Hong Kong Housing Authority

Environmental Study for Kiu Cheong Road East HOS

Air Ventilation Assessment – Initial Study

January 2014

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1 INTRODUCTION

1.1 Background

1.1.1 AECOM Asia Company Ltd. has been commissioned by the Hong Kong Housing Authority (HKHA) to undertake an Air Ventilation Assessment (AVA) Study – Initial Study for the Kiu Cheong Road East HOS to examine the air ventilation performance of its building design quantitatively and formulate effective and practicable measures enhancing the air ventilation as part of the continuous design improvement process.

1.2 Objectives

1.2.1 The AVA Study for the Kiu Cheong Road East HOS (i.e. the Subject Site) has been conducted in accordance with the methodology outlined in the Technical Guide for AVA for Developments in Hong Kong (the Technical Guide) annexed in HPLB and ETWB TC No. 1/06. The main purposes of this AVA Study, echoing the Technical Guide, are:

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

1.3 Content of this Report

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

- Section 2 on expert evaluation;
- Section 3 on assessment methodology;
- Section 4 on key findings of AVA study; and
- Section 5 with a summary and conclusion.

2 EXPERT EVALUATION

2.1 Wind Availability

2.1.1 The Subject Site, Kiu Cheong Road East HOS, is located in Yuen Long District, to the south of the West Rail Tin Shui Wai Station. The Site falls within the Approved Ping Shan Outline Zoning Plan (OZP) No.S/YL-PS/14. **Figure 2.1** shows the location of the Subject Site.

Figure 2.1 Location of the Subject Site – Kiu Cheong Road East HOS

2.1.2 The natural wind availability is crucial to investigate the wind ventilation performance of the Subject Site. The Hong Kong Planning Department (PlanD) has released a set of wind availability data of different locations in Hong Kong using MM5 mesoscale model for AVA studies. The set wind availability data can be obtained at the official website of Planning Department (http://www.pland.gov.hk/pland_en/misc/MM5/index.html).

2.1.3 For the Subject Site in the current study, the data from grid (14, 36) as shown in **Figure 2.2,** is used as the site wind availability data for wind analysis.

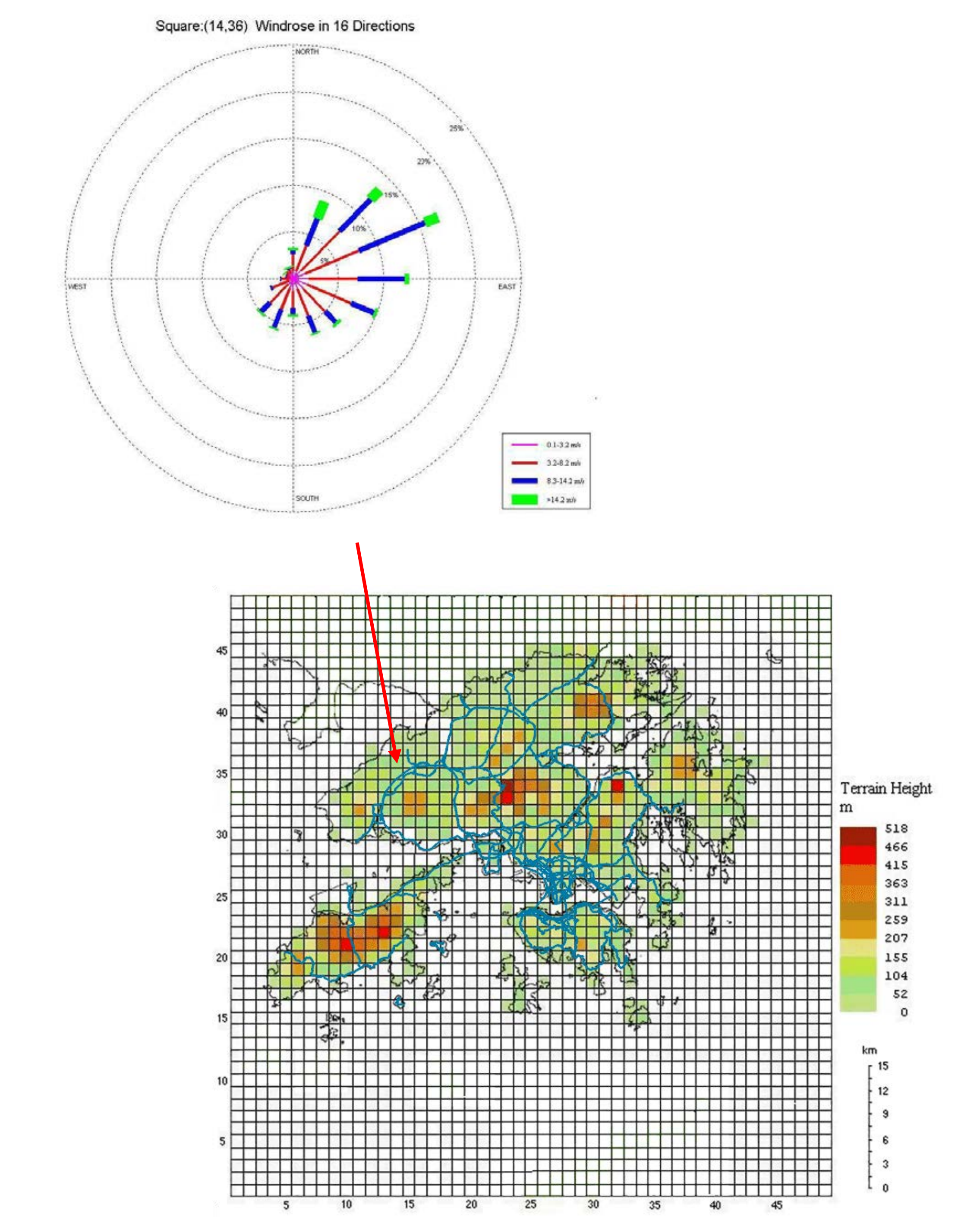


Figure 2.2 Wind Rose from PlanD website obtained from MM5 model (Grid 14, 36)

2.1.4 Other than MM5 data, an annual wind rose and monthly wind roses during 1986 to 2012 from the Lau Fau Shan Weather Station are presented and shown in **Figure 2.3** and **Figure 2.4**. The relative location for the Lau Fau Shan and Wetland Park weather station and the study area is indicated in **Figure 2.5**.

