Hong Kong Housing Authority

Proposed Public Housing Development at Pik Wan Road Site B

Air Ventilation Assessment – Initial Study

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Job number 228228

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ARUP

Contents

1 INTRODUCTION

1.1 Background

Ove Arup & Partners Hong Kong limited (Arup) will conduct an Air Ventilation Assessment (AVA) for the Proposed Public Housing Development at Pik Wan Road Site B (the Development).

The Development site is currently zoned as "Residential (Group A)" ("R(A)") on the Approved Cha Kwo Ling, Yau Tong, Lei Yue Mun Outline Zoning Plan (OZP) No. S/K15/25[1] with maximum building height of 150mPD. This document is to support the section 16 application for minor relaxation of building height to 185mPD. Quantitative AVA studies should be conducted to assess the air ventilation performance of the Development with the said height relaxation.

The *Technical Guide for Air Ventilation Assessment for the Developments in Hong Kong (Annex A of Technical Circular No.1/06 for Air Ventilation Assessments)*[2] *(termed as AVA Technical Circular hereafter)* dated 19 July 2006 lay down the foundation of methodology in this AVA Initial Study.

1.2 Objective of AVA Study

Among all available wind data, an Initial Study will be conducted by using Computational Fluid Dynamics (CFD) techniques. It aims to achieve the following tasks:

- Initially assesses the characteristics of the wind availability of the site;
- Gives a general pattern and a rough quantitative estimate of the wind performance at the pedestrian level using Velocity VR; and
- Identify good design features and problematic areas if any and recommend mitigation measures.

[1] Approved Cha Kwo Ling, Yau Tong, Lei Yue Mun Outline Zoning Plan (OZP) No. S/K15/25 (11 April 2017)
[2] Annex A of Technical Circular No. 1/06 issued by the Housing, Planning and Lands Bureau pertaining specifically to Air Ventilation Assessments (19th July, 2006)

2 LOCATION AND SITE CHARACTERISTICS

2.1 General

The Development is located in Yau Tong Area in Kwun Tong District, abutting Pik Wan Road and Ko Chiu Road. The Development is located on a slope in the upper Yau Tong area, the east of the slope area is the hilly Chiu Keng Wan Shan (~247m) and gradually flattened towards Kwun Tong Tsai Wan at the west.

The Development is mainly surrounded by high-rise building clusters in all directions with some open spaces and mid-rise buildings in between. To the north to northeast of the Development site, located the planned high-rise housing development at Pik Wan Road Site A (PWR Site A) (~162-210mPD) and Yau Tong Service Reservoir Playground.

To the east to south, are clusters of high-rise developments, including Ko Chun Court (~125mPD), Ko Yee Estate (~115mPD) and Ko Cheung Court (~154mPD), with mid-rise HK Chinese Women's Club WCSY Memorial Care and Attention Centre (~78.5mPD). Hilly topography of Yuen Tau Shan with peak height at ~375m is located at further south.

To the immediate west to northwest of the site, are Ko Chiu Road Rest Garden and mid-rise Ko Chiu Road Substation (~63mPD). Further across Lei Yue Mun Road to west are high-rise residential building clusters, namely Yau Mei Court (~154mPD), Yau Tong Estate (~145mPD) and Yau Chui Court (~154mPD).

Figure 1 indicates the location and surrounding buildings of the Development. And Figure 2 shows the 3D model of the Proposed Development and its surrounding building and topography.

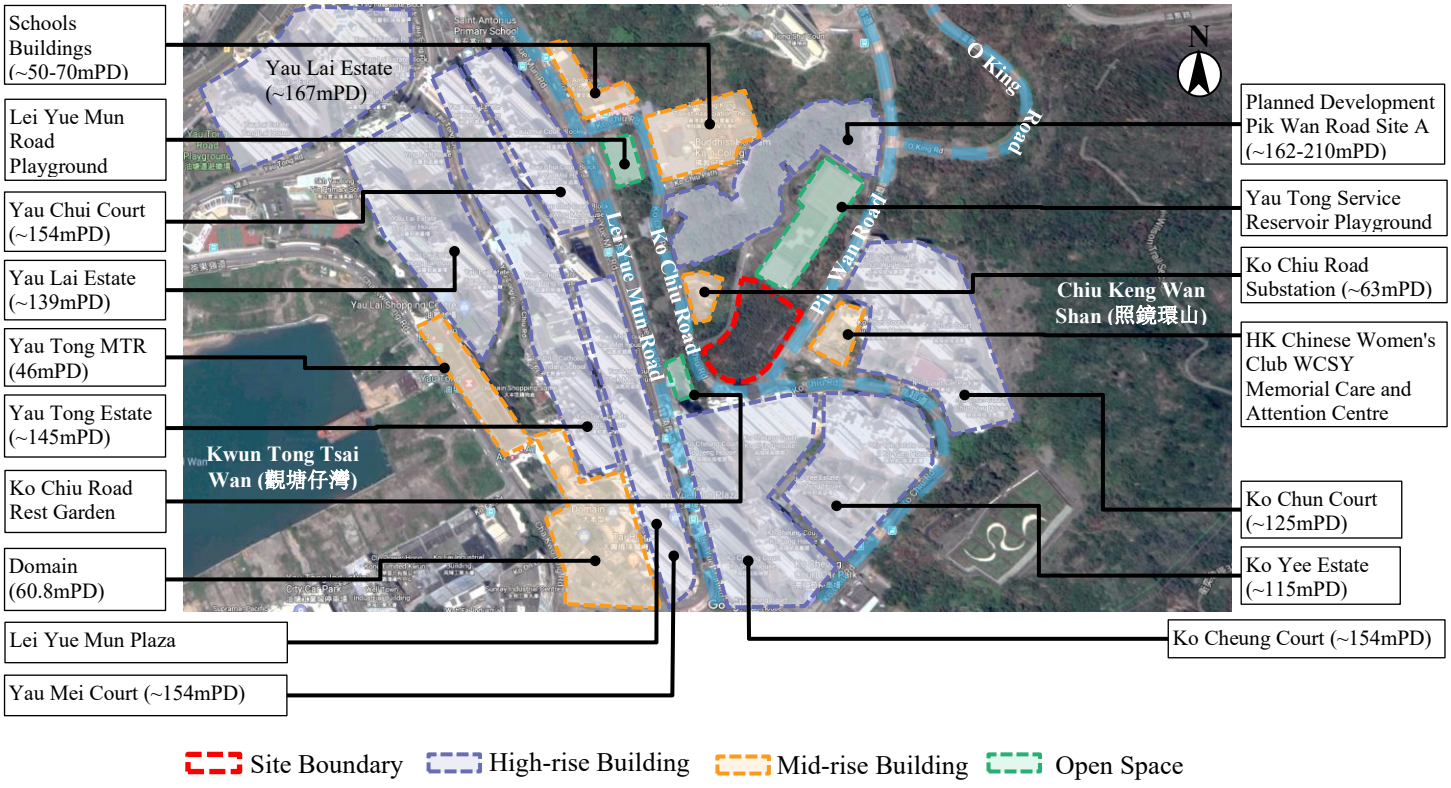


Figure 1 Site Location and Existing Surrounding Developments

Figure 2 3D Model of the Development and its Surroundings (Southerly View)

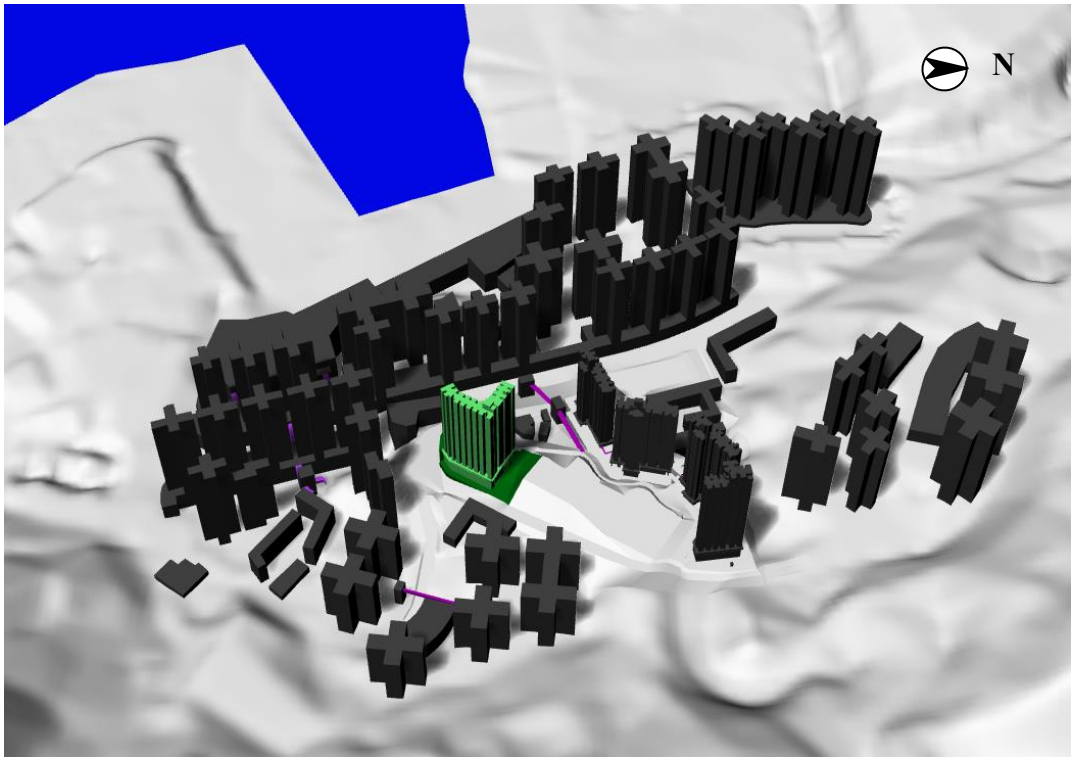


Figure 3 3D Model of the Development and its Surroundings (Easterly View)

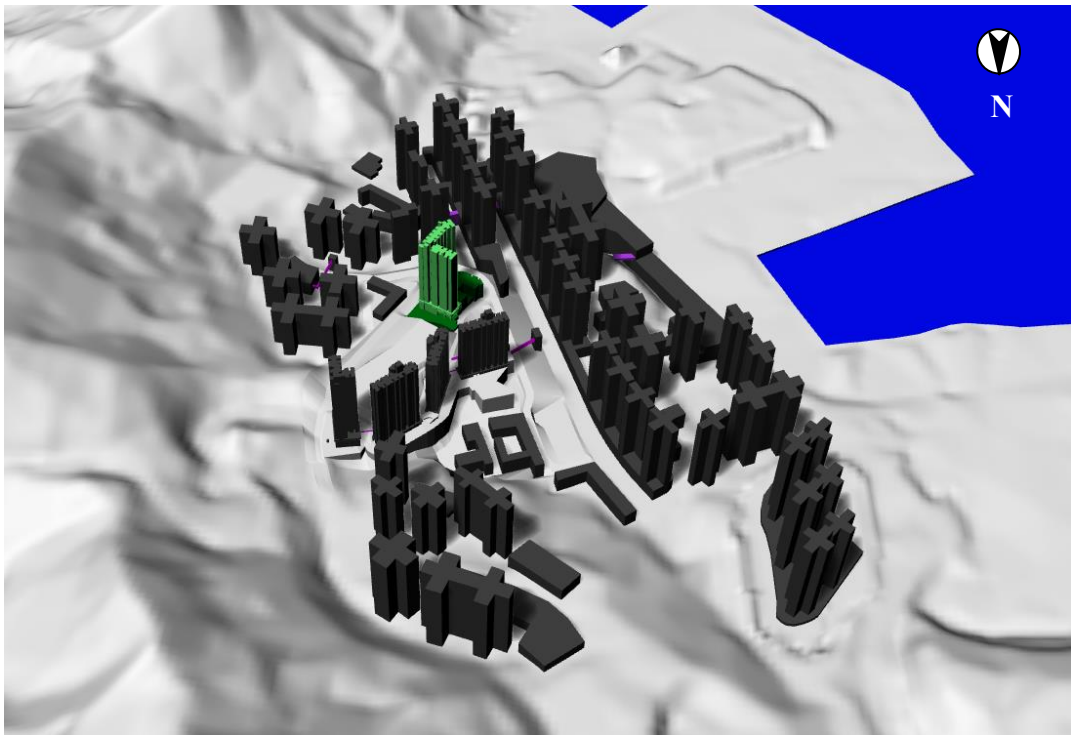


Figure 4 3D Model of the Development and its Surroundings (Northerly View)

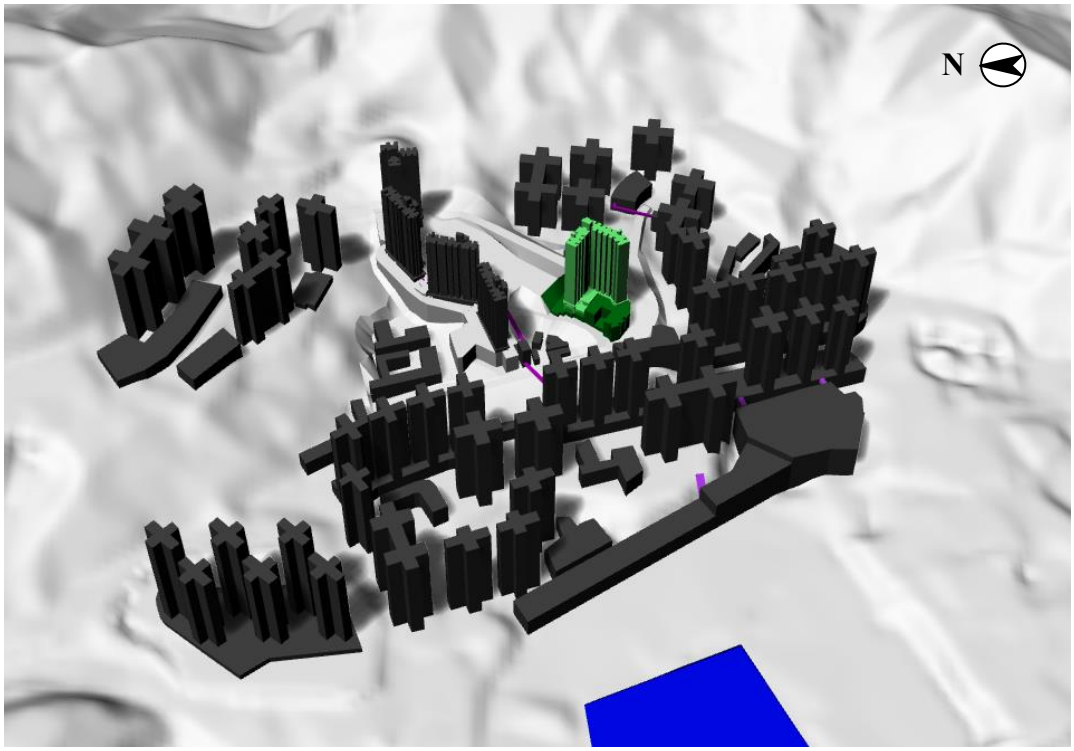


Figure 5 3D Model of the Development and its Surroundings (Westerly View)

Noise Barrier, Elevated Structure and Future Development

Noise Barrier

2.2 Noise barrier(s) are not found within the surrounding area (2H), the one in the closest vicinity to the surrounding area (2H) would be along Yau Tong Road near Yau Lai Estate, as shown in Figure 6.

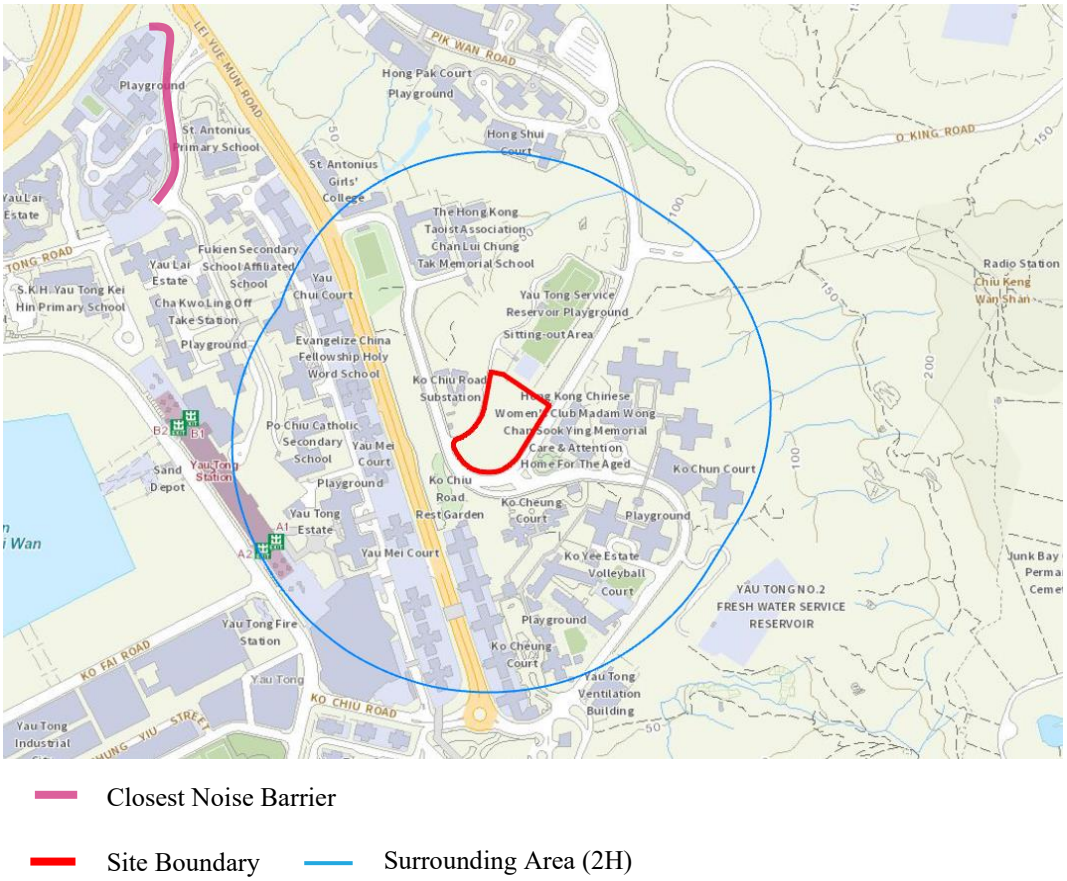


Figure 6 Location of the Closest Noise Barrier

Elevated Structures- Elevated Walkway

The elevated structure, such as elevated walkways, in the vicinity of the Development and within the 2H Surrounding Area are included in the AVA study. However, no elevated roads are identified within 2H Surrounding

There are 9 elevated walkways connecting to Ko Chun Court, Ko Yee Estate, Ko Cheung Court, Yau Mei Court, Yau Tong Estate, Lei Yue Mun Plaza, Yau Tong MTR Station and the Planned Development Pik Wan Road Site A as shown in Figure 7. The 3D model of the elevated walkways was built according to the Geoinfo Map website as shown in Figure 8. The elevated walkways are relatively bulky, Figure 9 shows the sample of the elevated walkways in the 3D model.

