AECOM

Hong Kong Housing Authority

CB20170587

Consultancy for Environmental Design Studies for Public Housing Development at Hin Fat Lane, Tuen Mun

Air Ventilation Assessment – Initial Study (AVA-IS)

February 2021

	Name	Signature
Prepared:	Tsang Hon Wai	
Checked:	Elaine Ma	
Reviewed & Approved:	YT Tang	

Version:	2	Date:	24/02/2021

AECOM Asia Co. Ltd.
13/F, Grand Central Plaza, Tower 2, 138 Shatin Rural Committee Road, Shatin, NT, Hong Kong
Tel: (852) 3922 9000 Fax: (852) 3922 9797 www.aecom.com

Table of Content

Page

List of Tables

List of Figures

Appendices

1 INTRODUCTION

Background

1.1 AECOM Asia Co. Ltd. has been commissioned by the HKHA to undertake an Air Ventilation Assessment (AVA) Study – Initial Study (IS) using Computational Fluid Dynamics (CFD) for the proposed Public Housing Development located at Hin Fat Lane, Tuen Mun to examine the air ventilation impact of the proposed building design qualitatively and formulate effective and practicable measures enhancing the air ventilation as part of the continuous design improvement process.

Objectives

1.2 The AVA Study for the proposed Public Housing Development at Hin Fat Lane (i.e. the Project Area) has been conducted in accordance with the methodology outlined in the Technical Guide for AVA for Developments in Hong Kong (the Technical Guide) annexed in HPLB and ETWB TC No. 1/06. The main purposes of this AVA Study, echoing the Technical Guide, are:

- To assess the characteristics of the wind availability (V_∞) of the Site;
- To give a general pattern and a rough quantitative estimate of wind performance at the pedestrian level reported using Wind Velocity Ratio (VR);
- To quantitatively assess the air ventilation performance in the neighbourhood of the Project Area; and
- To compare two design scenarios in terms of air ventilation performance aspect.

Content of This Report

1.3 Section 1 is the introduction section. The remainder of the report is organized as follows:

- Section 2 on site characteristics;
- Section 3 on assessment methodology;
- Section 4 on assessment criteria;
- Section 5 on key findings of AVA study;
- Section 6 on directional analysis; and
- Section 7 with a summary and conclusion.

2 SITE CHARACTERISTICS

Project Area and Its Surrounding Area

2.1 The Project Area with a gross area of about 0.56 hectares (ha) is located at Hin Fat Lane, Tuen Mun. The site is bounded by Hin Fat Lane, existing natural slopes and Castle Peak Road - Castle Peak Bay (Castle Peak Road). It was previously occupied by a 3-storey Hong Kong Christian Service (HKCS) Pui Oi school compound which was demolished by Architectural Services Department in October 2019.

2.2 According to the "Approved Tuen Mun Outline Zoning Plan (OZP) No. S/TM/35", the Project Area is zoned as "Residential (Group A)26" ("R(A)26") with overall maximum permissible plot ratio (PR) of 6.5 of which the domestic part should not exceed 6.0, and a building height restriction of 125mPD. To the west of the Project Area is a high-rise residential "R(A)" cluster with mid-rise "G/IC" sites.

2.3 To the immediate east is green slope on the uphill topography including the Castle Peak Pottery Kiln, a Grade III historic building, and a landscape area in the south-eastern portion of the Project Area is designated as a buffer area to the Pottery Kiln. To the immediate the north of the Project Area is a low-rise Tuen Mun Substation ("OU"). The four high-rise existing residential buildings near the Project Area are Handsome Court, Come On Building, Kai Hei Land Building and Man Bo Building.

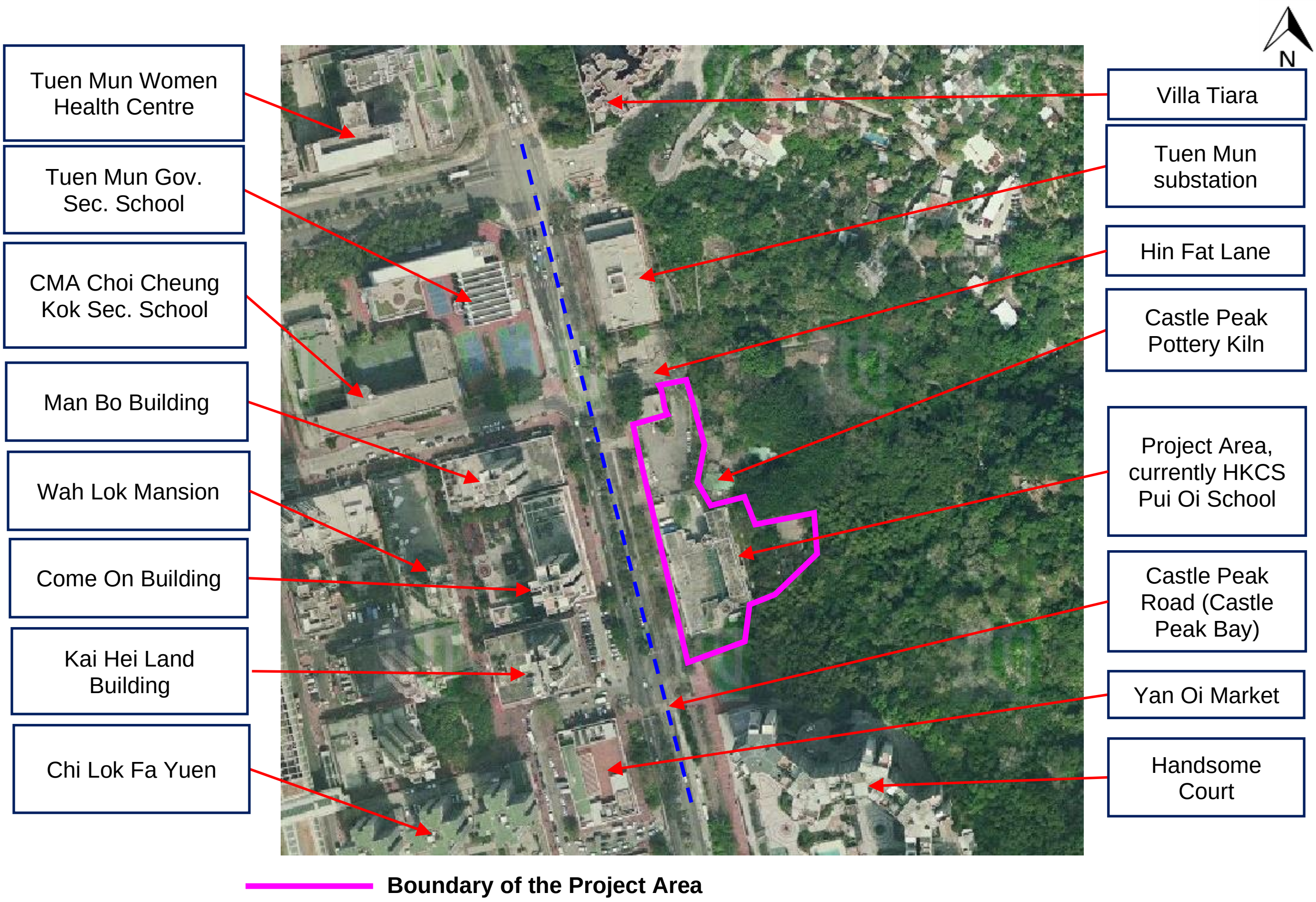
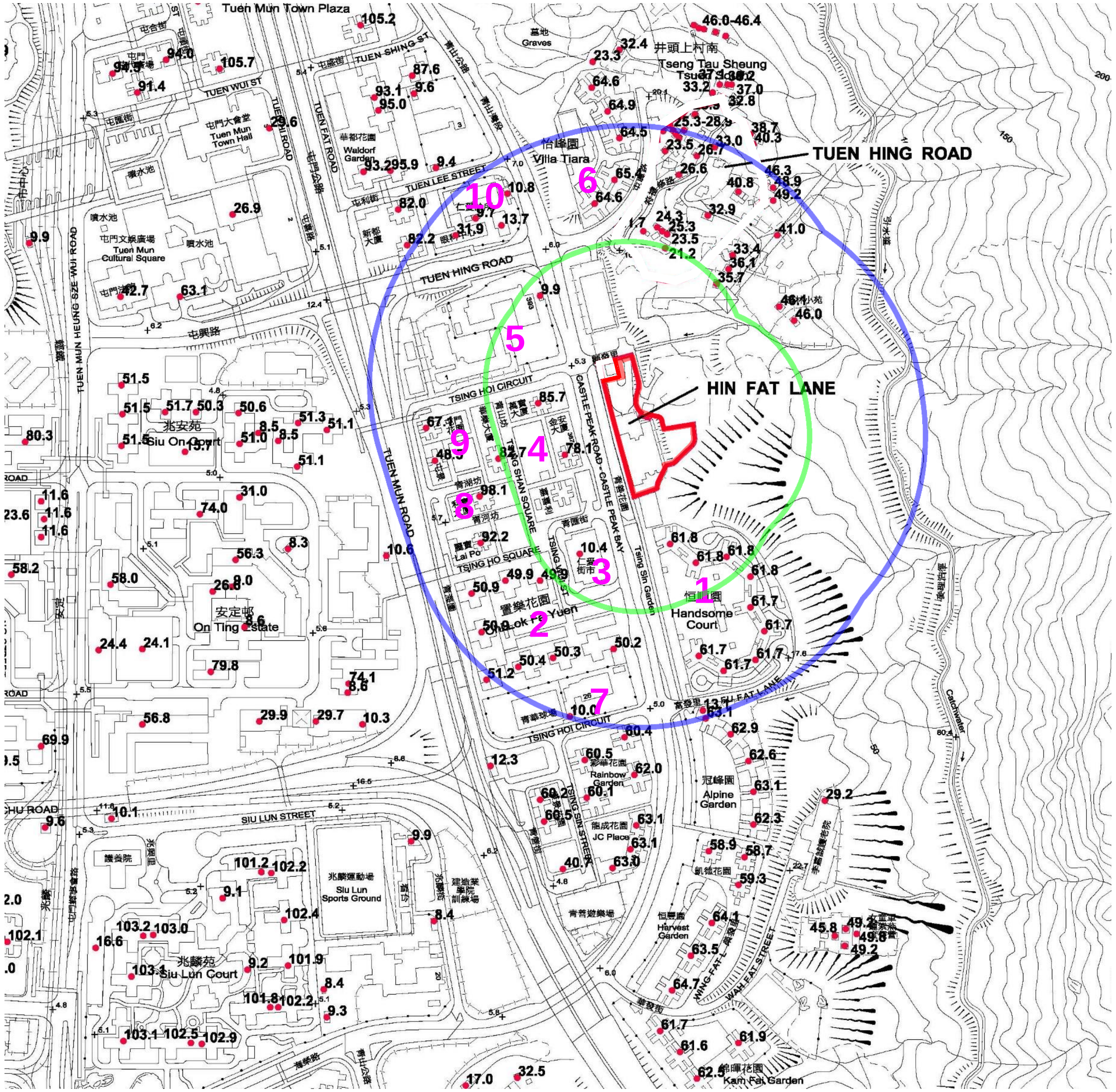


Figure 2.1 Overview of the Project Area and its Surroundings (Source: GeoInfo Map)Details of building heights of the existing developments within the Surrounding Area are shown in Figure 2.2.



1. Handsome Court (61.7mPD – 61.8mPD)	2. Chi Lok Fa Yuen (49.9 – 51.2mPD)	3. Yan Oi Market (10.4mPD)	4. Come On Building and Man Bo Building (78.1mPD – 85.7mPD)
5. Tuen Mun Secondary School and CMA Choi Sheung Kok Secondary School (8 storeys building)	6. Villa Tiara (64.5mPD – 65.4mPD)	7. Po Leung Kuk Hong Kong Taoist Association Yuen Yuen Primary School (8 storeys building)	8. Lee Bo Building (98.1mPD)
9. Wah Lok and Tuen King Building (48.5 – 67.1mPD)	10. Yan Oi Polyclinic (9.7 – 31.9mPD)		

Figure 2.2 Close-up view of the Project Area and its Surroundings (Source: GeoInfo Map)

3 ASSESSMENT METHODOLOGY

3.1 This AVA study was carried out in accordance with the guidelines stipulated in the Technical Guide for AVA for Developments in Hong Kong with regard to Computational Fluid Dynamics (CFD) modelling. Reference was also made to the "Recommendations on the use of CFD in Predicting Pedestrian Wind Environment" issued by a working group of the COST action C14 "Impact of Wind and Storms on City Life and Built Environment" (COST stands for the European Cooperation in the field of Scientific and Technical Research). COST action C14 is developed by European Laboratories/Institutes dealing with wind and/or structural engineering, whose cumulative skills, expertise and facilities had an internationally leading position. Thus, it was considered that the COST action C14 was a valid and good reference for CFD modelling in AVA study.

Modelling Tool and Model Setup

3.2 Assessment was conducted by means of 3-dimensional CFD model. The well-recognised commercial CFD package FLUENT was used in this exercise. FLUENT model has been widely applied for various AVA research and studies worldwide. The accuracy level of the FLUENT model was very much accepted by the industry for AVA application.

Computational Domain

3.3 A 3D CFD model including major topographical features and building morphology which would likely affect the wind flow was constructed. The methodology described in the Technical Guide was adopted for this assessment. According to the Technical Guide, the Assessment Area should include the project's surrounding up to a perpendicular distance of 1H while the Surrounding Area (marked in blue) should at least include the project's surrounding up to a perpendicular distance of 2H calculating from the project boundary, H being the height of the tallest building within Surrounding Area. In this study, the value of H being 125 meters with the computational domain size of around 2000m x 2000m x 1000m. In addition, grid expansion ratio and the blockage ratio should not excess 1.3 and 3% respectively. The ground of the computational domain should include topography.

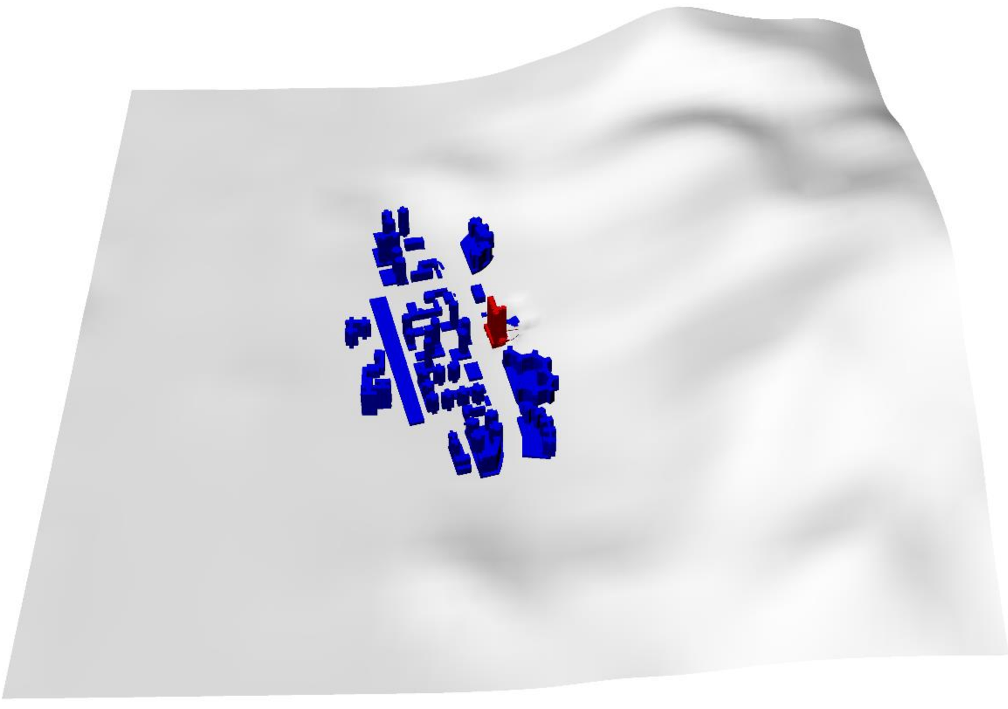


Figure 3.1 Geometry of Computational Model

Assessment and Surrounding Areas

3.4 Both the Baseline Scheme and Proposed Scheme were assessed under annual and summer wind conditions. A 3D model was built according to the GIS information obtained from Lands Department to include all existing, planned and committed development, if any, within the Surrounding Area. All other major elevated structures including the elevated road of Castle Peak Road, existing high-rise residential buildings and natural slopes within the Surrounding Area were also included in the model. The Assessment Area (marked in Green) and Surrounding Area (marked in Blue) have also been incorporated in the simulation model for Air Ventilation Assessment as shown in **Figure 3.2**.

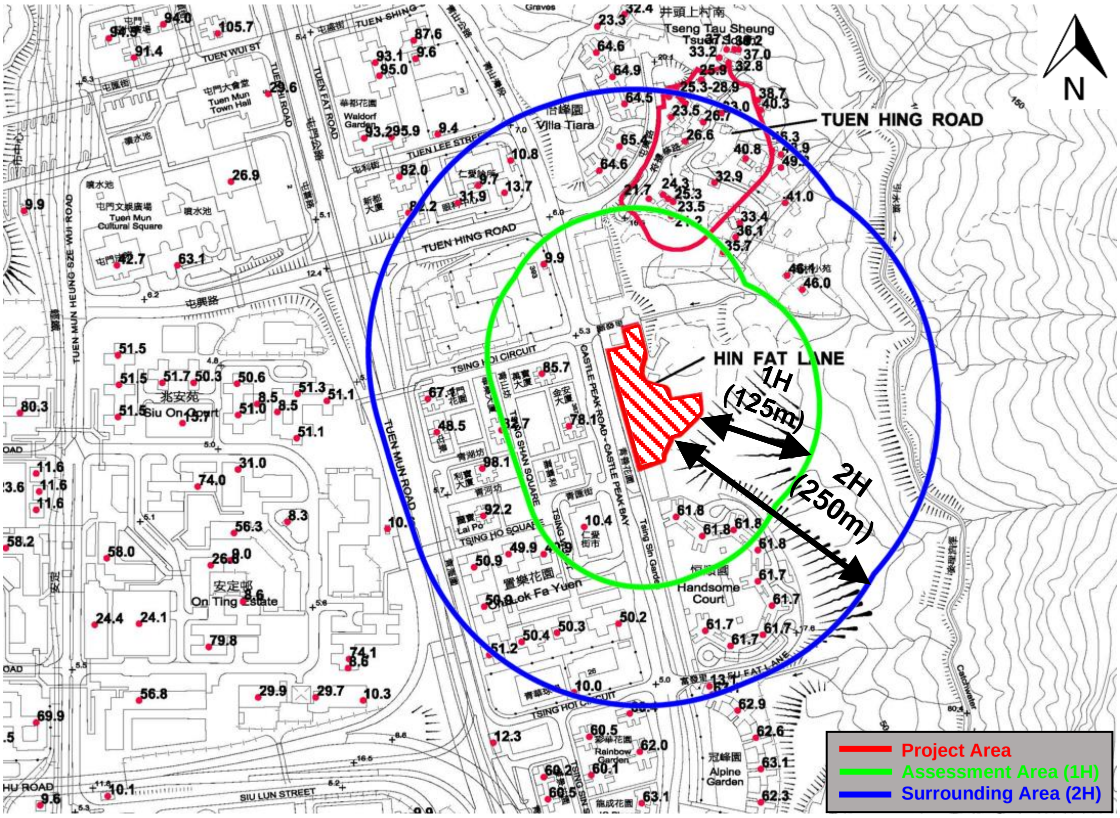


Figure 3.2 Boundaries of the Project Area, Assessment Area and Surrounding Area

Studied Schemes

3.5 The site is formed by two flat platforms at 5.65mPD and 11.7mPD. The main structure of the Project Area is required to be located 30m away from the Kiln as stated in the Preliminary Design Report (PDR) prepared by CEDD during rezoning exercise. The +11.7mPD platform is designated as a buffer zone between the Kiln and the Project Area. A set back of 15m from the southern site boundary (Non-building Area, NBA) is required and only low-rise building / open area is allowed within 50m from the northern site boundary for air ventilation and pedestrian comfort during rezoning application stage.

3.6 The site is zoned "R(A)26" for high-density residential developments according to the approved OZP No. S/TM/35. The site has an overall PR of 6.5 of which the domestic PR should not exceed 6.0, and a building height restriction of 125mPD.

3.7 A setback of 20m from the domestic block to Castle Peak Road is required due to noise and air quality issues from vehicular emission.

3.8 **Figure 3.13** and **Figure 3.14** demonstrated model geometry of the Baseline Scheme and the Proposed Scheme in the simulation. Both schemes have considered the above constraints and development parameters.

Baseline Scheme

3.9 The Baseline Scheme is a 37-storey domestic block at a maximum building height of 125mPD on a relatively small and 3-storey non-domestic podium in connection to the landscaped deck at 11.7mPD. Northern portion of the site is EVA and open carpark in low-rise nature. Southern portion of the site is NBA and drainage reserve. Air permeable space in the carpark and under the domestic tower allowed prevailing wind to penetrate through such that significant impact on the overall pedestrian wind environment would not be anticipated.

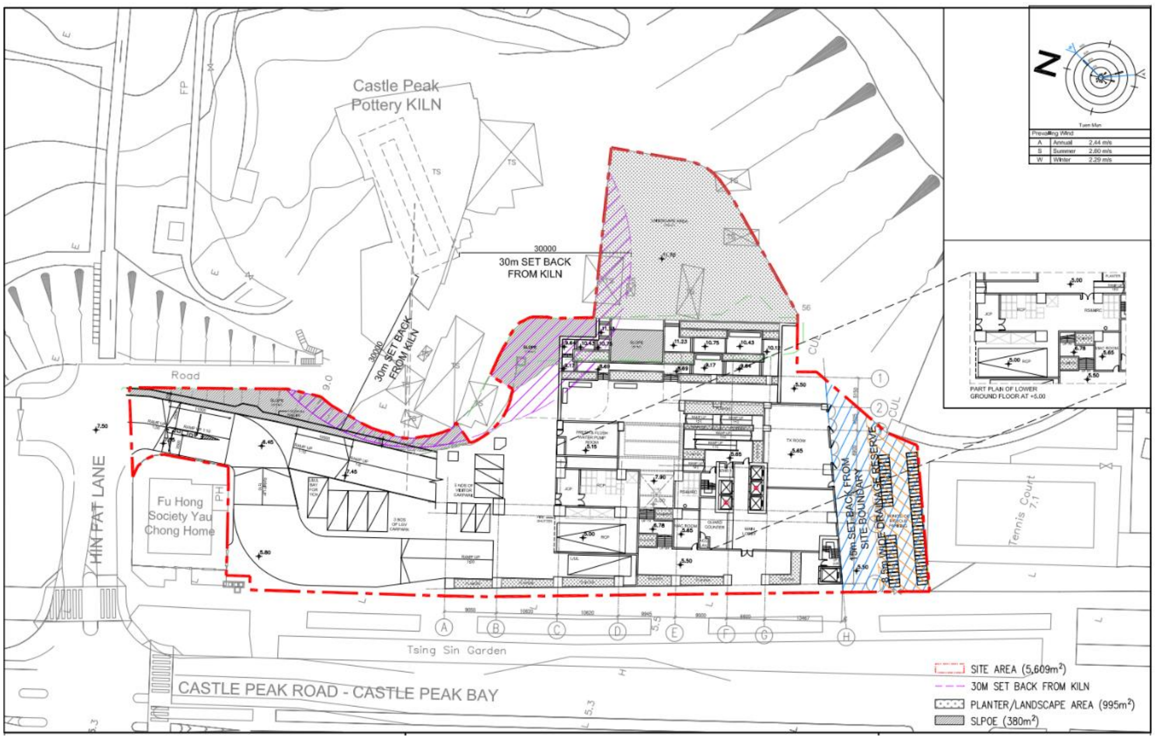


Figure 3.3 **Indicative Plan of Baseline Scheme (Ground Floor)**

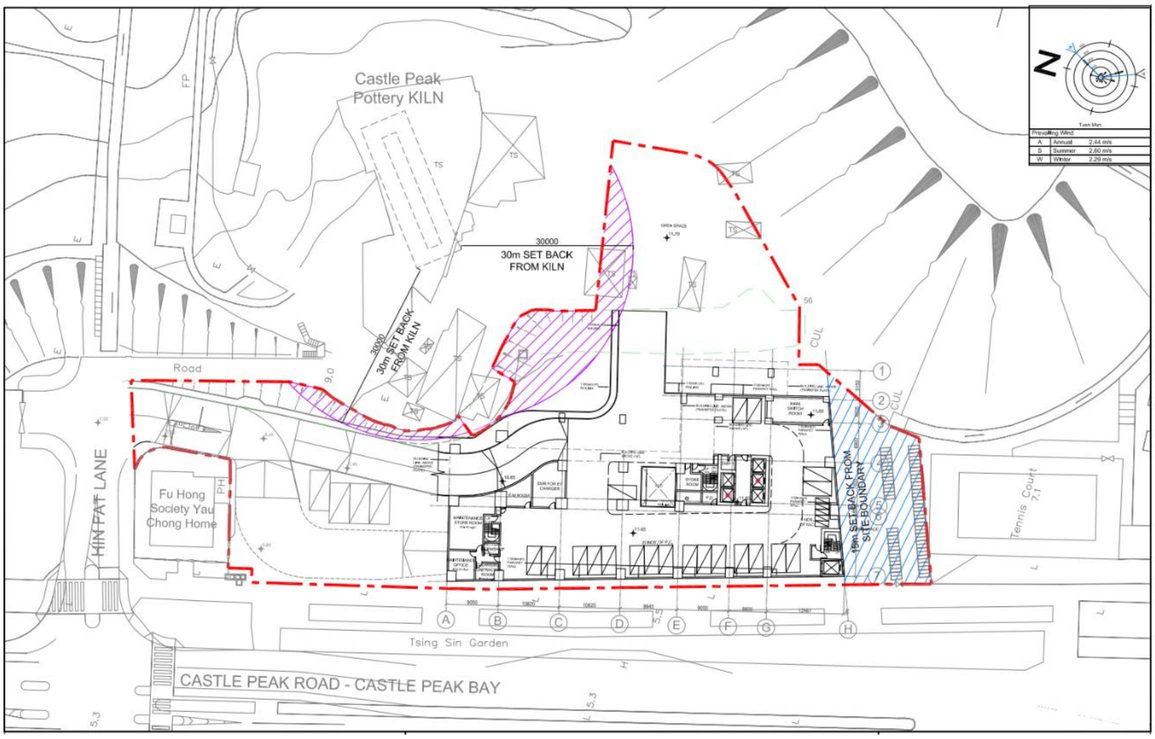


Figure 3.4 Indicative Plan of Baseline Scheme (Upper Ground Floor)

