Hong Kong Housing Authority

Consultancy for Environmental Design Studies for Subsidised Sale Flats Development at On Muk Street Phase 1, Shek Mun, Sha Tin

Air Ventilation Assessment Initial Study

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1 INTRODUCTION

1.1.1 AECOM Asia Co. Ltd was commissioned by the Hong Kong Housing Authority to undertake Air Ventilation Assessment – Initial Study on the proposed Subsidized Sale Flats (SSF) in On Muk Street Phase 1, Sha Tin. The study aimed to compare ventilation performance under Baseline and Proposed Schemes quantitatively by computational fluid dynamics (CFD) simulations, identify impact areas around the subject site and formulate possible measures to mitigate ventilation performance.

1.1.2 The study was carried in accordance with the Housing, Planning and Lands Bureau – Technical Circular No. 1/06, Environment, Transport and Work Bureau – Technical Circular No. 1/06, Air Ventilation Assessment and Annex A of the above mentioned Technical Circular "Technical Guide for Air Ventilation Assessment for Development in Hong Kong".

2 PROJECT AREA

2.1 Site Location

2.1.1 The proposed SSF Development is located at Shek Mun alongside the Siu Lek Yuen Nullah, bounded by On Muk Street on the north-east and On Muk Street Garden on the north-west. The total site area is approximately 0.433 hectares.

2.2 Site Topography

2.2.1 The Project Area is located on a flat terrain, and on which the average street level within 500m of the site is approximately +5 mPD. Terrain starts to elevate on the east side at around 500m from the project site boundary, which is connected with Nui Po Shan.

2.3 Site Vicinity

2.3.1 There are four open areas located in close proximity to the Project Area. Waterfront of Siu Lek Yuen Nullah and On Muk Street Garden are located next to the Project area on the south-west and north-west side respectively. An open area on the south-east side is proposed for future residential development. Siu Lek Yuen Playground is located across the Siu Lek Yuen Nullah on the south-west.

2.3.2 The majority of the buildings on the north-east of the Project area are high rise commercial and industrial buildings. Shatin City One, a large private housing estate with high rise residential buildings, is located across the Siu Lek Yuen Nullah on the south-west. Table 2.1 presents the approximate height of the surrounding buildings and structures.

2.3.3 Tai Chung Kiu Road is an elevated road across the Siu Lek Yuen Nullah with a level of about +8 mPD. Ma On Shan railway is also an elevated structure located about 250m on the south-east of the Project Area.

Figure 2.1 Project Area and its Surroundings

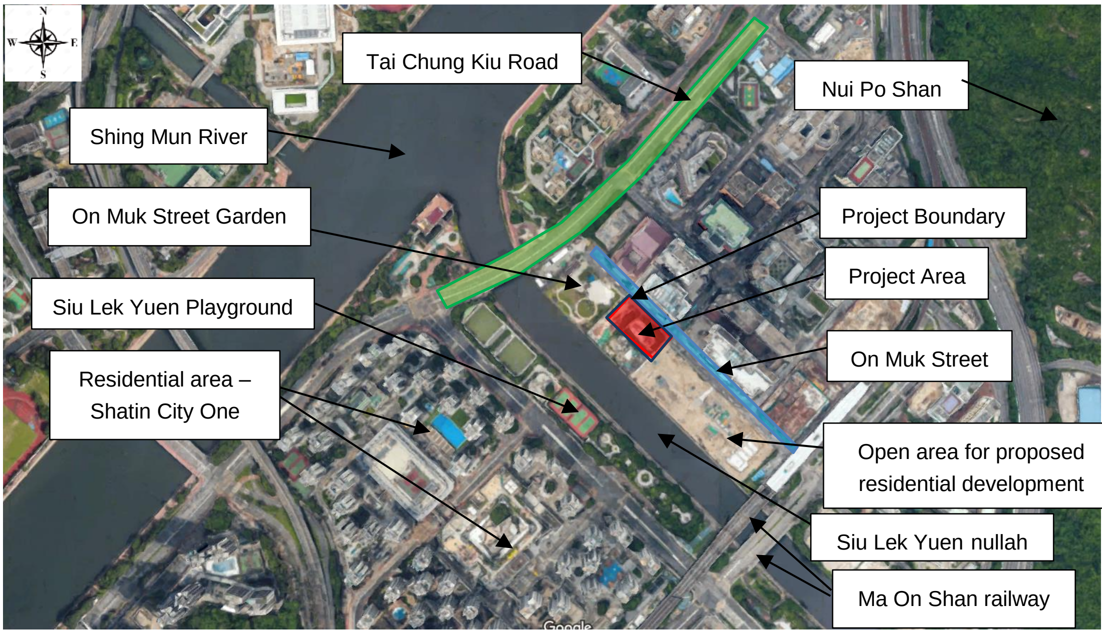


Table 2.1 Height of Surrounding Buildings

Surrounding Buildings	Building Height (mPD)
Residential towers of Shatin City One	80-100
Shopping mall in Shatin City One	~20
Commercial and Industrial buildings in Shek Mun	70-125
Ma On Shan Railway Line	~23
Elevated Tai Chung Kiu Road across Siu Lek Yuen nullah	~8

3 SITE WIND AVAILABILITY

3.1 RAMS Annual Wind Rose

3.1.1 Referred to the RAMS annual wind rose (500m) at grid (087, 058) as shown in Figure 3.1, sum of annual occurrence of wind from the E, ENE, NNE, NE, ESE, SE, SW and SSW exceeds 75%. Therefore, wind direction of E, ENE, NNE, NE, ESE, SE, SW and SSW were selected as the annual prevailing wind directions for the assessment.

3.1.2 Table 3.1 tabulates the annual occurrence of individual prevailing wind direction.

Figure 3.1 RAMS Annual Wind Rose (500m) at Grid (087, 058)

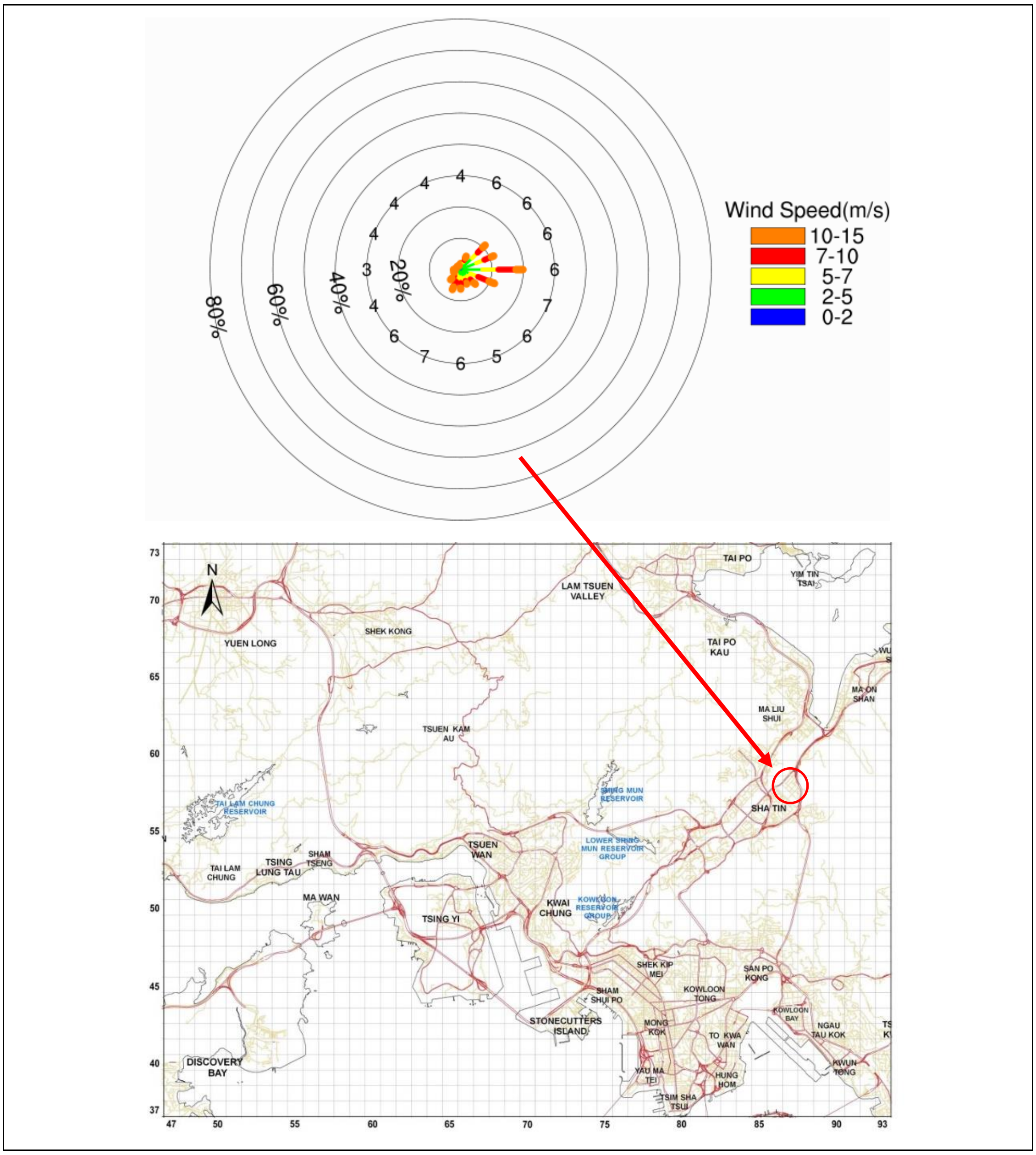


Table 3.1 Occurrence of RAMS Annual Wind Rose (500m) at Grid (087, 058)

Wind Direction (°)	Occurrence (%)
N (0°)	2.7
NNE (22.5°)	10.2
NE (45°)	10.2
ENE (67.5°)	10.4
E (90°)	16.3
ESE (112.5°)	10.2
SE (135°)	5.4
SSE (157.5°)	4.4
S (180°)	4.5
SSW (202.5°)	7.4
SW (225°)	8.6
WSW (247.5°)	2.9
W (270°)	2.2
WNW (292.5°)	0.8
NW (315°)	1.3
NNW (337.5°)	1.2