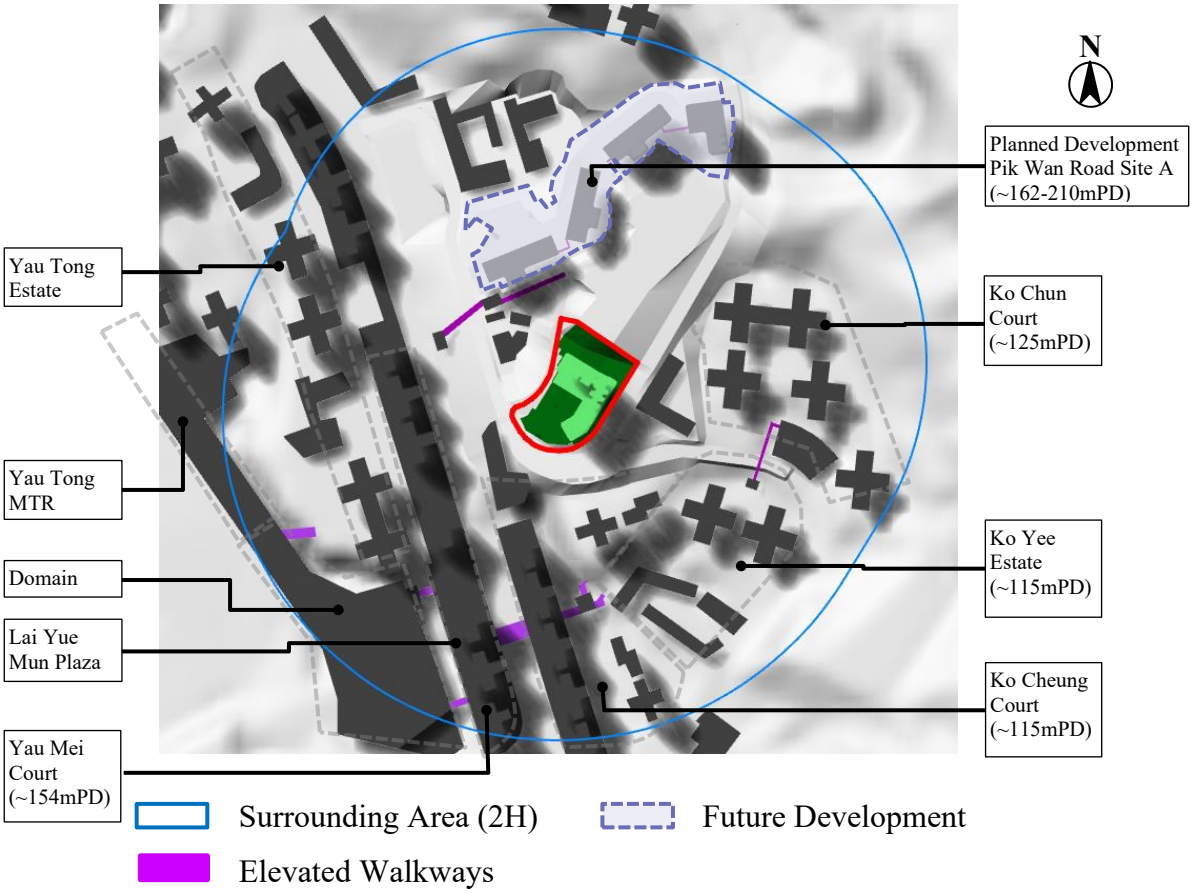


Figure 7 Elevated Structure and Future Development within Surrounding Area

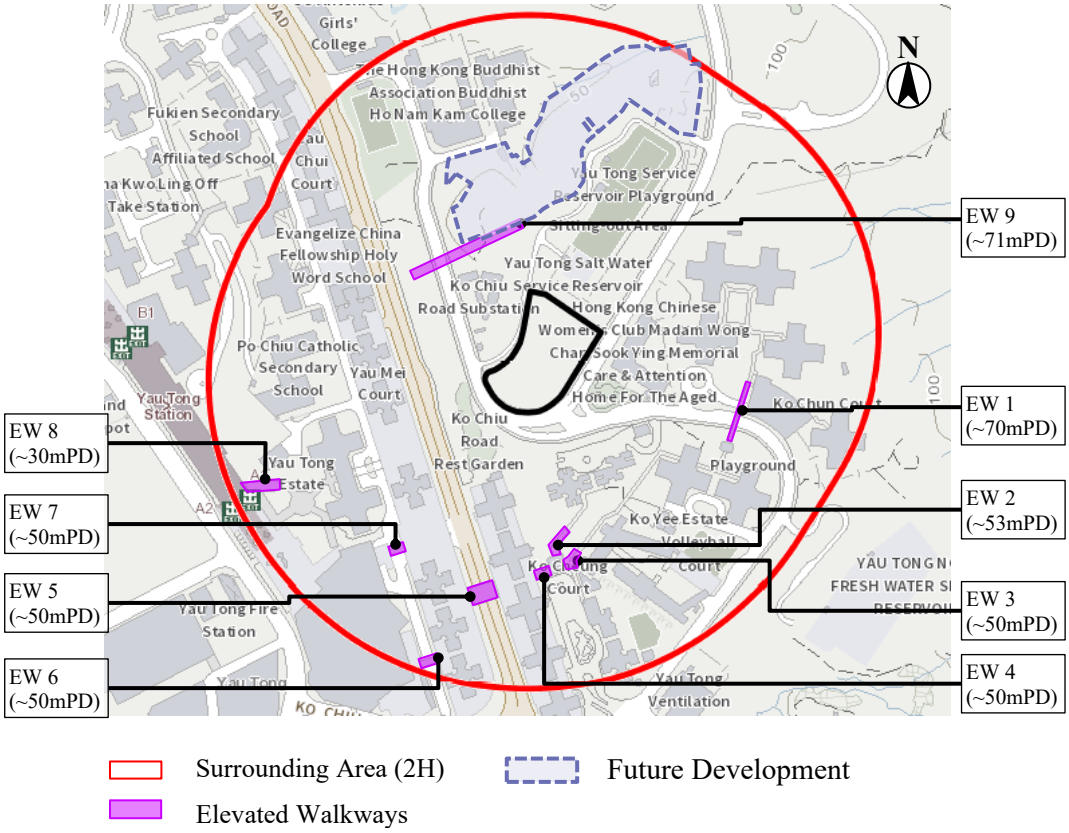


Figure 8 Location of Elevated Walkways and Future Development from Geoinfo Map

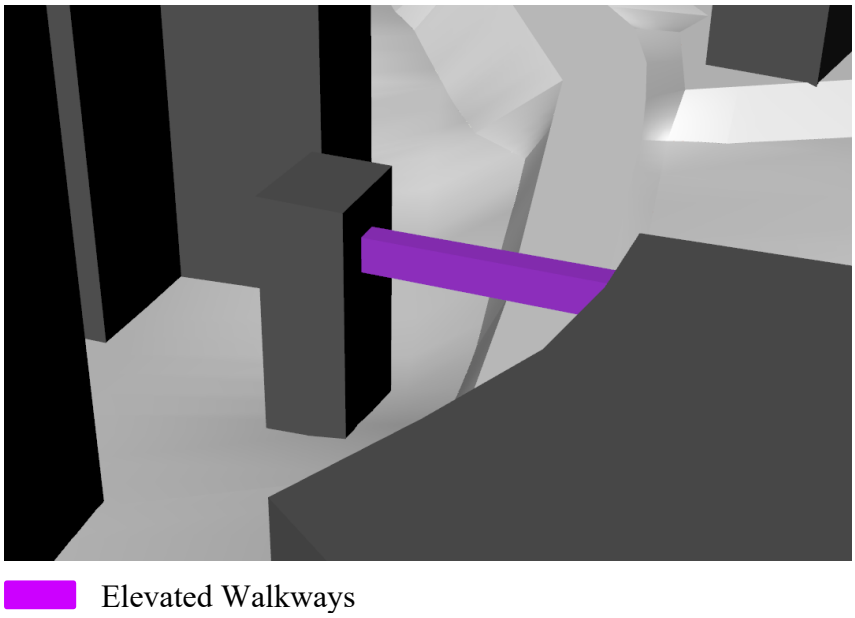


Figure 9 Elevated Walkways (EW 1) in 3D model

Future Development

There is one future development within the assessment area to be considered in this AVA – Initial Study.

The future development here is the Planned Development Pik Wan Road Site A (~162-210mPD). The Development consists of four residential towers (Block B to Block E). Block B contains a residential tower of 30 stories which sits atop a 6-storey General Out-Patient Clinic and Child Assessment Centre. Block C and D would each contain 32 and 36 stories for their residential towers respectively, both atop a 3-story podium structure containing an underground carpark. Block E contains a 38-story residential tower, below which would be a 3-storey Podium Structure. The top story and second story would be for welfare and kindergarten respectively.e

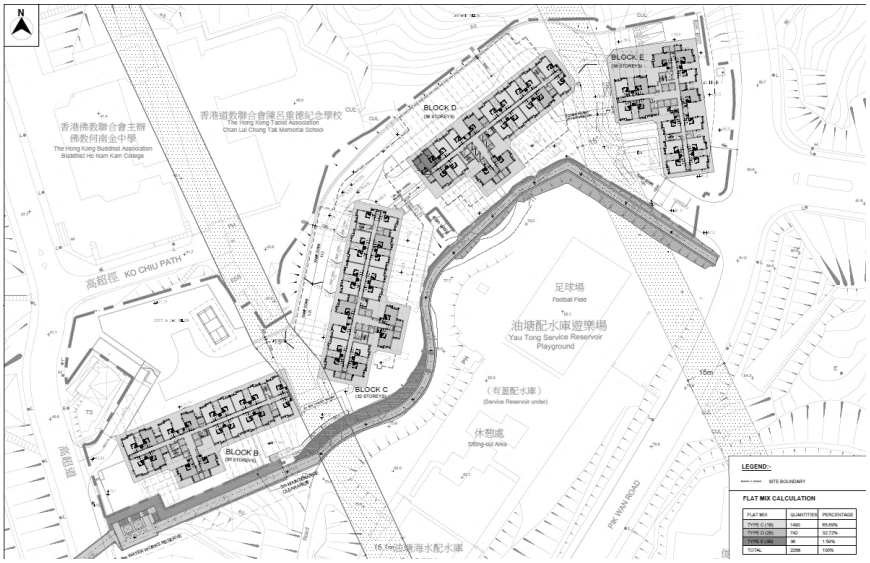


Figure 10 Plan of the Planned Development Pik Wan Road Site A

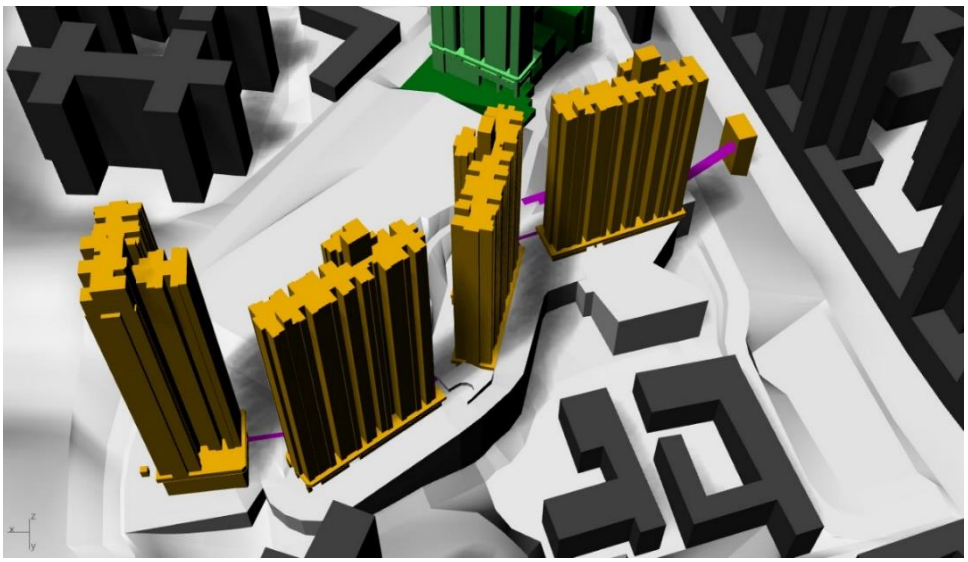


Figure 11 Northerly View of Planned Development Pik Wan Road Site A **(Orange)**

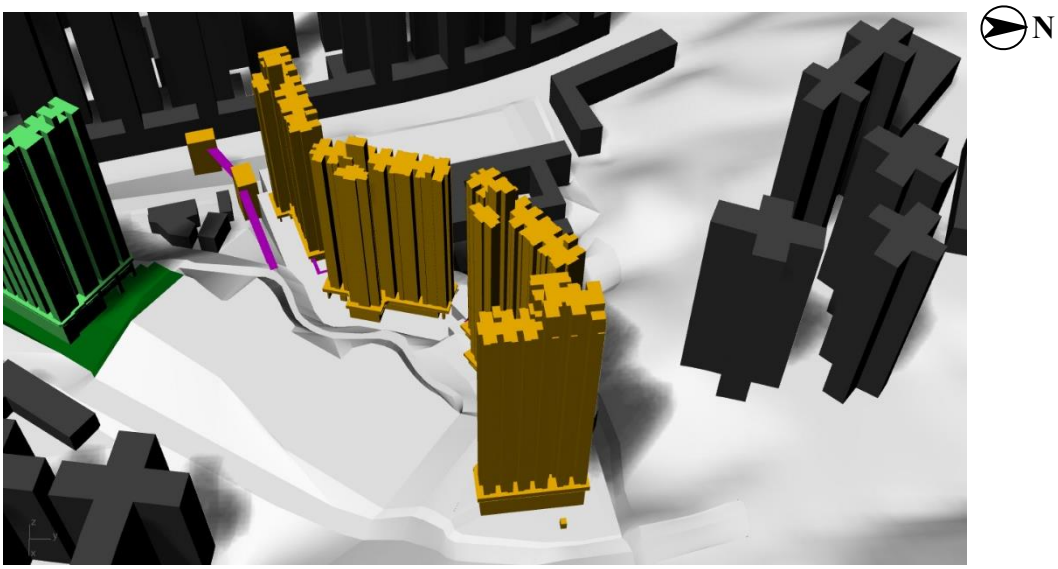


Figure 12 Easterly View of Planned Development Pik Wan Road Site A **(Orange)**

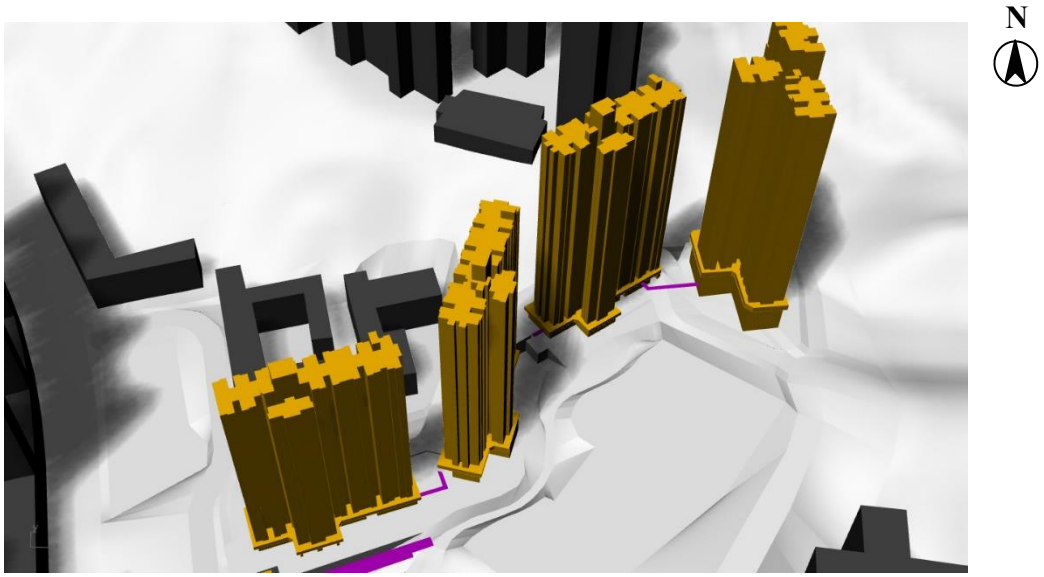


Figure 13 Southerly View of Planned Development Pik Wan Road Site A **(Orange)**

Figure 14 Westerly View of Planned Development Pik Wan Road Site A **(Orange)**

WIND AVAILABILITY DATA

3 As per the *AVA Technical Circular* [2], at least 75% of the time in a typical reference year (frequency of occurrence) would be studied under both annual and summer wind condition in the Initial Study when using a Computational Fluid Dynamics (CFD) modelling technique. Since the CFD approach is adopted for the present project's AVA, this criterion together with the following selected wind data are to be applied as the methodology.

The site wind availability of the Study Site and its surrounding is an essential parameter for AVA. As stipulated in the *AVA Technical Circular* [2] the site wind availability would be presented by using appropriate mathematical models. Planning Department (PlanD) has set up a set of simulated meso-scale data of Regional Atmospheric Modelling System (RAMS) of the territory for AVA study, which could be downloaded at Planning Department Website[3]. Simulated meso-scale data of Regional Atmospheric Modelling System (RAMS) from PlanD will therefore be adopted in this AVA Study. The location of the Development falls within the location grid (x:094, y:038) in the RAMS database as indicated in Figure 15.

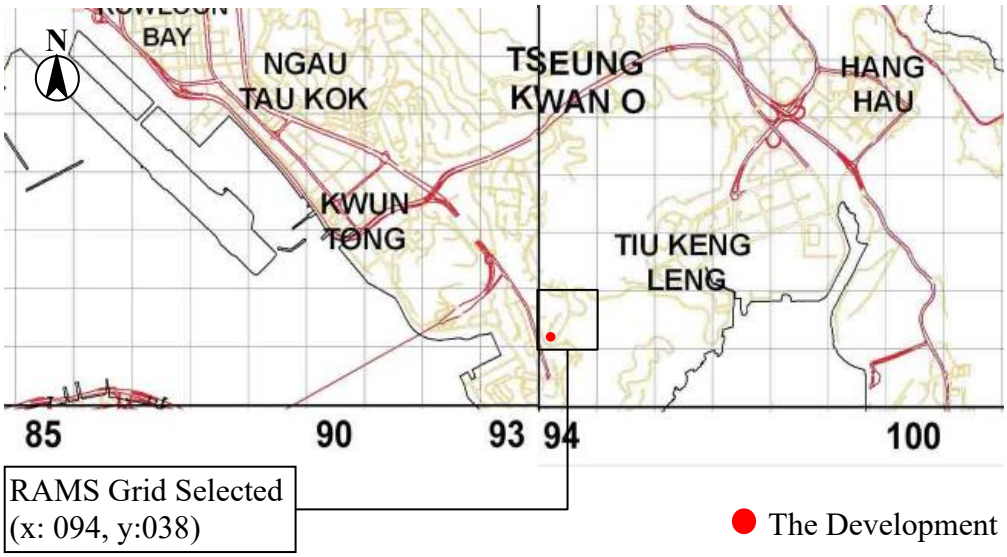


Figure 15 RAMS Grid and the Development Location

[3] Planning Department RAMS Data (*http://www.pland.gov.hk/pland_en/info_serv/site_wind/site_wind/*)

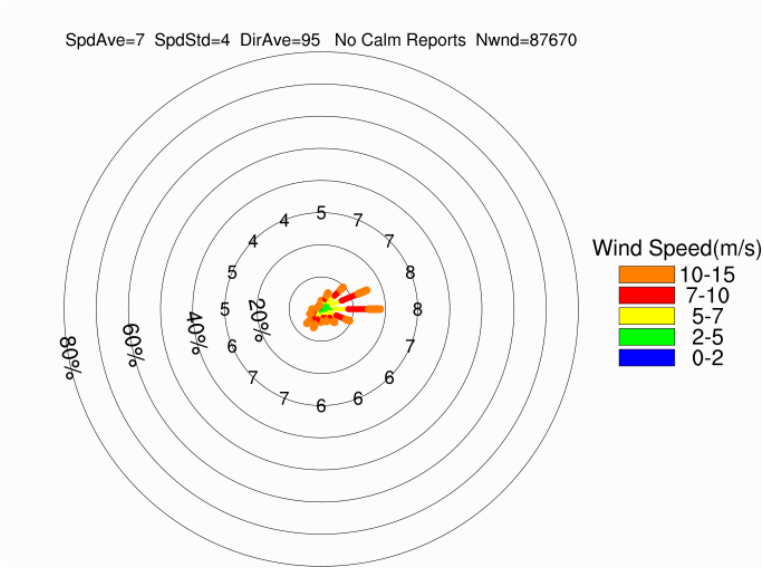


Figure 16 RAMS annual wind rose at 500mPD

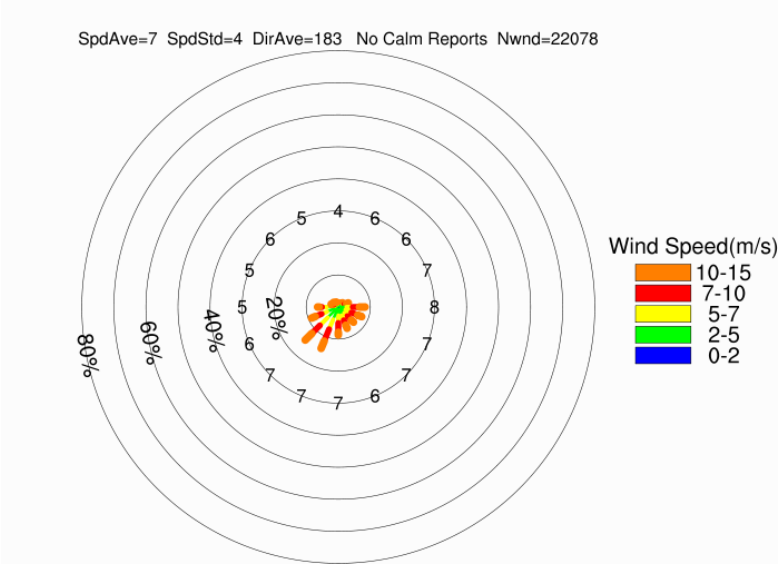


Figure 17 RAMS summer wind rose at 500mPD

3.1 Prevailing Wind Directions

3.1.1 As mentioned above, the RAMS wind data of location grid (x:094, y:038) is adopted for the site wind availability in this study.

