Land Use Review for Kam Tin South and Pat Heung
Air Ventilation Assessment – Expert Evaluation

MARCH 2014

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1.0 INTRODUCTION

Background and Project Description

A Land Use Review (LUR) has been conducted to examine the development potential of the Kam Tin South and Pat Heung Areas. The LUR has demonstrated that it would be technically feasible to transform Kam Tin South and Pat Heung into a sustainable suburban township with enhancement on infrastructure and utility services.

Based on the Proposed Land Use Planning Framework (Table 1), a total of 16,800 private and 16,900 public housing units would be provided, with an estimated additional population of about 92,800. A district shopping centre of about 40,000m^2 GFA will be provided at KSR, while local shopping facilities will be provided at the PHMC and public housing developments. New "Government, Institution and Community" (GIC) and public facilities will be provided in tandem with population built-up.

Table 1 Proposed Development Parameters for Kam Tin South and Pat Heung

Site ID	Residential Type	Gross Net Site Area (ha)	Total Plot Ratio	No. of Flat	Estimated Population
KSR	**Private**	**9.4**	**3.0**	**2,690**	**6,600**
PHMC	**Private**	**31.8**	**3.0**	**6,060**	**14,800**
1	**Public**	**7.9**	**3.0**	**3,700**	**11,300**
4a	**Public**	**6.5**	**3.0**	**3,200**	**9,800**
4b	**Public**	**13.0**	**3.0**	**5,700**	**17,400**
5a	**Public**	**7.3**	**3.0**	**3,300**	**10,100**
6	**Public**	**4.8**	**3.0**	**1,000**	**3,100**
2	**Private**	**2.5**	**2.1**	**450**	**1,100**
3	**Private**	**6.1**	**2.1**	**1,100**	**2,700**
4c	**Private**	**3.5**	**2.1**	**630**	**1,500**
5b	**Private**	**4.2**	**0.8**	**3,020**	**7,400**
7	**Private**	**23.5**	**1.5**	**880**	**2,200**
8	**Private**	**6.9**	**1.5**	**290**	**700**
9	**Private**	**24.4**	**0.8**	**1,680**	**4,100**
TOTAL		**151.8**	**---**	**33,700**	**92,800**

Notes
(1) Site areas are indicative subject to land survey.
(2) Gross site areas for KSR and PHMC have made reference to the KSR Station vesting boundary and the PHM private treaty grant boundary, which include the railway facilities between the two sites.
(3) A total of about 49,000m^2 GFA would be provided at KSR, PHMC and the public housing sites for commercial/retail purpose. Further GFA has been allowed for other non-domestic accommodations.
(4) Information provided is for technical assessment purpose only.

This Air Ventilation Assessment is prepared to examine the potential impacts arising from the Proposed Land Use Planning Framework, and to recommend practicable improvement measures to support the population growth.

An AVA Expert Evaluation and preliminary quantitative assessment for the Study Area have been conducted. The Expert Evaluation is based on the methodology of Air Ventilation Assessment as set out in the "Housing Planning and Lands Bureau – Technical Circular No. 1/06, Environment, Transport and Works Bureau – Technical Circular No. 1/06" issued on 19th July 2006 (the Technical Circular) and "Technical Guide for Air Ventilation Assessment for Development in Hong Kong – Annex A" (the Technical Guide).

2.0 OBJECTIVE OF THE STUDY

In accordance with the Technical Circular and the Technical Guide, the objective of this study is to assess the likely air ventilation performance of Kam Tin South and Pat Heung. The Expert Evaluation (EE) would be useful for large sites with specific and unique wind features, issues, concerns and its problems.

The objective of this assignment is to evaluate the overall air ventilation impact of the Proposed Land Use Planning Framework on the pedestrian wind environment to the Kam Tin South and Pat Heung Areas. A preliminary quantitative assessment on the conceptual development schemes of KSR, PHMC and the surrounding potential development include Site 1, 2, 3, 4a, 4b, 4c, 5a, 5b, 6, 7, 8 and 9 using Computational Fluid Dynamics (CFD) model is presented in Appendix A to provide supplementary information on the wind environment of the Study Area.

3.0 STUDY SCOPE

The scope of work includes the tasks as follows:

- Identify good design features;
- Identify potential area(s) for further wind enhancement and propose wind enhancement measures for consideration at the detailed design stage; and
- Recommend further air ventilation assessment.

4.0 SITE CHARACTERISTICS

Kam Tin South and Pat Heung are located in the south-eastern part of the North West New Territories. The Study Area lies within an inter-montane plane surrounded by various hilly ranges, such as Ho Hok Shan (rises to over +200mPD to the west of Tsing Long Highway), Kai Kung Leng (rises to about +570mPD) and Tai Lam Country Park (rises to over +290mPD to the west of Tsing Long Highway). The regional context is in a suburban setting with predominantly low-lying flat land. The Study Area is subject to building height restrictions from the Shek Kong Airfield, ranging from about +69mPD to +135.6mPD at the potential development sites (Figure 2).

The West Rail Line KSR Station and the PHMC, along with the Tsing Long Highway, are the prominent infrastructure facilities within the Study Area. Figure 1 below shows the Study Area and its surrounding areas.

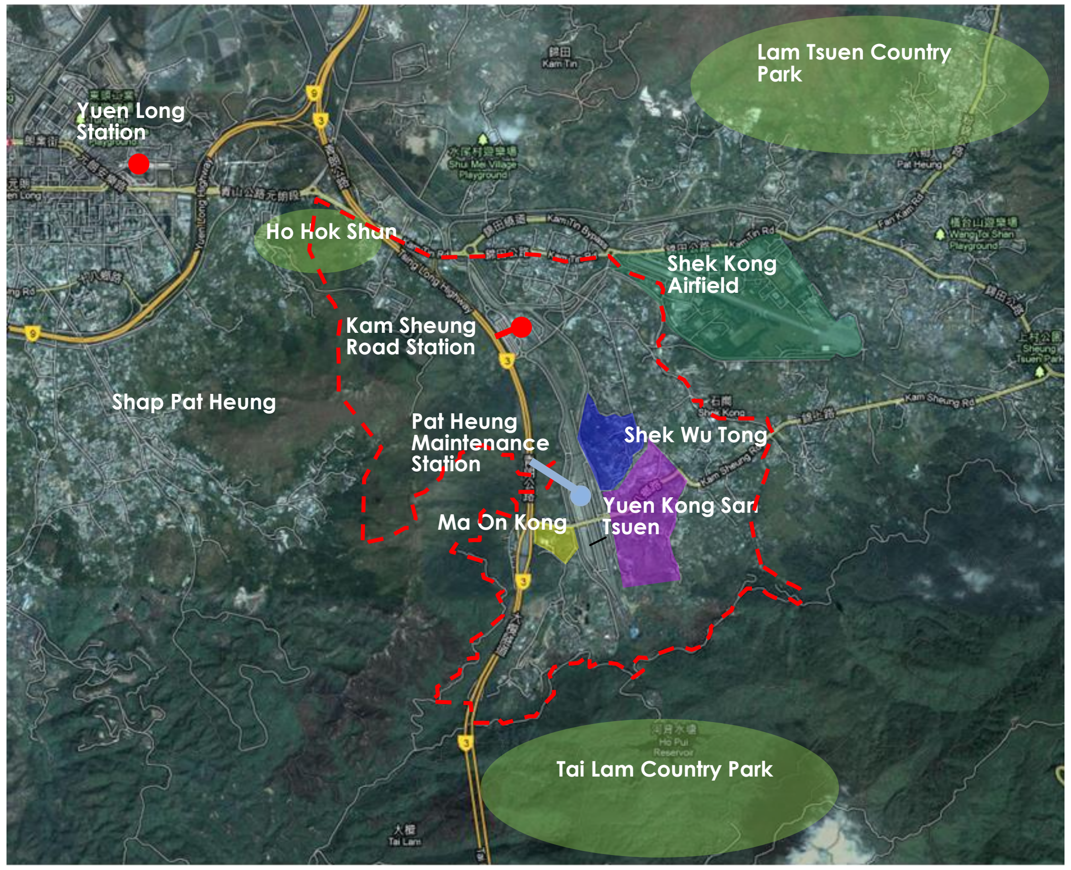


Figure 1 Study Area and its Surroundings

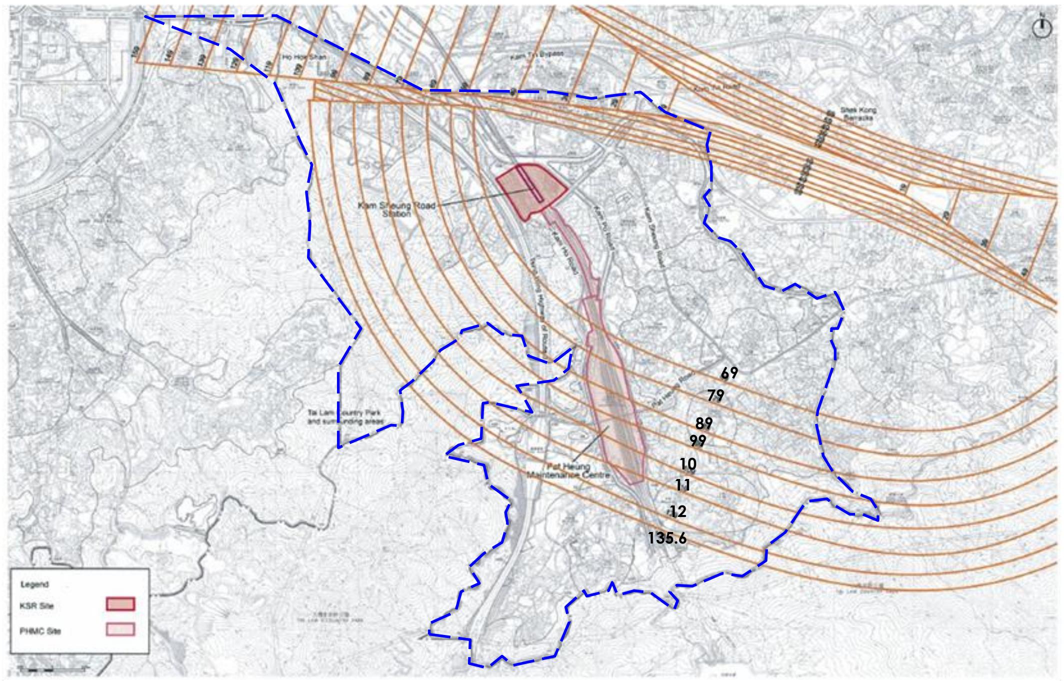


Figure 2 Shek Kong Airfield Height Restrictions (Indicative)

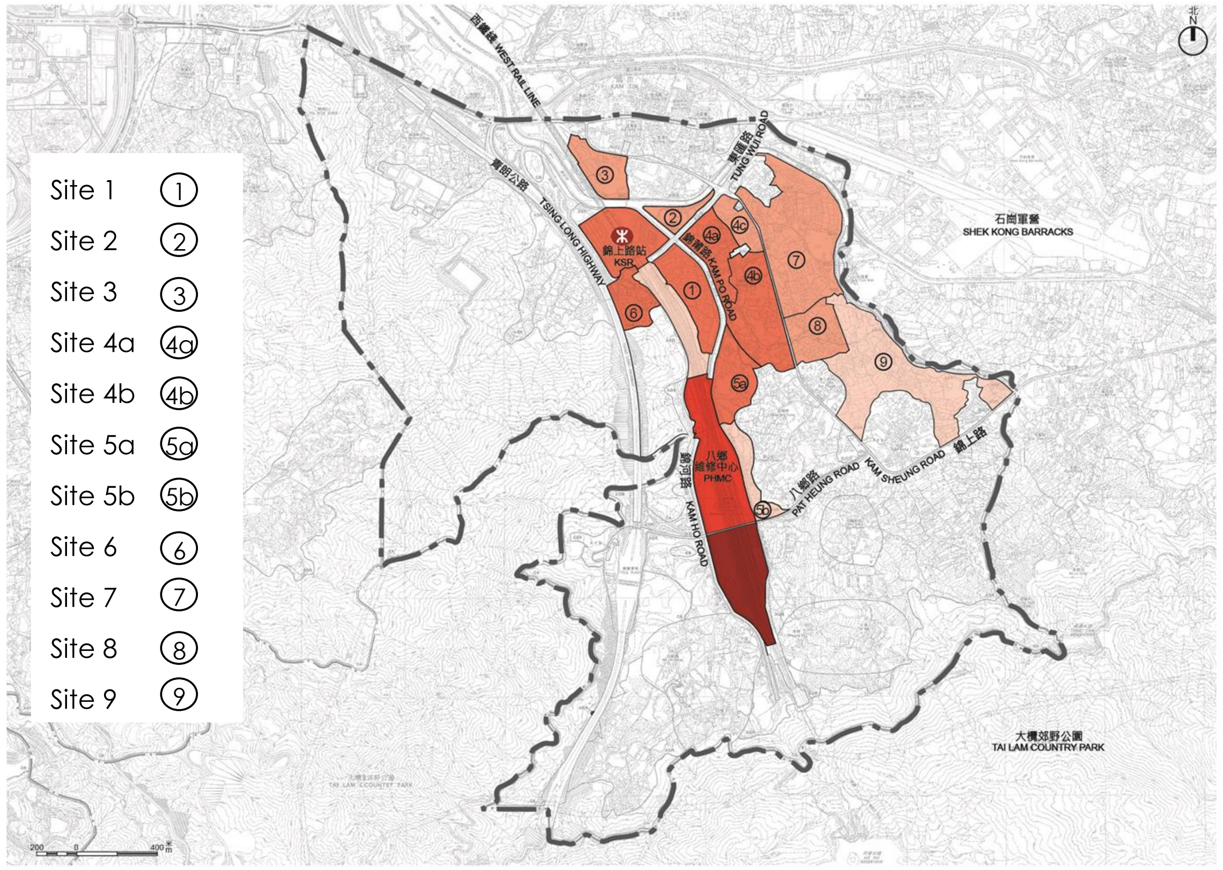


Figure 3 Potential Development Sites under the Proposed Land Use Planning Framework

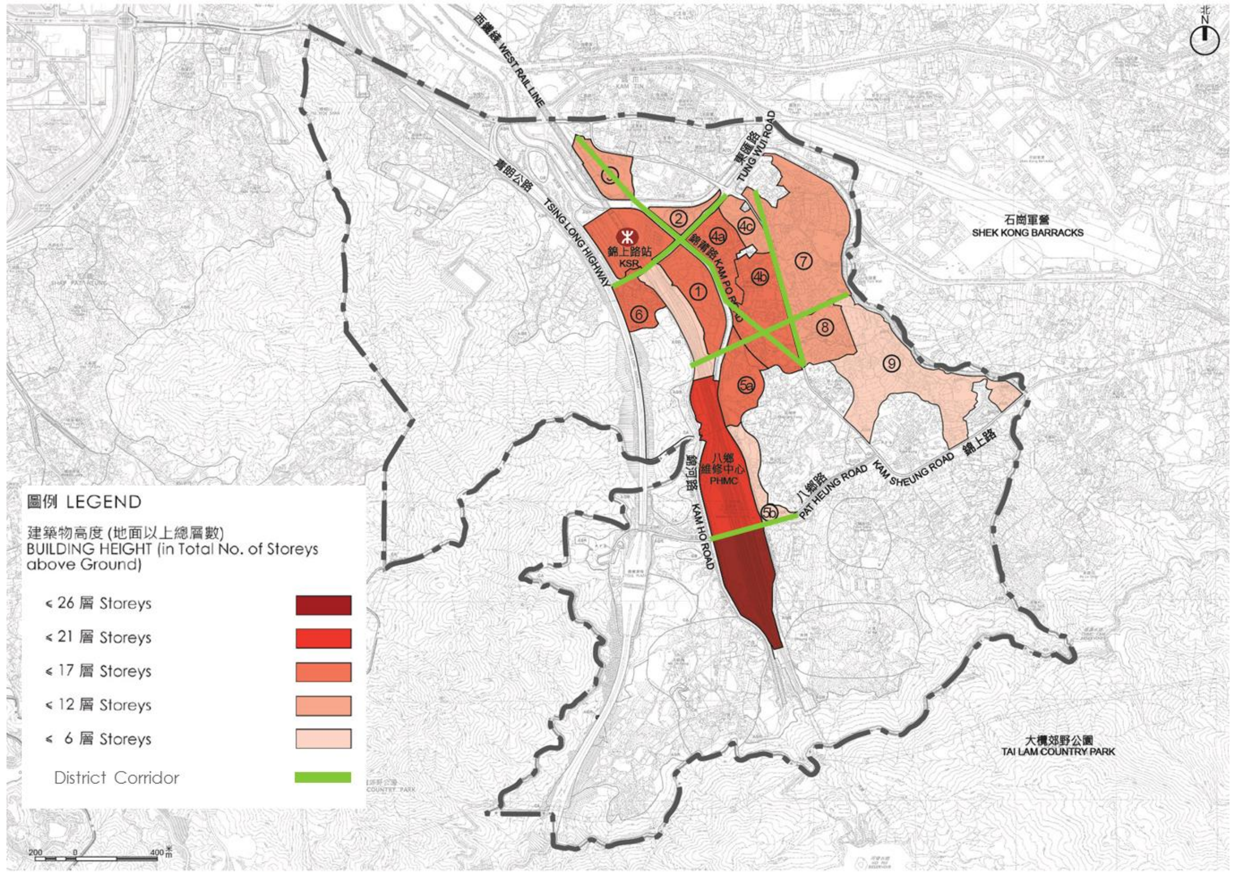


Figure 4 Proposed Building Height Profile and District Wind Corridors of the Potential Sites

Under the Proposed Land Use Planning Framework, the potential development sites are situated predominantly within 1.5km from the KSR Station with a total area of about 152ha (Figure 3).

A building height profile has been recommended as part of the Proposed Urban Design Framework (Figure 4). Based on the conceptual schemes, building height gradually descends from about +108.5mPD at the southern end of PHMC (max 26 storeys) to about +69mPD at KSR and the public housing developments (max 17 storeys). Maximum building height of 12 storeys has been recommended at Sites 4c, 7 and 8, with further reduction to 6-storey at Site 9 at the periphery. Figure 4 also shows the proposed district wind corridors at the potential development sites.

5.0 SITE WIND AVAILABILITY

The wind availability of the Study Area is an essential item for investigating the wind performance of the Site. Since the Study Area coverage is large, site wind availability data (V∞) might be different from site to site due to the effect of local terrains.

Site wind availability data presented in the wind rose could be used to assess the wind characteristics in terms of the magnitude and frequency of approaching wind from different wind directions. Surrounding building data shall be considered while obtaining the site wind availability data.

There are two sources of site wind data for this Study Area – measured data from Hong Kong Observatory (HKO) weather station and simulated MM5 data.

<u>Weather station</u>

Reference has been made to the nearest weather station at Shek Kong. From the HKO website, the annual wind rose measured at the station is shown in Figure 6.

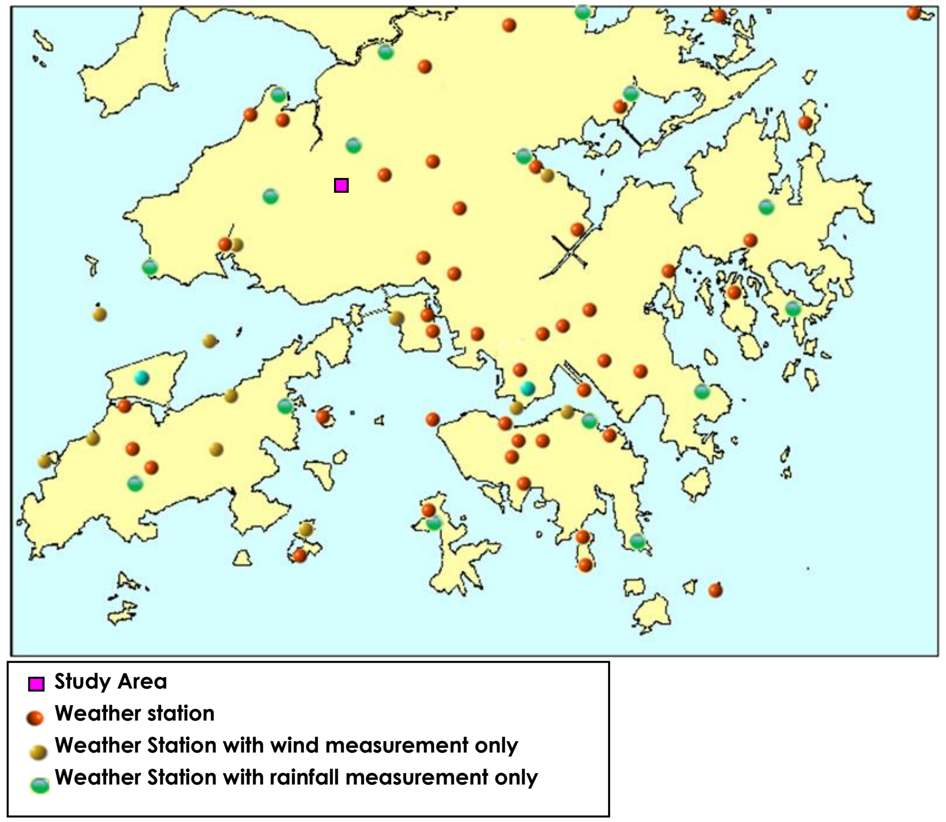


Figure 5 Weather stations in Hong Kong

From the measured data at Shek Kong Weather Station, the annual and summer prevailing wind directions are East (E) and Southerly (S), respectively.

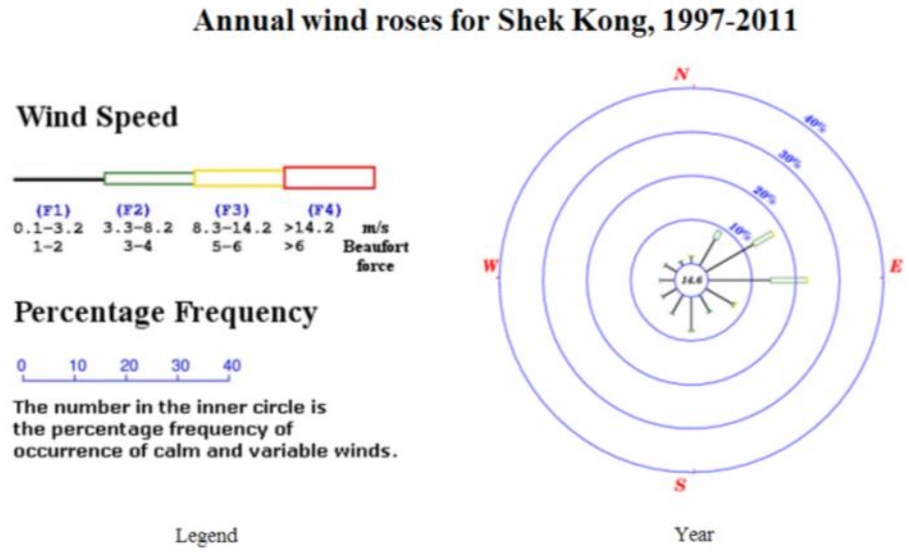
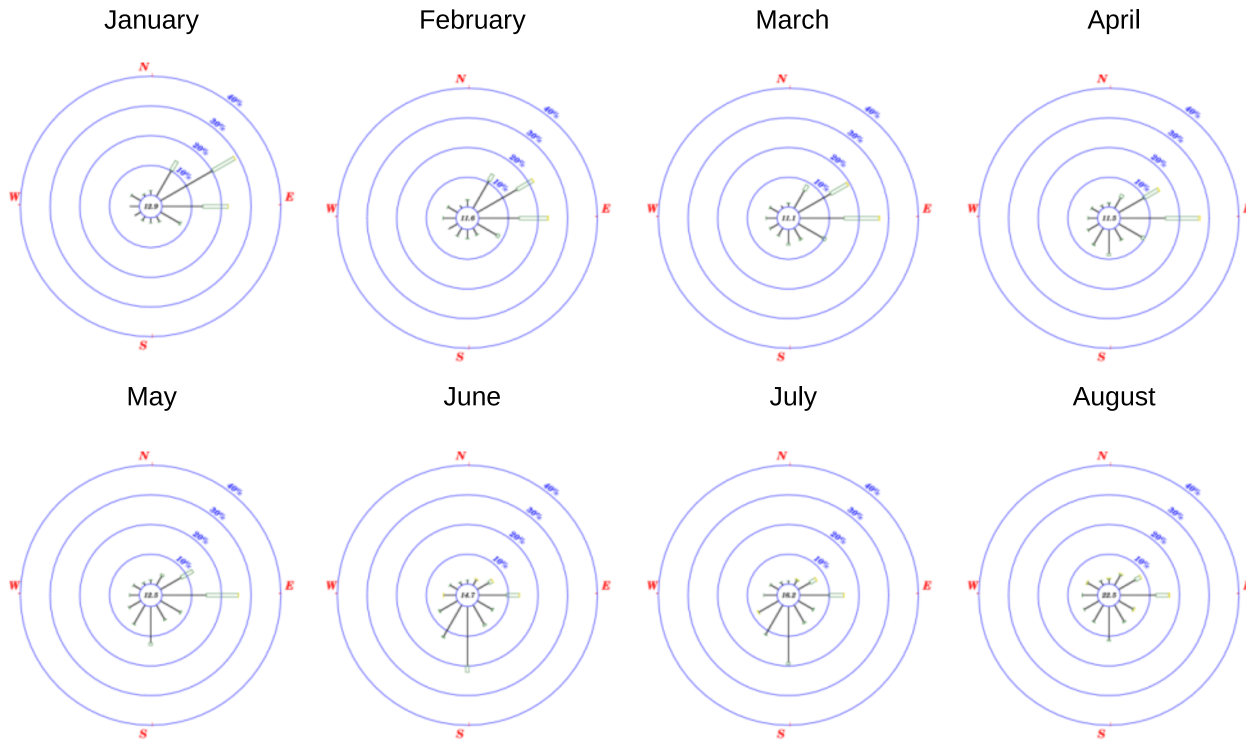


Figure 6 Annual wind rose measured at Shek Kong Weather Station (1997-2011)



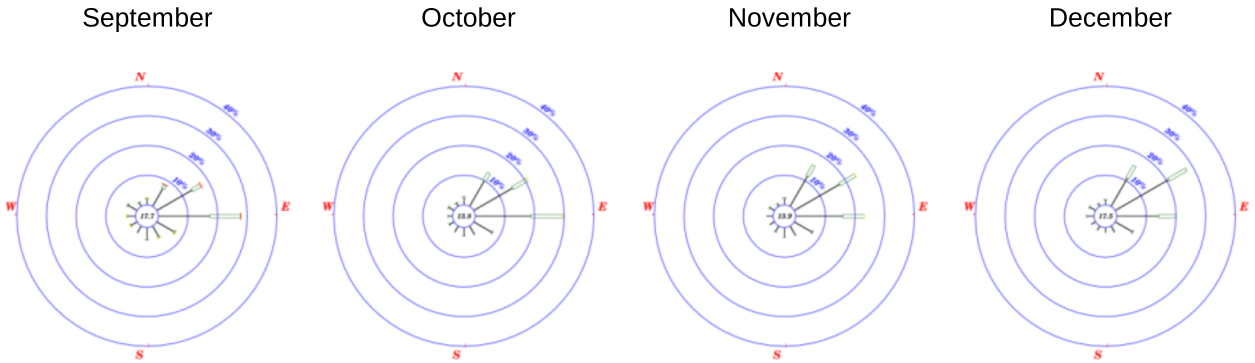


Figure 7 Monthly wind roses measured at Shek Kong Weather Station (1997-2011)

MM5 data (HKUST)

Other than HKO's data, the Institute for the Environment (IENV) of the Hong Kong University of Science and Technology (HKUST) also simulated a set of annual wind rose at three locations within the Study Area (as shown in Figure 8) – North and South of PHMC and KSR Station.

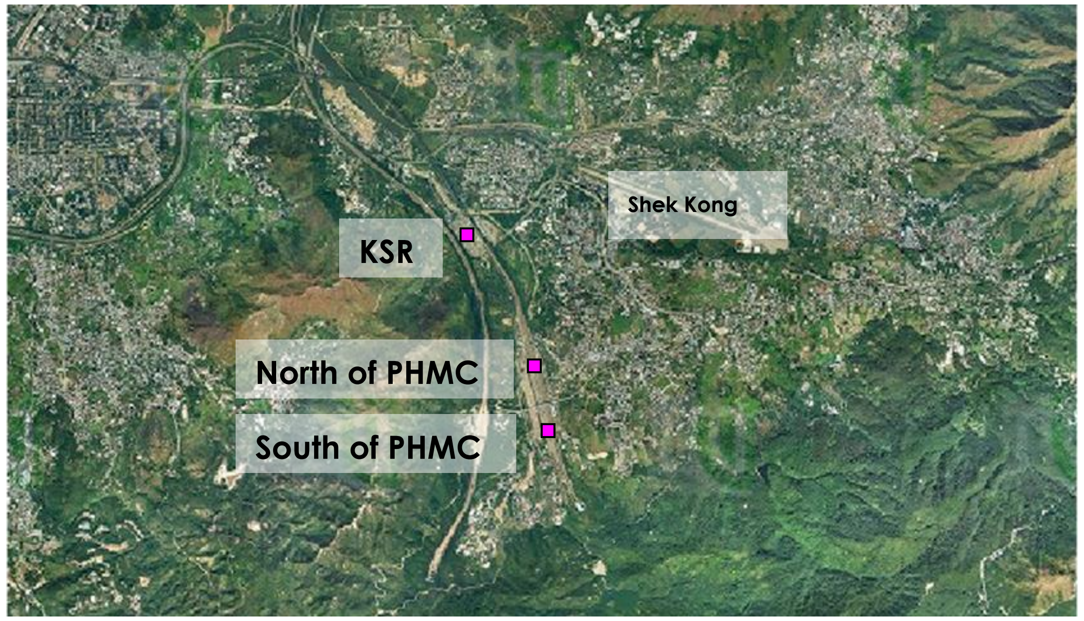


Figure 8 Measurement locations of wind roses for Kam Tin South (HKUST)

The summer and annual MM5 data at each location at different levels are shown in Figure 9– 14. The wind roses at +230mPD show that the annual prevailing wind direction is Northeast (NE) / East (E), while the summer wind comes from South (S) / Southeast (SE).