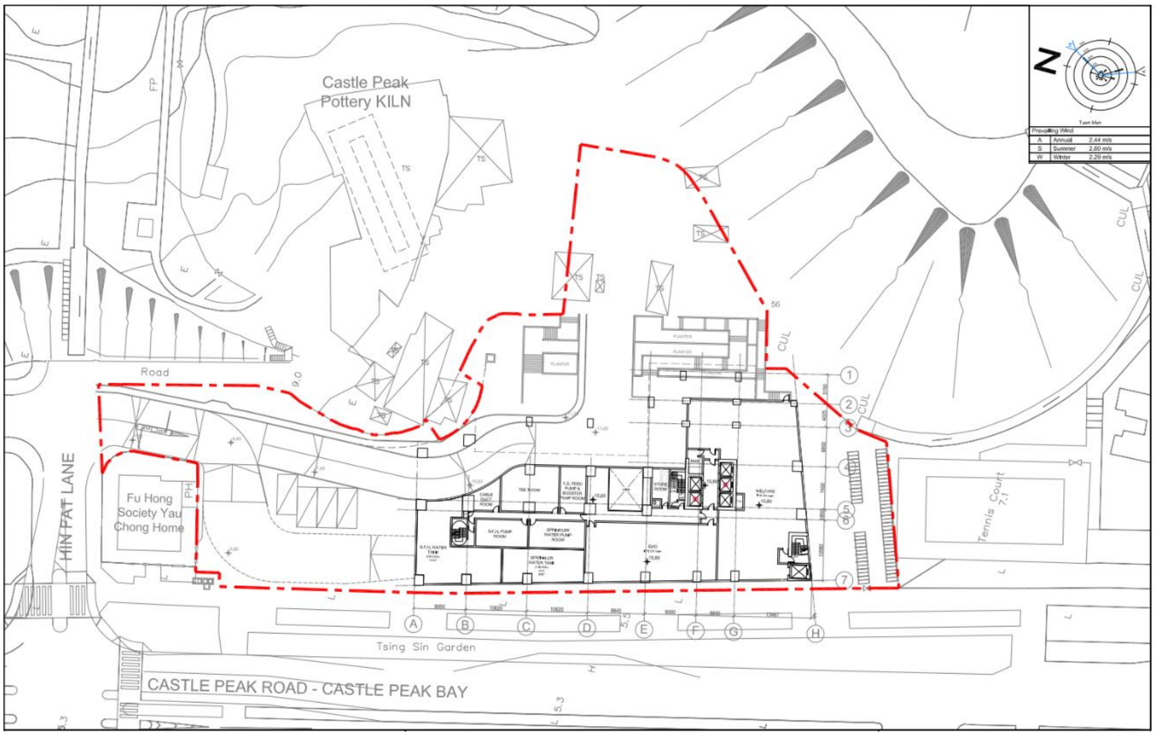


Figure 3.5 Indicative Plan of Baseline Scheme (First Floor)

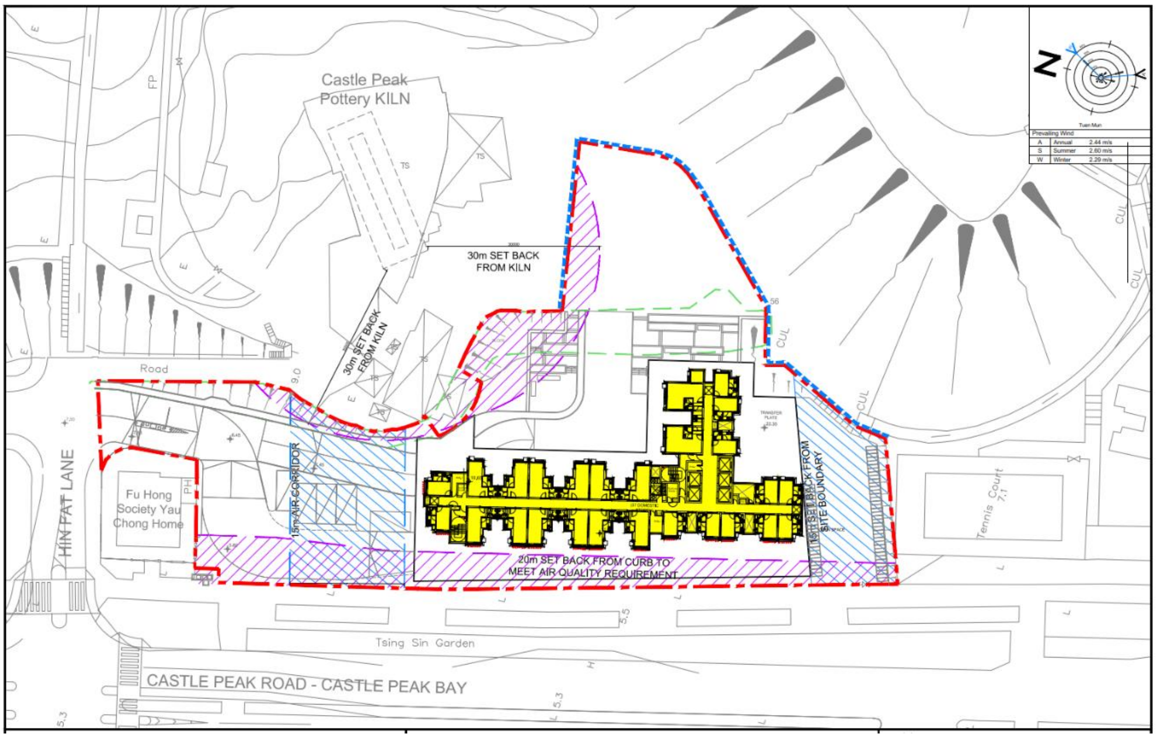


Figure 3.6 Indicative Plan of Baseline Scheme (Typical Floor)

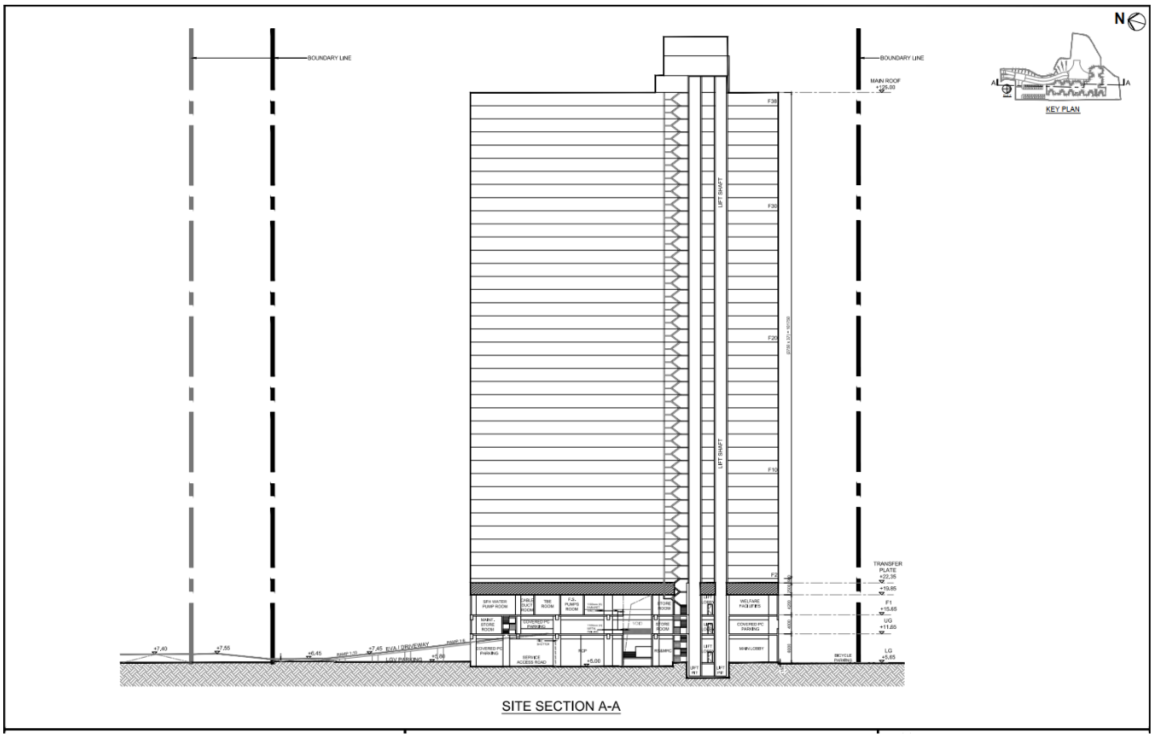


Figure 3.7 Indicative Plan of Baseline Scheme (Section A-A)

Proposed Scheme

3.10 The Proposed Scheme is a 34-storey residential block on a 3-storey non-domestic podium at a building height of 116.75mPD with a domestic PR of 6.0.

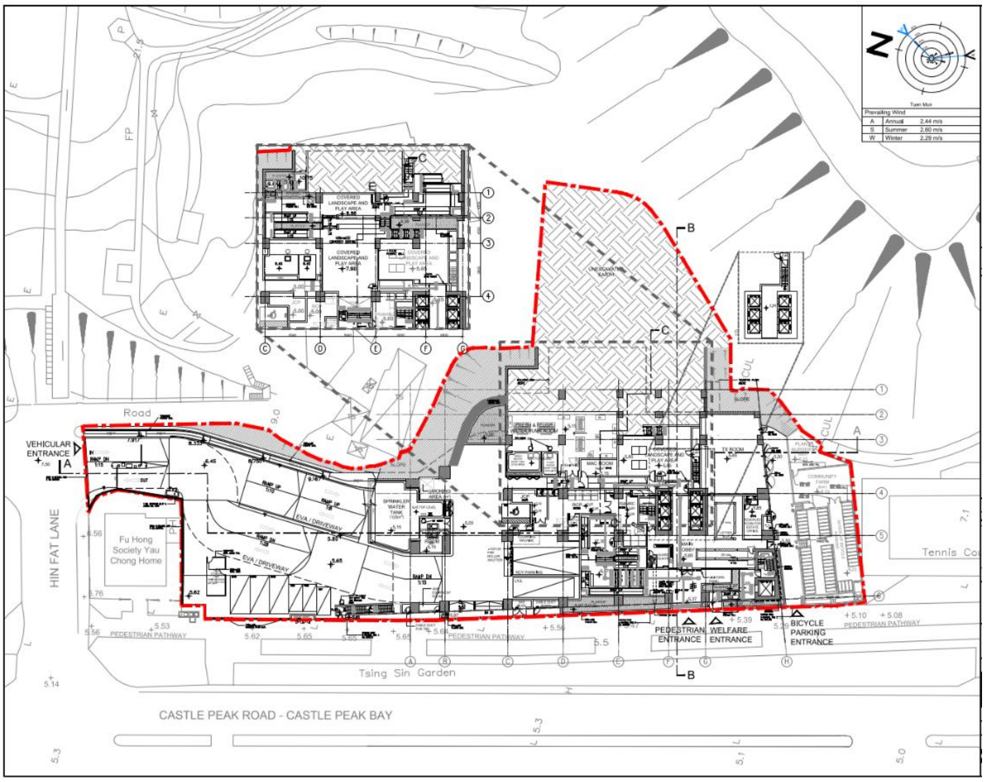


Figure 3.8 Indicative Plan of Proposed Scheme (Ground Floor)

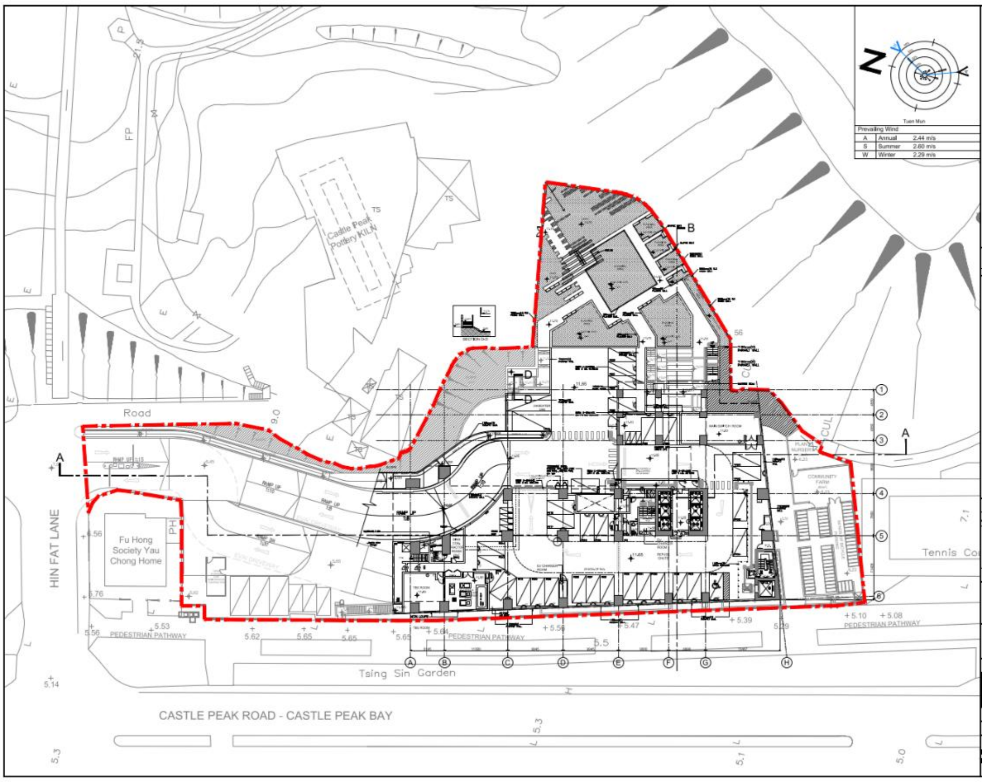


Figure 3.9 Indicative Plan of Proposed Scheme (Upper Ground Floor)

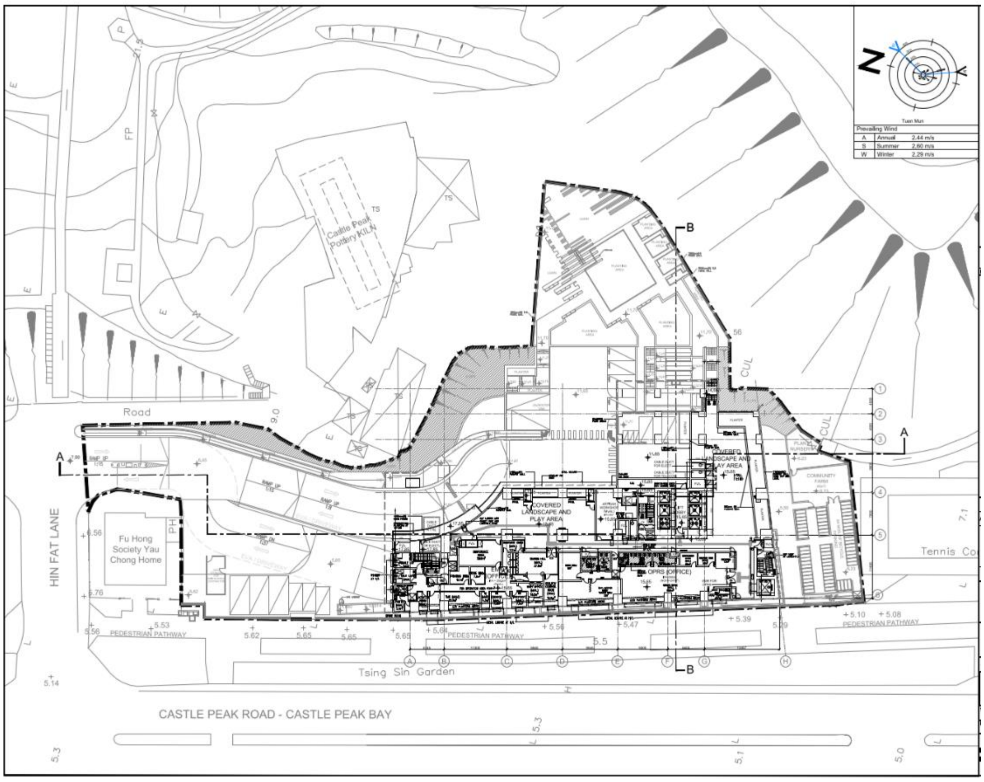


Figure 3.10 Indicative Plan of Proposed Scheme (First Floor)

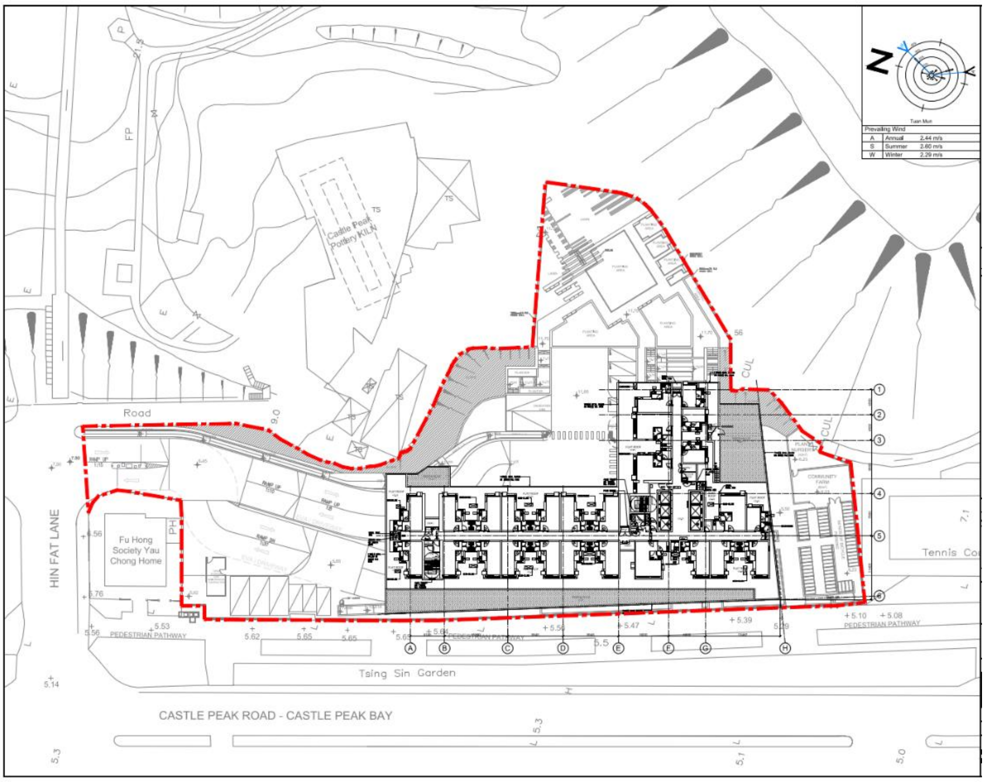


Figure 3.11 Indicative Plan of Proposed Scheme (Typical Floor)

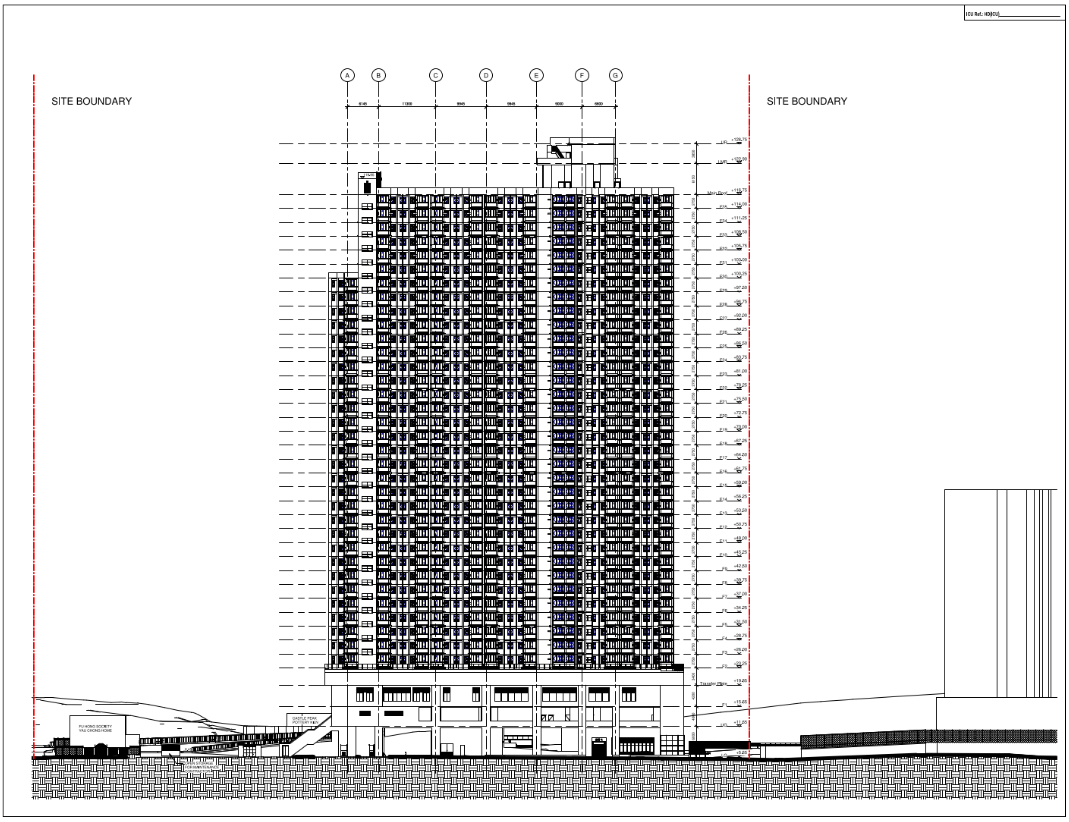
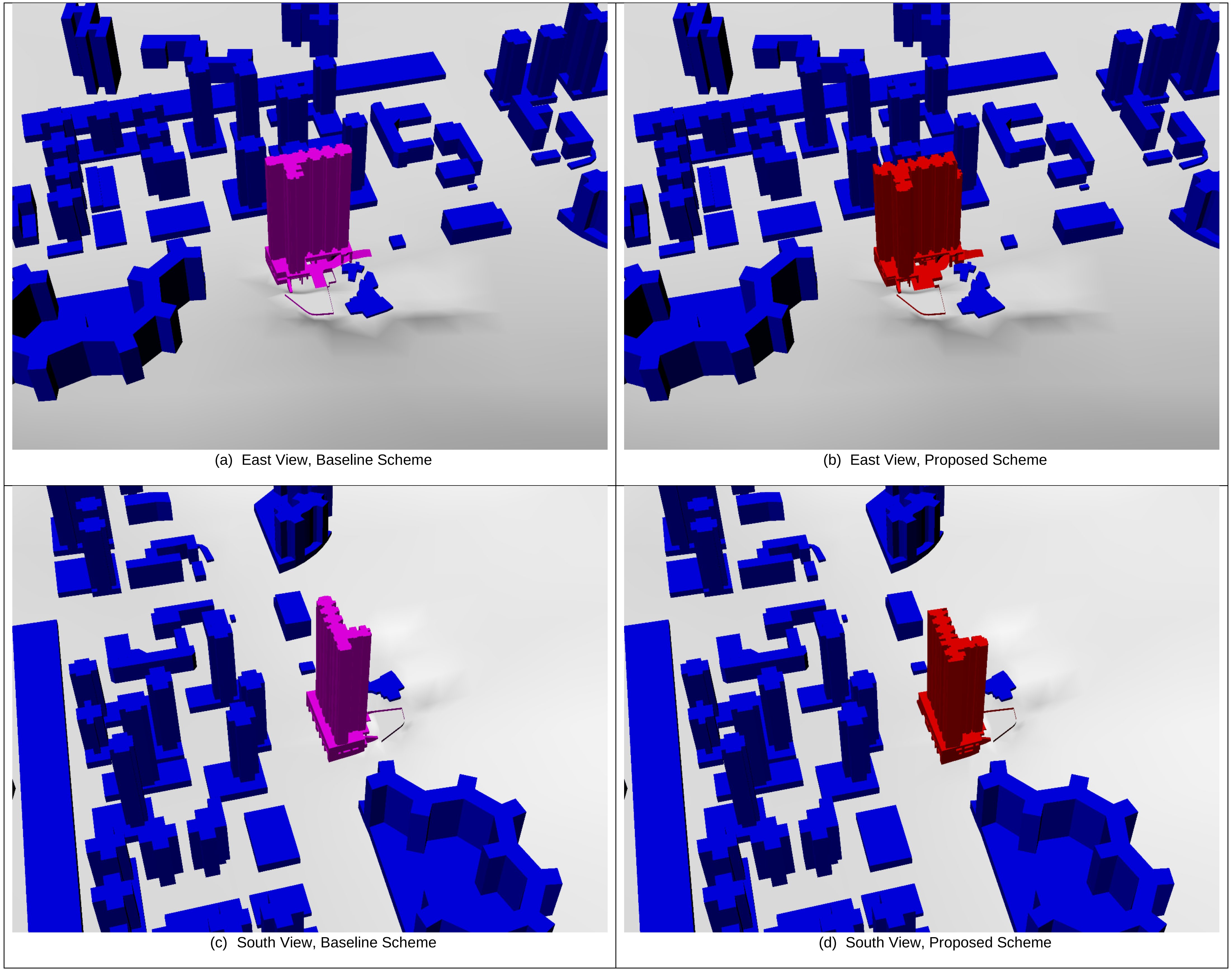


Figure 3.12 Indicative Plan of Proposed Scheme (Section A-A)



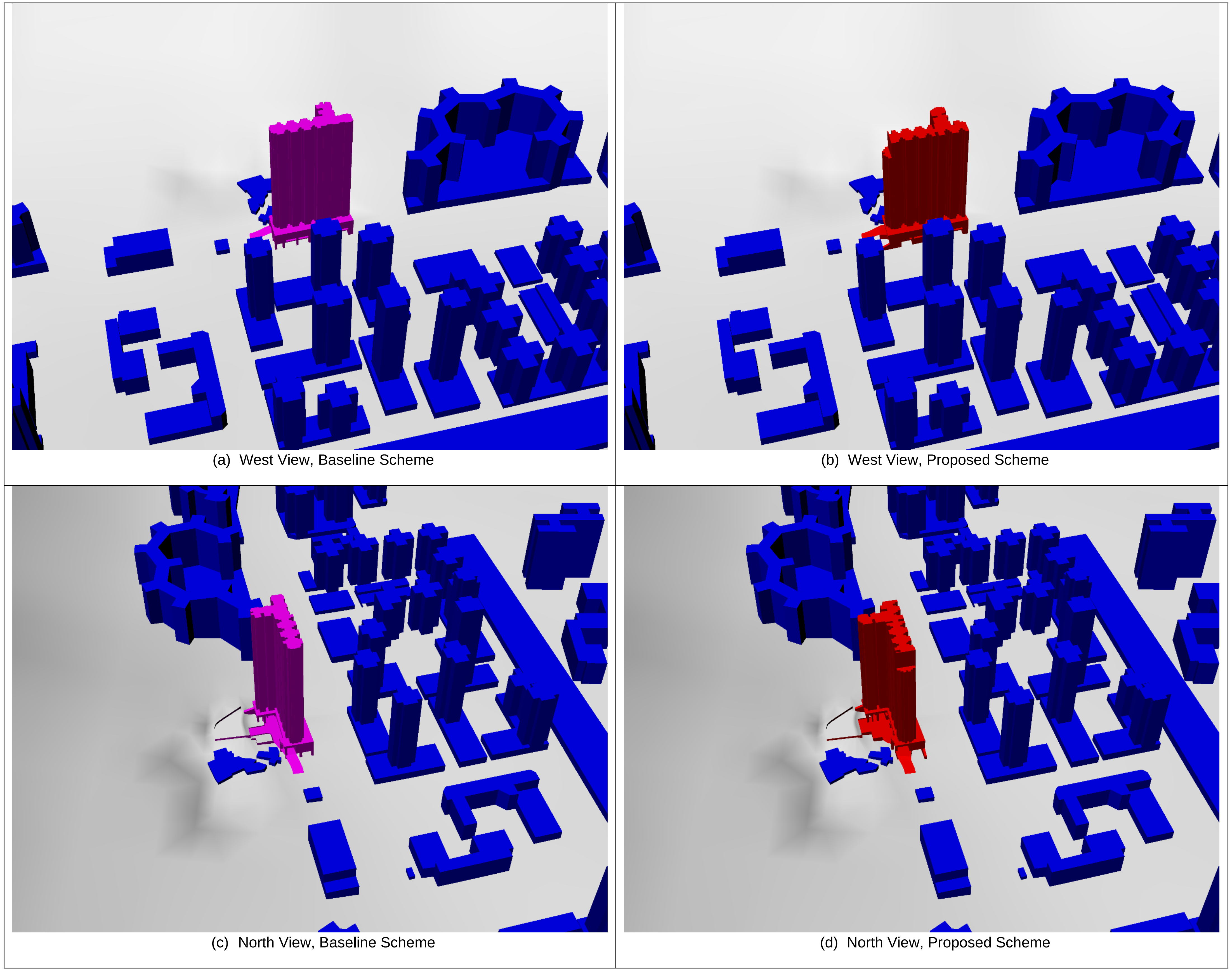
(a) East View, Baseline Scheme

(b) East View, Proposed Scheme

(c) South View, Baseline Scheme

(d) South View, Proposed Scheme

Figure 3.13 Model Geometry under East and South view



(a) West View, Baseline Scheme

(b) West View, Proposed Scheme

(c) North View, Baseline Scheme

(d) North View, Proposed Scheme

Figure 3.14 Model Geometry under West and North views

Wind Environment

3.11 The site wind availability of the Project Area was simulated under at least 8 probable prevailing wind directions (which would represent occurrence of more than 75% of time) under both annual and summer condition to illustrate the change in local wind condition due to the Project Area. These prevailing wind directions were determined based on the wind availability simulation result of Regional Atmospheric Modelling System (RAMS) model published by Planning Department (PlanD from hereafter). **Figure 3.15** shows the location of relevant wind data extraction while the wind roses representing annual and summer winds at the Project Area of this study were presented in **Figure 3.16** below. Furthermore, the summarized chosen prevailing wind directions and their related occurrence probability were listed in **Table 3.1**. Details of the wind probability table was presented in **Appendix A**.