Annual Prevailing Wind

Eight prevailing wind directions (highlighted in red Table 2) are considered in this AVA Study which covers 78.2% of the total annual wind frequency. They are north-north-easterly (5.6%), north-easterly (9.8%), east-north-easterly (15.7%), easterly (18.8%), east-south-easterly (9.7%), south-easterly (5.9%), south-south-westerly (6.3%) and south-westerly (6.4%) winds.

Table 1 Annual Wind Frequency

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	
Frequency	2.7%	5.6%	9.8%	15.7%	18.8%	9.7%	5.9%	4.2%	
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
Frequency	4.1%	6.3%	6.4%	3.9%	2.9%	1.3%	1.1%	1.4%	78.2%

** The wind frequency showing in red colour represents the selected winds for the CFD simulation.*

Summer Prevailing Wind

3.1.2 Eight prevailing wind directions (highlighted in red colour in Table 2) are considered in this AVA Study which covers 78.8% of the total summer wind frequency. They are easterly (8.8%), east-south-easterly (8.2%), south-easterly (6.9%), south-south-easterly (7.3%), southerly (9.0%), south-south-westerly (14.3%), south-westerly (15.1%) and west-south-westerly (9.2%) winds.

Table 2 Summer Wind Frequency

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	
Frequency	1.0%	1.4%	2.0%	3.7%	8.8%	8.2%	6.9%	7.3%	
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
Frequency	9.0%	14.3%	15.1%	9.2%	6.5%	2.4%	2.1%	1.7%	78.8%

** The wind frequency showing in red colour represents the recommended wind direction for the CFD simulation.*

3.2 Wind Profiles

The profiles of wind speed from the PlanD RAMS database (x:094, y:038) are shown in below.

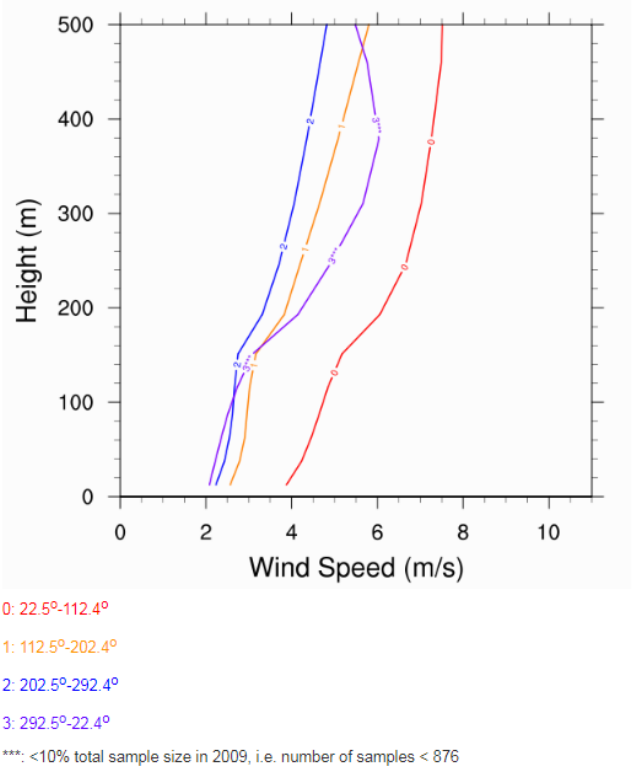


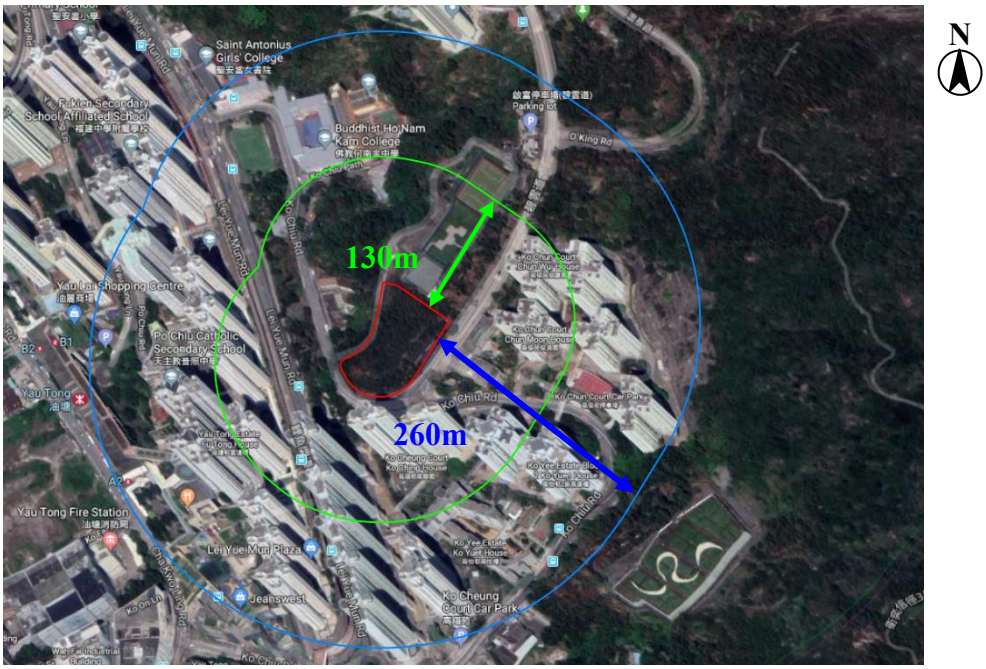
Figure 18 Normalised mean wind speed profile measured in 16 directions

The RAMS wind data is to be adopted in the AVA Initial study. It is recommended to extract the RAMS wind profile data directly as it can reflect the exact wind data. For wind data above 500m height, the velocity is assumed the same as the data at 500m. These wind data will be the input parameters in the CFD simulation.

Assessment and Surrounding Areas

3.3 With reference to the *AVA Technical Circular* [2], the areas of evaluation and assessment should include all area within the Project Area, as well as a belt up to 1H, where H is the height of the tallest building of the Proposed Development, around the site boundary.

With the building height of the proposed Development is around 122.67m, the Assessment Area and the Surrounding Area extended up to 130m (1H) and 260m (2H) respectively from the site boundary to include all concerned focus areas. As several high-rise buildings is located close to the 2H boundary, the surrounding area is extended to cover these high-rise building. The proposed Assessment Area and the Surrounding Area are indicated as below. The computational domain will be about 2730m(L) x 2650m(W) x 2200m(H).



3.4 Figure 19 Site boundary (red), Assessment Area (green) and Surrounding Area (blue)

Technical Details for CFD Simulation

Since there is no internationally recognized guideline or standard on using CFD for outdoor urban scale studies, reference was made to other CFD guidelines on different wind flow aspects to suggest a study approach for current study. The detail parameters are summarized in Table 3. The 3D model of the domain is given in below.

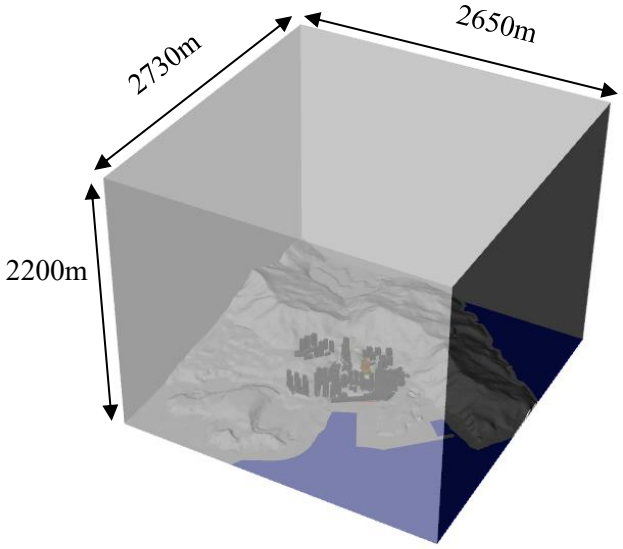


Figure 20 3D View of the Domain

3.4.1 Assessment Tools

Computational Fluid Dynamics (CFD) technique is utilized for this AVA study. With the use of three-dimensional CFD method, the local airflow distribution can be visualized in detail. The velocity distribution within the flow domain, being affected by the site-specific design and the nearby topography, will be simulated under selected wind directions as stated in Section 3.1 for annual and summer wind conditions.

3.4.2 CFD Model

Following the AVA Technical Circular, buildings within Surrounding Area shall be built in the CFD model. In order to simulate the approaching wind turbulence effect in a more accurate manner, the CFD model is built to include the highways or bridges as they may affect the approaching wind, even it is falling outside the Surrounding Area. In addition, the model domain is built far beyond the Surrounding Area as required in the Technical Circular in order to eliminate the boundary effects. Therefore, the studied size of CFD model of the development is approximately 2730m (Length) x 2650m (Width) x 2200m (Height).

The computational domain covers the site of the Development and provides sufficient consideration on surrounding topography. The model contains information of the surrounding buildings and site topography via Geographical Information System (GIS) platform. The site topography would be modelled within the whole computational domain. Body-fitted unstructured grid technique is used to fit the geometry and reflect the complexity of the development geometry. A prism layer of 3m above ground (totally 6 layers and each layer of 0.5m thick is incorporated in the meshing so as to better capture the approaching wind and wind condition at pedestrian level. A mesh expansion ratio of 1.3 is adopted and the blockage ratio was less than 2%.

Table 3 Detail parameters to be adopted in the CFD

	CFD Model
Model Scale	Real Scale model
Model details	Only include Topography, Buildings blocks, Streets/Highways, no landscape is included
Domain	2730m(L) x 2650m(W) x 2200m(H)
Assessment Area	≥ 1H area
Surrounding building Area	≥ 2H area
Grid Expansion Ratio	The grid should satisfy the grid resolution requirement with maximum expansion ratio = 1.3
Prismatic layer	6 layer of prismatic layers and 0.5m each (i.e. total 3m above ground)
Inflow boundary Condition	Incoming wind profile as measured from RAMS
Outflow boundary	Pressure boundary condition with dynamic pressure equal to zero
Wall boundary condition	Logarithmic law boundary
Turbulence Model	Realisable k-ε turbulence model
Solving algorithms	Rhie and Chow SIMPLE for momentum equation Hybrid model for all other equations
Blockage ratio	< 2%
Convergence criteria	Below $1.0E^{-4}$

Data Presentation

The wind speed information at pedestrian level (2m above ground) will be acquired to determine the Wind Velocity Ratio (*VR*) as stipulated in the *AVA Technical Circular* [2] and as defined as follows:

3.5

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

where V_p is the wind speed at the pedestrian height (2m above ground) and V_∞ is the wind velocity at the top of the boundary layer (defined as the height where wind is unaffected by urban roughness and determined by the topographical studies). Measurement will be taken in the following areas within the "Assessment Area":

Along the boundary of Development Area (defined as "Perimeter" test-points), such that the Site-Spatial Average Velocity Ratio (*SVR*) can be determined (as per the *AVA Technical Circular* [2].); and

Throughout the Assessment Area other than the perimeter test-points (defined as "Overall" Test-points), such that the Local Spatial Average Velocity Ratio (LVR) can be determined by taking an average of all overall and perimeter test-points (as the *AVA Technical Circular* [2])

According to Clause 6.14.11 of the Study Brief, wind speed of all test points will also be provided.

3.6 Locations of Test Points

As per the technical circular, three types of test point – perimeter test point, overall test point and special test point will be adopted to assess the wind performance. The allocation of these test points will be distributed evenly as stated in the *AVA Technical Circular* [2].

3.6.1

Perimeter Test Points

A total number of 31 perimeter test points (**Red spots**), namely P points, are positioned at intervals of around 15m along the project site boundary in accordance with the *AVA Technical Circular* [2]. The locations of perimeter test points are shown in Figure 21.

3.6.2

Overall Test Points

A total number of 121 overall test points (**Black spots**), namely O points, are evenly distributed in open areas within the assessment area, such as the streets and places where pedestrian frequently access. The locations of perimeter test points are shown in Figure 21.

Special Test Points

A total number of 17 (Pink spots) and 25 (Blue spots) Special test points are identified in the Baseline Scheme and Proposed Scheme respectively, namely S points. They are evenly distributed on the podium open spaces in order to compare the permeability of the podium in both schemes. The locations for special test points under Baseline Scheme and Proposed Scheme are shown in Figure 22 and Figure 23.

3.6.3

Within the proposed Assessment Area and the Development Area given in Figure 19, a total of 16 focus areas are proposed. The focus areas are tabulated in Table 4 below and their associated test points and location for each focus area are shown in Figure 21.

Table 4 Focus Areas and Corresponding Test Points

	Focus Area	Test Points
1	Ko Chiu Path	O1-O4
2	Ko Chiu Road	O5-O11,P10-P15, O12-O18
3	Lei Yue Mun Road	O19-O27
4	New Public Footpath	O28-O34, P16-P24
5	Pik Wan Road	O35-O39, P1-P9
6	Yau Tong Service Reservoir Playground	O40-O45
7	HK Chinese Women's Club WCSY Memorial Care and Attention Centre	O46-O49
8	Pik Wan Road Rest Garden	O50-O53
9	Ko Chun Court Open Spaces	O54-O69
10	Ko Yee Estate Open Spaces	O70-O75
11	Ko Cheung Court Open Spaces	O76-O83
12	Ko Chiu Road Rest Garden	O84-O91
13	Proposed Development Pik Wan Road Site A	O92-O106
14	Yau Mei Court Podium Open Space	O107-O115
15	Access Road in Yau Tong Estate	O116-O121
16	Podium Open Space	S1-S17 (Baseline) S1-S25 (Proposed)

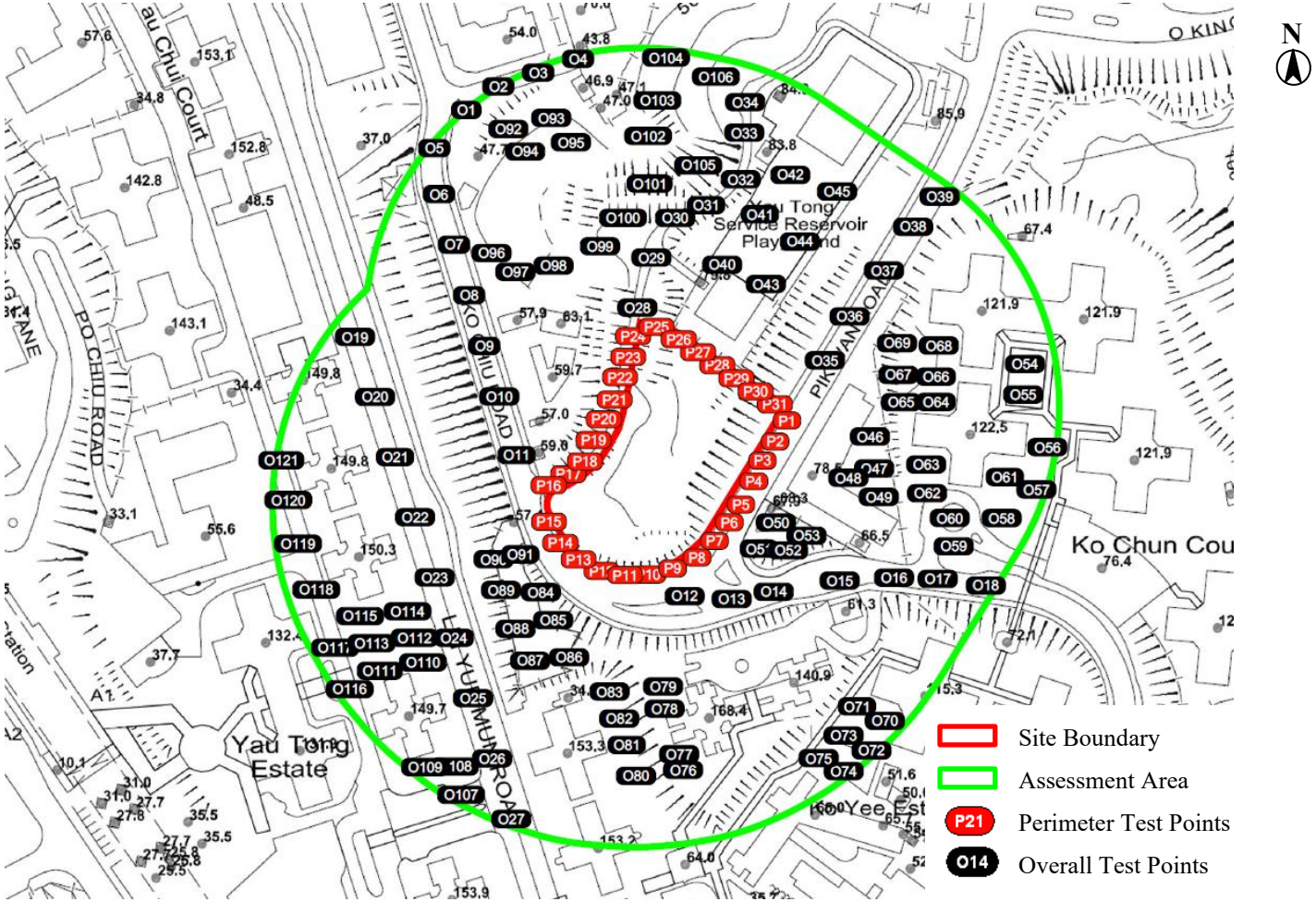


Figure 21 Location of Perimeter and Overall Test Points

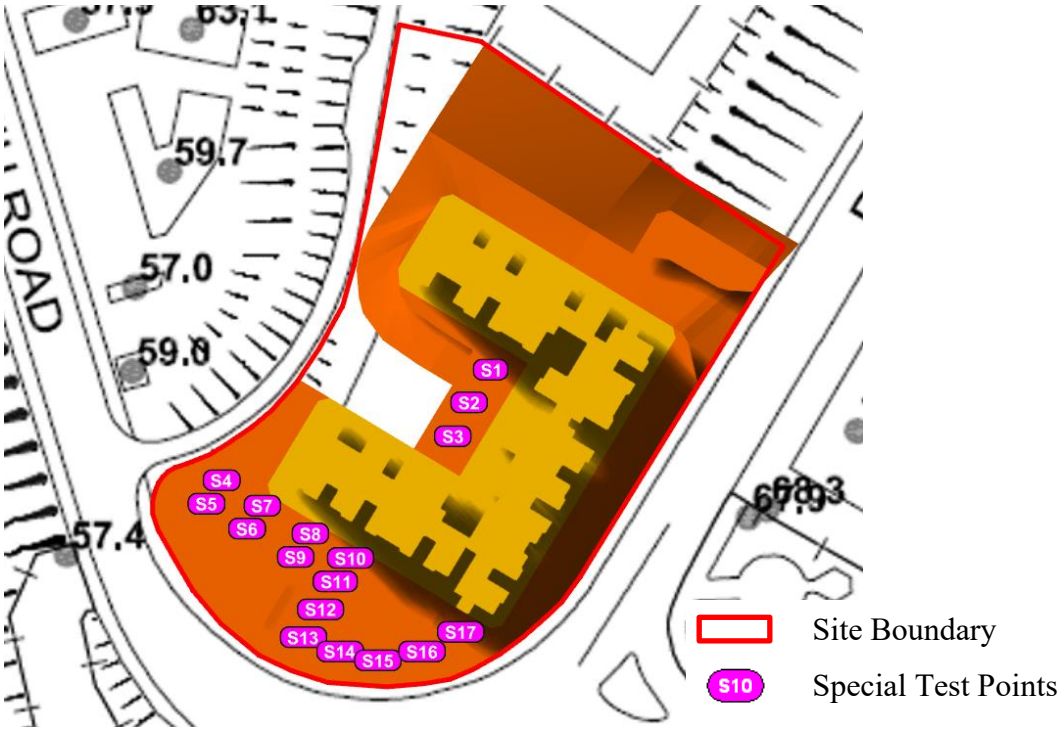


Figure 22 Special test points in Baseline Scheme

Figure 23 Special test points in Proposed Scheme

4 DESIGN SCHEMES FOR AVA STUDY

Two schemes will be analysed and compared in this AVA Initial Study, namely the Baseline Scheme and the Proposed Scheme.

4.1 Baseline Scheme (OZP Compliance Scheme)

Baseline Scheme is an OZP Compliance Scheme which make up to 150mPD as the building height restriction for the Development site. The baseline building tower is in U-Shape sitting on top of an extensive podium structure which would serve mostly as the Residential Care Home for the elderly (RCHE) and car park. The residential tower of the Baseline Scheme is 24-storey up to 150mPD. The RCHE block is 5-storey height which the top of it is the podium level of ~78mPD. Open Spaces are provided on the podium.

The Baseline Scheme has provide a ~78m tower separation with the Pik Wan Road Site A as shown in Figure 25, to allow the valley wind flowing down along O King Road to penetrate through, which can serve as a district air path.

The key development parameters of the Baseline Scheme are presented in Table 5.