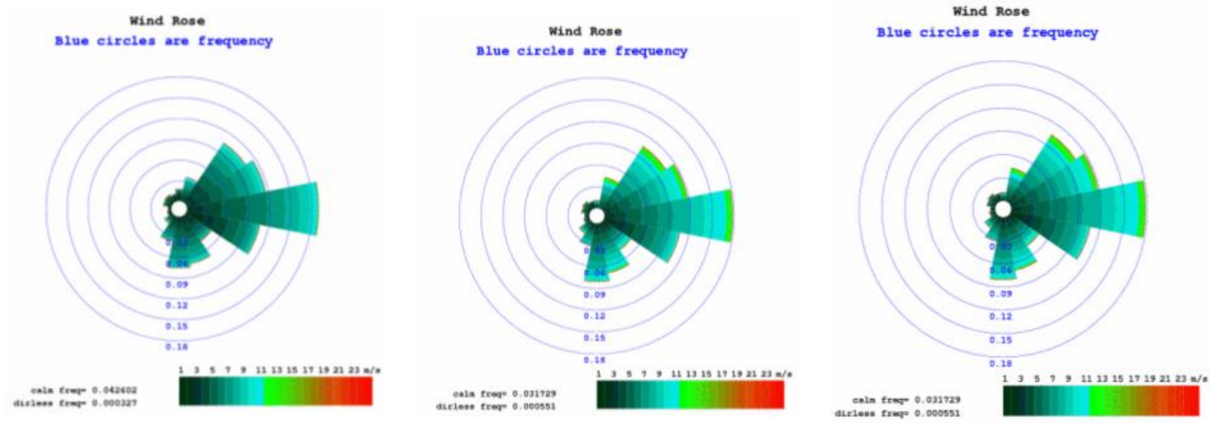


Figure 9 Annual wind roses at KSR (left: 60mPD; middle: 120mPD; right: 230mPD)

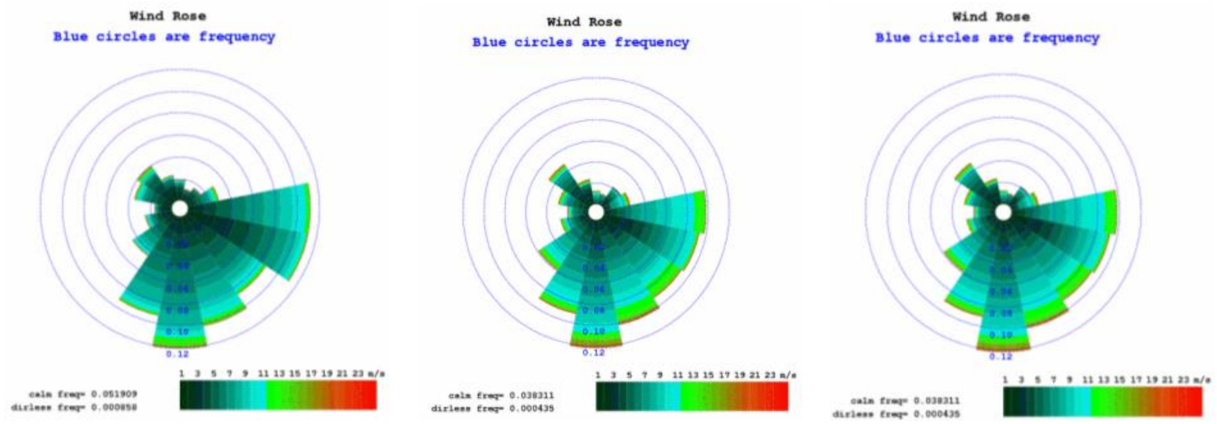
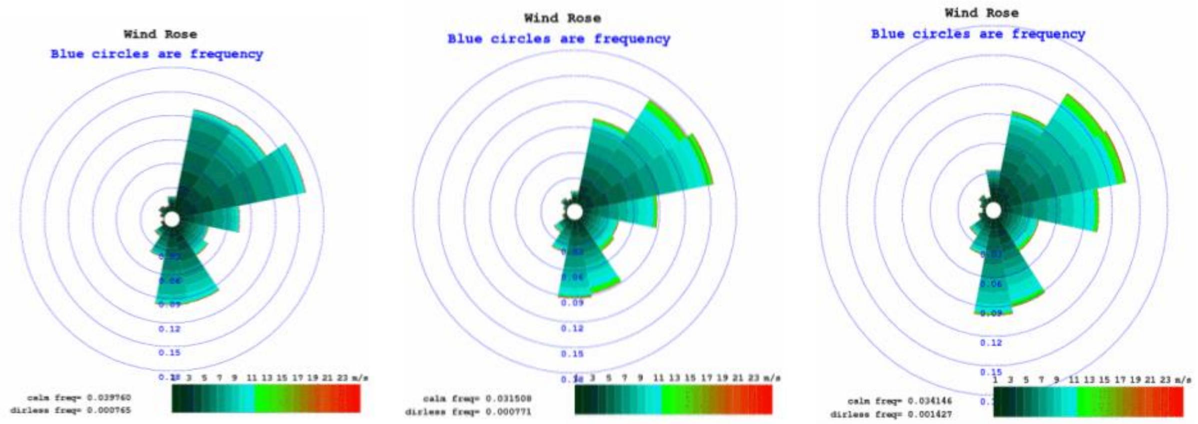


Figure 10 Summer wind roses at KSR (left: 60mPD; middle: 120mPD; right: 230mPD)



`Figure 11 Annual wind roses at North of PHMC (left: 60mPD; middle: 120mPD; right: 230mPD)

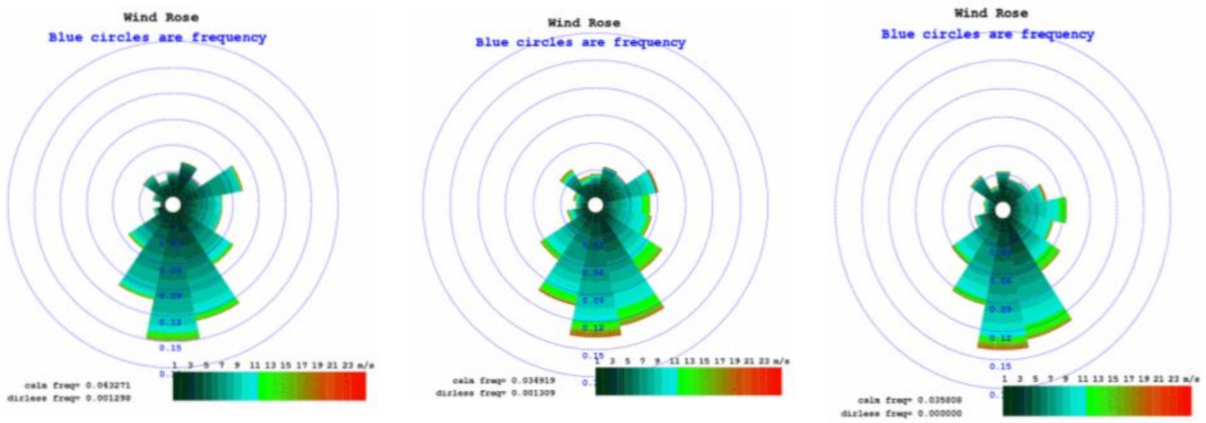


Figure 12 Summer wind roses at North of PHMC (left: 60mPD; middle: 120mPD; right: 230mPD)

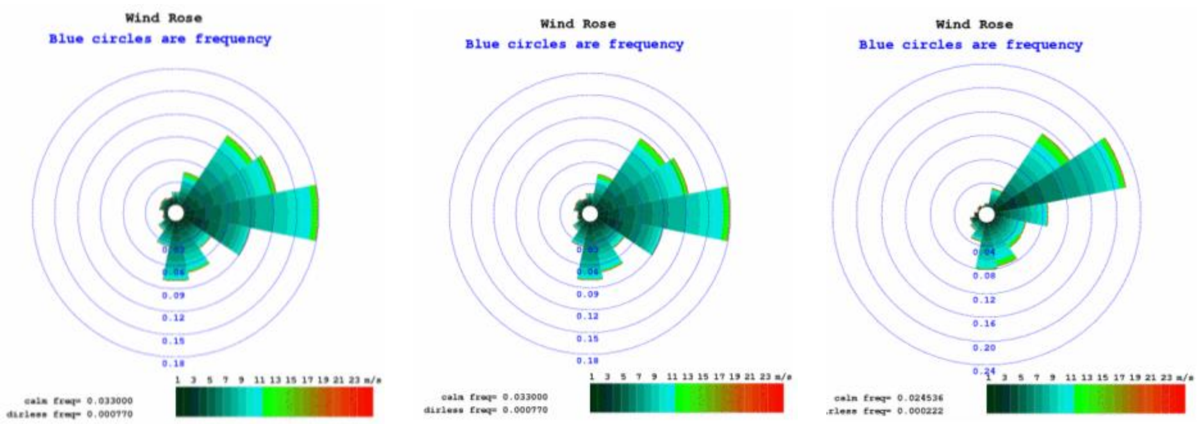


Figure 13 Annual wind roses at South of PHMC (left: 60mPD; middle: 120mPD; right: 230mPD)

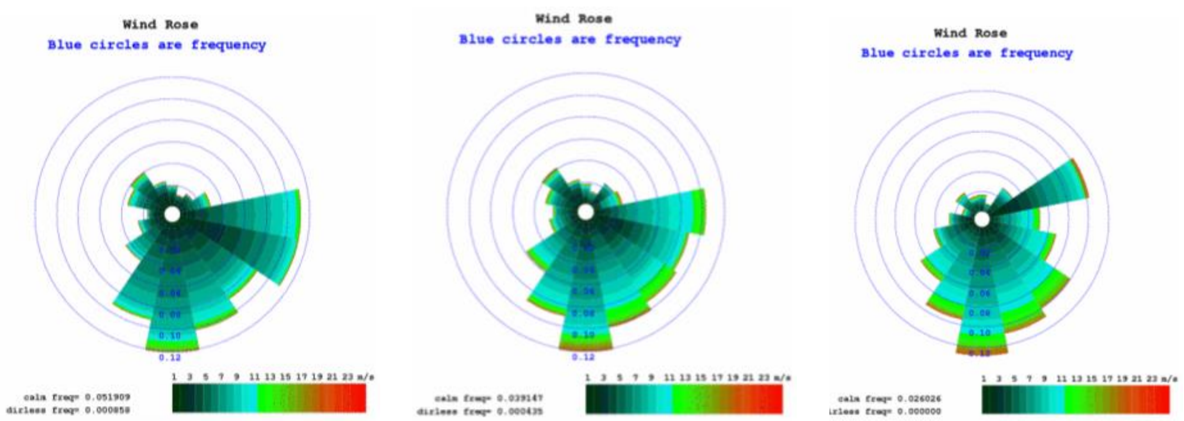


Figure 14 Summer wind roses at South of PHMC (left: 60mPD; middle: 120mPD; right: 230mPD)

These two sets of data are tabulated in Table 2 for easy reference. All data basically comes to a similar annual prevailing wind direction which is NE/ ENE/ E, whereas the summer prevailing wind direction varies from E, SE and S.

Table 2 Prevailing wind directions for the Study Area

Period	**HKO (Shek Kong)**	**MM5 HKUST**		
		60mPD	120mPD	230mPD
Annual	ENE / E	NE/ ENE / E	NE / ENE / E	NE / ENE /E
Summer	E / S	E / SE / S	E / SE / S	E / SE / S

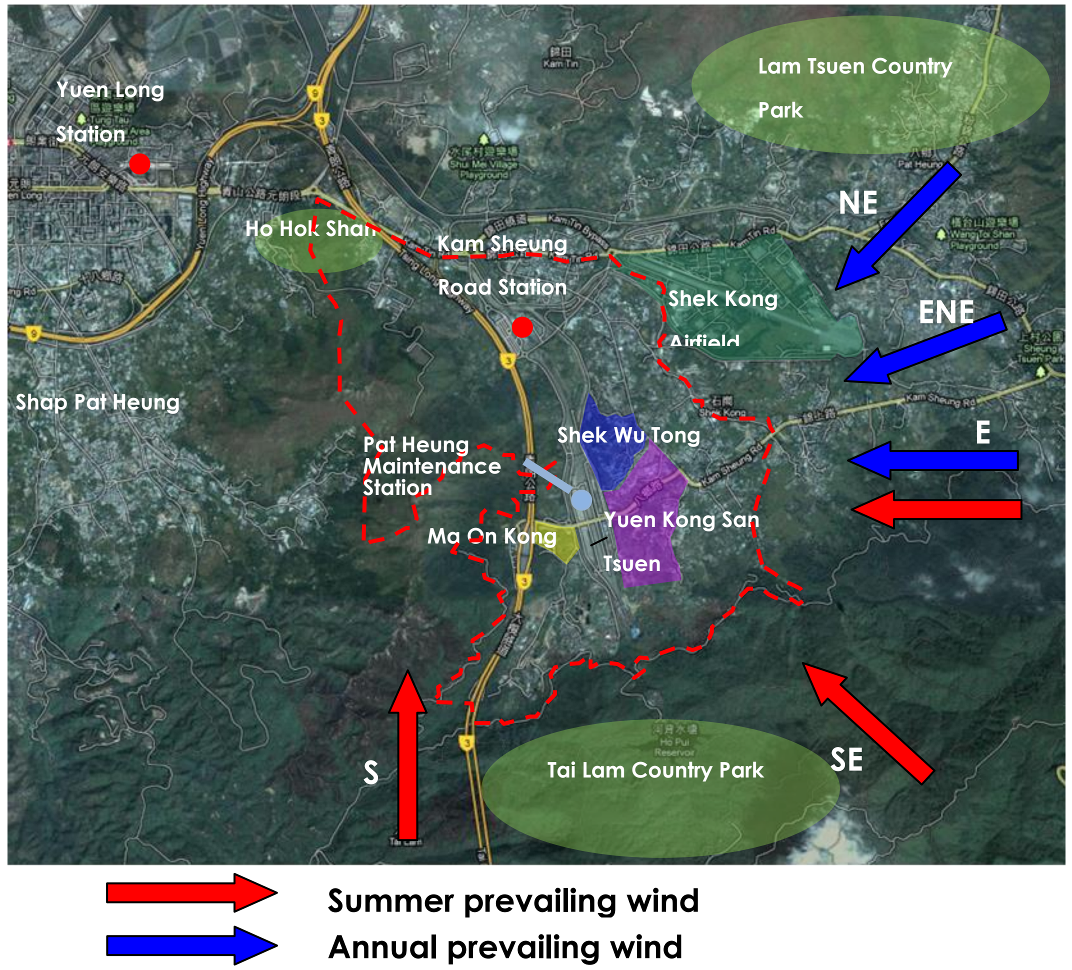


Figure 15 A summary of the prevailing winds of the Study Area

6.0 EXPERT EVALUATION ON EXISTING CONDITION

This section will discuss the general wind performance of the Study Area under existing condition as shown in Figure 16.

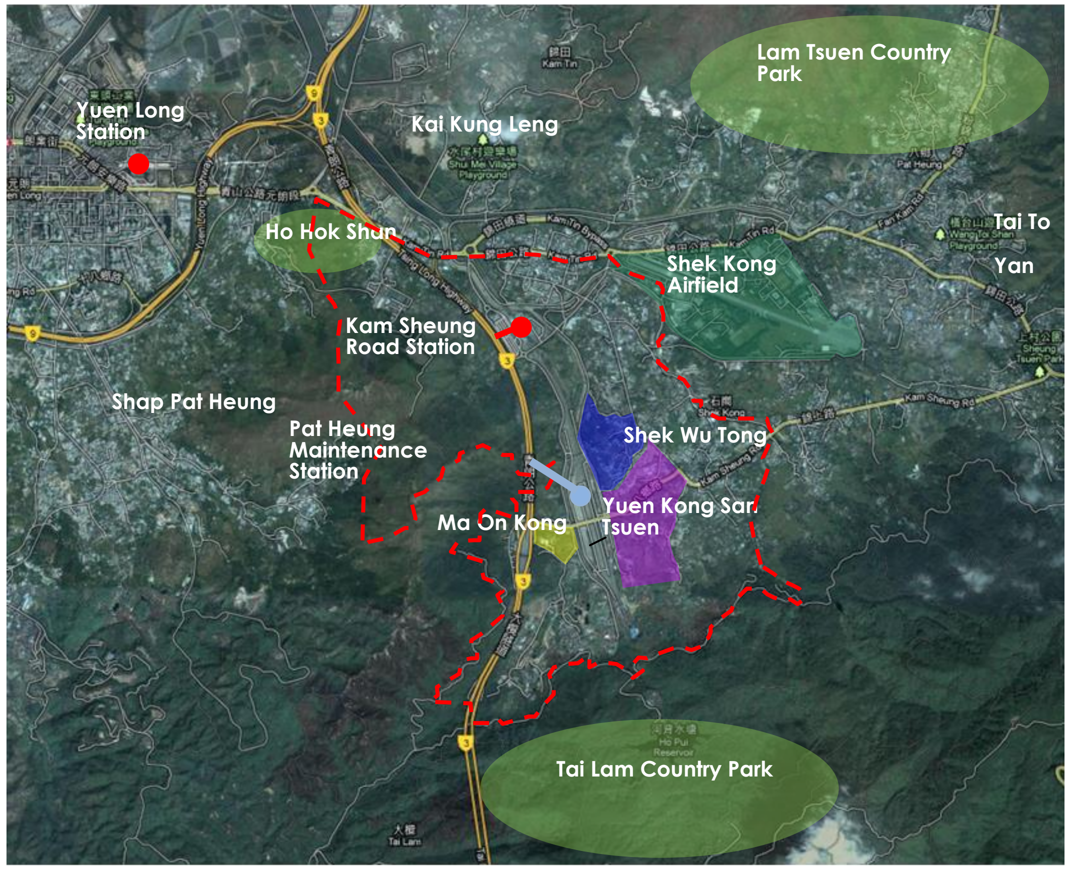


Figure 16 Existing condition of the Study Area

The characteristic of wind environment of the existing condition:

- The building clusters are scattered near the Shek Kong Airfield and most of them are built up to 32m. Some high-rise residential buildings of up to 110m are situated at the foot of Kai Kung Leng.
- As the Study Area is dominated with low-rise buildings, the annual prevailing wind would likely skim over the Study Area and no significant wind blockage at mid to high levels.
- Since the high-rise residential buildings at the Yuen Long Station areas are situated far from the Study Area, its impact in term of ventilation performance is minimal.
- The most possible wind obstruction would be the hilly ranges, such as Kai Kung Leng, Tai To Yan and Tai Lam Country Park.

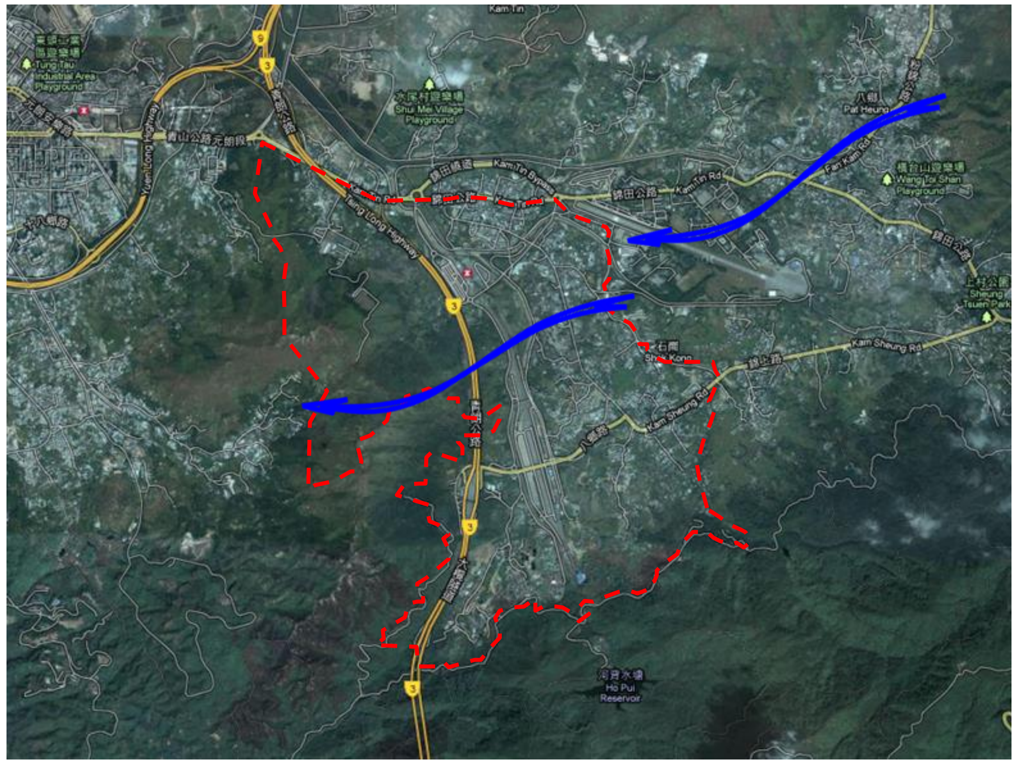


Figure 17 Existing wind condition under NE and ENE prevailing wind

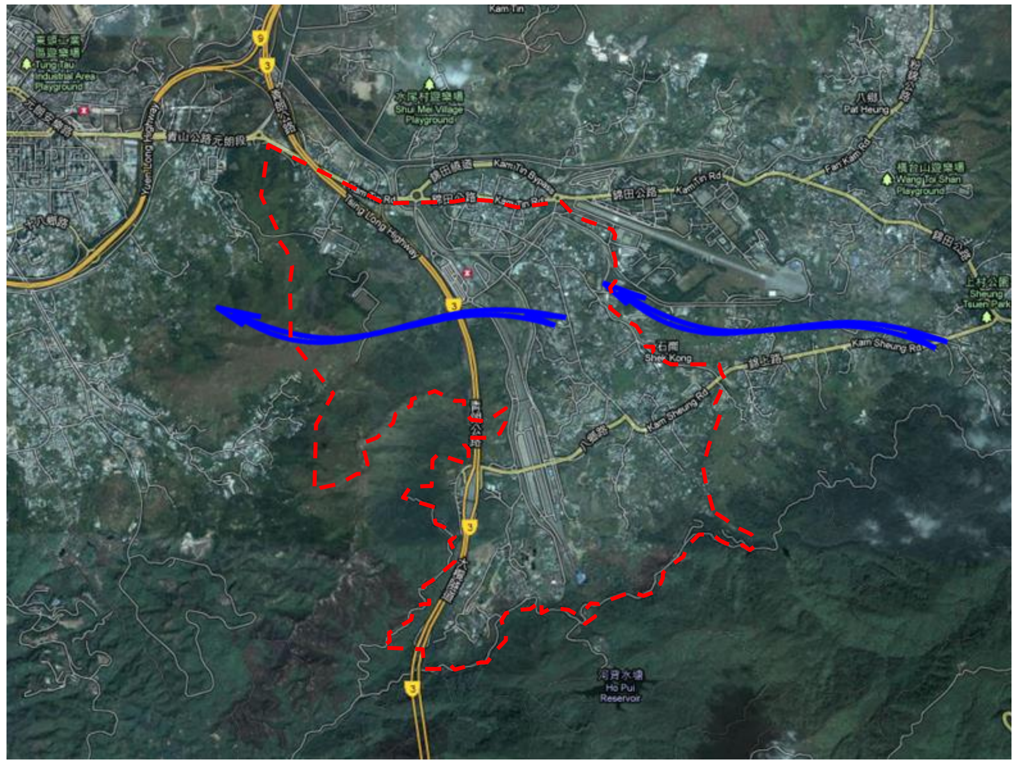


Figure 18 Existing wind condition under E prevailing wind

Figure 19 Existing wind condition under S prevailing wind

Figure 20 Existing wind condition under SE prevailing wind

7.0 LAND USE REVIEW PROPOSAL

District-wise wind enhancement features are proposed to minimize the potential air ventilation impact by the proposed land use:

- District wind corridors with a width of about 30m;
- Open space/ low-rise structures at the junction of the recommended wind corridors to promote air movement;
- Lower density at the upwind sites.

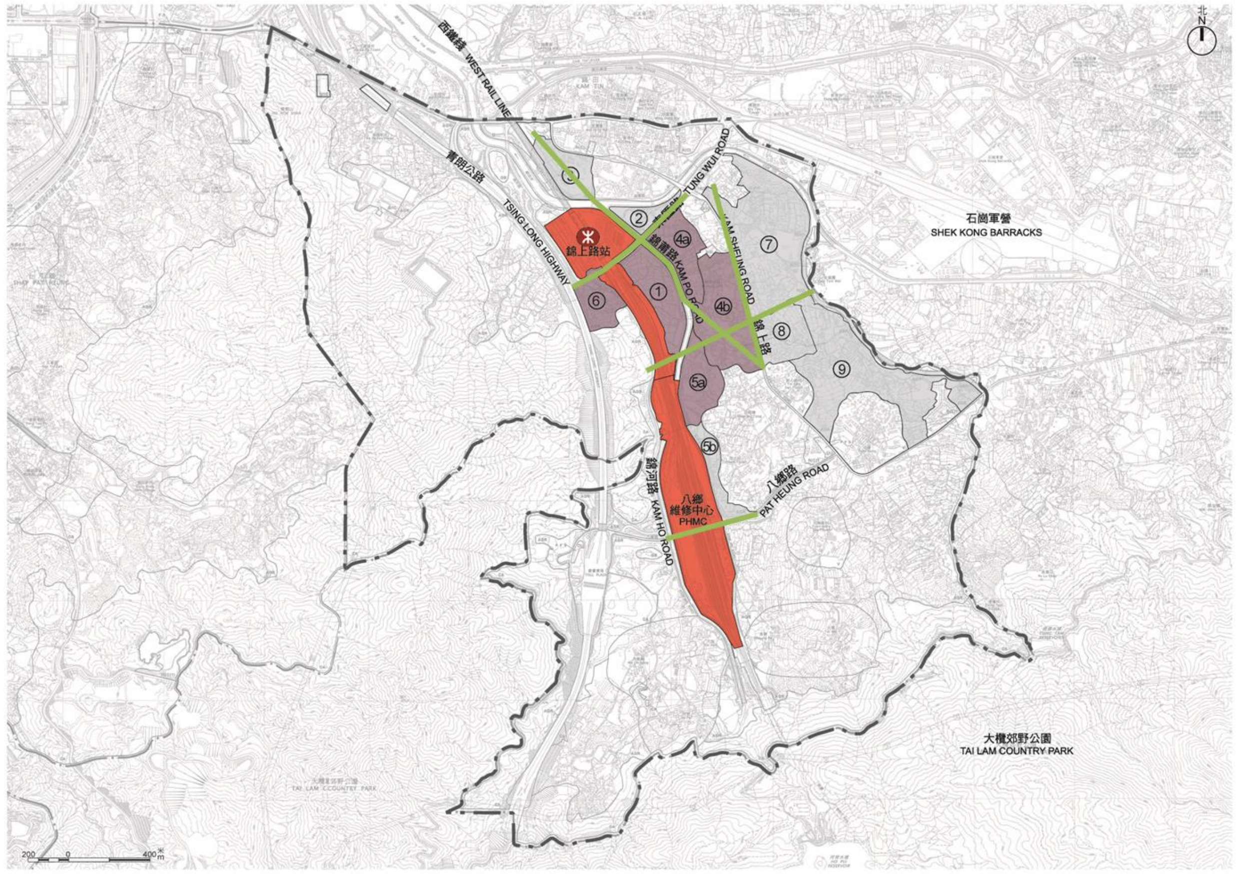


Figure 21 Proposed District Wind Corridors at the Potential Development Sites

8.0 EXPERT EVALUATION ON PRPOPOSED DEVELOPMET IN KAM TIN SOUTH

As concluded from Section 5, the annual and summer prevailing winds of the Study Area are NE/ ENE/ E and E/SE/ S respectively.

NE/ ENE/ E directions

Under NE/ENE/E annual prevailing wind directions, the incoming wind is not expected to have significant change due to the low rise characteristic of the existing building clusters at the upstream. Although the Study Area is located at the trough of a valley with hilly ranges surrounded as illustrated in Figure 22, the distance between the hills at upstream would be sufficient to allow incoming wind to reattach to the pedestrian level of the Study Area.

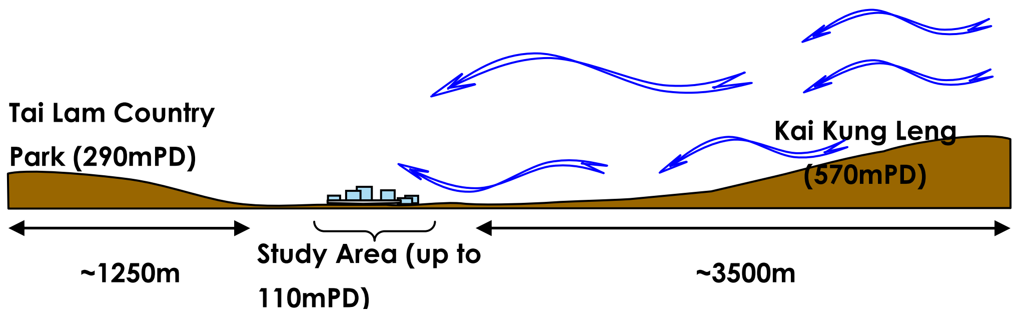


Figure 22 Wind Reattachment to Pedestrian Level under NE/ENE/E Prevailing Wind

Under the Proposed Land Use Planning Framework, potential development sites of higher development intensity (i.e. KSR, PHMC and the public housing developments) are located at the downwind positions from the existing building clusters in the Study Area.

Buildings are generally aligned along the prevailing wind directions under the conceptual development schemes. When such prevailing wind reaches the Study Area, the major breezeways (~30m)along Tung Wui Road, channel KT15 and Pet Heung Road allow the prevailing wind penetrating through the whole Study Area effectively. Some minor air paths (~15m) are also identified within the conceptual schemes which are mainly the eco-corridors, local green areas and building separations. Those air paths which are from gaps between buildings, building setbacks, open spaces and minor road are available for effective air dispersal as marked in Figure 23. With such breezeways and air paths available between buildings, air ventilation impact due to the proposed developments in Study Area is envisaged to be minimal.

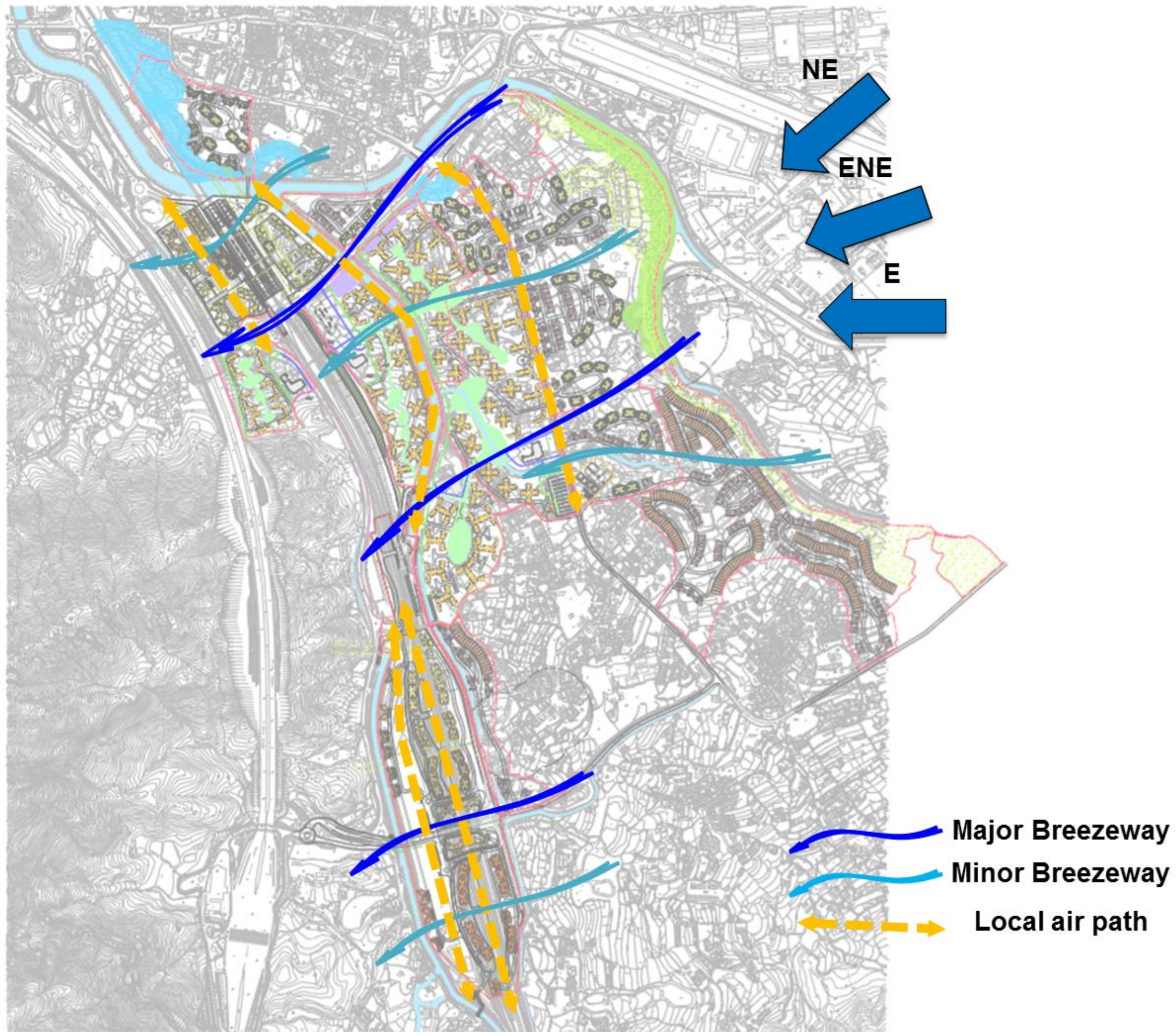


Figure 23 Wind Performance of Kam Tin South and Pat Heung under NE/ENE/E wind directions

S/SE directions

Under the S/SE summer prevailing wind directions, the winds come from the Tai Lam Country Park. The wind environment would be similar to that under NE/ENE/E wind condition as those potential buildings will be at the downwind side in which the leeward side of those potential building clusters would be hilly range and the impact to the existing building clusters would be minimal.

