Prepared for

**Hong Kong Housing Society**

Prepared by

**Ramboll Environ Hong Kong Limited**

# PROPOSED PUBLIC RENTAL HOUSING DEVELOPMENT AT TING ON STREET, NGAU TAU KOK

# AIR VENTILATION ASSESSMENT REPORT

In association with

**Urbis Limited**

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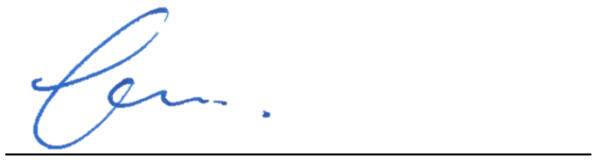
| Signed |  |
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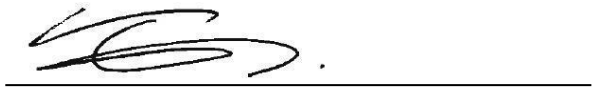
| Signed |  |
| Project Reference | **URBHSTOSEI00** |
| Document No. | **R4617_V2.2** |



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# 1. INTRODUCTION

## 1.1 Project Background

1.1.1 Ramboll Environ Hong Kong Limited has been commissioned by Urbis Limited on behalf of the Hong Kong Housing Society (the Project Proponent) to undertake an Air Ventilation Assessment (AVA) for proposed public rental housing (the Proposed Scheme) at Ngau Tau Kok, East Kowloon (the Subject Site).

1.1.2 To assess the Proposed Development potential of the Subject Site in regards to air ventilation, a detailed technical feasibility study has been undertaken as part of the AVA.

## 1.2 Objectives

1.2.1 This AVA contains a qualitative expert evaluation and quantitative computational fluid dynamics (CFD) assessment of the Proposed Scheme's air ventilation impacts on the existing pedestrian wind environment. The AVA considers the the Proposed Schemes and the Existing Scenario, i.e. the current "Government/ Institution and Community (GIC)" zoning. All the surrounding buildings, major noise barriers, elevated structures, planned and committed developments within the surrounding area have been modelled in the simulations appropriately.

## 1.3 Subject Site and its Environs

1.3.1 The Subject Site is roughly of trapezoidal shape and it is located in a sloped area.

1.3.2 There is gradual increase in ground elevation toward the north and east with Ngau Tau Kok Road bounding to the northeast at 17.2 mPD, whilst Ting On Street bounds the southwest at 7.2 mPD, of the Subject Site.

1.3.3 Major topographic features include Kowloon Peak's hill-top of 580 m located around 2.1 km to the north, whilst Mau Wu Shan's hill-top of 220 m is located approximately 2.8 km to the east of the Subject Site.

1.3.4 To the north of the Subject Site beyond Ngau Tau Kok Road are residential buildings and primary school, immediately to the east of the is Ngau Tau Kok Maternal and Child Health Centre, to the south beyond Ting On Street and immediately to the west are predominately mid-rise residential buildings with retail at ground level.

1.3.5 Figure 1 shows the location and the environs of the Subject Site.

## 1.4 Proposed Scheme

1.4.1 Appendix 1 shows the Master Layout Plan of the Proposed Scheme.

1.4.2 The Proposed Scheme comprises one 31 storeys with 27 storeys for domestic use and 4 storeys for non-domestic use, with a maximum building height restriction of 110 mPD. A 5m setback from the from the Ting On Street is provided. A 10 m setback distance to Ngau Tau Kok Road would be provided for typical floors, whilst at first to third floor podium levels there would be a setback distance of around 17 m from Ngau Tau Kok Road. Figure 7 indicated the setback to the Ngau Tau Kok Road and Tin On Street. Such setback distances increase building permeability and allow more wind penetration.

1.4.3 The Proposed Scheme would feature retail, car parking, loading/ unloading bays for good vehicles and Refuse Collection Point (RCP) at ground floor; first floor proposes commercial/ covered activities area; second floor for commercial and a basketball court whilst third floor is intended for GIC use.

## 1.5 Existing Scenario

1.5.1 The Subject Site is currently used as a RCP and a playground with a basketball court. Appendix 2 shows an aerial photo and site photos of the existing scenario. It is currently located in GIC zone under the Outline Zoning Plan (OZP) No. S/K14S/20 – Kwun Tong (South) OZP.

## 1.6 Proposed Scheme Design Constraints

1.6.1 The Proposed Scheme has been fine-tuned in response to the comments from local stakeholders, including District Councillors and the public on the design of the podium. There are no changes to the residential portion. In the revised podium design, the existing basketball court will be re-provided at the podium level of the Subject Site and the existing refuse collection point (RCP) will also be re-provided at Ting On Street within the site boundary of the Subject Site.

1.6.2 The Proposed Scheme would replace and upgrade the RCP to 308 $m^2$ with a 10 m diameter for refuse collection vehicle's to turn, in accordance with the Handbook on Standard Features for Refuse Collection Points of Food and Environmental Hygiene Department (February 2009).

1.6.3 Therefore, due to the sizing requirement of the RCP, it is not feasible to reduce the podium bulk and the building footprint of the Proposed Scheme.

# 2. SITE WIND AVAILABILITY

## 2.1 Site Wind Availability Data

2.1.1 According to the Planning Department's website, a meso-scale Regional Atmospheric Modeling System (RAMS) was used to produce a simulated 10-year wind climate at the horizontal resolution of 0.5 km x 0.5 km covering the whole territory of Hong Kong. The simulated wind data represents the annual, winter and summer wind condition at various levels, i.e. 200 m, 300 m, and 500 m above terrain.

2.1.2 It is considered an acceptable starting point to use the simulated RAMS data for site wind availability. The use of RAMS data (grid: 089, 042) is preferred over measurement data at Waglan Island as it can reflect the effect of topography to wind availability.

2.1.3 The relevant annual windrose for the district under concern has been extracted from the Planning Department's website for Subject Site wind availability data. Figure 2 shows the relevant windrose diagram (at 500 m) representing the frequency and wind speed distribution of the district concerned for both summer and annual conditions. The simulated windroses show the local area is dominated by winds from ENE to SE annually, with winds from NE to ESE accounting for approximately 53.5 % of all winds that occur at the Subject Site. On the other hand, the summer wind mainly comes from E to WSW; 86.5 % of all winds that occur at the Subject Site.

2.1.4 The windroses results illustrate the wind environment is affected by topography and buildings. Table 2.1 sets out a summary of the simulated Subject Site wind availability data including probability of occurrence and average wind speed. In this quantitative AVA a CFD software has been used. According to the Technical Guide, simplification of wind data for the initial study has been adopted. The wind directions with highest probability of occurrence are selected AVA purposes. A total of 11 wind directions were selected (as highlighted in Table 2.1) with overall frequency of occurrence equivalent to 90.6 % and 86.5 % respectively of the time in a year for both annual and summer conditions.

**Table 2.1 Summary of RAMS Data and Wind Direction**

| Wind Direction | Probability for Annual Condition (%) | Probability for Summer Condition (%) |
|---|---|---|
| N | 2.4 | 0.8 |
| NNE | 5.3 | 0.9 |
| NE | 7.6 | 1.4 |
| ENE | 14.9 | 3.0 |
| E | 19.9 | 8.8 |
| ESE | 11.1 | 9.6 |
| SE | 7.0 | 7.4 |
| SSE | 4.4 | 8.4 |
| S | 4.4 | 9.2 |
| SSW | 5.6 | 12.4 |
| SW | 6.2 | 14.8 |
| WSW | 4.2 | 10.6 |
| W | 2.9 | 6.4 |
| WNW | 1.4 | 2.8 |
| NW | 1.2 | 2.2 |
| NNW | 1.3 | 1.1 |

## 2.2 Building Morphology

*Building Morphology*

2.2.1 There are numerous mid-rise developments to the south and west of the Subject Site.; On Tai Building located to the south, Ting Hing Building to the southwest and Kathy's Court to the west. There are several high-rise developments located to the northwest of the Subject Site; Upper Ngau Tau Kok Estate Sheung Hing House, Upper Ngau Tau Kok Estate and Sheung Shing House. The building height information was extracted from Geo-Reference Database (BG1000) provided by Survey and Mapping Office/ Lands Department, as shown in Table 2.2 and indicated in Figure 4.

**Table 2.2 Surrounding Mid- to High-rise Development**

| Name of Development | Building Height mPD | Location from Site |
|---|---|---|
| Sheung Yat House | ~137.9 | North |
| Sheung Mun House | ~142.9 | North |
| Sheung Yuet House | ~89 | North |
| SKH Kei Hin Primary School | ~38 | North |
| Yick Fu House | ~25 | West |
| Dor Hei Building | ~34 | West |
| Tsut Hei Building | ~22 | West |
| Hing Fung Building | ~22 | West |
| Sheung Hei Building | ~22 | West |
| Ting Hing Building | ~75.2 | South |
| King Wah Building | ~26.6 | South |
| Ting On Building | ~29.4 | South |
| On Tai Building | ~30.1 | South |
| Lap Hing Building | ~34.1 | South |
| Ting Shing House | ~25 | South |
| Foo Yue Building | ~87.7 | South |
| Ngau Tau Kok Road Playground | ~33.1 | East |
| Garden Estate Hay Cheuk Lau | ~38.3 | Northeast |
| Garden Estate Yin Chee Lau | ~67.1 | Northeast |
| Mu Kuang English School | ~75 | Northeast |
| Believe Garden | ~92 | Northeast |

## 2.3 Summary of Existing Site Wind Availability

2.3.1 According to the wind availability data, the annual wind directions of the area include easterlies, and north-easterlies. From Table 2.1, the wind probability from the E direction is 19.9 % and is considered to be the dominant wind direction for the area. The ENE (14.9 %) and ESE (11.1 %) wind are also dominant prevailing wind directions other than the E wind. Higher topographic regions and mid-rise buildings to the north / northeast / east will slightly reduce the wind availability to the Subject Site, but it is considered that the potential blocking effect is not significant. It is anticipated that Ngau Tau Kok Road and On Shin Road would be the main air corridors under the annual condition. Katabatic wind would flow would occur from hill to the lower area at night or during the winter season, which would not benefit the downwind area during daytime or summer season.