Table 5 Development Parameters of Baseline Scheme

Development Parameter	Baseline Scheme
Plot Ratio (PR)	Domestic: 5.5
Maximum Building Height	150mPD
No. of Flats	552

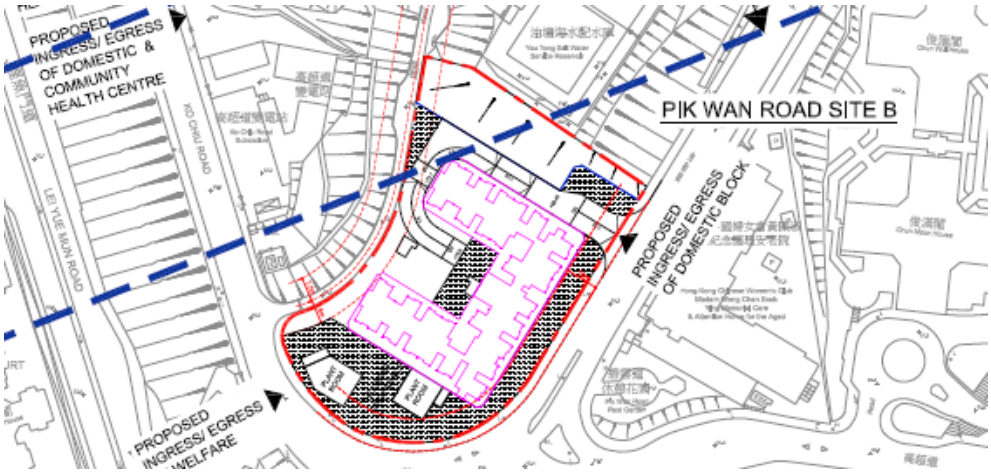


Figure 24 Site Layout Plan (Baseline)

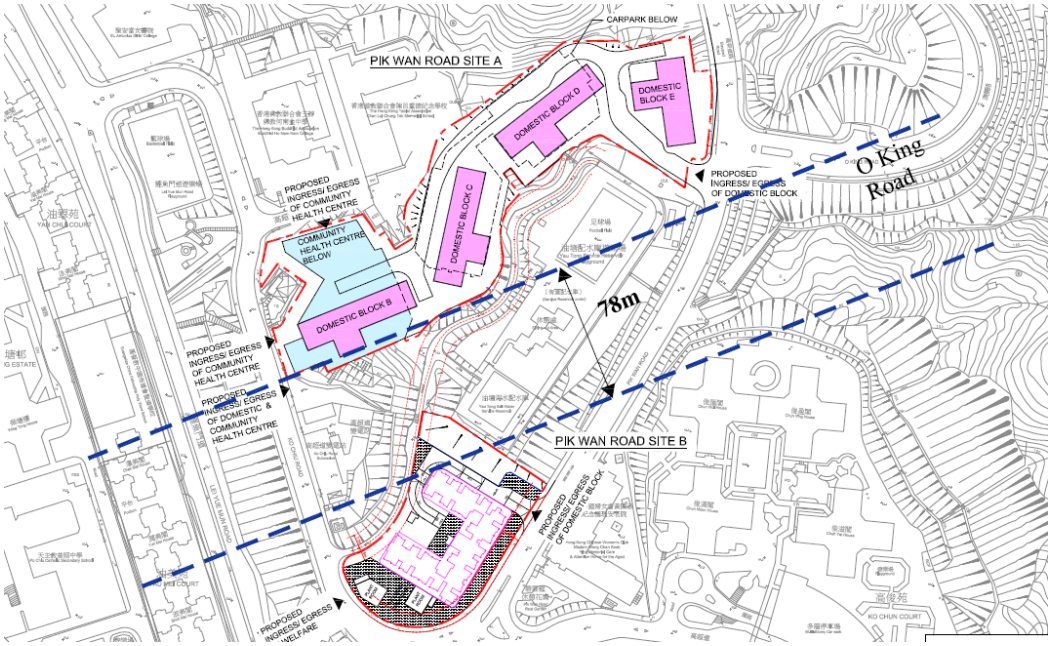


Figure 25 Air Path between the Baseline Development and Pik Wan Road Site A

By referring to the CAD drawings of the Baseline Scheme, the 3D model was constructed as shown in to Figure 29.

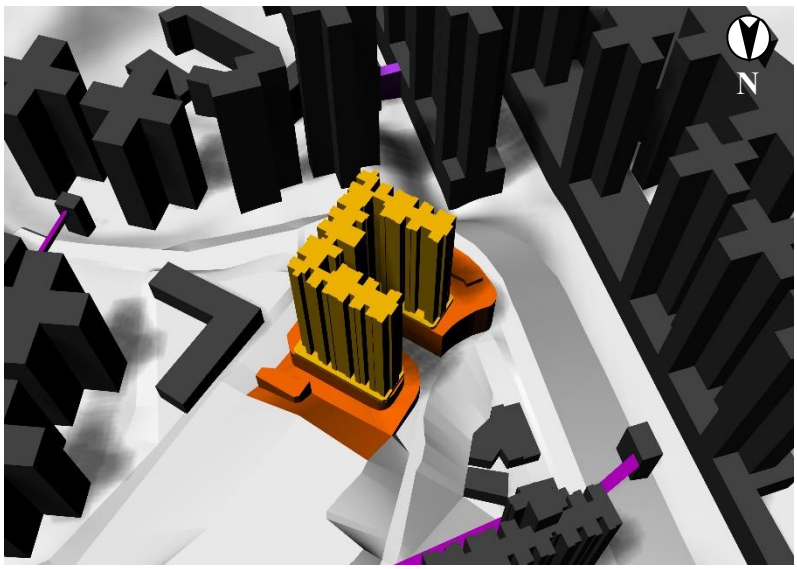


Figure 26 Northerly view of Baseline Scheme

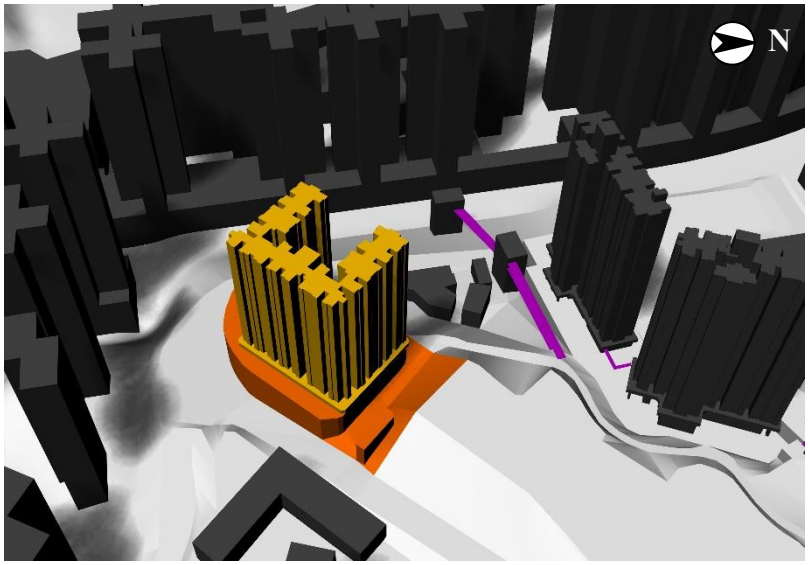


Figure 27 Easterly view of Baseline Scheme

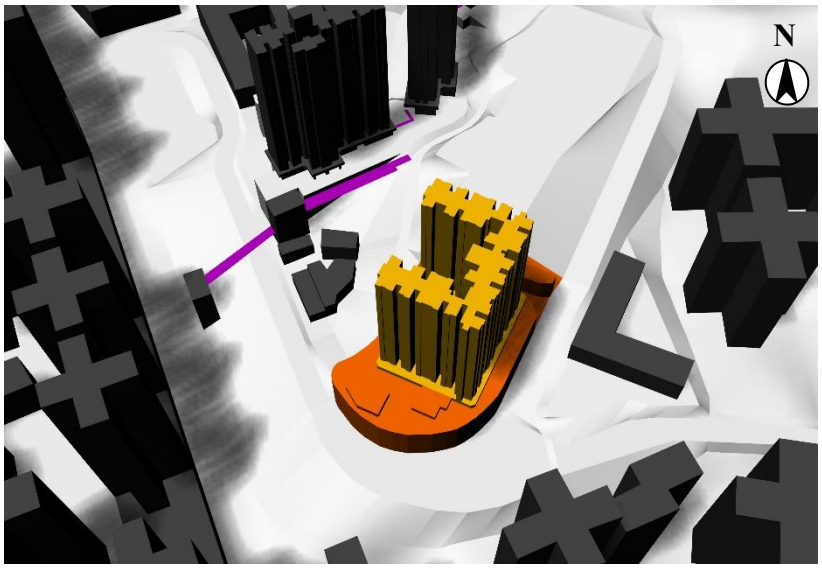


Figure 28 Southerly view of Baseline Scheme

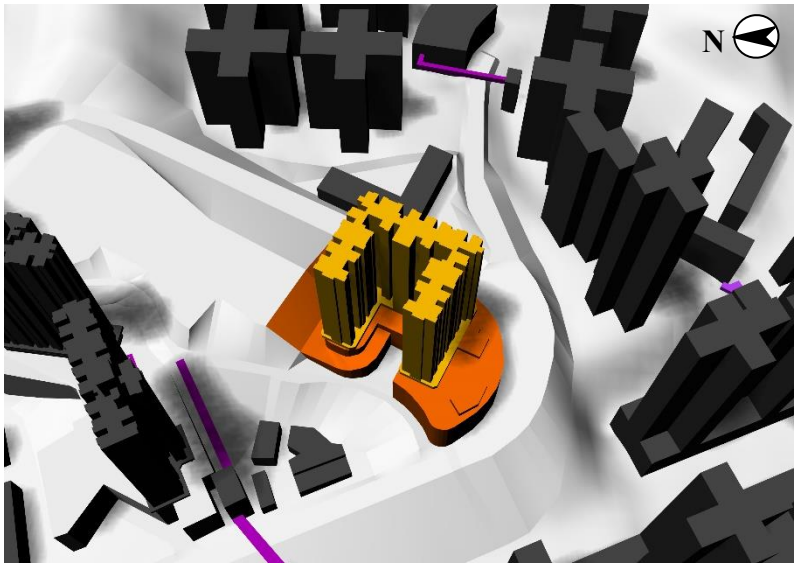


Figure 29 Westerly view of Baseline Scheme

4.2 Proposed Scheme

Proposed Scheme is the intended development scheme, which is formulated under the higher plot ratio and with higher building height, providing more domestic flats, comparing to Baseline Scheme.

The building tower is in L-shape, sitting top of a smaller podium structure compares with the Baseline Scheme. The podium structure consists of a 4-storey Residential Care Home for the elderly (RCHE) and a car park. The RCHE has a podium open space situated at ~81mPD.

The Proposed Scheme has preserved the ~78m tower separation with the Pik Wan Road Site A as shown in Figure 32, to allow the valley wind flowing down along O King Road to penetrate through, serving as the district air path.

The key development parameters of Proposed Scheme are presented in Table 6.

The changes made comparing to Baseline Scheme are listed as below:

- Smaller podium structure that would provide podium and tower setback from major roads, as show in Figure 24 and Figure 30
- A permeable podium design for enhanced ventilation as shown in Figure 31

Table 6 Development Parameters of Proposed Scheme

Development Parameter	Proposed Scheme
Maximum Plot Ratio (PR)	Domestic: 7.5 Non- Domestic: 1.5 Total: 9
Maximum Building Height	185mPD
No. of Flats	864

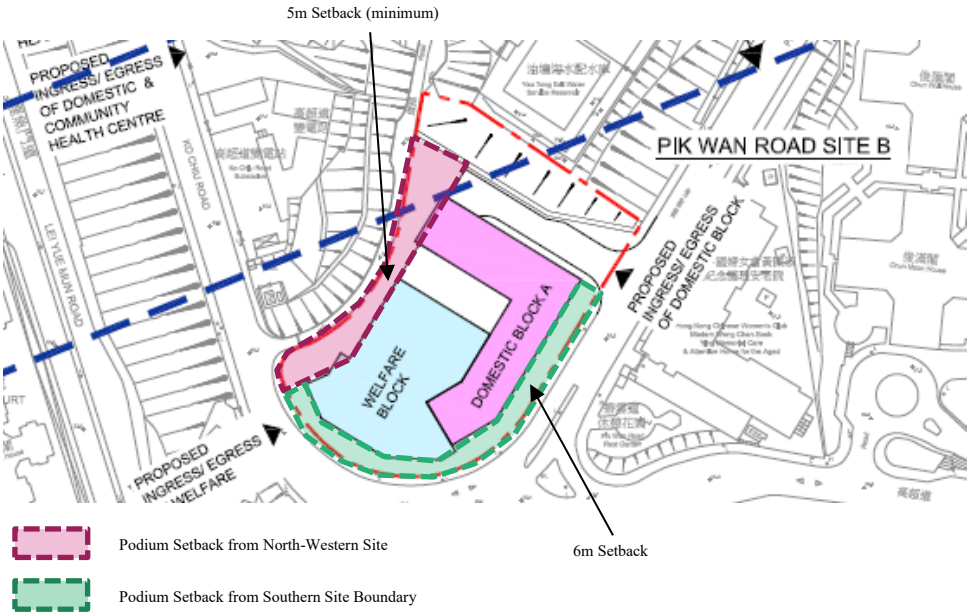


Figure 30 Site Layout Plan (Proposed)

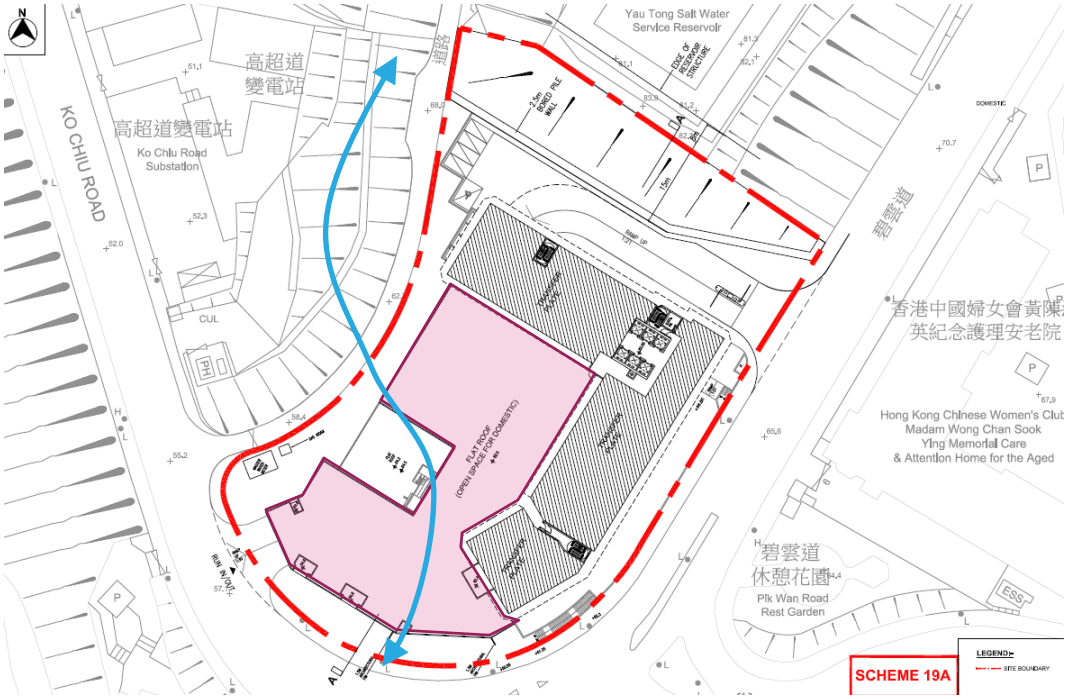


Figure 31 Permeable Podium

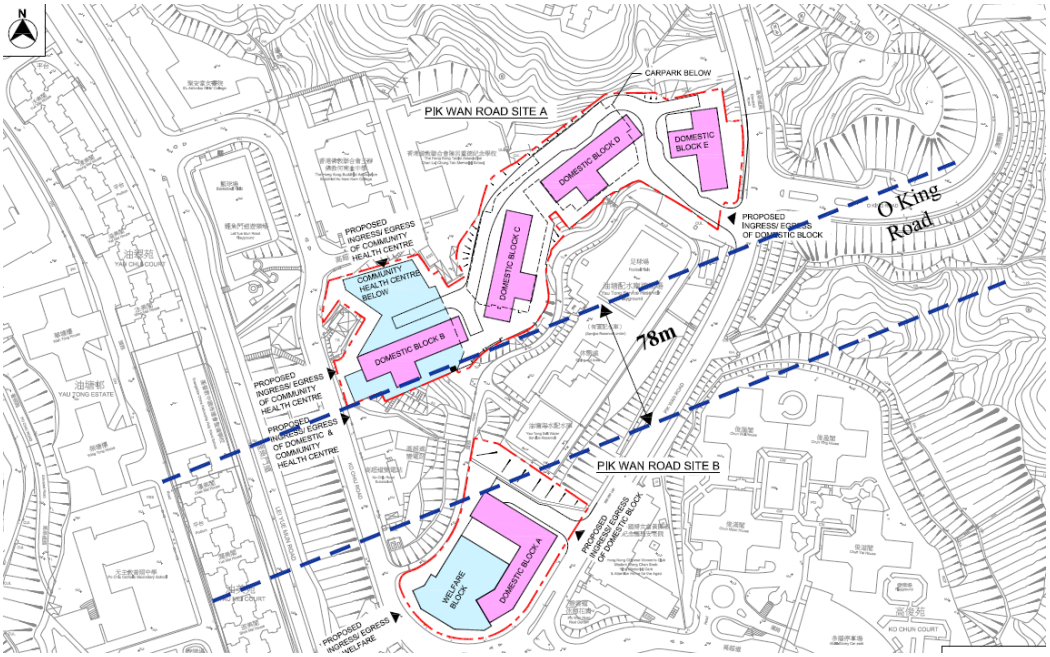


Figure 32 Air Path between the Proposed Development and Pik Wan Road Site A

By referring to the CAD drawings of the Proposed Scheme, the 3D model was constructed as shown in Figure 33 to Figure 36.