Major breezeways along Kam Po Road/Kam Tin River and Kam Sheung Road aligned with the prevailing wind directions are identified to allow effective air movements within the Study Area. Some of the building separations and green areas become the minor air paths and further enhance the wind performance. Those green space, landscape area and separation between buildings become local air paths, which are perpendicular or at an angle to the major breezeways, enhance wind penetration into inner parts of the Study Area (Figure 24). They help to improve the ventilation of local environment.

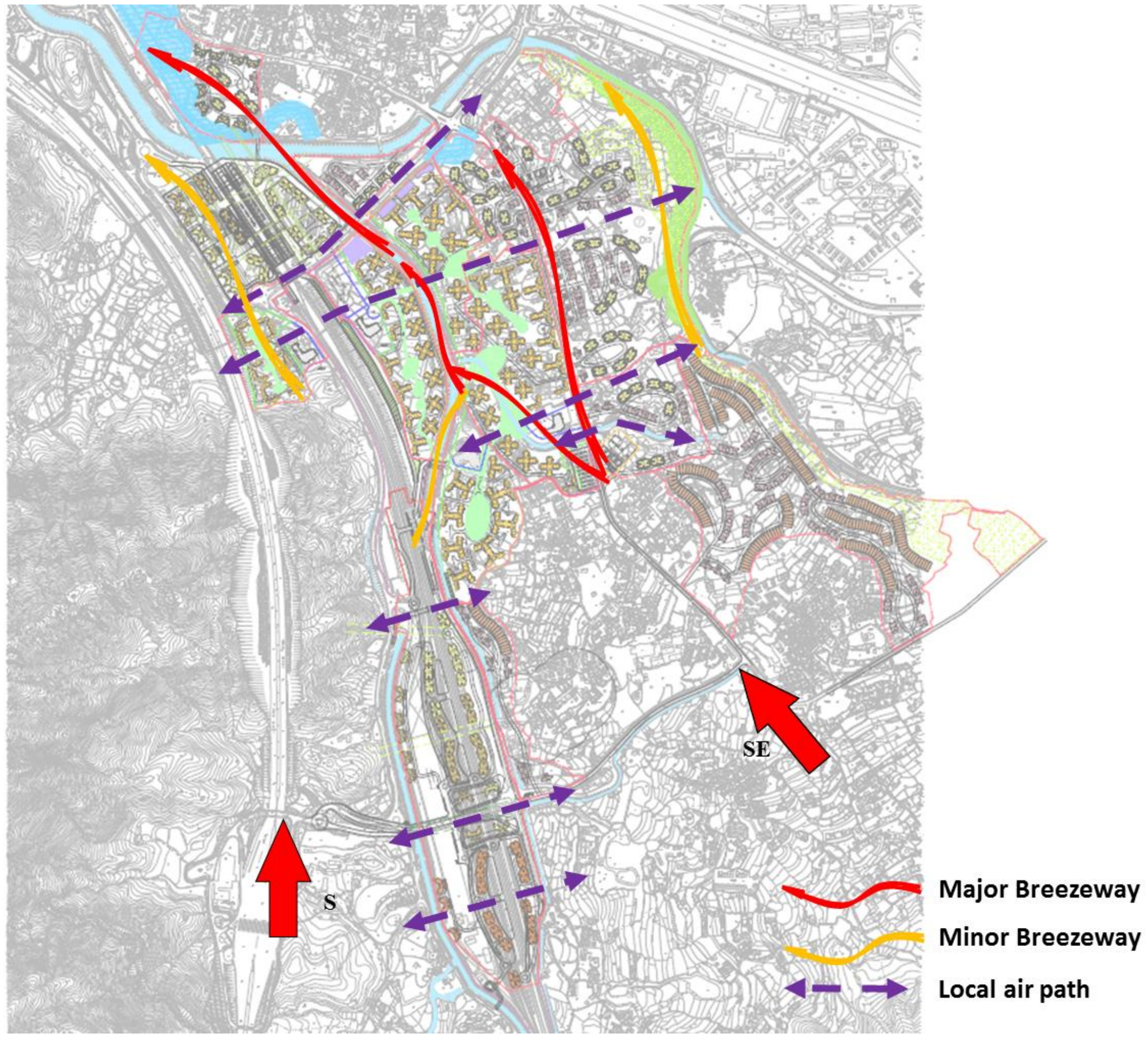


Figure 24 Wind Performance of Kam Tin South and Pat Heung under S/SE Wind directions

9.0 POTENTIAL AREAS FOR IMPROVEMENT AND RECOMMENDED MITIGATION MEASURES

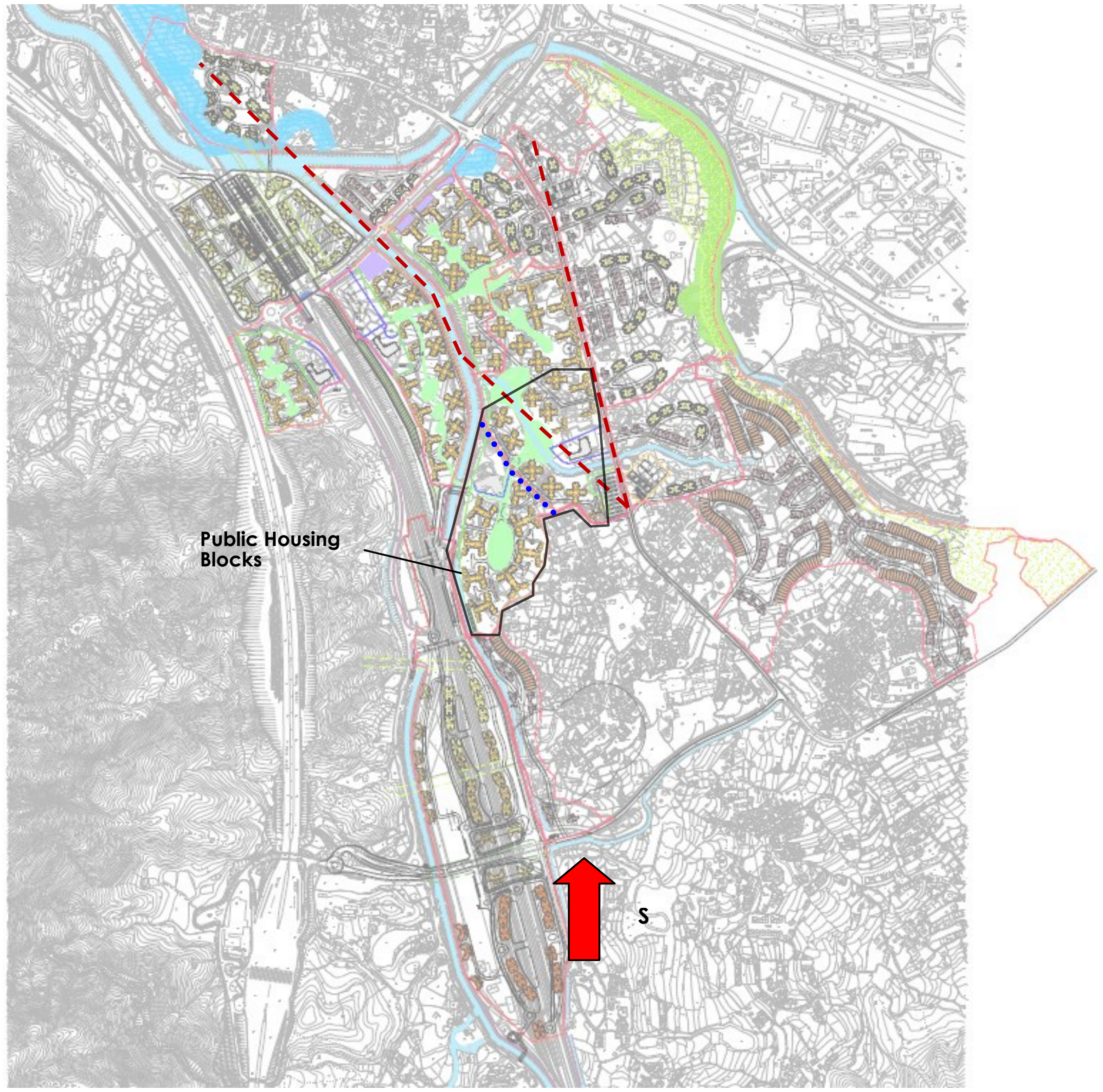


Figure 25 Potential Area for Further Wind Enhancement

Under the summer S/SE prevailing wind, the public housing blocks (Black circled area) at Site 4b and Site 5a are situated at the wind entrance area of the district wind corridor along Kam Tin River (Red dotted line). Wind enhancement measures including podium-free design and building setback in accordance with SBD Guidelines have been adopted in the conceptual schemes of the public housing development to minimize obstruction of air flow. To further enhance air permeability to the district wind corridor, it is recommended that additional local air paths align with the southerly and south easterly wind direction are introduced (Blue dotted line) at the detailed design stage.

10.0 RECOMMENDED WIND ENHANCEMENT FEAUTRES

The SBD Guidelines have identified 3 key building design elements, namely building separation, building setback and site coverage of greenery. The objectives are to achieve better air ventilation, enhance environmental quality of our living space, particularly at pedestrian level, provide more greenery and mitigate the heat island effect, as stipulated in the *Practice Note for Authorized Persons, Registered Structural Engineers and Registered Geotechnical Engineers (PNAP) APP-152*.

Qualitative guidelines on air ventilation are provided in Chapter 11 of the Hong Kong Planning Standards and Guidelines (HKPSG). In addition to the wind enhancement measures at "District Level" including site disposition, district wind corridors, road widening, building height profile and greening that have been incorporated in the Proposed Land Use Planning and Urban Design Frameworks, "Site Level" design considerations are recommended for refinement of the conceptual development schemes in the detailed design stage. Some of feasible recommendations are discussed as followings:

Orientation of developments

The potential developments are suggested to be in alignment with the prevailing wind direction in order to maximize penetration of prevailing wind throughout the Study Area. In addition, the length of developments perpendicular to the prevailing wind direction should be as short as possible in order to minimize stagnant zone as shown in Figure 26.

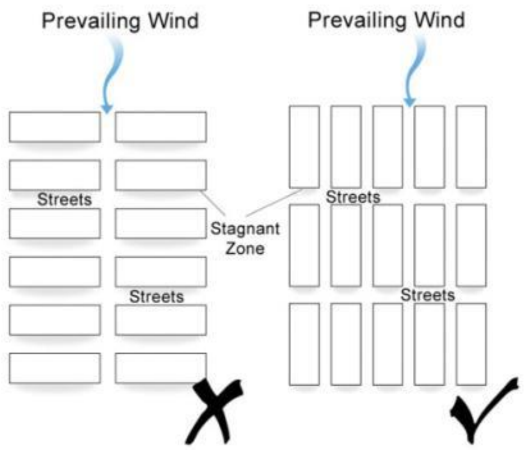


Figure 26 Alignment of developments

Building Setback

For those area with higher building density is recommended to setback from the street in order to widen the street to improve effectiveness of wind penetration. In particular to those wind corridors, building setback would also enhance the ventilation effectiveness.

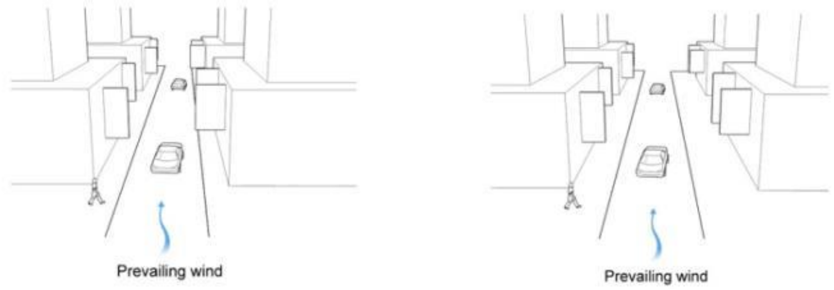


Figure 27 Building setback

Varying Building Height Profile

Varying building height profile has been adopted in the current planning of the potential sites to promote air movements. A strategic deposition of low- and medium-rise buildings in the Study Area with higher building density can help instigate wind flowing throughout the area. The height variation is recommended to increase from the direction where the prevailing wind comes from. The illustration is shown in Figure 28.

In addition, building gaps are provided as wide as possible to maximize the air permeability of the development and minimize the impact on wind capturing potential of adjacent developments.

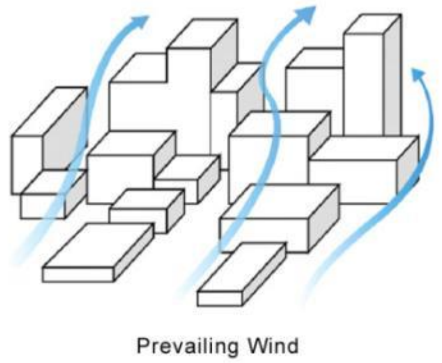


Figure 28 Varying building height profile

Terrence Podium Design

For those developments with podia, podium garden is recommended that allows wind to penetrate nearer to the pedestrian level. In addition, in order to further facilitate ventilation for those areas with podia, the podia have adopted terraced podium design as illustrated in Figure 29. Such design would direct downward airflow to the pedestrian level.

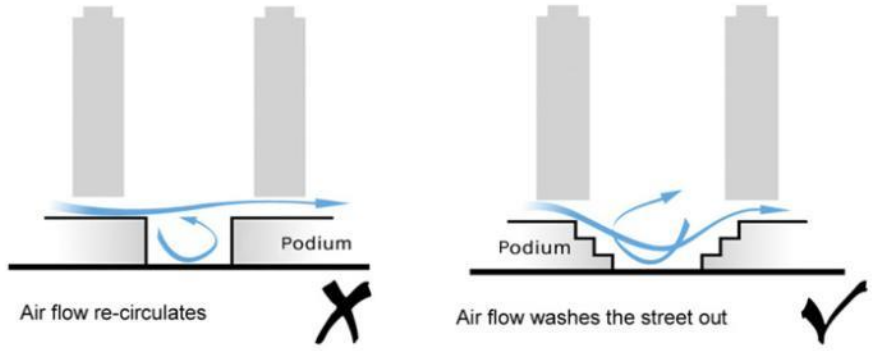


Figure 29 Terraced podium design

11.0 RECOMMENDATION ON FURTHER STUDY

The conceptual schemes for KSR, PHMC and public housing sites are prepared for technical assessment purpose to support rezoning of the sites as part of the Proposed Land Use Planning Framework. An AVA (Initial Study) is recommended to support the Master Layout Plan preparation to identify better design scenario(s) and suitable wind enhancement measures for individual sites. The AVA (Initial Study) should follow the Technical Circular and Technical Guides, with due consideration of the proposed district wind corridors and the Urban Design Framework.

12.0 CONCLUSION

An Air Ventilation Assessment (Expert Evaluation) on the Proposed Land Use Planning Framework at Kam Tin South and Pat Heung Areas has been carried out in accordance with the Government guidelines. Preliminary quantitative assessment on the conceptual development schemes of KSR, PHMC and the surrounding potential developments include Site 1, 2, 3, 4a, 4b, 4c, 5a, 5b, 6, 7, 8 and 9 using CFD model has been prepared to provide supplementary wind environment information.

Kam Tin South and Pat Heung lies within an inter-montane plane surrounded by various hilly ranges. Site wind availability data from HKO and MM5 have indicated that the annual prevailing winds are North-Easterly (NE), East-North-Easterly (ENE) and Easterly (E) directions; while the summer prevailing winds are East (E), South-Easterly (SE) and Southerly (S) directions.

NE, ENE and E prevailing wind conditions

Under NE, ENE and E prevailing wind, the potential development sites (particularly for KSR, PHMC and Public Housing Sites) are situated at the downwind side of existing building clusters. District wind corridors, breezeways and associate air paths have been proposed along the annual prevailing wind directions to optimise air permeability of the proposed developments to enhance wind performance.

SE and S prevailing wind conditions

District wind corridors have been proposed along the summer prevailing wind directions to optimise air permeability of the proposed developments. Air paths intersecting the breezeways are provided to allow effective air dispersal, thus enhance the local ventilation performance of the Study Area.

The public housing development at Site 4a and 5a located at the wind entrance area under the summer prevailing wind condition and may reduce the summer wind penetration.

An additional air path is suggested to include in the Site 4b and Site 5a to enhance the summer wind penetration.

Recommendation

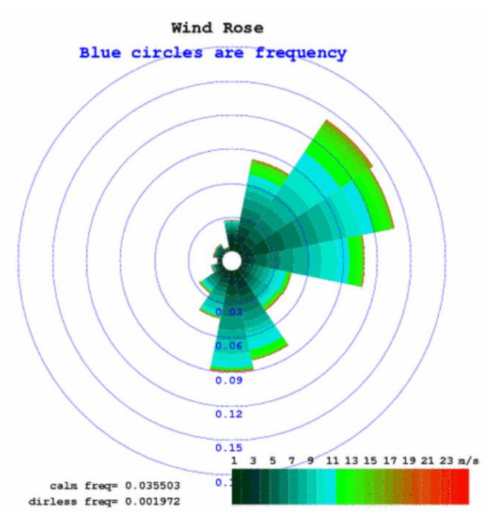
AVA Initial Study is recommended to support Master Layout Plan preparation for individual site to identify and optimal design option and suitable wind enhancement measures.

Appendix A - PRELIMAIRMAY QUANTITATIVE ANALYSIS ON THE KAM TIM SOUTH AND PAT HEUNG AREA

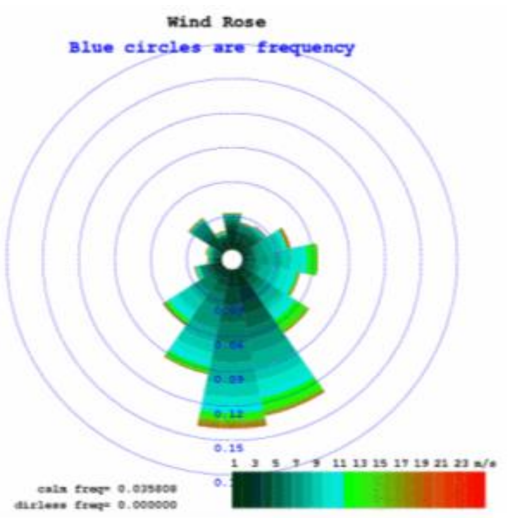
The following section describe of the study methodology of the preliminary quantitative analysis:

Site wind availability

The site wind availability data was obtained from a the MM5 data by the HKUST. A wind rose showing the frequencies of occurrence of different wind directions at 230mPD as well as a summary of the frequency for different wind directions are shown as below.



Annual wind rose



Summer wind rose

Table 3 Annual and summer wind frequency

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE
Annual Frequency	3.51%	9.17%	15.42%	15.21%	11.83%	5.32%	5.18%	9.16%
Summer Frequency	4.03%	2.90%	3.17%	4.30%	8.51%	6.20%	7.88%	13.72%
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW
Annual Frequency	10.16%	5.28%	3.37%	1.58%	0.95%	1.32%	1.54%	1.01%
Summer Frequency	13.90%	11.32%	7.88%	3.89%	2.08%	3.13%	4.26%	2.81%

In this preliminary quantitative analysis, all the 16 wind directions are studied.

Wind profile

The wind profiles, including the mean wind speed and the turbulence intensity were taken as input parameters in the CFD models. The wind profiles can be assumed by the power law for specific terrains as following equation:

$$\frac{U_z}{U_G} = \left(\frac{Z}{Z_G}\right)^n$$, where

U_G = reference velocity at height ZG
Uz = velocity at height Z
Z_G = reference height
Z = height above ground
n = power law exponent

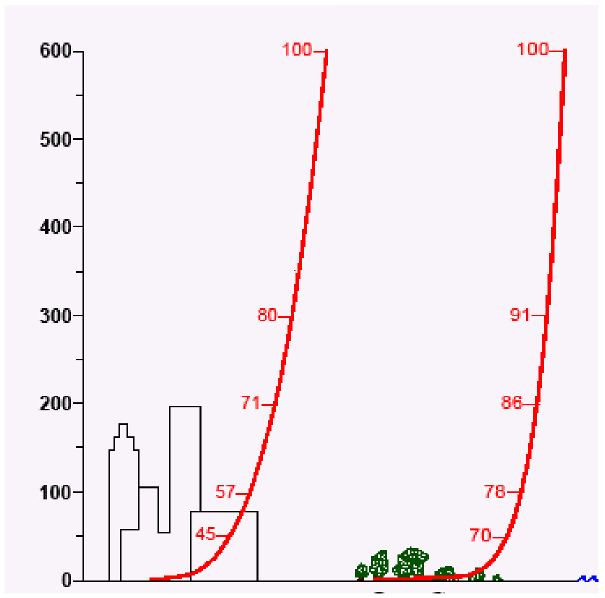


Figure 30 Wind Profile applied in Study

The power n is related to the ground roughness, which is determined by terrain types. A larger value of the power n represents the higher roughness of the ground i.e. the dense city. Alternatively, smaller n represents the lower ground roughness i.e. the sea surface. As the Study Area is rural area, the n-value of 0.15 is applied for simulation of all wind directions.

Terrain crossed by approaching wind	n-value
Sea and open space	~0.15
Suburban or mid-rise	~0.35
City center or high-rise	~0.50

Project Assessment and Surrounding Areas

The area of evaluation and assessment includes all areas within the Development Site, as well as a belt up to 1H (H being the height of the tallest building within the Development which is equivalent to 120m) from the site boundary (Assessment Area). Further, the model area was built to include another 120m meters (2H) beyond the Assessment Area (Surrounding Area). Nearby prominent topographical features beyond the Surrounding Area were also included in the model to take into account the topographic effect.

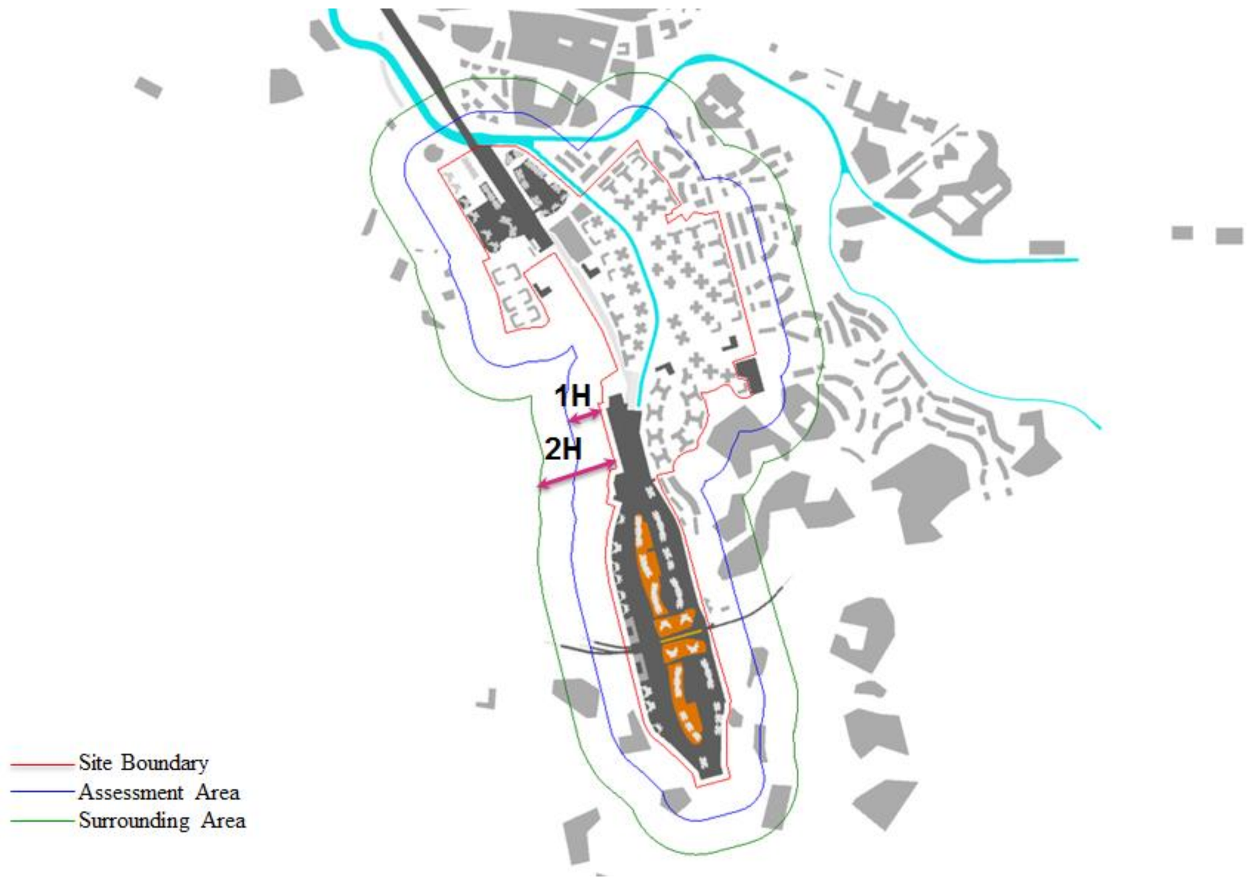


Figure 31 Site Boundary (red), Assessment Area (green) and Surrounding Area (blue)

Assessment Parameters

The Velocity Ratio (VR) as proposed by the Technical Circular for AVA was adopted to assess the impact of the proposed development and to the surroundings. The calculation of VR is given by the following formula:

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

Where

V∞ = the wind velocity at the top of the wind boundary layer (typically assumed to be approximately 600m above the centre of the site of concern, or at a height where wind is unaffected by the urban roughness below).

Vp = the wind velocity at the pedestrian level (2m above ground) after taking into account the effect of buildings.

Test point for Local and Site Ventilation Assessment

Monitoring test points are placed within the assessment area to determine the ventilation performance. There are two types of test points:

- Perimeter test point

Perimeter test points are used to assess the immediate effect of the project to the Assessment Area. Totally 82 perimeter test points (red spots) are located around the perimeters of the project site boundary at the junctions of all roads leading to the project sites, at the main entrances to the project, and at corners of the project. This group of perimeter test points will provide data for the Site Air Ventilation Assessment.

- Overall test point

Totally 163 overall test points (yellow spots) are evenly distributed and positioned in the open space, on the streets and places of the project and Assessment Areas where pedestrians frequently assess. This group of overall test points, together with the perimeter test points, will provide data for the Local Air Ventilation Assessment.

The locations of the perimeter test points and overall test points are illustrated in the following figures.

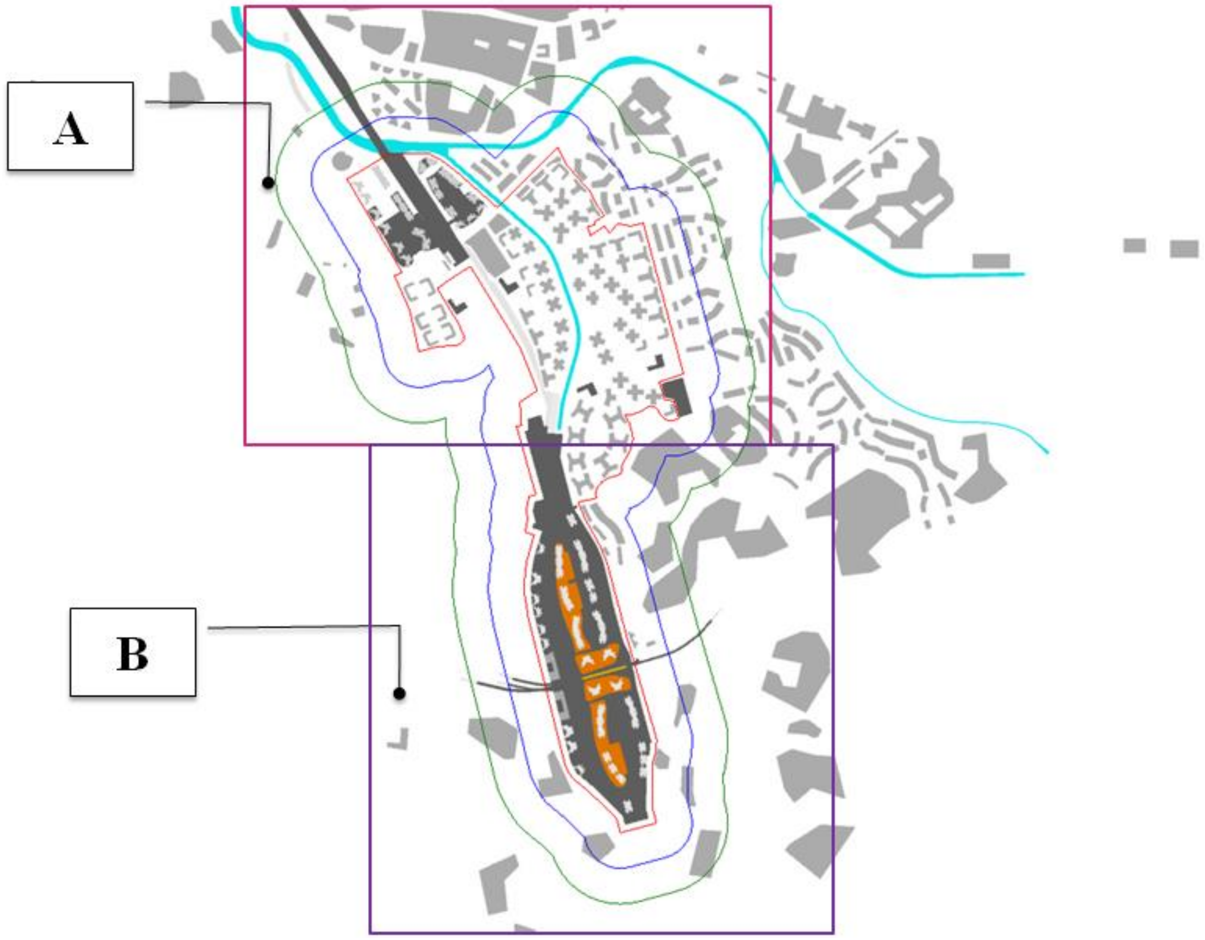


Figure 32 Demarcation of different zone for illustrating the test point for the Kam Tin South Area

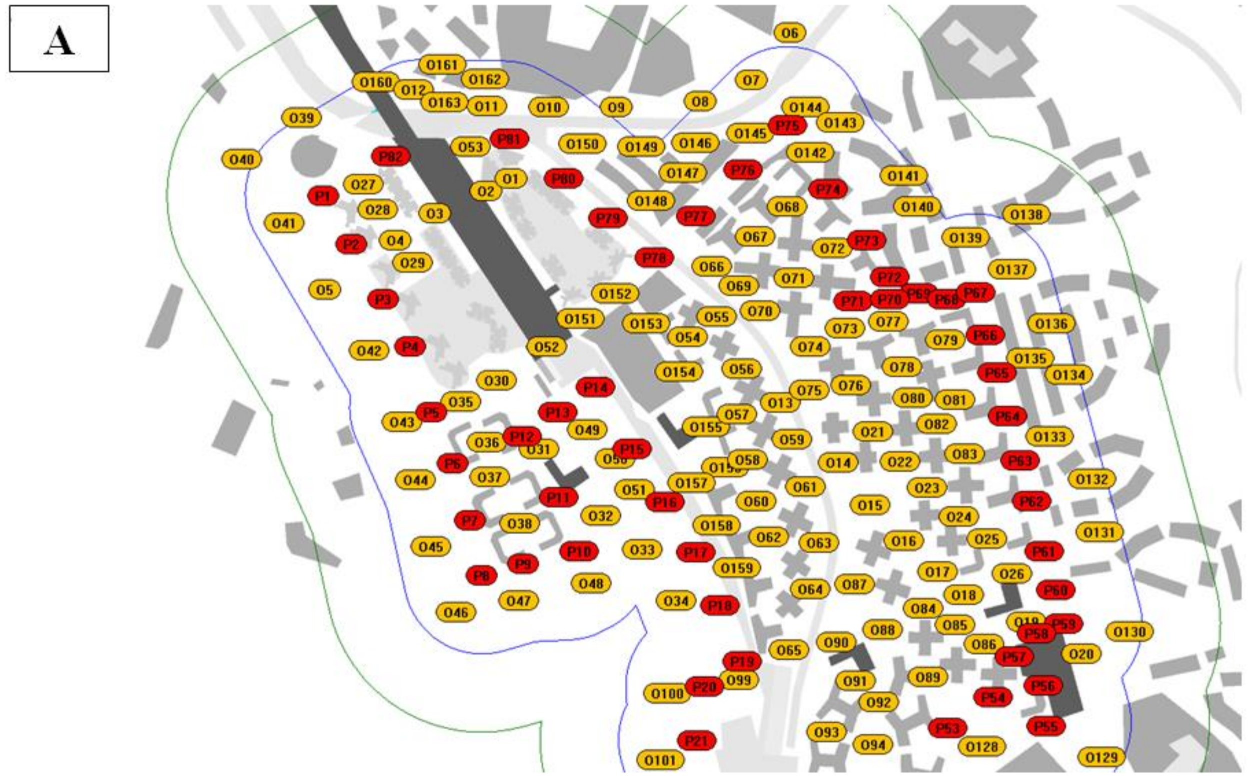


Figure 33 Demarcation of the test point locations Zone A

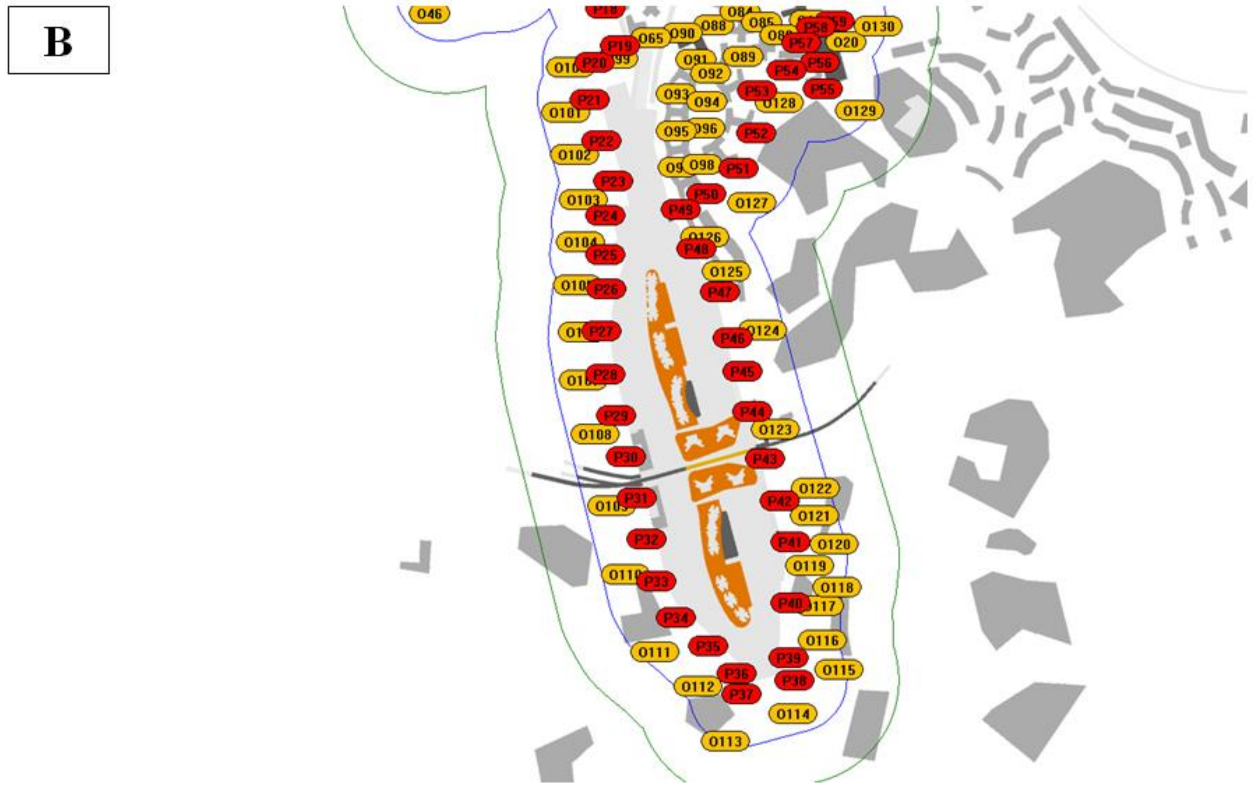


Figure 34 Demarcation of the test point locations Zone B

Simulation tool

Computational Fluid Dynamics (CFD) technique was utilized for this Study. With the use of three-dimensional CFD method, the local airflow distribution can be visualized in details. The velocity distribution within the flow domain, being affected by the site-specific design and the nearby topography, was simulated under the prevailing wind conditions. A commercial software STAR –CCM+ was applied as the simulation tool for this study.