Table 2.1 Annual Wind Frequencies Table from MM5 model (Grid 14, 36)

Wind Direction	% of Annual Occurrence^
0º (N)	3.30%
22.5º (NNE)	**8.80%**
45º (NE)	**13.3%**
67.5º (ENE)	**17.0%**
90º (E)	**12.6%**
112.5º (ESE)	**9.80%**
135º (SE)	**6.80%**
157.5º (SSE)	**6.30%**
180º (S)	4.00%
202.5º (SSW)	**5.70%**
225º (SW)	5.10%
247.5º (WSW)	2.70%
270º (W)	1.40%
292.5º (WNW)	0.90%
315º (NW)	1.10%
337.5º (NNW)	1.30%

^ Percentage of occurrence directly extracted from wind probability table

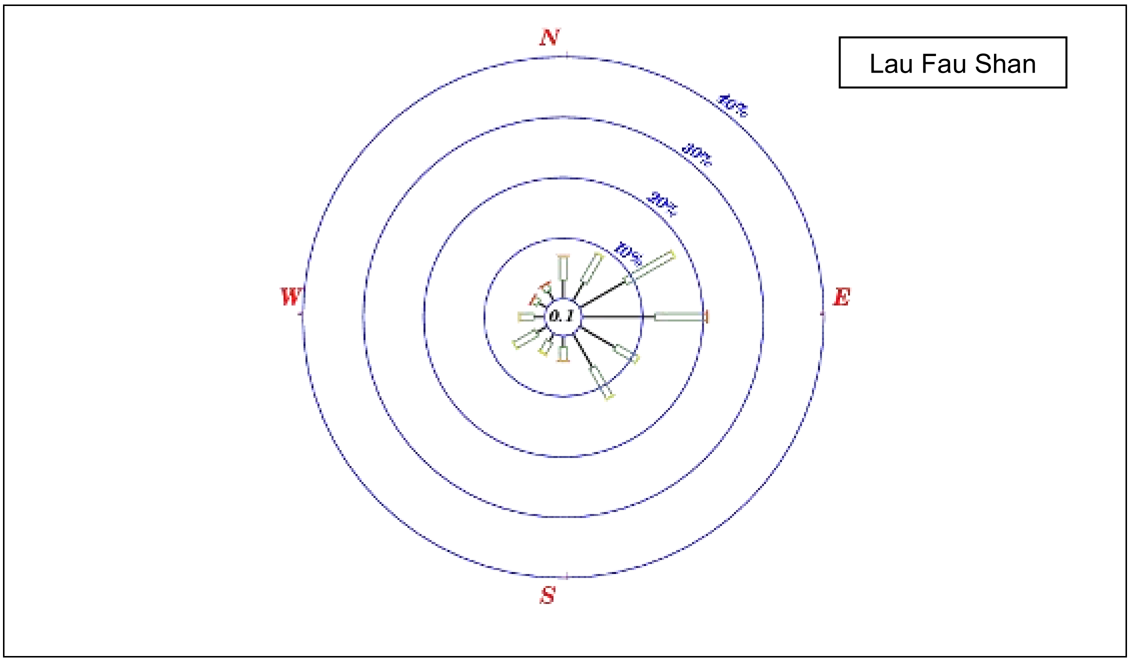
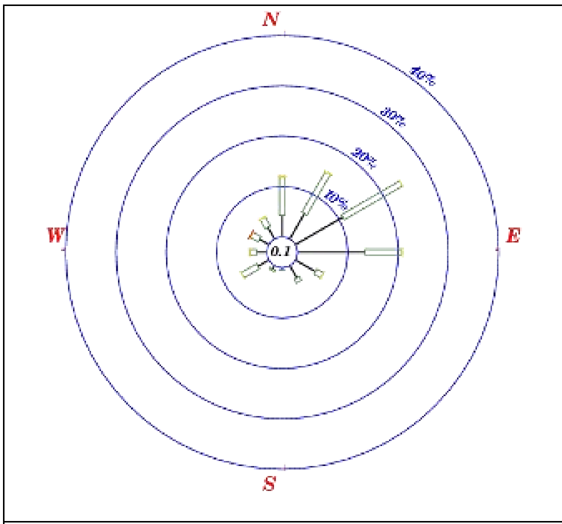


Figure 2.3 Annual Wind Rose from Lau Fau Shan Automatic Weather Station, 1986 to 2012