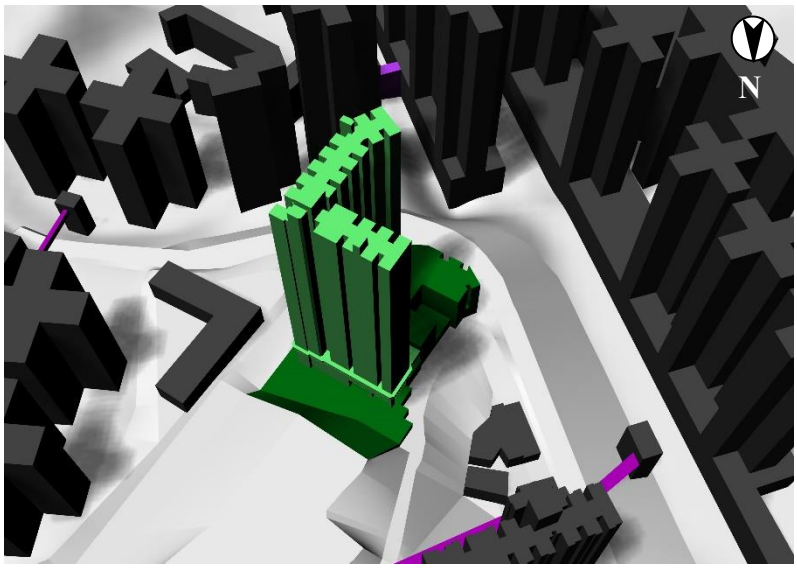


Figure 33 Northerly view of Proposed Scheme

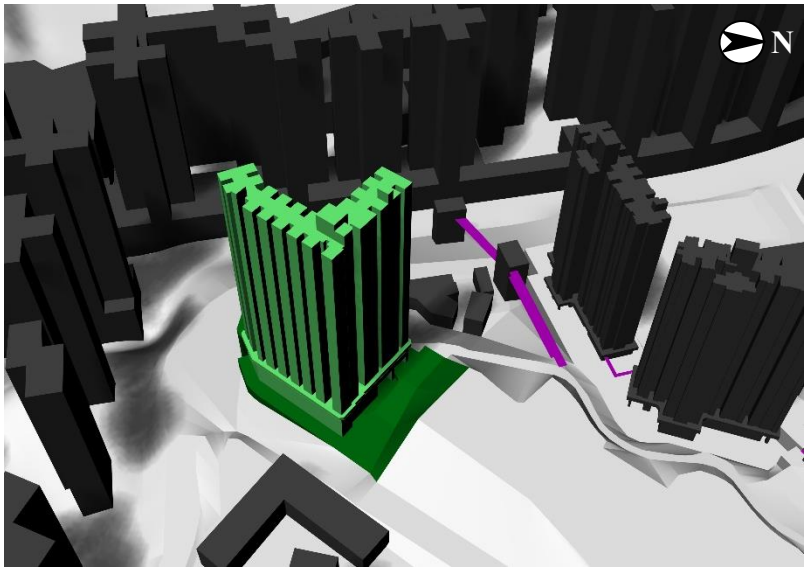


Figure 34 Easterly view of Proposed Scheme

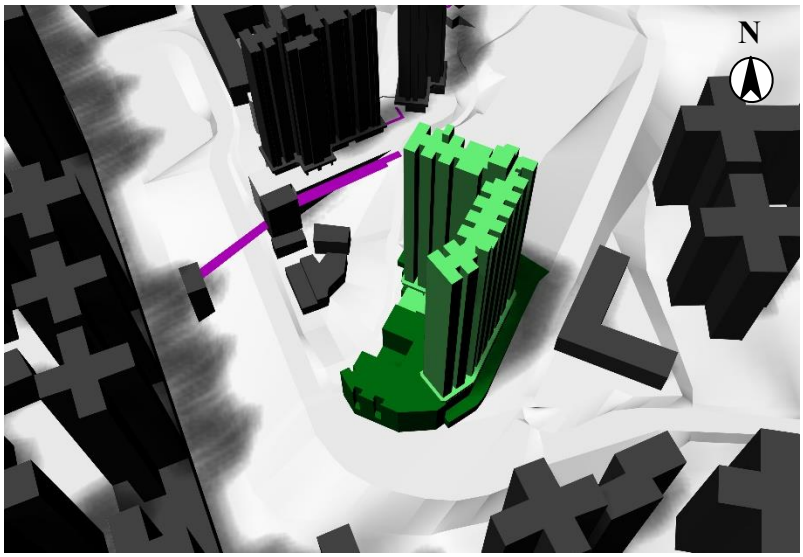


Figure 35 Southerly view of Proposed Scheme

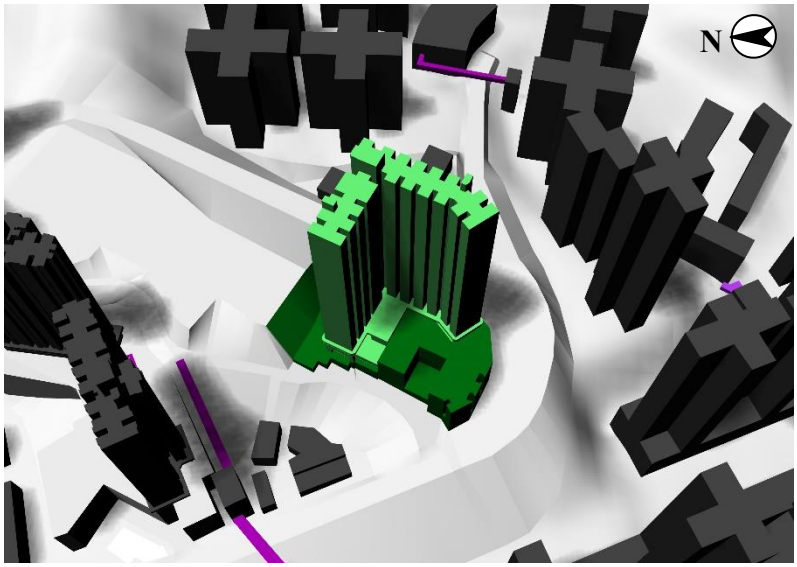


Figure 36 Westerly view of Proposed Scheme

5 RESULTS AND DISCUSSION

5.1 Annual Overall Wind Performance

The prevailing wind would generally come from NNE to E quadrant. The SVR and LVR are tabulated in Table 7.

Table 7 SVR and LVR under Annual Condition

	Baseline Scheme	Proposed Scheme
SVR	0.26	0.29
LVR	0.25	0.26

The Proposed Scheme has achieved higher SVR and LVR by 0.03 and 0.01 comparing to Baseline Scheme.

Generally, the overall wind environment of Proposed Scheme is slightly better than that in Baseline Scheme The annual prevailing wind would contribute to approximately 78.2% of the annual condition.

The hilly Chiu Keng Wan Shan and high-rise residential clusters located to the east of the site, which would hinder the incoming prevailing E quadrant wind. The incoming prevailing wind thus channelled through the valley at northeast of the site. The wind from the northeast would channel along Pik Wan Road to the southern side. Therefore, Pik Wan Road generally has a satisfactory wind environment.

Under Proposed Scheme, in which the Development is ~35m taller than that in Baseline Scheme. With the major building frontage facing NE and SE directions, a larger portion of wind would be captured and downwash to Pik Wan Road and the surrounding areas nearby. Combined with the widened ventilation path along Pik Wan Road under Proposed Scheme, the ventilation performance around these areas would be improved.

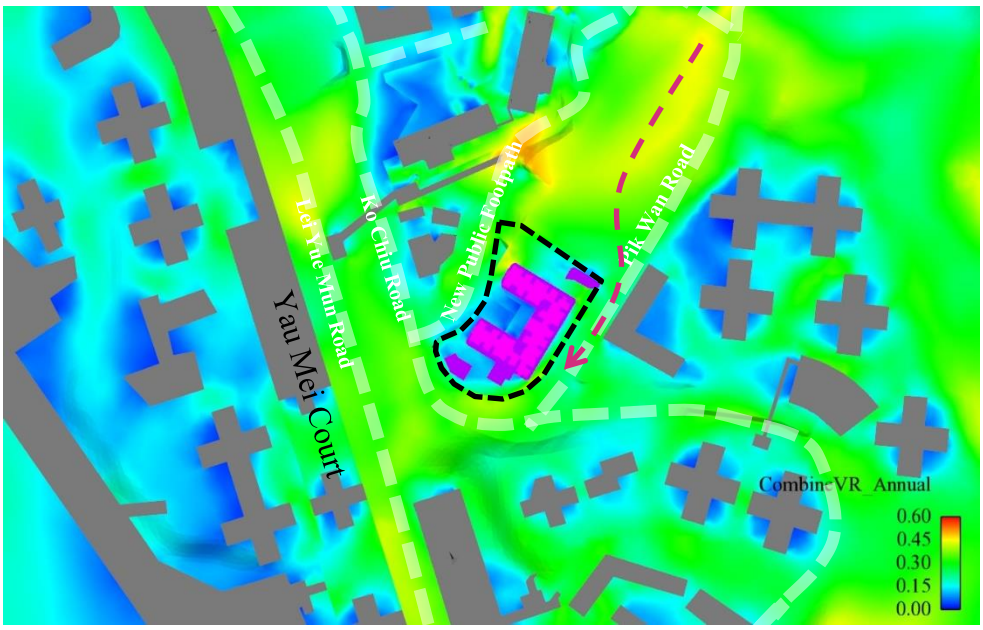


Figure 37 Baseline Scheme Contour Plot for Annual Prevailing Wind Condition

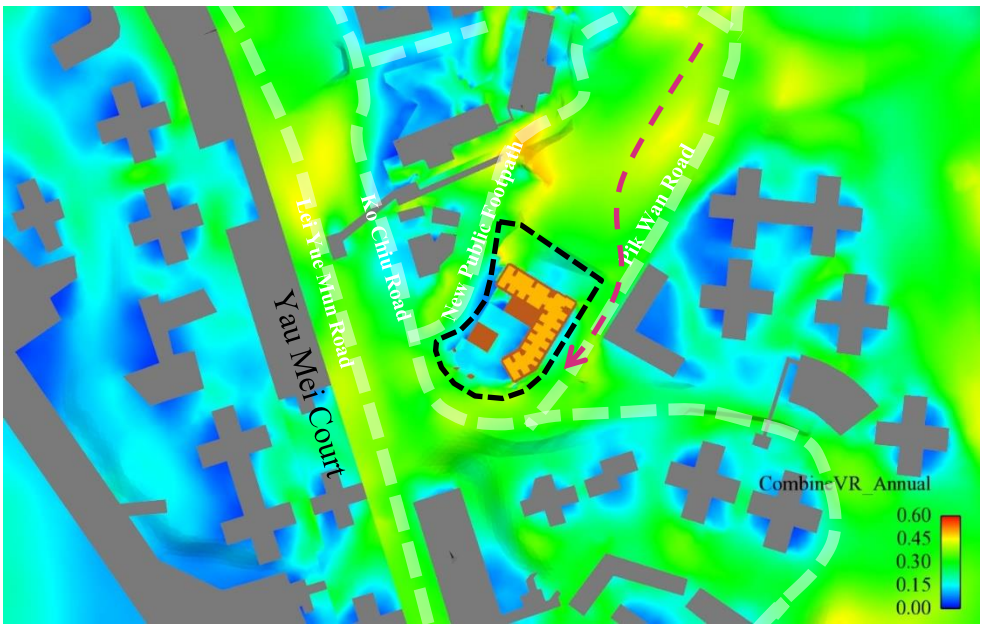


Figure 38 Proposed Scheme Contour Plot for Annual Prevailing Wind Condition

5.2 Summer Overall Wind Performance

Summer prevailing wind comes generally from the S to SW quadrant. The SVR and LVR are tabulated in Table 8.

Table 8 SVR and LVR under Summer Condition

	Baseline	Proposed Scheme
SVR	0.20	0.20
LVR	0.22	0.22

The Proposed Scheme here has achieved an equivalent performance as the Baseline Scheme. The summer prevailing wind would contribute to approximately 78.8% of the annual condition.

The upwind side of the site is Yau Mei Court and Ko Cheung Court, which consists of high density cluster of high-rise residential development. Such high-rise cluster would inevitably block a large portion of summer wind approaching to the site. The summer wind could only flow towards the site through its relatively larger building separations such as between Ho Mei House and Ying Mei House (~45m).

Owing to the large podium of RCHE block, the summer wind from the SW quadrant would be diverted by the block and flow towards Ko Chiu Road and Pik Wan Road. The permeable design of the podium in Proposed Scheme also allows more summer wind could flow across the site towards the New Public Footpath and Pik Wan Road Site A, enhancing the ventilation performance there.

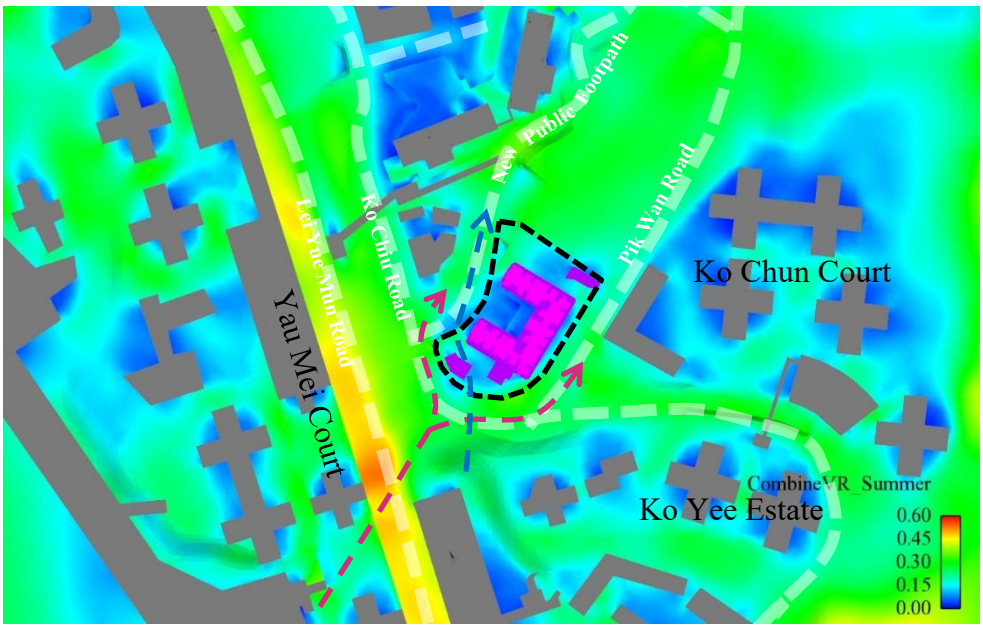


Figure 39 Baseline Scheme Contour Plot for Summer Prevailing Wind Condition

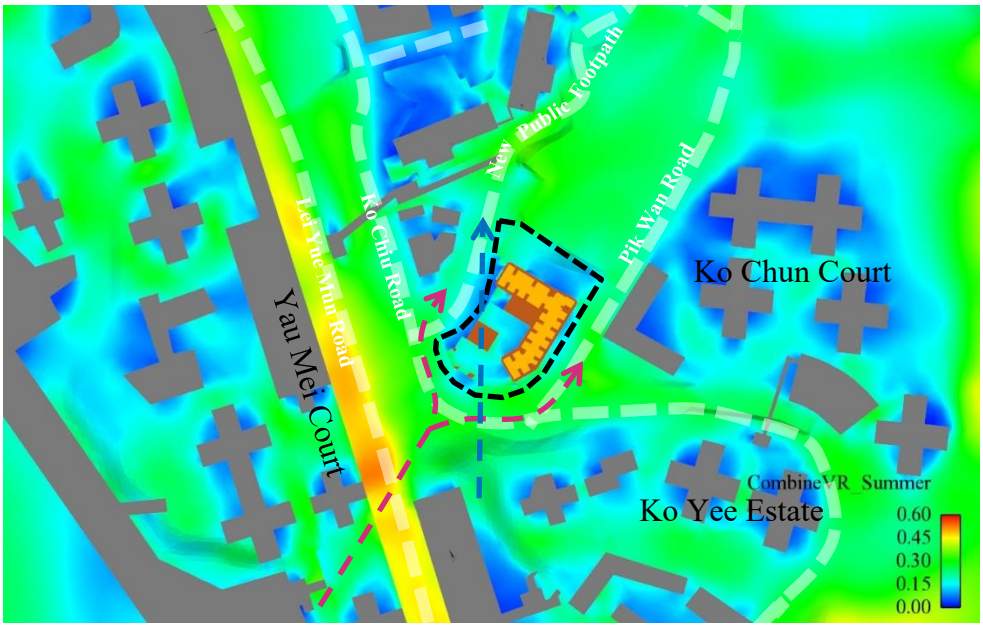


Figure 40 Proposed Scheme Contour Plot for Summer Prevailing Wind Condition

5.3 Directional Analysis

5.3.1 NNE wind

The prevailing wind coming from NNE wind would contribute to 5.6% to the annual condition respectively. The overall ventilation performance under NNE wind can be summarised as below:

- Pik Wan Road, Pik Wan Road Rest Garden, Ko Cheung Court Open Spaces, Yau Mei Court Podium Open Space and Site Perimeter (P points) would have a higher VR under PROPOSED Scheme.
- New Public Footpath, HK Chinese Women's Club WCSY Memorial Care and Attention Centre would have a slightly higher VR under Baseline Scheme.

For both Baseline and Proposed Scheme, at pedestrian level, the NNE incoming wind coming from the mountain valley would be downwashed to the pedestrian level and diverted by the NE facing façade of both the Baseline and Proposed Development, the diverted NNE wind would stream along the New Public Footpath and Pik Wan Road and flow towards Lei Yue Mun Road. (**Red Arrow**)

Under Proposed Scheme, due to the podium setback form the eastern site boundary (~6m), there exists a larger building separation between the Development the HK Chinese Women's Club WCSY Memorial Care and Attention Center. This would further widen the ventilation path along Pik Wan Road, a larger portion of wind would then be able to travel down Pik Wan Road and enhance the vicinity area's ventilation. Thus, Pik Wan Road Rest Garden, Ko Cheung Court Open Spaces and Yau Mei Court Podium Open Space would be slightly improved in its wind environment.

The widening of Pik Wan Road by the podium setback under Proposed Scheme would promote wind to travel along Pik Wan Road while the wind would be diverted by Baseline scheme towards the HK Chinese Women's Club WCSY Memorial Care and Attention Center. Hence, higher VR would be observed along the eastern site boundary of Proposed Scheme while slightly lower VR would be resulted around HK Chinese Women's Club WCSY Memorial Care and Attention Center.

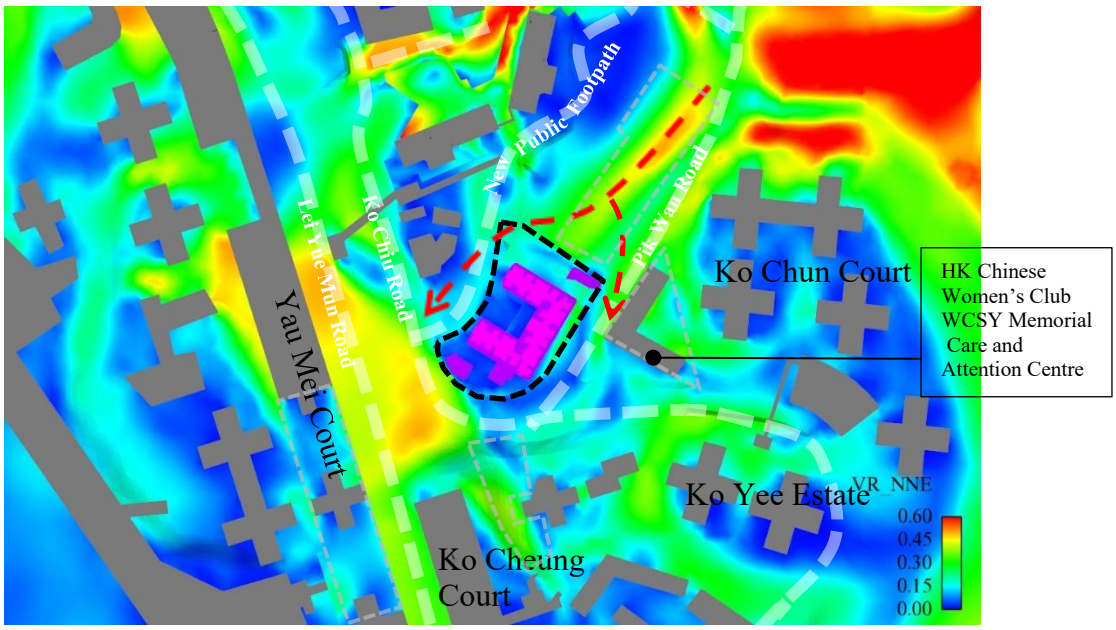


Figure 41 VR Contour Plot under NNE Wind (Baseline Scheme)

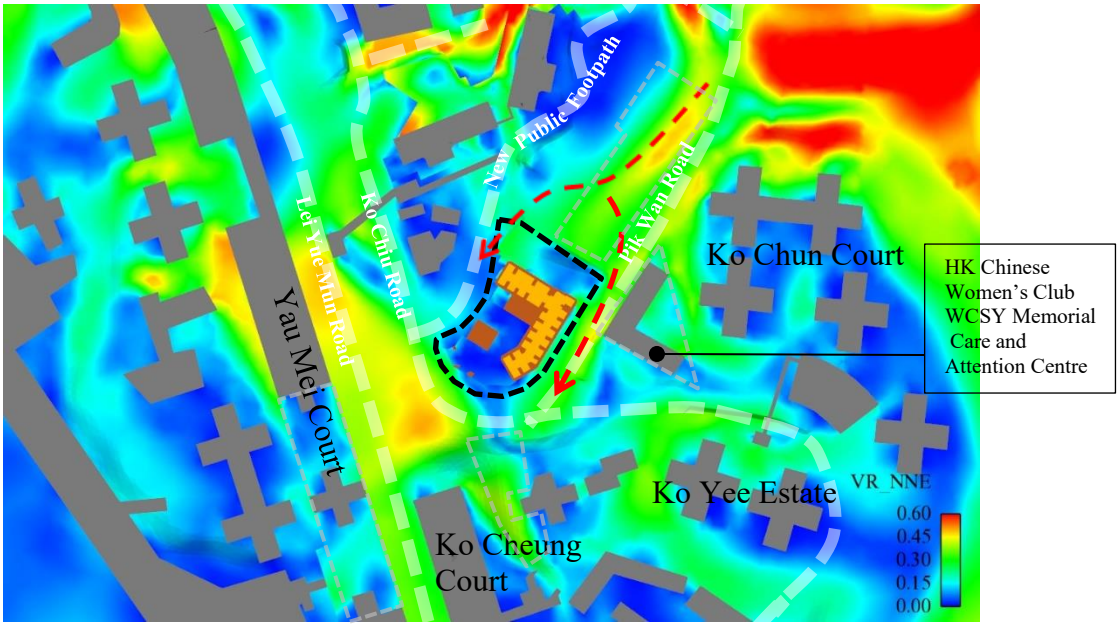


Figure 42 VR Contour Plot under NNE Wind (Proposed Scheme)

5.3.2 NE wind

The prevailing wind coming from NE wind would contribute to 9.8% to the annual condition respectively. The overall ventilation performance under NE wind can be summarised as below:

- New Public Footpath, Pik Wan Road, Yau Tong Service Reservoir Playground, Pik Wan Road Rest Garden, Ko Chiu Road Rest Garden, Access Road in Yau Tong Estate would have a higher VR under PROPOSED Scheme.
- Lei Yue Mun Road would have a slightly higher VR under Baseline Scheme.