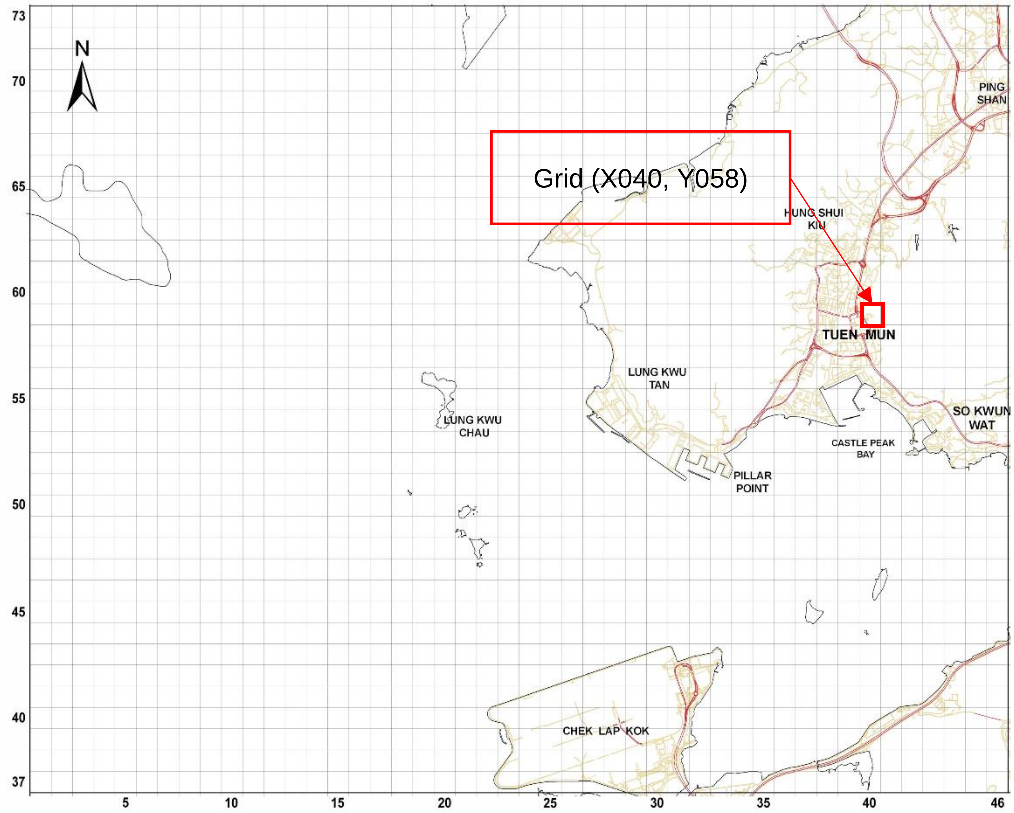
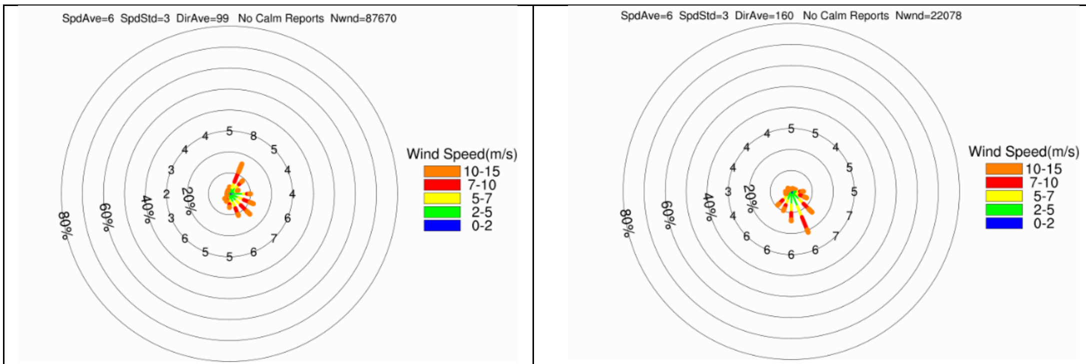


Figure 3.15 Location of Data Extraction in RAMS Model



(a) Annual Wind Rose (b) Summer Wind Rose

Figure 3.16 Wind Rose at Grid (X040, Y058)

Table 3.1 Simulated Wind Directions and their Corresponding Percentage Occurrence

Annual Wind Direction	% of Annual Occurrence	Summer Wind Direction	% of Summer Occurrence
NNE	15.6%	E	5.9%
NE	8.8%	ESE	8.1%
ENE	4.5%	SE	14.3%
E	10.1%	SSE	21.2%
ESE	12.4%	S	14.1%
SE	13.8%	SSW	9.9%
SSE	11.2%	SW	9.2%
S	6.7%		
Total occurrence	83.1%	**Total occurrence**	82.7%

Vertical Wind Profiles

3.12 Wind environment under different wind directions was defined in the CFD environment. According to the Technical Guide (HPLB and ETWB, 2006) Para 20, wind profile for the Project Area could be appropriated from the V∞ data developed from RAMS and with reference to the Power Law or Log Law using coefficients appropriate to the site conditions. In this assessment, vertical wind profile condition below 20mPD was determined using the Log Law while the wind speed above 20mPD was adopted from the RAMS wind and wind profile in PlanD's website.

3.13 Vertical wind profile and roughness lengths were determined accordingly as follow:

Log Law $$U_z = \frac{u^*}{\sigma} \ln\left(\frac{Z}{Z_0}\right)$$

Where
U_Z : wind speed at height z from ground
u^* : friction velocity
σ : von Karman constant = 0.4 for fully rough surface
Z : height z from ground
Z_0 : roughness length.

3.14 The roughness length for determining vertical wind profiles under different wind direction was tabulated in **Table 3.2**. In this study, the land further away from the surrounding area were urban areas with mid to high-rise developments, as a result, a roughness length with Z_0=3 was adopted for the inflow wind profiles.

Table 3.2 Roughness Length for Determining Vertical Wind Profiles under Different Wind Directions

Land Type of Upwind Area(1)	Roughness Length(2), Z_O
Urban area with mid and high-rise developments	3
Sea or open space	0.1

Notes:
(1) The land type refers to the area upwind of the model domain further away from the Surrounding Area
(2) With reference to Feasibility Study for Establishment of Air Ventilation Assessment System (CUHK, 2005)

Mesh Setup

3.15 The total number of cells for this study was about 6,000,000 cells in tetrahedral mesh. Polyhedral mesh cells counted could often be much smaller than comparable tetrahedral meshes with equivalent accuracy as well as improve mesh quality and manner of convergence (Franklyn, 2006). Grids might be converted to polyhedral mesh, if necessary. The horizontal grid size employed in the CFD model in the vicinity of the Project Area was taken as a global minimum size of about 2m (smaller grid size was also employed for specific fine details) and increased for the grid cells further away from the Project Area. The maximum mesh size within the whole computational domain was about 60m. Besides, six layers of prism cells (each layer of 0.5m thick) were employed above the terrain. The blockage ratio and grid expansion ratio of this computational model was 1.2 and 3% respectively.

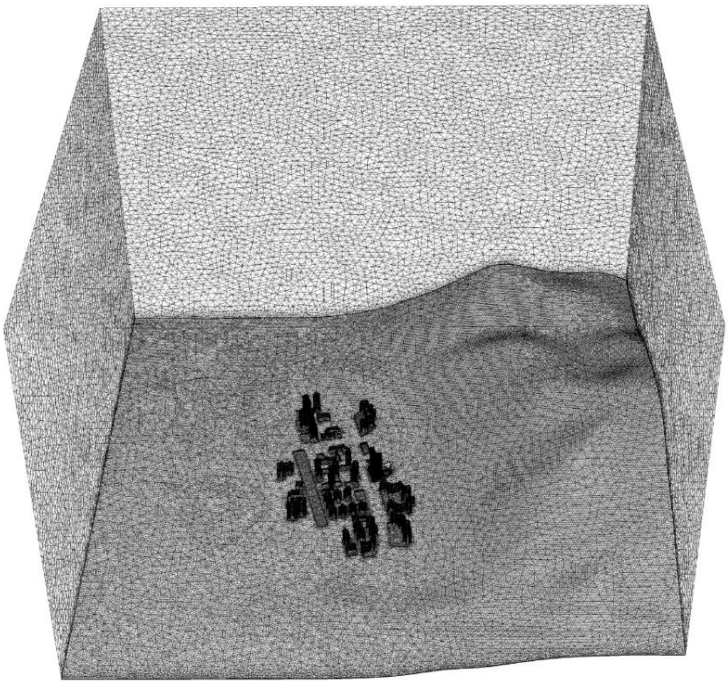


Figure 3.17 Mesh of the Simulation Domain

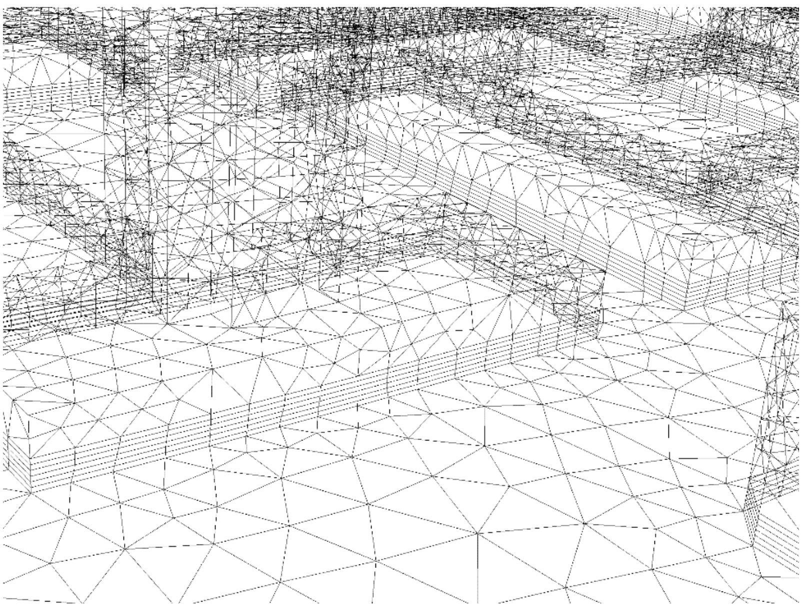


Figure 3.18 Prism Layers Near Ground

Turbulence Model

3.16 As recommended in COST action C14, realizable K-epsilon turbulence model was adopted in the CFD model to simulate the real life problem. Common computational fluid dynamics equations were adopted in the analysis.

3.17 Variables including fluid velocities and fluid static pressure were calculated throughout the domain. The CFD code captures, simulates and determines the air flow inside the domain under study based on viscous fluid turbulence model. Solutions were obtained by iterations.

Calculation Method and Boundary Condition

3.18 The advection terms of the momentum and viscous terms are resolved with the second order numerical schemes. The scaled residuals were converged to an order of magnitude of at least 1×10^{-4} as recommended in COST action C14.

3.19 The inflow face of the computational domain was set as the velocity inlet condition and the outflow face was set as the zero gradient condition. For the two lateral and top faces, symmetric boundary condition was used. Lastly for the ground and building walls, no slip condition was employed.

4 ASSESSMENT CRITERIA AND TEST POINTS LOCATION

Wind Velocity Ratio (VR)

4.1 Wind velocity ratio (VR) indicates how much of the wind availability is experienced by pedestrians on the ground which is a relatively simple indicator to reflect the wind environment of the study site. VR is defined as VR = Vp /V_{INF} where V_{INF} is the wind velocity at the top of the wind boundary layer (greater than 500m in height) would not be affected by the ground roughness and local site features and Vp is the wind velocity at the 2m pedestrian level.

4.2 VRw is the frequency weighted wind velocity ratio calculated based on the frequency of occurrence of 8 selected wind directions or over 75% of occurrence for annual and summer respectively for the purpose of comparison.

4.3 For Site Air Ventilation Assessment, the Site Spatial Average Wind Velocity Ratio (SVRw) and individual VR_W of all perimeter test points were reported. SVRw was the average of VRw of all perimeter test points.

4.4 For Local Air Ventilation Assessment, the Local Spatial Average Wind Velocity Ratio (LVRw) of all overall test points and perimeter test points, and individual VRw of the overall test points were reported. LVRw was the average of all overall test points and perimeter test points.

4.5 The SVRw and LVRw were worked out so as to understand the overall impact of air ventilation on the immediate and further surroundings of the Project Area.

Test Points

4.6 Both perimeter test points and overall test points were selected within the Assessment Area in order to assess the impact on the immediate surroundings and local areas respectively. Overall test points were evenly distributed over surrounding open spaces, streets and other parts of the Assessment Area where pedestrian could or would mostly access. There were 30 Perimeter Test Points and 64 Overall Test Points. Preliminary locations of perimeter and overall test points were illustrated in **Figure 4.1**.

4.7 The Test Points were further divided into 6 groups in order to analyse the respective localized wind environment performances. The coverage of the Test Points Groups were shown in **Figure 4.1** while the description of major covering regions of each group were summarized in **Table 4.1.**

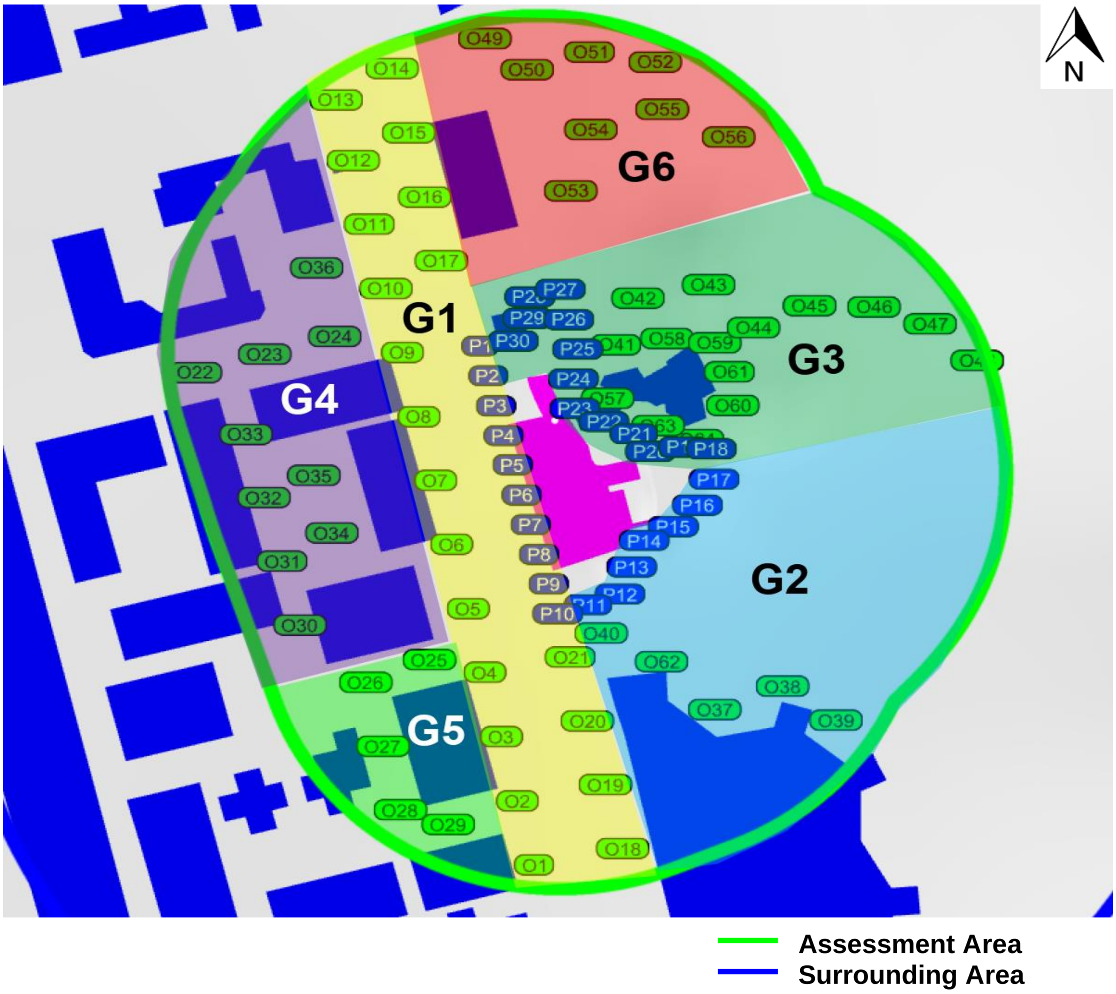


Figure 4.1 Distribution of Test Points

Table 4.1 Test Point Groups and Respective Represented Locations

Test Point Groups	Test Point Numbers	Major Location Covered
G1*	P1 – P10, O1 – O21	Castle Peak Road
G2*	P11 – P17, O37 – O40, O62	Project Site Boundary at south portion and Handsome Court
G3*	P18 – P30, O41 – O48, O57 – O61, O63 – O64	Pottery Kiln and Foot Path of Kau Keng Shan
G4	O22 – O24, O30 – O36	Tsing Hoi Circuit and Tsing Shan Square
G5	O25 – O29	Tsing Wui Street
G6	O49 – O56	Tseng Tau Tsuen

* Perimeter test points were selected within interval similar to overall test points

5 KEY FINDINGS OF AVA STUDY

5.1 Both the Proposed Scheme and Baseline Scheme had similar configuration that consisted of a single tower on top of a 3-storey podium to house the supporting facilities. The 11.7mPD landscaped deck was reserved as buffer zone to Pottery Kiln such that the Project Area would have a relatively short frontage that aligned with Castle Peak Road. In addition, the building setback of the domestic block maintained the effectiveness of Castle Peak Road as the major air path for prevailing wind.

5.2 The Project Area is a single block development having a continuous projected façade length (Lp) of less than 70m abut Castle Peak Road that would minimize wall effect across prevailing wind direction as far as possible.

5.3 Buffer between the Project Area and adjacent developments was maximized as far as possible. Adjoining street canyons, the Lp along a street should not exceed 5 times the mean width of street canyon (U) as far as possible.

5.4 The low-rise nature and NBA at the north and the south of the site minimized the coverage of podium that allowed easterly wind skimmed over or flew though the site. Also, empty bays at driveway allowed prevailing wind to enter the carpark. To mitigate the air ventilation impact, air permeable space of the Project Area in the car park could promote air movement at pedestrian level.

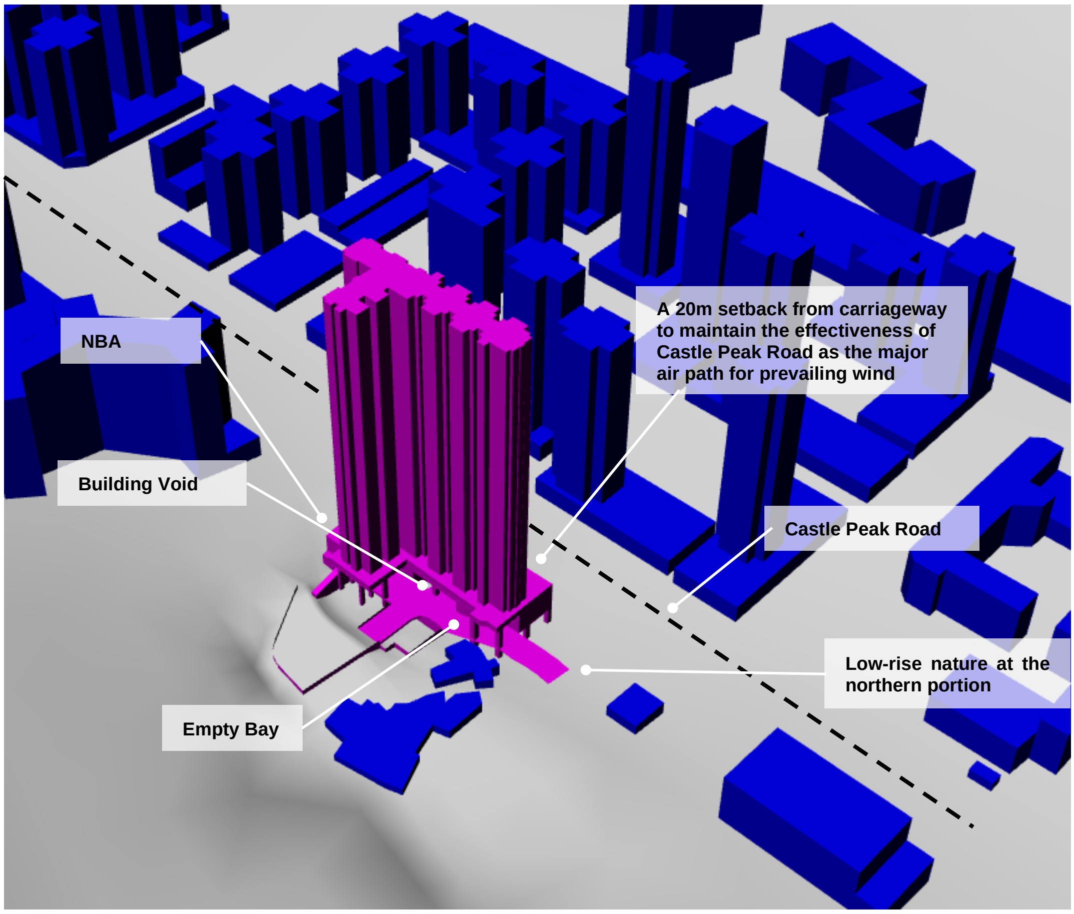


Figure 5.1 Good Design Features in Baseline Scheme

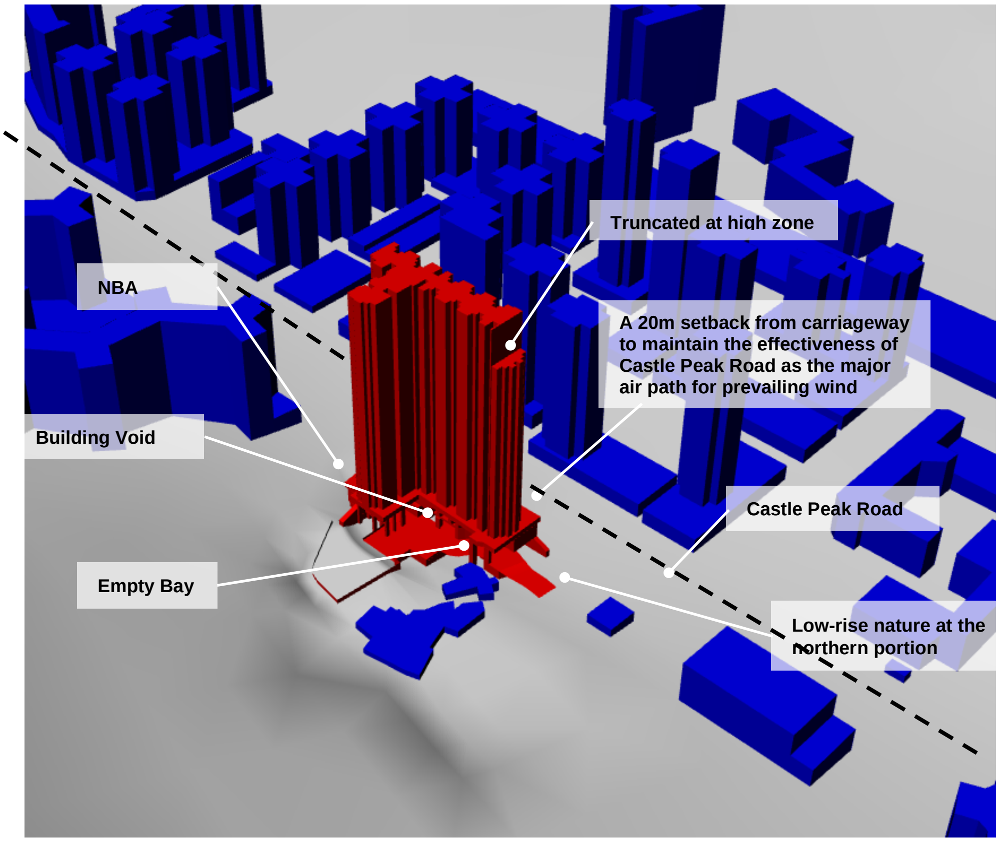


Figure 5.2 Good Design Features in Proposed Scheme

Wind Velocity Ratio Results

5.5 A summary of the predicted wind velocity ratios for the Perimeter Test Points and the Overall Test Points i.e. SVR_W and LVR_W under both annual and summer prevailing winds were presented in **Table 5.1** below. Details of the predicted wind velocity ratios were presented in **Appendix B**.