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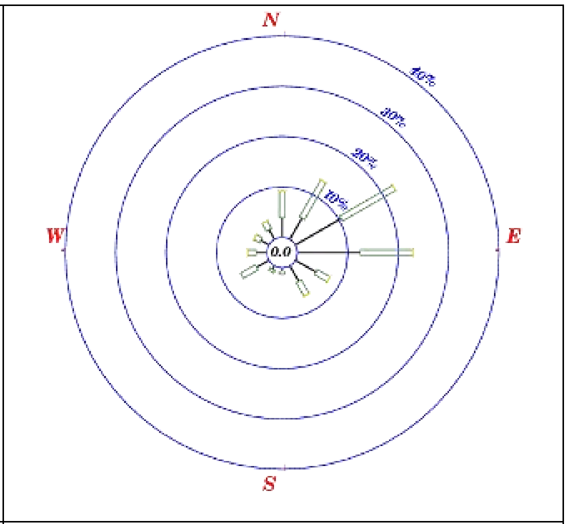

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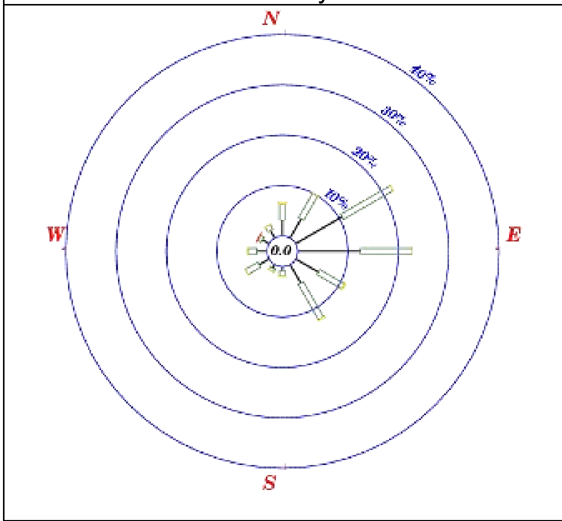

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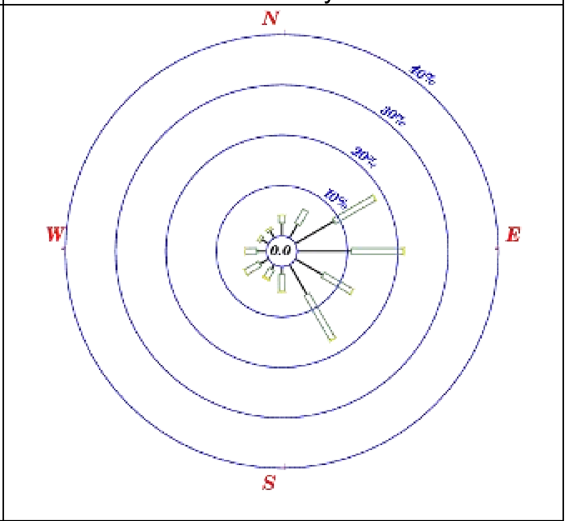

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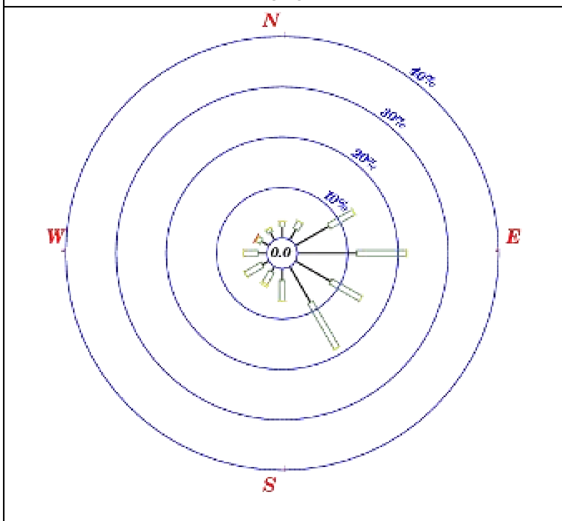

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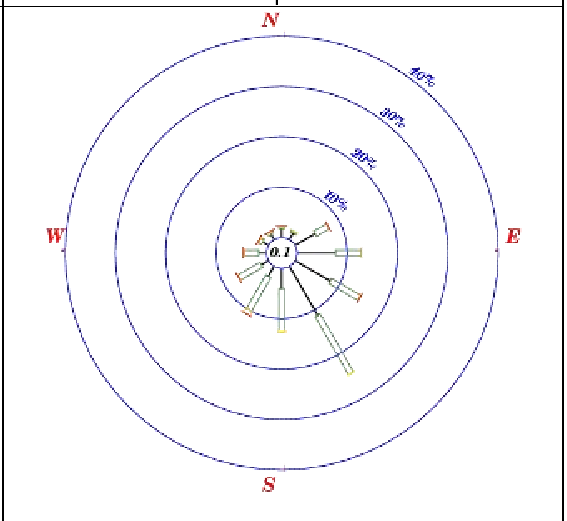

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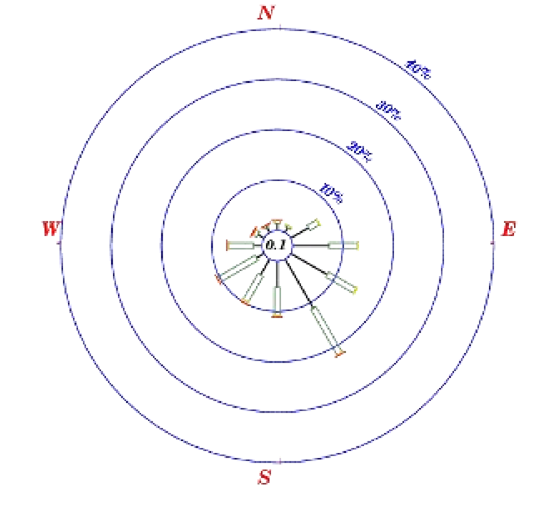