CFD Model

The domain size of the CFD model for study is shown Figure 35. The model contains more than 6,000,000 cells. They cover the entire Study Area and provide sufficient considering on surrounding topography. The model contains information of the surrounding buildings and site topography via Geographical Information System (GIS) platform. To model more accurately the approaching wind flow condition, the CFD model includes not only the surrounding buildings within the 2H boundary as required by the Technical Circular, but also the buildings at certain distance away from the 2H boundary which are considered to have significant effect on the approaching airflow pattern. Body-fitted unstructured grid technique is used to fit the geometry to reflect the complexity of the development geometry. Finer grid system (with the smallest grid size of 0.5m per grid) is applied to the most concerned area based on preliminary judgment, while coarse grid system (more than 20m per grid at location far away from the site) is applied to the area of surrounding buildings for better computational performance while maintaining satisfactory result.

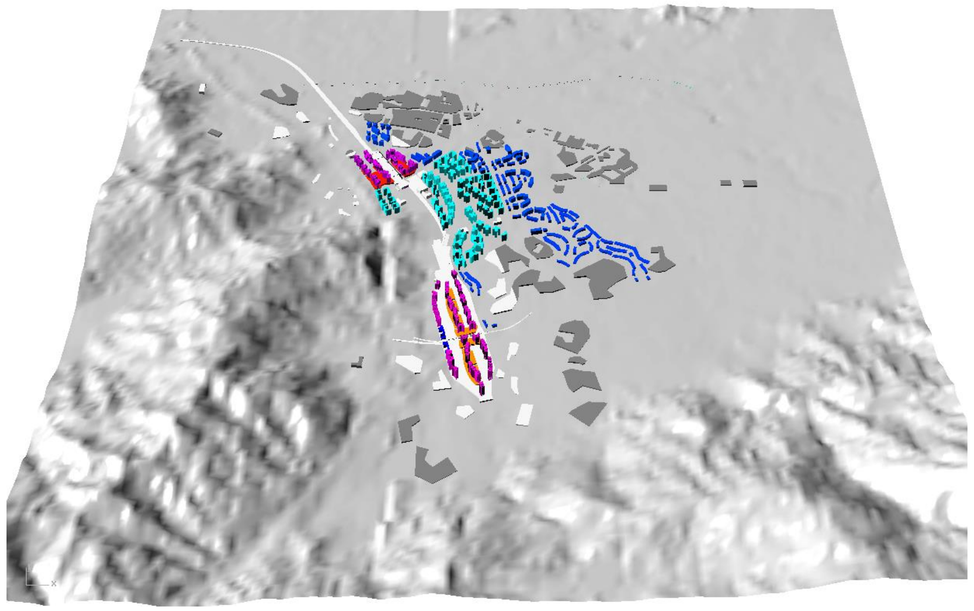


Figure 35 3D model of the study

Turbulence modelling

As highlighted in recent academic and industrial research literatures by CFD practitioners, the widely used standard k - ε turbulence model technique may not adequately model the effects of large scale turbulence around buildings and ignores the wind gusts leading to the relatively poor prediction in the recirculation regions around building. Therefore in this simulation, realizable k–ε turbulence modelling method is applied. This technique provides more accurate representation of the levels of turbulence that can be expected in an urban environment.

Calculation method

The SIMPLE algorithm was adopted to solve the pressure-velocity linked equations. The SFCD differencing scheme was applied to discretize the momentum equation and other equations. The convergence criterion is 0.0105 on mass conservation. The calculation loop will repeat until the total errors satisfy this convergence criterion.

The prevailing wind direction is set to inlet boundary with wind profile according to the wind tunnel test. The downwind boundary is set to pressure with value of zero. The top and side boundaries are set to symmetry. In addition, to eliminate the boundary effects, the model domain is built beyond the Surrounding Area.

Table 4 Summary of the CFD model settings

	CFD Model
Physical Model Scale	Real model, 1:1 scale
Model details	Only include Topography, Buildings blocks, Streets/Highways, no landscape is included
Domain	5000m(L) x 5000m(W) x 780m(H)
Grid Expansion Ratio	The grid should satisfy the grid resolution requirement with maximum expansion ratio = 1.3
Prismatic layer	Prism layer must cover pedestrian level at least 2m, spacing recommend 0.5m for the first 2m above ground level
Wall boundary condition	Logarithmic law boundary

	CFD Model
Solving algorithms	Rhie and Chow type pressure-velocity coupling SIMPLE type solver Hybrid model for all other equations
Blockage ratio	< 3%

RESULT AND DISUCSSION

In order to provide an overall picture of the wind environment for the purpose of this study, contour plots of the average VR are plotted at 2m above the ground. This, in comparison with the results at the discrete test points, provides a more complete picture as it shows the overall pattern of ventilation performance and it is easier to assess the physical reasons for some of the predictions of the VR results of the test points. Figure 36 and Figure 37 illustrated the contour map of the annual and summer weighted average VR of the Study Area respectively.

Two ratios were determined to give a simple quantity to summarize the ventilation performance:

- Site spatial average Velocity Ratio (SVR) - This gives a hint of how the development proposal impacts the wind environment of its immediate vicinity. This is the average of VR values of all perimeter test points.
- Local spatial average Velocity Ratio (LVR) - This gives a hint of how the development proposal impacts the wind environment of the local area. This is the average of VR values of all overall and perimeter test points.

The SVR and LVR are indicators of the ventilation performance of the development site. If the averaged VR is high then the site is well ventilated, whereas if the values are low, improvement might be necessary. The values for SVR and LVR for the study are presented below:

Table 5 SVR and LVR for the study

	Annual	Summer
SVR	0.19	0.20
LVR	0.18	0.18

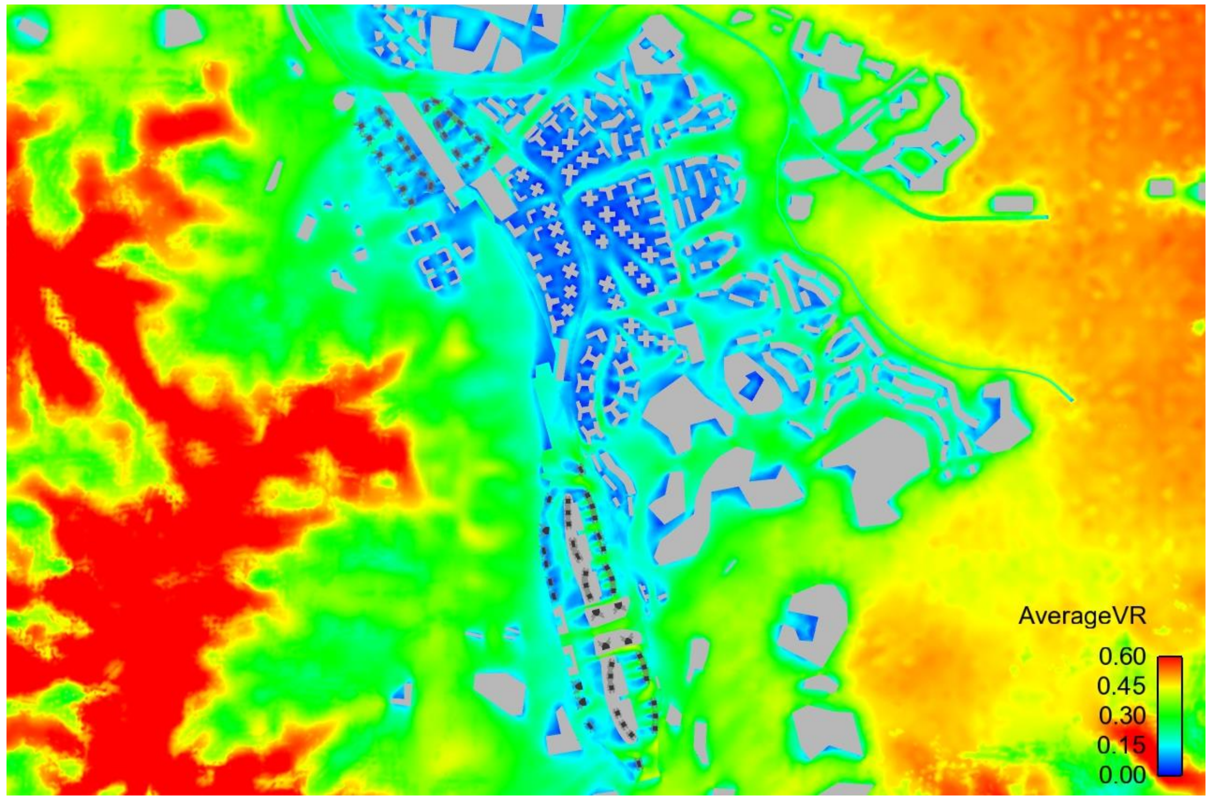


Figure 36 Contour map of the annual weighted average VR for the study area

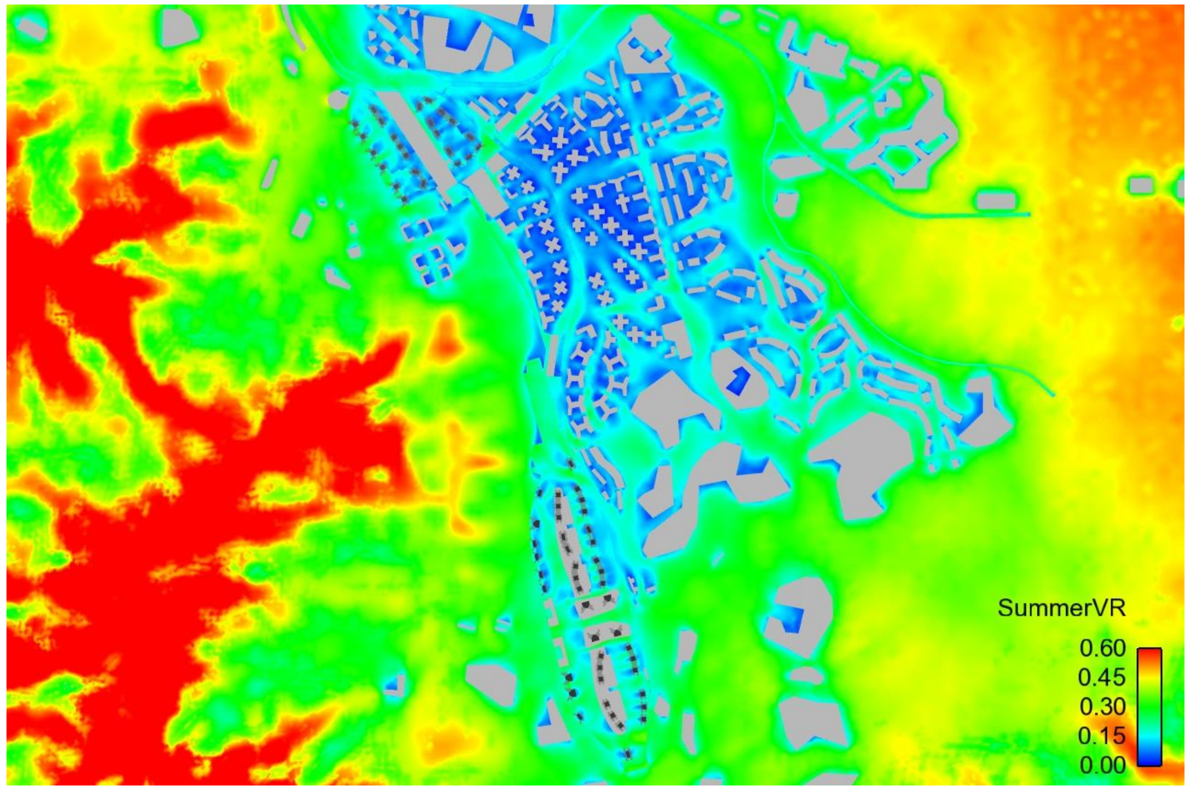


Figure 37 Contour map of the summer weighted average VR for the study area

Directional Analysis

N Wind Direction

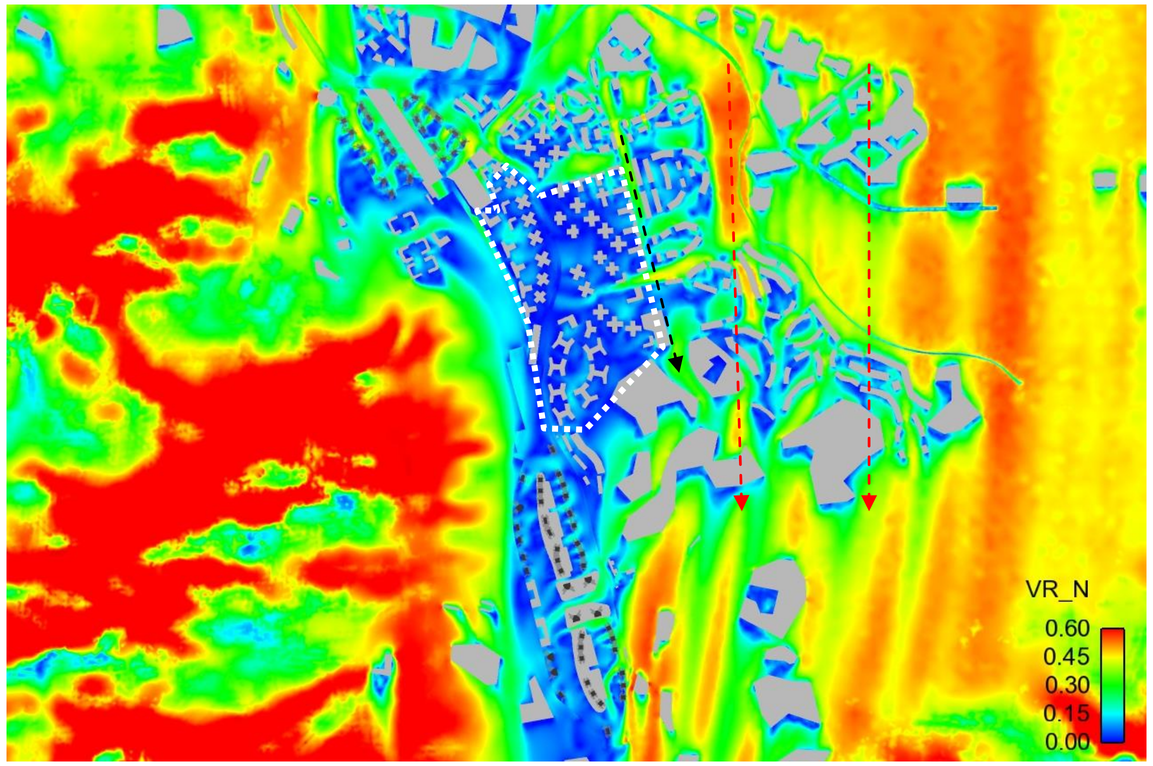


Figure 38 Contour map of N wind for the study area

The open space and the relatively low rise developments at the eastern region of the Study Area allow the prevailing wind to skim over on top of the building and reach the downwind region (Red arrow). The district wind corridor also enable the incoming wind penetrate through and enhance the ventilation performance at leeward side (Black arrow).

Relative stagnant area is identified in the center part of the study area (white dotted region) due to the blockage of the upstream Site 1 and Site 4a. Wind enhancement feature as listed in the HKPSG should be considered to enhance the local ventilation performance during the detail design stage.

NNE Wind Direction

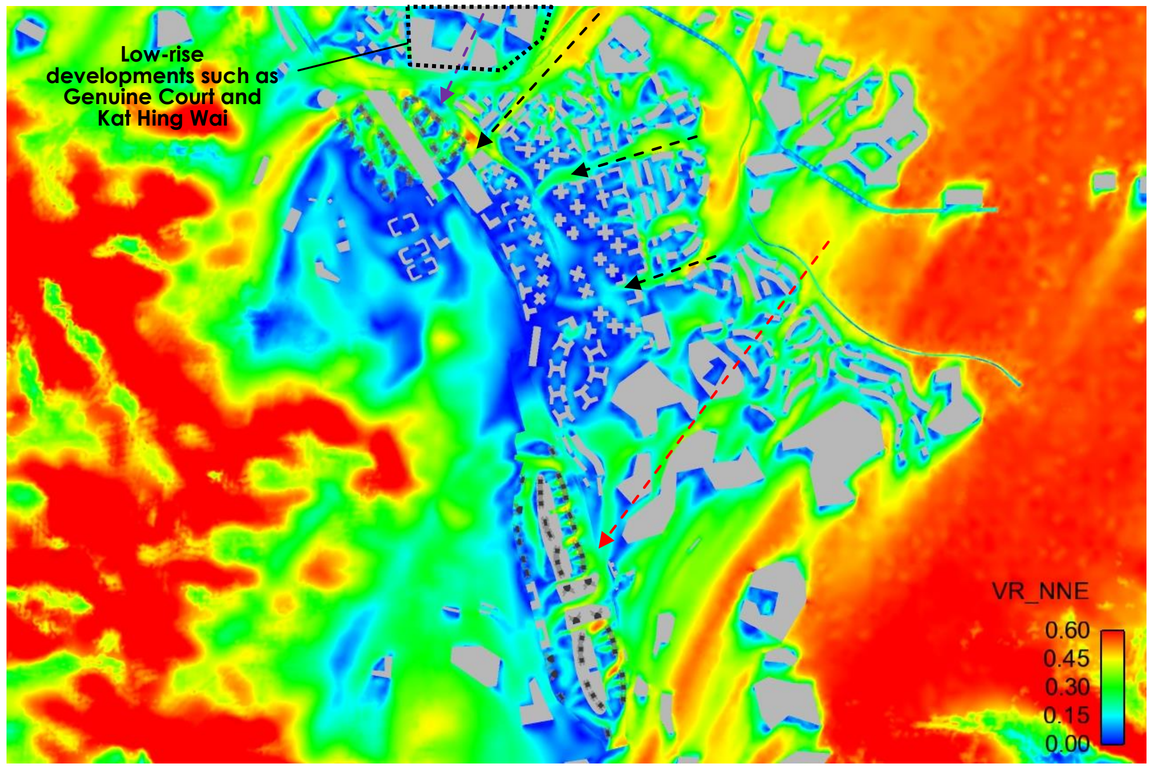


Figure 39 Contour map of NNE wind for the study area

The low rise developments at the upwind regions, such as Genuine Court and Kat Hing Wai allows the prevailing wind to skim over with less wind blockage at the mid and high level and reach KSR development (Purple arrow). The district wind corridor and breezeways enable the incoming wind penetrate to the core of the Study Area and enhance the wind environment (Black arrow). The open space and the relatively low rise developments at the eastern region of the Study Area allow the prevailing wind to skim over on top of the building and reach the downwind region (Red arrow) of PHMC development.

NE Wind Direction

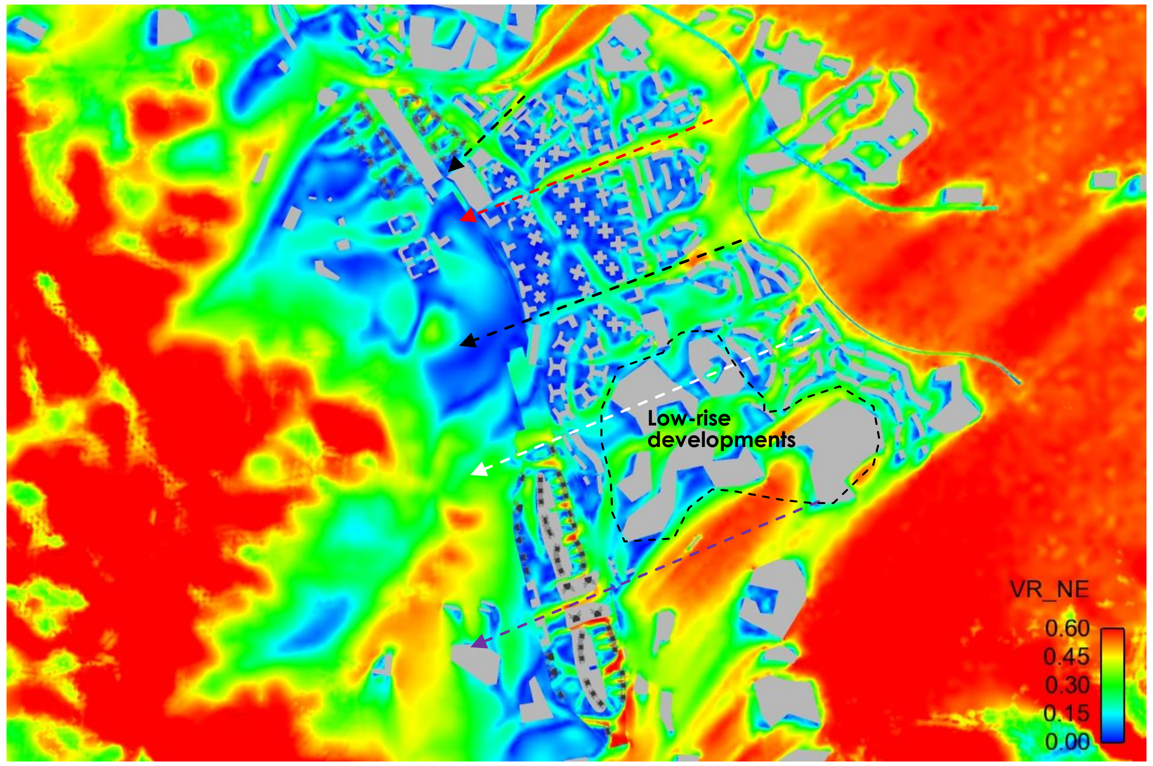


Figure 40 Contour map of NE wind for the study area

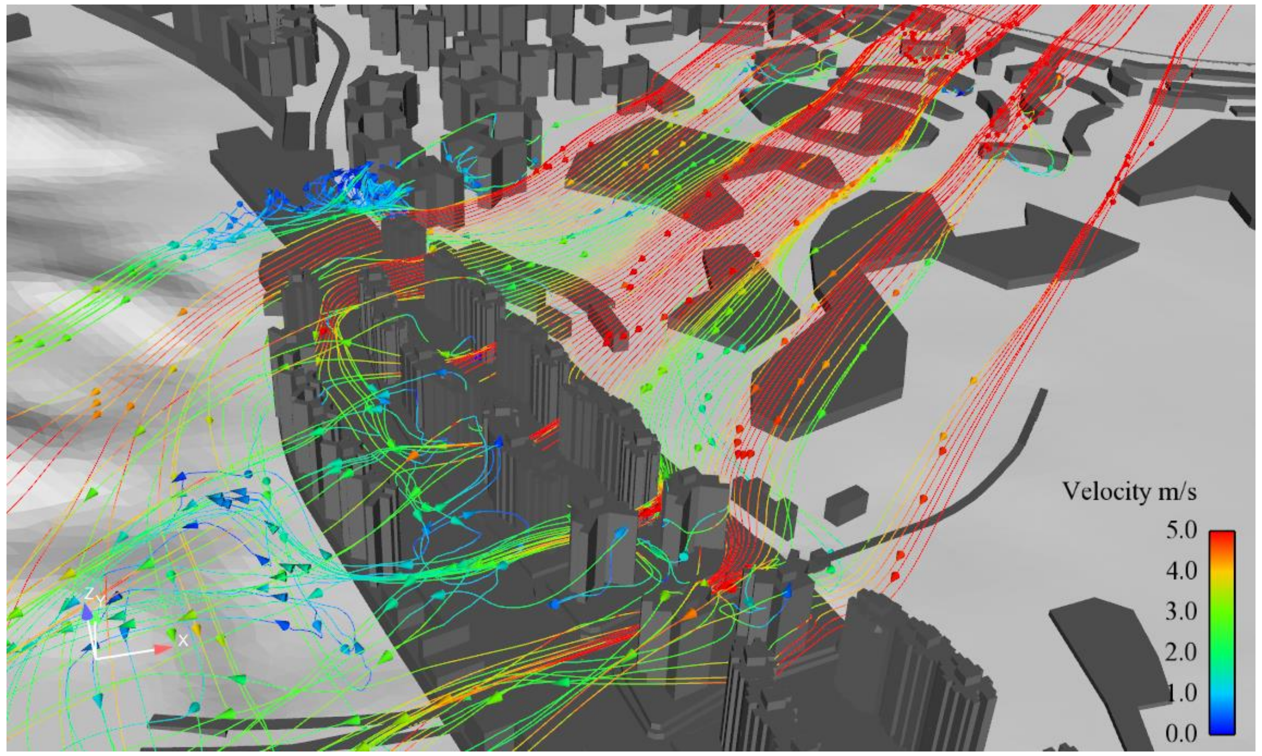


Figure 41 prevailing wind skim through the upstream low rise development

The NE prevailing wind is able to penetrate through the Study Area by using the two proposed district wind corridors (Black arrow) to direct the prevailing wind to the leeward region. The local air path across the Sites 4a and 1 also help to bring the NE prevailing wind into the Study Area and enhance the ventilation performance. The relatively low-rise existing developments at the upstream area also allows the prevailing wind to skim over on top of the building (Figure 41) and penetrate through the building gap between Sites 5a and 5b (White arrow). At the southern portion, the large building separations on the PHMC development allow effective wind penetration (Purple arrow).

ENE Wind Direction

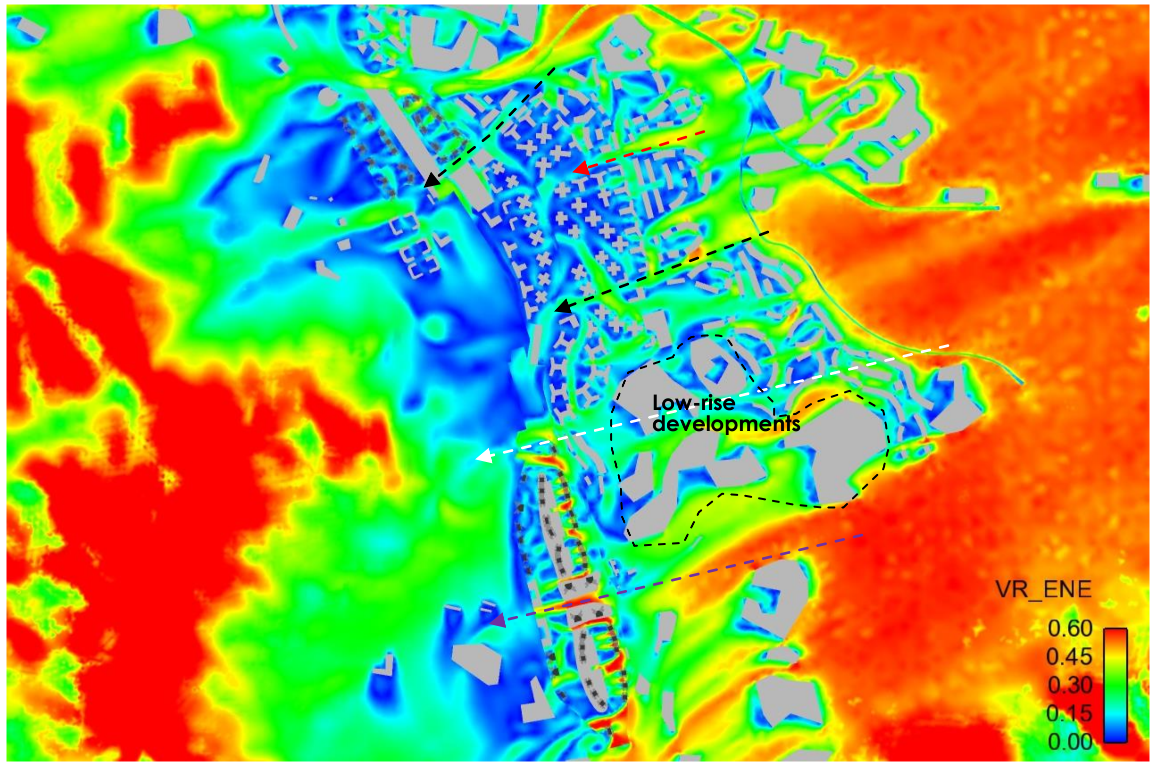


Figure 42 Contour map of ENE wind for the study area

Similar to the NE prevailing wind condition, the proposed district wind corridors (Black arrow), local air path (red arrow) and large building separations on the PHMC development (Purple arrow) enhanced the wind permeability of the Study area. The relatively low-rise existing developments similar to the NE wind condition (Figure 41) also allow the prevailing wind to skim over on top of the building and penetrate to the leeward regions (White arrow).