For both Baseline and Proposed Scheme, the NE incoming prevailing wind would travel through the building separation between Ko Chun Court and Ko Yee Estate to reach the Development. Some wind would be downwashed by the towers of Ko Yee Estate to the pedestrian level, which would then travel towards the Baseline and also the Proposed Development. Wind reaching the Development would then be diverted to flow along Pik Wan Road and also Ko Chiu Road. (**Black Arrow**)

Under Proposed Scheme, due to the podium setback form the eastern site boundary (~6m), there exists a larger building separation between the Development the HK Chinese Women's Club WCSY Memorial Care and Attention Center. This would further widen the ventilation path along Pik Wan Road, more wind is able to travel up Pik Wan Road and further to Yau Tong Service Reservoir Playground.

Similarly, due to the podium setback from the southern site boundary, the ventilation path along Ko Chiu Road would be widened, therefore more wind is able to travel to Ko Chiu Road to ventilate Ko Chiu Road Rest Garden, and also localized portions of Ko Chiu Road.

Also, the curved shaped of the eastern façade of the Proposed Scheme would better facilitate the NE incoming wind to channel along Ko Chiu Road and further to the downstream area, significantly more wind can stream along Ko Chiu Road as also the Access Road under the Proposed Scheme. Since the NE wind could be more efficiently distribute along Ko Chiu Road, lower VR is observed around the upstream Ko Chun Court Area.

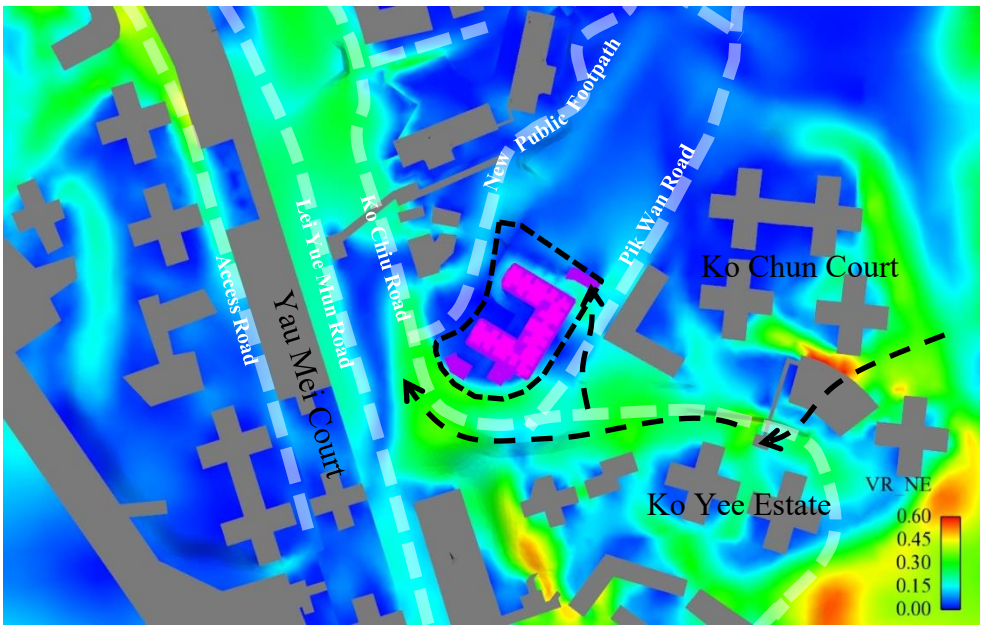


Figure 43 VR Contour Plot under NE Wind (Baseline Scheme)

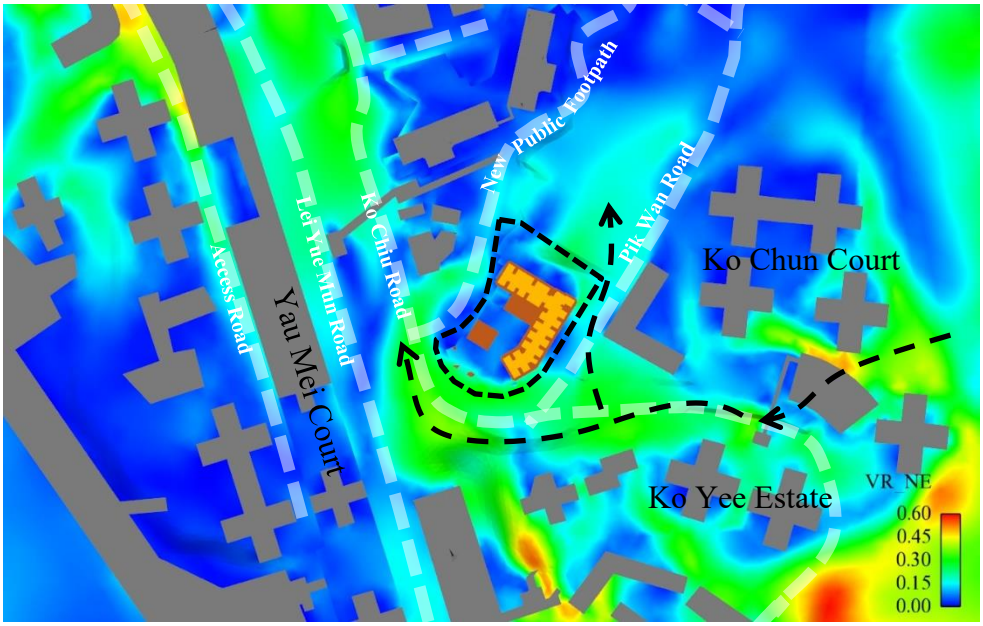


Figure 44 VR Contour Plot under NE Wind (Proposed Scheme)

5.3.3 ENE wind

The prevailing wind coming from ENE wind would contribute to 15.7% to the annual condition respectively. The overall ventilation performance under ENE wind can be summarised as below:

- Lei Yue Mun Road, Pik Wan Road Rest Garden, Ko Yee Estate Open Space would have a higher VR under PROPOSED Scheme.
- HK Chinese Women's Club WCSY Memorial Care and Attention Centre, Ko Chun Court Open Space, Ko Chiu Road Rest Garden, Yau Mei Court Podium Open Space would have a slightly higher VR under Baseline Scheme.

For both Baseline and Proposed Scheme, the incoming ENE prevailing wind would travel along Pik Wan Road and also Yau Tong Service Reservoir Playground to reach the Development. Wind would then be downwashed by the north-eastern façade to then travel along the Pik Wan Road and the New Public Footpath on the pedestrian level. (**Pink Arrow**)

Under both schemes, a portion of the ENE incoming prevailing wind would travel through Ko Chun Court and Ko Yee Estate to reach the study site from Ko Chiu Road. With the taller building height under Proposed Scheme, more high-level ENE wind would be downwashed by the south-eastern façade. Together with the provided setback south-eastern corner and curved shape of the domestic tower, the ENE wind would be promoted to travel towards Ko Chiu Road, Lei Yue Mun Road and Cha Kwo Ling Road at leeward side (**Red Arrow**).

In addition, the stronger downwash effect induced due to taller building height under Proposed Scheme would also enhance the wind environment at some localized area at leeward side such as Pik Wan Road Rest Garden and part of Pik Wan Road. Some of the downwashed wind would also be able to reach the Ko Yee Estate Open Space to improve the ventilation there.

Under both schemes, south-eastern façade of the Development would, as discussed, downwash wind onto Pik Wan Road. Under Baseline Scheme, however, due to the shorter building height, less high level wind would be downwashed to Pik Wan Road as compared to Proposed Scheme; thus, more wind would be able to reach Yau Mei Court Podium Open Space (**Red Arrow**), hence a slightly better wind environment at the Yau Mei Court Podium Open Space under Baseline Scheme.

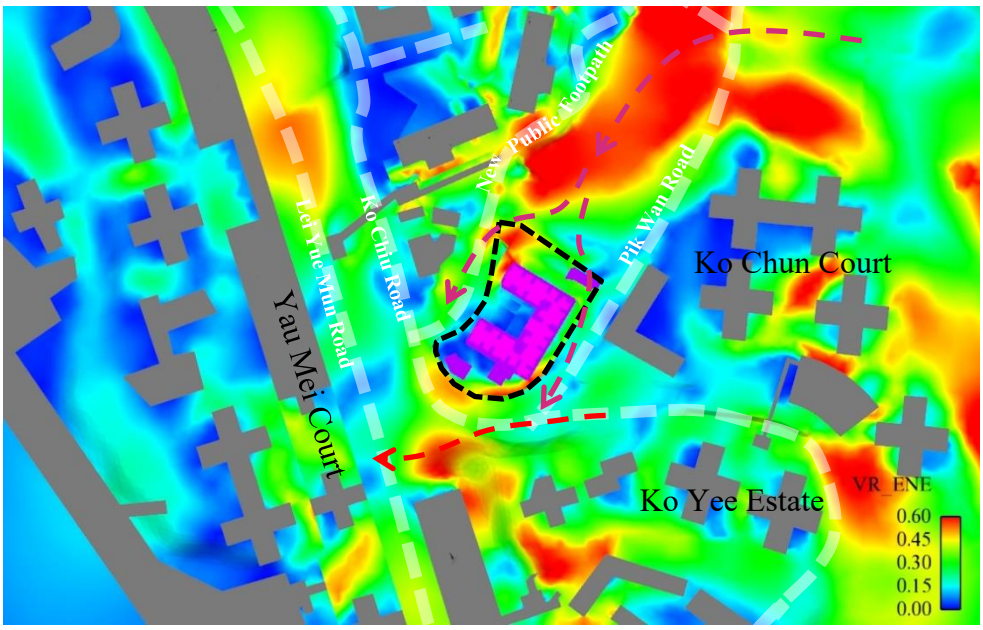


Figure 45 VR Contour Plot under ENE Wind (Baseline Scheme)

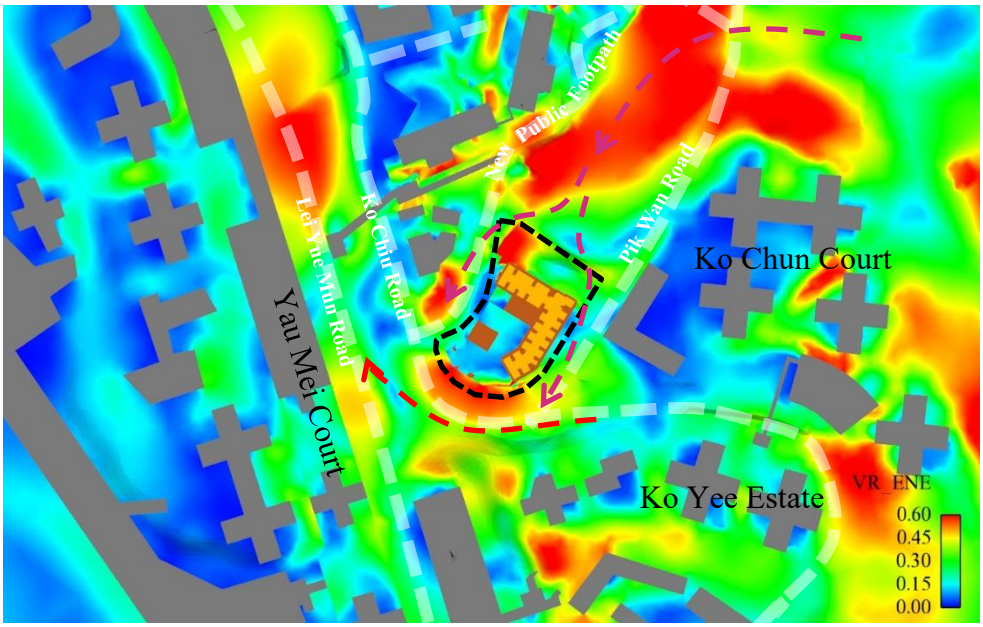


Figure 46 VR Contour Plot under ENE Wind (Proposed Scheme)

5.3.4 E wind

The prevailing wind coming from E wind would contribute to 18.8% and 8.8% to the annual and summer condition respectively. The overall ventilation performance under E wind can be summarised as below:

- Lei Yue Mun Road, Pik Wan Road Rest Garden and Yau Mei Court Podium Open Space would have a higher VR under PROPOSED Scheme.
- Yau Tong Service Reservoir Playground, Ko Yee Court Open Space, Ko Cheung Court Open Space and Access Road in Yau Tong Estate would have a slightly higher VR under Baseline Scheme.

For both Baseline and Proposed Scheme, at pedestrian level, the E incoming wind coming from the mountain valley would be downwashed to the pedestrian level and diverted by the NE facing façade of the Development, the diverted E wind would stream along the New Public Footpath and Pik Wan Road and flow towards Lei Yue Mun Road (**Blue Arrow**).

For both Baseline and Proposed Scheme, the district air path (~78m) would allow valley wind to flow down towards the lower slope area of Yau Tong District. A portion of the wind would be downwashed by Yau Mei Court to Lei Yue Mun Road (**Black Arrow**). Under Proposed Scheme, combining the downwashed wind streaming along Pik Wan Road, the overall ventilation performance along Lei Yue Mun Road would be better than that in Baseline Scheme.

Moreover, under Proposed Scheme, due to the setback of the podium from the southern site boundary, the ventilation path along Pik Wan Road would be widened, therefore more wind would be able to stream down Pik Wan Road. This would provide better ventilation to Pik Wan Road Rest Garden and Ko Chiu Road Rest Garden.

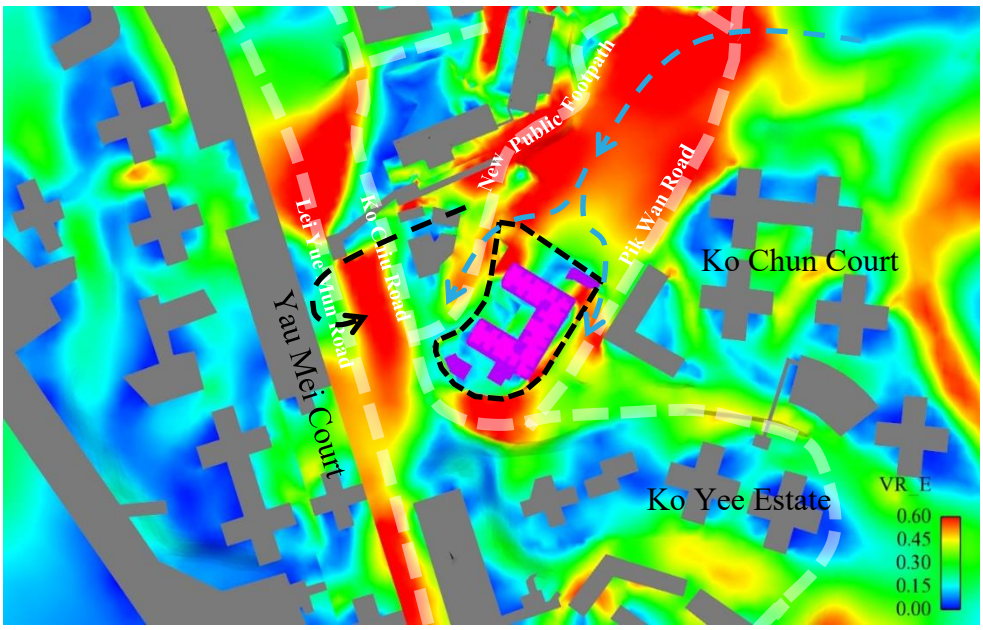


Figure 47 VR Contour Plot under E Wind (Baseline Scheme)

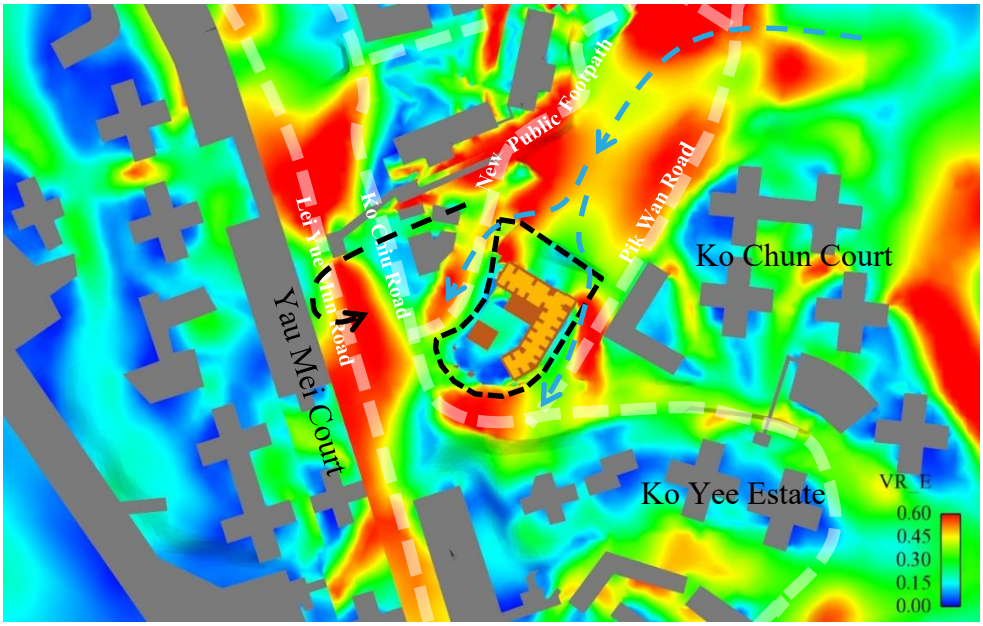


Figure 48 VR Contour Plot under E Wind (Proposed Scheme)

5.3.5 ESE Wind

The prevailing wind coming from ESE wind would contribute to 9.7% and 8.2% to the annual and summer condition respectively. The overall ventilation performance under ESE wind can be summarised as below:

- Pik Wan Road Rest Garden, Ko Cheung Court Open Space, Ko Chiu Road Rest Garden, Site Perimeter (P points) and the Podium Open Space (S points) would have a higher VR under Proposed Scheme.
- Ko Chiu Path, HK Chinese Women's Club WCSY Memorial Care and Attention Centre, Ko Chun Court Open Space, Proposed Development Pik Wan Road Site A would have a slightly higher VR under Baseline Scheme.

Under both Baseline and Proposed Scheme, at pedestrian level, the ESE incoming wind would stream down the mountain valley and reach the Proposed Pik Wan Road Site Development. Wind would be captured by the NE facing façade of Proposed Pik Wan Road Site Development and be downwashed to the two sides of the Development, one towards New Public Footpath and one towards Pik Wan Road (**Blue Arrow**).

Under Proposed Scheme, due to the podium setback from the southern site boundary, the ventilation path along Pik Wan Road would be widened. Therefore, a larger portion of the incoming prevailing wind would be able to travel down Pik Wan Road. This would ventilate Pik Wan Road Rest Garden, the Ko Chiu Road Rest Garden and Ko Cheung Court Open Space. Wind streaming along Pik Wan Road would also then reach Ko Chiu Road and Lei Yue Mun Road ventilate localized portions of both roads (**Blue Arrow**).

Since air path along Pik Wan Road would be widened under the Proposed Scheme, more wind tends to travel along Pik Wan Road and thus less wind is distributed towards the HK Chinese Women's Club WCSY Memorial Care and Attention Centre and Ko Chun Court Open Spaces. Hence, slightly lower VR is found near the HK Chinese Women's Club WCSY Memorial Care and Attention Centre and Ko Chun Court Open Spaces.

On the other hand, under Baseline Scheme, a larger portion of the prevailing wind would be diverted towards along the New Public Footpath and some further penetrate towards Pik Wan Road Site A and Ko Chiu Path, slightly higher VR is observed in these areas.

Also, higher VRs are observed around the Site Perimeter and the Podium Open Space in the Proposed Scheme. The permeable design of the podium would allow the ESE wind to penetrate across the Site towards the downstream areas, enhancing the wind environment on the Podium Open Space and the immediate Site boundary and Ko Chiu Road Rest Garden.