2.3.2 During summer conditions, prevailing winds from the SSW to WSW are the dominant wind directions. Under S/ SSW wind directions, the existing compact industrial buildings located between Tai Yip Street and Wai Yip Street would obstruct incoming wind to the Subject Site. Besides, existing developments to the southwest side of Ting Fu Street would also block summer wind from the southwest quadrant. Therefore, it is expected that the wind availability at the Subject Site would be low to medium during summer condition.

2.3.3 It is also anticipated that Ngau Tau Kok Road would be the main air corridor for the Subject Site under summer condition.

# 3. DISCUSSION ON IMPORTANT PEDESTRIAN AREAS AND FOCUS AREA

## 3.1 Important Pedestrian Areas

3.1.1 Important pedestrian areas that the public would often access have been identified as the following:

- Ngau Tau Kok Road;
- Ting Fu Street;
- Ting On Street;
- Tai Yip Street;
- Kai Fu Road;
- Ting Yip Street;
- On Shin Road;
- On Tak Road;
- Upper Ngau Tau Kok Estate;
- Garden Estate Yin Chee Lau;
- Garden Estate Carpark;
- SKH Kei Hin Primary School;
- Ting Yue Square;
- Ting Yue Square Temporary Sitting-out Area;
- Ngau Tau Kok Maternal and Child Health Centre; and
- Ngau Tau Kok Playground.

## 3.2 Problem Areas

3.2.1 It is anticipated that there would be some areas behind the existing buildings in the vicinity that have relatively low wind speed when the wind direction is from the upstream of these buildings. For example, the Tin Yue Square Temporary Sitting-out area.

3.2.2 On the other hand a wind from west over flat topography can cause high wind flow along different streets such as Ting On Street, Ting Fu Street and Ngau Tau Kok Road.

## 3.3 Good Design Features

3.3.1 Chapter 11 of Hong Kong Planning Standards Guidelines on Air Ventilation was referenced in order to determine the good features and problem areas from an air ventilation standpoint. Building disposition and building permeability have thus been considered for this Proposed Scheme.

## 3.4 Podium Structure and Building Height

3.4.1 It is anticipated that the introduction of a podium structure and high-rise building height would induce larger wake area to leeward side. However, on the other hand, the high-rise building tower would also induce some downwash wind and benefit the windward side.

## 3.5 Building Disposition and Setback

3.5.1 Part of the tower in the Proposed Scheme is relatively close to Ngau Tau Kok Road. It is expected that a downwash wind could be generated, and this would enhance the

wind flow at the pedestrian level of Ngau Tau Kok Road. Therefore the disposition of the Proposed Scheme should likely result in positive impact along Ngau Tau Kok Road compare to the existing condition.

## 3.6 Building Permeability

3.6.1 Building permeability mainly relies on void and building gap provision with an aim to minimise wind blockage. Compared to the existing RCP and open area, the Proposed Scheme should reduce the existing permeability to the downwind area.

## 3.7 Landscaping, Projecting Obstruction and Cool Materials

3.7.1 Greening and use of cool materials can help to reduce heat island effects. Landscaping will be provided to ameliorate possible wind amplification problems. Greening and cool materials will be incorporated into the Proposed Schemes where practicable. Cool materials including water features, materials with high emissivity will be employed where appropriate. It is expected that it is possible to adopt similar extent of greening and cool materials for both schemes.

## 3.8 Conclusions

3.8.1 Both the Proposed Scheme and existing scenario of the Subject Site have been evaluated from an air ventilation standpoint.

3.8.2 In order to minimise the adverse air ventilation impact induced by the high-rise building tower in the Proposed Scheme, the following mitigation measures have already adopted in the building design:

- A 10 m setback to the Ngau Tau Kok Road is provided in the typical floor to minimise the blockage effect along Ngau Tau Kok Road; and
- Minimised podium design, apart from RCP and GIC area at the podium, the Proposed Scheme try to maximise the open landscape/ playground area at the podium.

3.8.3 Under the design constraint in Section 1.6, it is not feasible to reduce the podium bulk and the building footprint of the Proposed Scheme, due to the minimal area requirement of the RCP. However, the Proposed Scheme has maximised the setback and building permeability in order to mitigate the potential adverse air ventilation impact induced by the high-rise building tower.

# 4. QUANTITATIVE ASSESSMENT METHODOLOGY

## 4.1 CFD Code and Major Parameters

4.1.1 A quantitative AVA based on requirement for initial study stipulated in the technical guide was conducted for the purpose to verify the air ventilation performance for the Proposed Scheme over the Existing Scenario .

4.1.2 The quantitative AVA was conducted using a commercial CFD code, PHOENICS. PHOENICS employs structured grid with fine-grid embedding to fit small-scale flow features without the computational overhead of fully-unstructured grids. Turbulence models include various versions of K-epsilon model (such as RNG & Low Reynolds Number Model), LVEL, Kolmogorov-Wilcox two- equation k-f model and other models such as RSM and Sub-Grid-Scale LES model.

4.1.3 Modified version of K-epsilon turbulence models which give better prediction of separation and vortexes are adopted for the AVA. In this study, the Chen-Kim modified KE-EP turbulence model has been employed. The Chen-Kim model is a variant of K- • based on comparison with experimental data. This model involves a modification which improves the dynamic response of the EP equation by introducing an additional time scale (KE/PK), where PK is the volumetric production rate of KE. The model maintains good agreement with experimental data on classical turbulent shear layers. Moreover, this is based on the KE-EP model which is appropriate for high-reynolds number problems such as external flow. These models are statistical turbulence models and are generally regarded as practical to model steady state condition. It uses different constants, and has an addition term in the ε equation. The effect of the changes is to reduce the turbulent viscosity in regions of high shear - e.g. in recirculation zones. Hence, it predicts a longer recirculation zone, in agreement with experimental evidence. The Chen-Kim model gives better prediction of separation and vortexes. It does not only keep the merits or Renormalization Group (RNG) model but also improve results to jet stream fluid and feather fluid. The equation and parameters adopted in Chen-Kim turbulence model are shown below for reference:

| Equation | $\Phi$ | $\Gamma_\Phi$ | $S_\Phi$ |
|---|---|---|---|
| Turbulent Kinetic Energy | k | $\nu_t/\sigma_k$ | $\rho(G-\varepsilon)$ |
| Dissipation Rate | ε | $\nu_t/\sigma_\varepsilon$ | $\rho(\varepsilon/k)(C_{\varepsilon 1}G - C_{\varepsilon 2}\varepsilon) + \rho C_{\varepsilon 3}G^2/k$ |

$$G = \nu_t (\partial_k U_i + \partial_i U_k)\partial_k U_i$$

$$\nu_t = C_\mu k^2 / \varepsilon$$

$\sigma_k = 0.75$, $\sigma_\varepsilon = 1.15$, $C_{\varepsilon 1} = 1.15$, $C_{\varepsilon 2} = 1.9$, $C_{\varepsilon 3} = 0.25$, $C_\mu = 0.09$

4.1.4 It is understood that LES/DES generally requires careful application by the user, because compared to statistical turbulence modelling, the approach requires more accurate spatial resolution on finer meshes and small time steps, and as a consequence significant amounts of computer time. Typically, the time step should be in the range 1/200 to 1/50 of the large-eddy turnover time. Otherwise, there will be inadequate time resolution. Also, there is always the possibility of numerical damping of the fluctuations. LES and DES have the potential to produce more accurate solutions than statistical turbulence models, but misuse of these methods is fairly common due to

inadequate temporal and spatial resolution. Considering the practicability issue, statistical turbulence model is considered a viable choice which can achieve generally acceptable level of accuracy.

4.1.5 The assessment area and surrounding area covered 150 m and 300 m respectively from the Subject Site boundary. The surrounding area is determined by two times the height of the highest building within the surrounding area therefore at least 2H of the highest building nearby (i.e. ~120 m at Sheung Mun House) from the site boundary.

4.1.6 The domain dimension is about 2800 m x 2400 m and with an elevation of 1000 m. 1-phase fluid is modelled at standard pressure. Nearly 11,850,000 grid cells are defined to simulate the air flow. Cartesian coordinate cell grid system is adopted with refinement within an area which is within about H from the Subject Site (and with denser grid near ground level). The grid size was generally smaller within the assessment area (<1 m) and coarse outside and within the study area. The grid expansion ration is controlled to not more than 1.2. The grid size near the domain boundary on four sides and ceilings are >50 m. It is defined in such a way that there was at least three cells within major building gaps. For relevant streets/ roads containing the test point, generally eight to ten cells would be defined between walls/ objects. The test point was assigned in such a way that there was at least two to three cells from the building façade or major obstacle. Within the level of 0 to 2 m aboveground, the grid height of the layer near ground is about 0.5 m and there were four cells defined so that the result taken would be taken at the third cell, instead of the cell adjacent to ground. Similarly, all test points would not be taken at the cell adjacent to wall/ object.

4.1.7 Lateral clearance is around 1,040 m (more than 5H) on each side. The vertical distance between the Proposed Scheme and the ceiling of the CFD domain amounts to more than 800 m. Top and lateral boundary area defined as symmetric plane in the CFD model. The distance between the Proposed Scheme and the inflow amounts to around 1,300 m. The distance between the Proposed Scheme and the outflow amounts to around 1,300 m. The percentage blockage is less than 3 % with the surrounding public housing and private residential developments considered. The convergence criteria adopted in this study is 0.1 %. In addition, spot values are checked to ensure that steady value can be obtained from simulation. Wind Object is defined in the PHOENICS programme environment when defining the boundary conditions. The windward boundary is defined as inflow with the wind profile defined (as discussed below). The leeward boundary is defined as outflow. The sky and lateral boundaries are defined as neutral.