4 METHODOLOGY FOR INITIAL STUDY

4.1 Technical Details of CFD Simulations

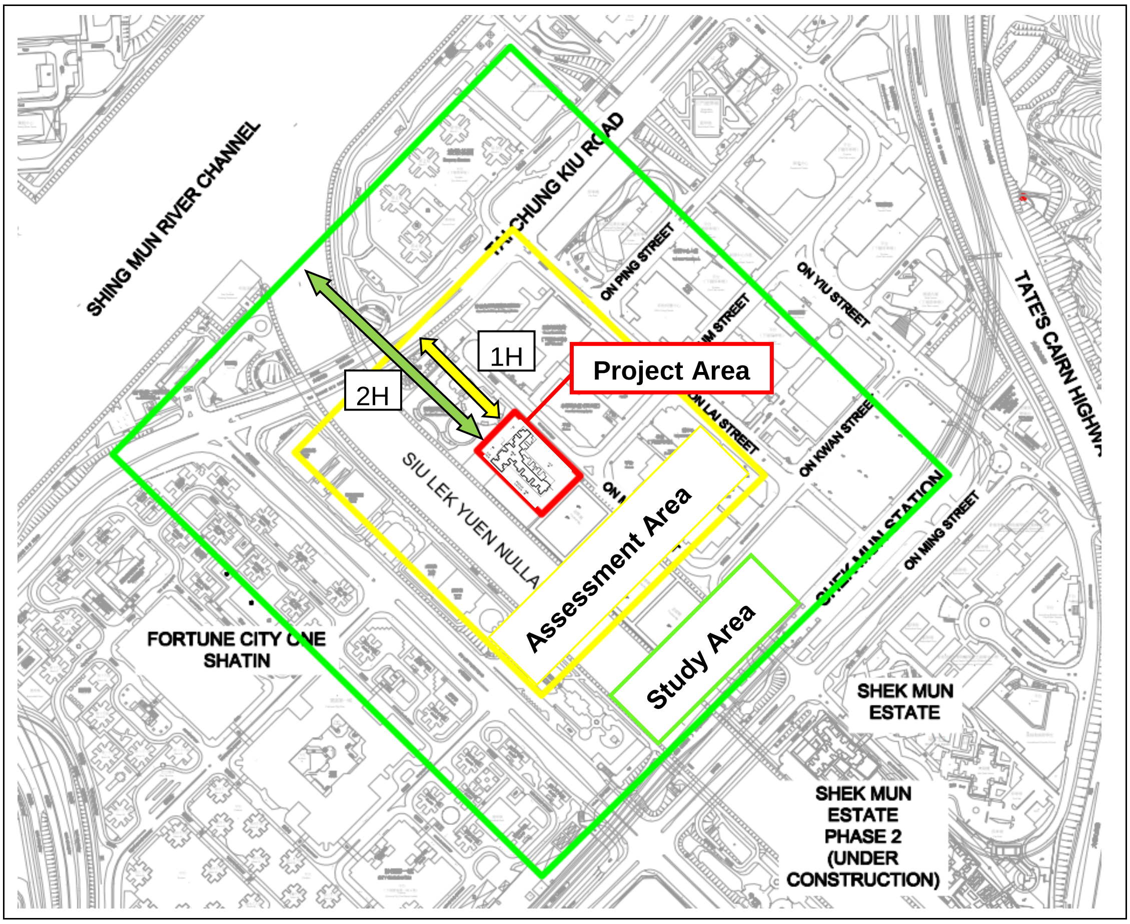
4.1.1 This AVA study was carried out in accordance with the guidelines stipulated in the Housing, Planning and Lands Bureau Technical Circular No.1/06 and Environment, Transport and Works Bureau Technical Circular No.1/06 and Annex A of the above mentioned Technical Circular "Technical Guide for Air Ventilation Assessment for Development in Hong Kong" with regards to CFD modelling. Reference is 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. It is, therefore, considered that the COST action C14 is a valid and good reference for CFD modelling in AVA study.

4.1.2 The well-recognized commercial CFD package PHOENICS 2016 was used in this exercise. PHOENICS model has been widely applied for various AVA research and studies worldwide, and has been very much accepted by the industry for AVA application.

4.1.3 A 3-dimensional CFD model including major topographical features and building morphology, which would likely affect the wind flow, was constructed. According to the Technical Guide, the assessment area should include the project's surrounding up to a perpendicular distance of at least 1H, while the surrounding area should include that distance of at least 2H, both counted from the project boundary (H refers to the height of the tallest building on site, and is 120m in this study). Large structures just outside the 2H boundary layers were also included in the simulation model in order to address the ventilation impact more accurately. In this study, Shatin Industrial Building Block and Shek Mun Station of the Ma On Shan Railway which located outside the 2H boundary were also included into the simulation model.

4.1.4 Figure 4.1 shows the boundaries of project area, assessment area and surrounding area in this study.

Figure 4.1 Project Area, Assessment Area and Surrounding Area



4.2 Solution Parameters and Boundary Conditions

4.2.1 The computational domain of the model is approximately 4390m x 4390m x 690m (L x W x H) in size. There is at least 15H distance from simulated objects to the domain boundary in any direction as suggested by COST action C14 (Franke et al. 2004). The ground of the computational domain includes the topography.

4.2.2 The computational domain comprises about 5,800,000 structured cells. The horizontal grid size in the CFD model in the project area was about 1.5m (smaller grid size was employed for specific fine details), and increased further away from the project area with a growth *expansion ratio* of at most 1.2. Vertically, four layers of cells were employed in 2m above the terrain (each layer of 0.5m thickness).

4.2.3 *Grid Expansion Ratio* – Referring to the COST action C14 (Franke et al. 2004), the expansion ratio between two consecutive cells should be below 1.2. In this study, the expansion ratio of cells was at a maximum value of 1.2.

4.2.4 *Turbulence Model* – As recommended in COST action C14 (Franke et al. 2004), k-epsilon turbulence model was adopted in the CFD model. Common CFD equations were adopted in the analysis to capture spatial fidelity of the atmospheric wind flow on a three-dimensional basis.

4.2.5 Variables including fluid velocity and static pressure were calculated throughout the domain. Solutions were obtained by computational iterations.

4.2.6 *Convergence Criteria* – Convergence criteria for the simulations were 10^{-4} per COST action C14 (Franke et al. 2004).

4.2.7 *Boundary Conditions* - Boundary conditions adopted in this study are tabulated in Table 4.1.

Table 4.1 Boundary Conditions for CFD Simulations

Boundary Component	Boundary Condition
Inlet Boundary	Velocity Inlet
Outlet Boundary	Fixed pressure boundary
Lateral Boundary	Fixed pressure boundary
Top Boundary	Fixed pressure boundary
Ground Boundary/ Wall Treatment	Standard Wall Function

4.2.8 *Wind Directions* – The CFD model assessed the most prevailing wind directions with sum annual occurrence of not less than 75% at the project area. As mentioned in section 3.1, 8 most frequent wind directions were chosen for the study.

4.2.9 *Vertical Wind Profiles* – The wind speed in reference height at 500m for different wind directions were extracted based on RAMS wind data issued by PlanD. Vertical wind profiles was extrapolated by log law function in the simulation.

4.3 Assessment Criteria

4.3.1 *Wind velocity ratio (VR)* – VRs, per aforesaid technical circular (HPLB and ETWB, 2006), are defined as

$VR = V_P/V_{INF}$, where

V_{INF} is the wind velocity at the top of the wind boundary layer and would not be affected by the ground roughness and local site features;

V_P is the wind velocity at 2m pedestrian level.

VRs were adopted as the indicator of wind performance at pedestrian level, taking into account of surrounding buildings, topography and the project site. Per the velocity ratio method (CUHK, 2008), the analysed CFD results would determine the extent to which the proposed development affected the wind environment of its immediate vicinity and local areas.

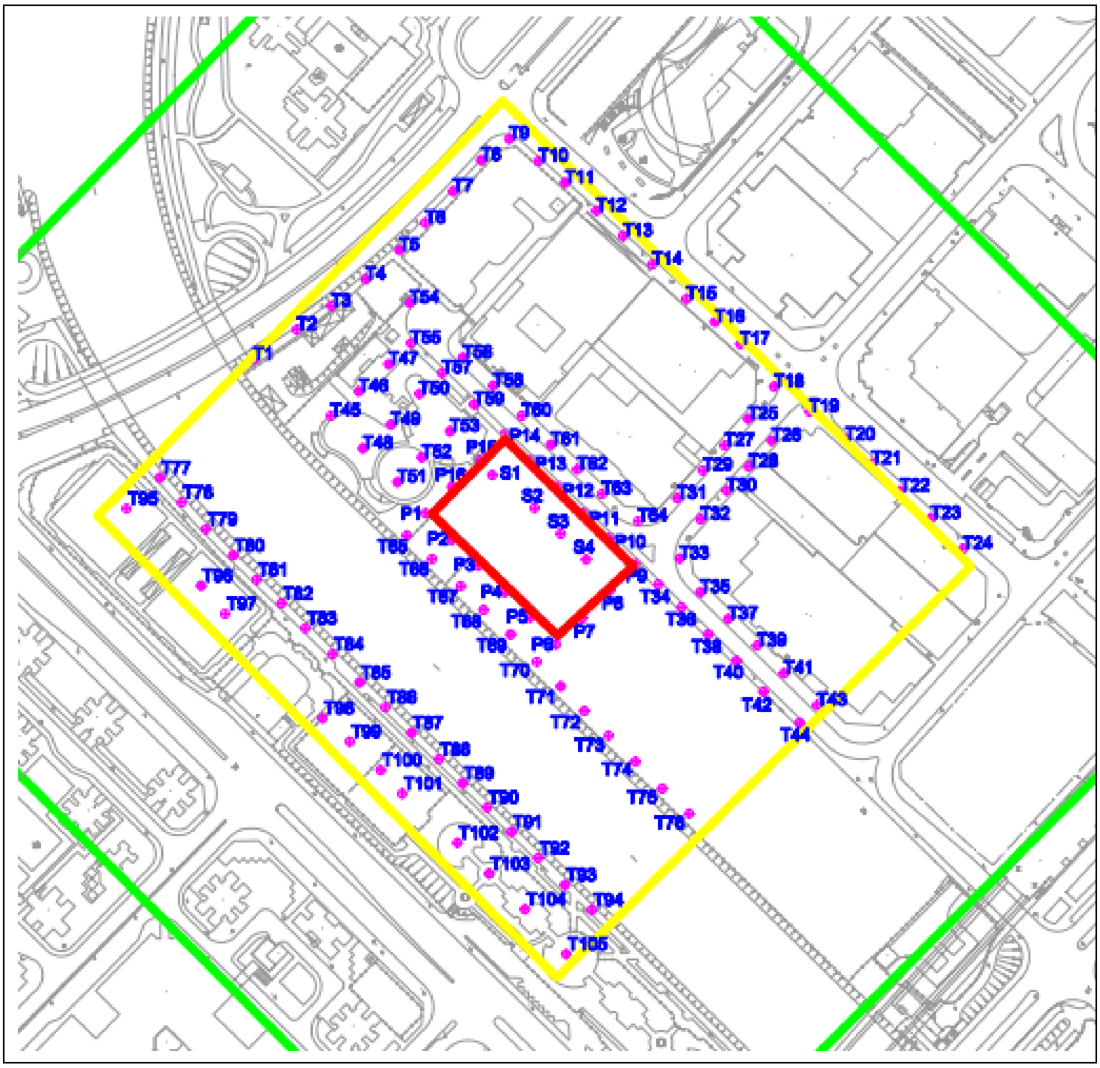
4.3.2 Site Velocity Ratio (SVR) and Local Velocity Ratio (LVR) were worked out so as to evaluate the overall impact of air ventilation on the immediate and further surroundings of the subject site respectively. SVR is the average of VR of all perimeter test points while LVR is the average of all overall test points and perimeter test points.

4.4 Test Point Locations

4.4.1 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 can or will mostly access to.

4.4.2 Figure 4.2 shows the locations of perimeter, overall and special test points. There were 16 perimeter test points (P1 – P16) around the site boundary and 105 overall test points (T1 – T105) within the assessment area. Besides, 4 special test points (S1 – S4) were placed within the project area to assess the air ventilation performance.

Figure 4.2 Test Point Location Map



4.5 Studied Schemes

4.5.1 There were two schemes, namely Baseline Scheme and Proposed Scheme, studied by CFD simulations quantitatively and qualitatively in this assessment.

4.5.2 Both the Baseline and Proposed Scheme had a single residential tower. The typical floor layouts in these two schemes were similar. Figure 4.3 and Figure 4.4 show the Baseline and Proposed Schemes respectively.