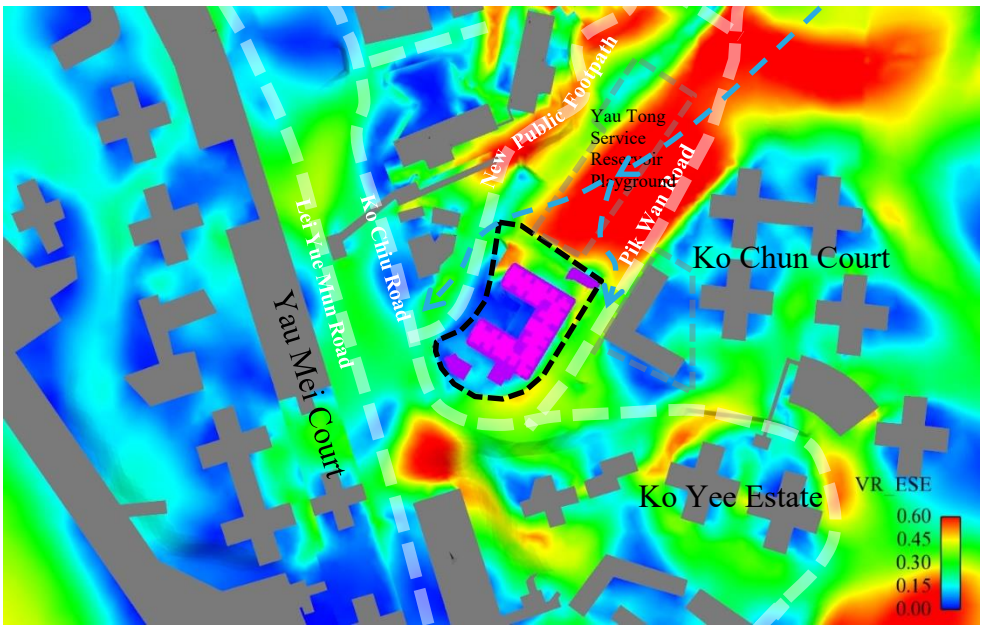


Figure 49 VR Contour Plot under ESE Wind (Baseline Scheme)

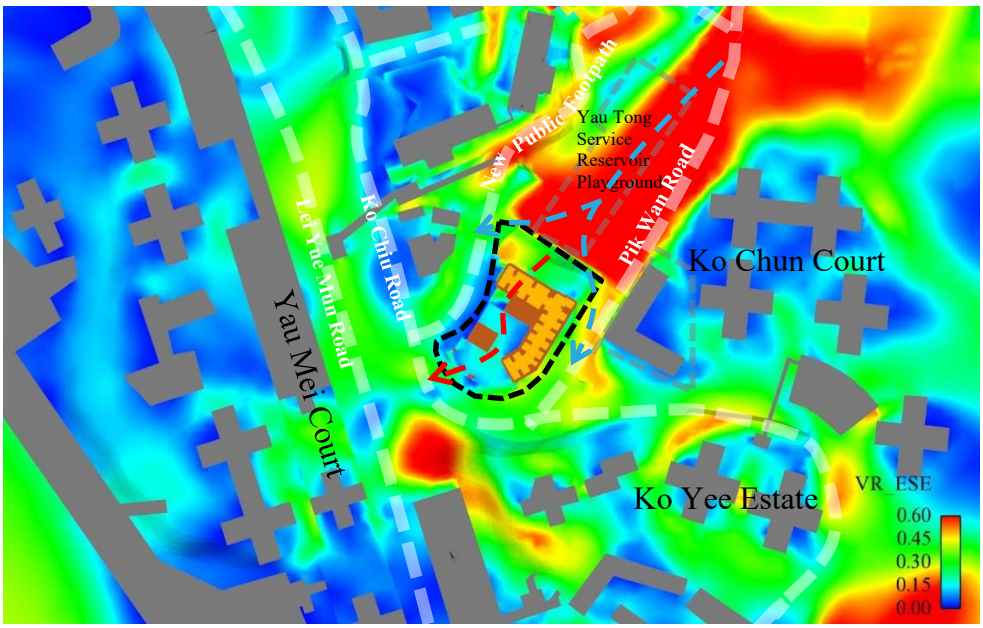


Figure 50 VR Contour Plot under ESE Wind (Proposed Scheme)

5.3.6 SE Wind

The prevailing wind coming from SE wind would contribute to 5.9% and 6.9% to the annual and summer condition respectively. The overall ventilation performance under SE wind can be summarised as below:

- Pik Wan Road Rest Garden, Ko Yee Estate Open Spaces would have a higher VR under Proposed Scheme.
- The ventilation environment at other locations would be generally similar between Baseline Scheme and Proposed Scheme.

Under both Baseline and Proposed Scheme, at pedestrian level, the SE incoming wind would stream down the mountain valley and reach the Proposed Pik Wan Road Site Development. Wind would be captured by the NE facing façade of Proposed Pik Wan Road Site Development and be downwashed to the two sides of the Development, one towards New Public Footpath and one towards Pik Wan Road.

Under Proposed Scheme, due to the podium setback from the southern site boundary, the ventilation path along Pik Wan Road would be widened. Therefore, a larger portion of the incoming prevailing wind would be able to travel down Pik Wan Road. This would ventilate Pik Wan Road Rest Garden and facilitates wind penetration further to Ko Yee Estate Open Spaces.

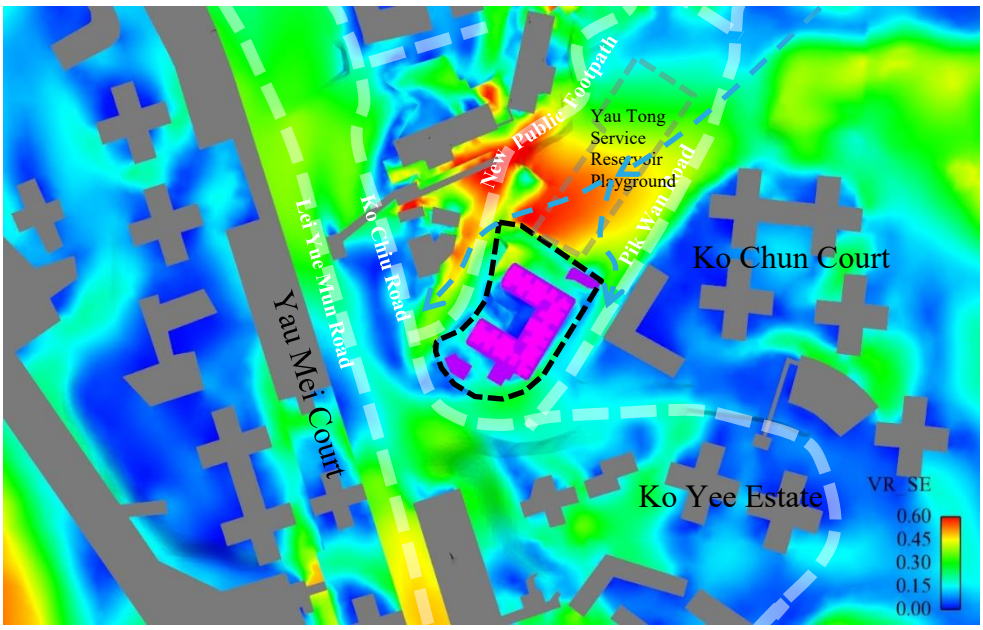


Figure 51 VR Contour Plot under SE Wind (Baseline Scheme)

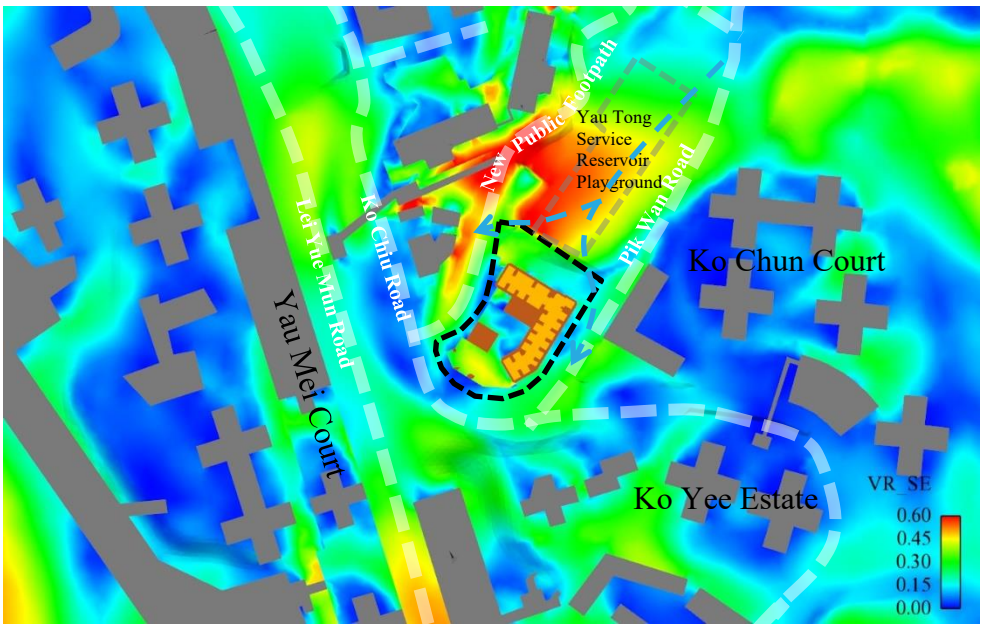


Figure 52 VR Contour Plot under SE Wind (Proposed Scheme)

5.3.7 SSE Wind

The prevailing wind coming from SSE wind would contribute to 7.3% to the summer condition. The overall ventilation performance under SSE wind can be summarised as below:

- Ko Chiu Road would have a higher VR under Proposed Scheme.
- New Public Footpath, Pik Wan Road Rest Garden would have slightly higher VR under Baseline Scheme.

Under both schemes, a strong stream of the incoming wind would flow along Lei Yue Mun Road towards north.

Under Baseline Scheme, the building height of the Development is relatively lower, which allows the incoming wind to flow atop of the building tower and reach Pik Wan Road Site A. The wind would then be downwashed by the building façade of Pik Wan Road Site A, towards pedestrian level (**Orange Arrow**), and results in a better wind environment at New Public Footpath under Baseline Scheme.

Proposed Scheme building is ~35m taller than that under Baseline Scheme. The larger SE facing façade would capture more SSE wind and downwash it towards Ko Chiu Road and Yau Tong Service Reservoir Playground (**Red Arrow**). Meanwhile, the downwash effect also creates a counter-flow at the region near Pik Wan Road Rest Garden (**Red Circle**). As a result, slightly lower VR would be observed at the location under Proposed Scheme.

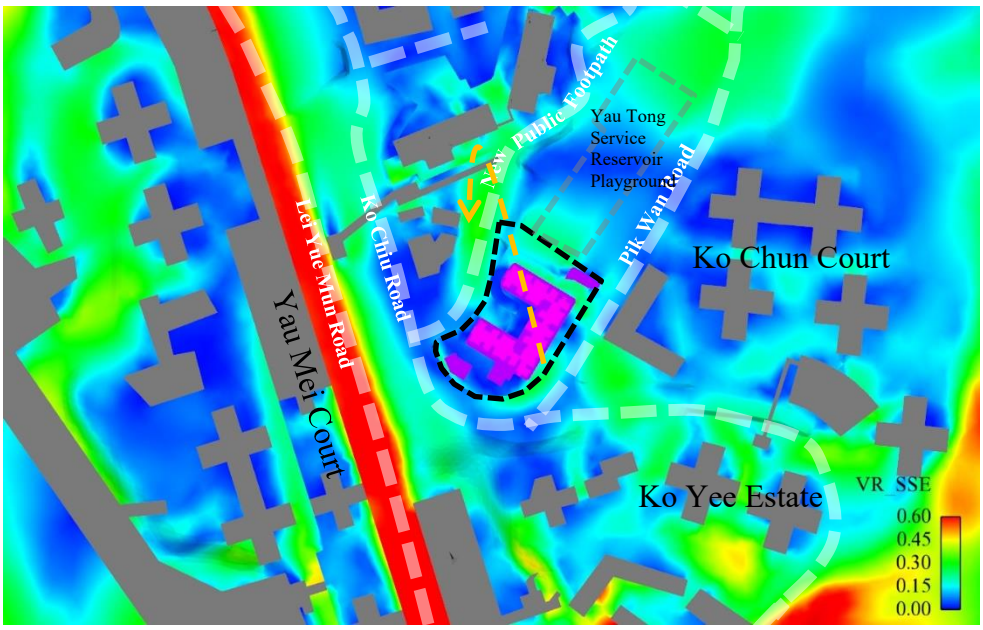


Figure 53 VR Contour Plot under SSE Wind (Baseline Scheme)

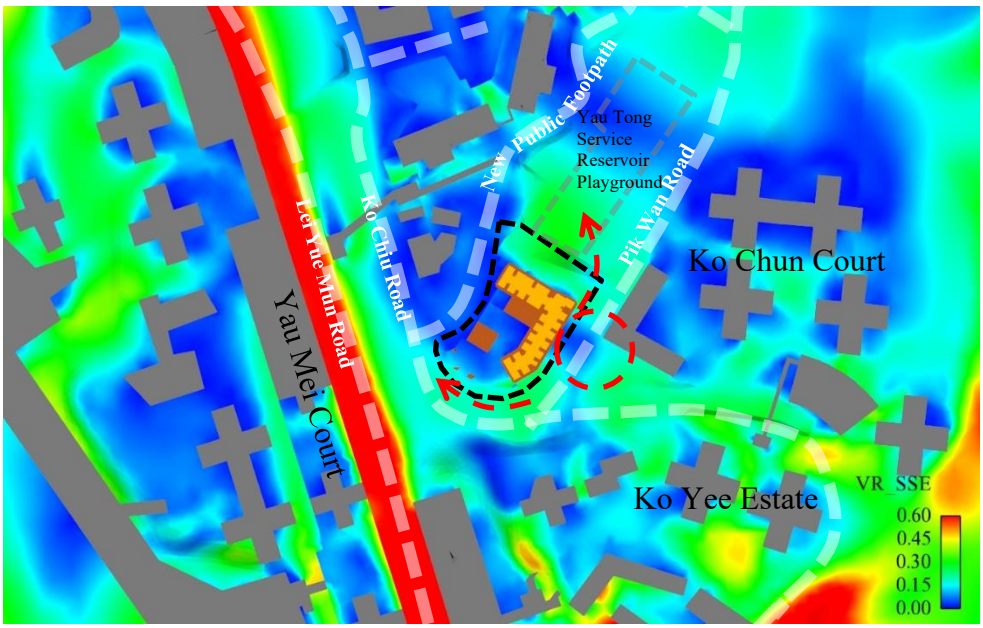


Figure 54 VR Contour Plot under SSE Wind (Proposed Scheme)

5.3.8 S Wind

The prevailing wind coming from S would contribute to 9.0% under summer condition. The overall ventilation performance under S wind can be summarised as below:

- New Public Footpath, Yau Tong Service Reservoir Playground would likely have a higher VR under Proposed Scheme.
- Pik Wan Road, Pik Wan Road Rest Garden and Ko Chun Court Open Space would likely have a slightly higher VR under Baseline Scheme.

Under the Baseline Schemes, the U-shaped residential tower would significantly obstruct the southerly prevailing and prevent the S wind from travel through the Development to reach the downstream New Public Footpath and Pik Wan Road Site A. (**Red Arrow**)

Whereas in Proposed Scheme, the S wind would be able to penetrate across the site by skimming through the permeable Podium Open Space and reach the leeward area of New Public Footpath. Thus, the ventilation performance is improved there under Proposed Scheme.

Under both schemes, a portion of the S wind would flow towards Pik Wan Road Site A passing by the Baseline or Proposed Development. Since the Proposed Development is ~35m taller than that of the Baseline Scheme, a portion of S wind would be disturbed and captured by the Proposed Development and ventilate towards the Yau Tong Reservoir Playground (**Pink Arrow**). Therefore, a slightly higher VR is observed at the southern portion of the Yau Tong Service Reservoir Playground.

Under Baseline Scheme, as the Development's building height is shorter, more wind would be able to travel freely towards Pik Wan Road Site A, especially at the higher level and eventually reach residential tower of Pik Wan Road Site A Development. In this case, more S prevailing wind could be downwashed by Pik Wan Road Site A towers and ventilate towards the northern portion of the Yau Tong Reservoir Playground, as well as the northern portion of Pik Wan Road, hence a slightly better higher VR is found at these areas under Baseline Scheme.

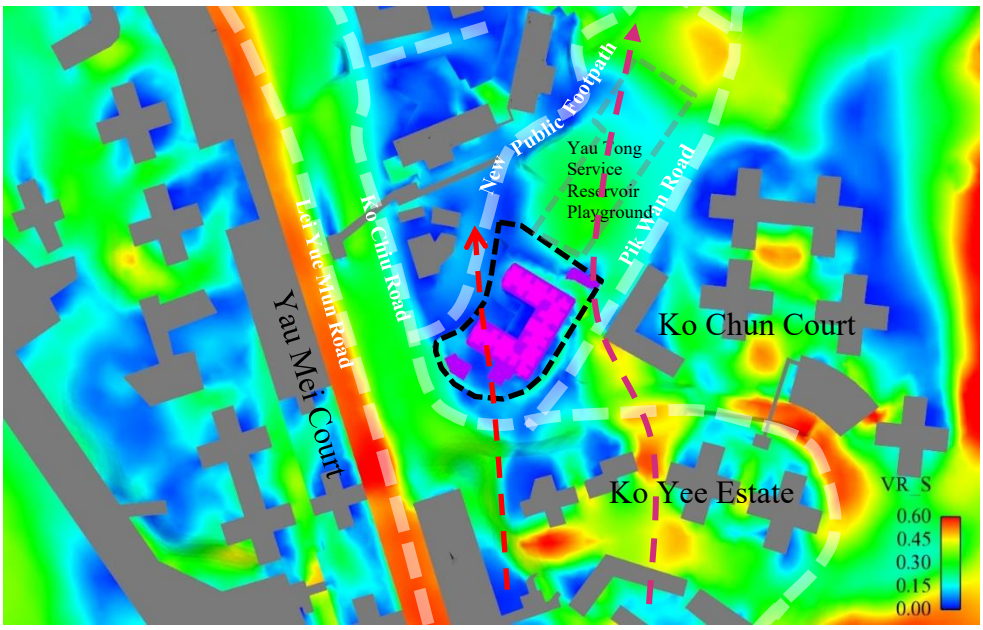


Figure 55 VR Contour Plot under S Wind (Baseline Scheme)

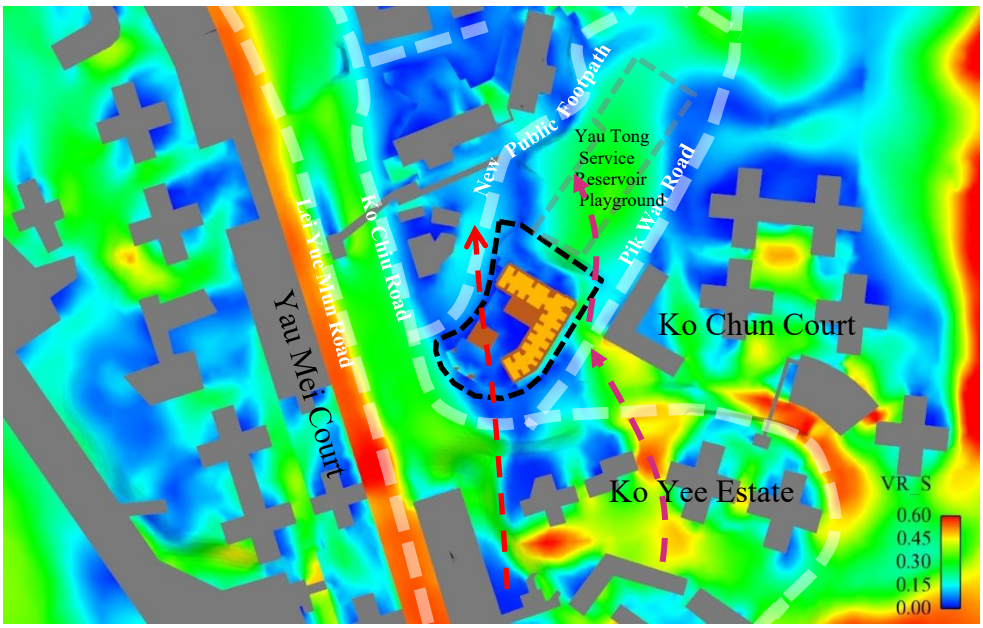


Figure 56 VR Contour Plot under S Wind (Proposed Scheme)

5.3.9 SSW Wind

The prevailing wind coming from SSW wind would contribute to 6.3% and 14.3% to the annual and summer condition respectively. The overall ventilation performance under SSW wind can be summarised as below:

- The ventilation performance is generally similar between Baseline Scheme and Proposed Scheme.

The incoming wind would travel along Lei Yue Mun Road towards north direction. The wind environment would be predominately influenced by the dense high-rise developments such as Ko Cheung Court and Yau Mei Court at the upwind location. As a result, the wind environment would be generally calm within the study site and the ventilation performance is generally similar between Baseline Scheme and Proposed Scheme.