4.1.8 The commonly used hybrid-differencing numerical scheme in PHOENICS is adopted (this scheme employs the 1st-order upwind-differencing scheme (UDS) in high-convection regions; and the 2nd-order central-differencing scheme (CDS) in low-convection regions automatically to strike a balance between accuracy and computing efficiency with the low-convection region using higher order scheme).

## 4.2 Atmospheric Conditions

4.2.1 Simulated wind profile curves were extracted from the Planning Department's website and adopted for this quantitative AVA. Appendix 5 shows the wind profile curve for the grid area (x: 089, y: 042), which corresponds to the region where the Subject Site resides.

4.2.2 Appendix 3 shows captures of the CFD models.

## 4.3 Test Point Location

4.3.1 On-site survey was conducted to identify major pedestrian areas and features. Test points are selected and shown in Figure 3. Test points include perimeter test point defined along the boundary of the Subject Site and overall test points representing the area within the Assessment Area.

# 5. KEY FINDINGS

## 5.1 Spatial Average Wind Velocity Ratios

5.1.1 The velocity ratio under a specific wind direction at a test point was calculated by dividing the simulated wind speed at the test point under this wind direction with the velocity at gradient height under the same wind direction. All test points were located at 2 m above ground level.

5.1.2 A total of 155 test points were selected, including 31 perimeter test points, 110 overall test points and 14 special test points (due to the re-provision of the existing landscape area and basketball court within the Subject Site, the test points location are different between Existing Scenario and Proposed Scheme, i.e. S01 – S07 for existing scenario and S08 – S14 for Proposed Scheme (2m above those area)). Figure 3a shows the location of the perimeter test points and overall test points within the assessment area. Figure 3b shows the special test points within the Subject Site.

5.1.3 Table 5.1 shows the Subject Site spatial average velocity ratio (SVR), local spatial average velocity ratio (LVR) and average wind velocity ratio along surrounding air sensitive uses area during annual condition and summer condition respectively for the Proposed Scheme (PS) and existing scenario (EX).

5.1.4 The wind velocity ratios of individual test points are shown in Figure 4a and Figure 5a for annual condition of the existing scenario and Proposed Scheme respectively, and Figure 4b and Figure 5b for summer condition of the existing scenario and Proposed Scheme respectively. Appendix 3 shows detailed simulation result of the Proposed Scheme and the existing scenario respectively.

**Table 5.1 Summary of Spatial Average Wind Velocity Ratios (VR) – Annual and Summer Condition**

| Spatial Average Wind Velocity Ratio (VR) | Test Point | Annual | | Summer | |
|---|---|---|---|---|---|
| | | PS | EX | PS | EX |
| SVR | P01-P31,T01-T110 | **0.12** | 0.09 | **0.09** | 0.07 |
| LVR | T01-T110 | 0.11 | 0.11 | 0.10 | 0.10 |
| Tai Yip Street | T01-T07 | 0.10 | 0.10 | 0.09 | 0.09 |
| Kai Fuk Road | T08-T13,T17 | 0.18 | 0.18 | 0.14 | 0.14 |
| Ting Fu Street | T18-T23,T28,T35-T38,T46 | **0.11** | 0.10 | **0.10** | 0.09 |
| Ting On Street | P17-P23,T14-T15,T24-T33,T105-T106 | **0.09** | 0.08 | **0.09** | 0.08 |
| Ting Yip Street | T39-T45 | 0.08 | 0.08 | 0.08 | 0.08 |
| Ngau Tau Kok Road | P01-P07,T47-T58,T64,T82 | **0.14** | 0.13 | **0.13** | 0.12 |
| On Shin Road | T83-T89 | 0.13 | **0.14** | 0.13 | 0.13 |
| On Tak Road | T76-T81,T87 | 0.13 | **0.14** | 0.14 | **0.15** |
| Upper Ngau Tau Kok Estate | T59 - T67 | 0.12 | 0.12 | 0.13 | 0.13 |
| Garden Estate Yin Chee Lau | T90-T94 | 0.07 | 0.07 | 0.08 | 0.08 |

| Spatial Average Wind Velocity Ratio (VR) | Test Point | Annual | | Summer | |
|---|---|---|---|---|---|
| | | PS | EX | PS | EX |
| Garden Estate Carpark | T71-T75,T84 | 0.09 | 0.09 | 0.09 | 0.09 |
| SKH Kei HIN Primary School | T68-T70 | 0.11 | 0.11 | 0.10 | 0.10 |
| Ting Yu Square | T43,T106-T107 | 0.07 | **0.08** | 0.06 | **0.07** |
| Ting Yu Square Temporary Sitting-out Area | T103-T105 | 0.06 | **0.07** | 0.05 | **0.06** |
| Ngau Tau Kok Maternal and Child Health Centre | T100-T102,T30 | 0.08 | 0.08 | **0.07** | 0.06 |
| Ngau Tau Kok Playground | T95-T99 | 0.11 | 0.11 | 0.08 | 0.08 |
| Kwun Tong Government Pimary School | T34, T35, T108-T110 | 0.10 | 0.10 | 0.08 | 0.08 |
| Public Landscape Area and Basketball Court within Subject Site | (EX)S01-S07 (PS)S08-S14 | **0.15** | 0.09 | **0.13** | 0.08 |

*Note:*

*Highlighted in **red** where VR is higher in the Proposed Scheme*

*Highlighted in **blue** where VR is higher in the Existing Scenario*

## 5.2 Discussions on Air Ventilation Performance

5.2.1 The SVR is higher in the Proposed Scheme but LVR are the same for both schemes under annual and summer condition. Generally, Proposed Scheme and the Existing Scenario are similar in both annual and summer condition, while there are some areas where slight improvements in VR are found in the Proposed Scheme.

5.2.2 The VRs are better in the Proposed Scheme in SVR (annual and summer condition), Ting On Street (annual and summer condition), Ngau Tau Kok Road (annual and summer condition), Ngau Tau Kok Maternal and Child Health Centre (summer condition) and public landscape area and basketball court within the Subject Site (annual and summer condition).

5.2.3 VRs are better in the existing scenario in On Shin Road (annual condition), On Tak Road (annual and summer condition), Tin Yu Square (annual and summer condition) and Ting Yu Square Temporary Sitting-out Area (annual and summer condition).

5.2.4 It is believed that the high-rise tower in the Proposed Scheme induces downwash wind and benefits areas close to the site boundary, i.e. SVR, Ting On Street, Ngau Tau Kok Road and Ngu Tau Kok Maternal and Child Health Centre.

5.2.5 It also noted that the re-provision of the existing landscape area and basketball court within the Subject Site to second floor in the Proposed Scheme improved the ventilation performance in the recreational area within Subject Site. Generally, the ventilation is better at higher level.

5.2.6 On the other hand, the high-rise building tower also induce a wake area to the leeward side. However, as discussed previously it is not feasible to reduce the podium bulk and the building footprint of the Proposed Scheme.

## 5.3 Direction Analysis

Wind performance under Wind Direction of NNE

5.3.1 Under NNE winds, wind flow is obstructed by the existing mid-rise buildings situated to the north and northeast of the Subject Site, i.e. Sheung Yuet House and Upper Ngau Tau Kok Estate Sheung Shing & Sheung Hing House. Hence, wind availability of the Subject Site mainly relies on wind flow coming from the existing air path of On Shin Road and Ngau Tau Kok Road.

5.3.2 Due to the level difference between Ngau Tau Kok Road (~+17 mPD) and Ting On Street (~+6 mPD), there is a wake area at the Subject Site under existing scenario. Since the Proposed Scheme sits on the wake area, it is anticipated that it would unlikely have a significant impact induced by the high-rise tower. It is observed that the VRs are similar for both the existing scenario and the Proposed Scheme under NNE wind.

5.3.3 According to the contour plot the wind flow along Ting On Street is slightly enhanced under Proposed Scheme, due to the channelized effect induced by the proposed podium design. Also, the Proposed Scheme also redistributes and diverts the NNE wind flow from On Shin Road toward northwest and slightly enhance the VR near northern boundary.

Wind performance under Wind Direction of NE

5.3.4 Similar to the NNE wind, it is found that wind flow is obstructed by the existing mid-rise buildings situated to the north and northeast of the Subject Site. Thus, the wind availability of the Subject Site mainly relies on wind flow coming from the existing air path of On Shin Road and Ngau Tau Kok Road. A wake area at the Subject Site is observed behind the Ngau Tau Kok Maternal and Child Health Centre which is located at the immediate upwind area.

5.3.5 Since the Proposed Scheme sits on the wake area, there is not significant blockage to the leeward side (i.e. Ting On Street) induced by the high-rise tower. On the other hand, the high-rise tower redistributes and diverts more wind from the On Shin Road toward the northwest and this would benefit the Ngau Tau Kok Road. It is observed that the VR are better to the northwest of the Subject Site (along Ngau Tau Kok Road) in the Proposed Scheme. However, the stronger wind to the windward side also countered the wind flow from the Ngau Tau Kok Road Playground.

5.3.6 However, the proposed high-rise tower reduce the wind penetration at higher levels; and therefore the VR at Ting Yu Square Temporary Sitting-out Area and Ting On Street (near Ting Yu Square) would be lower in the Proposed Scheme.