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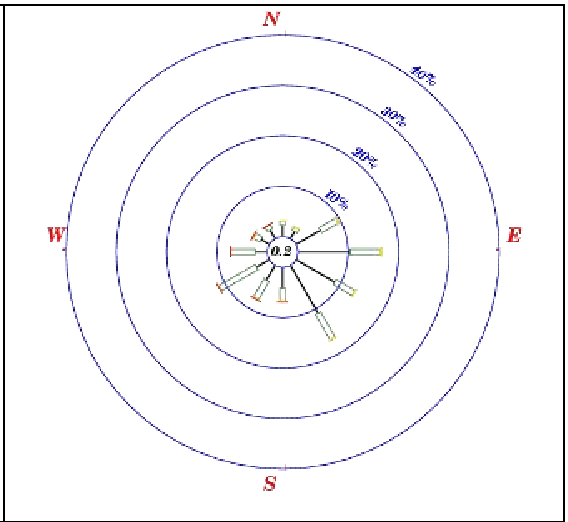

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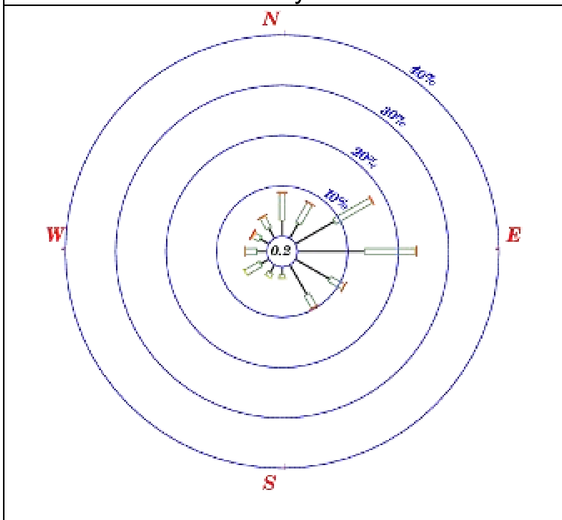

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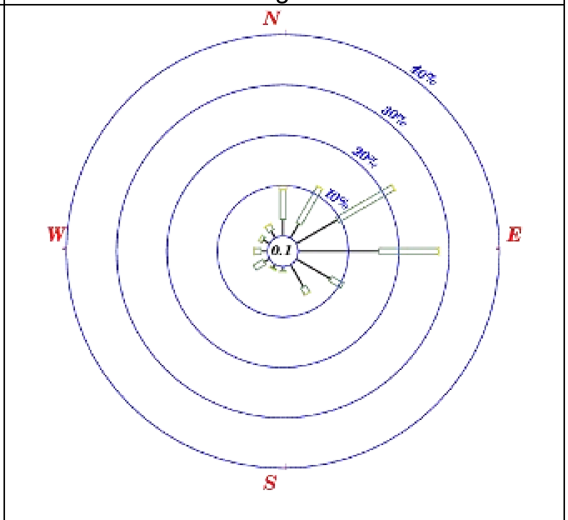

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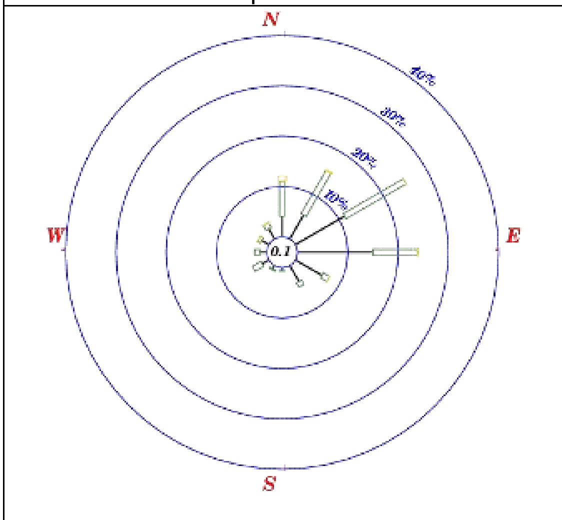

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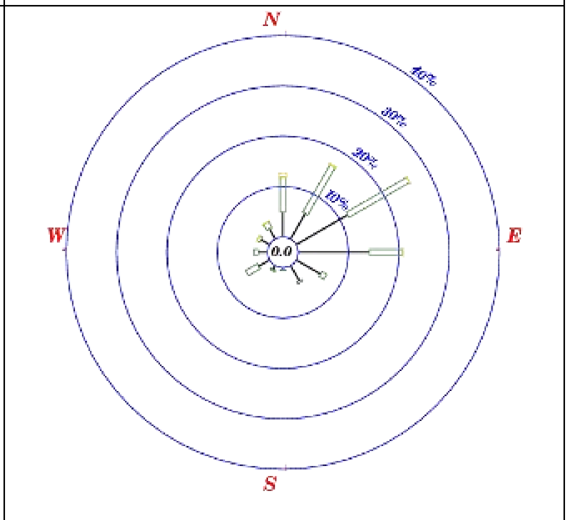

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Figure 2.4 Monthly Wind Rose from Lau Fau Shan Automatic Weather Station, 1986 to 2012