Table 5.1 Summary of Wind Velocity Ratio

	Annual Winds		Summer Winds	
	Baseline Scheme	Proposed Scheme	Baseline Scheme	Proposed Scheme
SVR_W	0.24	0.24	0.23	0.23
LVR_W	0.25	0.25	0.23	0.24

5.6 The results of VRw for different groups of test points were summarized in **Table 5.2** below.

Table 5.2 Summary of Wind Velocity Ratio for Different Test Point Groups

Group	Description	Test Points	Average VR_w (Annual Winds)		Average VR_w (Summer Winds)	
			Baseline Scheme	Proposed Scheme	Baseline Scheme	Proposed Scheme
G1*	Castle Peak Road	P1 – P10, O1 – O21	0.25	0.25	0.24	0.25
G2*	Project Site Boundary at south portion and Handsome Court	P11 – P17, O37 – O40, O62	0.27	0.28	0.22	0.24
G3*	Pottery Kiln and Foot Path of Kau Keng Shan	P18 – P30, O41 – O48, O57 – O61, O63 – O64	0.28	0.28	0.27	0.28
G4	Tsing Hoi Circuit and Tsing Shan Square	O22 – O24, O30 – O36	0.21	0.21	0.15	0.15
G5	Tsing Wui Street	O25 – O29	0.17	0.19	0.14	0.15
G6	Tseng Tau Tsuen	O49 – O56	0.32	0.33	0.27	0.31

* Perimeter test points were selected within interval similar to overall test points

5.7 Contour plots of wind velocity ratio at 2m above the pedestrian level of assessment area under prevailing wind directions were shown in directional analysis in Section 6.

Site Air Ventilation Assessment

5.8 The SVRw indicated how the lower portion of the buildings within the Project Area affecting the wind environment of its immediate vicinity. Under annual winds, the average of predicted SVRw over these prevailing winds for the Baseline Scheme and Proposed Scheme were both 0.24, indicated a similar wind environment around the development site boundary. In summer, the SVRw were both maintained at 0.23 which indicated a similar wind environment during summer conditions.

5.9 Test points P1 to P10 were located along the portion of Castle Peak Road at the west perimeter of the Project Area. This focus area aligned with Castle Peak Road as major wind corridor under annual and summer conditions. The VRw was maintained at 0.22 for the Baseline and Proposed Scheme under annual condition, while they were 0.27 and 0.29 in summer condition due to air permeable space of podium in Proposed Scheme to allow easterly wind penetration.

5.10 It was expected that the Proposed Scheme would impact the east perimeter of the site under summer condition when compared to Baseline Scheme. The ventilation performance was monitored by test points P11 – P30, which VR of annual conditions were maintained at 0.24 for the Baseline and Proposed Scheme but reduced from 0.21 to 0.20 because less wind was diverted to this area in summer conditions.

Local Air Ventilation Assessment

5.11 The LVRw indicated the overall wind environment within the Assessment Area of the two schemes under the annual and summer winds. The LVRw for the Baseline Scheme and the Proposed Scheme were both maintained at 0.25 under the annual prevailing winds. While during the summer seasons, the LVRw were increased from 0.23 to 0.24. The results indicated that the Proposed Scheme would have slightly improvement on the pedestrian wind environment compared to the Baseline Scheme at the Project Area boundary and throughout the Assessment Area.

5.12 The average wind velocity ratio of Group 1 test points reflected the wind environment along the Castle Peak Road to the west of the Project Area. The Proposed Scheme maintained a similar wind environment within the Group 1 area that the average VRw in Group 1 test points were both 0.25 for the Baseline Scheme and the Proposed Scheme. While in summer season, the average VRw for the Baseline Scheme and the Proposed Scheme were increased from 0.24 to 0.25, indicating a slightly better wind environment.

5.13 The VRw values of Group 2 Test Points indicated the air ventilation performance of the foot path between the Project Area and Handsome Court. The results indicated that the VRw values were increased from 0.27 to 0.28 for the Baseline Scheme and the Proposed Scheme respectively for annual winds. As for summer, a slightly better wind environment was observed between the Baseline Scheme and the Proposed Scheme with increased in VRw from 0.22 to 0.24.

5.14 The ventilation performance of the Pottery Kiln and foot path to Maclehose Trail of Kau Keng Shan was assessed by Group 3 test points. The VRw of both schemes were maintained at 0.28, indicating a similar ventilation performance in this area under annual conditions. For the summer winds, VRw increased from 0.27 to 0.28. There was slight ventilation enhancement for this monitoring region for the Proposed Scheme.

5.15 Group 4 test points located at the west to the Project Area, covering Tsing Hoi Circuit and Tsing Shan Square. It was observed that the Proposed Scheme would have similar air ventilation compared to Baseline Scheme with VRw were both at 0.21 annually and 0.15 during summer season.

5.16 Group 5 test points located at Tsing Wui Street to the southwest of the Project Area, and the VRw indicated a slightly better pedestrian wind environment. It was noticed that the average velocity ratio was increased from 0.17 to 0.19 for the Baseline Scheme and the Proposed Scheme under annual conditions. While summer VRw were 0.14 and 0.15 respectively for the Baseline Scheme and the Proposed Scheme.

5.17 Group 6 test points were equally spaced at foot path of Tseng Tau Tsuen at the north of the Project Area. Under annual condition, the VRw could be maintained at 0.32 and 0.33 for the Baseline Scheme and the Proposed Scheme which implied slight improvement on air ventilation performance within this region. As for summer winds, there was better ventilation performance between the Baseline Scheme and the Proposed Scheme with the overall VRw of 0.27 increased to 0.31.

Pedestrian level wind criteria using the equivalent average - Frank H. Durgin 1997

6 DIRECTIONAL ANALYSIS

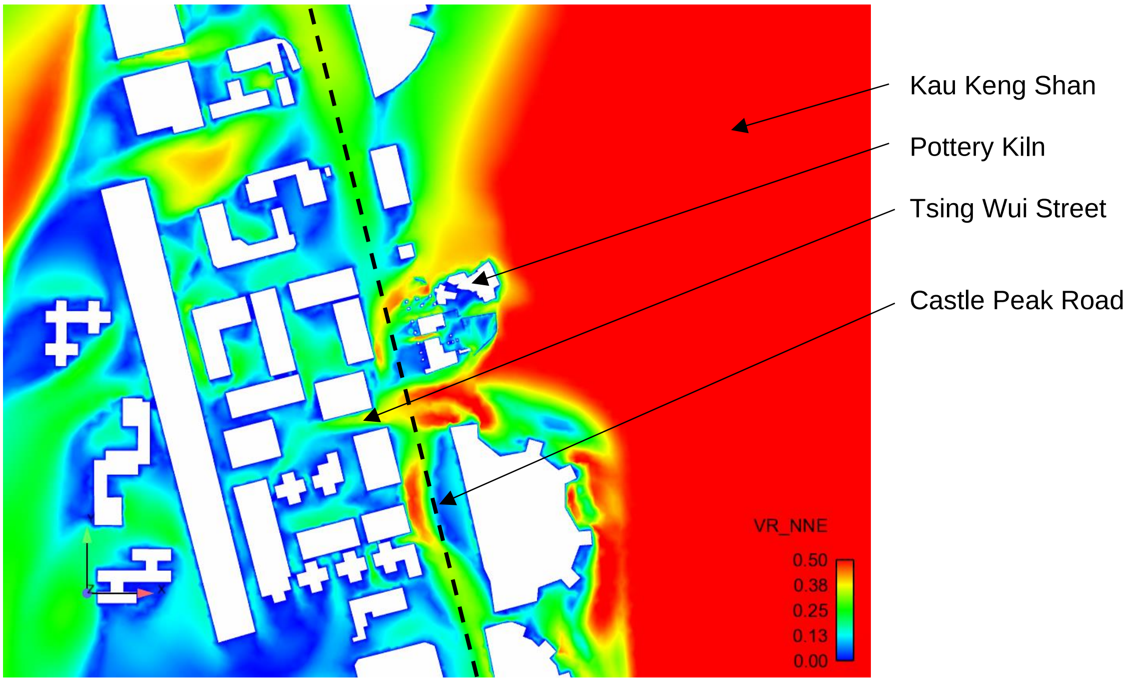
NNE: (Annual: 15.6%)

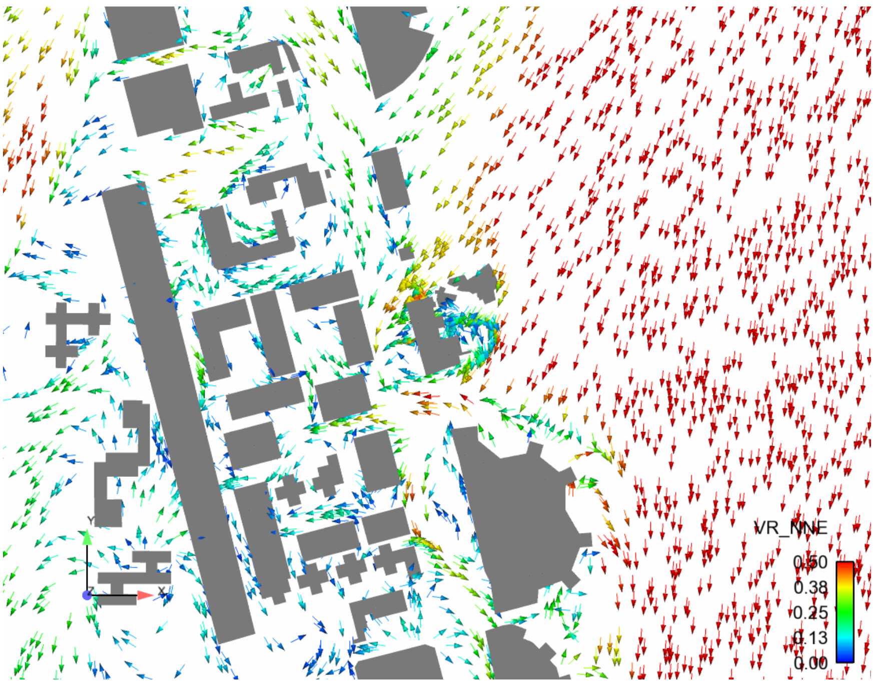
6.1 Under NNE wind, site wind availability of the Project Area mainly relied on katabatic wind from natural slopes of Kau Keng Shan to the east. The incoming wind was unobstructed and then diverted by the Pottery Kiln located to the immediate east of the Project Area.

6.2 In the Baseline Scheme, incoming wind was diverted by the Pottery Kiln to skim over the low-rise structure at northern portion of the site to ventilate Castle Peak Road. A portion of incoming wind could reach Tsing Hui Street via the NBA at southern of the site to ventilate the downstream.

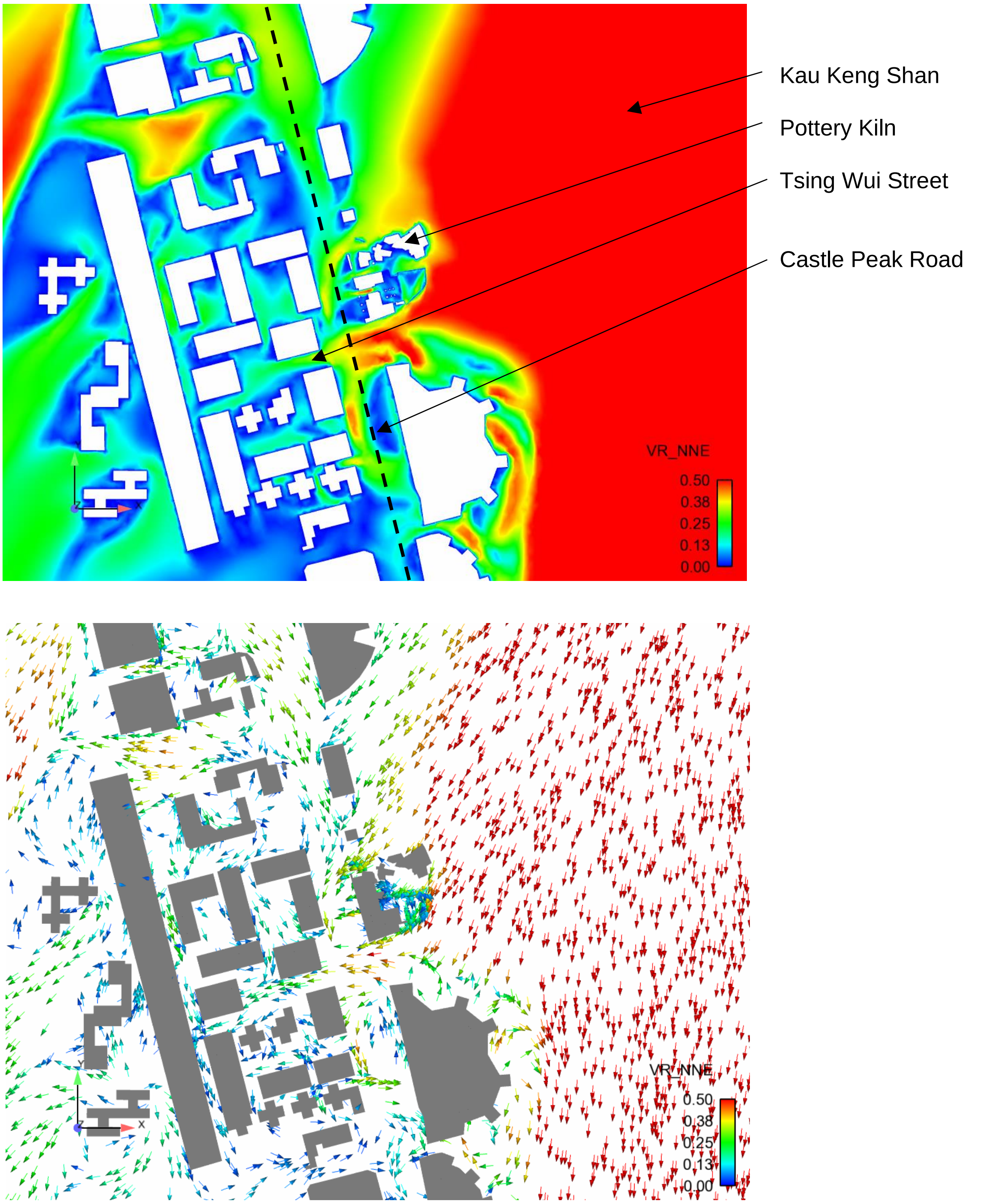
6.3 Similar wind effect was observed in the Proposed Scheme. A drawback was observed at a section of Castle Peak Road to the west of the Project Area as the plant rooms and staircases at grade of the Proposed Scheme could weaken the incoming wind.

Baseline Scheme





Proposed Scheme



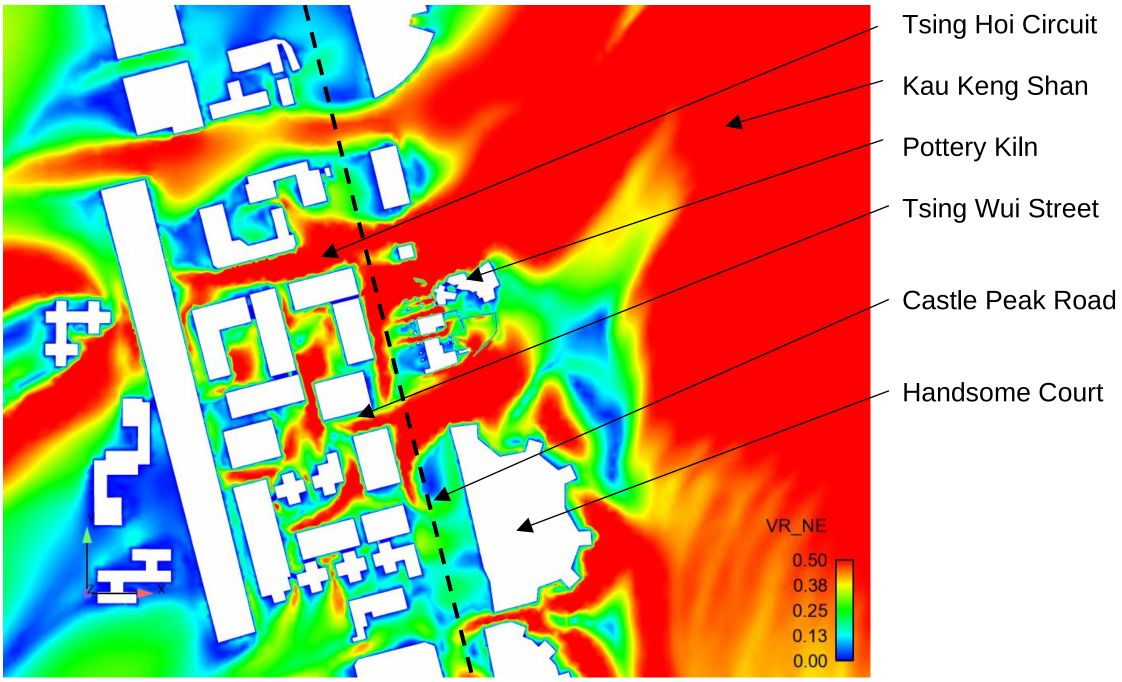
NE: (Annual: 8.8%)

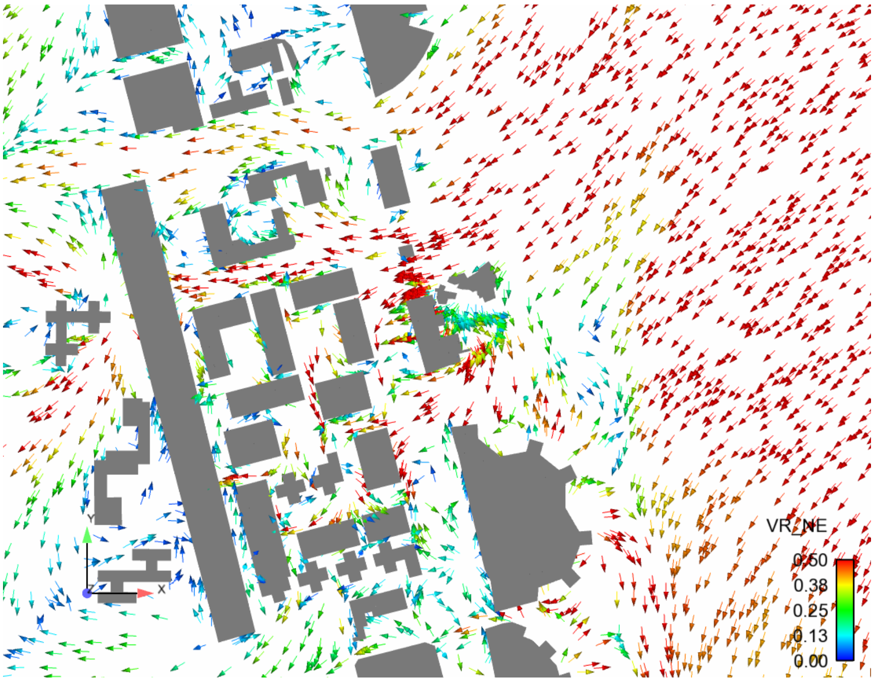
6.4 Under NE wind, site wind availability of the Project Area mainly relied on katabatic wind from natural slopes of Kau Keng Shan to the east. The incoming wind was unobstructed and then diverted by the Pottery Kiln located to the immediate east of the Project Area.

6.5 In the Baseline Scheme, incoming wind was diverted by the Pottery Kiln to skim over the low-rise structure at northern portion of the site to ventilate Castle Peak Road and Tsing Hoi Circuit. A portion of incoming wind could reach Tsing Hui Street via the NBA at southern of the site to ventilate the downstream.

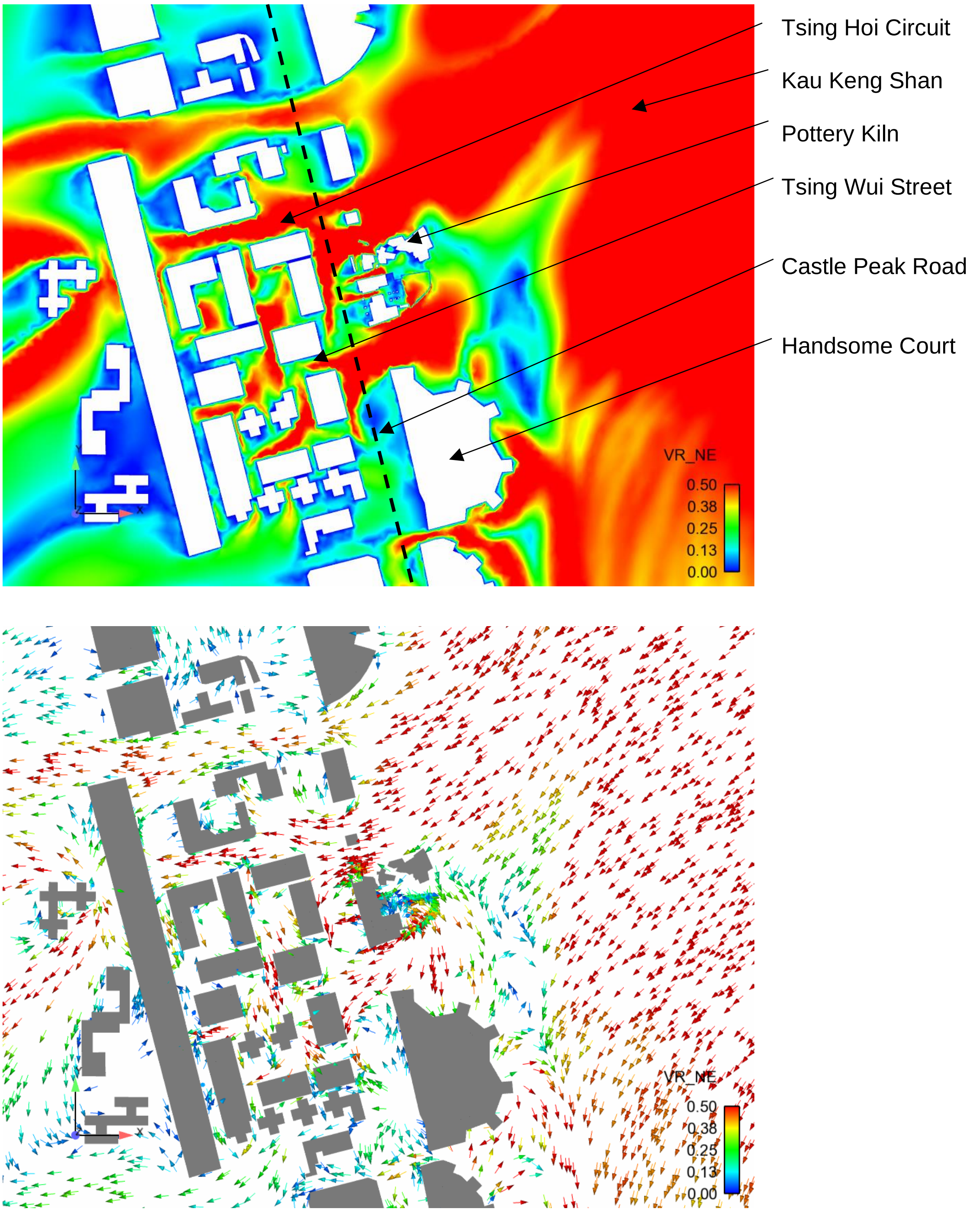
6.6 Similar wind effect was observed in the Proposed Scheme. A drawback was observed at a section of Castle Peak Road to the west the Project Area as the plant rooms and staircases at grade of the Proposed Scheme could weaken the incoming wind. Smaller portion of wind was diverted to pedestrian level to the north of Handsome Court due to building height and morphology of the Proposed Scheme.

Baseline Scheme





Proposed Scheme



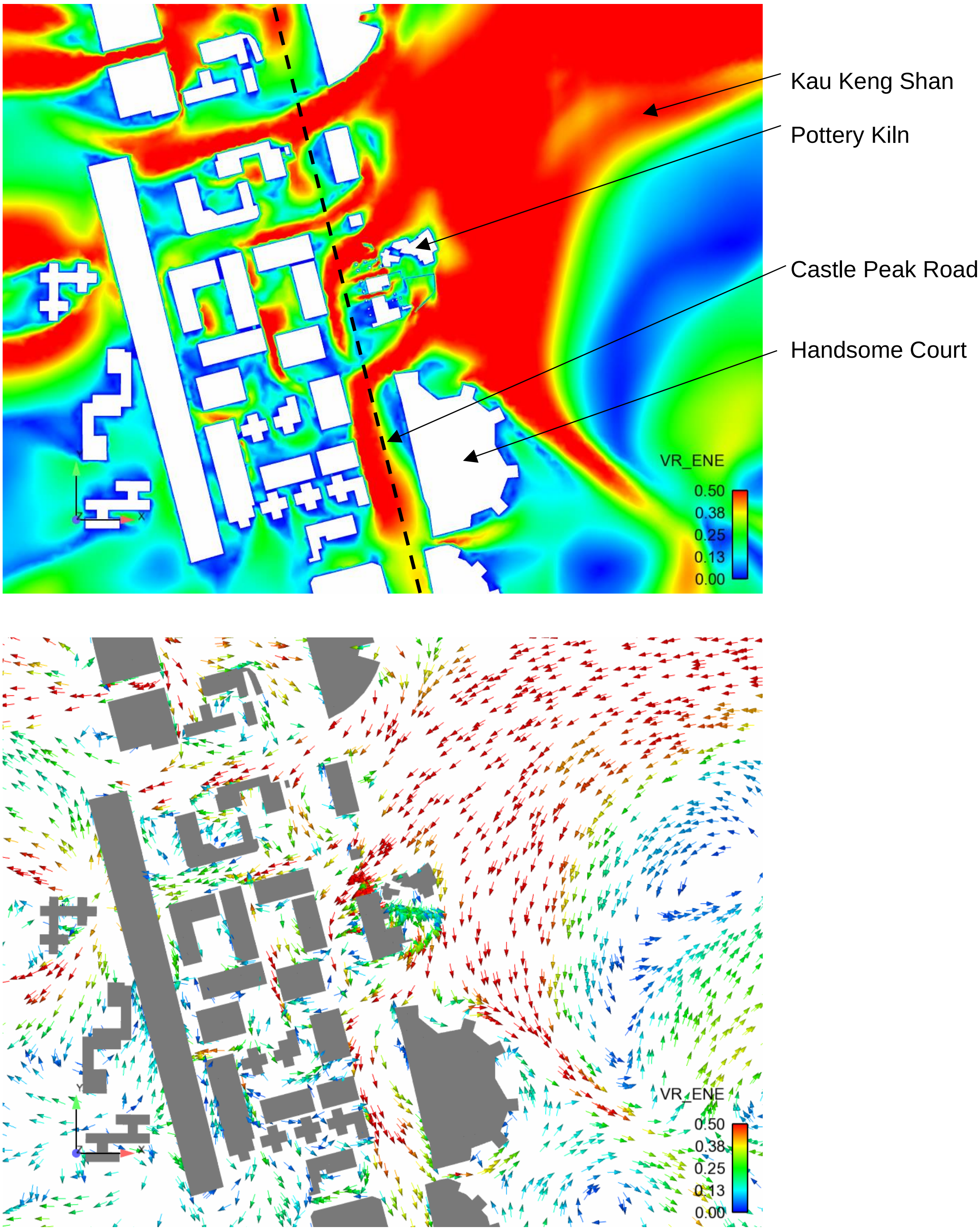
ENE: (Annual: 4.5%)

6.7 Under ENE wind, site wind availability of the Project Area mainly relied on katabatic wind from natural slopes of Kau Keng Shan to the east. The incoming wind was modulated by the topography and then diverted by the Pottery Kiln located to the immediate east of the Project Area.