4.5.3 In the Proposed Scheme, a building void was incorporated at the podium floor to improve air ventilation. Figure 4.5 shows the sectional view of the proposed building with position of the void indicated.

Figure 4.3 Indicative Plan of the Baseline Scheme

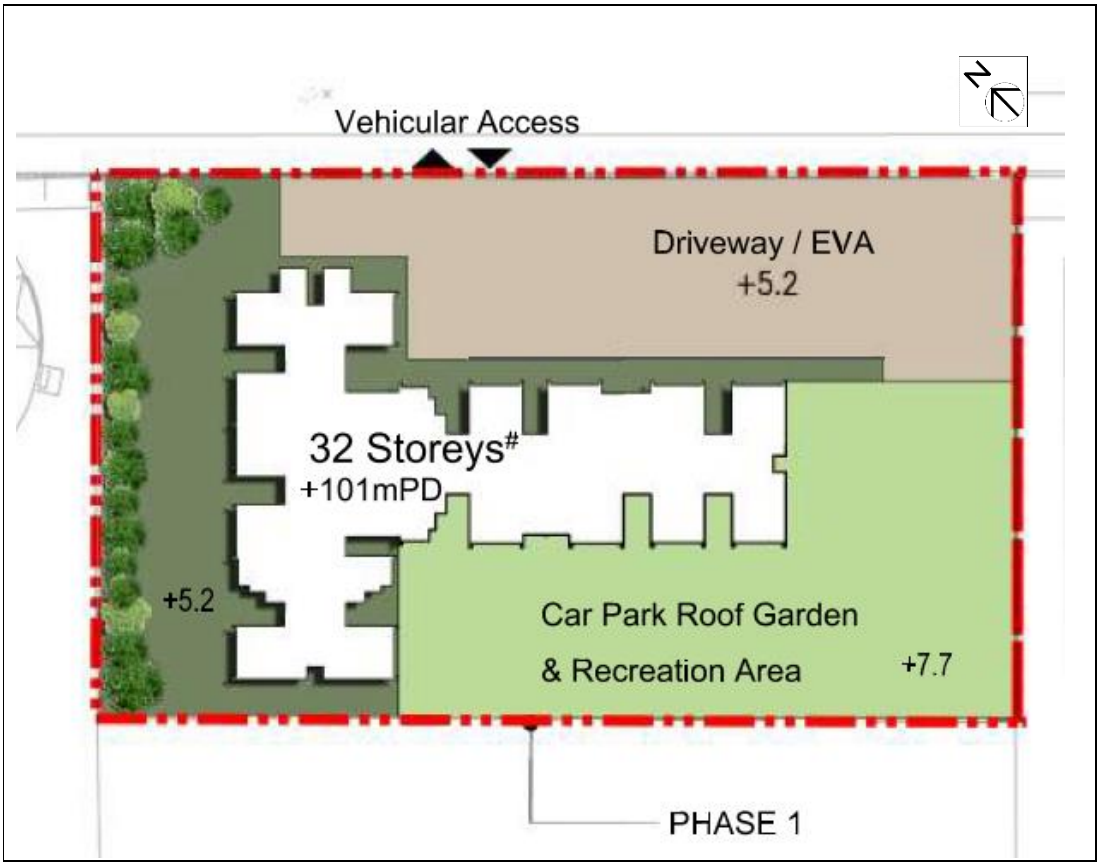


Figure 4.4 Typical Floor Plan of the Proposed Scheme

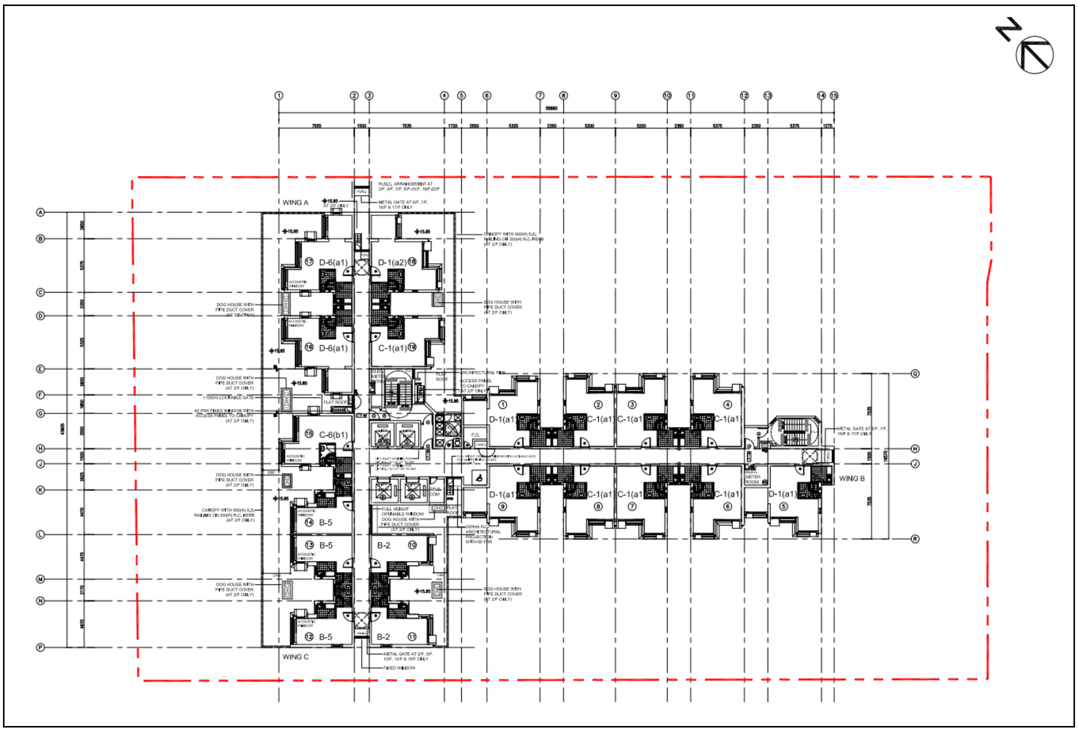
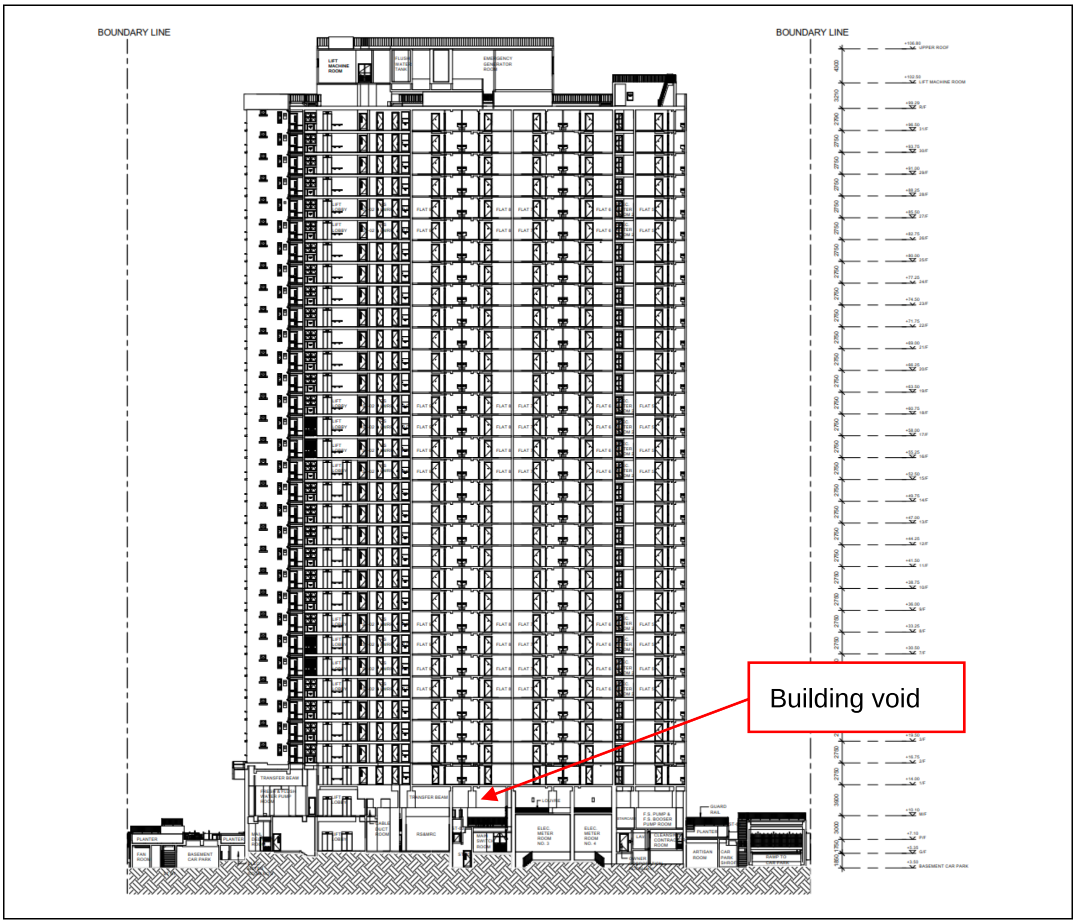


Figure 4.5 Sectional View of the Proposed Scheme



5 KEY FINDINGS

5.1 NNE and NE Prevailing Winds

5.1.1 Under NNE and NE prevailing wind directions, most of the incoming wind breeze penetrate the assessment area along Tai Chung Kiu Road. Wind breeze then reaches a large open area at Siu Lek Yuen Nullah and diffuses into it. Wind breeze finally passes by the project area on north-west.

5.1.2 Commercial and industrial buildings to the north-east side of the assessment area blocks incoming north-easterly wind effectively. Project area is located in close proximity to Heung Yee Kuk Building and Ever Gain building on the south-west. Thus, limited wind from NNE and NE direction reaches the project area. Wind mainly approaches the site in NE direction which is diverted from Tai Chung Kiu Road.

5.1.3 Under Baseline Scheme, podium garden is to the leeward side of the tower, incoming wind from NW direction is effectively blocked and thus the ventilation on the podium garden is poor.

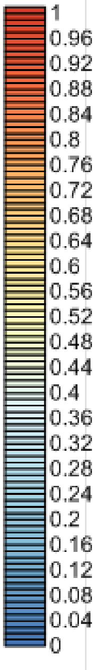
5.1.4 Under Proposed Scheme, building void located on the podium garden act as a wind passage. Wind can flow through the building at lower level and reach the podium garden. The ventilation on the podium garden is better in Proposed Scheme than in Baseline Scheme.

5.1.5 Average VR on the podium garden in baseline scenario is approximately 0.05, while is 0.12 in Proposed Scheme. This further indicates that the podium garden in the Proposed Scheme under NNE and NE wind conditions can achieve better wind environment.