Wind performance under Wind Direction of ENE

5.3.7 Under ENE wind, wind flow is obstructed by the existing mid-rise buildings situated to the north and northeast of the Subject Site, i.e. Sheung Yuet House and Upper Ngau Tau Kok Estate Sheung Shing & Sheung Hing House. Wind availability of the Subject Site mainly relies on wind flow coming from the existing air path of On Shin Road and Ting On Street. A wake area at the Subject Site is observed behind the Ngau Tau Kok Maternal and Child Health Centre which is located at the immediate upwind area.

5.3.8 The high-rise tower redistributes and diverts more wind from the On Shin Road toward the northwest and this would benefit the Ngau Tau Kok Road. It is observed that the VR are slightly better to the northwest of the Subject Site (along Ngau Tau Kok Road) in the Proposed Scheme. However, the stronger wind to the windward side also countered the wind flow from the Ngau Tau Kok Road Playground.

5.3.9 However, the proposed high-rise tower reduce the wind penetration at higher levels and the podium of the Proposed Scheme may induce larger surface roughness along Ting On Street. Therefore, the VR at sitting out area between Kwun Tong Road and Tin Yu Square, Ting Yu Square Temporary Sitting-out Area and Ting On Street (near Ting Yu Square) would be lower in the Proposed Scheme. However, since the wind flow is stronger at the junction of Ting On Street and Ting Fu Street, it countered the wind flow from Kwun Tong Road toward Ting Fu Street under existing condition. Therefore a lower VR is observed in the existing condition along Ting Fu Street (between Ting On Street and Kwun Tong Road).

5.3.10 In addition, it is noted that the wind flow is enhanced at the basketball court (within Subject Site) in the Proposed Scheme since it is relocated to higher level.

Wind performance under Wind Direction of E

5.3.11 Under E winds, wind flow is obstructed by the slightly elevated topography to the north east and the existing mid-rise buildings situated to the east and northeast of the Subject Site, i.e. Pak Ling Lau, Garden Estate Hay Cheuk Lau and Garden Estate Yin Chee Lau. Wind availability of the Subject Site mainly relies on wind flow coming from the existing air path of On Shin Road, Ngau Tak Kok Road and Ting On Street.

5.3.12 A wake area at the Subject Site is observed behind the Ngau Tau Kok Maternal and Child Health Centre which is located at the immediate upwind area. Since the Proposed Scheme sits on the wake area, there is no significant blockage to the test point along site boundary. However, the proposed high-rise tower reduce the wind penetration at higher levels and the podium of the Proposed Scheme may induce larger surface roughness along Ting On Street. Therefore, the VR at sitting out area between Kwun Tong Road and Tin Yu Square, Ting Yu Square Temporary Sitting-out Area and Ting On Street (near Ting Yu Square) would be lower in the Proposed Scheme. However, since the wind flow is stronger at the junction of Ting On Street and Ting Fu Street, it countered the wind flow from Kwun Tong Road toward Ting Fu Street under existing condition. Therefore a lower VR is observed in the existing condition along Ting Fu Street (between Ting On Street and Kwun Tong Road).

5.3.13 On the other hand, the high-rise tower in Proposed Scheme induce a downwash wind to benefit the Ngau Tau Kok Road (near the northen boundary of the Subject Site). However, such stronger downwashed wind countered the wind flow at windward side. Thus, the VR is slightly low to the north of the Ngau Tau Kok Road Playground.

5.3.14 In addition, it is noted that the wind flow is enhanced at the basketball court (within Subject Site) in the Proposed Scheme since it is relocated to higher level.

Wind performance under Wind Direction of ESE and SE

5.3.15 Under ESE winds, Ting On Street and Ngau Tau Kok Road are the main air corridors near Subject Site. Several open area (e.g. Ngau Tau Kok Road Playground, Elegance Goad Garden, etc) and low-rise building (e.g. Kwon Tong Government Primary School) to the southeast of the Subject Site allowed SE wind flow from the Kwun Tong Road.

5.3.16 A wake area at the Subject Site is observed behind the Ngau Tau Kok Maternal and Child Health Centre which is located at the immediate upwind area. Since the Proposed Scheme sits on the wake area, there is no significant blockage to the test point along site boundary. However, the proposed high-rise tower may reduce the wind penetration at higher level; and therefore, the VR at the Ting Yu Square Temporary Sitting-out Area and the sitting out area between Kwun Tong Road and Tin Yu Square are lower in the Proposed Scheme.

5.3.17 On the other hand, the Proposed Scheme would induce a stronger channelised wind along Ting On Street. A better wind flow is observed along Ting On Street and Ting Fu Street under Proposed Scheme. On the other hand, the high-rise tower induced a downwash wind which would benefit the Ngau Tau Kok Road (near the northern boundary of the Subject Site).

5.3.18 In addition, it is noted that the wind flow is enhanced at the basketball court (within Subject Site) in the Proposed Scheme since it is relocated to higher level.

Wind performance under Wind Direction of SSE

5.3.19 Under SSE wind, it is observed that most of the wind is obstructed by mid-rise building cluster to the south. The wind performance of the Subject Site and that of the Ting Yue Square Temporary Sitting-out area is poor, as there are existing buildings at the immediate upwind area to create wake area behind.

5.3.20 According to the contour plot, the southeast façade of Proposed Scheme induce a stronger channelised wind along Ting On Street, and thus induced a downwash wind benefiting the Ngau Tau Kok Road. The VR at Ting Fu Street is also higher in the Proposed Scheme benefiting from the stronger incoming wind from Ting On Street.

5.3.21 In addition, the high-rise tower redistributes and diverts more SSE wind toward northeast at higher level. Therefore, more wind flow toward Upper Ngau Tau Kok Estate at higher level and downwashed by the Shung Yuet House to benefit area near SKH Kei Hin Primary School in the Proposed Scheme.

5.3.22 In addition, it is noted that the wind flow is enhanced at the basketball court (within Subject Site) in the Proposed Scheme since it is relocated to higher level.

Wind performance under Wind Direction of S

5.3.23 Under S wind, it is observed that most of the wind is obstructed by the existing mid-rise buildings cluster to the south. The wind performance of the Subject Site is poor as there are existing buildings at the immediate upwind area to create wake area behind.

5.3.24 According to the contour plot, the Proposed Scheme may induce a downwash; and thus benefit the Ting On Street. But the stronger wind along Ting On Street also obstructed the wind flow from the Kwun Tong Road to the Ting Fu Street. Thus, the VR is slightly lower in the Tin Fu Street under Proposed Scheme. Also, the building separation between the Proposed Scheme and the Ngau Tau Kok Maternal and Child Health Centre may induce a strong channelised wind and thus benefit the On Shin Road.

5.3.25 However, on the other hand, the proposed high-rise tower reduce the wind penetration at higher levels; and therefore the VR at Ting Yu Square Temporary Sitting-out Area, and Ngau Tau Kok Road to the northeast would be lower in the Proposed Scheme.

Wind performance under Wind Direction of SSW and SW

5.3.26 Under SSW and SW wind, it is observed that most of the wind is obstructed by the existing mid-rise buildings cluster to the south. The wind performance of the Subject Site is very poor as there are existing buildings at the immediate upwind area to create wake area behind.

5.3.27 Since the Proposed Scheme sits on the wake area, there are no significant impact induced by the proposed high-rise tower. It is observed that the VRs are similar for both the existing scenario and Proposed Scheme under SSW and SW wind.

5.3.28 According to the Contour plot, there is a downwashed wind to the southeast of the Subject Site and benefit the Ting On Street in the Proposed Scheme. But the stronger wind along Ting On Street also obstructed the wind flow from the Kwun Tong Road to the Ting Fu Street. Thus, the VR is slightly lower in the Tin Fu Street under Proposed Scheme

5.3.29 It is observed that the VR is slightly lower in the Ting Fu Street in the Proposed Scheme, due to the high-rise tower direct and redistribute the wind to the northwest.

5.3.30 In addition, it is noted that the wind flow is enhanced at the basketball court (within Subject Site) in the Proposed Scheme since it is relocated to higher level.

Wind performance under Wind Direction of WSW

5.3.31 Under WSW winds, generally the wind availability in the assessment area is high under all scenarios. The wind performance of the Subject Site is poor as there are existing buildings at the immediate upwind area to create wake area behind. The wind availability of the Subject Site mainly relies on wind flow coming from the existing air path of On Shin Road and Ngau Tau Kok Road.

5.3.32 It is observed that the high-rise tower of the Proposed Scheme may induce a stronger channelised wind along Ngau Tau Kok Road and Ting On Street and further leeward area. Therefore, the VR at Ngau Tau Kok Road Playground is slight higher in the Proposed Scheme. However, since more wind diverted toward Ting On Street, less wind flow to Ting Fu Street under Ting On Street.

5.3.33 However, on the other hand, the proposed high-rise tower reduce the wind penetration at higher levels; and therefore the VR to the northeast of Garden Estate would be lower in the Proposed Scheme.

5.3.34 In addition, it is noted that the wind flow is enhanced at the basketball court (within Subject Site) in the Proposed Scheme since it is relocated to higher level.

# 6. CONCLUSION

6.1.1 The existing scenario and Proposed Schemes at the Site situated at Ting On Street, Ngau Tau Kok have been evaluated from an air ventilation standpoint.

6.1.2 According to the quantitative AVA result, a comparison study was performed using CFD. The VRs are better in the Proposed Scheme in SVR (annual and summer condition), Ting On Street (annual and summer condition), Ngau Tau Kok Road (annual and summer condition), Ngau Tau Kok Maternal and Child Health Centre (summer condition) and public landscape area and basketball court within the Subject Site (annual and summer condition). On the other hand, VRs are better in the existing scenario in On Shin Road (annual condition), On Tak Road (annual and summer condition), Tin Yu Square (annual and summer condition) and Ting Yu Square Temporary Sitting-out Area (annual and summer condition).

6.1.3 It also noted that the re-provision of the existing landscape area and basketball court within the Subject Site to second floor in the Proposed Scheme improved the ventilation performance in the recreational area within Subject Site. Generally, the ventilation is better at higher level.