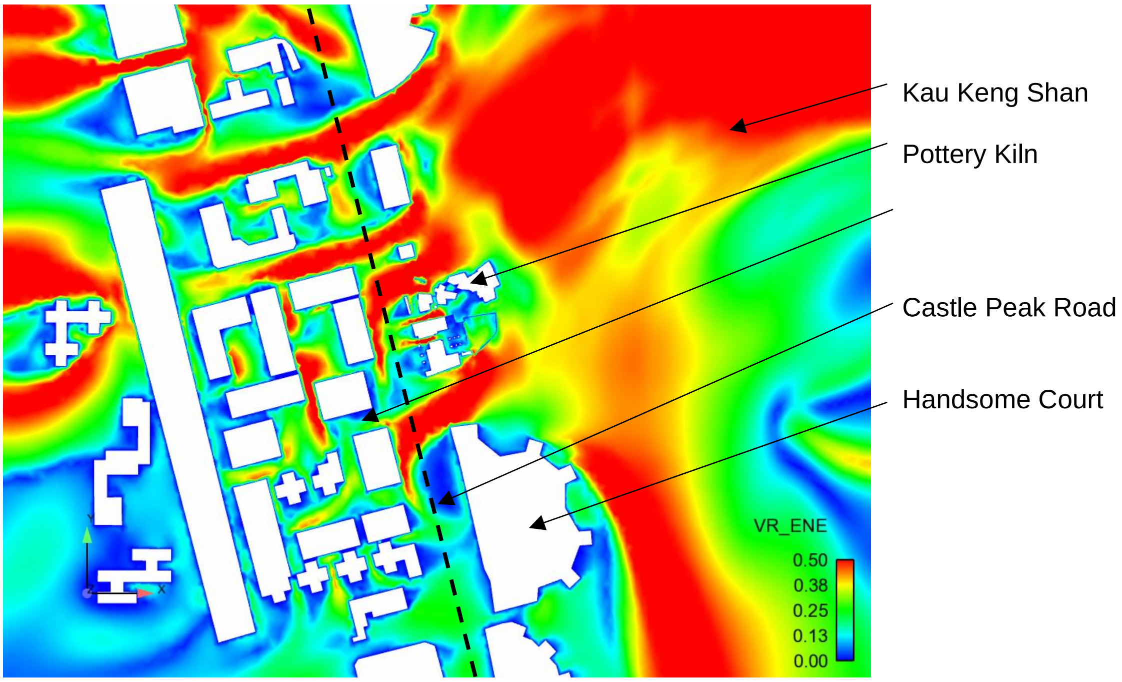
6.8 In the Baseline Scheme, incoming wind was diverted by the Pottery Kiln to skim over the low-rise structure at northern portion of the site to ventilate Castle Peak Road. A portion of incoming wind could reach downstream of Castle Peak Road via the NBA at southern of the site to ventilate area.

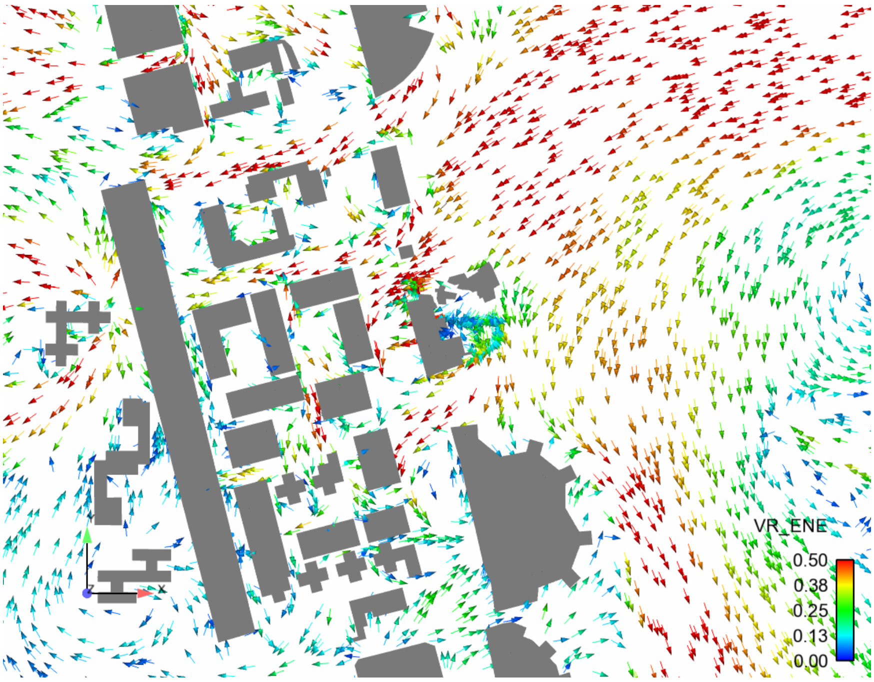
6.9 As for the Proposed Scheme, a drawback was observed at a section of Castle Peak Road to the west the Project Area as the plant rooms and staircases at grade of the Proposed Scheme could weaken the incoming wind. Smaller portion of wind was diverted to pedestrian level to the east of Handsome Court due to morphology of the Proposed Scheme.

Baseline Scheme



Proposed Scheme





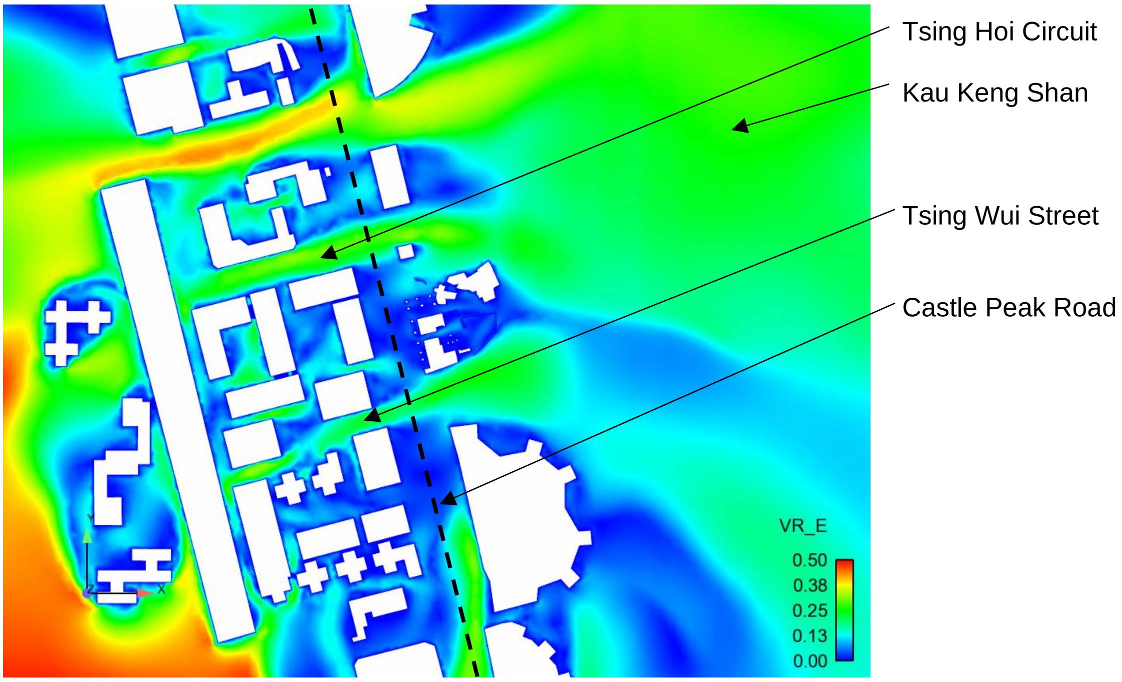
E: (Annual: 10.1%; Summer: 5.9%)

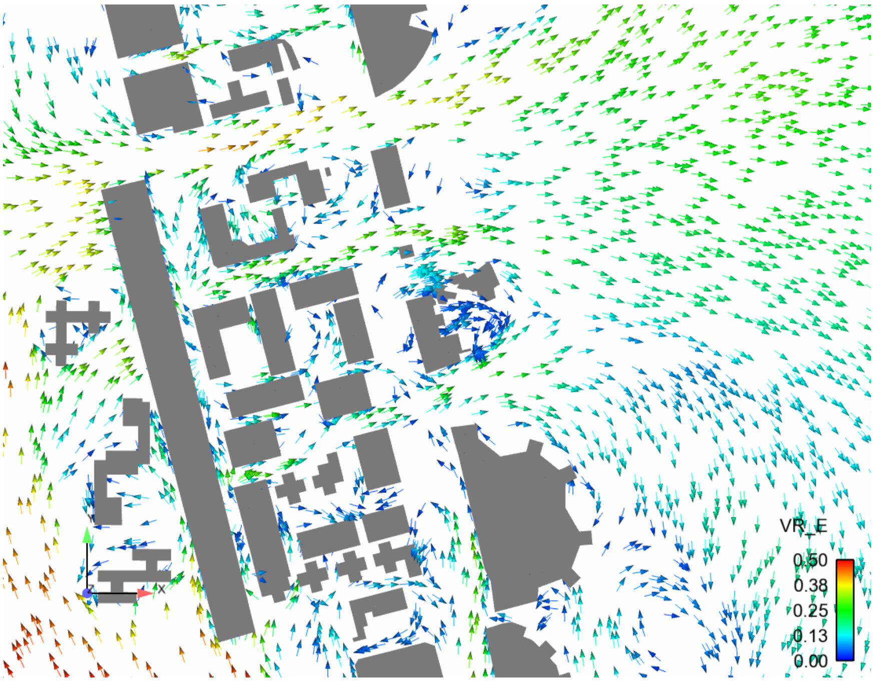
6.10 E incoming wind was weakened by Kau Keng Shan topography, creating a large turbulent zone at leeward side of the Kau Keng Shan. Site wind availability was mainly by the recirculating flow. A relatively low VR zone around the Project Area was observed.

6.11 In the Baseline Scheme, the induced air flow would reach the Project Area via Tsing Hoi Circuit and Tsing Wui Street, which adopted the air permeable space at northern and southern of the site respectively and reached the natural slopes of Kau Keng Shan freely.

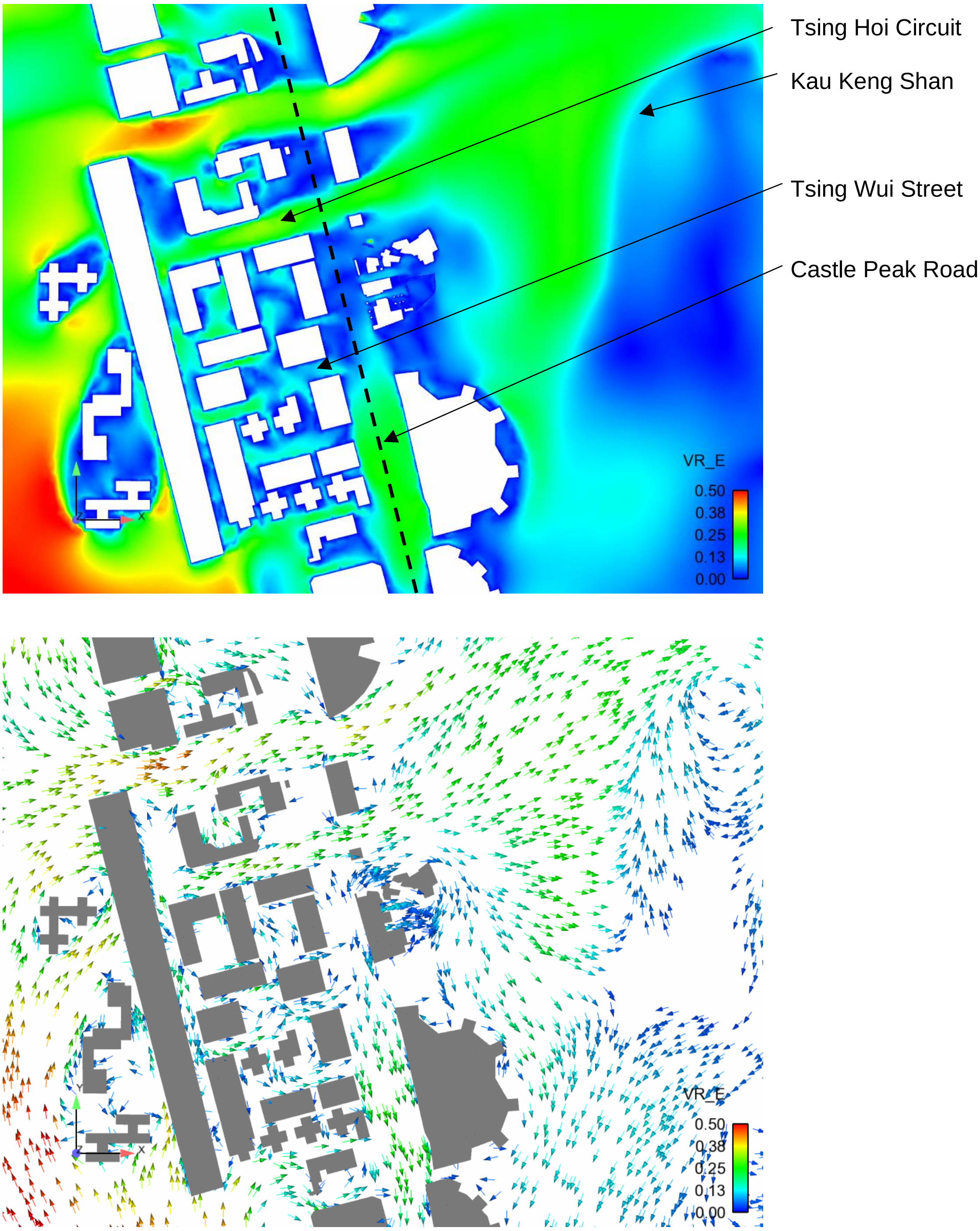
6.12 In the Proposed Scheme, similarly, the induced air flow would adopt Tsing Hoi Circuit to reach the Project Area and natural slopes of Kau Keng Shan. Incoming wind from Tsing Wui Street would enter Castle Peak Road instead of flowing through the NBA towards Kau Keng Shan.

Baseline Scheme





Proposed Scheme



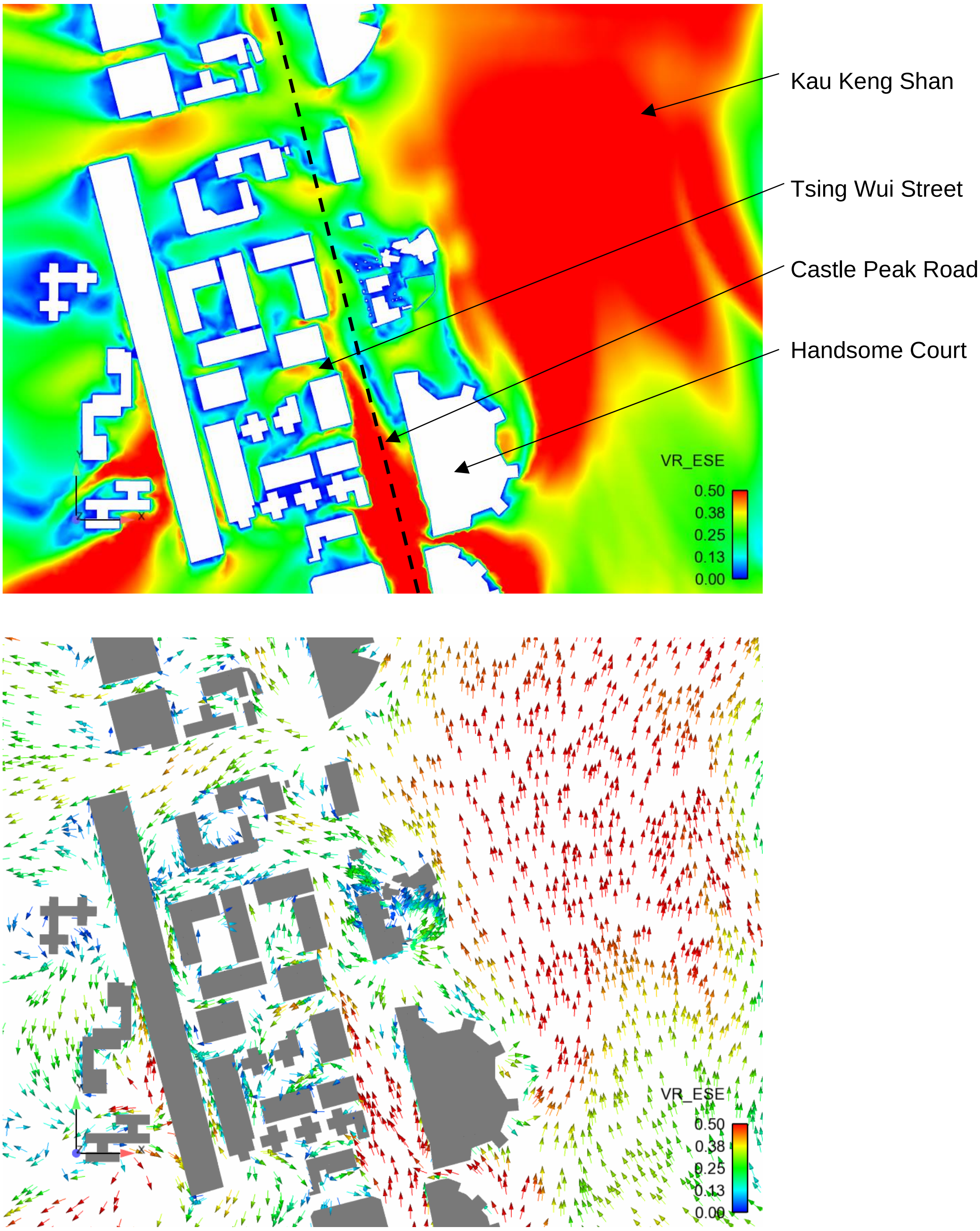
ESE: (Annual: 12.4%; Summer: 8.1%)

6.13 ESE incoming wind was modulated by Kau Keng Shan topography towards south, and then diverted by the high-rise residential development to the south of the Project Area, Handsome Court, creating a wind influencing zone in the Project Area.

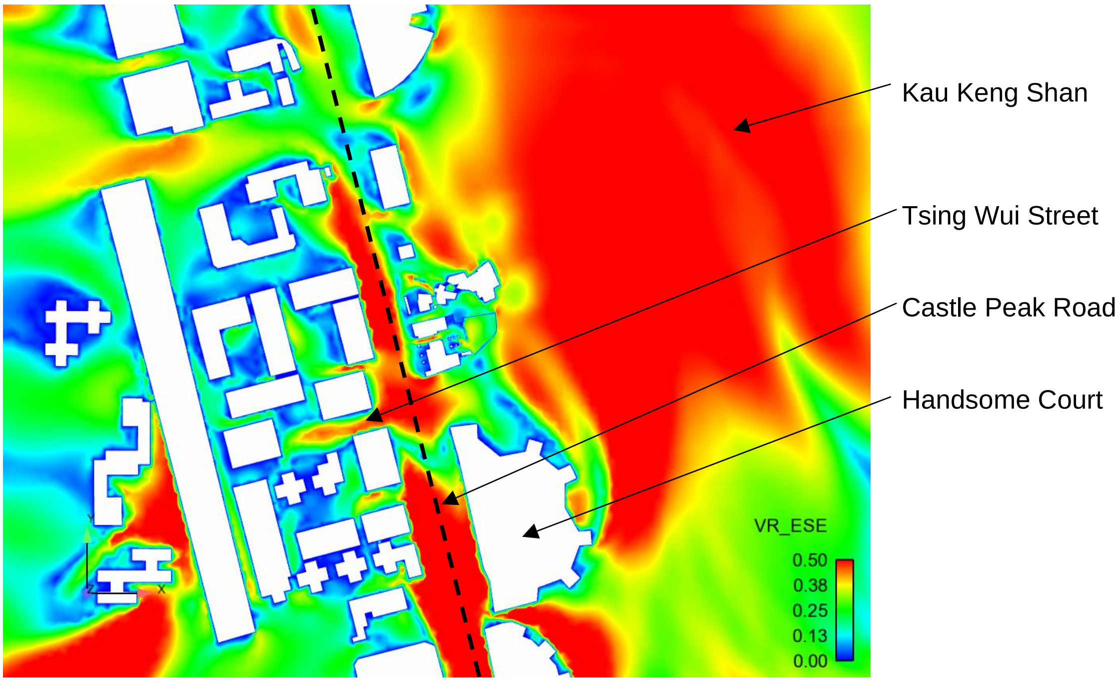
6.14 In the Baseline Scheme, the incoming wind was split by Handsome Court, flowing into Castle Peak Road and natural slopes of Kau Keng Shan. Due to relatively short frontage of the site, the Baseline Scheme would not create a large wake at the leeward region.

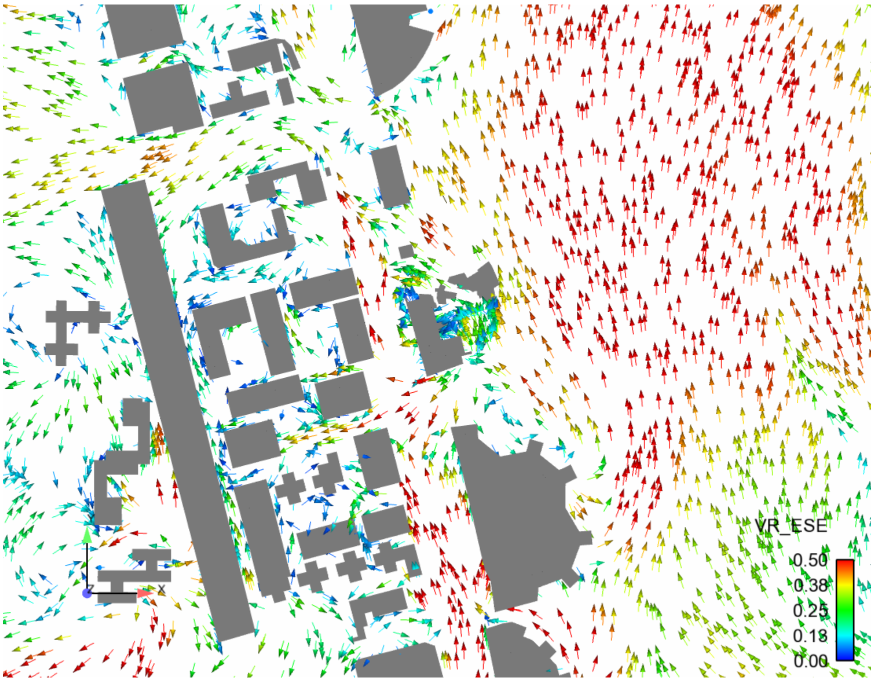
6.15 When compared to Proposed Scheme, the diverted air flow would reach Castle Peak Road and Tsing Wui Street due to the morphology of the Proposed Scheme, resulting a better air ventilation performance in focus area along Castle Peak Road.

Baseline Scheme



Proposed Scheme





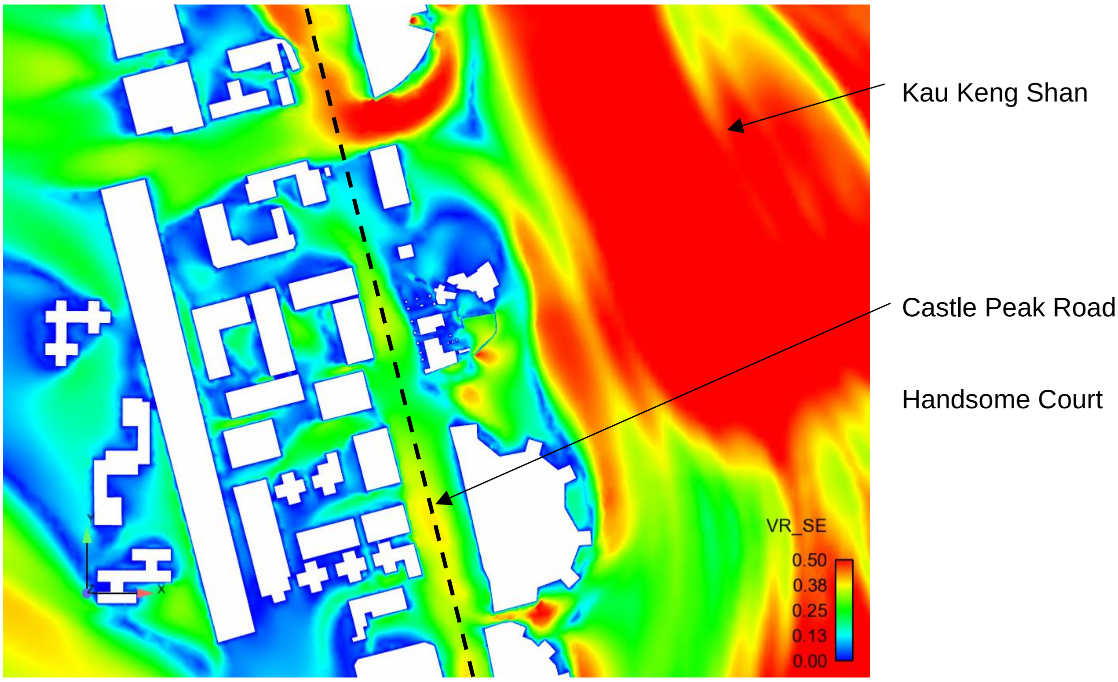
SE: (Annual: 13.8%; Summer: 14.3%)

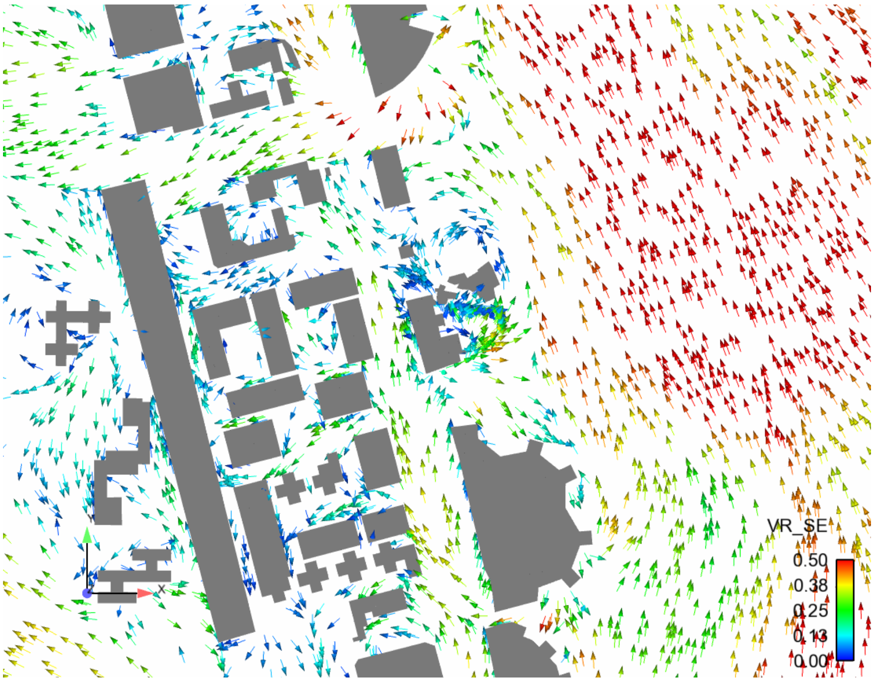
6.16 SE incoming wind flew over the Kau Keng Shan topography freely to the east of the Project Area. A portion of wind adopted Castle Peak Road as the major air path and reached the west perimeter of the Project Area.