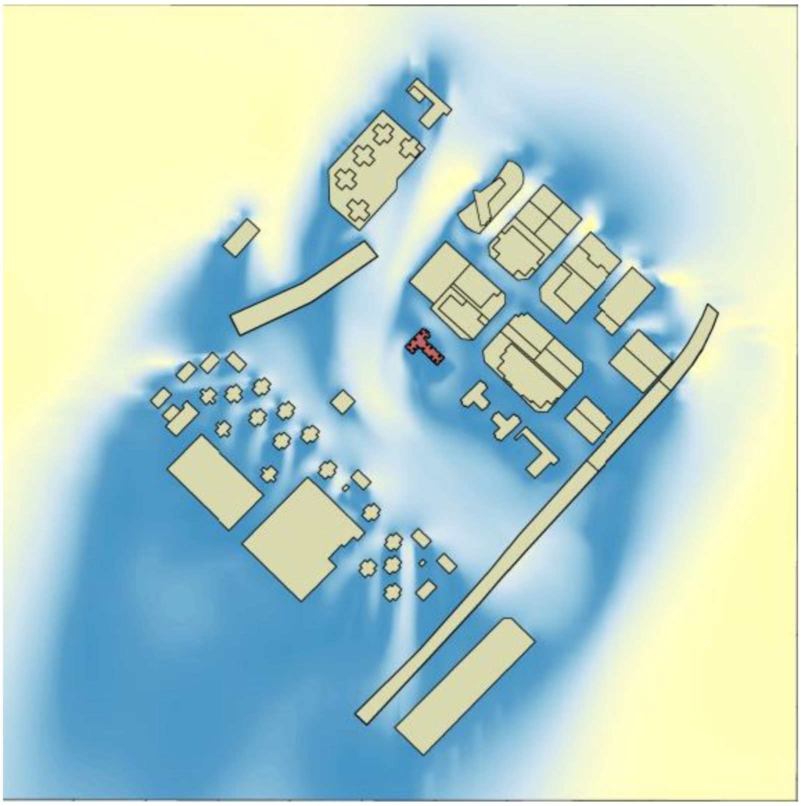
5.1.6 Figure 5.1 and Figure 5.2 illustrate the VR contours for Baseline and Proposed Schemes under NNE prevailing wind and NE prevailing wind respectively.

Figure 5.1 VR Contours for Baseline and Proposed Schemes under NNE Prevailing Wind

VR



Baseline Scheme



Proposed Scheme

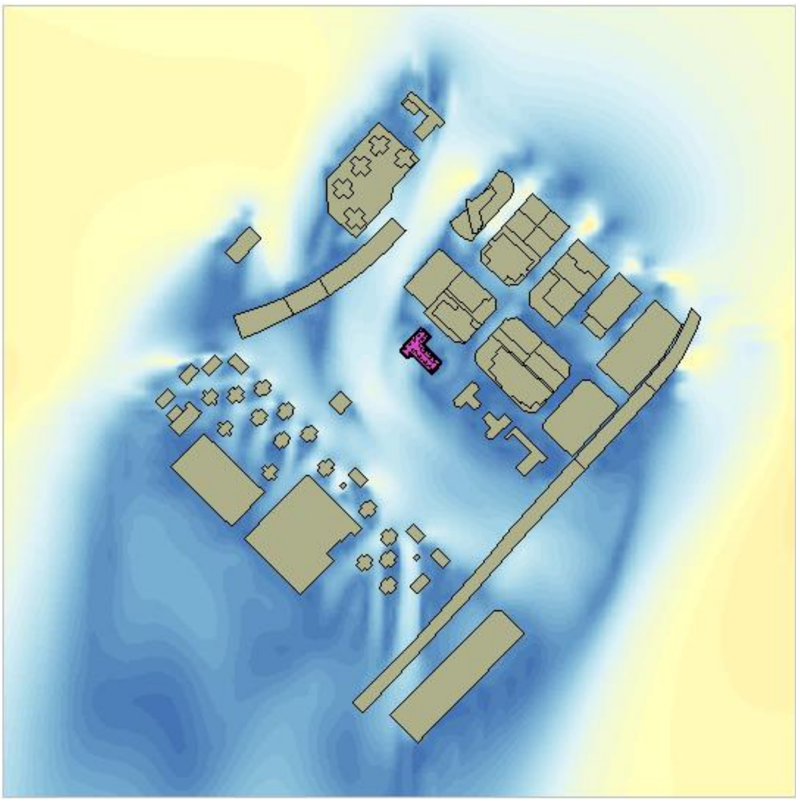
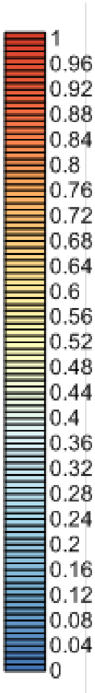
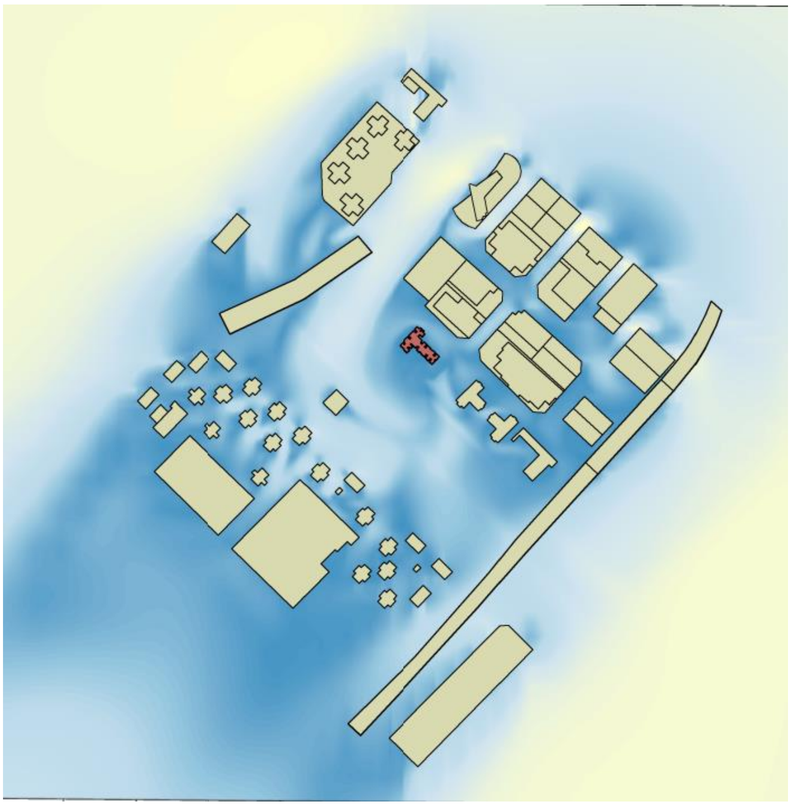


Figure 5.2 VR Contours for Baseline and Proposed Schemes under NE Prevailing Wind

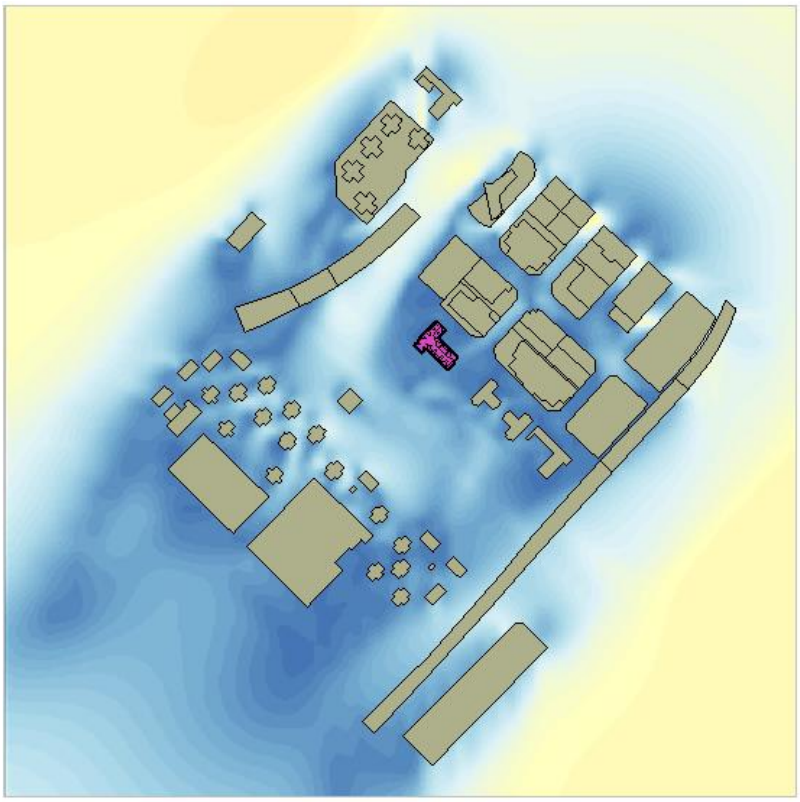
VR



Baseline Scheme



Proposed Scheme



5.2 ENE and E Prevailing Wind

5.2.1 Under ENE prevailing wind, similar to NNE and NE direction, the project site has a weak wind environment due to the blockage by buildings on the north-east. Most of the wind bypasses On Sum Street and reaches On Muk Street, then deflects at the street conjunction, and approaches the project area from the east.

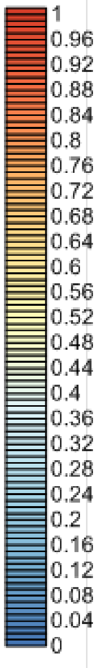
5.2.2 Under E prevailing wind, most wind bypasses Siu Lek Yuen nullah and reaches the project site on the south. Wind from Siu Lek Yuen nullah does not approach the building directly, but passes through the project building on sideway and continues its breezeway towards Shing Mun River. Compared to ENE wind direction, less amount of wind reaches the site in East direction due to the mismatch of street alignment and incoming wind direction.

5.2.3 Since wind breezeway in these two wind directions does not encounter the project building directly, the effect of building design on the nearby wind environment is insignificant.

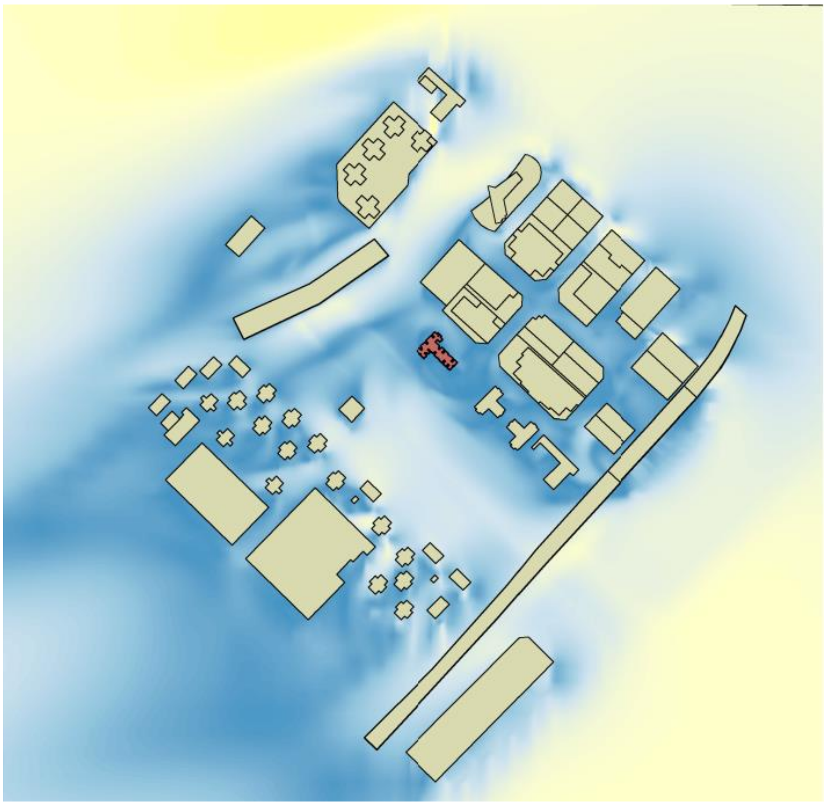
5.2.4 Figure 5.3 and Figure 5.4 illustrates the VR contours for Baseline and Proposed Schemes under ENE prevailing wind and E prevailing wind respectively.