6.1.4 In order to minimise the adverse air ventilation impact induced by the high-rise building tower in the Proposed Scheme, following mitigation measure have already been adopted in the building design:

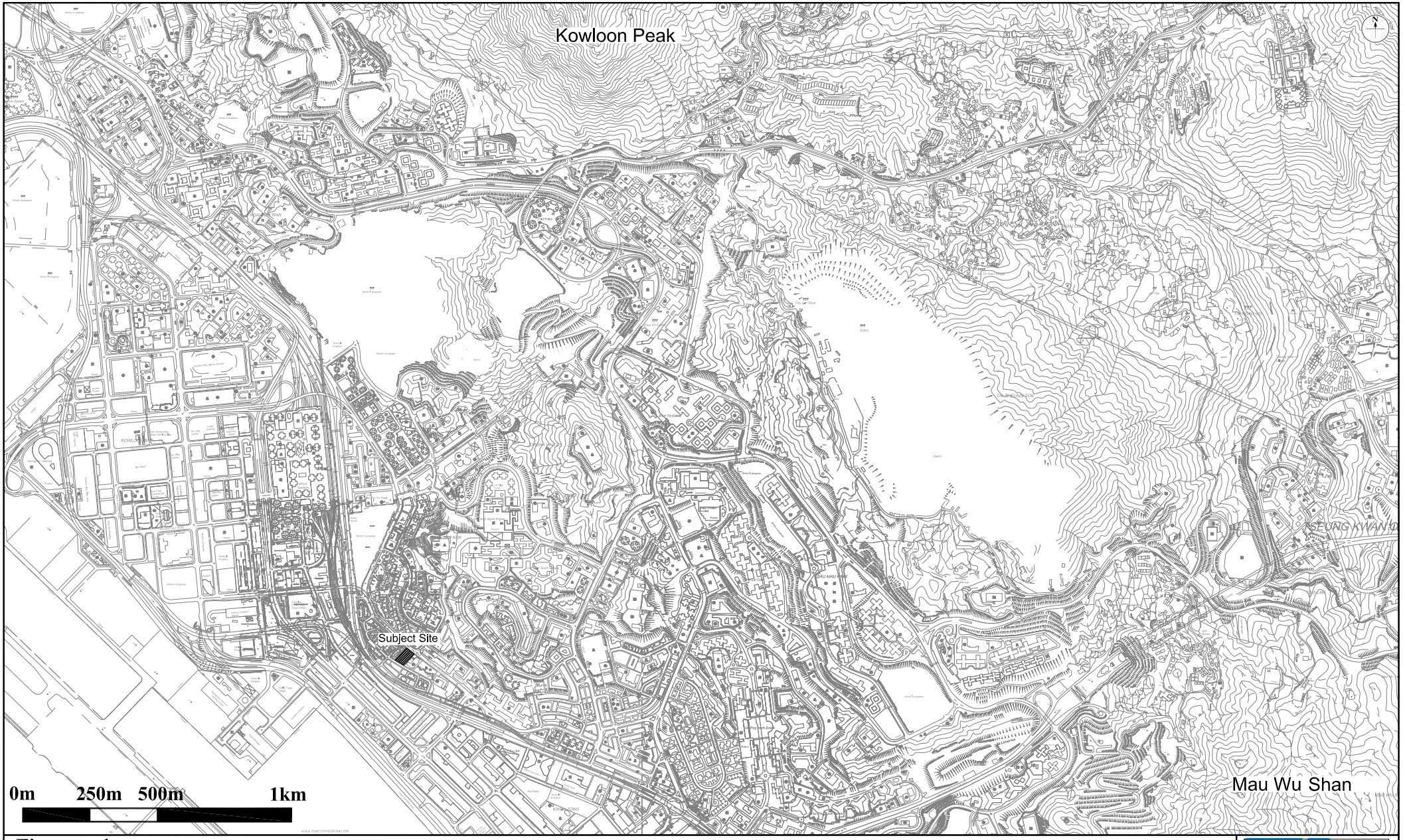
- A 10 m setback to the Ngau Tau Kok Road is provided in the typical floor; and
- Minimised podium design.

6.1.5 Since there are slight adverse impact to some focus areas (e.g. Ting Tu Square, Ting Yu Square Temporary Sitting-out Area, etc), it is recommended that further quantitative AVA should be carry out in later design stage to explore more opportunity on scheme improvement.

6.1.6 However, due to the sizing requirement of the RCP (which is response to the comments from the local stakeholders, including District Councillors and public), it is not feasible to further reduce the podium bulk and the building footprint of the Proposed Scheme.

6.1.7 In conclusion, the air ventilation performance of the Proposed Scheme would not induce a significant adverse impact to the surrounding concerned area when compare with the existing scenario.

**Figures**

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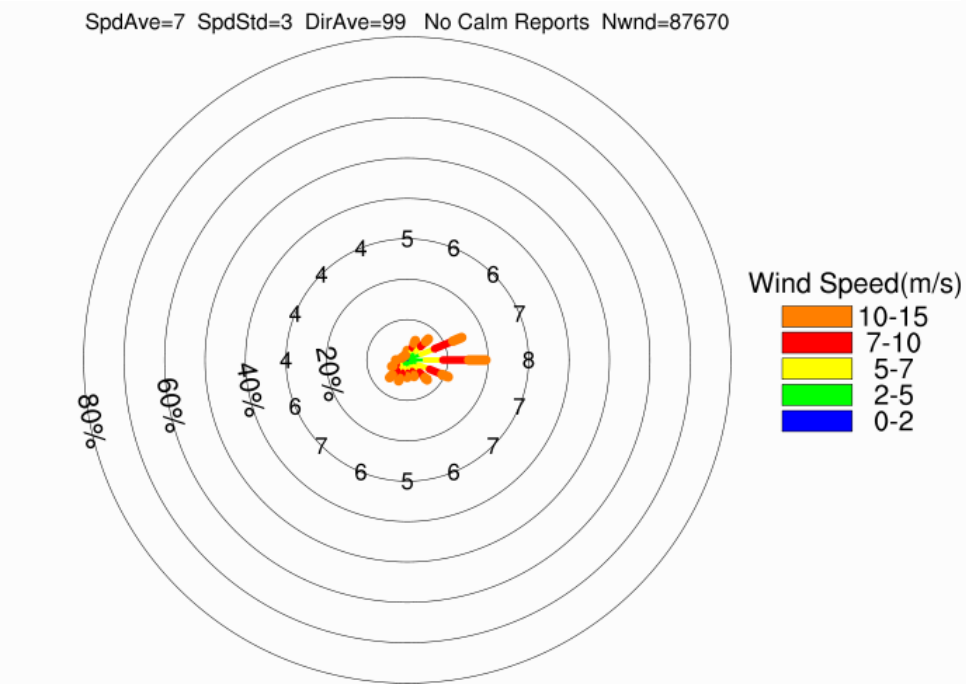
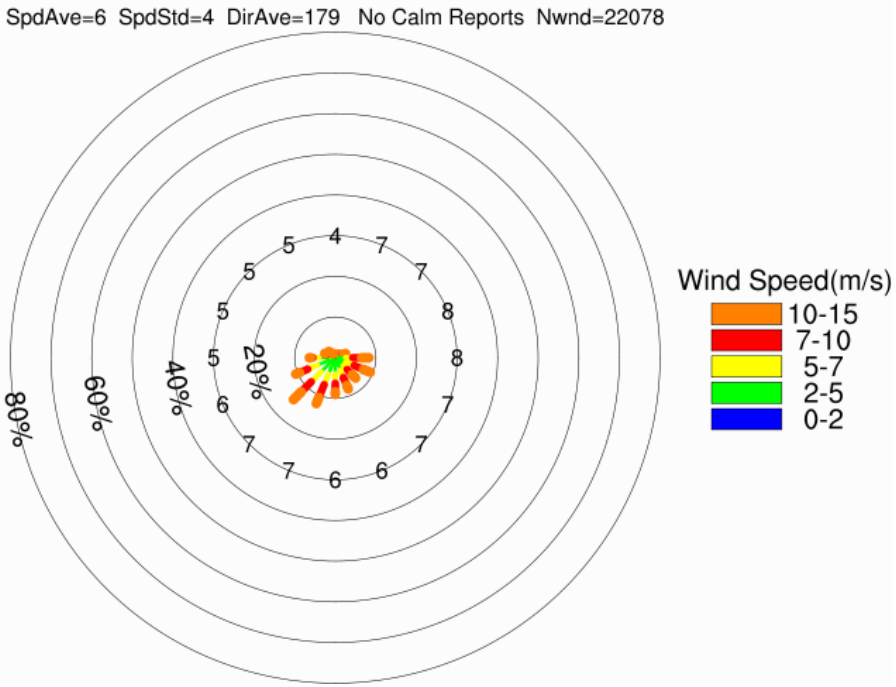
|---|---|
| **Figure:** 1 | RAMBOLL ENVIRON |
| **Title:** Location of the Subject site and its Environs | Drawn by: JL<br>Checked by: SLo |
| **Project: :** Air Ventilation Assessment for the Proposed Public Rental Housing Development at Ting On Street in Ngau Tai Kok, Kowloon | Rev.: 1.0<br>Date: May 2017 |