6.17 In the Baseline Scheme, the incoming wind was split by Handsome Court and the developments upstream, flowing into Castle Peak Road and natural slopes of Kau Keng Shan. Due to relatively short frontage of the site, the Baseline Scheme would not create a large wake at the leeward region.

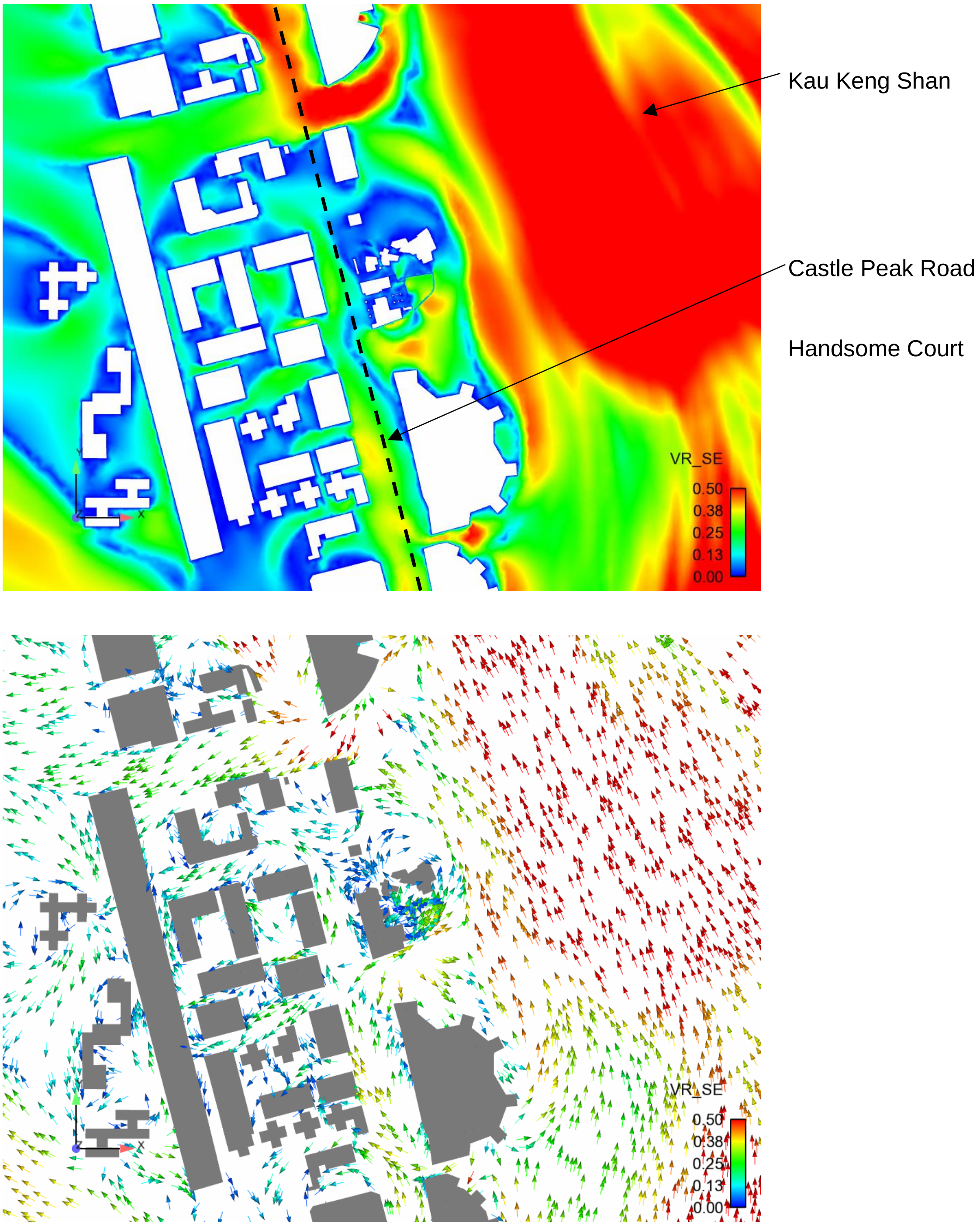
6.18 Similar VR was observed in the Proposed Scheme, indicating a similar air ventilation performance for both schemes.

Baseline Scheme





Proposed Scheme



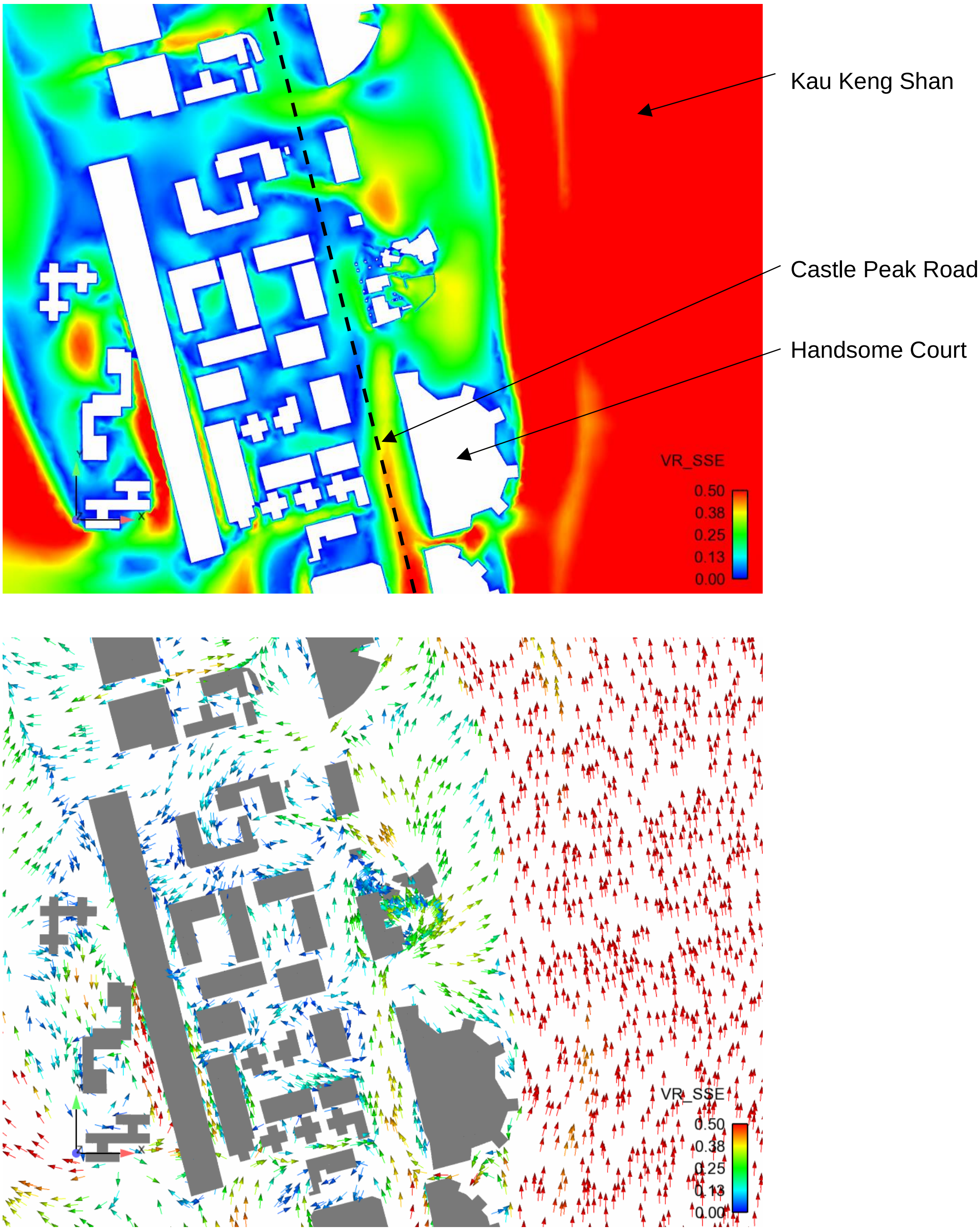
SSE: (Annual: 11.2%; Summer: 21.2%)

6.19 SSE incoming wind flew over the Kau Keng Shan topography freely to the east of the Project Area. A portion of wind adopted Castle Peak Road as the major air path and reached the west perimeter of the Project Area.

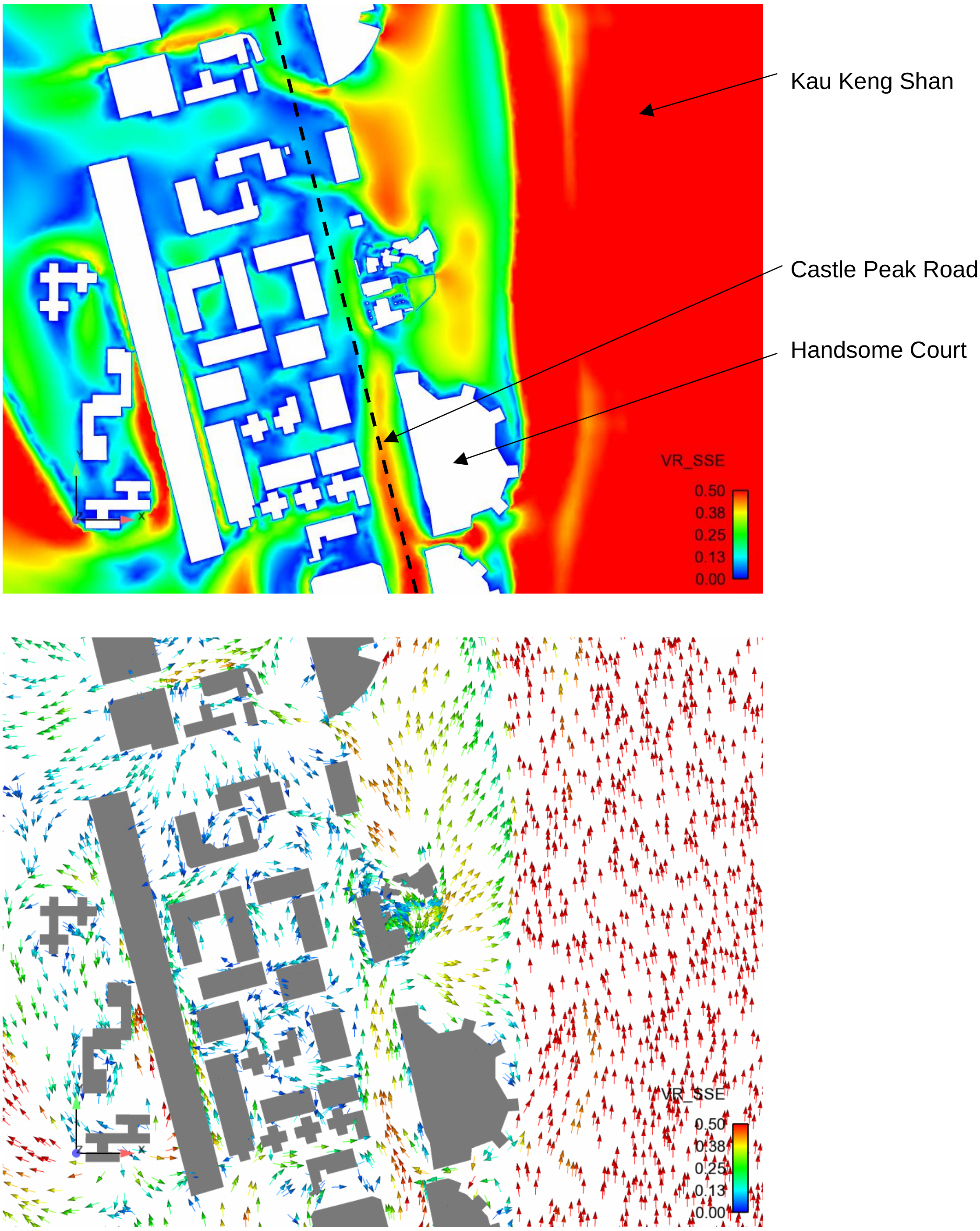
6.20 In the Baseline Scheme, the incoming wind was split by Handsome Court and the developments upstream, flowing into Castle Peak Road and natural slopes of Kau Keng Shan. Due to relatively short frontage of the site, the Baseline Scheme would not create a large wake at the leeward region.

6.21 Similar VR was observed in the Proposed Scheme while there was slightly higher to the east and north of the Project Area, indicating a slightly better air ventilation performance in the immediate vicinity.

Baseline Scheme



Proposed Scheme



VR_SSE
0.50
0.38
0.25
0.13
0.00

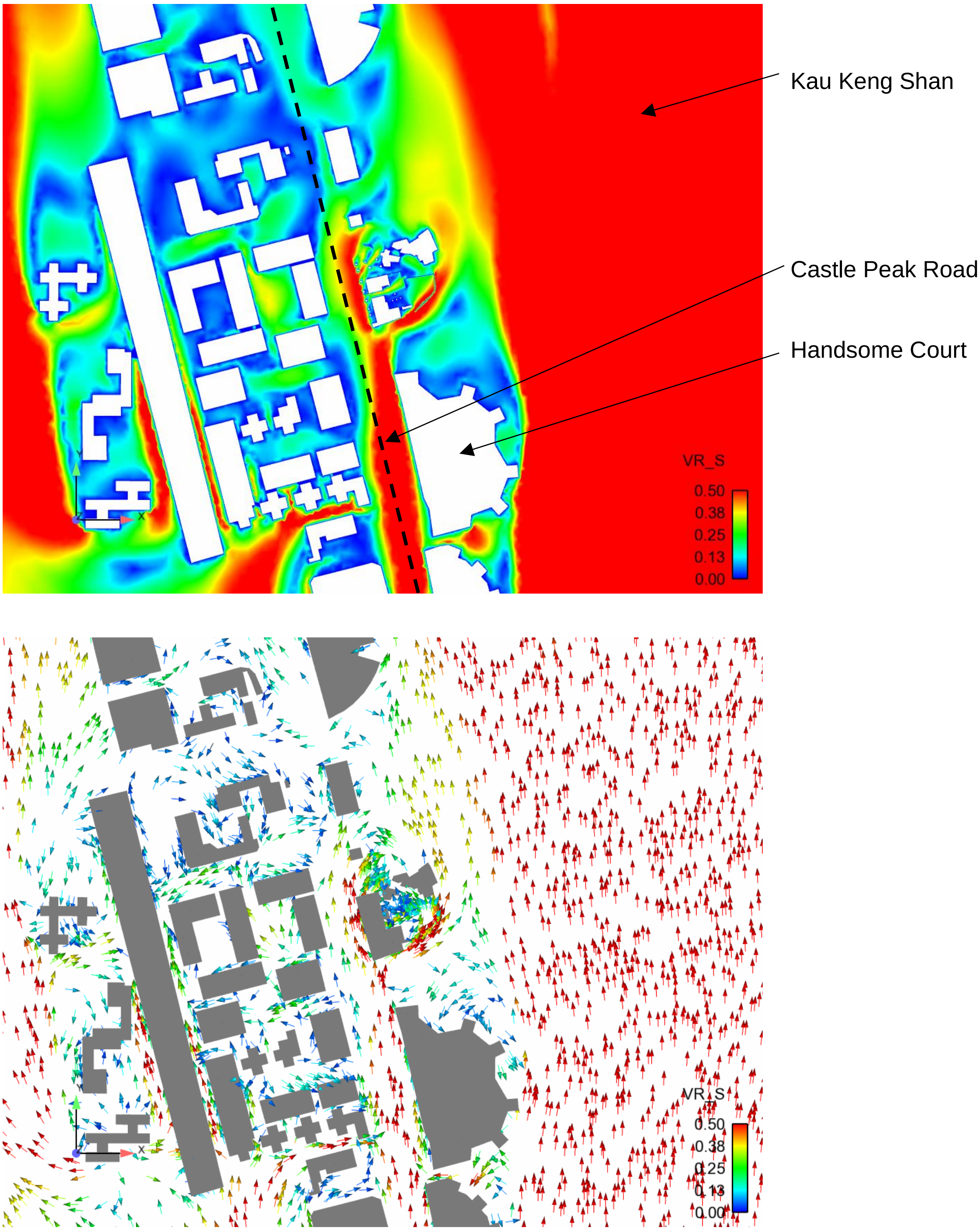
S: (Annual: 6.7%; Summer: 14.1%)

6.22 S incoming wind flew over the Kau Keng Shan topography freely to the east of the Project Area. A portion of wind adopted Castle Peak Road as the major air path and was diverted by the Project Area.

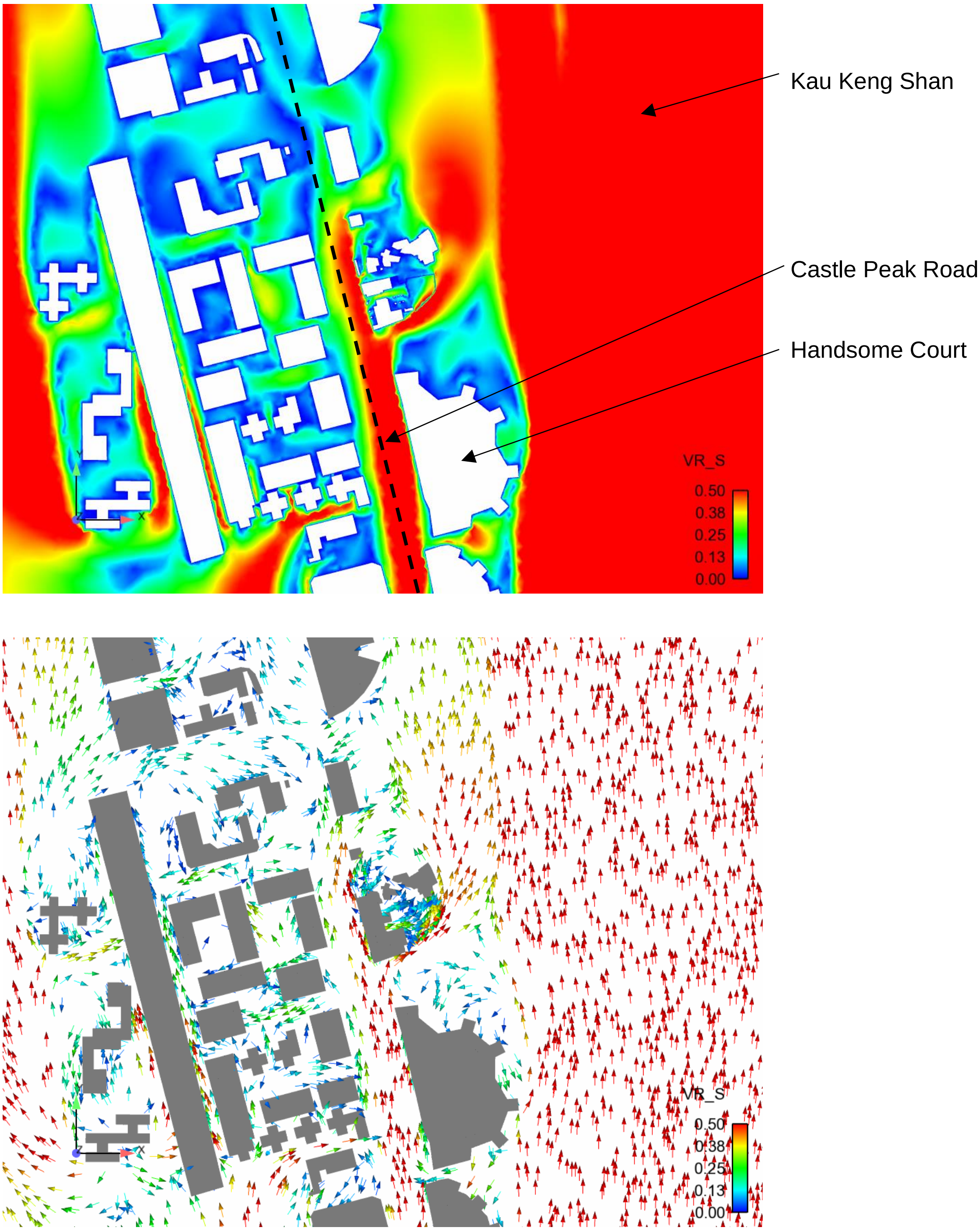
6.23 In the Baseline Scheme, the incoming wind was split by Handsome Court and the developments upstream, flowing into Castle Peak Road and natural slopes of Kau Keng Shan. Due to relatively short frontage of the site, the Baseline Scheme would not create a large wake at the leeward region.

6.24 Similar VR was observed in the Proposed Scheme while there was slightly higher to the northeast of the Project Area, indicating a slightly better air ventilation performance in the immediate vicinity.

Baseline Scheme



Proposed Scheme



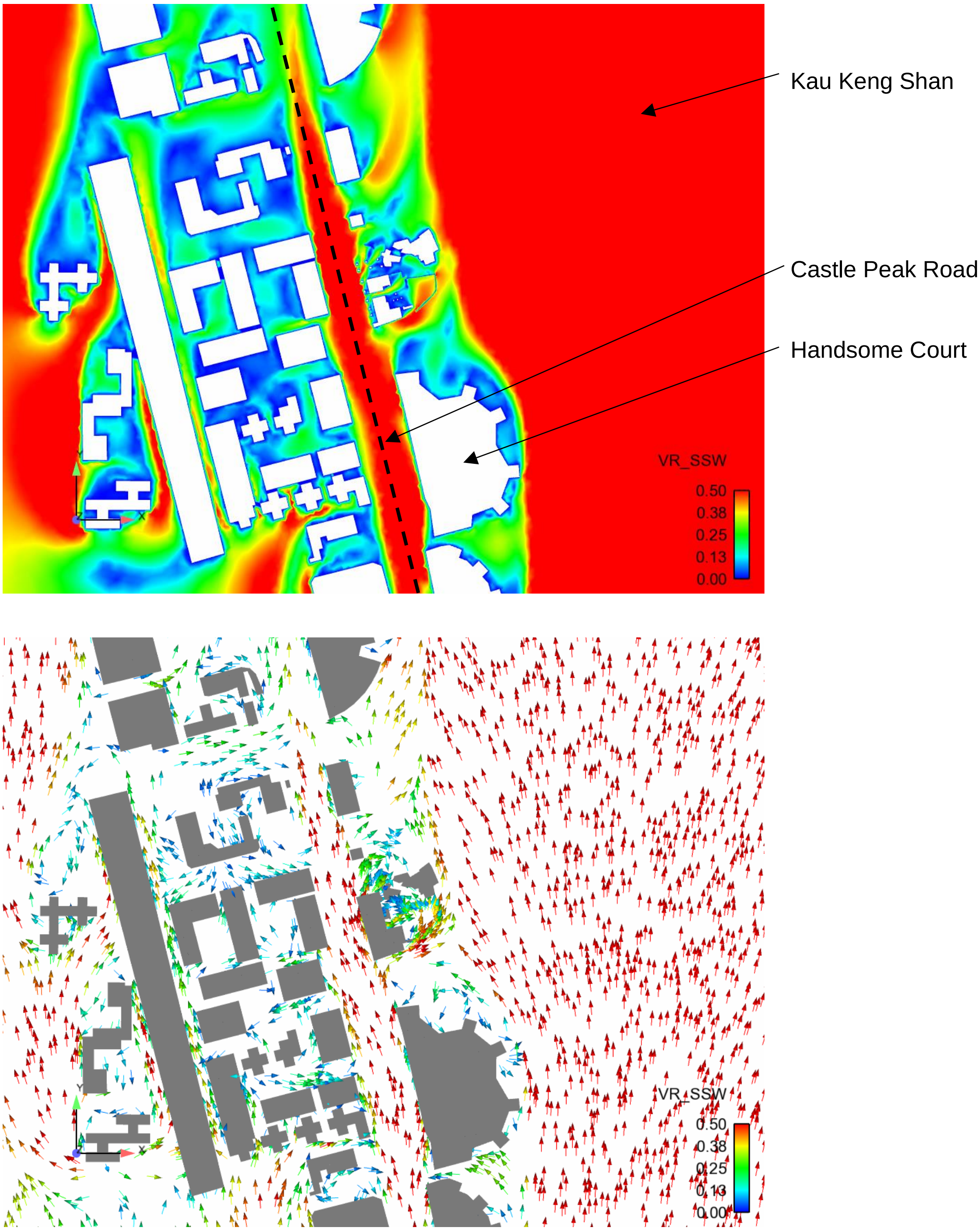
SSW: (Summer: 9.9%)

6.25 SSW incoming wind was modulated by Kau Keng Shan topography and Castle Peak Road to flow through the area freely to the east and west of the Project Area.

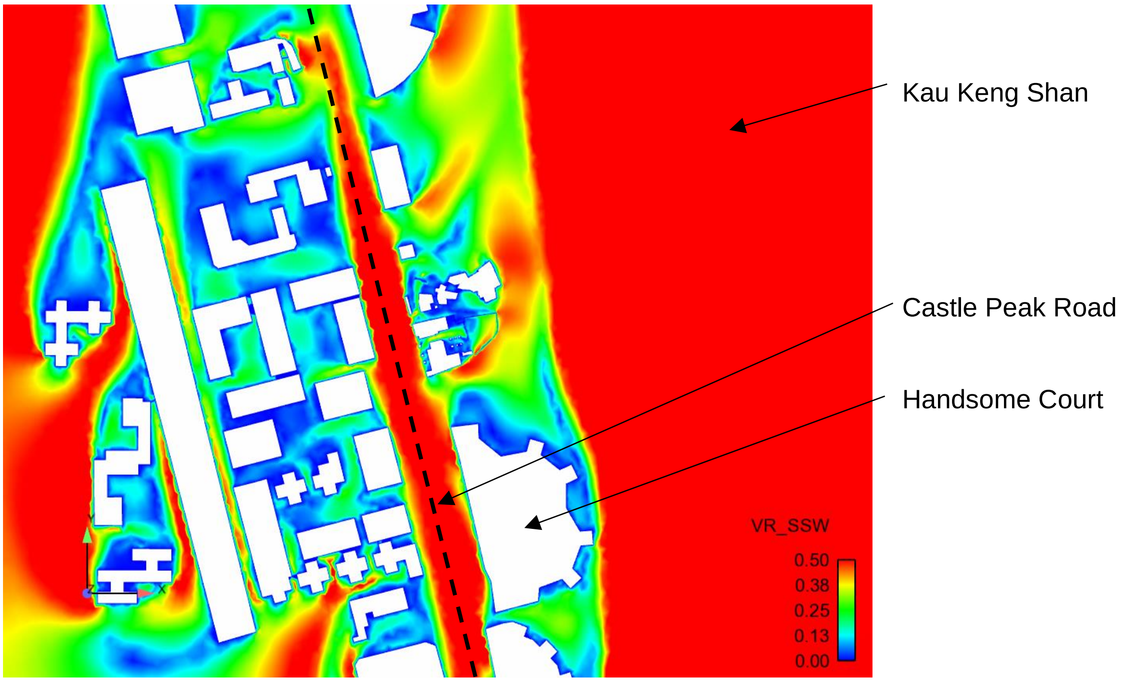
6.26 In the Baseline Scheme, the incoming wind was split by Handsome Court and the developments upstream, flowing into Castle Peak Road and natural slopes of Kau Keng Shan. Due to relatively short frontage of the site, the Baseline Scheme would not create a large wake at the leeward region.