E Wind Direction

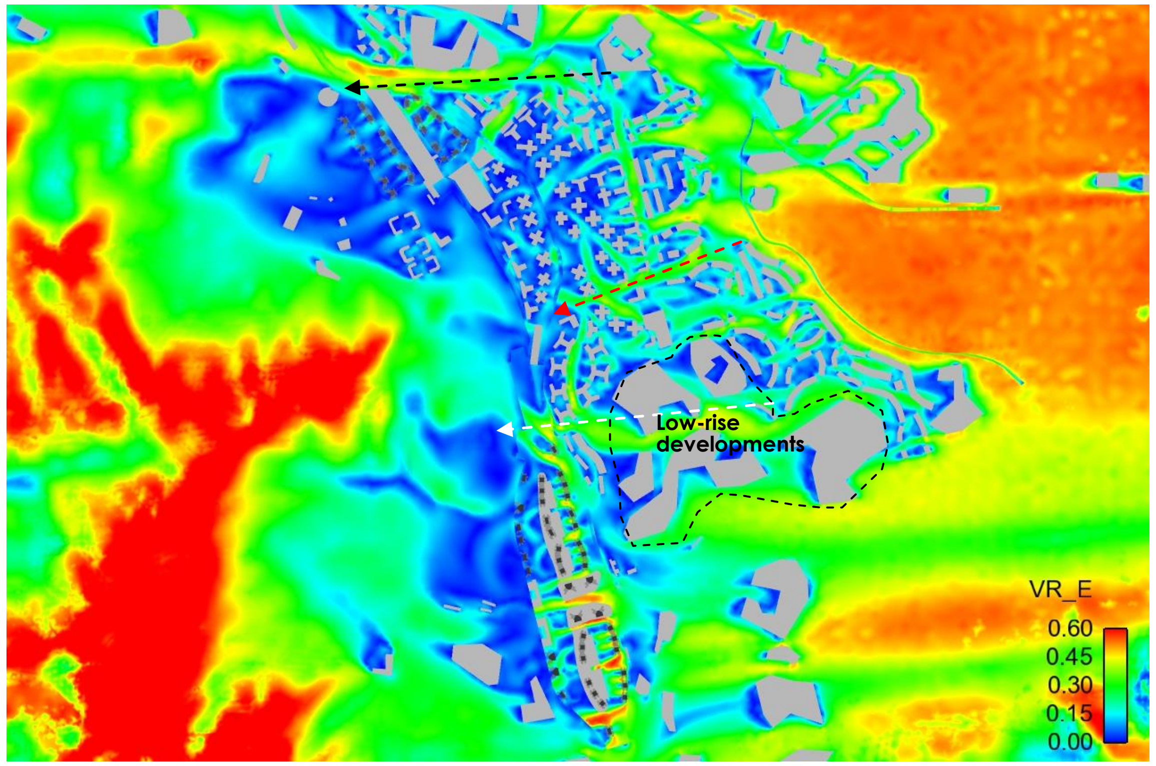


Figure 43 Contour map of E wind for the study area

At the northern portion of the Study area, the E prevailing wind able to penetrate through the Study Area using the river (Black arrow) as a local air path. At the center, the proposed district wind corridor (Red arrow) across the Study Area allows the prevailing wind penetrate in through the site effectively. The relatively low-rise existing developments at Shek Wu Tong and Yuen Kong San Tsuen similar to the NE wind condition (Figure 41) also allows the prevailing wind to skim over on top of the building and penetrate through the building gap between Sites 5a and 5b (White arrow).

S Wind Direction

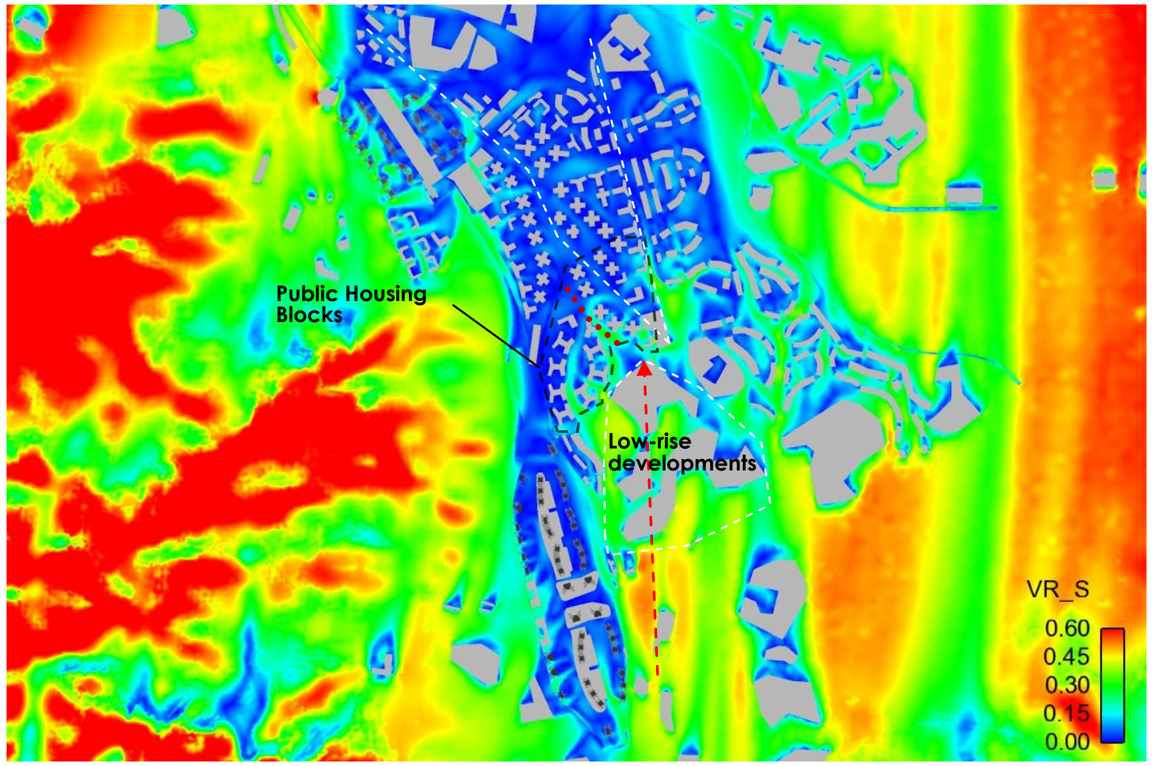


Figure 44 Contour map of S wind for the study area

The open space and the relatively low rise developments (white dotted region) at the southern region of the Study Area allow the prevailing wind to skim over effectively and enter the future development site (Red arrow). Under the S prevailing wind, the public housing blocks (Black circled area) at Site 4b and Site 5a are situated at the wind entrance area of the district wind corridor along Kam Tin River (Red dotted line).
Under such prevailing condition, a relatively calm wind environment is identified in the downstream area as the effectiveness of the wind corridor is reduced due to the high rise high density future housing site development. Wind enhancement measures including podium-free design and building setback in accordance HKPSG should be considered to adopt in the conceptual schemes of the public housing development to minimize obstruction of air flow
To further enhance air permeability to the district wind corridor, it is recommended that additional local air path aligning with the southerly wind direction are introduced (red dotted line) at the detailed design stage.

SSE Wind Direction

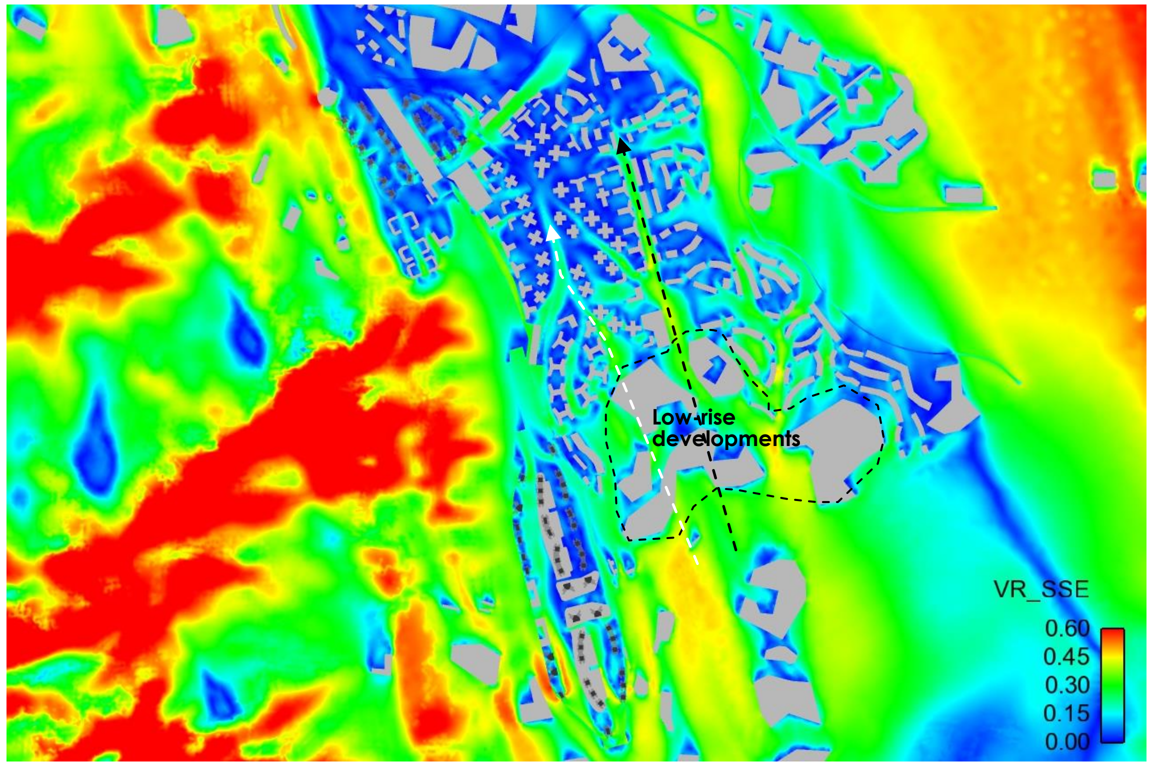


Figure 45 Contour map of SSE wind for the study area

Under the SSE wind, the low rise developments at the upwind regions allows the wind to skim over (Figure 46) with less wind blockage at the mid and penetrate into the Study area. One proposed district wind corridors (black arrow) and local air path (white arrow) are in alignment with the prevailing wind direction and direct the incoming wind towards the core of the Study area.

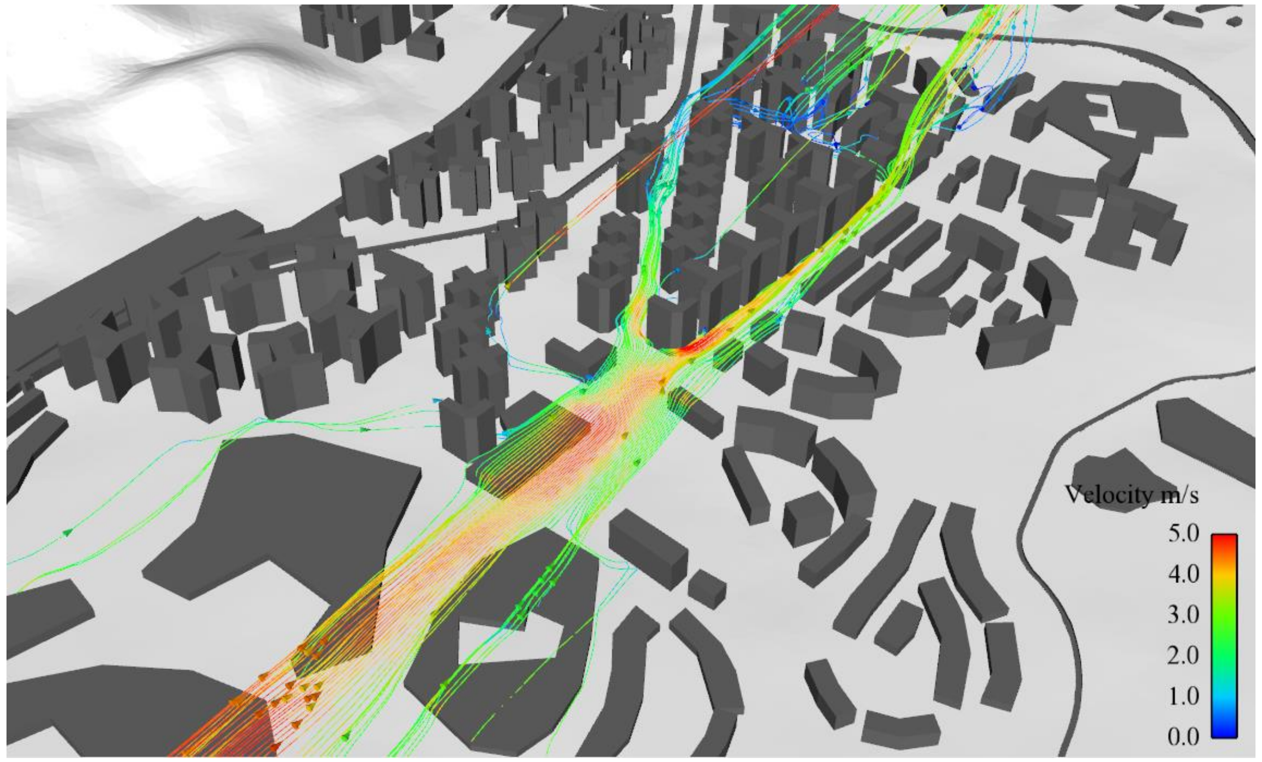


Figure 46 Prevailing wind skim over the upstream low rise development

SE Wind Direction

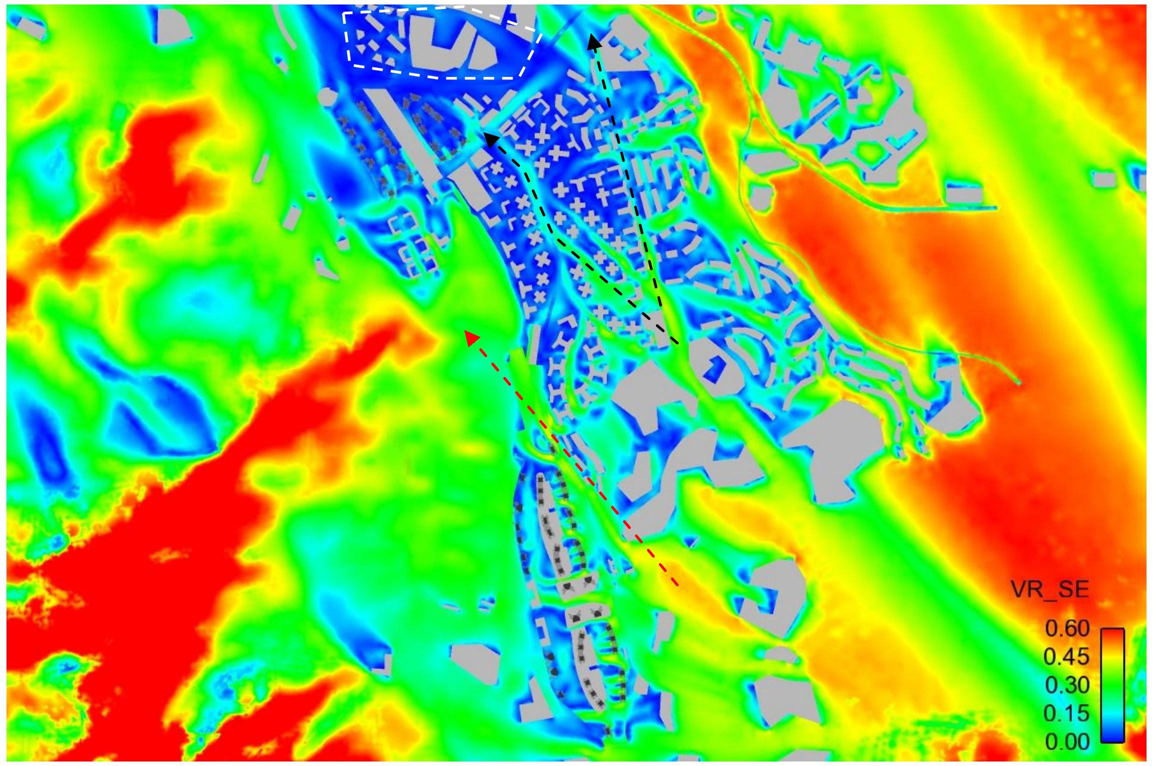


Figure 47 Contour map of SE wind for the study area

Two proposed district wind corridors are designed for SE prevailing wind. Under the SE wind, relatively good ventilation performance is obtained inside the wind corridors. The incoming wind is able to penetrate through the Study Area using the proposed wind corridors and ventilate the northern region of the KTS area (Black arrow). The large building separations on the PHMC development also allow effective wind penetration (Red arrow) to the leeward side. Relative calm area is identified in the downstream region near the Site 1 and the existing development such as the Genuine Garden (White dotted region). Wind enhancement features as listed in the HKPSG should be considered to incorporate into the design of the future development especially the Site 2 to enhance the local wind environment of that area. .

SSW Wind Direction

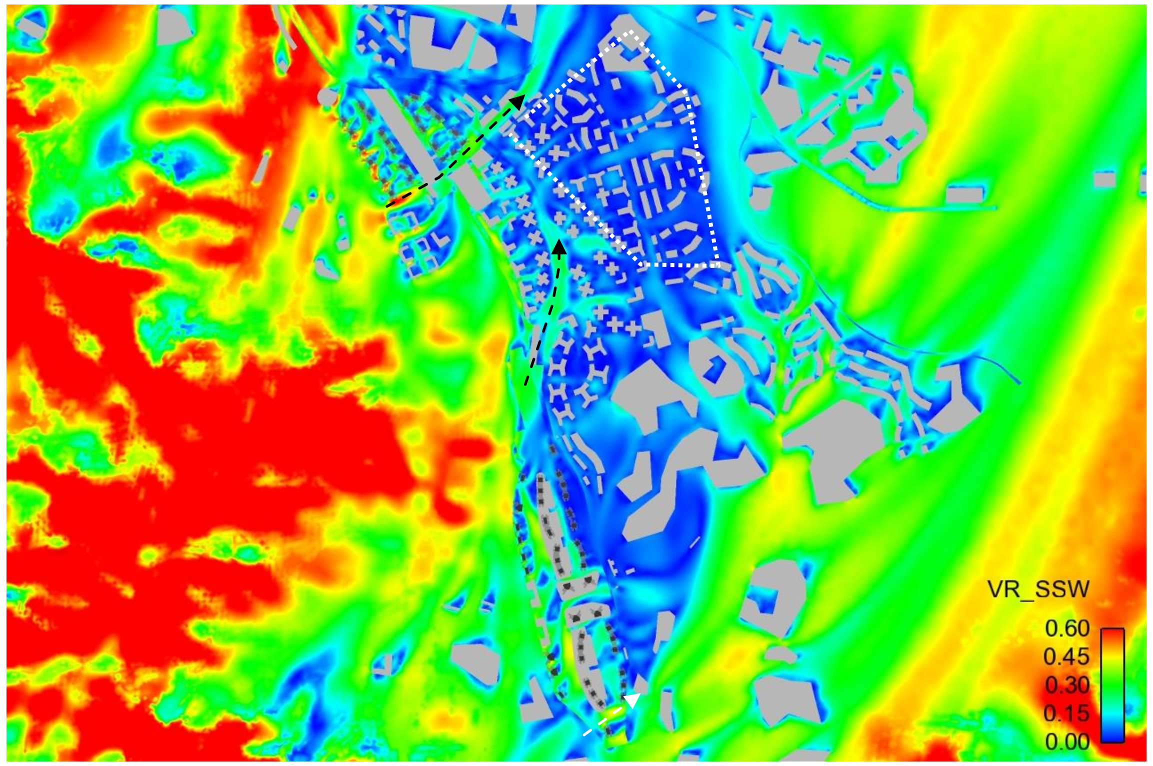


Figure 48 Contour map of SSW wind for the study area

The two proposed wind corridor allow the SSW prevailing wind (Black arrow) to enter the center part of the Study area. The large building separations on the PHMC development also allow wind penetration (White arrow) to the leeward region. The downstream area (White dotted region) is found to have a relative calm wind environment and wind enhancement features should be considered during the detail design stage in the future development especially the Site 4a and 4b.

SW Wind Direction

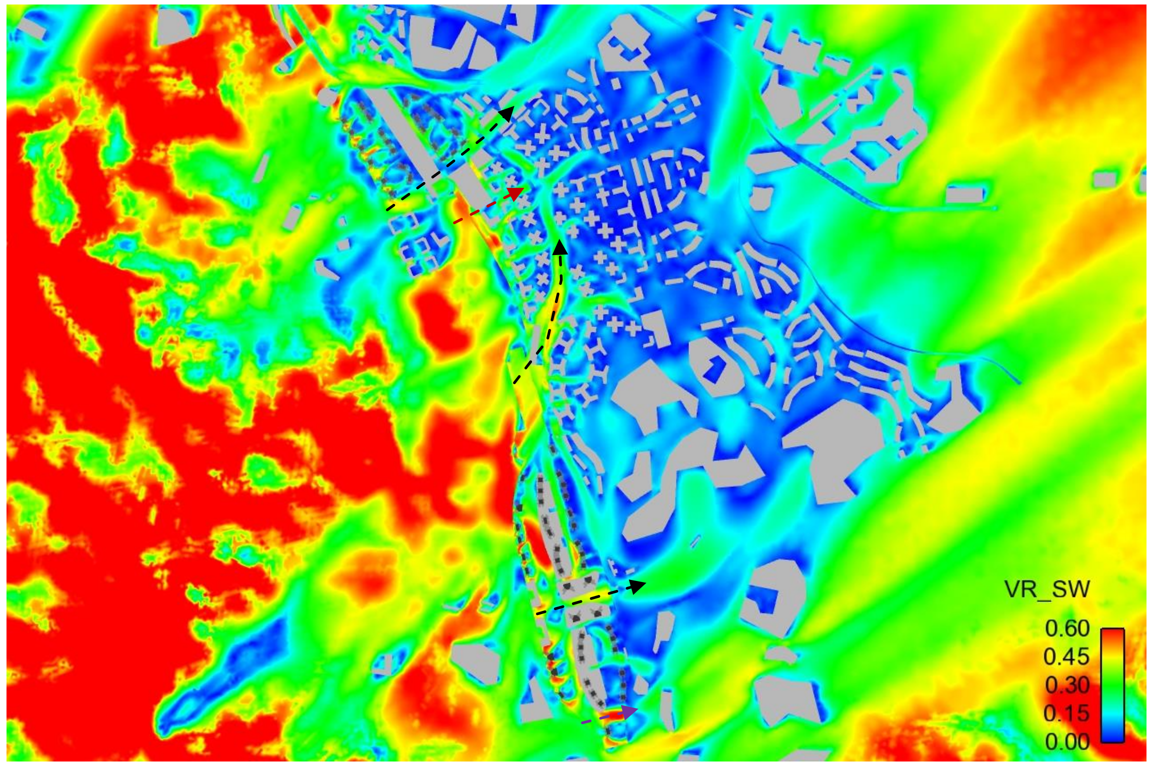


Figure 49 Contour map of SW wind for the study area

Similar to the SSW prevailing condition, the SW prevailing wind able to penetrate into the Study Area though the proposed district wind corridors (Black arrow). The local air path (Red arrow) and the building separation on PHMC development (Purple arrow) improved the building permeability and thus enhancing the ventilation performance of the Study area.

W Wind Direction

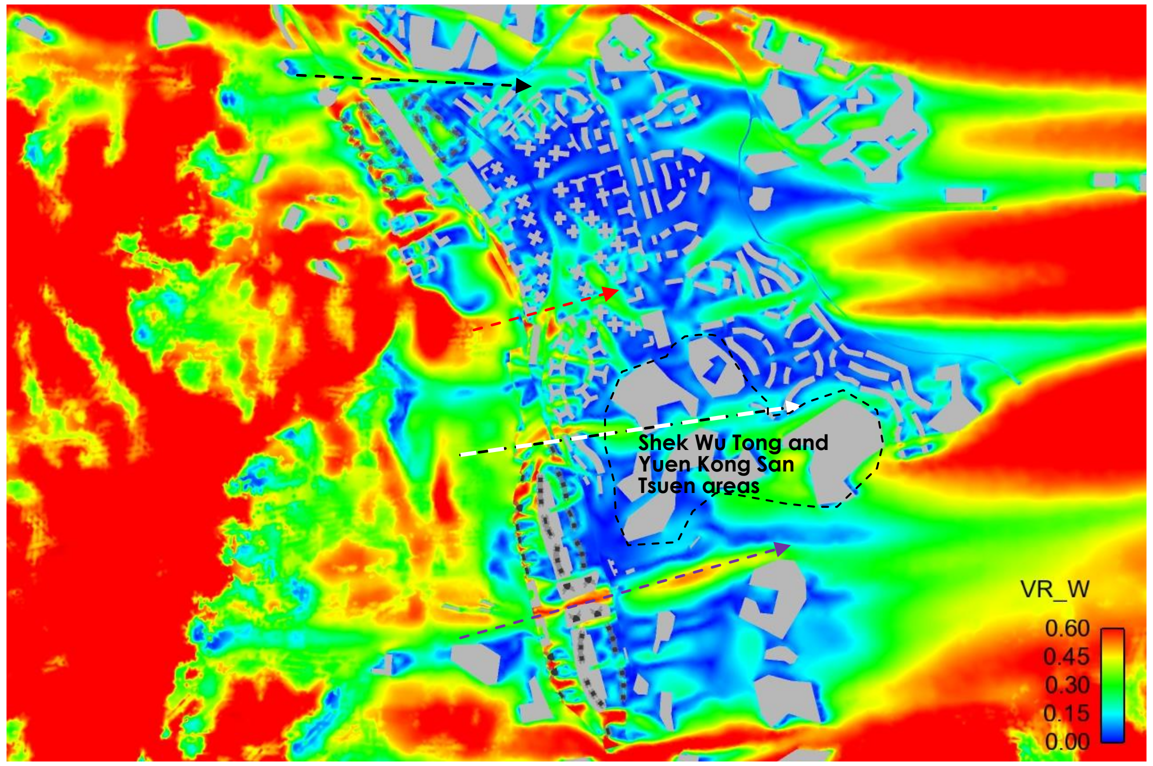


Figure 50 Contour map of W wind for the study area

At the northern portion of the Study area, the W prevailing wind able to penetrate through the Study Area using the river (Black arrow) as a local air path. At the center, the proposed district wind corridor (Red arrow) able to direct the prevailing wind to the center of the Kam Tin South area, enhancing the ventilation performance. The building gap between Sites 5a and 5b (White arrow) also allows the incoming wind penetrates to the Shek Wu Tong and Yuen Kong San Tsuen areas. The large building separations on the PHMC development also allow effective wind penetration (Purple arrow).

Focus area

To further assess the impact of the Development on the wind environment of its immediate vicinity, some focus areas were identified. The following figure indicated the locations of the focus areas and the relevant test points.