Figure 5.3 VR Contours for Baseline and Proposed Schemes under ENE Prevailing Wind

VR



<u>Baseline Scheme</u>



<u>Proposed Scheme</u>

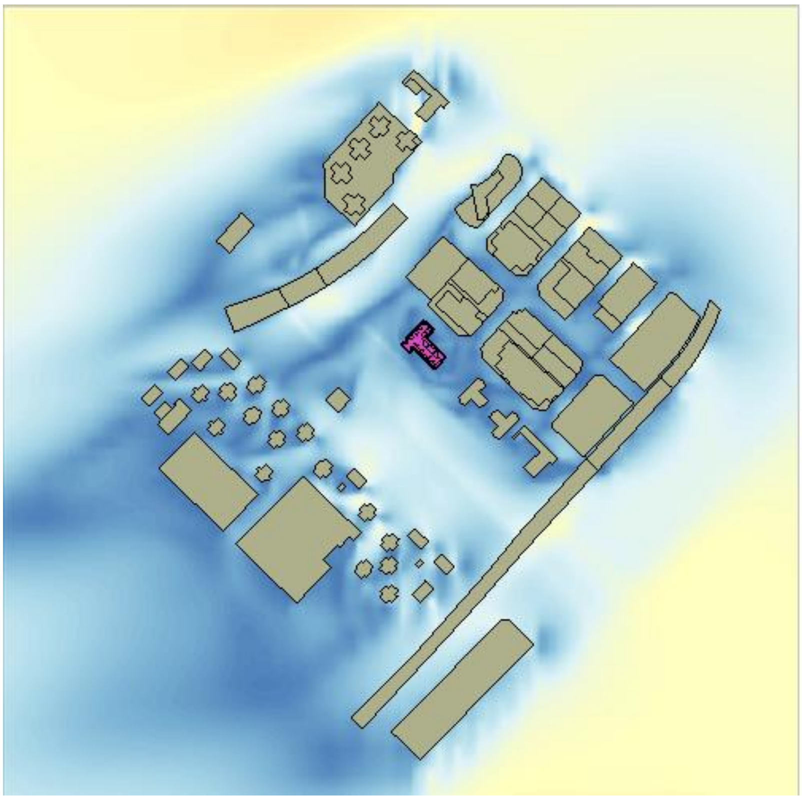
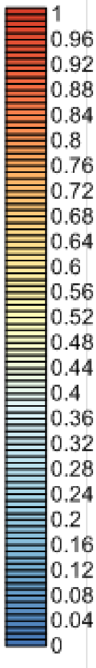
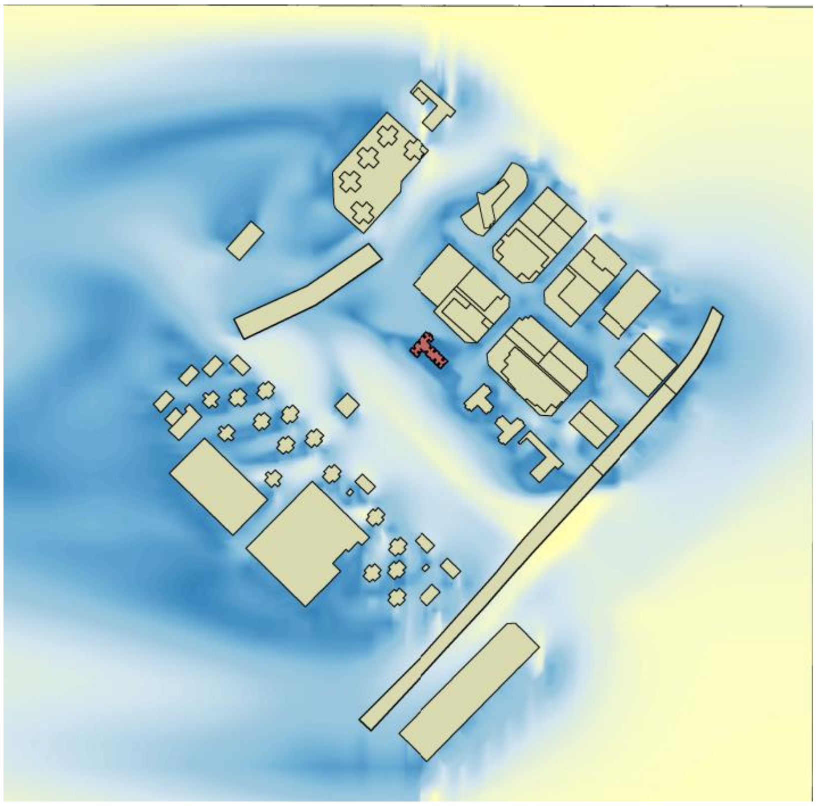


Figure 5.4 VR Contours for Baseline and Proposed Schemes under E Prevailing Wind

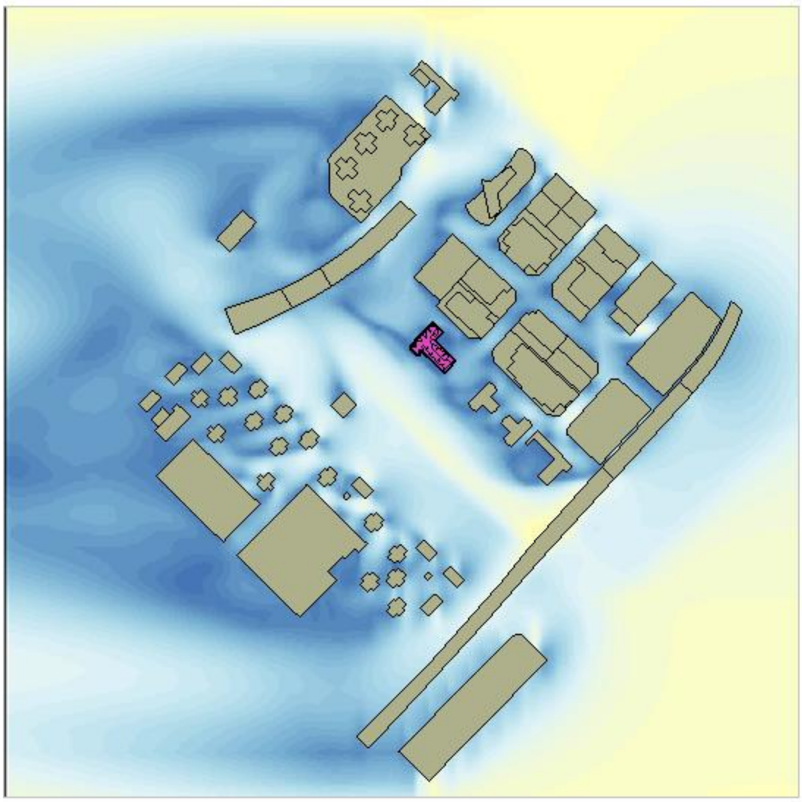
VR



Baseline Scheme



Proposed Scheme



5.3 ESE and SE Prevailing Winds

5.3.1 Under ESE and SE Prevailing wind, most wind bypasses On Muk Street and Siu Lek Yuen Nullah because their road alignment parallel to the incoming wind direction. Wind breeze also bypasses the project area on two sides of the proposed building.

5.3.2 Wind passing through the project area continues its breezeway to the Shing Mun River and encounter small obstruction or deflection in overall wind pattern.

5.3.3 Unlike E wind condition, wind passes through Siu Lek Yuen Nullah with a larger magnitude and is closer to the project building. Wind flow thus has more interaction with the project building.

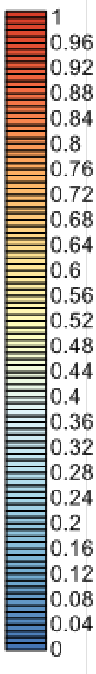
5.3.4 Similar to NNE and NE wind, wind can flow through the building void located on the podium and is able to benefit the wind environment to the leeward side of the building. Under ESE and SE wind directions, G/F garden, the EVA and the main entrance, which are to leeward side, achieve better ventilation in Proposed Scheme than Baseline Scheme.

5.3.5 The VRs in Baseline and Proposed Schemes are similar under ESE and SE prevailing wind.

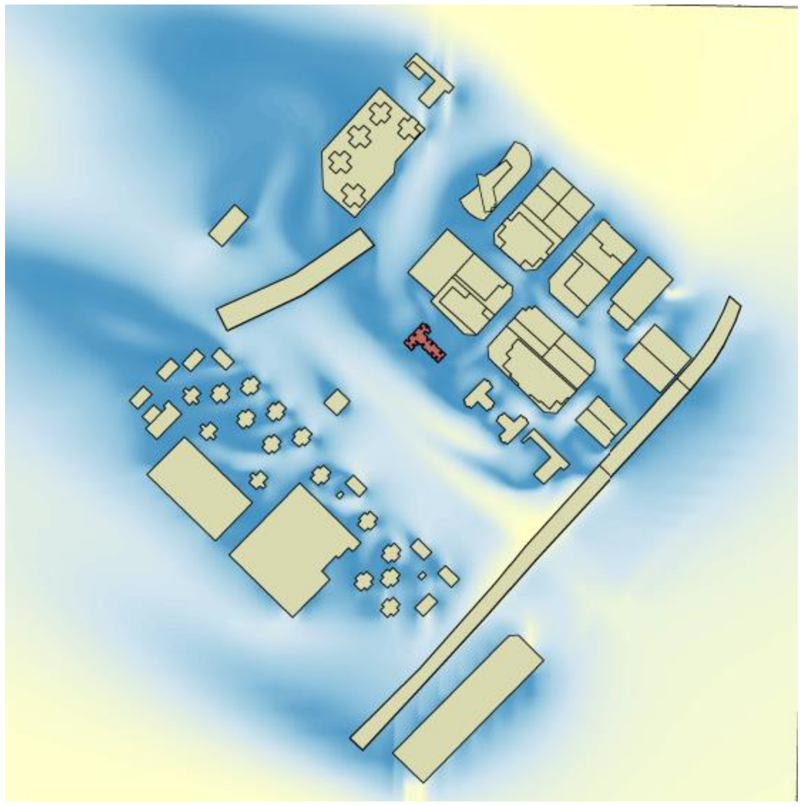
5.3.6 Figure 5.5 and Figure 5.6 illustrate the VR contours for Baseline and Proposed Schemes under ESE prevailing wind and SE prevailing wind respectively.