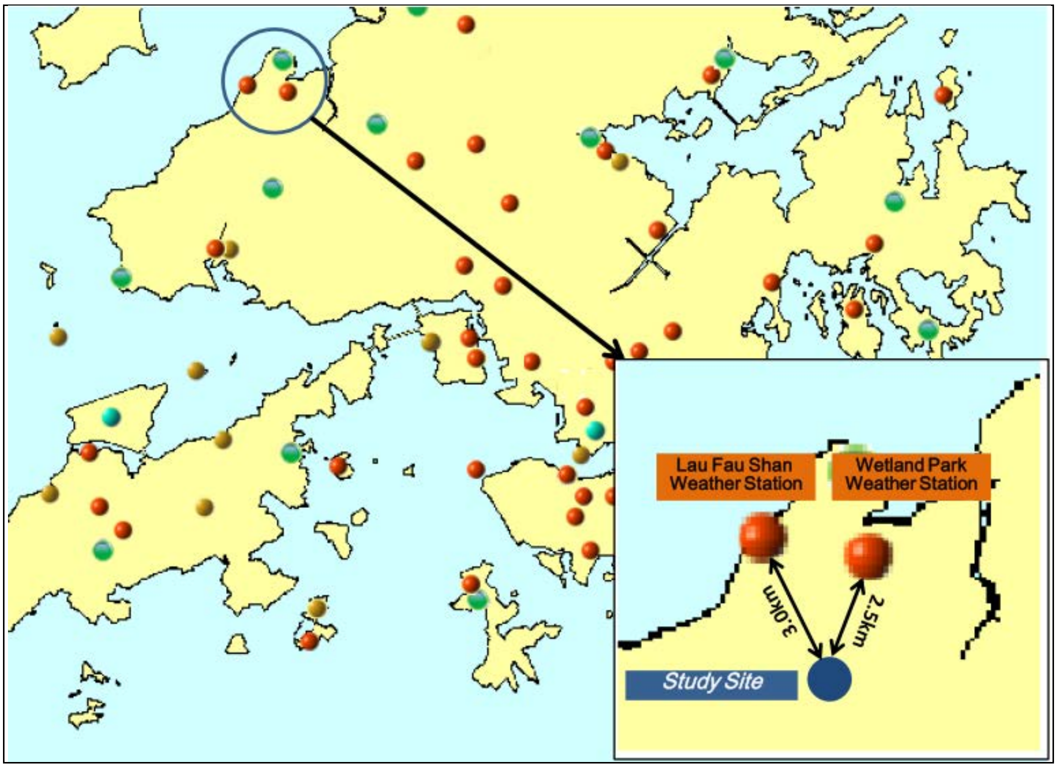


Fig 2.5 Location and distance between the two weather stations and the study site

2.1.5 The MM5 natural wind availability data and the HKO data are compared in this report in order to identify the annual and summer prevailing wind directions for analysis on the existing wind environment of Ping Shan Area.

2.1.6 From the wind rose obtained from the Planning Department's website (see **Table 2.1**), it is noted that the occurrence of wind from E, NE and ENE directions occupy over 42% of the annual wind direction. According to the wind probability table (**Table 2.1**) provided together with the wind rose analysis result shown in **Figure 2.2**, the winds from the E, NE and ENE directions are considered to be the most predominant winds in the area with contributions over 12% per wind of the time in a year.

2.1.7 In addition, from the annual wind rose obtained from the Lau Fau Shan Automatic Weather Station (see **Figure 2.3**), it is noted that the occurrence of wind from E and NE directions each occupies over 15% of the annual wind direction.

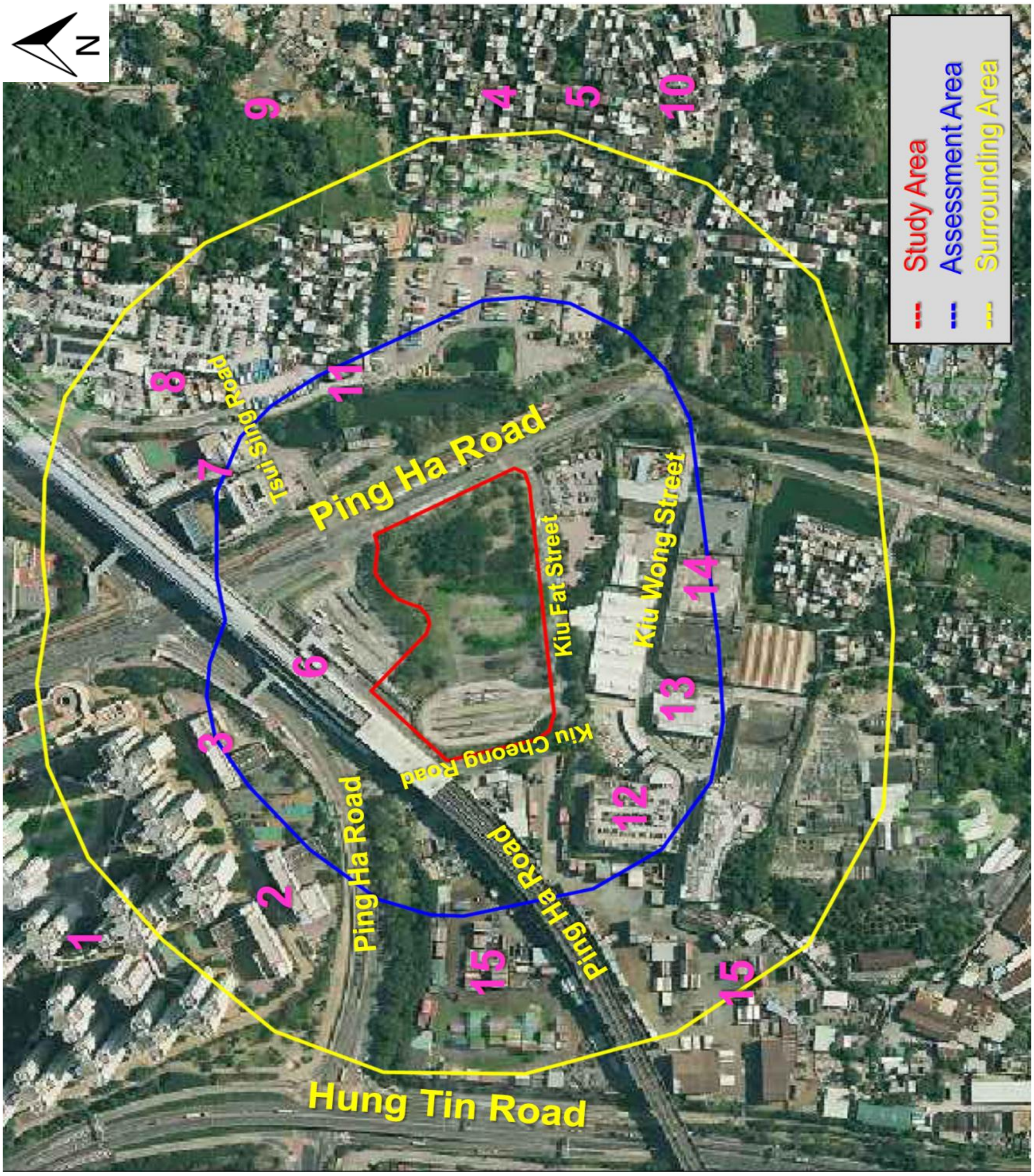
2.1.8 From the summer wind roses (June to August) for Lau Fau Shan in the year of 1986 -2012 as shown in **Figure 2.4**, the wind directions from the E, SE, SSE are the major dominant ones for the summer season in which these directions possesses occurrence percentage of over 15%.