Annual Condition




Summer Condition

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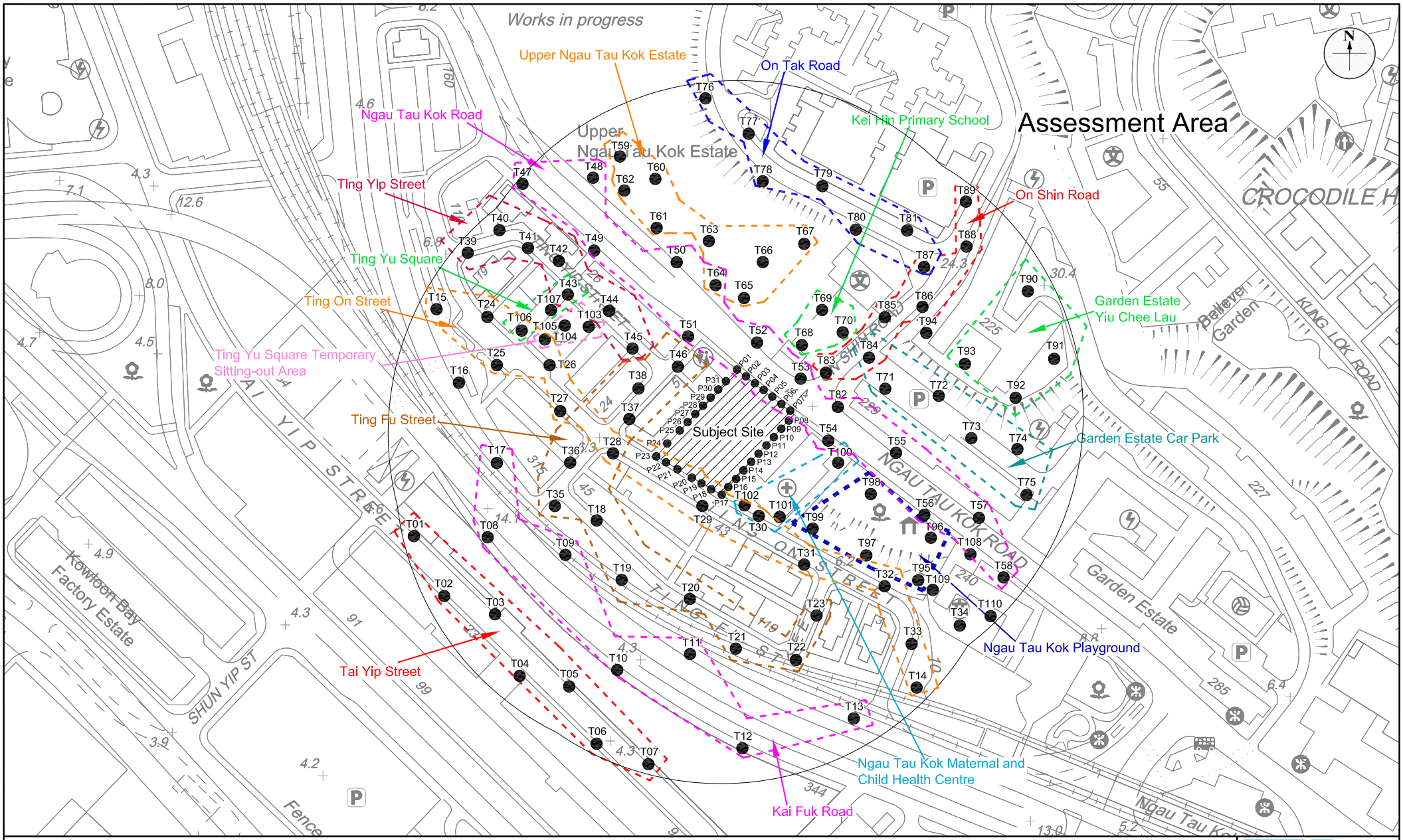
| **Figure:** | **2** | RAMBOLL ENVIRON |
| **Title:** | **Windrose Diagram representing V∞ of the Area under Concern** | Drawn by: JL<br>Checked by: TC |
| **Project:** | **Air Ventilation Assessment for the Proposed Public Rental Housing Development at Ting On Street in Ngau Tai Kok, Kowloon** | Rev.: 1.1<br>Date: Feb 2016 |

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| **Figure:** 3a | RAMBOLL ENVIRON |
| **Title:** Test Points selected for Quantitative Air Ventilation Assessment (Perimeter and Overall Test Points) | Drawn by: JL<br>Checked by: TC |
| **Project:** : Air Ventilation Assessment for the Proposed Public Rental Housing Development at Ting On Street in Ngau Tai Kok, Kowloon | Rev.: 1.3<br>Date: May 2017 |

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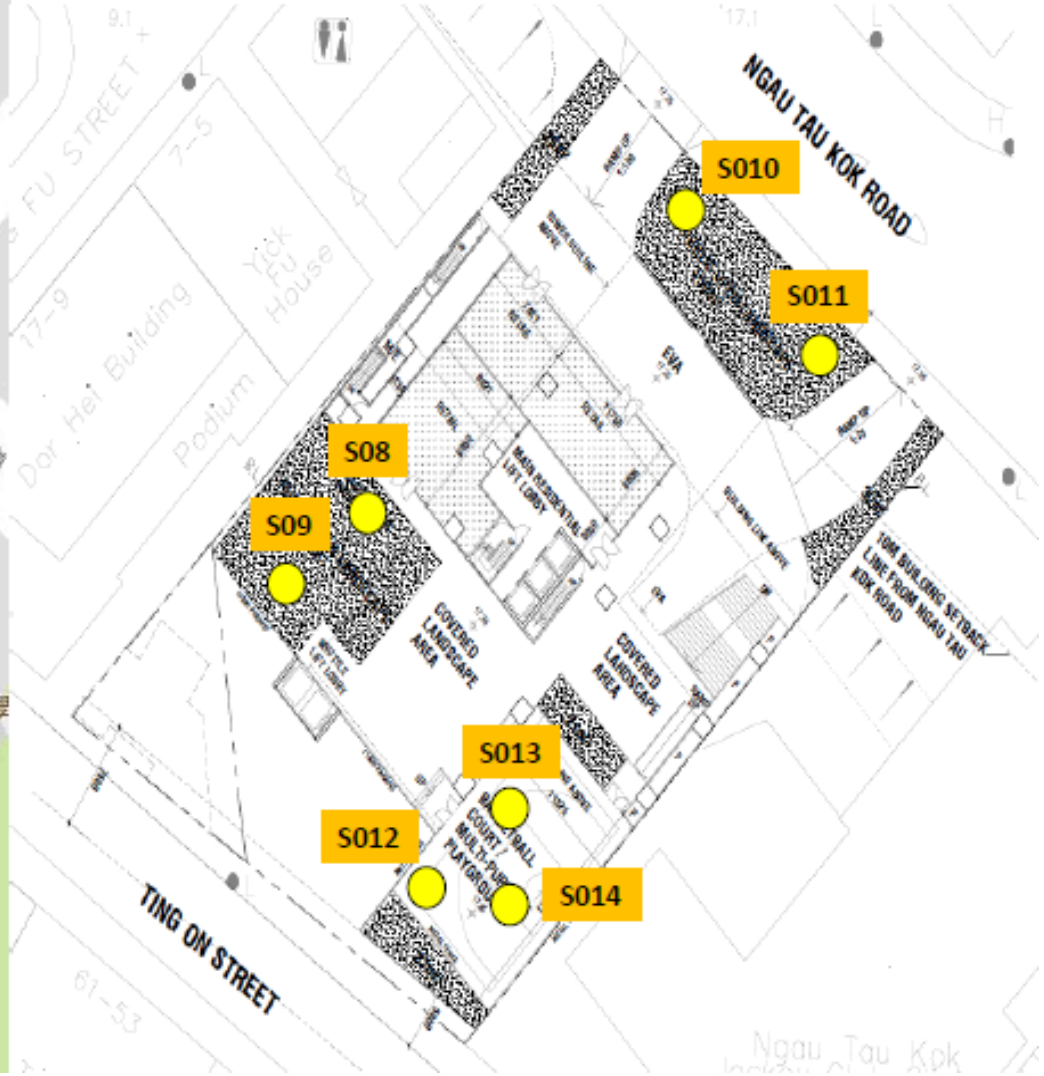