Figure 5.5 VR Contours for Baseline and Proposed Schemes under ESE Prevailing Wind

VR



Baseline Scheme



Proposed Scheme

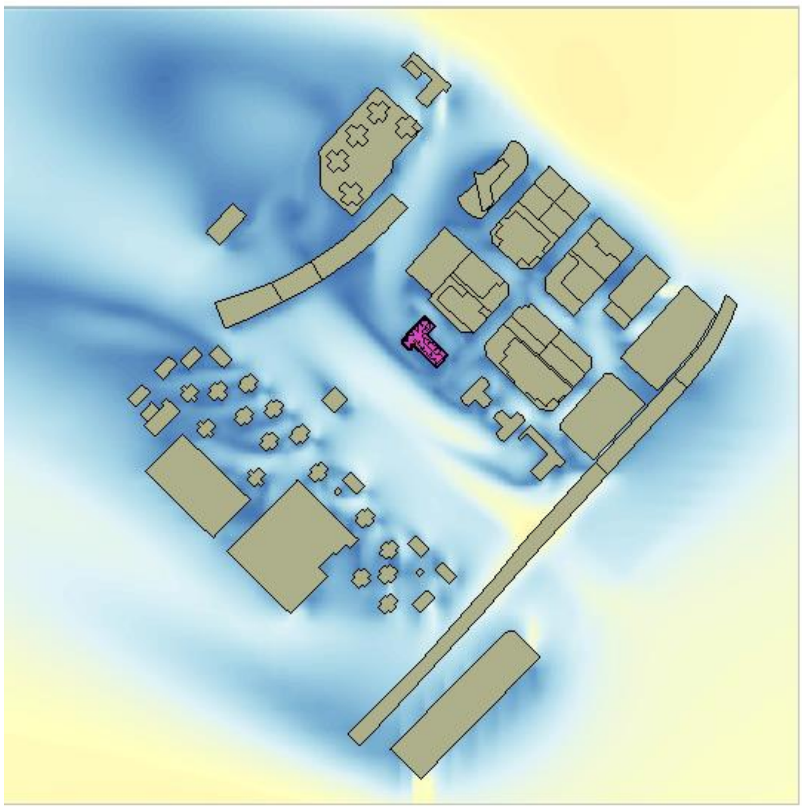
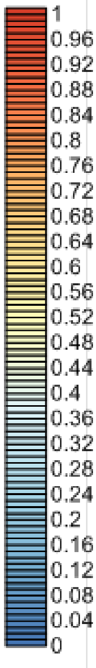
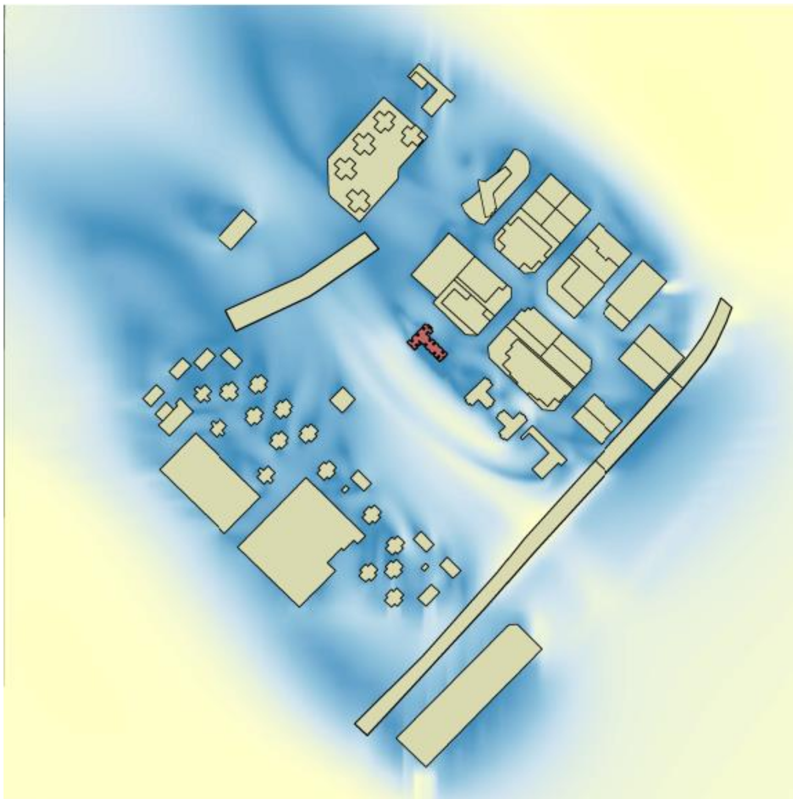


Figure 5.6 VR Contours for Baseline and Proposed Schemes under SE Prevailing Wind

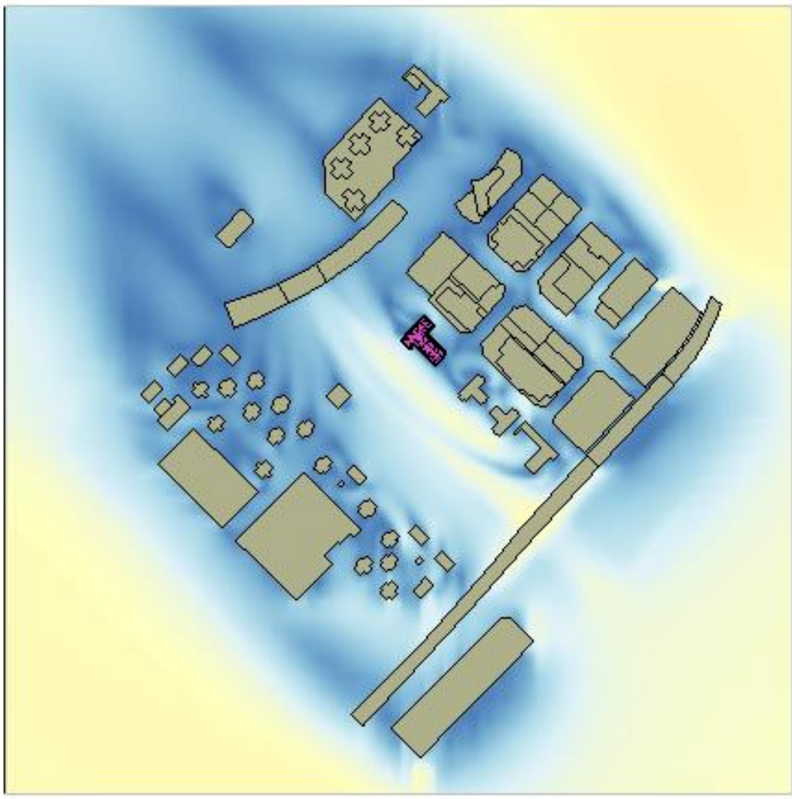
VR



Baseline Scheme



Proposed Scheme



5.4 SW and SSW Prevailing Winds

5.4.1 Under SW and SSW prevailing wind, incoming winds penetrate a large scaled private housing estate – Shatin City One and approach the project area mainly from the south-west.

5.4.2 The building void continues acting as an important building feature to improve wind environment to the leeward side of the building.

5.4.3 In Baseline Scheme, wind breeze is diverted into two sides of the building continuing its path afterwards. Some winds will be obstructed by the car park roof garden & recreation area and slightly divert the wind pattern.

5.4.4 In Proposed Scheme, wind breeze is also diverted into two sides of the building and through the building void. Wind amplification at two sides of the building is less intense compared to the Baseline Scheme. No wind stagnant area is found.

5.4.5 Figure 5.7 and Figure 5.8 illustrate the VR contours for Baseline and Proposed Schemes under SSW prevailing wind and SW prevailing wind respectively.

Figure 5.7 VR Contours for Baseline and Proposed Schemes under SW Prevailing Wind

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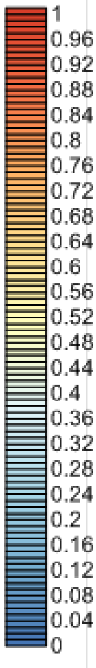
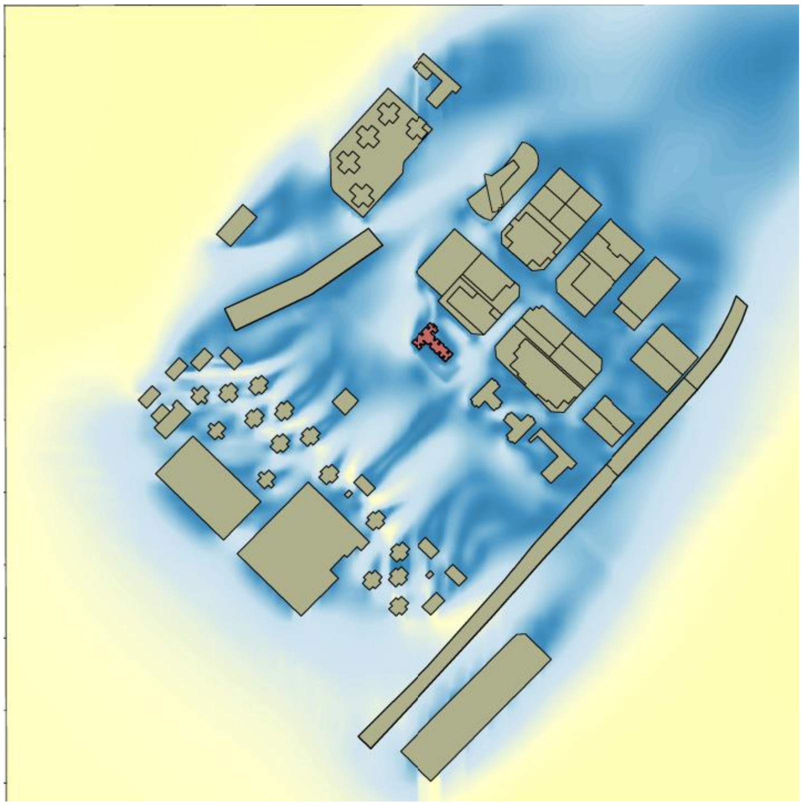
</td><td><u>Baseline Scheme</u>
</td></tr>
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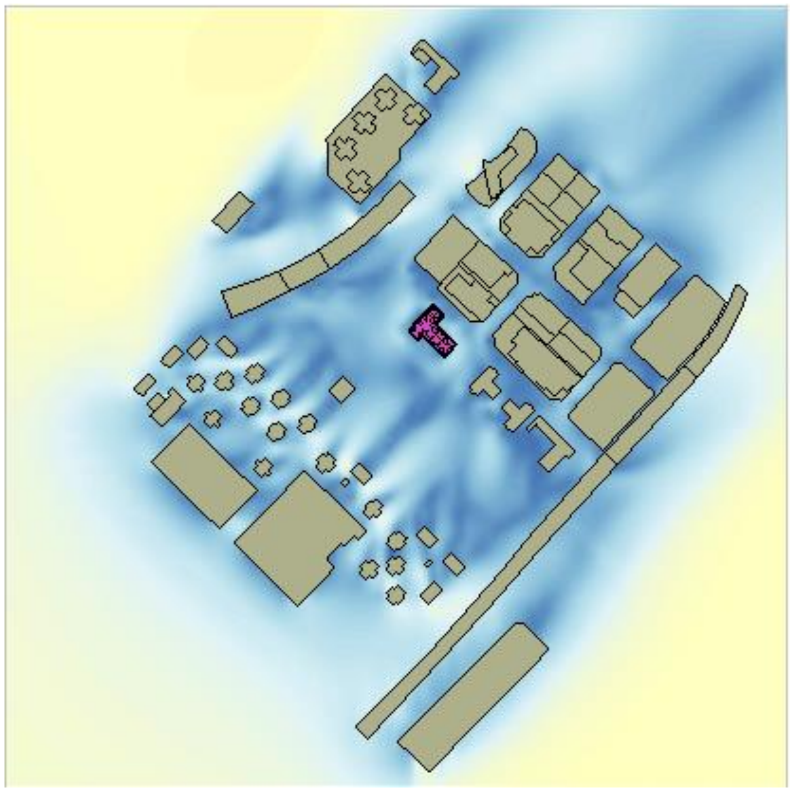</td></tr>
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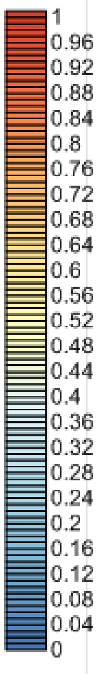
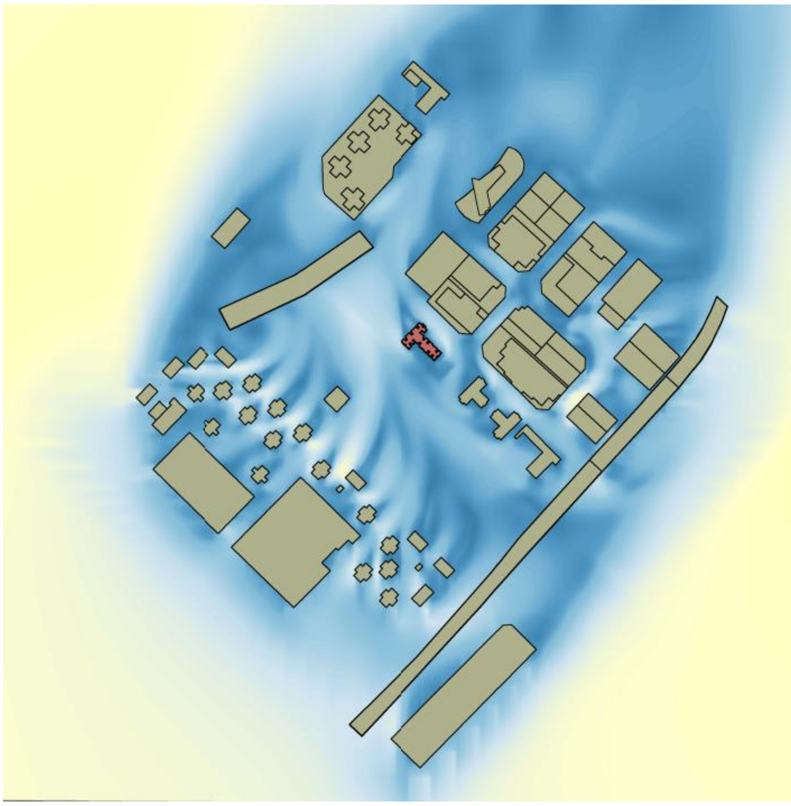
Figure 5.8 VR Contours for Baseline and Proposed Schemes under SSW Prevailing Wind