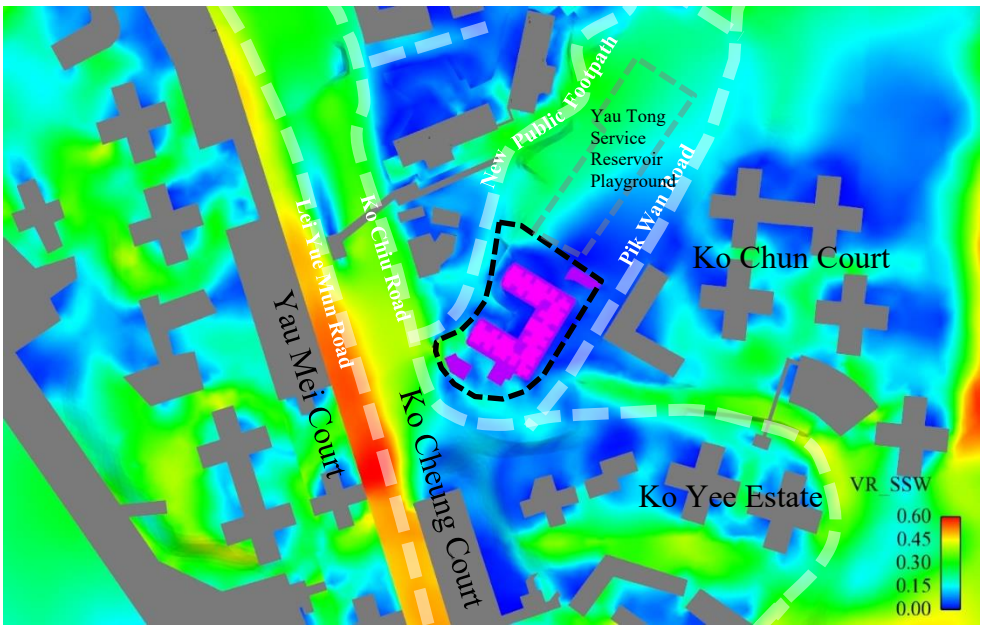


Figure 57 VR Contour Plot under SSW Wind (Baseline Scheme)

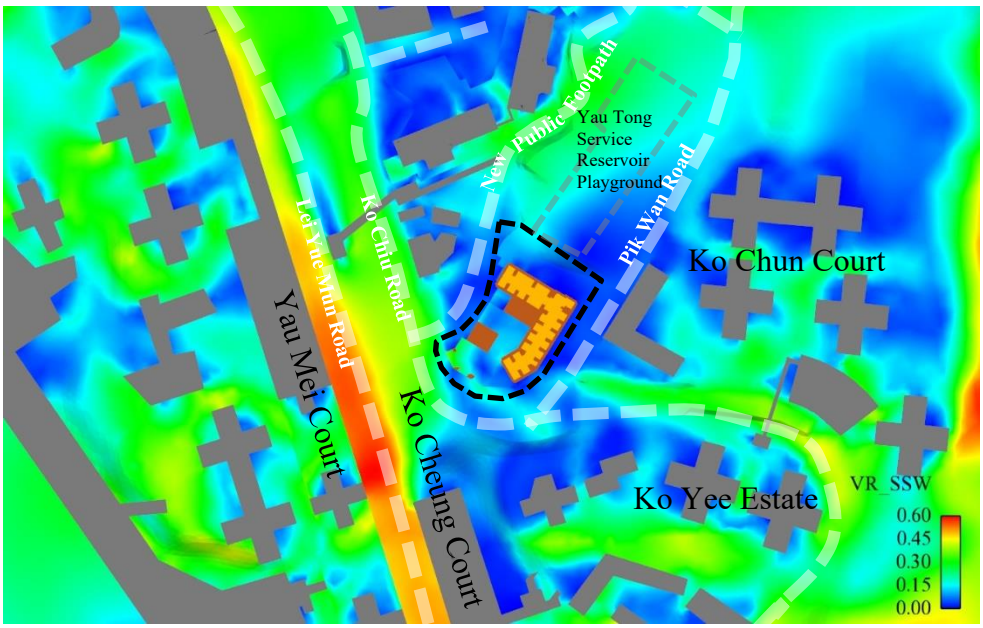


Figure 58 VR Contour Plot under SSW Wind (Proposed Scheme)

5.3.10 SW Wind

The prevailing wind coming from SW would contribute to 6.4% and 15.1% to the summer and annual condition respectively. The overall ventilation performance under SW wind can be summarised as below:

- New Public Footpath, Ko Chiu Path, Pik Wan Road, Pik Wan Road Rest Garden, Ko Chun Court Open Space has a higher VR under Proposed Scheme
- Ko Chiu Road would likely have a slightly higher VR under Baseline Scheme

The RCHE block is bulkier in shape under Baseline Scheme whereas podium setback along site boundary is present under Proposed Scheme. The southern and eastern podium setback of the Proposed Scheme would induce more wind to travel along Pik Wan Road. This would in turn ventilate the area nearby, including Pik Wan Road, Pik Wan Road Rest Garden, Ko Chun Court Open Space, slightly higher VRs are observed there. (**Black Arrow**)

Nonetheless, the podium setback at the north-western site boundary from the New Public Footpath, helps to induce more wind to travel along the New Public Footpath under the Proposed Scheme. (**Black Arrow**). Moreover, the permeable Podium Open Space would allow the SW wind to skim over (**Red Arrow**), and ventilates towards the New Public Footpath, Pik Wan Road Site A and Ko Chiu Path further down the stream.

On the other hand, under the Baseline Scheme, the SW wind would be diverted by bulkier podium of Baseline scheme to ventilate along Ko Chiu Road and higher VE would be observed at localised portion of the Ko Chiu Road, as compared to Proposed Scheme.

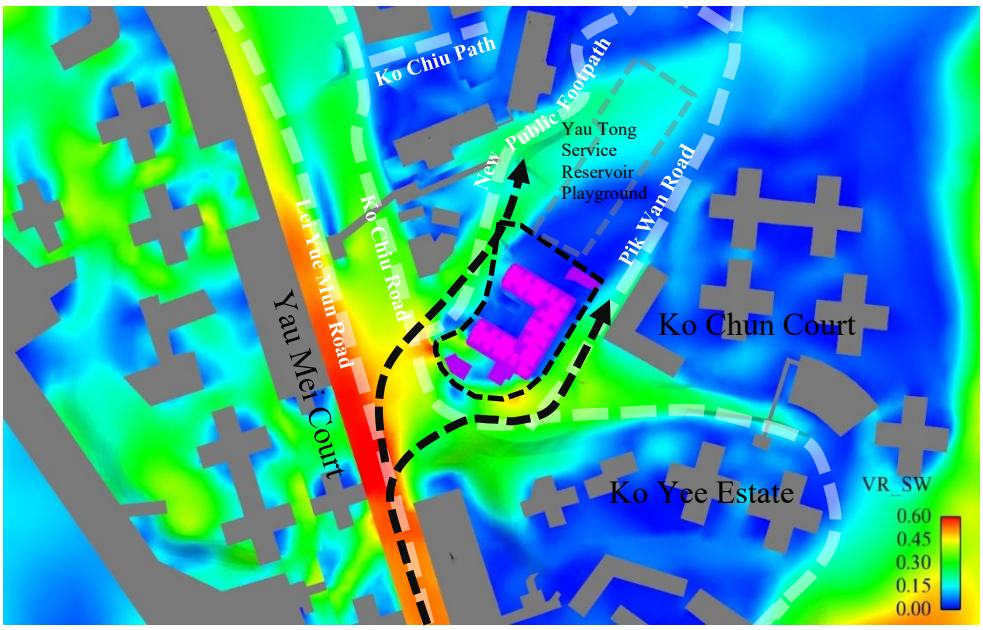


Figure 59 VR Contour Plot under SW Wind (Baseline Scheme)

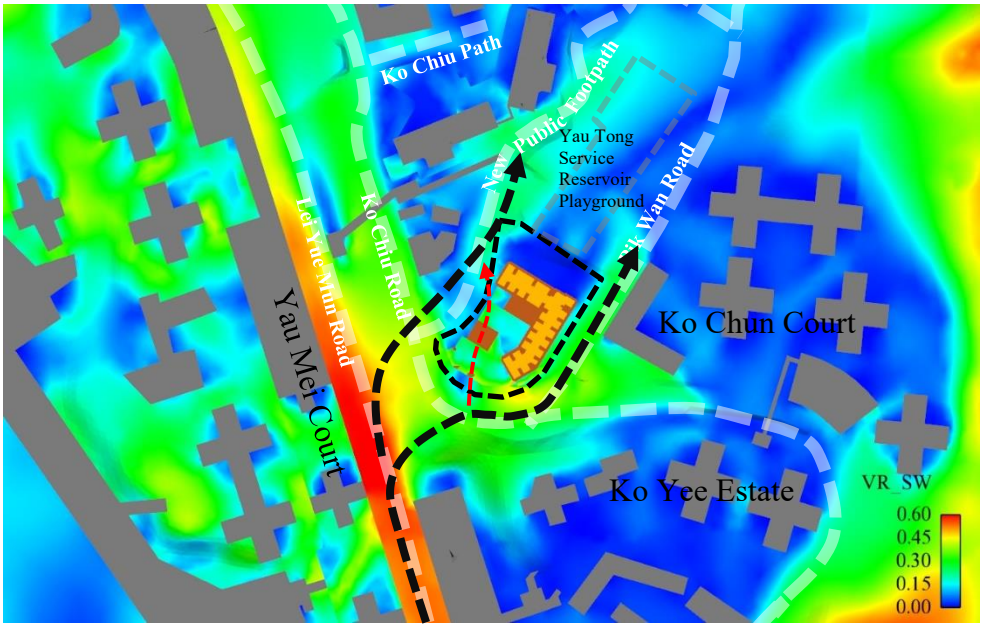


Figure 60 VR Contour Plot under SW Wind (Proposed Scheme)

5.3.11 WSW Wind

The prevailing wind coming from WSW would contribute 9.2% to the summer condition. The overall ventilation performance under WSW wind can be summarised as below:

- New Public Footpath, Yau Tong Service Reservoir Playground, HK's Chinese Women's Club WCSY Memorial Care and Attention Centre, Pik Wan Road Rest Garden, Ko Chun Court Open Space has a higher VR under Proposed Scheme
- Ko Chiu Road would likely have a slightly higher VR under Baseline Scheme

Under both the Baseline and Proposed Scheme, the WSW incoming wind coming from along Lei Yue Mun Road would arrived at the Development at the south-western boundary of the Development. The podium block of the Development would then divert the WSW wind towards Ko Chiu Road and Pik Wan Road respectively. Due to the southern and eastern podium setback of the Proposed Scheme, more wind is allowed to divert towards Pik Wan Road side, this would in turn ventilate the area nearby, including HK's Chinese Women's Club WCSY Memorial Care and Attention Centre, Pik Wan Road Rest Garden and Ko Chun Court Open Space.

Whereas under Baseline Scheme, comparably less wind would be diverted towards Pik Wan Road while more wind would reach the Ko Chiu Road. Higher VR in Ko Chiu Road is found in the Baseline Scheme.

Nonetheless, the permeable Podium Open Space under Proposed Scheme would allow the WSW wind to skim over (Red Arrow) and ventilates towards the New Public Footpath and Yau Tong Service Reservoir Playground down the stream.

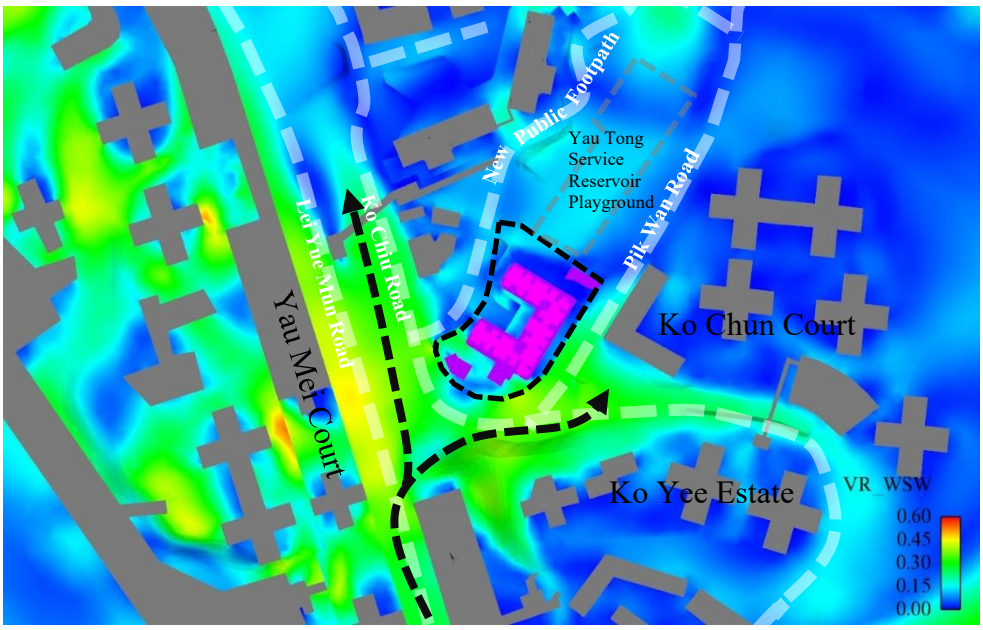


Figure 61 VR Contour Plot under WSW Wind (Baseline Scheme)

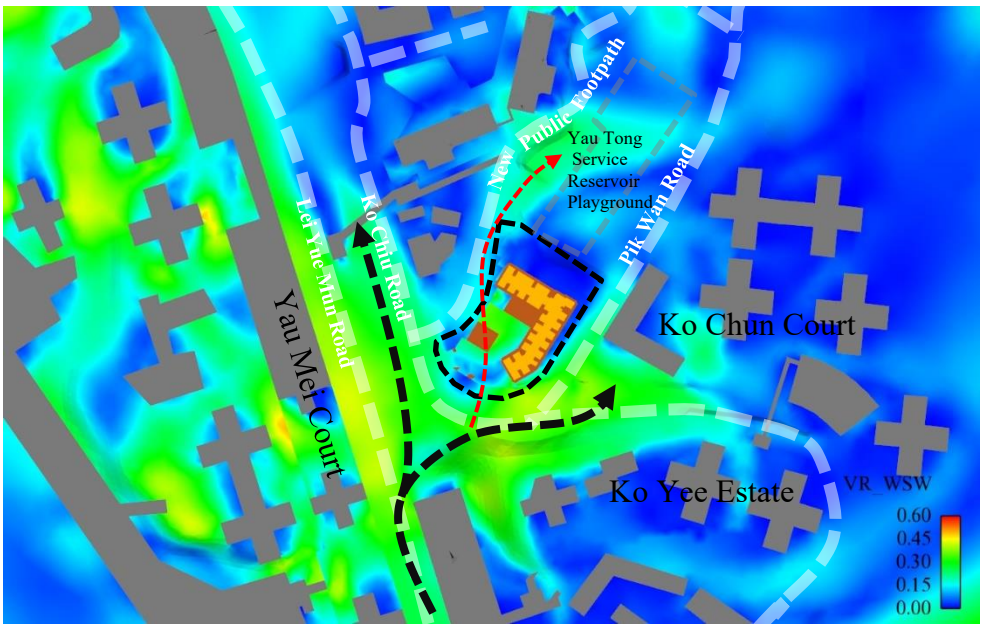


Figure 62 VR Contour Plot under WSW Wind (Proposed Scheme)

5.4 Focus Areas

Various focus areas with frequent pedestrian access were defined and shown in Figure 3.7. The associated test points for each of the focus areas were tabulated in Table 4 in Section 3.6. The VR results of each focus area under annual and summer condition were summarized Table 9 below.

Figure 63 Location of Focus Areas

Table 9 VR Results for Focus Areas under Annual and Summer Wind Condition

	Focus Areas	Annual Condition		Summer Condition	
		Baseline Scheme	Proposed Scheme	Baseline Scheme	Proposed Scheme
1	Ko Chiu Path	0.16	0.17	0.12	0.12
2	Ko Chiu Road	0.27	0.28	0.24	0.24
3	Lei Yue Mun Road	0.35	0.37	0.46	0.47
4	New Public Footpath	0.28	0.29	0.22	0.22
5	Pik Wan Road	0.29	0.32	0.24	0.23
6	Yau Tong Service Reservoir Playground	0.40	0.39	0.27	0.27
7	HK Chinese Women's Club WCSY Memorial Care and Attention Centre	0.09	0.09	0.10	0.10
8	Pik Wan Road Rest Garden	0.25	0.33	0.26	0.29
9	Ko Chun Court Open Spaces	0.15	0.15	0.13	0.13
10	Ko Yee Estate Open Spaces	0.21	0.24	0.17	0.18
11	Ko Cheung Court Open Spaces	0.27	0.26	0.20	0.20
12	Ko Chiu Road Rest Garden	0.33	0.34	0.30	0.31
13	Proposed Development Pik Wan Road Site A	0.19	0.19	0.14	0.14
14	Yau Mei Court Podium Open Space	0.25	0.23	0.23	0.24
15	Access Road in Yau Tong Estate	0.18	0.17	0.20	0.20
16	Podium Open Space	0.14	0.15	0.14	0.14

5.4.1 Annual Condition

In general, the Baseline Scheme would achieve similar average VR with Proposed Scheme for HK Chinese Women's Club WCSY Memorial Care and Attention Centre, Ko Chun Court Open Spaces and Proposed Development Pik Wan Road Site A. This indicates that the ventilation performances are considered comparable in the aforementioned areas.

Proposed Scheme has a higher VR for Ko Chiu Path, Ko Chiu Road, Lei Yue Mun Road, New Public Footpath, Pik wan Road, Pik wan Road Rest Garden, Ko Yee Estate Open Space, Ko Chiu Road Rest Garden and the Podium Open Space. This may due to the taller building height and larger building frontage facing Pik Wan Road in the Proposed Scheme, inducing more downwash to the pedestrian level. The podium setback also helps to further widen the air path along Ko Chiu Road and Pik Wan Road, enhancing the ventilation in those areas.

Baseline Scheme would have a slightly higher VR at Yau Tong Service Reservoir Playground, Ko Cheung Court Open Spaces, Yau Mei Court Podium Open Space and Access Road in Yau Tong Estate. This could be resulted from the U-shape façade of the Baseline Scheme, which facilitate downwash towards the Yau Mei Court and Yau Tong Estate areas.

5.4.2 Summer Condition

In general, the Baseline Scheme would achieve similar average VR with Proposed Scheme for Ko Chiu Path, HK Chinese Women's Club WCSY Memorial Care and Attention Centre, Ko Chun Court Open Space, Ko Cheung Court Open Spaces, Proposed Development Pik Wan Road Site A and Access Road in Yau Tong Estate. This indicates that the ventilation performances are considered comparable in the aforementioned areas.

Proposed Scheme has a better ventilation performance at Lei Yu Mun Road, New Public Footpath, Pik Wan Road Rest Garden, Ko Yee Estate Open Spaces, Ko Chiu Road Rest Garden and Yau Mei Court Podium Open Space.

Baseline Scheme would have a slightly higher wind speed at Ko Chiu Road, Pik Wan Road and Yau Tong Service Reservoir Playground.

6 CONCLUSIONS

6.1 Overview

An AVA – Detailed Study was conducted using CFD modelling to assess the ventilation performance of the Proposed Scheme of the Proposed Public Housing Development at Pik Wan Road Site B, in accordance with the *AVA Technical Circular* No. 1/06, "*Environment, Transport and Works Bureau - Technical Circular No. 1/06*" issued on 19th July 2006 and "*Annex A of Technical Circular - Technical Guide for Air Ventilation Assessment for Development in Hong Kong*".

Ventilation performance under Baseline Scheme and Proposed Scheme was assessed using Computation Fluid Dynamics (CFD) techniques. A series of CFD simulation using Realizable k–ε turbulence model were performed with 11 wind directions covering 78.2% and 78.8% of wind frequency for annual and summer conditions respectively.

The Velocity Ratio (VR) as proposed by the *AVA Technical Circular*[2] was employed to assess the ventilation performance. The wind speed would also be reported.

With reference to the *AVA Technical Circular*[2], a total of 31 perimeter test points and 121 overall test points, together with 17 and 25 special test points Baseline and Proposed Case have been allocated within the study site and assessment area to assess the overall and local ventilation performance.

6.2 Results

Upon the CFD simulation Proposed Scheme achieved higher SVR and LVR by 0.01 to 0.03 comparing to Baseline Scheme under both annual and summer conditions.

The results of the SVR, LVR are summarized as below.

	Annual Condition		Summer Condition	
	Baseline Scheme	**Proposed Scheme**	**Baseline Scheme**	**Proposed Scheme**
SVR	0.26	0.29	0.20	0.20
LVR	0.25	0.26	0.22	0.22

7 REFERENCE

[1] Approved Cha Kwo Ling, Yau Tong, Lei Yue Mun Outline Zoning Plan (OZP) No. S/K15/25,
11th April, 2017

(https://www2.ozp.tpb.gov.hk/plan/ozp_plan_notes/en/S_K15_25_e.pdf)

[2] Annex A of Technical Circular No. 1/06 issued by the Housing, Planning and Lands Bureau pertaining specifically to Air Ventilation Assessments, 19th July, 2006

(https://www.devb.gov.hk/filemanager/en/content_679/hplb-etwb-tc-01-06.pdf)

[3] Planning Department RAMS Data
(http://www.pland.gov.hk/pland_en/info_serv/site_wind/site_wind/)