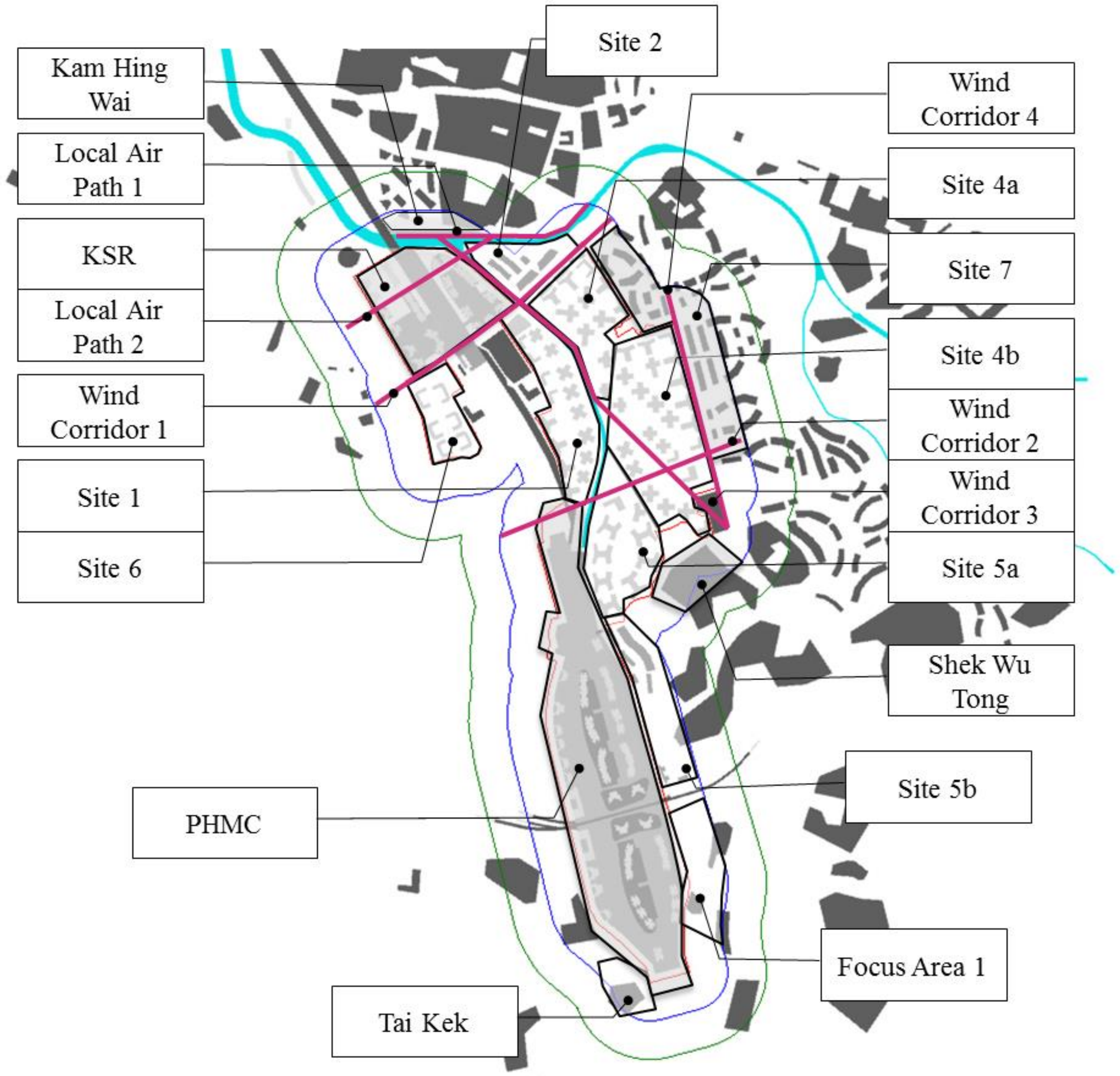


Figure 51 Location of Focus areas

Table 6 VR value for different focus area

	Focus area	Test points	Annual	Summer
1	Site 6	P5-P12, O35-O38	0.17	0.21
2	KSR	P1-P5, P78-P82, O1-O4, O27-O30, O35, O52-O53, O151-O152	0.19	0.19
3	Site2	O145-O150	0.15	0.12
4	Site 7	P61-P69 P72-P75,O131-O143,	0.17	0.14
5	Site 4a	P71-P77, O14, O21,O66-O76	0.13	0.12
6	Site 4b	P54-P70,O15-O19, O22-O26, O77-O86,	0.17	0.14
7	Site 1	O13,O54-O65, O153-O159	0.11	0.13
8	Site 5a	O89, O91-98, P49-P53	0.16	0.16
9	Site 5b	P44-P48, O123-O127	0.16	0.16
10	Shek Wu Tong	P51-P52, P55, O127-O129	0.17	0.15
11	Focus Area1	P40, O115-O122	0.31	0.27
12	PHMC	P20-P49, O99	0.21	0.24
13	Tai Kek	O111-O113	0.24	0.27
14	Kat Hing Wai	O9-O12,O161-163	0.19	0.16
15	Local Air Path 1	O6-O12	0.22	0.17
16	Local Air Path 2	O1-O5	0.19	0.19
17	Wind Corridor 1	P5, P75-P78, O30, O35, O43, O52, O144, O151-O152	0.21	0.22
18	Wind Corridor 2	P24, P65, O18, O26, O65, O84, O88, O90, O99-O100, O131	0.19	0.19
19	Wind Corridor 3	P58, O13-O20, O55, O59, O66, O69-O70, O75	0.14	0.12
20	Wind Corridor 4	O20, O139, P59-P67	0.22	0.19

DIRECTIONAL CONTOUR PLOT

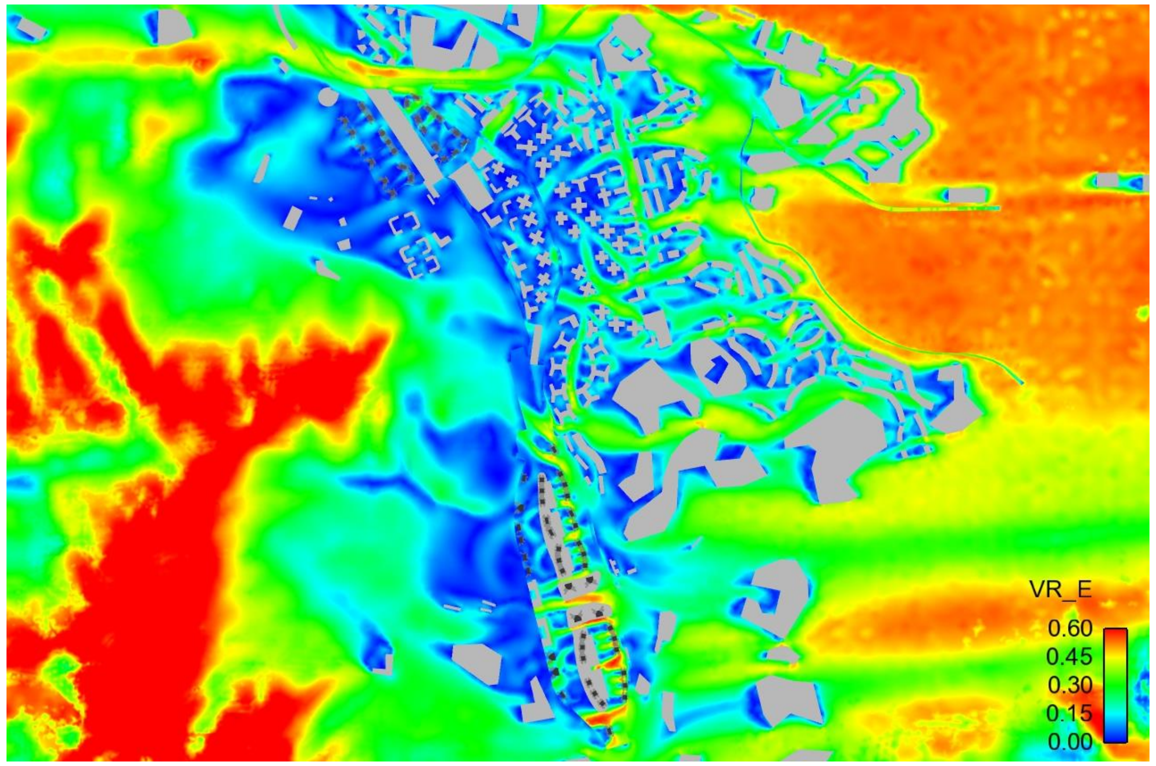


Figure 52 2m contour of VR (E wind)

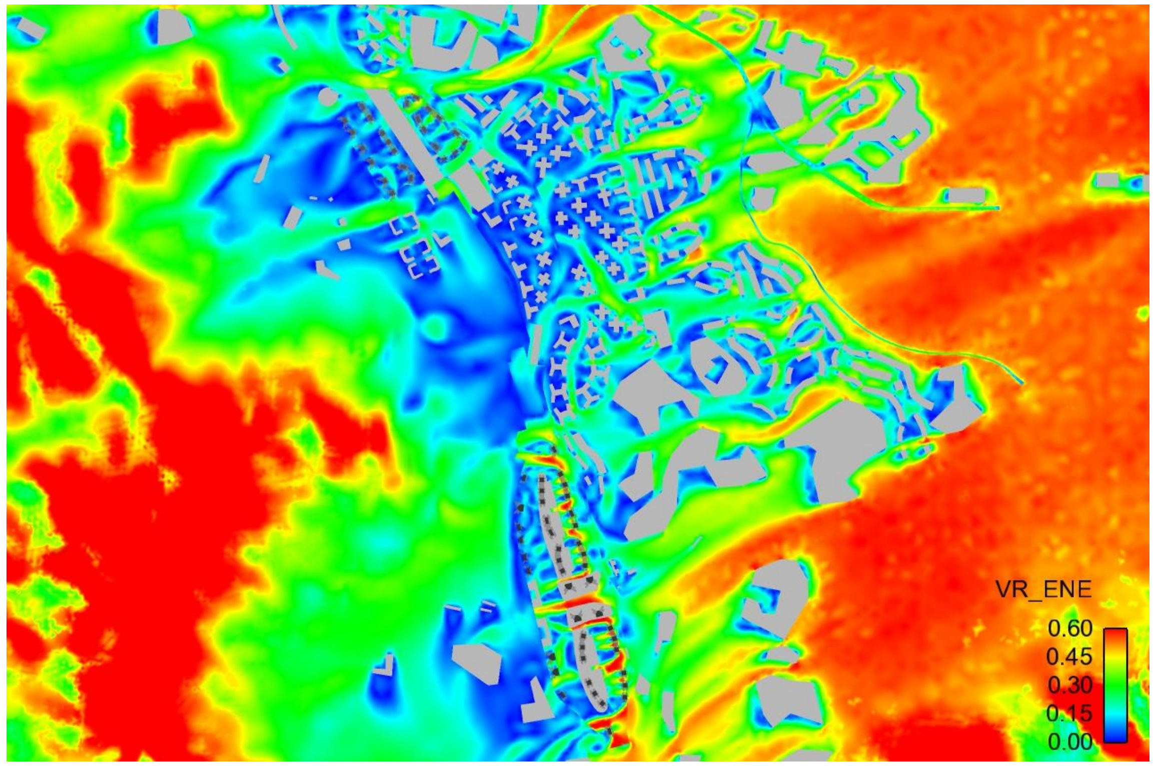


Figure 53 2m contour of VR (ENE wind)

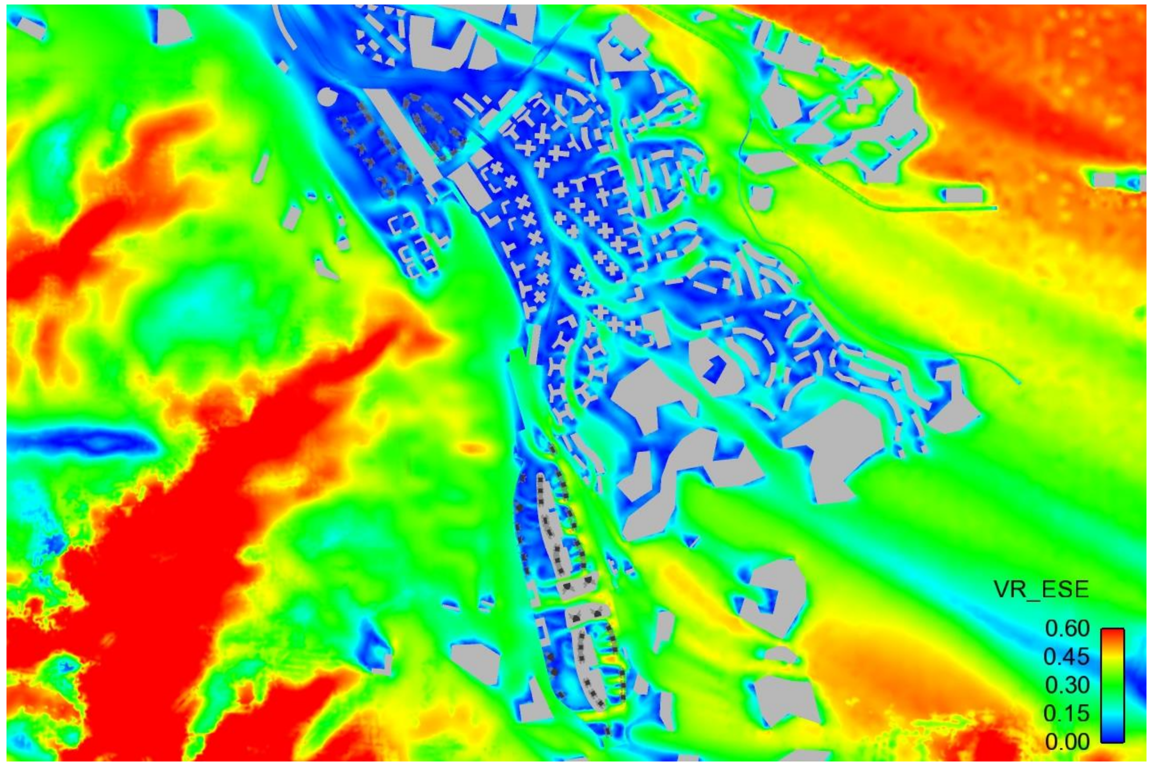


Figure 54 2m contour of VR (ESE wind)

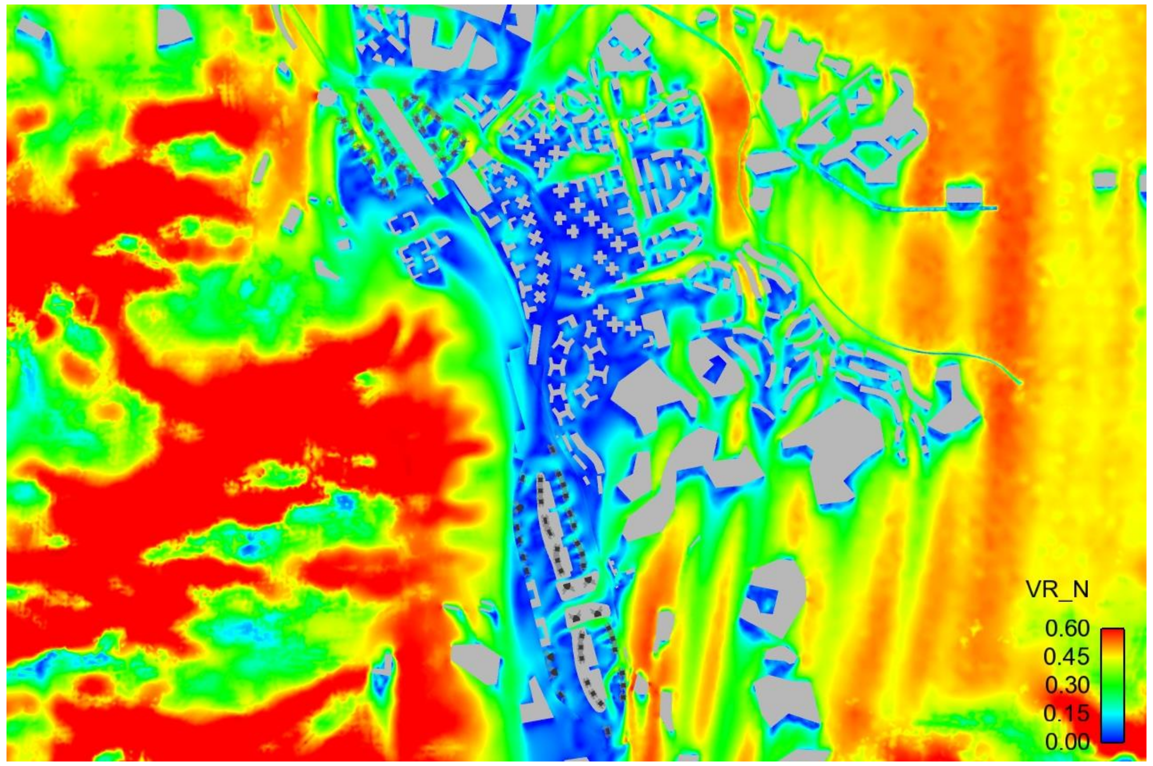


Figure 55 2m contour of VR (N wind)

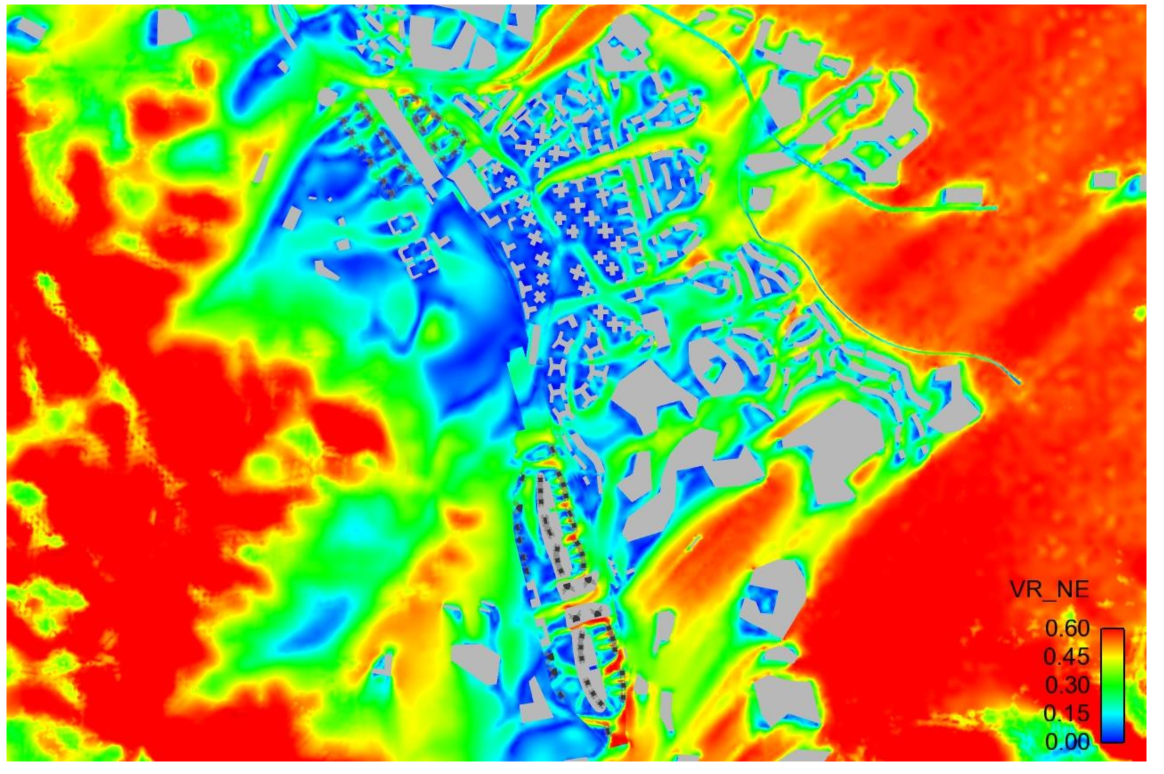


Figure 56 2m contour of VR (NE wind)

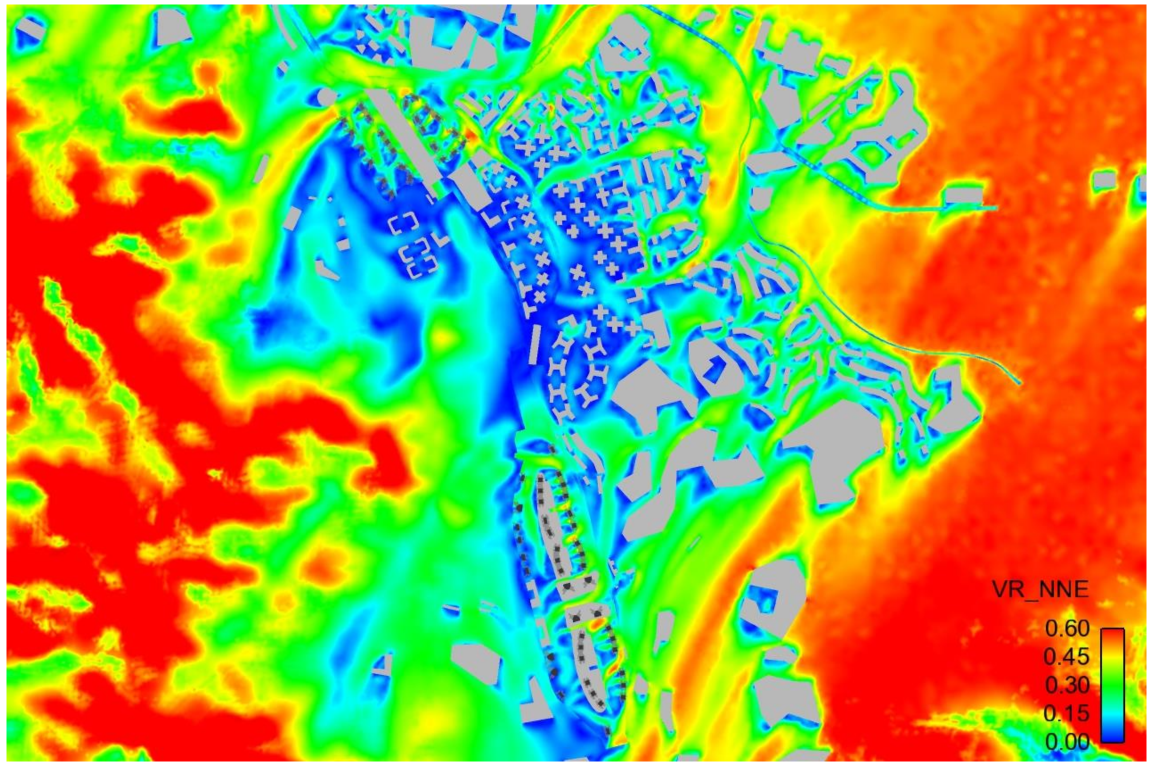


Figure 57 2m contour of VR (NNE wind)

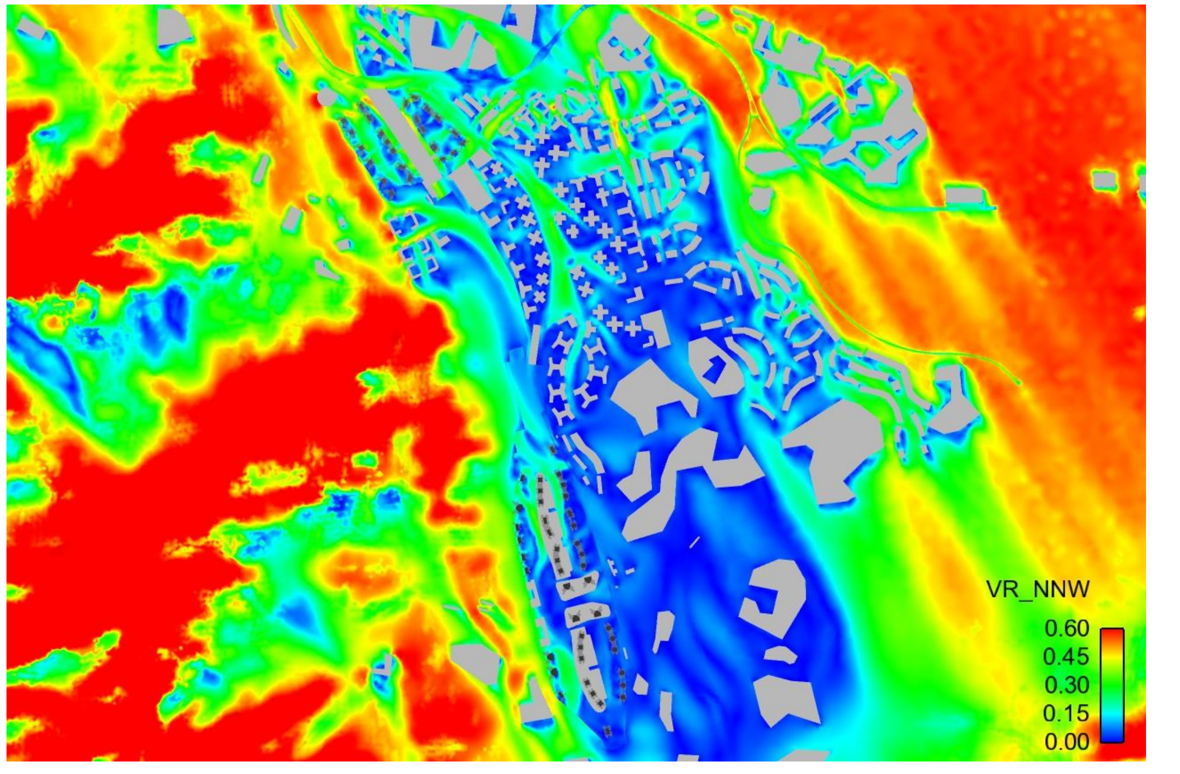


Figure 58 2m contour of VR (NNW wind)

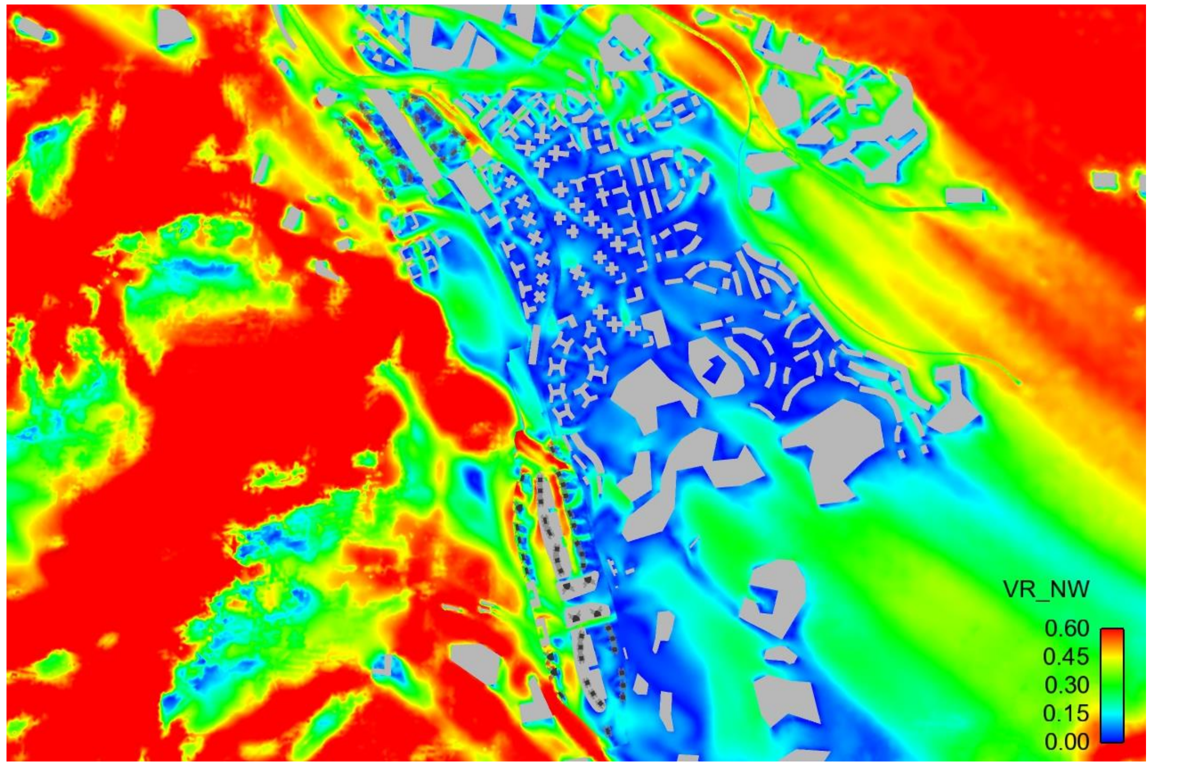


Figure 59 2m contour of VR (NW wind)

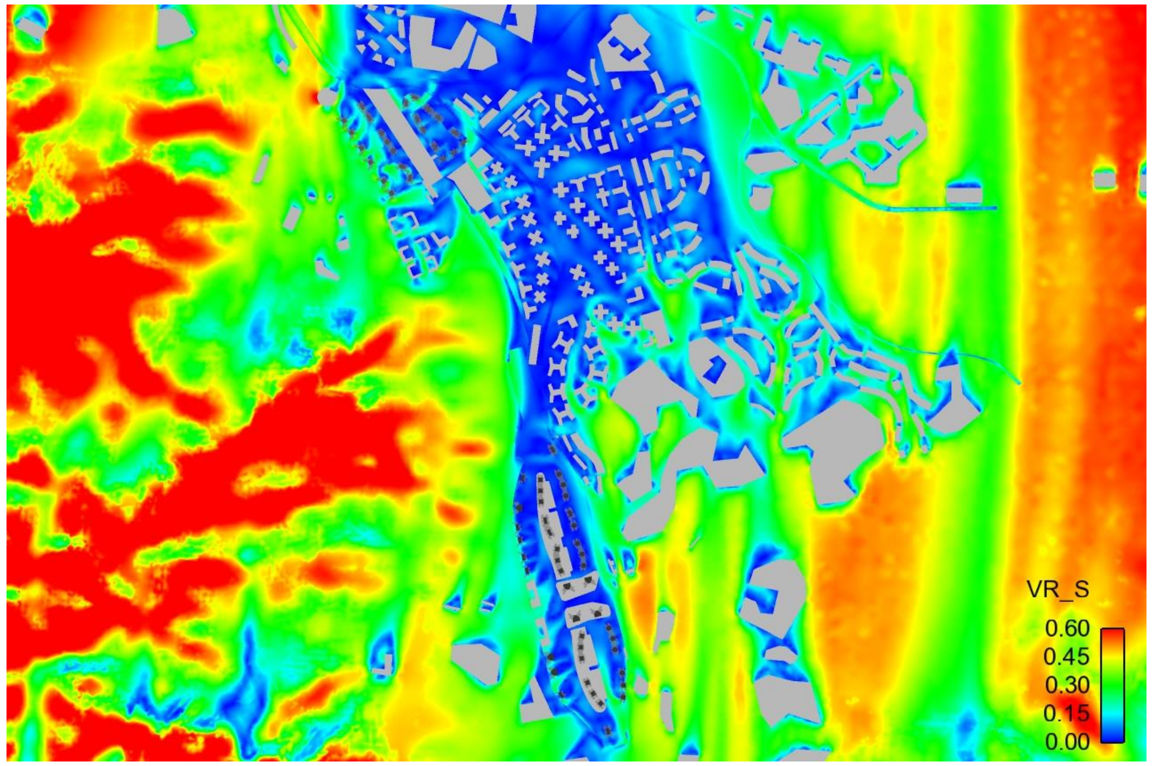


Figure 60 2m contour of VR (S wind)

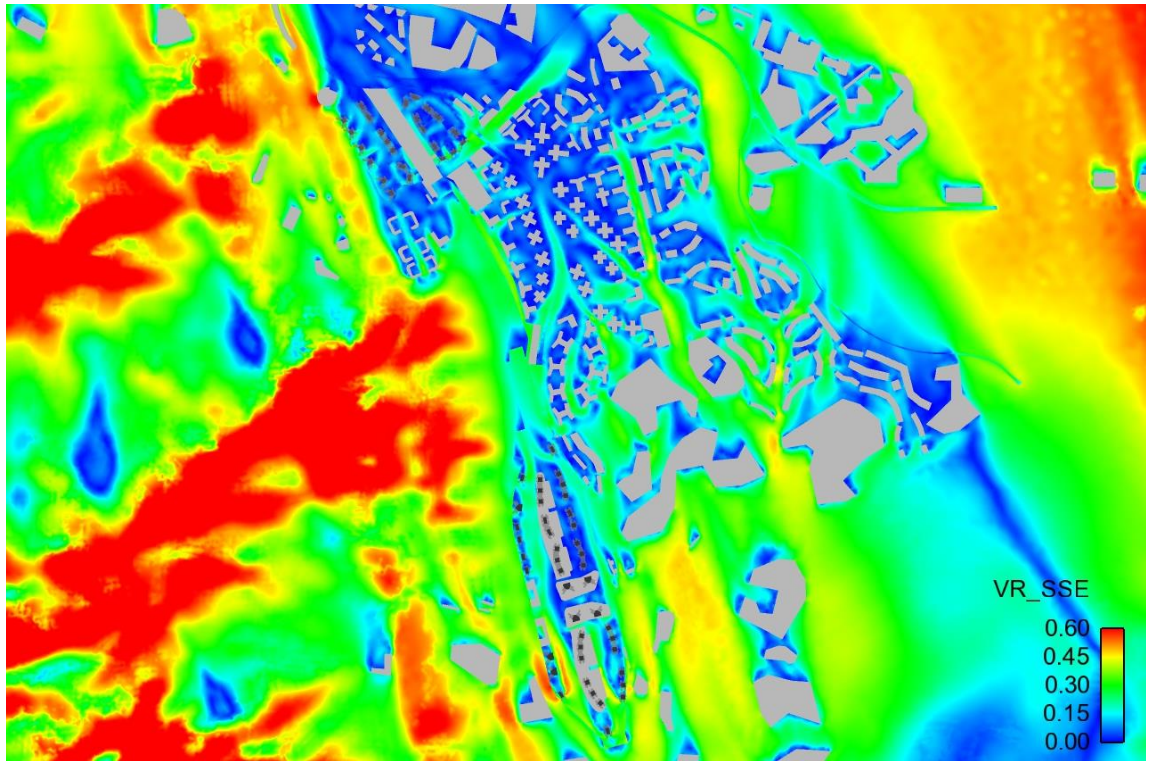


Figure 62 2m contour of VR (SSE wind)

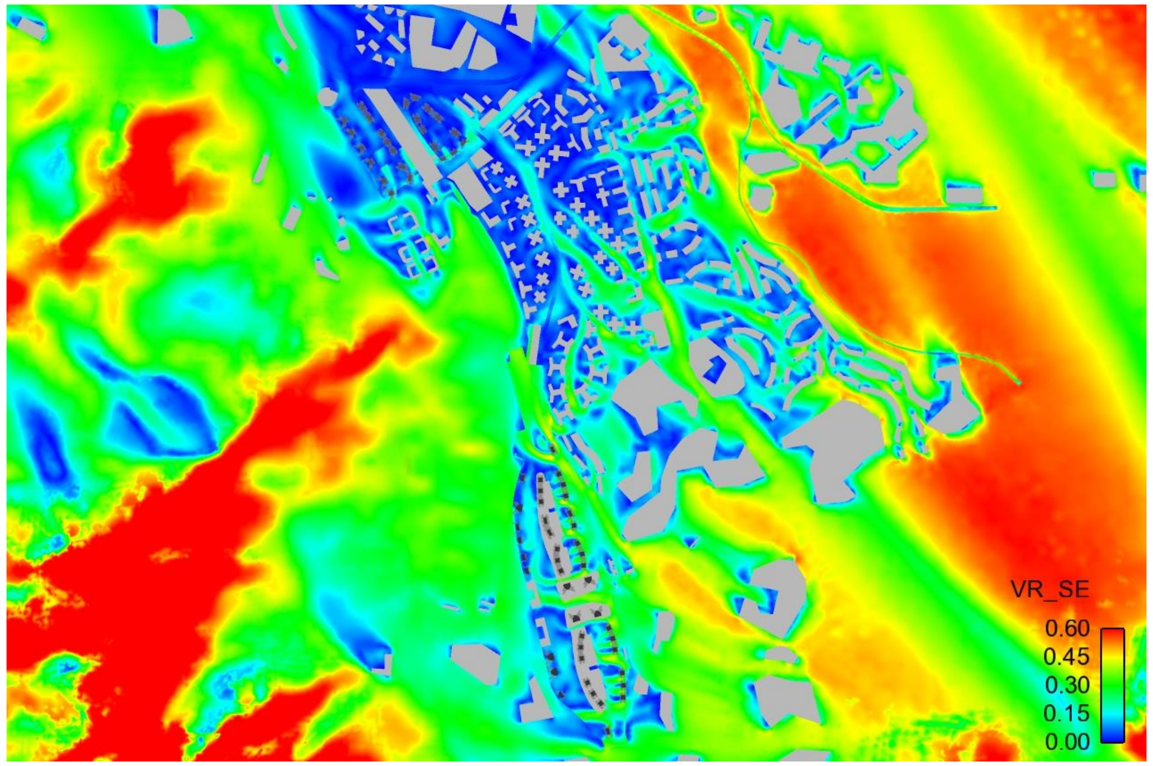


Figure 61 2m contour of VR (SE wind)