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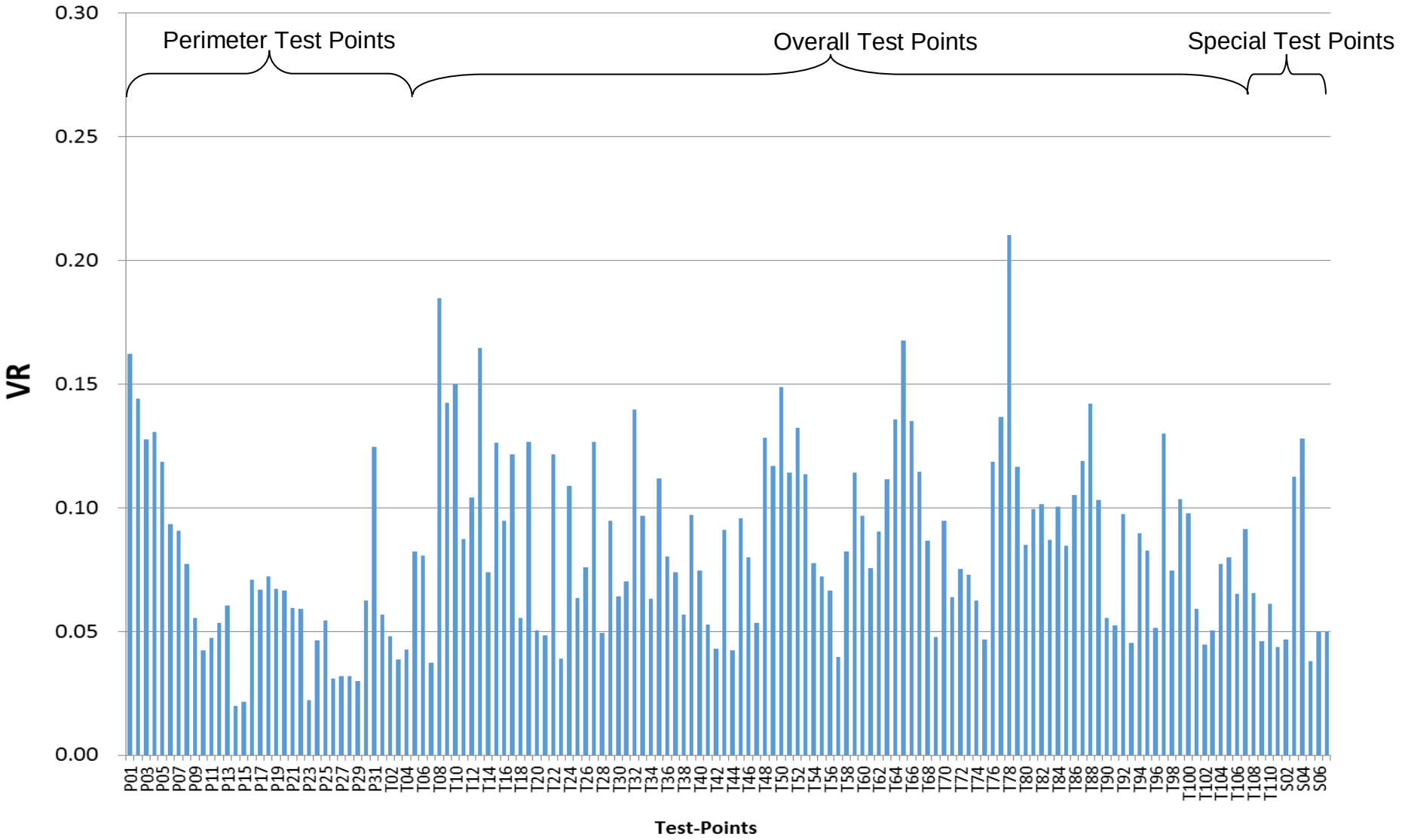
| **Figure:** | **3b** | RAMBOLL ENVIRON |
| **Title:** | **Test Points selected for Quantitative Air Ventilation Assessment (Special Test Points)** | Drawn by: KCK<br>Checked by: SL |
| **Project:** | **Air Ventilation Assessment for the Proposed Public Rental Housing Development at Ting On Street in Ngau Tai Kok, Kowloon** | Rev.: 1.0<br>Date: Jul 2017 |

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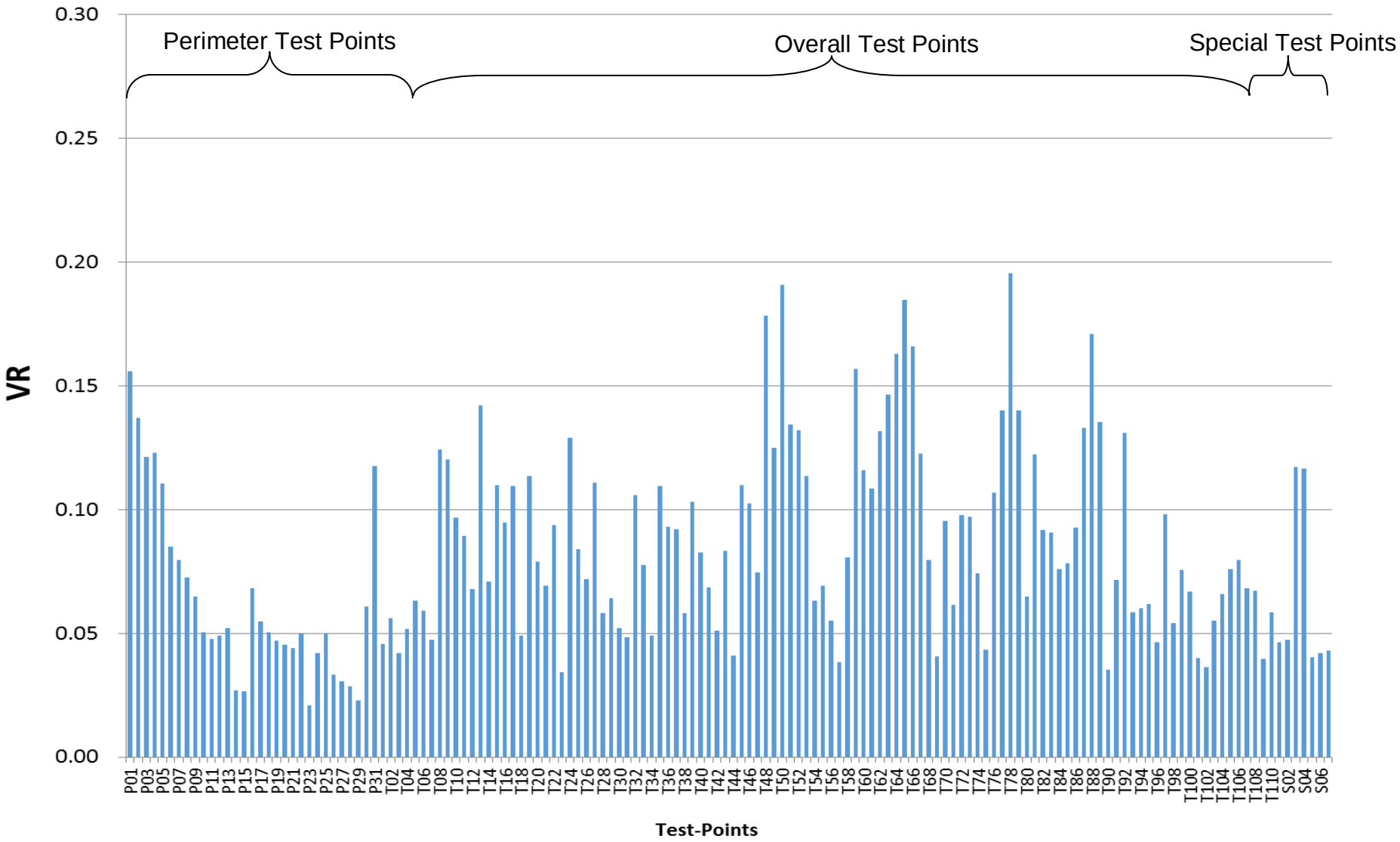
| **Figure:** | **4a** | RAMBOLL ENVIRON |
| **Title:** | **Wind Velocity Ratios of Individual Test Points for Existing Scenario (Annual)** | Drawn by: KCK |
| | | Checked by: SL |
| **Project:** | **Air Ventilation Assessment for the Proposed Rental Housing Development at Ting On Street in Ngau Tai Kok, Kowloon** | Rev.: 1.0 |
| | | Date: Aug 2017 |

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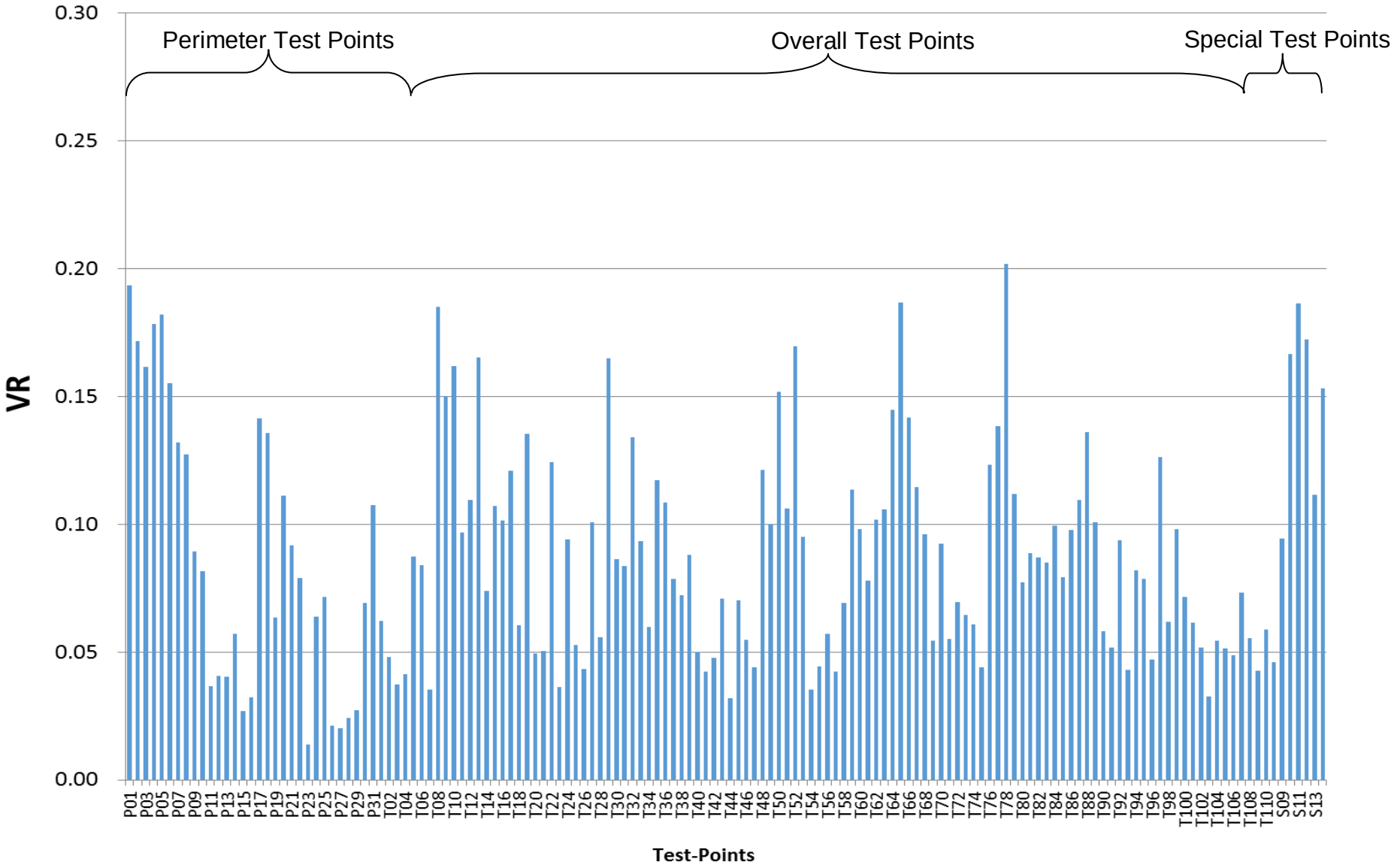
| **Figure:** | **4b** | RAMBOLL ENVIRON |
| **Title:** | **Wind Velocity Ratios of Individual Test Points for Existing Scenario (Summer)** | Drawn by: KCK<br>Checked by: SL |
| **Project:** | **Air Ventilation Assessment for the Proposed Rental Housing Development at Ting On Street in Ngau Tai Kok, Kowloon** | Rev.: 1.0<br>Date: Aug 2017 |