2.1.9 Therefore, the winds from the north east quadrant are considered to be the annual prevailing wind for the Kiu Cheong Road East HOS study area. Apart from that, the summer non- typhoon wind rose from the Lau Fau Shan Automatic Weather Station suggests that summer prevailing wind is coming from the south eastern quadrant. As a result, the prevailing wind for the study area is considered to be E/NE/ENE (annual) and E/SE/SSE (summer).

2.2 Topography and Building Morphology within Study Site and Surroundings

2.2.1 **Figure 2.6(a)** shows land use of the subject area and its surroundings while **Figure 2.6(b)** is the aerial photo of the study area and the surroundings.

Figure 2.6(a) Land use of the Development Site and its Surrounding Area



1. Ting Shing Court (120mPD)	2. Lions Clubs International Ho Tak Sum Primary School and Ylpmsaa Tang Siu Tong Secondary School (30mPD)	3. QE School(30mPD)	4. Tang Ancestral Hall (13mPD)
5. Yu Kiu Ancestral Hall (10mPD)	6. Tin Shui Wai Station (26.5mPD)	7. Twghs Kwok Yat Wai College (28mPD)	8. Elle Garden Block (10mPD)
9. Yeung Hau Temple (8mPD)	10. Hung Shing Temple (16mPD)	11. Ping Shan Heritage Trail	12. Crown Motors Limited (19mPD)
13. Ying Cheong Industrial Building (14mPD)	14. Lai Tak Group Building (13mPD)	15. Open Storage Areas	

Figure 2.6(b) Location of the Study Area and its Surrounding Area

2.2.2 The Subject Site, Kiu Cheong Road East HOS area, is located in Yuen Long District. West Rail Tin Shui Wai Station is located at the north east of the Subject Site. The terrain in the immediate vicinity of the Subject Site is flat with some village houses, residential areas and Industrial areas. The Kiu Cheong Road East HOS area falls within the Approved Ping Shan Outline Zoning Plan (OZP) No. S/YL-PS/14. **Figure 2.6(a)** shows the major land use of the Subject Site and its surrounding areas.

2.2.3 The Subject Site circled with the red line as shown in the **Figure 2.6(b)** is bounded by Ping Ha Road to the north and east, Kiu Fat Street to the south and Kiu Cheong Road to the west. The Subject Site area possesses a Comprehensive Development Area (CDA) land use type which will expect to be developed and constructed into commercial and residential building blocks.

2.2.4 To the northwest area of the Subject Site are mostly residential areas with minor commercial and GIC land uses with medium building density. The major buildings in that location are residential development (Tin Shing Court), and two primary schools (Lions Clubs International Ho Tak Sum Primary School and QE School).

2.2.5 Apart from the residential buildings to the northern/north western portion of the study area, there are some major industrial building blocks in the south vicinity of the Subject Site, including Crown Motors Limited, Ying Cheong Industrial Building and Lai Tak Group Building. The major industrial blocks are marked in **Figure 2.6(b)**.

2.2.6 To the immediate east of the Subject Site, there is the Ping Shan Heritage Trail, there are some historic spots including but not limited to Yeung Hau Temple, Tang Ancestral Hall, Yu Kiu Ancestral Hall and Hung Shing Temple etc. These historic spots are marked in **Figure 2.6(b)**.

2.2.7 Apart from that, some Village type blocks (about 1- 3 storey high) are sparsely located in the east and southeast part of the subject area, these village houses include but not limited to Sheung Cheung Wai, Hang Tau Tsuen Village, Tong Fong Tsuen Village, Ping Shan Sin Tsuen Village etc.

2.2.8 To the northeast of the site, there are residential developments including Ping Wu Garden and Elle Garden, Twghs Kwok Yat Wai College and Ping Shan Tin Shui Wai Leisure and Cultural Building. To the west and south western part of Subject Site, there is large area of open storage with low-rise building blocks in low density.