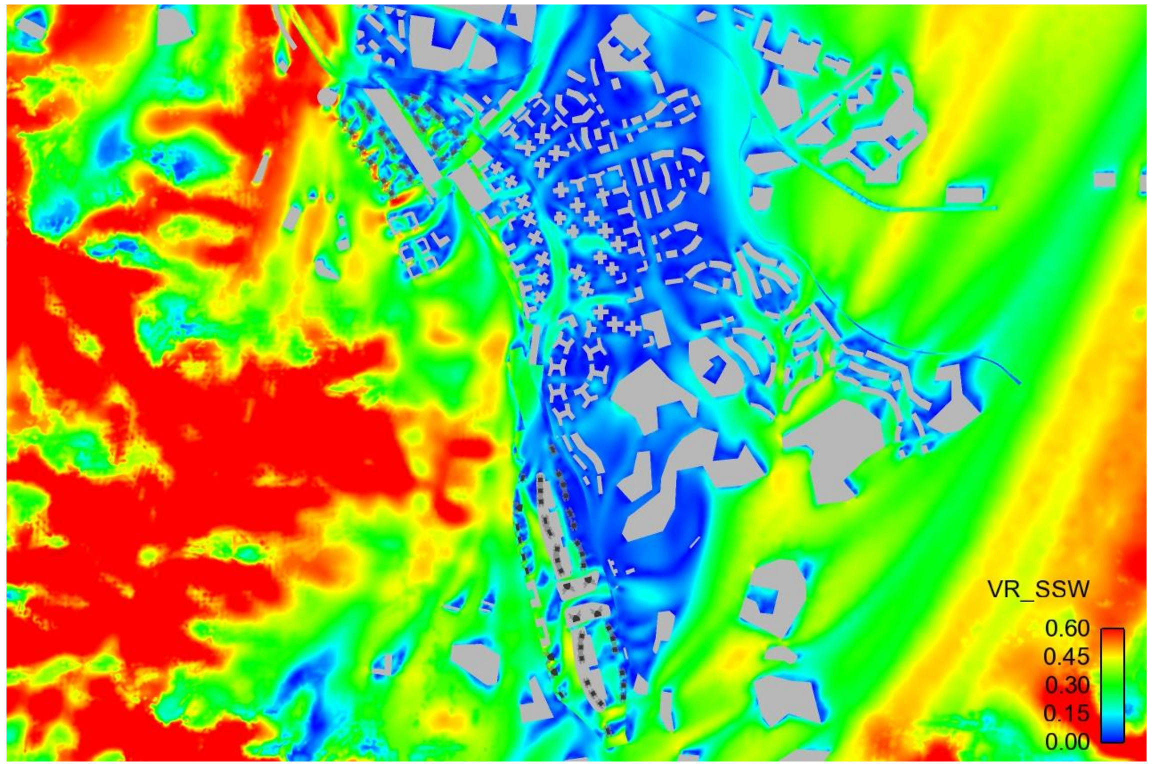


Figure 63 2m contour of VR (SSW wind)

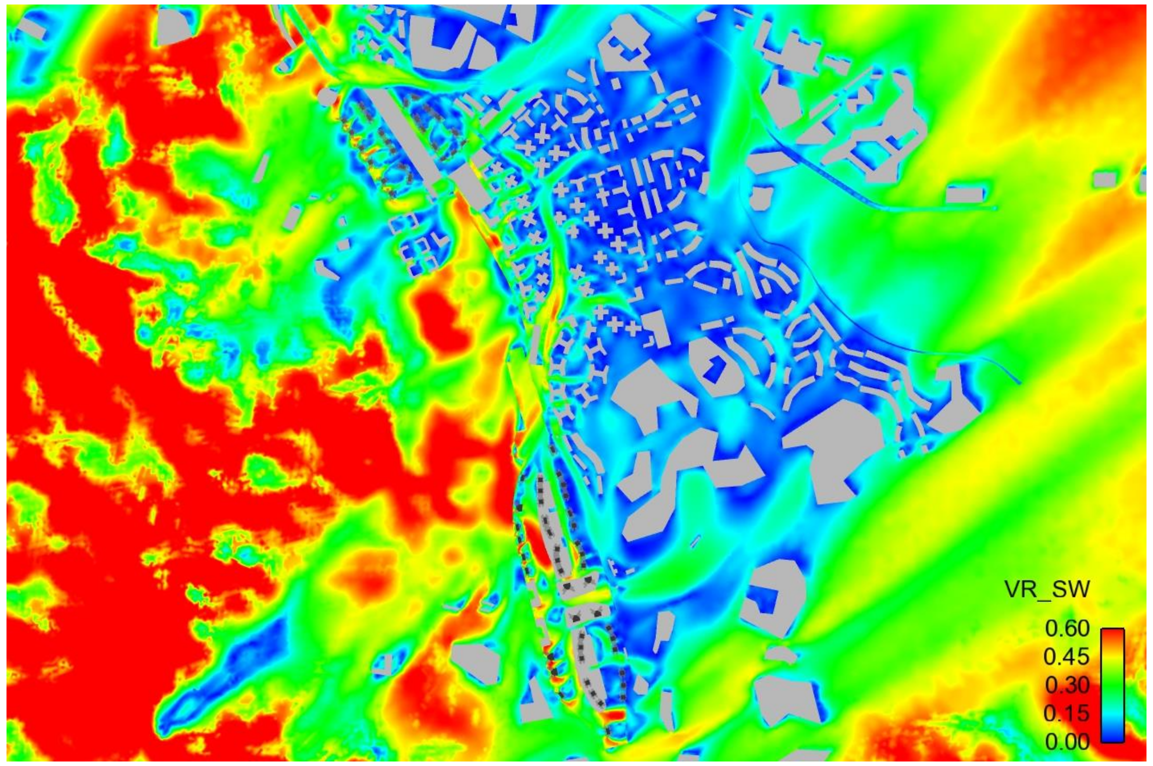


Figure 64 2m contour of VR (SW wind)

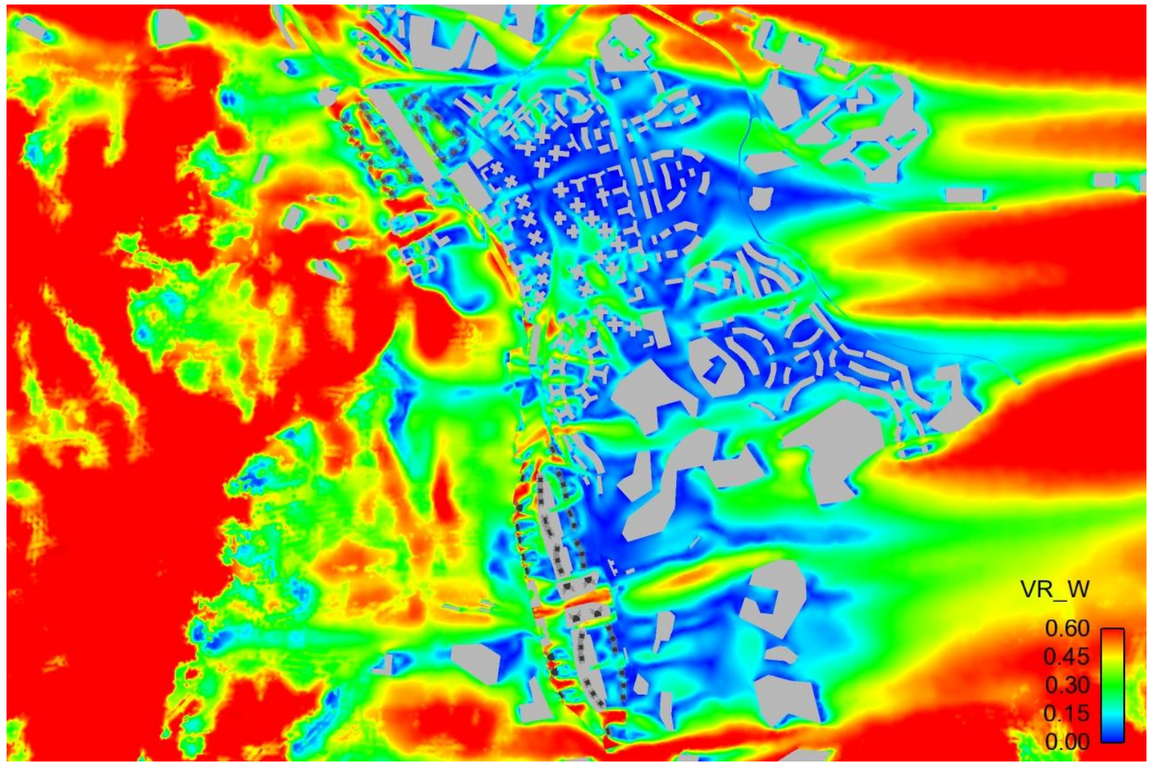


Figure 65 2m contour of VR (W wind)

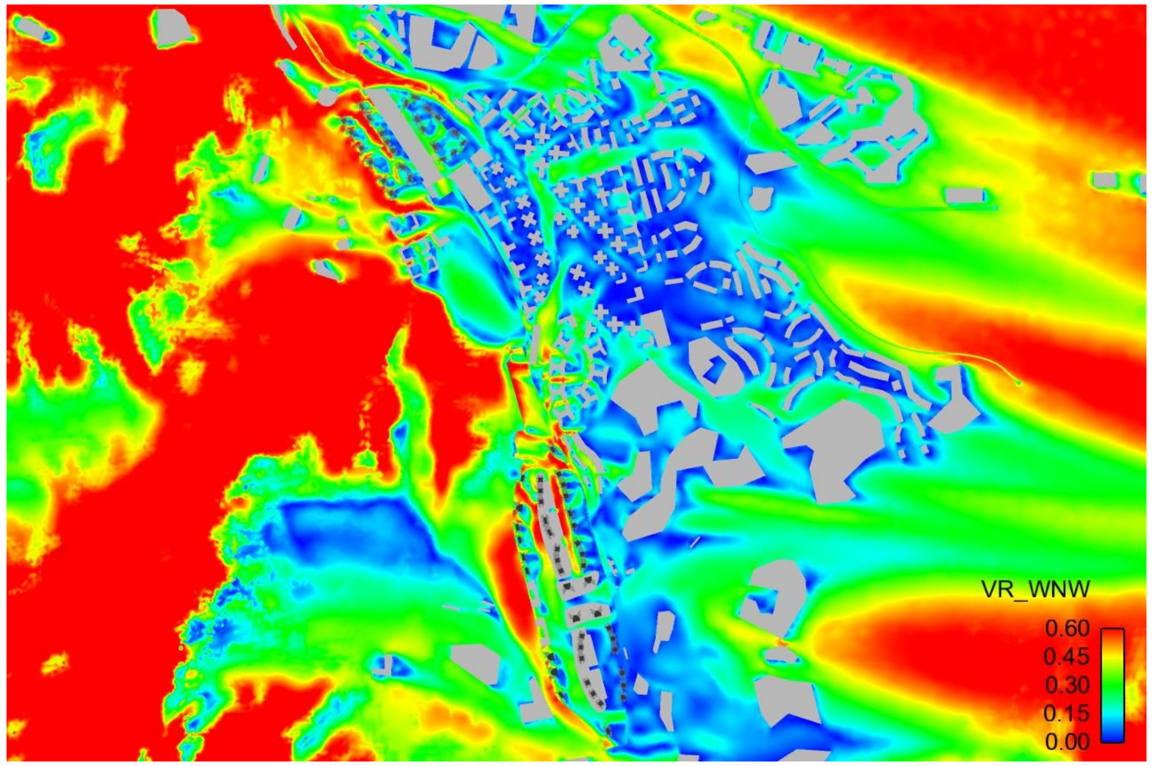


Figure 66 2m contour of VR (WNW wind)

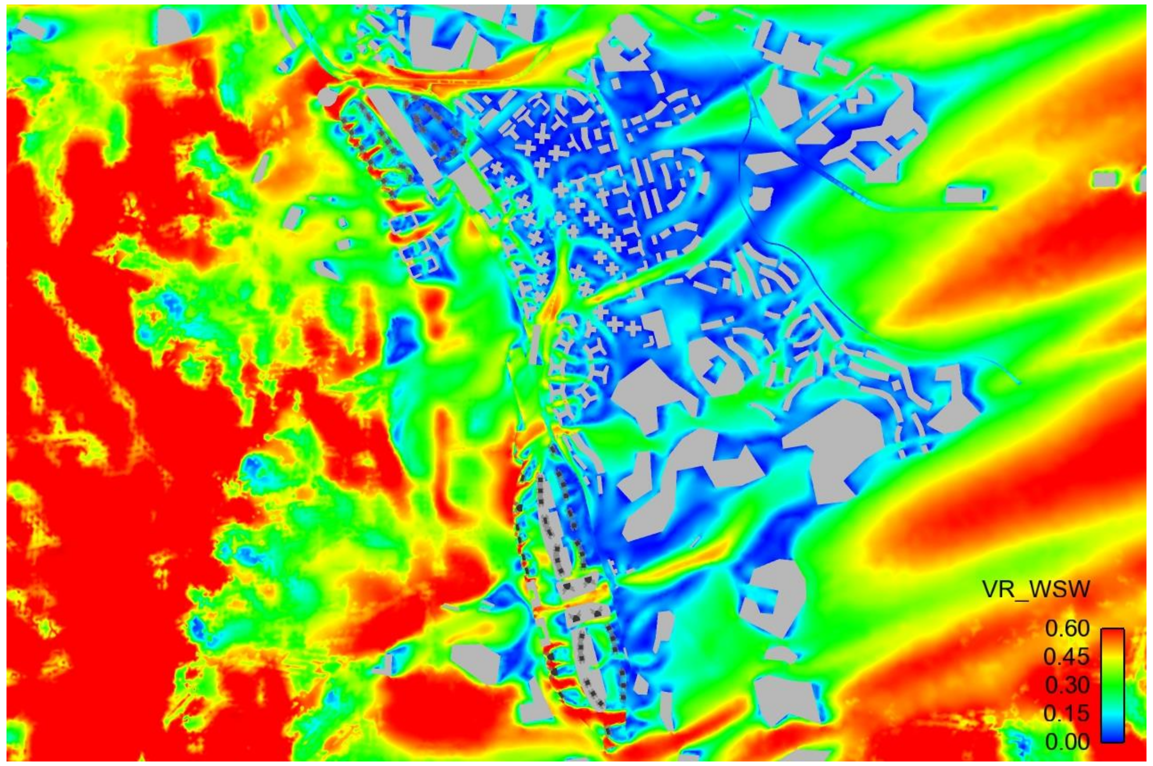


Figure 67 2m contour of VR (WSW wind)

VELOCITY RATIO FOR PARIMETER TEST POINTS

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Annual average VR	Summer Average VR
Annual Frequency	3.5%	9.2%	15.4%	15.2%	11.8%	5.3%	5.2%	9.2%	10.2%	5.3%	3.4%	1.6%	1.0%	1.3%	1.5%	1.0%	1.00	1.00
Summer Frequency	4.0%	2.9%	3.2%	4.3%	8.5%	6.2%	7.9%	13.7%	13.9%	11.3%	7.9%	3.9%	2.1%	3.1%	4.3%	2.8%	1.00	1.00
P1	0.32	0.50	0.36	0.16	0.09	0.01	0.10	0.41	0.41	0.54	0.50	0.68	0.53	0.45	0.24	0.40	0.31	0.35
P2	0.12	0.04	0.06	0.05	0.07	0.02	0.14	0.37	0.20	0.26	0.12	0.12	0.18	0.45	0.38	0.50	0.13	0.20
P3	0.16	0.16	0.04	0.09	0.05	0.01	0.11	0.32	0.36	0.51	0.19	0.14	0.11	0.59	0.46	0.45	0.17	0.26
P4	0.09	0.06	0.15	0.05	0.05	0.01	0.09	0.13	0.26	0.34	0.05	0.29	0.04	0.61	0.45	0.40	0.13	0.18
P5	0.16	0.02	0.22	0.33	0.11	0.09	0.23	0.12	0.37	0.46	0.23	0.28	0.25	0.44	0.26	0.44	0.22	0.25
P6	0.21	0.09	0.09	0.05	0.06	0.11	0.12	0.16	0.25	0.05	0.09	0.46	0.54	0.62	0.59	0.54	0.14	0.19
P7	0.21	0.03	0.10	0.04	0.05	0.13	0.06	0.25	0.34	0.27	0.27	0.17	0.28	0.36	0.46	0.49	0.15	0.22
P8	0.40	0.13	0.17	0.10	0.25	0.38	0.27	0.42	0.29	0.25	0.29	0.34	0.63	0.63	0.70	0.45	0.26	0.33
P9	0.05	0.12	0.04	0.03	0.13	0.08	0.20	0.06	0.17	0.42	0.47	0.08	0.10	0.13	0.11	0.10	0.12	0.17
P10	0.19	0.10	0.18	0.14	0.10	0.25	0.27	0.31	0.31	0.41	0.55	0.03	0.03	0.25	0.16	0.05	0.21	0.26
P11	0.13	0.08	0.24	0.09	0.12	0.34	0.40	0.36	0.13	0.04	0.03	0.05	0.05	0.27	0.14	0.21	0.17	0.18
P12	0.11	0.03	0.20	0.30	0.10	0.21	0.25	0.03	0.06	0.09	0.02	0.09	0.12	0.06	0.05	0.06	0.14	0.10
P13	0.09	0.05	0.10	0.12	0.04	0.07	0.07	0.07	0.07	0.25	0.03	0.27	0.53	0.61	0.49	0.30	0.11	0.15
P14	0.03	0.02	0.03	0.07	0.06	0.06	0.18	0.17	0.13	0.14	0.49	0.27	0.24	0.10	0.11	0.08	0.10	0.15
P15	0.13	0.11	0.05	0.09	0.10	0.24	0.31	0.26	0.21	0.27	0.47	0.52	0.40	0.19	0.33	0.27	0.17	0.25
P16	0.16	0.15	0.07	0.10	0.06	0.25	0.30	0.26	0.21	0.16	0.30	0.35	0.38	0.06	0.28	0.22	0.16	0.21
P17	0.15	0.14	0.10	0.08	0.06	0.26	0.31	0.27	0.22	0.30	0.03	0.17	0.50	0.05	0.25	0.16	0.16	0.20
P18	0.14	0.09	0.06	0.07	0.10	0.27	0.32	0.27	0.17	0.32	0.19	0.14	0.44	0.04	0.23	0.14	0.15	0.21
P19	0.12	0.04	0.02	0.02	0.13	0.20	0.25	0.19	0.03	0.03	0.07	0.07	0.12	0.18	0.20	0.13	0.09	0.11
P20	0.14	0.11	0.05	0.06	0.05	0.24	0.29	0.19	0.34	0.44	0.42	0.30	0.34	0.18	0.14	0.11	0.17	0.25
P21	0.18	0.12	0.06	0.08	0.14	0.20	0.23	0.28	0.39	0.50	0.53	0.41	0.39	0.57	0.13	0.19	0.21	0.30
P22	0.19	0.02	0.16	0.03	0.17	0.18	0.22	0.25	0.33	0.38	0.38	0.21	0.12	0.53	0.33	0.23	0.19	0.26
P23	0.15	0.01	0.05	0.04	0.16	0.14	0.18	0.20	0.28	0.33	0.51	0.38	0.31	0.39	0.52	0.21	0.16	0.25
P24	0.24	0.11	0.15	0.10	0.09	0.26	0.23	0.25	0.31	0.43	0.66	0.56	0.45	0.27	0.48	0.24	0.22	0.31
P25	0.23	0.20	0.13	0.13	0.04	0.24	0.26	0.25	0.25	0.40	0.62	0.55	0.38	0.17	0.23	0.18	0.21	0.27
P26	0.21	0.09	0.28	0.16	0.11	0.26	0.30	0.20	0.21	0.42	0.65	0.63	0.38	0.29	0.42	0.17	0.24	0.30
P27	0.28	0.08	0.32	0.13	0.04	0.28	0.33	0.34	0.25	0.47	0.69	0.58	0.27	0.48	0.54	0.34	0.26	0.34
P28	0.23	0.12	0.32	0.15	0.05	0.25	0.28	0.36	0.19	0.34	0.39	0.32	0.09	0.61	0.43	0.39	0.23	0.28
P29	0.10	0.09	0.25	0.01	0.02	0.24	0.25	0.37	0.17	0.25	0.16	0.08	0.24	0.59	0.34	0.36	0.17	0.22
P30	0.04	0.08	0.17	0.04	0.03	0.24	0.22	0.36	0.21	0.24	0.28	0.20	0.23	0.64	0.45	0.38	0.17	0.24

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Annual average VR	Summer Average VR
Annual Frequency	3.5%	9.2%	15.4%	15.2%	11.8%	5.3%	5.2%	9.2%	10.2%	5.3%	3.4%	1.6%	1.0%	1.3%	1.5%	1.0%	1.00	1.00
Summer Frequency	4.0%	2.9%	3.2%	4.3%	8.5%	6.2%	7.9%	13.7%	13.9%	11.3%	7.9%	3.9%	2.1%	3.1%	4.3%	2.8%	1.00	1.00
P31	0.10	0.17	0.19	0.14	0.08	0.18	0.13	0.34	0.23	0.29	0.32	0.08	0.27	0.58	0.35	0.36	0.20	0.24
P32	0.13	0.19	0.12	0.04	0.02	0.25	0.16	0.48	0.24	0.24	0.31	0.36	0.33	0.45	0.24	0.36	0.18	0.25
P33	0.09	0.17	0.09	0.03	0.05	0.28	0.17	0.55	0.05	0.15	0.32	0.53	0.36	0.47	0.50	0.38	0.17	0.25
P34	0.10	0.12	0.12	0.12	0.12	0.30	0.19	0.44	0.02	0.11	0.17	0.43	0.30	0.53	0.70	0.44	0.18	0.23
P35	0.04	0.04	0.09	0.12	0.13	0.19	0.10	0.38	0.15	0.16	0.28	0.49	0.39	0.48	0.67	0.19	0.17	0.23
P36	0.06	0.08	0.09	0.10	0.06	0.21	0.06	0.36	0.13	0.15	0.29	0.43	0.59	0.41	0.57	0.09	0.15	0.21
P37	0.07	0.05	0.18	0.37	0.36	0.36	0.39	0.41	0.11	0.18	0.31	0.44	0.67	0.42	0.71	0.15	0.27	0.31
P38	0.49	0.46	0.53	0.52	0.31	0.10	0.31	0.39	0.35	0.35	0.45	0.61	0.66	0.06	0.11	0.10	0.40	0.35
P39	0.51	0.40	0.50	0.46	0.29	0.20	0.19	0.31	0.36	0.13	0.08	0.03	0.11	0.12	0.13	0.10	0.34	0.25
P40	0.50	0.42	0.53	0.46	0.30	0.21	0.17	0.40	0.36	0.18	0.08	0.08	0.01	0.07	0.08	0.03	0.35	0.26
P41	0.50	0.30	0.38	0.27	0.10	0.22	0.20	0.35	0.32	0.10	0.13	0.14	0.14	0.04	0.03	0.06	0.26	0.22
P42	0.40	0.23	0.24	0.11	0.19	0.33	0.24	0.39	0.35	0.05	0.03	0.06	0.06	0.09	0.03	0.04	0.22	0.21
P43	0.03	0.16	0.18	0.23	0.33	0.36	0.25	0.31	0.26	0.08	0.12	0.04	0.10	0.12	0.03	0.07	0.22	0.20
P44	0.07	0.24	0.28	0.26	0.11	0.32	0.06	0.19	0.16	0.03	0.11	0.15	0.02	0.18	0.11	0.08	0.19	0.14
P45	0.16	0.16	0.23	0.24	0.11	0.27	0.17	0.14	0.16	0.07	0.19	0.04	0.04	0.15	0.06	0.08	0.17	0.14
P46	0.05	0.09	0.12	0.09	0.12	0.25	0.19	0.20	0.19	0.07	0.20	0.08	0.03	0.05	0.08	0.10	0.13	0.14
P47	0.03	0.10	0.02	0.04	0.20	0.29	0.32	0.22	0.22	0.07	0.15	0.20	0.03	0.30	0.09	0.07	0.14	0.17
P48	0.12	0.22	0.21	0.26	0.22	0.19	0.20	0.04	0.02	0.11	0.25	0.34	0.29	0.48	0.20	0.06	0.18	0.16
P49	0.12	0.21	0.28	0.26	0.18	0.25	0.30	0.25	0.15	0.12	0.35	0.56	0.56	0.66	0.20	0.06	0.24	0.25
P50	0.09	0.11	0.16	0.21	0.22	0.11	0.09	0.10	0.12	0.09	0.19	0.15	0.15	0.22	0.06	0.04	0.15	0.13
P51	0.06	0.09	0.34	0.23	0.05	0.01	0.27	0.11	0.19	0.11	0.08	0.15	0.11	0.10	0.05	0.03	0.16	0.13
P52	0.08	0.14	0.23	0.19	0.09	0.06	0.09	0.20	0.26	0.01	0.10	0.05	0.08	0.12	0.06	0.06	0.15	0.13
P53	0.04	0.02	0.23	0.24	0.12	0.18	0.21	0.34	0.24	0.02	0.04	0.05	0.25	0.15	0.04	0.07	0.18	0.16
P54	0.04	0.04	0.04	0.20	0.10	0.06	0.17	0.14	0.20	0.09	0.05	0.04	0.03	0.14	0.09	0.03	0.11	0.11
P55	0.11	0.14	0.26	0.24	0.16	0.11	0.12	0.17	0.20	0.08	0.04	0.11	0.03	0.22	0.04	0.05	0.17	0.13
P56	0.09	0.11	0.26	0.20	0.25	0.20	0.26	0.02	0.15	0.05	0.03	0.01	0.05	0.14	0.03	0.04	0.16	0.12
P57	0.02	0.19	0.31	0.37	0.35	0.10	0.13	0.13	0.21	0.05	0.11	0.05	0.28	0.16	0.06	0.04	0.22	0.16
P58	0.08	0.03	0.06	0.18	0.05	0.10	0.21	0.14	0.06	0.07	0.05	0.09	0.18	0.01	0.04	0.02	0.09	0.09
P59	0.12	0.19	0.30	0.28	0.26	0.20	0.41	0.42	0.23	0.12	0.10	0.14	0.07	0.02	0.11	0.04	0.25	0.22
P60	0.14	0.08	0.09	0.14	0.20	0.10	0.39	0.39	0.29	0.11	0.09	0.12	0.05	0.03	0.09	0.03	0.18	0.20
P61	0.40	0.20	0.33	0.41	0.25	0.12	0.35	0.35	0.31	0.10	0.07	0.36	0.08	0.12	0.08	0.06	0.28	0.24
P62	0.09	0.27	0.25	0.34	0.22	0.13	0.35	0.39	0.23	0.07	0.10	0.03	0.07	0.03	0.11	0.01	0.24	0.20

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Annual average VR	Summer Average VR
Annual Frequency	3.5%	9.2%	15.4%	15.2%	11.8%	5.3%	5.2%	9.2%	10.2%	5.3%	3.4%	1.6%	1.0%	1.3%	1.5%	1.0%	1.00	1.00
Summer Frequency	4.0%	2.9%	3.2%	4.3%	8.5%	6.2%	7.9%	13.7%	13.9%	11.3%	7.9%	3.9%	2.1%	3.1%	4.3%	2.8%	1.00	1.00
P63	0.23	0.34	0.19	0.11	0.22	0.11	0.26	0.38	0.06	0.05	0.01	0.05	0.08	0.02	0.06	0.12	0.18	0.15
P64	0.28	0.23	0.26	0.15	0.29	0.07	0.15	0.33	0.02	0.08	0.01	0.03	0.06	0.06	0.01	0.03	0.18	0.14
P65	0.34	0.05	0.35	0.28	0.34	0.17	0.11	0.35	0.02	0.07	0.04	0.09	0.08	0.17	0.04	0.12	0.21	0.16
P66	0.34	0.18	0.34	0.28	0.35	0.26	0.11	0.32	0.04	0.06	0.07	0.13	0.08	0.18	0.05	0.24	0.23	0.18
P67	0.36	0.27	0.43	0.17	0.28	0.28	0.17	0.28	0.01	0.10	0.05	0.16	0.11	0.24	0.15	0.14	0.23	0.18
P68	0.37	0.24	0.39	0.20	0.08	0.08	0.02	0.07	0.03	0.11	0.08	0.05	0.04	0.30	0.16	0.36	0.17	0.12
P69	0.37	0.12	0.38	0.24	0.25	0.23	0.26	0.17	0.03	0.04	0.12	0.07	0.04	0.31	0.10	0.23	0.21	0.16
P70	0.43	0.22	0.26	0.11	0.10	0.03	0.12	0.06	0.11	0.05	0.08	0.06	0.07	0.33	0.11	0.22	0.14	0.12
P71	0.31	0.02	0.14	0.07	0.07	0.04	0.01	0.11	0.10	0.06	0.24	0.10	0.05	0.22	0.02	0.13	0.10	0.10
P72	0.10	0.29	0.32	0.31	0.08	0.03	0.04	0.03	0.03	0.04	0.12	0.02	0.05	0.18	0.16	0.07	0.16	0.09
P73	0.15	0.23	0.09	0.29	0.23	0.10	0.04	0.13	0.04	0.02	0.03	0.02	0.01	0.04	0.09	0.22	0.14	0.10
P74	0.31	0.12	0.14	0.12	0.19	0.14	0.02	0.03	0.04	0.03	0.03	0.03	0.03	0.23	0.26	0.33	0.11	0.10
P75	0.21	0.36	0.27	0.07	0.13	0.11	0.14	0.25	0.08	0.18	0.16	0.38	0.26	0.32	0.35	0.27	0.19	0.19
P76	0.38	0.43	0.39	0.14	0.17	0.16	0.15	0.29	0.11	0.22	0.23	0.13	0.09	0.07	0.04	0.38	0.24	0.20
P77	0.41	0.41	0.33	0.25	0.36	0.18	0.15	0.30	0.06	0.22	0.25	0.13	0.18	0.05	0.23	0.35	0.27	0.23
P78	0.34	0.47	0.38	0.17	0.23	0.18	0.15	0.32	0.08	0.32	0.31	0.10	0.19	0.18	0.50	0.28	0.27	0.25
P79	0.23	0.24	0.32	0.23	0.13	0.06	0.03	0.10	0.03	0.06	0.07	0.07	0.13	0.10	0.49	0.25	0.17	0.12
P80	0.16	0.16	0.17	0.17	0.07	0.04	0.03	0.08	0.04	0.01	0.03	0.04	0.05	0.04	0.49	0.24	0.11	0.09
P81	0.12	0.30	0.35	0.33	0.32	0.02	0.01	0.05	0.08	0.02	0.05	0.56	0.27	0.56	0.47	0.38	0.22	0.17
P82	0.16	0.37	0.42	0.26	0.18	0.15	0.01	0.01	0.02	0.16	0.06	0.35	0.49	0.62	0.35	0.43	0.21	0.16