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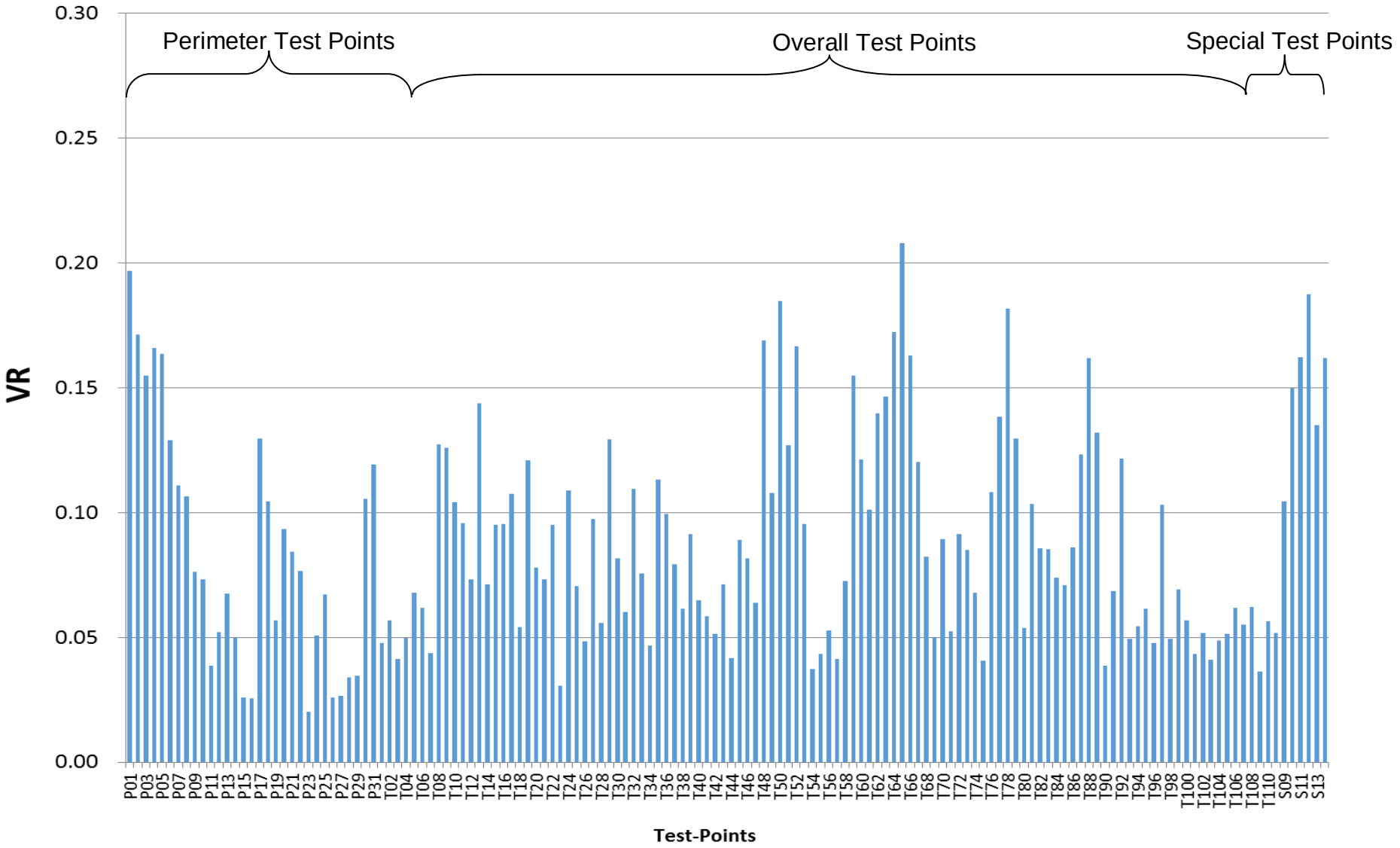
| **Figure:** 5a | RAMBOLL ENVIRON |
| **Title:** Wind Velocity Ratios of Individual Test Points for Proposed Scheme (Annual) | Drawn by: KCK<br>Checked by: SL |
| **Project:** Air Ventilation Assessment for the Proposed Rental Housing Development at Ting On Street in Ngau Tai Kok, Kowloon | Rev.: 1.0<br>Date: Aug 2017 |

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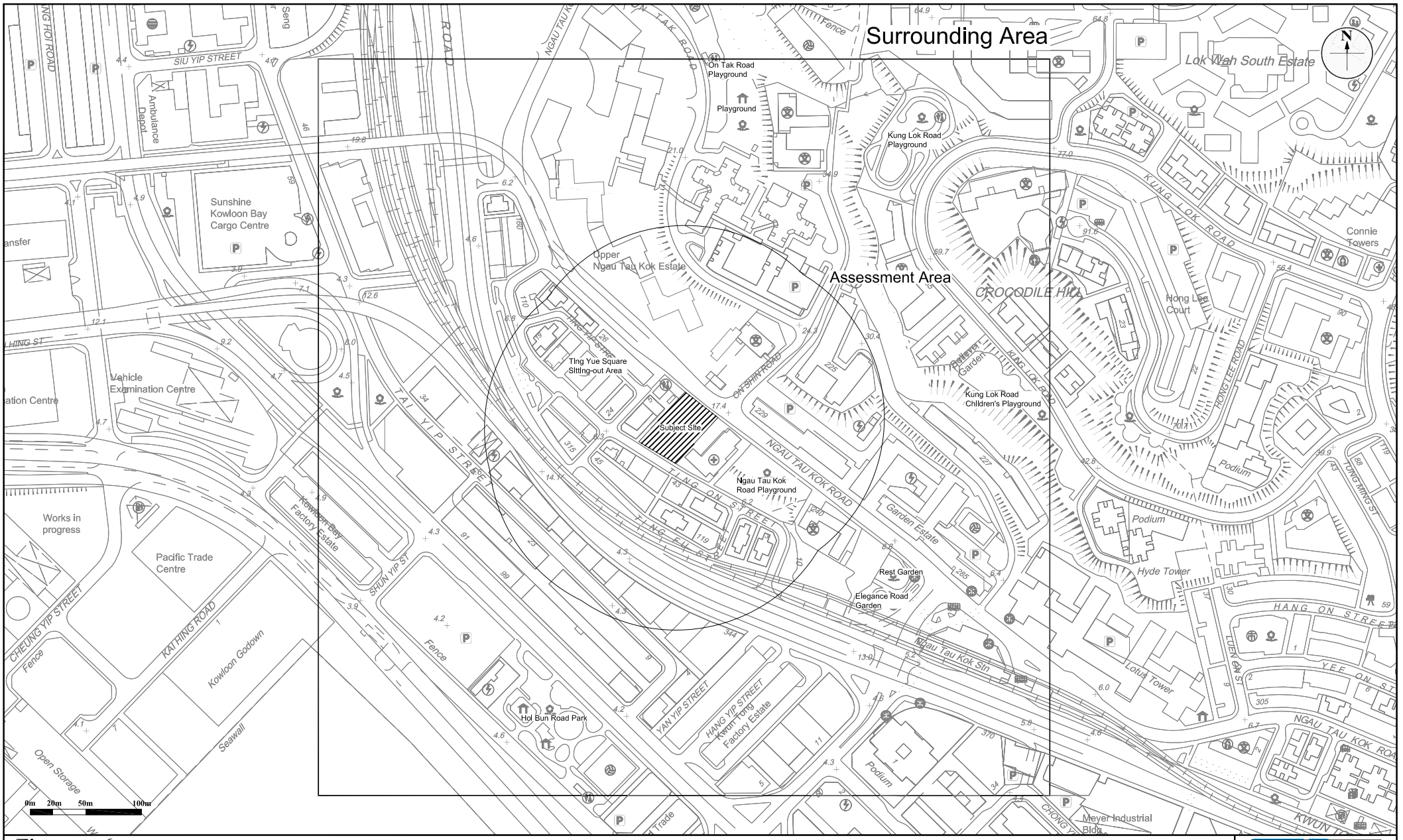
| **Figure:** | **5b** | RAMBOLL ENVIRON |
| **Title:** | **Wind Velocity Ratios of Individual Test Points for Proposed Scheme (Summer)** | Drawn by: KCK<br>Checked by: SL |
| **Project:** | **Air Ventilation Assessment for the Proposed Rental Housing Development at Ting On Street in Ngau Tai Kok, Kowloon** | Rev.: 1.0<br>Date: Aug 2017 |

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| **Figure:** 6 | RAMBOLL ENVIRON |
| **Title:** Surrounding Development and Important Pedestrian Areas | Drawn by: JL<br>Checked by: TC |
| **Project:** : Air Ventilation Assessment for the Proposed Public Rental Housing Development at Ting On Street in Ngau Tai Kok, Kowloon | Rev.: 1.3<br>Date: May 2017 |

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