2.2.9 From the above paragraphs, the buildings morphology in the area surrounding the subject site varies from high-rise residential clusters to low-rise industrial buildings / village houses (with the buildings' height range from 8mPD to 19mPD) and open areas. The industrial buildings and village houses are located south and east to the development area, while the open areas are located to its east and west. The high-rise clusters (with about 120mPD building height) are mainly located north and north north-west to the subject site.

2.2.10 It is understood that a building of height H is generally possible to induce a wind wake of approximately H from the building. Inside the wake region, there exist weaker and more turbulent winds which are collectively referred to as a "wind shadow region" behind the building. In the current study, the high-rise building would generate a wind wake of approximately 120m away from the building under northern quadrant winds, but the distance between this cluster and the project area is more than 120m, furthermore, a wind corridor named Ping Ha Road lies between the cluster and the project site. Thus, the high-rise cluster to the north is expected to have little influence upon the project site. On the other hand, the low-rise industrial buildings / village buildings surround the study area would generate wakes no more than 19m in length, and their influence to the study area is minor.

2.3 Wind Environment of Existing Scenario

2.3.1 In accordance with the wind availability data, the Subject Site relies on easterly, north easterly and east north easterly winds for ventilation throughout the year. Summer prevailing wind is coming from the east, south east and south southern east direction. Therefore, any blockage to these prevailing winds should be avoided as far as possible.

2.3.2 Tsui Sing Road, Tin Fuk Road acts as wind breezeways under the north easterly annual wind direction. Apart from these two major roads, Kiu Fat Street and Kiu Wong Street also acts as wind breezeways under the easterly wind directions as shown in **Figure 2.7**.

2.3.3 As shown in **Figure 2.7**, Ping Ha Road and Tin Yiu Road serve as two major wind breezeways under the summer prevailing wind directions (i.e. the south east directions and south southeast directions respectively).

2.3.4 In addition, Ping Ha Road and Tin Yiu Road mentioned in paragraph 2.3.3 above creates linkage to Tin Fuk Road and Tsui Sing Road which links up the wind breezeway to create a network and promote air ventilation to the Subject Site and its vicinity areas.

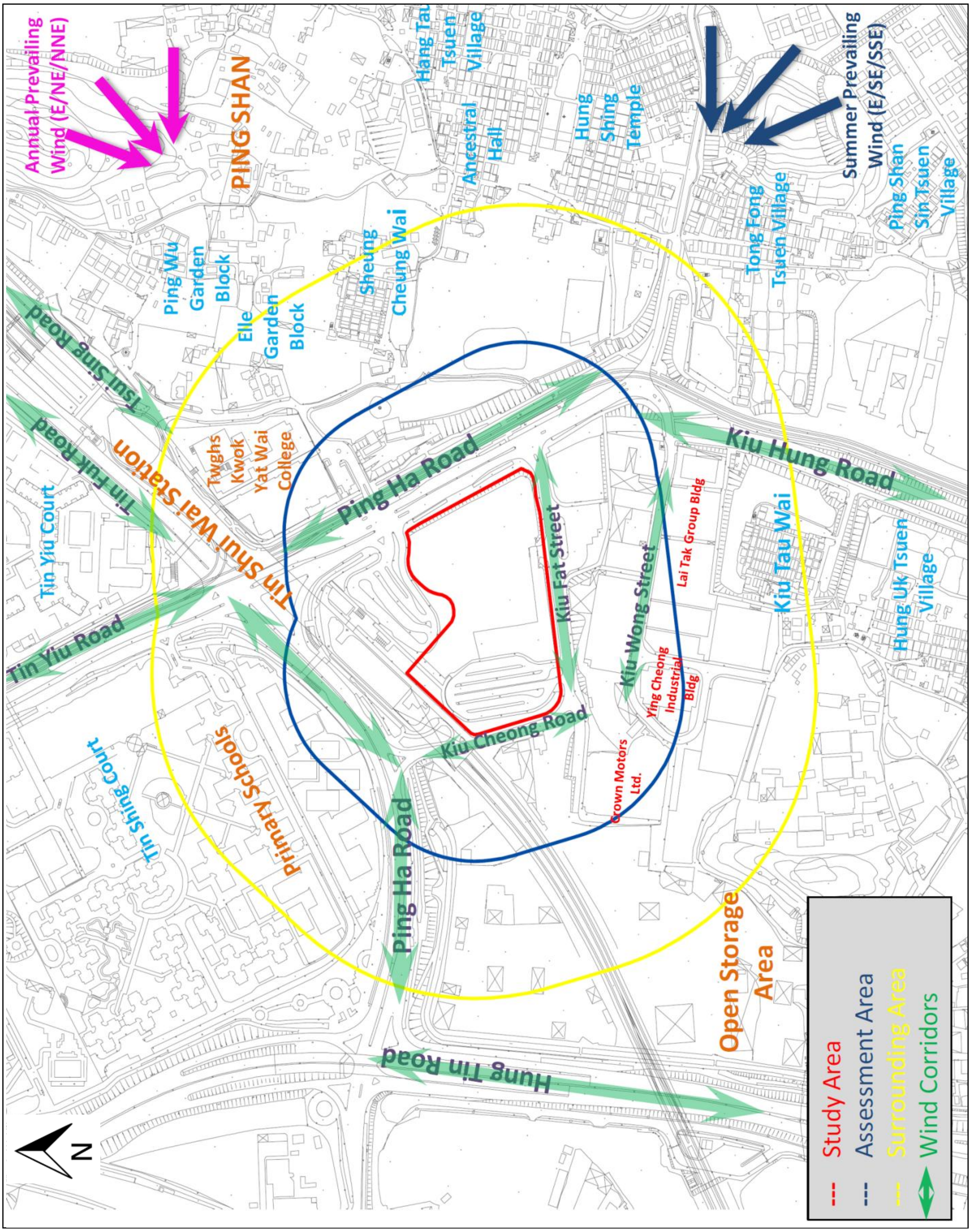
2.3.5 Major wind breezeways are marked in **Figure 2.7** as green arrows which include but not limited to Tsui Sing Road, Tin Yiu Road, Ping Ha Road, Kiu Hung Road, as well as Kiu Fat street and Kiu Cheong Road which surrounded the Subject Site. These wind breezeways will enhance and promote ventilation performance at the surrounding areas of the Subject Site.