VELCOITY RATIO FOR OVERALL TEST POINTS

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Annual average VR	Summer Average VR
Annual Frequency	3.5%	9.2%	15.4%	15.2%	11.8%	5.3%	5.2%	9.2%	10.2%	5.3%	3.4%	1.6%	1.0%	1.3%	1.5%	1.0%	1.00	1.00
Summer Frequency	4.0%	2.9%	3.2%	4.3%	8.5%	6.2%	7.9%	13.7%	13.9%	11.3%	7.9%	3.9%	2.1%	3.1%	4.3%	2.8%	1.00	1.00
O1	0.33	0.39	0.39	0.35	0.26	0.04	0.04	0.07	0.16	0.06	0.04	0.09	0.22	0.11	0.25	0.17	0.23	0.15
O2	0.04	0.09	0.11	0.21	0.21	0.10	0.09	0.09	0.05	0.29	0.29	0.15	0.31	0.36	0.47	0.44	0.15	0.18
O3	0.22	0.38	0.27	0.21	0.15	0.11	0.02	0.03	0.02	0.16	0.14	0.41	0.04	0.14	0.04	0.19	0.17	0.12
O4	0.30	0.33	0.28	0.14	0.12	0.08	0.07	0.06	0.14	0.25	0.46	0.15	0.44	0.24	0.52	0.26	0.20	0.20
O5	0.30	0.11	0.14	0.06	0.09	0.12	0.12	0.49	0.38	0.42	0.25	0.43	0.28	0.55	0.49	0.54	0.22	0.31
O6	0.31	0.27	0.42	0.42	0.30	0.09	0.05	0.08	0.01	0.19	0.19	0.05	0.08	0.04	0.05	0.08	0.23	0.14
O7	0.08	0.17	0.42	0.48	0.30	0.20	0.04	0.06	0.02	0.05	0.21	0.53	0.31	0.26	0.18	0.28	0.24	0.17
O8	0.12	0.28	0.24	0.43	0.36	0.03	0.06	0.09	0.04	0.13	0.21	0.54	0.04	0.20	0.21	0.15	0.22	0.17
O9	0.09	0.20	0.27	0.25	0.41	0.03	0.07	0.08	0.05	0.15	0.01	0.54	0.22	0.04	0.31	0.10	0.19	0.15
O10	0.07	0.27	0.22	0.16	0.43	0.07	0.03	0.04	0.11	0.08	0.08	0.52	0.34	0.18	0.24	0.19	0.18	0.15
O11	0.16	0.31	0.32	0.24	0.46	0.07	0.06	0.08	0.13	0.08	0.40	0.62	0.45	0.21	0.23	0.19	0.24	0.21
O12	0.09	0.42	0.18	0.14	0.46	0.06	0.02	0.04	0.01	0.10	0.38	0.38	0.54	0.70	0.33	0.04	0.20	0.18
O13	0.09	0.18	0.29	0.16	0.14	0.06	0.18	0.06	0.03	0.11	0.27	0.15	0.09	0.04	0.09	0.20	0.15	0.12
O14	0.03	0.15	0.15	0.11	0.12	0.19	0.18	0.08	0.07	0.18	0.22	0.22	0.10	0.02	0.06	0.23	0.13	0.13
O15	0.07	0.09	0.21	0.19	0.07	0.18	0.25	0.06	0.04	0.15	0.10	0.03	0.15	0.16	0.15	0.11	0.13	0.11
O16	0.08	0.08	0.29	0.29	0.22	0.21	0.29	0.10	0.08	0.05	0.08	0.13	0.40	0.09	0.08	0.18	0.18	0.14
O17	0.02	0.18	0.21	0.29	0.19	0.22	0.29	0.17	0.05	0.12	0.11	0.11	0.36	0.09	0.03	0.12	0.18	0.15
O18	0.12	0.15	0.21	0.24	0.30	0.20	0.32	0.29	0.05	0.04	0.13	0.47	0.23	0.01	0.05	0.05	0.20	0.18
O19	0.03	0.13	0.14	0.28	0.14	0.11	0.22	0.15	0.10	0.05	0.08	0.15	0.06	0.01	0.07	0.05	0.15	0.12
O20	0.17	0.23	0.19	0.18	0.20	0.19	0.41	0.42	0.31	0.11	0.08	0.14	0.10	0.04	0.11	0.05	0.22	0.22
O21	0.02	0.07	0.07	0.12	0.20	0.16	0.22	0.17	0.07	0.10	0.18	0.10	0.23	0.11	0.13	0.21	0.12	0.14
O22	0.05	0.06	0.02	0.08	0.14	0.09	0.16	0.18	0.07	0.17	0.02	0.08	0.26	0.07	0.04	0.02	0.09	0.11
O23	0.04	0.01	0.03	0.17	0.26	0.17	0.30	0.26	0.04	0.20	0.03	0.19	0.23	0.05	0.01	0.14	0.14	0.15
O24	0.05	0.07	0.11	0.16	0.30	0.21	0.29	0.31	0.04	0.06	0.11	0.16	0.16	0.14	0.03	0.04	0.16	0.15
O25	0.12	0.08	0.29	0.26	0.18	0.18	0.39	0.35	0.04	0.02	0.06	0.13	0.15	0.11	0.05	0.04	0.19	0.16
O26	0.38	0.35	0.34	0.33	0.38	0.23	0.31	0.25	0.09	0.05	0.03	0.42	0.11	0.03	0.03	0.05	0.27	0.20
O27	0.36	0.41	0.21	0.05	0.06	0.02	0.10	0.12	0.03	0.06	0.04	0.28	0.25	0.45	0.48	0.31	0.15	0.14
O28	0.38	0.23	0.32	0.13	0.14	0.03	0.08	0.06	0.04	0.15	0.17	0.46	0.35	0.52	0.57	0.37	0.18	0.18
O29	0.31	0.38	0.06	0.04	0.03	0.02	0.08	0.12	0.22	0.19	0.10	0.11	0.50	0.39	0.44	0.26	0.14	0.17
O30	0.14	0.06	0.23	0.14	0.08	0.09	0.17	0.07	0.26	0.51	0.35	0.31	0.47	0.33	0.32	0.16	0.18	0.23

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Annual average VR	Summer Average VR
Annual Frequency	3.5%	9.2%	15.4%	15.2%	11.8%	5.3%	5.2%	9.2%	10.2%	5.3%	3.4%	1.6%	1.0%	1.3%	1.5%	1.0%	1.00	1.00
Summer Frequency	4.0%	2.9%	3.2%	4.3%	8.5%	6.2%	7.9%	13.7%	13.9%	11.3%	7.9%	3.9%	2.1%	3.1%	4.3%	2.8%	1.00	1.00
O31	0.23	0.07	0.14	0.23	0.02	0.02	0.02	0.20	0.20	0.41	0.21	0.53	0.66	0.31	0.19	0.31	0.17	0.21
O32	0.03	0.04	0.19	0.08	0.11	0.28	0.34	0.27	0.31	0.40	0.52	0.31	0.21	0.19	0.08	0.12	0.20	0.26
O33	0.09	0.17	0.16	0.16	0.13	0.30	0.36	0.23	0.33	0.30	0.47	0.29	0.32	0.18	0.12	0.11	0.22	0.26
O34	0.13	0.13	0.12	0.10	0.17	0.30	0.37	0.26	0.35	0.25	0.35	0.31	0.23	0.26	0.15	0.13	0.20	0.25
O35	0.12	0.04	0.23	0.29	0.12	0.11	0.18	0.12	0.13	0.54	0.45	0.57	0.65	0.69	0.47	0.36	0.22	0.28
O36	0.06	0.03	0.15	0.18	0.03	0.03	0.12	0.16	0.14	0.29	0.14	0.05	0.07	0.30	0.22	0.11	0.13	0.14
O37	0.24	0.10	0.23	0.19	0.11	0.11	0.17	0.18	0.04	0.22	0.05	0.58	0.66	0.61	0.47	0.39	0.18	0.20
O38	0.16	0.09	0.11	0.08	0.07	0.03	0.09	0.32	0.19	0.24	0.17	0.29	0.40	0.29	0.32	0.25	0.14	0.19
O39	0.34	0.37	0.34	0.27	0.24	0.05	0.07	0.20	0.40	0.53	0.49	0.70	0.46	0.56	0.33	0.38	0.31	0.34
O40	0.43	0.17	0.28	0.07	0.01	0.19	0.27	0.50	0.44	0.62	0.42	0.59	0.25	0.64	0.48	0.38	0.28	0.38
O41	0.33	0.52	0.32	0.02	0.15	0.15	0.22	0.47	0.43	0.47	0.26	0.45	0.42	0.62	0.49	0.44	0.30	0.36
O42	0.05	0.07	0.03	0.06	0.04	0.06	0.02	0.43	0.24	0.30	0.27	0.33	0.43	0.43	0.43	0.51	0.15	0.23
O43	0.16	0.06	0.17	0.35	0.10	0.05	0.18	0.47	0.33	0.50	0.32	0.46	0.48	0.49	0.55	0.55	0.26	0.33
O44	0.25	0.09	0.20	0.08	0.03	0.33	0.08	0.42	0.31	0.44	0.09	0.32	0.45	0.39	0.46	0.36	0.21	0.27
O45	0.34	0.16	0.07	0.15	0.20	0.44	0.35	0.48	0.34	0.38	0.13	0.25	0.65	0.65	0.74	0.44	0.26	0.35
O46	0.45	0.10	0.19	0.21	0.33	0.48	0.44	0.47	0.33	0.28	0.24	0.30	0.55	0.78	0.81	0.59	0.31	0.39
O47	0.38	0.16	0.08	0.06	0.22	0.28	0.14	0.37	0.34	0.33	0.56	0.49	0.68	0.65	0.66	0.47	0.24	0.35
O48	0.23	0.08	0.14	0.12	0.18	0.32	0.34	0.40	0.28	0.27	0.39	0.29	0.09	0.26	0.23	0.11	0.22	0.27
O49	0.10	0.18	0.06	0.20	0.09	0.21	0.23	0.10	0.11	0.09	0.36	0.16	0.58	0.35	0.36	0.29	0.15	0.18
O50	0.15	0.19	0.13	0.16	0.13	0.30	0.37	0.25	0.32	0.24	0.47	0.40	0.06	0.14	0.16	0.21	0.21	0.26
O51	0.11	0.16	0.15	0.15	0.11	0.29	0.35	0.22	0.31	0.35	0.46	0.40	0.32	0.13	0.10	0.03	0.21	0.25
O52	0.03	0.01	0.07	0.23	0.17	0.06	0.10	0.01	0.20	0.49	0.13	0.04	0.20	0.02	0.09	0.01	0.13	0.15
O53	0.27	0.39	0.44	0.45	0.27	0.02	0.01	0.07	0.09	0.09	0.07	0.08	0.26	0.22	0.24	0.06	0.25	0.15
O54	0.02	0.13	0.03	0.03	0.04	0.06	0.07	0.17	0.17	0.23	0.37	0.07	0.09	0.03	0.08	0.15	0.10	0.13
O55	0.10	0.10	0.04	0.09	0.02	0.04	0.05	0.09	0.10	0.11	0.15	0.08	0.02	0.09	0.08	0.09	0.07	0.08
O56	0.18	0.12	0.26	0.18	0.15	0.02	0.05	0.17	0.14	0.22	0.39	0.09	0.16	0.18	0.13	0.12	0.17	0.17
O57	0.07	0.08	0.02	0.13	0.02	0.04	0.03	0.12	0.09	0.12	0.34	0.21	0.02	0.03	0.07	0.04	0.08	0.10
O58	0.19	0.08	0.06	0.05	0.10	0.05	0.06	0.08	0.06	0.05	0.07	0.05	0.07	0.02	0.04	0.17	0.07	0.07
O59	0.02	0.02	0.14	0.18	0.13	0.07	0.17	0.03	0.03	0.17	0.08	0.25	0.02	0.14	0.09	0.18	0.11	0.10
O60	0.10	0.06	0.06	0.12	0.15	0.02	0.03	0.05	0.05	0.20	0.34	0.29	0.06	0.03	0.17	0.04	0.10	0.11
O61	0.03	0.13	0.08	0.18	0.10	0.03	0.09	0.04	0.06	0.09	0.29	0.05	0.09	0.27	0.10	0.18	0.10	0.10
O62	0.09	0.08	0.04	0.11	0.09	0.06	0.07	0.04	0.06	0.12	0.28	0.07	0.10	0.08	0.08	0.04	0.08	0.09

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Annual average VR	Summer Average VR
Annual Frequency	3.5%	9.2%	15.4%	15.2%	11.8%	5.3%	5.2%	9.2%	10.2%	5.3%	3.4%	1.6%	1.0%	1.3%	1.5%	1.0%	1.00	1.00
Summer Frequency	4.0%	2.9%	3.2%	4.3%	8.5%	6.2%	7.9%	13.7%	13.9%	11.3%	7.9%	3.9%	2.1%	3.1%	4.3%	2.8%	1.00	1.00
O63	0.04	0.03	0.14	0.10	0.12	0.12	0.03	0.05	0.04	0.12	0.16	0.11	0.15	0.09	0.06	0.14	0.09	0.09
O64	0.06	0.08	0.05	0.10	0.14	0.08	0.06	0.02	0.02	0.03	0.06	0.05	0.13	0.07	0.10	0.07	0.07	0.06
O65	0.02	0.02	0.15	0.17	0.12	0.14	0.13	0.18	0.05	0.13	0.40	0.44	0.45	0.39	0.10	0.02	0.14	0.16
O66	0.02	0.08	0.02	0.03	0.02	0.08	0.15	0.07	0.06	0.04	0.17	0.08	0.08	0.15	0.22	0.10	0.06	0.08
O67	0.10	0.08	0.09	0.06	0.03	0.01	0.04	0.04	0.02	0.10	0.05	0.05	0.17	0.12	0.14	0.16	0.06	0.06
O68	0.28	0.29	0.20	0.14	0.05	0.03	0.06	0.08	0.11	0.03	0.07	0.04	0.32	0.10	0.21	0.38	0.14	0.11
O69	0.04	0.03	0.06	0.02	0.05	0.08	0.12	0.04	0.06	0.11	0.25	0.14	0.03	0.02	0.16	0.13	0.06	0.09
O70	0.14	0.04	0.17	0.09	0.04	0.12	0.17	0.05	0.07	0.13	0.38	0.19	0.02	0.16	0.10	0.19	0.11	0.12
O71	0.03	0.11	0.17	0.06	0.08	0.03	0.05	0.04	0.06	0.11	0.12	0.02	0.05	0.18	0.11	0.02	0.08	0.07
O72	0.06	0.06	0.21	0.14	0.14	0.12	0.02	0.08	0.03	0.07	0.08	0.05	0.06	0.15	0.11	0.08	0.11	0.08
O73	0.33	0.29	0.43	0.08	0.08	0.07	0.03	0.08	0.11	0.04	0.20	0.10	0.12	0.31	0.08	0.14	0.17	0.12
O74	0.24	0.27	0.43	0.17	0.17	0.05	0.03	0.08	0.06	0.14	0.29	0.08	0.13	0.29	0.12	0.03	0.19	0.14
O75	0.02	0.04	0.07	0.09	0.04	0.08	0.08	0.05	0.06	0.06	0.19	0.14	0.02	0.27	0.18	0.32	0.07	0.09
O76	0.02	0.04	0.03	0.08	0.07	0.05	0.04	0.04	0.03	0.05	0.11	0.06	0.04	0.15	0.11	0.07	0.05	0.06
O77	0.40	0.24	0.43	0.16	0.17	0.06	0.02	0.03	0.11	0.10	0.09	0.13	0.05	0.33	0.08	0.25	0.18	0.13
O78	0.14	0.10	0.14	0.16	0.04	0.04	0.02	0.10	0.05	0.06	0.09	0.10	0.03	0.12	0.03	0.04	0.09	0.07
O79	0.20	0.07	0.30	0.26	0.19	0.02	0.09	0.14	0.05	0.15	0.02	0.14	0.01	0.08	0.07	0.24	0.16	0.12
O80	0.04	0.10	0.10	0.08	0.05	0.09	0.04	0.06	0.09	0.11	0.05	0.16	0.02	0.10	0.01	0.07	0.08	0.07
O81	0.09	0.04	0.03	0.05	0.20	0.07	0.03	0.08	0.04	0.02	0.04	0.04	0.03	0.16	0.02	0.05	0.07	0.06
O82	0.05	0.10	0.08	0.09	0.14	0.03	0.02	0.04	0.08	0.09	0.03	0.14	0.04	0.08	0.02	0.03	0.08	0.07
O83	0.06	0.05	0.05	0.14	0.08	0.08	0.10	0.02	0.04	0.01	0.01	0.06	0.02	0.09	0.08	0.08	0.07	0.05
O84	0.02	0.13	0.22	0.36	0.42	0.19	0.23	0.19	0.18	0.25	0.37	0.54	0.37	0.05	0.12	0.11	0.25	0.24
O85	0.10	0.15	0.23	0.38	0.36	0.23	0.21	0.10	0.07	0.07	0.15	0.14	0.36	0.05	0.05	0.05	0.21	0.15
O86	0.16	0.11	0.26	0.31	0.42	0.18	0.19	0.12	0.22	0.10	0.12	0.12	0.30	0.01	0.16	0.08	0.22	0.18
O87	0.04	0.05	0.07	0.14	0.08	0.06	0.19	0.17	0.04	0.09	0.15	0.36	0.15	0.09	0.06	0.26	0.10	0.12
O88	0.09	0.09	0.15	0.16	0.18	0.18	0.18	0.13	0.04	0.19	0.27	0.33	0.26	0.21	0.06	0.16	0.15	0.16
O89	0.04	0.09	0.18	0.11	0.12	0.24	0.38	0.35	0.29	0.07	0.13	0.23	0.51	0.26	0.04	0.20	0.18	0.21
O90	0.01	0.03	0.17	0.04	0.07	0.04	0.12	0.04	0.08	0.08	0.07	0.13	0.04	0.11	0.02	0.17	0.07	0.07
O91	0.14	0.23	0.07	0.10	0.11	0.04	0.06	0.02	0.02	0.05	0.07	0.27	0.43	0.20	0.06	0.09	0.09	0.08
O92	0.05	0.07	0.21	0.23	0.22	0.19	0.22	0.16	0.12	0.06	0.16	0.12	0.28	0.34	0.04	0.22	0.17	0.16
O93	0.04	0.10	0.14	0.20	0.20	0.17	0.16	0.05	0.06	0.06	0.02	0.38	0.42	0.48	0.08	0.01	0.14	0.13
O94	0.06	0.08	0.18	0.19	0.17	0.12	0.08	0.16	0.12	0.05	0.17	0.27	0.47	0.22	0.08	0.11	0.15	0.14

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Annual average VR	Summer Average VR
Annual Frequency	3.5%	9.2%	15.4%	15.2%	11.8%	5.3%	5.2%	9.2%	10.2%	5.3%	3.4%	1.6%	1.0%	1.3%	1.5%	1.0%	1.00	1.00
Summer Frequency	4.0%	2.9%	3.2%	4.3%	8.5%	6.2%	7.9%	13.7%	13.9%	11.3%	7.9%	3.9%	2.1%	3.1%	4.3%	2.8%	1.00	1.00
O95	0.05	0.10	0.06	0.09	0.14	0.13	0.16	0.09	0.04	0.12	0.42	0.44	0.43	0.64	0.13	0.06	0.12	0.16
O96	0.13	0.11	0.04	0.03	0.02	0.03	0.03	0.03	0.02	0.05	0.21	0.33	0.21	0.45	0.05	0.04	0.06	0.08
O97	0.03	0.09	0.12	0.06	0.16	0.08	0.11	0.08	0.03	0.03	0.38	0.56	0.49	0.57	0.14	0.01	0.11	0.14
O98	0.15	0.12	0.21	0.30	0.46	0.36	0.42	0.33	0.34	0.07	0.27	0.40	0.38	0.41	0.07	0.11	0.29	0.29
O99	0.13	0.06	0.04	0.02	0.06	0.21	0.27	0.11	0.01	0.13	0.28	0.24	0.16	0.15	0.16	0.09	0.09	0.13
O100	0.27	0.18	0.04	0.06	0.10	0.29	0.27	0.38	0.42	0.42	0.37	0.32	0.50	0.06	0.22	0.25	0.21	0.30
O101	0.27	0.14	0.07	0.02	0.16	0.24	0.20	0.33	0.33	0.37	0.42	0.34	0.42	0.57	0.18	0.15	0.20	0.28
O102	0.38	0.12	0.14	0.08	0.18	0.33	0.27	0.40	0.39	0.47	0.49	0.31	0.23	0.61	0.73	0.31	0.26	0.36
O103	0.37	0.13	0.13	0.09	0.04	0.30	0.25	0.35	0.32	0.32	0.33	0.33	0.25	0.26	0.49	0.33	0.21	0.28
O104	0.45	0.23	0.27	0.22	0.02	0.41	0.36	0.46	0.43	0.51	0.60	0.52	0.42	0.33	0.46	0.42	0.32	0.40
O105	0.36	0.23	0.31	0.24	0.03	0.28	0.29	0.31	0.29	0.32	0.48	0.46	0.29	0.29	0.30	0.27	0.26	0.30
O106	0.43	0.19	0.41	0.32	0.11	0.31	0.31	0.40	0.35	0.40	0.55	0.48	0.24	0.39	0.19	0.39	0.32	0.35
O107	0.37	0.15	0.38	0.27	0.09	0.28	0.25	0.34	0.27	0.28	0.36	0.27	0.02	0.54	0.27	0.37	0.27	0.28
O108	0.32	0.19	0.32	0.21	0.05	0.30	0.28	0.31	0.17	0.21	0.20	0.25	0.14	0.56	0.43	0.40	0.23	0.25
O109	0.17	0.16	0.25	0.15	0.01	0.29	0.24	0.35	0.24	0.28	0.34	0.26	0.15	0.49	0.44	0.36	0.22	0.26
O110	0.18	0.20	0.09	0.04	0.08	0.25	0.21	0.35	0.37	0.24	0.23	0.07	0.13	0.22	0.61	0.51	0.19	0.25
O111	0.07	0.06	0.02	0.04	0.20	0.33	0.13	0.35	0.34	0.09	0.33	0.52	0.47	0.26	0.33	0.07	0.17	0.24
O112	0.06	0.07	0.11	0.10	0.29	0.32	0.34	0.06	0.16	0.10	0.25	0.44	0.58	0.38	0.47	0.31	0.17	0.21
O113	0.07	0.22	0.46	0.54	0.45	0.39	0.28	0.36	0.20	0.33	0.37	0.55	0.63	0.42	0.36	0.13	0.37	0.34
O114	0.48	0.54	0.52	0.50	0.36	0.25	0.29	0.40	0.33	0.40	0.36	0.46	0.60	0.42	0.04	0.14	0.42	0.37
O115	0.37	0.34	0.31	0.27	0.14	0.31	0.33	0.33	0.42	0.38	0.47	0.57	0.46	0.15	0.09	0.07	0.31	0.33
O116	0.52	0.42	0.40	0.37	0.19	0.09	0.09	0.42	0.43	0.28	0.25	0.16	0.18	0.08	0.12	0.07	0.32	0.28
O117	0.50	0.42	0.46	0.36	0.22	0.10	0.04	0.40	0.42	0.28	0.31	0.10	0.11	0.07	0.06	0.05	0.32	0.27
O118	0.48	0.42	0.39	0.25	0.29	0.37	0.35	0.21	0.27	0.25	0.20	0.12	0.18	0.13	0.03	0.08	0.30	0.26
O119	0.54	0.38	0.37	0.19	0.10	0.30	0.28	0.41	0.36	0.04	0.23	0.13	0.09	0.06	0.03	0.02	0.27	0.24
O120	0.52	0.36	0.42	0.33	0.26	0.35	0.30	0.30	0.41	0.22	0.11	0.07	0.18	0.11	0.04	0.04	0.32	0.27
O121	0.57	0.37	0.40	0.32	0.19	0.27	0.23	0.47	0.49	0.08	0.08	0.02	0.09	0.09	0.02	0.04	0.31	0.27
O122	0.57	0.37	0.44	0.32	0.14	0.30	0.30	0.32	0.51	0.06	0.11	0.06	0.08	0.08	0.09	0.03	0.31	0.26
O123	0.14	0.16	0.20	0.08	0.19	0.35	0.31	0.38	0.43	0.07	0.10	0.31	0.12	0.14	0.09	0.06	0.21	0.23
O124	0.20	0.15	0.16	0.04	0.03	0.15	0.14	0.24	0.30	0.05	0.12	0.07	0.02	0.10	0.09	0.05	0.13	0.14
O125	0.02	0.07	0.11	0.05	0.09	0.18	0.13	0.15	0.16	0.05	0.10	0.07	0.05	0.16	0.15	0.05	0.10	0.11
O126	0.09	0.21	0.13	0.24	0.10	0.06	0.04	0.03	0.09	0.09	0.09	0.19	0.18	0.34	0.09	0.05	0.13	0.10

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Annual average VR	Summer Average VR
Annual Frequency	3.5%	9.2%	15.4%	15.2%	11.8%	5.3%	5.2%	9.2%	10.2%	5.3%	3.4%	1.6%	1.0%	1.3%	1.5%	1.0%	1.00	1.00
Summer Frequency	4.0%	2.9%	3.2%	4.3%	8.5%	6.2%	7.9%	13.7%	13.9%	11.3%	7.9%	3.9%	2.1%	3.1%	4.3%	2.8%	1.00	1.00
O127	0.09	0.24	0.19	0.16	0.32	0.16	0.18	0.25	0.40	0.09	0.16	0.26	0.39	0.15	0.10	0.05	0.22	0.22
O128	0.02	0.17	0.15	0.16	0.11	0.09	0.13	0.25	0.04	0.06	0.11	0.06	0.09	0.20	0.07	0.08	0.13	0.11
O129	0.34	0.16	0.16	0.15	0.04	0.16	0.33	0.33	0.10	0.13	0.11	0.09	0.07	0.09	0.05	0.10	0.16	0.16
O130	0.12	0.22	0.21	0.28	0.11	0.11	0.09	0.14	0.21	0.02	0.04	0.11	0.06	0.05	0.07	0.02	0.16	0.12
O131	0.45	0.20	0.38	0.37	0.36	0.29	0.04	0.12	0.10	0.02	0.01	0.31	0.10	0.04	0.05	0.08	0.24	0.16
O132	0.18	0.11	0.02	0.11	0.10	0.05	0.09	0.09	0.17	0.01	0.10	0.06	0.04	0.07	0.04	0.13	0.09	0.09
O133	0.24	0.30	0.14	0.16	0.38	0.27	0.28	0.13	0.06	0.06	0.05	0.09	0.05	0.05	0.02	0.02	0.18	0.15
O134	0.13	0.14	0.13	0.07	0.10	0.14	0.12	0.06	0.06	0.04	0.03	0.04	0.01	0.07	0.04	0.18	0.09	0.08
O135	0.13	0.17	0.24	0.22	0.13	0.25	0.16	0.07	0.05	0.05	0.07	0.03	0.03	0.05	0.02	0.16	0.15	0.10
O136	0.13	0.16	0.07	0.08	0.06	0.14	0.05	0.11	0.10	0.02	0.04	0.02	0.03	0.07	0.06	0.08	0.09	0.08
O137	0.10	0.39	0.42	0.42	0.09	0.07	0.23	0.15	0.02	0.08	0.03	0.08	0.13	0.16	0.14	0.10	0.22	0.13
O138	0.44	0.27	0.28	0.17	0.36	0.26	0.24	0.27	0.09	0.13	0.11	0.05	0.17	0.21	0.41	0.37	0.24	0.22
O139	0.43	0.11	0.25	0.26	0.29	0.27	0.17	0.10	0.07	0.09	0.02	0.13	0.14	0.12	0.21	0.48	0.20	0.16
O140	0.19	0.16	0.06	0.12	0.14	0.10	0.12	0.10	0.02	0.03	0.01	0.03	0.04	0.03	0.07	0.15	0.09	0.08
O141	0.16	0.07	0.15	0.05	0.07	0.08	0.03	0.02	0.02	0.02	0.04	0.02	0.20	0.14	0.05	0.12	0.07	0.05
O142	0.17	0.23	0.10	0.41	0.35	0.06	0.03	0.03	0.03	0.09	0.05	0.07	0.11	0.21	0.10	0.17	0.17	0.11
O143	0.11	0.24	0.09	0.37	0.33	0.05	0.03	0.10	0.04	0.07	0.10	0.37	0.26	0.29	0.25	0.21	0.18	0.15
O144	0.27	0.39	0.39	0.31	0.35	0.07	0.11	0.24	0.02	0.07	0.12	0.44	0.19	0.29	0.24	0.22	0.25	0.19
O145	0.18	0.31	0.38	0.02	0.08	0.07	0.02	0.07	0.05	0.17	0.12	0.37	0.19	0.22	0.36	0.32	0.15	0.14
O146	0.02	0.33	0.53	0.07	0.23	0.05	0.05	0.03	0.01	0.10	0.16	0.14	0.24	0.07	0.18	0.23	0.18	0.11
O147	0.08	0.24	0.12	0.02	0.05	0.01	0.03	0.09	0.01	0.10	0.03	0.03	0.21	0.12	0.28	0.40	0.08	0.08
O148	0.15	0.24	0.06	0.06	0.04	0.07	0.11	0.23	0.12	0.21	0.27	0.15	0.21	0.20	0.29	0.33	0.13	0.16
O149	0.04	0.10	0.33	0.20	0.22	0.02	0.03	0.05	0.04	0.03	0.11	0.13	0.13	0.10	0.26	0.14	0.14	0.10
O150	0.09	0.24	0.28	0.36	0.22	0.03	0.03	0.07	0.03	0.14	0.24	0.47	0.04	0.28	0.32	0.13	0.20	0.15
O151	0.08	0.09	0.06	0.23	0.14	0.08	0.10	0.15	0.16	0.41	0.06	0.10	0.25	0.27	0.31	0.25	0.15	0.17
O152	0.30	0.22	0.20	0.27	0.11	0.15	0.15	0.23	0.05	0.28	0.13	0.15	0.13	0.09	0.21	0.25	0.19	0.17
O153	0.14	0.07	0.10	0.25	0.14	0.01	0.05	0.16	0.24	0.37	0.52	0.36	0.04	0.11	0.12	0.18	0.17	0.20
O154	0.18	0.04	0.16	0.19	0.09	0.03	0.05	0.07	0.07	0.14	0.19	0.37	0.09	0.12	0.27	0.18	0.12	0.12
O155	0.14	0.07	0.07	0.02	0.09	0.02	0.03	0.06	0.06	0.11	0.12	0.32	0.21	0.17	0.19	0.02	0.07	0.09
O156	0.23	0.10	0.10	0.07	0.18	0.03	0.02	0.08	0.07	0.10	0.35	0.44	0.22	0.14	0.14	0.15	0.12	0.13
O157	0.04	0.03	0.04	0.07	0.10	0.07	0.06	0.29	0.20	0.46	0.64	0.49	0.56	0.17	0.09	0.04	0.15	0.24
O158	0.04	0.09	0.08	0.09	0.15	0.04	0.02	0.24	0.11	0.37	0.43	0.32	0.58	0.23	0.09	0.11	0.14	0.19

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Annual average VR	Summer Average VR
Annual Frequency	3.5%	9.2%	15.4%	15.2%	11.8%	5.3%	5.2%	9.2%	10.2%	5.3%	3.4%	1.6%	1.0%	1.3%	1.5%	1.0%	1.00	1.00
Summer Frequency	4.0%	2.9%	3.2%	4.3%	8.5%	6.2%	7.9%	13.7%	13.9%	11.3%	7.9%	3.9%	2.1%	3.1%	4.3%	2.8%	1.00	1.00
O159	0.03	0.06	0.09	0.06	0.09	0.04	0.04	0.06	0.08	0.31	0.42	0.33	0.45	0.22	0.01	0.07	0.10	0.14
O160	0.31	0.42	0.24	0.13	0.48	0.08	0.02	0.07	0.08	0.21	0.36	0.42	0.40	0.65	0.52	0.43	0.24	0.24
O161	0.05	0.04	0.30	0.24	0.07	0.04	0.07	0.04	0.07	0.03	0.10	0.10	0.05	0.02	0.08	0.04	0.12	0.07
O162	0.08	0.16	0.25	0.18	0.02	0.05	0.06	0.09	0.08	0.05	0.24	0.36	0.50	0.31	0.26	0.25	0.14	0.13
O163	0.18	0.41	0.12	0.37	0.54	0.08	0.03	0.03	0.04	0.04	0.41	0.42	0.54	0.65	0.17	0.14	0.23	0.20