0.58	1.08
A58	1.05	0.64	1.33
Mean	1.14	0.65	1.51

Table C10: Mean wind speeds (50% probability of exceedance) for all pedestrian level test points on Tin Chiu Street

Test Point	$V_{p,i,,j}$ – annual	$V_{p,i,,j}$ – summer	$V_{p,i,,j}$ – winter
A67	1.01	0.43	1.46
A71	1.08	0.55	1.45
A73	1.16	0.71	1.61
A76	0.98	0.61	1.37
A77	1.18	0.71	1.56
A78	1.49	0.92	1.93
A79	1.09	0.53	1.55
A80	1.55	0.71	2.14
A81	1.34	0.68	1.89
Mean	1.21	0.65	1.66