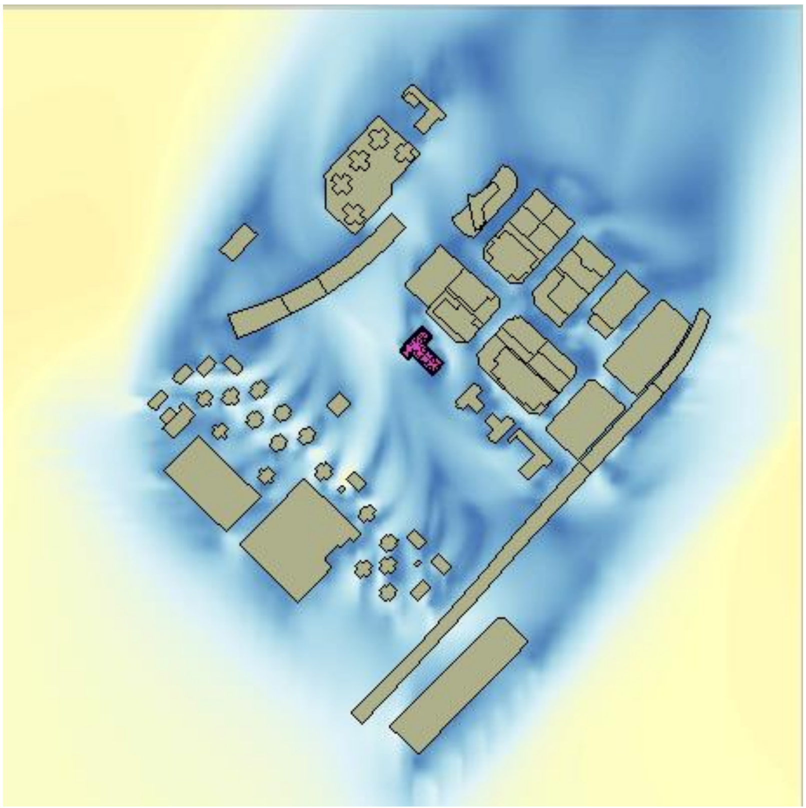
VR



<u>Baseline Scheme</u>



<u>Proposed Scheme</u>



5.5 Annual Ventilation Performance

5.5.1 Under annual condition, Proposed Scheme achieves similar SVR compared with Baseline Scheme. Under Baseline Scheme, more wind is diverted and deflected to the surrounding area, causing strong wind amplification. While in Proposed Scheme, wind pattern is less impacted by the new development due to the building void, wind velocity is less intense but more averagely distributed in close proximity to the site.

5.5.2 LVR in both Baseline and Proposed Schemes are considered to be the same, since the outlines of the building in two Schemes are similar. The small difference in building outline does not impose any difference in wind environment within the assessment area.

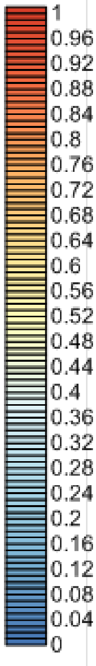
5.5.3 Table 5.1 tabulates SVR and LVR under annual condition. Figure 5.9 shows the annual averaged VR contours for Baseline and Proposed Schemes.

Table 5.1 Summary of SVR and LVR under Annual Condition

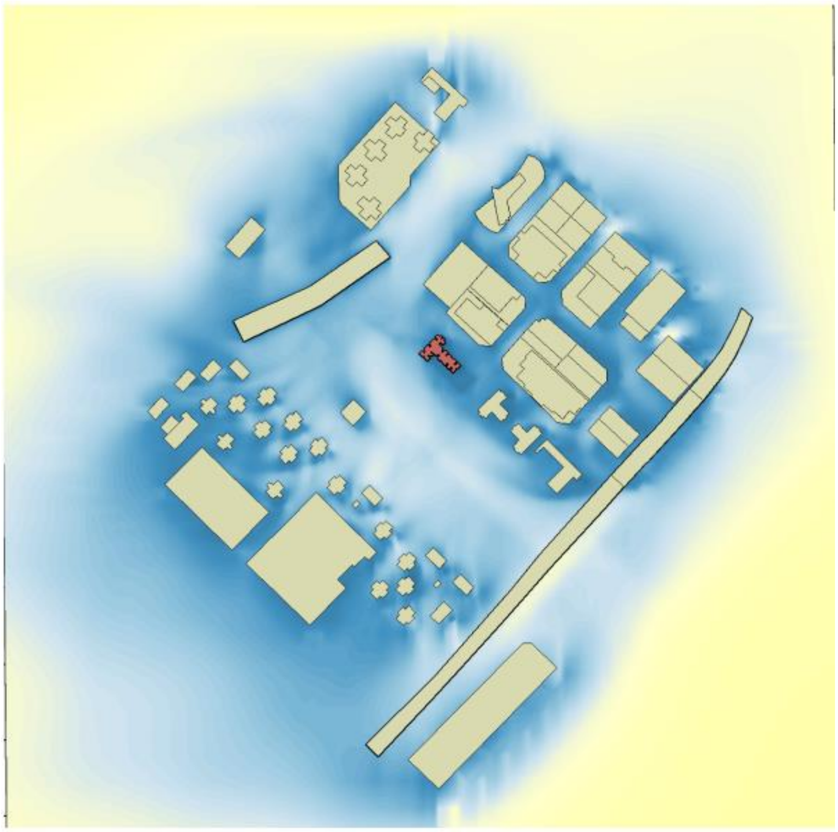
	Baseline Scheme	Proposed Scheme
SVR	0.12	0.12
LVR	0.18	0.18

Figure 5.9 Annual Averaged VR Contours for Baseline and Proposed Schemes

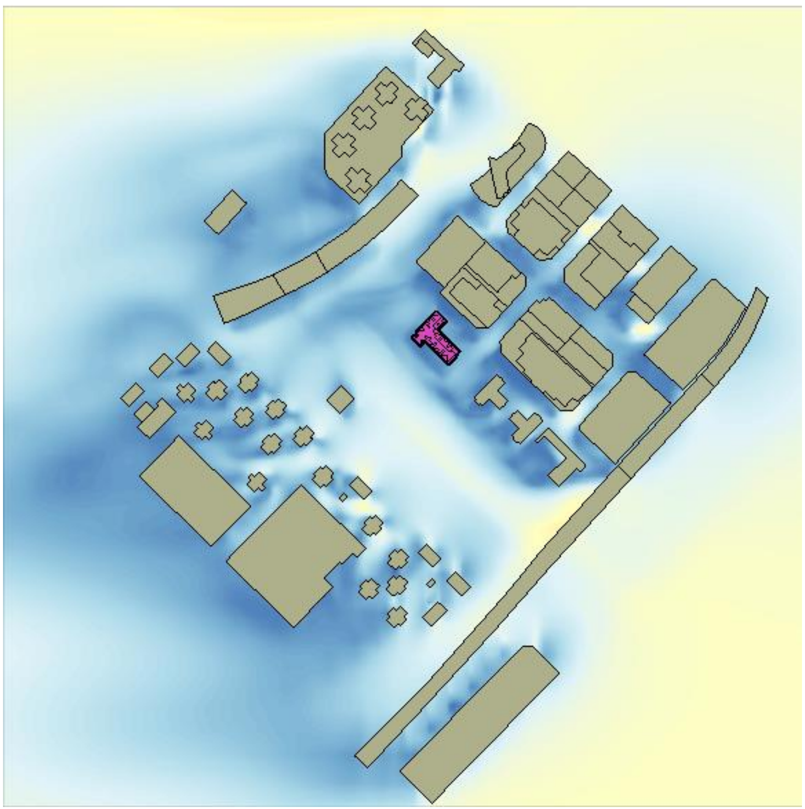
VR



Baseline Scheme



Proposed Scheme



5.6 Summer Ventilation Performance

5.6.1 For summer ventilation performance, SVR in both Baseline Scheme and Proposed Scheme are considered to be the same.

5.6.2 The building void act as a good wind permeability features to allow more wind to pass through the development without much obstruction in its original breezeway.

5.6.3 Meanwhile, Proposed Scheme achieves same LVR as Baseline Scheme, indicating that the proposed development would induce similar ventilation impact to the assessment area in both Baseline and Proposed Schemes.

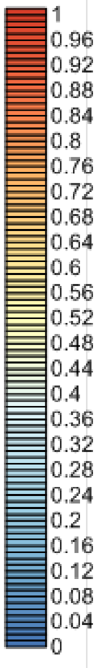
5.6.4 Table 5.2 tabulates SVR and LVR under summer condition. Figure 5.10 illustrates the summer averages VR contours for Baseline and Proposed Schemes.