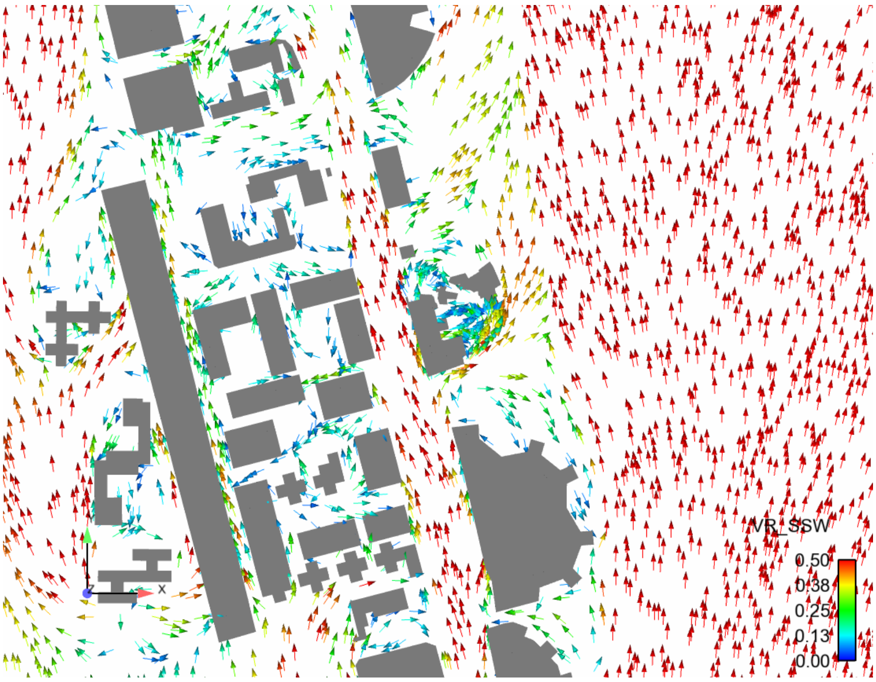
6.27 Similar VR was observed in the Proposed Scheme while there was slightly higher to the northeast of the Project Area, indicating a slightly better air ventilation performance in the immediate vicinity.

Baseline Scheme



Proposed Scheme





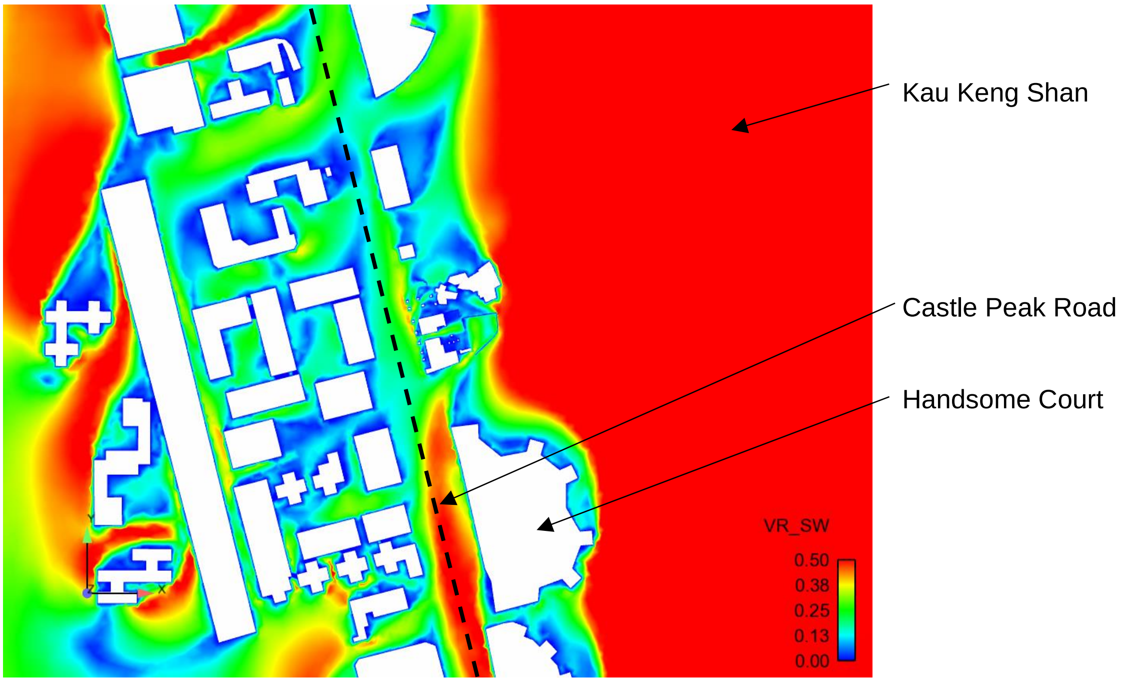
SW: (Summer: 9.2%)

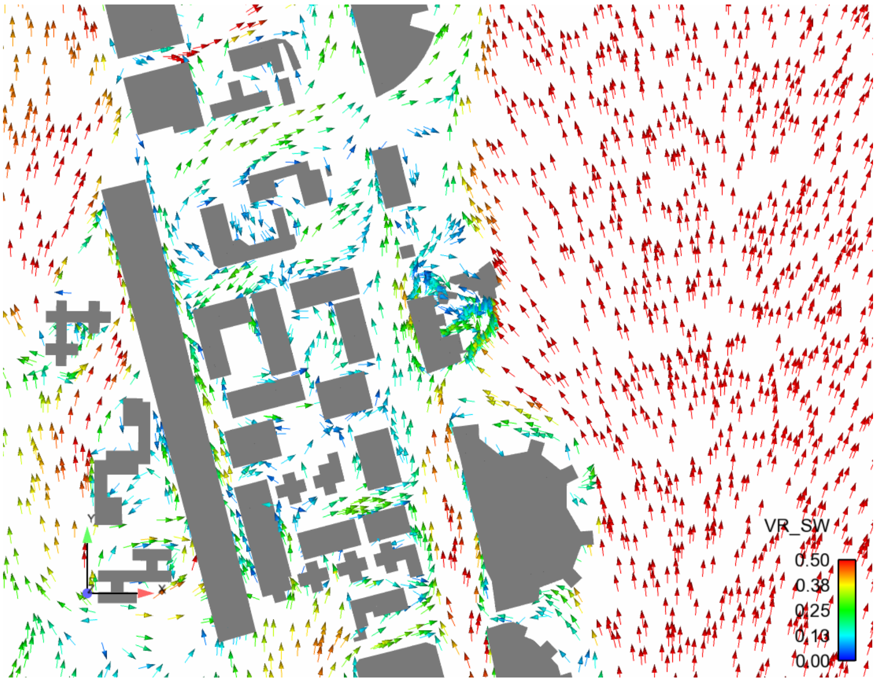
6.28 SW incoming wind was modulated by Kau Keng Shan topography to flow through the area freely to the east of the Project Area. A portion of wind adopted Castle Peak Road as air path and reached the Project Area.

6.29 In the Baseline Scheme, the incoming wind was split by Handsome Court and the developments upstream, flowing into Castle Peak Road and natural slopes of Kau Keng Shan. Due to relatively short frontage of the site, the Baseline Scheme would not create a large wake at the leeward region.

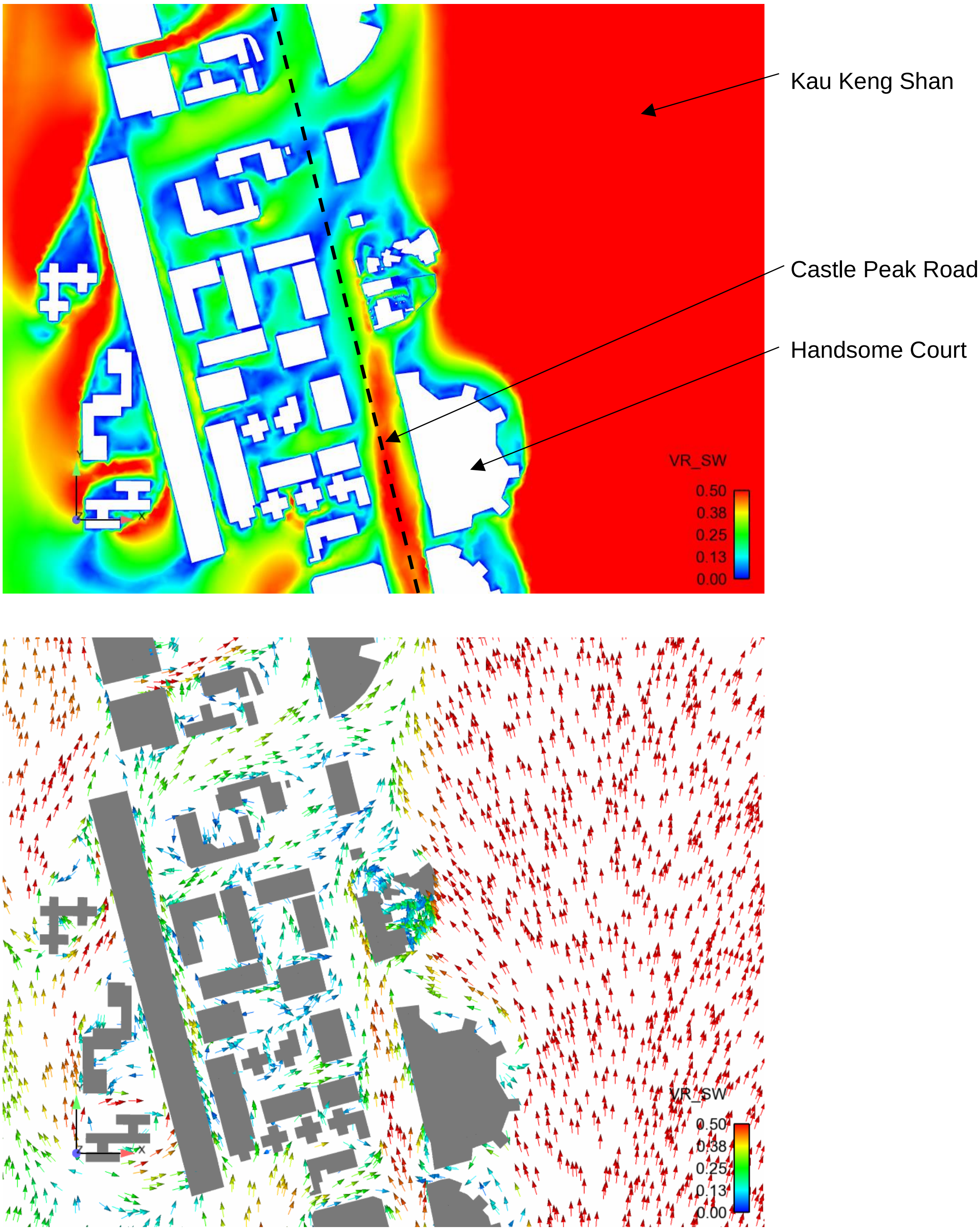
6.30 Similar VR was observed in the Proposed Scheme while there was slightly higher to the northeast of the Project Area, indicating a slightly better air ventilation performance in the immediate vicinity.

Baseline Scheme





Proposed Scheme

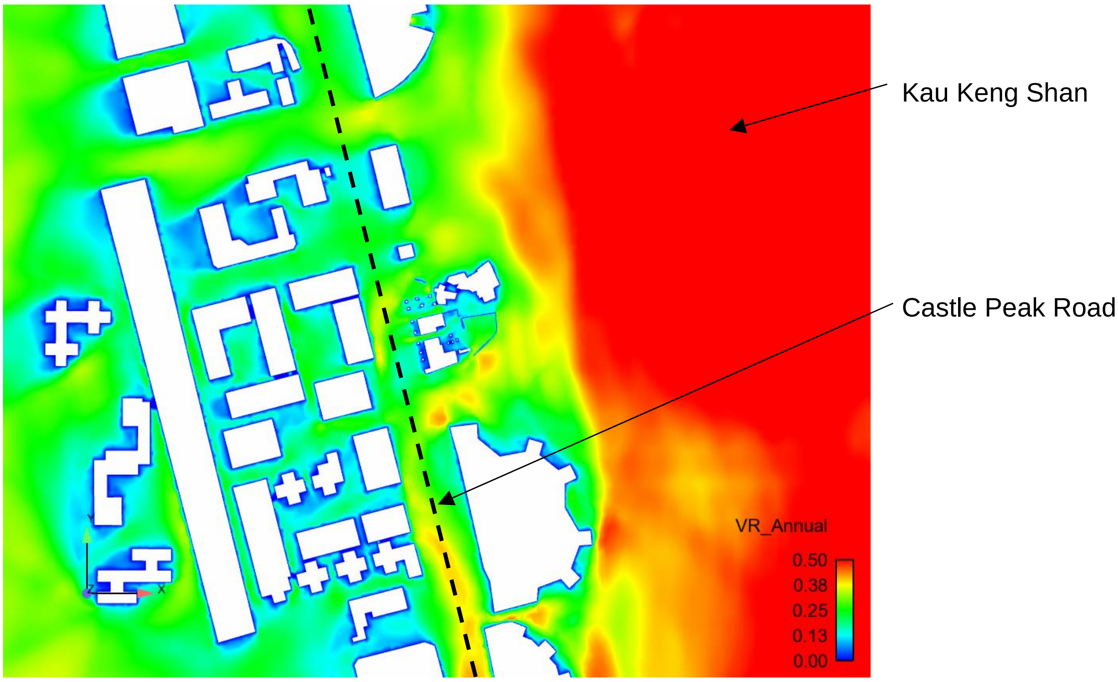


Overall Annual Frequency Weighted VR: (83.1%)

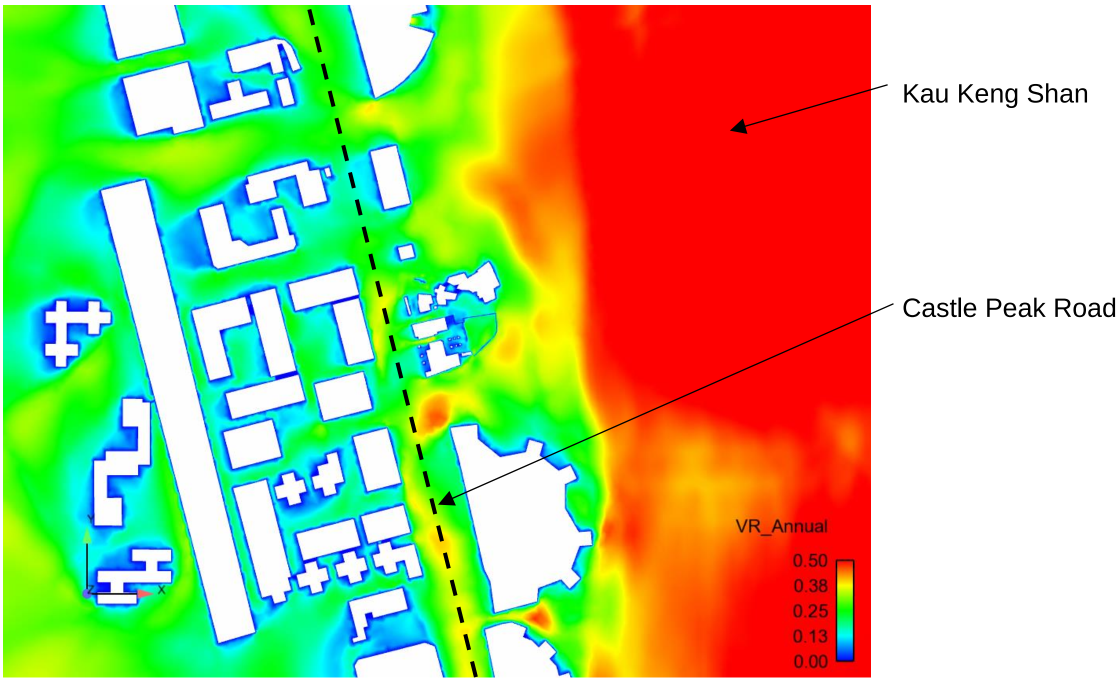
6.31 According to the overall annual frequency weighted VR plot, observable air ventilation enhancements and drawbacks were summarized as follow:

- Domestic block of the Proposed Scheme would divert more south-eastern winds to pedestrian level at southern portion of the site but weaken the wind over the natural slopes of Kau Keng Shan to the northeast

Baseline Scheme



Proposed Scheme

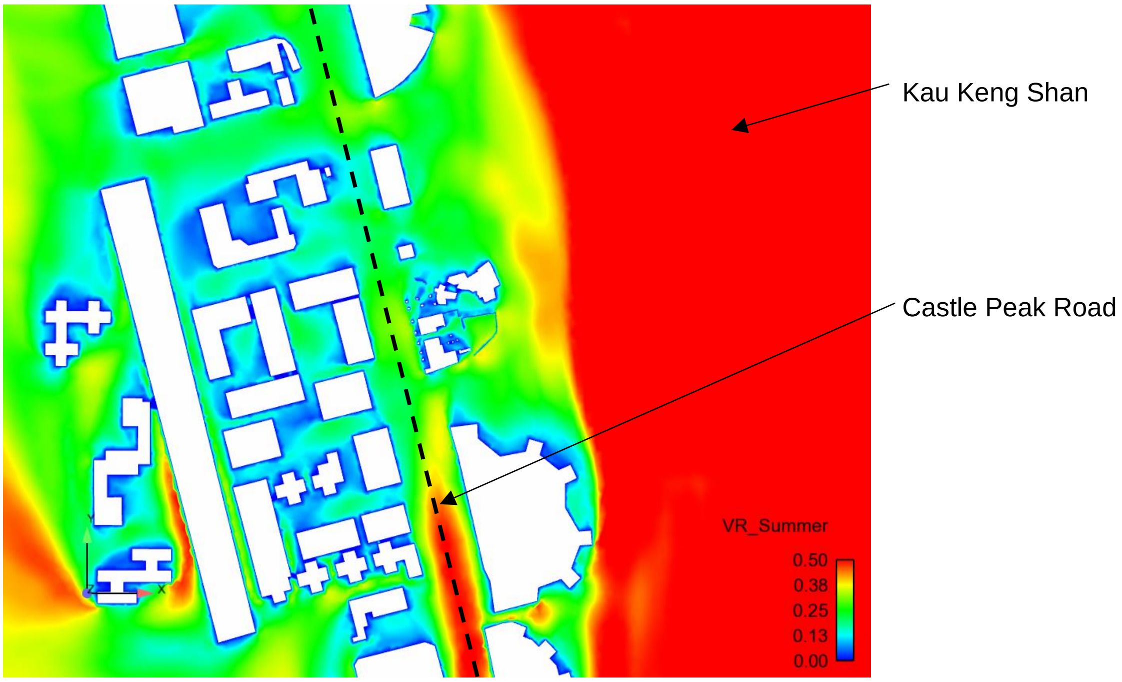


Overall Summer Frequency Weighted VR: (82.7%)

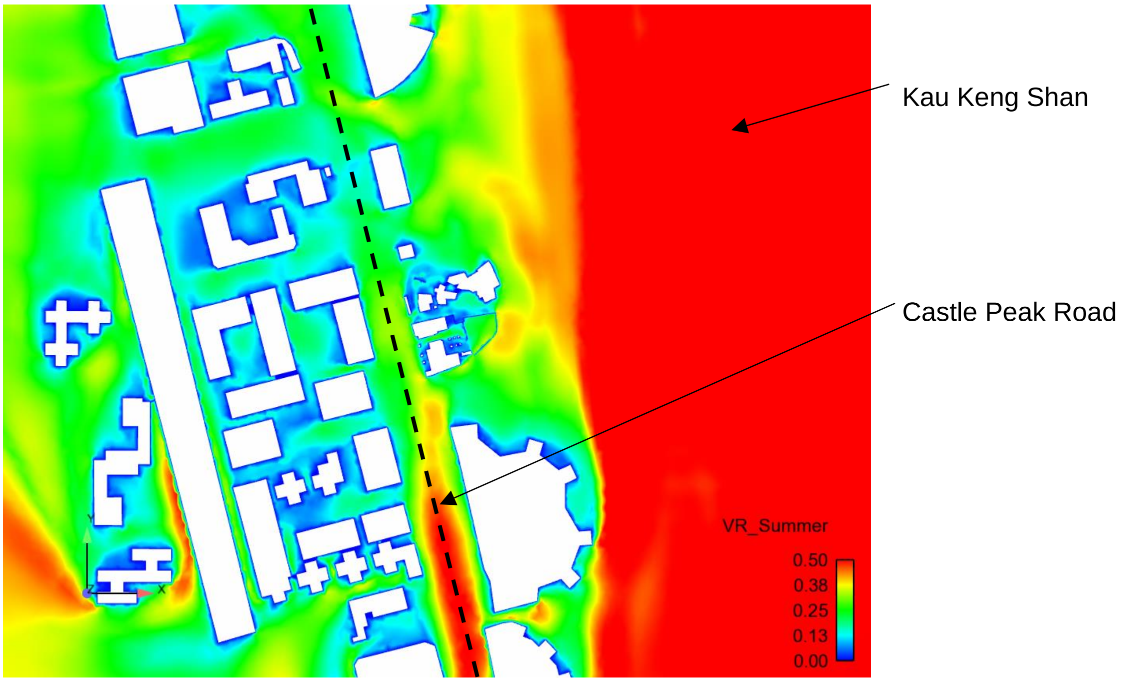
6.32 According to the overall summer frequency weighted VR plot, observable air ventilation enhancements and drawbacks were summarized as follow:

- Domestic block of the Proposed Scheme would divert more southern winds to pedestrian level at natural slopes of Kau Keng Shan to the northeast and downstream to the north

Baseline Scheme



Proposed Scheme



7 SUMMARY AND CONCLUSIONS

7.1 This AVA Study Report aimed at assessing the characteristics of the wind availability of the site, providing a general pattern and a quantitative estimate of wind performance at the pedestrian level under the annual and summer wind directions with the highest occurrence and investigating the effectiveness of ventilation for the scheme designs for the Proposed Public Housing Development at Hin Fat Lane, namely the Baseline Scheme and the Proposed Scheme.

7.2 To mitigate the potential air ventilation impact on site perimeter of the Project Area, several good design features were considered in the Proposed Scheme, such as building setback, empty bays at grade and podium level, stepped podium and elevated podium design, noise mitigation measures other than noise barrier as far as practicable to enhance wind environment in the immediate vicinity.

7.3 From the finding of this AVA Initial Study, the SVRw for both the Baseline Scheme and the Proposed Scheme were maintained at 0.24 under the annual prevailing wind from NNE, NE, ENE, E, ESE, SE, SSE and S directions which accounted for about 83.1% of the whole year time, which indicated a similar air ventilation performance in the vicinity of the Proposed Scheme under annual prevailing winds. This was due to the fact that the Baseline Scheme and the Proposed Scheme had similar configuration considered in the rezoning application. The Project Area aligned with Castle Peak Road and would not affect the width of Chiu Shun Road and the ventilation performance of Castle Peak Road as a wind corridor under southeast quadrant prevailing winds. Mitigation measures included setback of domestic block from carriageway, minimized podium size and coverage due to non-building area (NBA) at the southern portion, low-rise nature at the northern portion and reserved landscaped deck at 11.7mPD to the east as buffer to Pottery Kiln, increased air permeability such as building void and empty bays would allow prevailing wind to skim over and penetrate through the Project Area to ventilate the pedestrian level around podium.

7.4 The LVRw for the Baseline Scheme and the Proposed Scheme were maintained at 0.25 under the annual wind directions stated above. It could be concluded that the Proposed Scheme would not impact the air ventilation performance compared to Baseline Scheme under the major annual winds.

7.5 From the finding of this AVA Initial Study, the SVRw for the Baseline Scheme and the Proposed Scheme were both 0.23 under the summer prevailing wind from E, ESE, SE, SSE, S, SSW and SW directions which accounted for about 82.7% of the whole year time, which implied no significant impact on the wind environment of the Proposed Scheme when compared to the Baseline Scheme.

7.6 The LVRw for the Baseline Scheme and the Proposed Scheme were increased from 0.23 to 0.24 under summer wind conditions. It could be concluded that the Proposed Scheme would have a slightly better air ventilation performance compared to the Baseline Scheme.

7.7 In addition to the good design features identified, the followings were some general recommendations that would be adopted as far as practical in the detailed design stage of the Project Area to facilitate wind penetration:

- Building Permeability (refer to P in the PNAP APP-152 Sustainable Building Design Guideline);
- Building setback;
- Greenery (preferably tree planting) of no less than 20% for sites below 1 ha, preferably at grade;
- Avoidance of long continuous facades;
- Reference could also be made to recommendations of design measures in the Hong Kong Planning Standards and Guidelines;
- Alternative approach (such as acoustic window and/ or acoustic balcony) in resolving noise issue to eliminate the use of noise barriers for more effective air paths; and
- Elevated podium design to further mitigate the ventilation impact at site perimeter.

7.8 To conclude, according to the simulation results in **Table 5.1**, it was anticipated that the Proposed Scheme would have similar slightly better pedestrian wind environment when compared with the Baseline Scheme under annual and summer wind conditions.