Table 5.2 Summary of SVR and LVR under Summer Condition

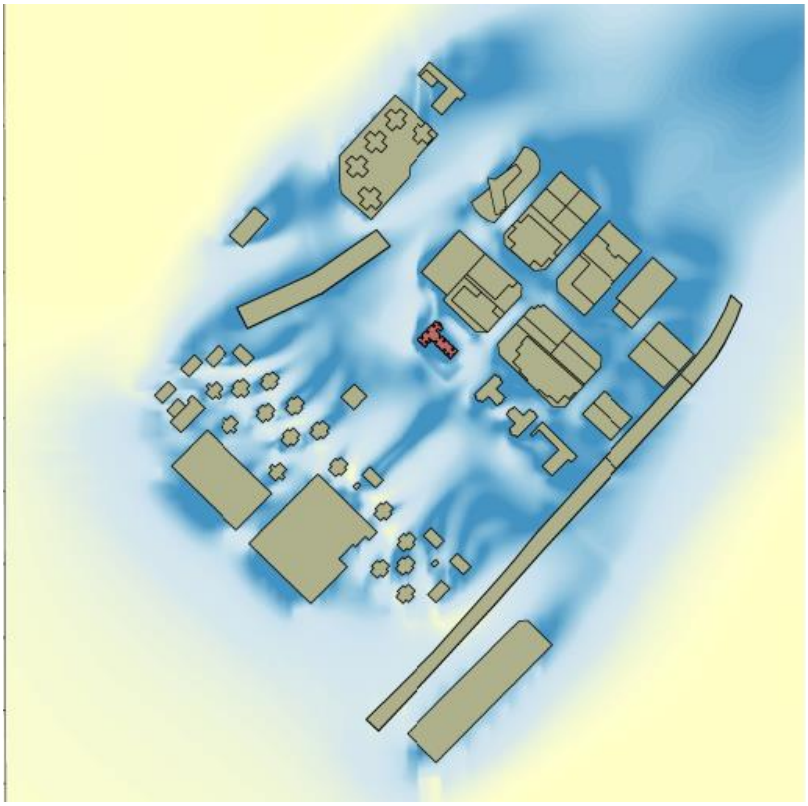
	Baseline Scheme	Proposed Scheme
SVR	0.19	0.19
LVR	0.16	0.16

Figure 5.10 Summer Averaged VR Contours for Baseline and Proposed Schemes

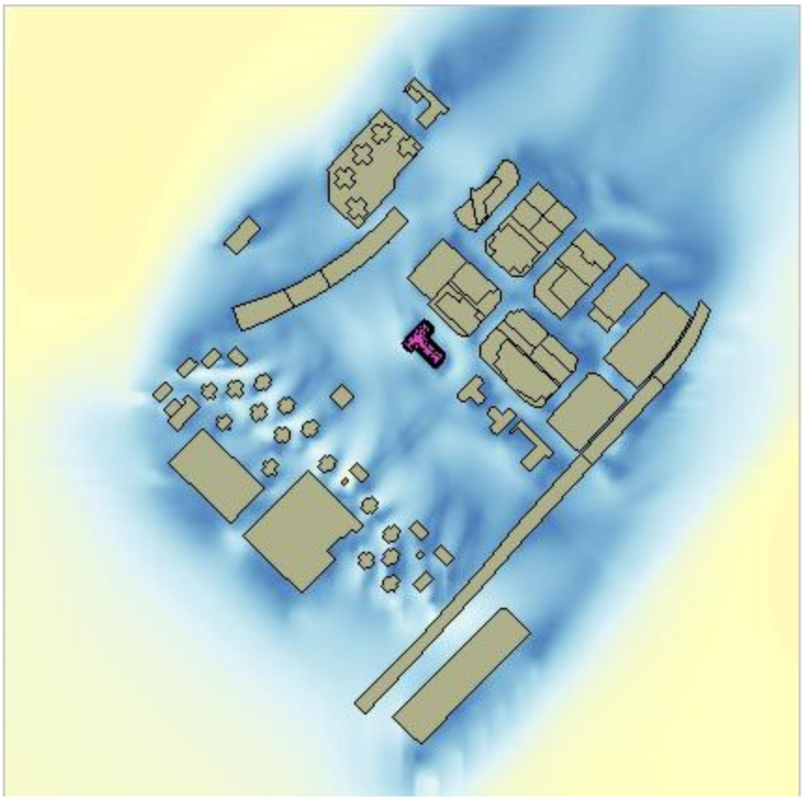
VR



Baseline Scheme



Proposed Scheme



5.7 Focus Areas

5.7.1 In total of 8 focus areas are identified to study the difference on wind environment between Baseline and Proposed Schemes. Figure 5.11 shows the 8 areas highlighted in green and their corresponding test points.

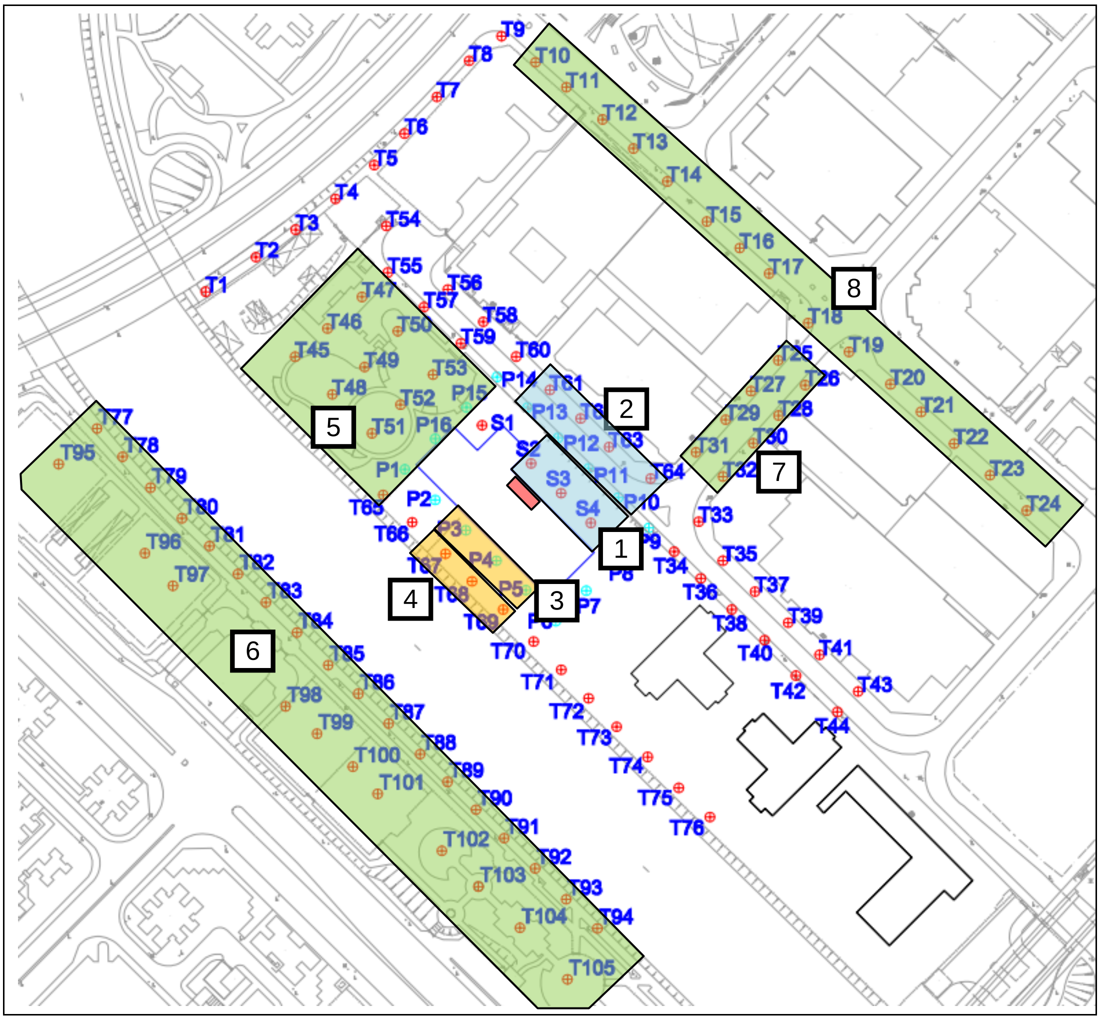
5.7.2 The building void which is located at the podium floor level is highlighted with red box.

5.7.3 Focus area 1 and 2 are specially chosen to study the ventilation condition under SW wind for the effect of building void. These two locations are to the leeward side of the project building under SW wind and expected to have a weak wind condition when wind approaches the site from the south-west.

5.7.4 Similarly, focus area 3 and 4 are chosen to study the ventilation condition under NE and NNE wind. Under these wind directions, wind approaches the site mainly from the north-west and weak ventilation condition is expected in focus area 3 and 4.

5.7.5 Focus area 5 to 8 are representing major roads or open areas in close proximity of the site.

Figure 5.11 Focus Area Locations



5.7.6 Table 5.3 tabulate the average VR at focus area 1 & 2 under SW summer prevailing wind condition.

5.7.7 The result shows that under the design of building void, the area in between the project site and Ever Green Building achieves better wind environment under summer prevailing wind condition.

Table 5.3 Average VR at Focus Areas under South-west Wind Condition

No.	Focus Area	Test Points	Baseline Scheme	Proposed Scheme
1	Main entrance and EVA Area of the project site	S2 - S4	0.12	0.18
2	On Muk Street (Between Project site and Ever Gain Building	P10 – P13 T61 – T64	0.18	0.19

5.7.8 Table 5.4 tabulates the average VR at focus area 3 & 4 under NE and NNE wind condition.

5.7.9 Under NE and NNE wind condition, average VR at focus area 3 & 4 achieve slightly better wind environment in Proposed Scheme then Baseline Scheme.

Table 5.4 Average VR at Focus Areas under South-west Wind Condition

No.	Focus Area	Test Points	Baseline Scheme	Proposed Scheme
3	Project site boundary at the south-west side	P3 – P5	0.05	0.08
4	River side at the south-west side of the project building	T67 – T69	0.10	0.12

5.7.10 Average VR of 8 wind directions in all focus area is shown in Table 5.5. It is observed that VR in Proposed and Baseline Schemes are similar in most of the areas.

Table 5.5 Average VR at Focus Areas under 8 Prevailing Wind Conditions

No.	Focus Area	Test Points	Baseline Scheme	Proposed Scheme
1	Main entrance and EVA Area of the project site	S2 - S4	0.10	0.11
2	On Muk Street (Between Project site and Ever Gain Building	P10 – P13 T61 – T64	0.13	0.14
3	Project site boundary at the south-west side	P3 – P5	0.11	0.13
4	River side at the south-west side of the project building	T67 – T69	0.15	0.15
5	On Muk Street Garden	T45 – T53 P1, P15–P16	0.18	0.19
6	Siu Lek Yuen Playground	T77 – T105	0.23	0.23
7	On Sum Street	T25 – T32	0.13	0.13
8	On Lai Street	T17 – T24	0.10	0.10

6 QUANTITATIVE EVALUATION ON BASELINE AND PROPOSED SCHEMES

6.1.1 The Proposed Scheme has incorporated the following mitigation measures to alleviate the ventilation impact on the surrounding.

6.1.2 *Preservation of Existing Breezeway along On Muk Street and On Sum Street* – On Muk Street and On Sum Street are identified as the principal breezeway for annual and summer prevailing winds. The proposed development is well located such that the building will not block the breezeway and thus impose lower impact to the wind environment nearby.

6.1.3 *Provide Building Void at the Podium Floor* – A building void is incorporated on the podium floor such that wind from south-west and north-east can flow through the void to the leeward of the building. The design reduces impact on the exiting wind environment and lowers wind amplification at the site surrounding.

6.1.4 The Proposed Scheme is no worse off than the Baseline Scheme on the existing wind environment in close proximity to the site, and therefore considered to be better in terms of wind environment.

6.1.5 The design of Baseline and Proposed Scheme is similar to each other and they have similar effect on wind environment in surrounding environment.