Appendix A

Wind Probability Table

Tabulated Results - Percentage Occurrence of Directional Winds
Annual

d_00730	Wind direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
V infinity (m/s)	Sum	0.033	0.156	0.088	0.045	0.101	0.124	0.138	0.112	0.066	0.039	0.033	0.012	0.012	0.008	0.015	0.018
00_to_01	0.045	0.002	0.003	0.003	0.004	0.008	0.004	0.003	0.003	0.002	0.002	0.001	0.002	0.004	0.001	0.001	0.001
01_to_02	0.091	0.003	0.004	0.007	0.009	0.015	0.011	0.009	0.008	0.006	0.004	0.003	0.002	0.003	0.002	0.002	0.003
02_to_03	0.100	0.004	0.005	0.008	0.008	0.014	0.010	0.011	0.011	0.008	0.004	0.003	0.002	0.002	0.002	0.003	0.003
03_to_04	0.103	0.005	0.008	0.010	0.006	0.014	0.011	0.011	0.011	0.008	0.005	0.004	0.002	0.001	0.001	0.003	0.004
04_to_05	0.107	0.005	0.011	0.012	0.005	0.014	0.011	0.013	0.012	0.008	0.005	0.004	0.001	0.001	0.000	0.002	0.003
05_to_06	0.109	0.004	0.014	0.012	0.004	0.011	0.013	0.013	0.014	0.009	0.005	0.004	0.001	0.000	0.000	0.001	0.002
06_to_07	0.104	0.003	0.017	0.011	0.003	0.008	0.014	0.016	0.014	0.008	0.004	0.004	0.000	0.000	0.000	0.001	0.001
07_to_08	0.093	0.002	0.017	0.009	0.002	0.006	0.012	0.016	0.014	0.007	0.003	0.003	0.000	0.000	0.000	0.000	0.001
08_to_09	0.078	0.002	0.018	0.006	0.001	0.004	0.011	0.014	0.011	0.005	0.002	0.002	0.000	0.000	0.000	0.000	0.000
09_to_10	0.059	0.001	0.017	0.004	0.001	0.003	0.009	0.011	0.006	0.003	0.001	0.002	0.000	0.000	0.000	0.000	0.000
10_to_11	0.041	0.001	0.014	0.002	0.001	0.002	0.007	0.008	0.003	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
11_to_12	0.029	0.000	0.011	0.001	0.000	0.001	0.005	0.006	0.002	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000
12_to_13	0.018	0.000	0.008	0.001	0.000	0.001	0.003	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13_to_14	0.010	0.000	0.004	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14_to_15	0.005	0.000	0.002	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15_to_16	0.003	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16_to_17	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17_to_18	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18_to_19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19_to_20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20_to_21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21_to_22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22_to_23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23_to_24	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Tabulated Results - Percentage Occurrence of Directional Winds
Summer

d_00730	Wind direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
V infinity (m/s)	Sum	0.012	0.016	0.017	0.023	0.059	0.081	0.143	0.212	0.141	0.099	0.092	0.028	0.027	0.014	0.023	0.012
00_to_01	0.039	0.001	0.001	0.002	0.002	0.006	0.003	0.004	0.003	0.003	0.002	0.001	0.002	0.005	0.001	0.001	0.001
01_to_02	0.090	0.002	0.003	0.003	0.003	0.006	0.008	0.012	0.013	0.011	0.008	0.005	0.005	0.006	0.003	0.002	0.001
02_to_03	0.106	0.001	0.002	0.002	0.002	0.006	0.006	0.013	0.018	0.016	0.010	0.008	0.006	0.005	0.004	0.004	0.003
03_to_04	0.108	0.001	0.002	0.002	0.002	0.006	0.006	0.012	0.019	0.017	0.012	0.010	0.006	0.004	0.002	0.005	0.002
04_to_05	0.108	0.001	0.001	0.002	0.002	0.007	0.005	0.013	0.022	0.017	0.014	0.011	0.003	0.002	0.001	0.004	0.002
05_to_06	0.112	0.001	0.001	0.002	0.002	0.005	0.007	0.014	0.028	0.021	0.014	0.010	0.001	0.001	0.001	0.003	0.001
06_to_07	0.109	0.001	0.002	0.001	0.002	0.005	0.010	0.015	0.027	0.018	0.010	0.013	0.001	0.001	0.001	0.002	0.000
07_to_08	0.096	0.001	0.002	0.001	0.002	0.003	0.008	0.012	0.029	0.015	0.007	0.010	0.001	0.001	0.001	0.001	0.000
08_to_09	0.081	0.001	0.001	0.001	0.001	0.003	0.008	0.013	0.024	0.011	0.007	0.008	0.001	0.001	0.000	0.001	0.000
09_to_10	0.056	0.000	0.001	0.000	0.001	0.003	0.006	0.011	0.013	0.007	0.005	0.007	0.001	0.000	0.000	0.000	0.000
10_to_11	0.035	0.000	0.000	0.001	0.001	0.002	0.004	0.008	0.007	0.002	0.004	0.003	0.001	0.000	0.000	0.000	0.000
11_to_12	0.021	0.000	0.000	0.000	0.000	0.002	0.003	0.005	0.003	0.001	0.002	0.002	0.000	0.000	0.000	0.000	0.000
12_to_13	0.014	0.000	0.000	0.000	0.000	0.001	0.003	0.004	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
13_to_14	0.008	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
14_to_15	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15_to_16	0.005	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16_to_17	0.002	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17_to_18	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18_to_19	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19_to_20	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20_to_21	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21_to_22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22_to_23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23_to_24	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix B

Wind Velocity Ratios

VRs of Baseline Scheme

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	Annual	Summer
Annual	**15.6%**	**8.8%**	**4.5%**	**10.1%**	**12.4%**	**13.8%**	**11.2%**	**6.7%**			**83.1%**	
Summer				**5.9%**	**8.1%**	**14.3%**	**21.2%**	**14.1%**	**9.9%**	**9.2%**		**82.7%**
O1	0.45	0.15	0.58	0.05	0.62	0.37	0.18	0.28	0.38	0.27	0.34	0.30
O2	0.46	0.58	0.59	0.03	0.52	0.34	0.07	0.13	0.37	0.18	0.34	0.21
O3	0.22	0.73	0.43	0.02	0.46	0.32	0.02	0.04	0.41	0.12	0.27	0.18
O4	0.29	0.56	0.09	0.10	0.46	0.29	0.06	0.05	0.48	0.14	0.26	0.20
O5	0.26	0.52	0.51	0.05	0.35	0.23	0.12	0.10	0.50	0.15	0.25	0.20
O6	0.39	0.83	0.70	0.13	0.40	0.26	0.16	0.24	0.49	0.16	0.36	0.25
O7	0.31	0.84	0.55	0.03	0.40	0.32	0.13	0.28	0.56	0.15	0.33	0.26
O8	0.14	0.57	0.22	0.04	0.33	0.30	0.08	0.20	0.55	0.09	0.23	0.22
O9	0.12	0.42	0.28	0.09	0.22	0.26	0.02	0.03	0.42	0.05	0.17	0.14
O10	0.17	0.62	0.28	0.24	0.34	0.25	0.04	0.08	0.41	0.14	0.24	0.18
O11	0.16	0.30	0.44	0.10	0.31	0.13	0.18	0.07	0.32	0.21	0.20	0.18
O12	0.20	0.22	0.48	0.04	0.16	0.10	0.04	0.07	0.29	0.03	0.14	0.10
O13	0.22	0.44	0.59	0.22	0.27	0.38	0.19	0.04	0.22	0.10	0.28	0.20
O14	0.27	0.46	0.61	0.29	0.27	0.49	0.31	0.16	0.41	0.16	0.34	0.30
O15	0.27	0.05	0.24	0.07	0.25	0.09	0.06	0.12	0.47	0.15	0.15	0.15
O16	0.23	0.14	0.08	0.13	0.13	0.08	0.11	0.17	0.53	0.17	0.14	0.18
O17	0.20	0.25	0.21	0.11	0.36	0.13	0.27	0.17	0.50	0.21	0.21	0.25
O18	0.09	0.15	0.17	0.14	0.37	0.24	0.27	0.62	0.52	0.40	0.24	0.37
O19	0.11	0.19	0.07	0.04	0.06	0.22	0.28	0.59	0.47	0.37	0.18	0.32
O20	0.06	0.14	0.08	0.06	0.19	0.23	0.36	0.59	0.55	0.46	0.20	0.37
O21	0.50	0.93	0.62	0.10	0.25	0.23	0.35	0.55	0.50	0.42	0.40	0.36
O22	0.16	0.66	0.28	0.26	0.17	0.10	0.06	0.14	0.10	0.20	0.21	0.13
O23	0.16	0.72	0.43	0.27	0.16	0.06	0.09	0.17	0.16	0.21	0.22	0.14
O24	0.10	0.62	0.42	0.28	0.18	0.08	0.12	0.14	0.14	0.18	0.21	0.14
O25	0.38	0.48	0.05	0.23	0.24	0.14	0.10	0.11	0.11	0.09	0.23	0.13
O26	0.19	0.35	0.13	0.20	0.38	0.26	0.10	0.28	0.14	0.10	0.24	0.20
O27	0.09	0.42	0.09	0.05	0.08	0.08	0.07	0.05	0.16	0.11	0.11	0.08
O28	0.08	0.51	0.21	0.03	0.15	0.11	0.11	0.13	0.17	0.25	0.15	0.13
O29	0.06	0.25	0.07	0.04	0.20	0.14	0.14	0.10	0.08	0.27	0.13	0.14
O30	0.15	0.86	0.67	0.14	0.10	0.11	0.04	0.18	0.04	0.19	0.23	0.11
O31	0.21	0.78	0.67	0.12	0.24	0.08	0.11	0.22	0.11	0.16	0.25	0.14
O32	0.20	0.20	0.17	0.06	0.32	0.27	0.18	0.33	0.14	0.13	0.22	0.21
O33	0.14	0.44	0.45	0.09	0.29	0.20	0.12	0.33	0.10	0.05	0.23	0.17
O34	0.19	0.45	0.38	0.11	0.15	0.10	0.10	0.24	0.06	0.17	0.19	0.13
O35	0.10	0.33	0.23	0.05	0.23	0.15	0.16	0.30	0.08	0.13	0.18	0.17
O36	0.04	0.49	0.12	0.07	0.30	0.21	0.04	0.17	0.02	0.22	0.17	0.14
O37	0.22	0.31	0.20	0.05	0.09	0.11	0.14	0.07	0.14	0.05	0.15	0.10
O38	0.27	0.33	0.48	0.04	0.14	0.17	0.18	0.09	0.11	0.19	0.20	0.14
O39	0.23	0.36	0.26	0.06	0.20	0.07	0.04	0.10	0.11	0.08	0.16	0.08
O40	0.40	0.88	0.59	0.16	0.36	0.13	0.25	0.34	0.32	0.31	0.36	0.26
O41	0.40	0.70	0.47	0.18	0.26	0.02	0.32	0.17	0.15	0.10	0.29	0.18
O42	0.40	0.65	0.50	0.27	0.34	0.05	0.30	0.34	0.22	0.08	0.33	0.23
O43	0.44	0.56	0.41	0.20	0.38	0.07	0.22	0.38	0.40	0.45	0.32	0.28
O44	0.53	0.51	0.53	0.23	0.46	0.32	0.24	0.40	0.65	0.57	0.40	0.39
O45	0.58	0.60	0.59	0.23	0.52	0.39	0.18	0.39	0.70	0.60	0.43	0.40
O46	0.60	0.48	0.57	0.20	0.55	0.40	0.43	0.58	0.74	0.65	0.47	0.51
O47	0.62	0.36	0.56	0.19	0.55	0.45	0.65	0.77	0.79	0.69	0.52	0.62
O48	0.64	0.29	0.56	0.18	0.56	0.54	0.62	0.72	0.83	0.73	0.52	0.62
O49	0.18	0.45	0.63	0.36	0.23	0.55	0.26	0.15	0.21	0.20	0.33	0.28
O50	0.24	0.44	0.42	0.33	0.29	0.48	0.21	0.10	0.26	0.09	0.31	0.25
O51	0.31	0.50	0.52	0.33	0.31	0.33	0.14	0.17	0.36	0.08	0.31	0.23
O52	0.39	0.47	0.55	0.29	0.38	0.04	0.21	0.31	0.35	0.41	0.31	0.26
O53	0.32	0.30	0.26	0.05	0.38	0.16	0.35	0.26	0.43	0.18	0.26	0.27
O54	0.34	0.36	0.39	0.08	0.38	0.27	0.29	0.23	0.39	0.18	0.29	0.27
O55	0.41	0.46	0.59	0.18	0.41	0.15	0.26	0.32	0.32	0.43	0.33	0.29
O56	0.49	0.63	0.65	0.16	0.47	0.25	0.23	0.35	0.58	0.52	0.38	0.35
O57	0.04	0.31	0.13	0.05	0.11	0.05	0.25	0.21	0.17	0.18	0.13	0.16
O58	0.40	0.54	0.37	0.18	0.22	0.05	0.19	0.27	0.21	0.07	0.26	0.17
O59	0.40	0.27	0.37	0.16	0.42	0.03	0.24	0.40	0.44	0.53	0.28	0.30
O60	0.36	0.22	0.37	0.07	0.34	0.12	0.23	0.38	0.37	0.49	0.25	0.28
O61	0.37	0.18	0.37	0.13	0.41	0.08	0.22	0.39	0.44	0.55	0.26	0.30

O62	0.29	0.46	0.20	0.11	0.24	0.24	0.11	0.11	0.09	0.06	0.23	0.14
O63	0.06	0.06	0.15	0.05	0.12	0.11	0.22	0.26	0.19	0.19	0.12	0.18
O64	0.35	0.13	0.21	0.04	0.06	0.06	0.04	0.16	0.19	0.34	0.13	0.12
P1	0.08	0.42	0.12	0.09	0.16	0.06	0.04	0.37	0.52	0.30	0.14	0.20
P2	0.26	0.89	0.56	0.09	0.21	0.05	0.10	0.46	0.59	0.34	0.27	0.25
P3	0.41	0.85	0.67	0.10	0.07	0.02	0.18	0.52	0.62	0.38	0.30	0.27
P4	0.23	0.27	0.30	0.03	0.10	0.08	0.21	0.52	0.62	0.41	0.19	0.29
P5	0.27	0.60	0.49	0.04	0.17	0.18	0.23	0.55	0.61	0.41	0.28	0.32
P6	0.14	0.32	0.19	0.04	0.22	0.21	0.23	0.49	0.53	0.34	0.21	0.30
P7	0.06	0.10	0.07	0.02	0.18	0.18	0.21	0.47	0.46	0.30	0.15	0.27
P8	0.05	0.09	0.07	0.02	0.14	0.12	0.20	0.44	0.40	0.24	0.13	0.24
P9	0.23	0.34	0.17	0.13	0.25	0.11	0.22	0.38	0.34	0.17	0.22	0.23
P10	0.51	0.63	0.15	0.24	0.25	0.14	0.23	0.47	0.44	0.27	0.33	0.29
P11	0.52	0.70	0.27	0.25	0.21	0.13	0.23	0.47	0.36	0.33	0.34	0.28
P12	0.47	0.78	0.43	0.25	0.22	0.29	0.18	0.18	0.25	0.13	0.34	0.21
P13	0.37	0.78	0.39	0.22	0.10	0.19	0.21	0.47	0.47	0.18	0.31	0.27
P14	0.28	0.65	0.39	0.11	0.17	0.15	0.28	0.59	0.49	0.33	0.29	0.32
P15	0.32	0.64	0.55	0.09	0.29	0.46	0.30	0.60	0.47	0.30	0.38	0.38
P16	0.31	0.50	0.46	0.10	0.22	0.32	0.36	0.54	0.41	0.36	0.33	0.36
P17	0.48	0.33	0.50	0.03	0.19	0.34	0.37	0.52	0.40	0.45	0.33	0.36
P18	0.43	0.27	0.47	0.04	0.17	0.29	0.38	0.48	0.48	0.49	0.30	0.36
P19	0.35	0.21	0.29	0.03	0.10	0.05	0.16	0.25	0.19	0.15	0.17	0.15
P20	0.26	0.25	0.19	0.02	0.09	0.07	0.11	0.06	0.13	0.08	0.13	0.09
P21	0.03	0.19	0.24	0.05	0.11	0.14	0.34	0.05	0.08	0.06	0.13	0.15
P22	0.01	0.03	0.04	0.01	0.01	0.02	0.06	0.01	0.02	0.01	0.02	0.03
P23	0.06	0.05	0.08	0.04	0.13	0.08	0.03	0.11	0.07	0.08	0.07	0.07
P24	0.37	0.68	0.41	0.12	0.15	0.07	0.20	0.15	0.10	0.19	0.25	0.14
P25	0.39	0.76	0.56	0.16	0.19	0.12	0.26	0.18	0.16	0.14	0.30	0.18
P26	0.37	0.74	0.56	0.19	0.29	0.10	0.40	0.11	0.13	0.11	0.32	0.21
P27	0.36	0.68	0.49	0.29	0.32	0.07	0.42	0.09	0.25	0.15	0.32	0.24
P28	0.30	0.66	0.38	0.30	0.25	0.04	0.34	0.06	0.11	0.12	0.28	0.17
P29	0.13	0.24	0.15	0.01	0.09	0.03	0.11	0.03	0.08	0.04	0.09	0.06
P30	0.03	0.53	0.07	0.04	0.12	0.04	0.04	0.26	0.28	0.14	0.12	0.13

<u>VRs of Proposed Scheme</u>

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	Annual	Summer
Annual	**15.6%**	**8.8%**	**4.5%**	**10.1%**	**12.4%**	**13.8%**	**11.2%**	**6.7%**			**83.1%**	
Summer				**5.9%**	**8.1%**	**14.3%**	**21.2%**	**14.1%**	**9.9%**	**9.2%**		**82.7%**
O1	0.29	0.07	0.08	0.24	0.64	0.37	0.26	0.29	0.43	0.29	0.31	0.34
O2	0.43	0.50	0.41	0.20	0.54	0.32	0.14	0.21	0.42	0.17	0.35	0.26
O3	0.25	0.76	0.55	0.13	0.29	0.29	0.02	0.16	0.46	0.10	0.28	0.19
O4	0.30	0.59	0.43	0.10	0.41	0.25	0.05	0.17	0.52	0.13	0.28	0.21
O5	0.22	0.19	0.19	0.03	0.50	0.19	0.12	0.20	0.53	0.15	0.21	0.23
O6	0.34	0.76	0.55	0.09	0.38	0.26	0.18	0.26	0.51	0.16	0.33	0.26
O7	0.23	0.73	0.54	0.03	0.53	0.25	0.13	0.29	0.53	0.14	0.32	0.26
O8	0.14	0.56	0.39	0.06	0.56	0.21	0.10	0.24	0.57	0.07	0.27	0.24
O9	0.08	0.52	0.26	0.11	0.50	0.23	0.08	0.10	0.50	0.04	0.23	0.20
O10	0.08	0.57	0.13	0.23	0.52	0.14	0.05	0.04	0.43	0.16	0.22	0.18
O11	0.09	0.29	0.40	0.02	0.49	0.08	0.08	0.12	0.37	0.24	0.18	0.18
O12	0.18	0.18	0.38	0.03	0.43	0.17	0.09	0.07	0.29	0.08	0.19	0.15
O13	0.25	0.48	0.61	0.25	0.18	0.38	0.06	0.02	0.22	0.15	0.26	0.16
O14	0.27	0.47	0.61	0.29	0.26	0.51	0.03	0.15	0.43	0.17	0.31	0.24
O15	0.26	0.05	0.20	0.06	0.16	0.16	0.06	0.15	0.46	0.08	0.14	0.15
O16	0.26	0.14	0.07	0.03	0.08	0.06	0.08	0.23	0.50	0.15	0.12	0.16
O17	0.22	0.22	0.14	0.14	0.36	0.12	0.16	0.25	0.49	0.10	0.20	0.22
O18	0.05	0.08	0.07	0.23	0.45	0.17	0.26	0.63	0.49	0.35	0.23	0.36
O19	0.08	0.13	0.04	0.23	0.32	0.13	0.27	0.61	0.45	0.36	0.21	0.34
O20	0.05	0.12	0.03	0.19	0.11	0.08	0.37	0.63	0.52	0.44	0.18	0.35
O21	0.44	0.94	0.71	0.13	0.49	0.27	0.36	0.62	0.48	0.44	0.45	0.41
O22	0.10	0.65	0.55	0.30	0.15	0.19	0.11	0.13	0.11	0.19	0.23	0.15
O23	0.13	0.68	0.66	0.31	0.13	0.09	0.09	0.17	0.18	0.22	0.23	0.15
O24	0.05	0.59	0.63	0.29	0.07	0.15	0.07	0.13	0.14	0.18	0.20	0.13
O25	0.34	0.54	0.14	0.12	0.47	0.10	0.10	0.14	0.12	0.09	0.25	0.14
O26	0.18	0.29	0.17	0.10	0.42	0.24	0.10	0.28	0.17	0.08	0.22	0.19
O27	0.09	0.45	0.26	0.05	0.16	0.06	0.09	0.05	0.17	0.11	0.13	0.09
O28	0.09	0.48	0.25	0.07	0.15	0.10	0.12	0.15	0.15	0.25	0.16	0.14
O29	0.12	0.31	0.26	0.09	0.34	0.17	0.15	0.12	0.08	0.27	0.19	0.17
O30	0.17	0.82	0.65	0.11	0.18	0.11	0.05	0.18	0.07	0.19	0.23	0.12
O31	0.18	0.79	0.68	0.14	0.20	0.08	0.08	0.20	0.10	0.15	0.24	0.13
O32	0.17	0.31	0.27	0.05	0.36	0.21	0.17	0.34	0.17	0.14	0.23	0.21
O33	0.12	0.46	0.48	0.12	0.23	0.13	0.12	0.32	0.12	0.06	0.21	0.16
O34	0.17	0.47	0.35	0.08	0.12	0.12	0.12	0.22	0.05	0.17	0.18	0.13
O35	0.08	0.21	0.13	0.08	0.13	0.23	0.16	0.26	0.07	0.14	0.15	0.17
O36	0.07	0.42	0.08	0.04	0.33	0.14	0.08	0.17	0.02	0.23	0.16	0.14
O37	0.23	0.28	0.11	0.06	0.18	0.22	0.16	0.06	0.02	0.07	0.18	0.12
O38	0.27	0.26	0.18	0.06	0.11	0.17	0.31	0.11	0.10	0.19	0.19	0.18
O39	0.21	0.34	0.16	0.09	0.09	0.08	0.10	0.09	0.07	0.08	0.14	0.09
O40	0.38	0.90	0.66	0.05	0.44	0.37	0.23	0.42	0.29	0.22	0.40	0.30
O41	0.39	0.61	0.47	0.09	0.44	0.05	0.37	0.11	0.17	0.06	0.31	0.20
O42	0.39	0.61	0.41	0.14	0.37	0.08	0.40	0.22	0.15	0.21	0.32	0.24
O43	0.43	0.44	0.35	0.13	0.36	0.09	0.31	0.47	0.42	0.45	0.31	0.32
O44	0.53	0.40	0.40	0.11	0.46	0.30	0.35	0.53	0.48	0.55	0.38	0.40
O45	0.58	0.52	0.48	0.15	0.51	0.38	0.33	0.50	0.50	0.58	0.43	0.42
O46	0.60	0.38	0.45	0.19	0.53	0.40	0.21	0.49	0.77	0.64	0.41	0.44
O47	0.63	0.33	0.42	0.21	0.54	0.48	0.62	0.77	0.81	0.69	0.51	0.62
O48	0.64	0.23	0.37	0.24	0.55	0.55	0.60	0.76	0.84	0.72	0.51	0.63
O49	0.14	0.42	0.59	0.38	0.21	0.58	0.34	0.20	0.20	0.24	0.34	0.32
O50	0.21	0.39	0.38	0.29	0.26	0.51	0.40	0.14	0.23	0.16	0.32	0.31
O51	0.28	0.45	0.48	0.25	0.30	0.35	0.38	0.24	0.33	0.12	0.33	0.30
O52	0.35	0.54	0.50	0.16	0.37	0.06	0.37	0.35	0.35	0.35	0.31	0.29
O53	0.28	0.43	0.26	0.10	0.38	0.23	0.43	0.19	0.40	0.16	0.29	0.29
O54	0.30	0.45	0.38	0.05	0.36	0.28	0.42	0.25	0.31	0.21	0.31	0.30
O55	0.38	0.53	0.56	0.14	0.40	0.10	0.37	0.38	0.37	0.38	0.33	0.31
O56	0.48	0.66	0.55	0.25	0.46	0.22	0.34	0.44	0.32	0.49	0.41	0.35
O57	0.06	0.21	0.20	0.03	0.31	0.07	0.28	0.04	0.08	0.08	0.15	0.14
O58	0.40	0.38	0.34	0.06	0.35	0.07	0.28	0.25	0.29	0.19	0.26	0.22
O59	0.40	0.13	0.23	0.08	0.42	0.06	0.30	0.48	0.46	0.52	0.26	0.33
O60	0.36	0.22	0.24	0.08	0.33	0.10	0.32	0.39	0.41	0.48	0.25	0.31
O61	0.37	0.14	0.21	0.07	0.40	0.03	0.29	0.45	0.45	0.53	0.24	0.31

O62	0.25	0.42	0.36	0.06	0.25	0.29	0.19	0.10	0.09	0.05	0.24	0.16
O63	0.13	0.06	0.03	0.03	0.26	0.06	0.25	0.15	0.22	0.25	0.13	0.18
O64	0.36	0.21	0.28	0.06	0.29	0.04	0.09	0.20	0.24	0.40	0.19	0.17
P1	0.10	0.50	0.29	0.06	0.13	0.06	0.14	0.46	0.52	0.21	0.18	0.23
P2	0.20	0.90	0.64	0.05	0.11	0.06	0.23	0.52	0.56	0.31	0.27	0.27
P3	0.37	0.80	0.58	0.07	0.15	0.06	0.26	0.54	0.58	0.36	0.31	0.30
P4	0.02	0.11	0.09	0.04	0.13	0.02	0.27	0.55	0.60	0.39	0.13	0.30
P5	0.27	0.52	0.46	0.04	0.13	0.11	0.24	0.55	0.58	0.41	0.25	0.31
P6	0.05	0.10	0.10	0.07	0.07	0.14	0.21	0.49	0.52	0.39	0.14	0.28
P7	0.05	0.10	0.07	0.08	0.13	0.11	0.12	0.46	0.45	0.40	0.12	0.24
P8	0.07	0.12	0.09	0.10	0.09	0.09	0.12	0.46	0.41	0.41	0.13	0.24
P9	0.32	0.43	0.28	0.12	0.56	0.30	0.31	0.49	0.36	0.36	0.35	0.36
P10	0.45	0.51	0.29	0.11	0.48	0.31	0.26	0.51	0.39	0.38	0.37	0.35
P11	0.52	0.61	0.39	0.03	0.40	0.32	0.16	0.52	0.32	0.30	0.36	0.30
P12	0.47	0.75	0.52	0.05	0.33	0.20	0.15	0.28	0.30	0.12	0.33	0.21
P13	0.41	0.74	0.48	0.03	0.23	0.25	0.18	0.56	0.47	0.30	0.33	0.30
P14	0.23	0.52	0.39	0.04	0.16	0.14	0.25	0.31	0.31	0.28	0.23	0.23
P15	0.39	0.58	0.55	0.03	0.19	0.34	0.25	0.62	0.48	0.26	0.34	0.34
P16	0.36	0.50	0.36	0.03	0.32	0.37	0.37	0.56	0.42	0.36	0.35	0.38
P17	0.48	0.40	0.31	0.08	0.41	0.32	0.40	0.47	0.42	0.45	0.36	0.38
P18	0.43	0.33	0.32	0.08	0.45	0.29	0.43	0.43	0.46	0.49	0.35	0.39
P19	0.35	0.17	0.26	0.06	0.24	0.07	0.18	0.13	0.18	0.22	0.19	0.15
P20	0.26	0.27	0.11	0.03	0.17	0.07	0.15	0.07	0.05	0.09	0.15	0.10
P21	0.16	0.25	0.06	0.07	0.16	0.14	0.30	0.06	0.09	0.08	0.16	0.15
P22	0.02	0.04	0.03	0.00	0.03	0.03	0.07	0.02	0.01	0.01	0.03	0.03
P23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P24	0.34	0.68	0.42	0.08	0.32	0.06	0.20	0.11	0.05	0.14	0.26	0.14
P25	0.36	0.73	0.53	0.09	0.33	0.08	0.20	0.08	0.17	0.14	0.28	0.15
P26	0.34	0.71	0.51	0.12	0.46	0.06	0.37	0.05	0.12	0.13	0.31	0.20
P27	0.32	0.65	0.46	0.20	0.46	0.03	0.42	0.21	0.28	0.12	0.33	0.26
P28	0.26	0.64	0.43	0.19	0.40	0.04	0.26	0.20	0.19	0.09	0.28	0.19
P29	0.11	0.23	0.15	0.00	0.14	0.01	0.06	0.03	0.03	0.02	0.09	0.04
P30	0.05	0.45	0.18	0.05	0.13	0.03	0.09	0.21	0.18	0.14	0.13	0.12