2.3.6 To the vicinity of the Subject Site, there are large area of open storages located on the south western side with low density and height; these storage containers (if not stacked up to considerable height) are expected not to create blockages to the wind from the south western quadrant and will not lead to significant ventilation issues towards the Subject Site.

2.3.7 Clusters of village houses are located at various directions from the Subject Site. These village houses include Kiu Tau Wai and Hung Uk Tsuen Village to the south, Tong Fong Tsuen Village and Ping Shan Sin Tsuen Village to the south eastern direction, Hang Tau Tsuen Village and Sheung Cheung Wai located to the east. Although these village houses exists in high density, they are low in building heights (2-3 storeys in height) plus the relatively flat terrain, therefore annual and summer prevailing wind are not expected to be blocked by these village houses.

2.3.8 The low density residential buildings such as Elle Garden Block and Ping Wu Garden block which is located at the north eastern direction of the Subject Site is relatively low in building heights, thus the annual prevailing wind from the north eastern quadrant towards the Subject Site is not expected to be blocks by these existing developments.

2.3.9 To the northern and north western direction of the Subject Site are medium packed residential building blocks named Tin Shing Court and Tin Yiu Court, these residential blocks are approximately over 100mPD in height. These high rise developments might partially block the winds from the north western quadrants towards the Subject Site.



Notes:

- Width and Length of arrows **do not** have any special meanings and just for illustration purpose

Figure 2.7 Breezeways movement through Subject Site

3 ASSESSMENT METHODOLOGY

3.1 General

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

3.2 Modelling Tool and Model Setup

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

3.2.2 Wind Directions: In the CFD model, the average wind speed of individual prevailing wind directions identified for the Study Area was adopted for simulation of air ventilation performance for each direction (**Table 2.1** refers). Wind environment surrounding the Project Area was simulated using CFD under the 8 most prevailing wind directions (which represent occurrence of more than 75% of time) to illustrate the change in microclimate due to the proposed development. They are NNE, NE, ENE, E, ESE, SE, SSE and SSW, with ENE wind being the most predominant wind and contribute 16.9% of time in a year. The occurrence for the 8 prevailing simulated wind directions (NNE, NE, ENE, E, ESE, SE, SSE and SSW) has a cumulative percentage value of 80.3%.

3.2.3 Vertical Wind Profile: Wind environment under different wind directions will be defined in the CFD environment. According to the Technical Guide Para 20, wind profile for the site could be appropriated from the V∞ data developed from MM5 and with reference to the Power Law or Log Law using coefficients appropriate to the site conditions. In this assessment, vertical wind profile condition is determined using the Log Law:

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

where
U_Z : wind speed at height z from ground
u^* : friction velocity
σ : von Karman constant
Z : height z from ground
Z_o : roughness length

Table 3.1 Simulated Wind Directions and their corresponding percentage occurrence, Velocity at 596m and Roughness Length

Wind Direction	% of Annual Occurrence	Average V at infinity, m/s	Roughness Length (Z_o)
22.5º (NNE)	8.8%	9.10	3
45º (NE)	13.3%	8.20	3
67.5º (ENE)	17.0%	8.80	1
90º (E)	12.6%	7.50	1
112.5º (ESE)	9.8%	7.00	1
135º (SE)	6.8%	5.70	1
202.5º (SSE)	6.3%	6.70	1
225º (SSW)	5.7%	6.70	1

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

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

3.2.6 Computational Domain: A 3-dimensional CFD model was constructed to capture all major components such as topographical features and buildings within and in the vicinity of the Project Area that would likely affect the wind flow. The methodology described in the Technical Guide was adopted for this assessment. According to the Technical Guide, the Assessment Area should include the project's surrounding up to a perpendicular distance of 1H while the Surrounding Area should at least include the project's surrounding up to a perpendicular distance of 2H calculating from the project boundary, H being the height of the tallest building on site. In this study, the value of H is 110 meters with the computational domain size of approximately 3900 m (L) x 2400 m (W) x 800 m (H). In addition, the blockage ratio is not greater than 3%.

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

3.2.8 In the CFD model, the horizontal and vertical grid size employed in the CFD model in the vicinity of the Project Area was taken as a global minimum size of 2m and was increased for the grid cells further away from the Project Area at a growth expansion ratio of at most 1.2 with a maximum cell size of approximately 50 meters. Four layers of prism cells (each layer of 0.5m thick) were employed above the terrain. In the CFD model, the pedestrian level test points were all located at 2m above ground level at the fourth cell away from the terrain to ensure a better resolution of flow close to the ground as per the recommendation of COST action C14.

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

3.2.10 **Figure 3.1** shows the boundaries of the Study Area, Surrounding Area and Assessment Area that were examined in this AVA. **Figure 3.2** shows the extent of the computational domain that was adopted in the CFD model. Images of the general model setup and grid cell setup in the CFD model are shown in **Figure 3.3** and **Figure 3.4** respectively.

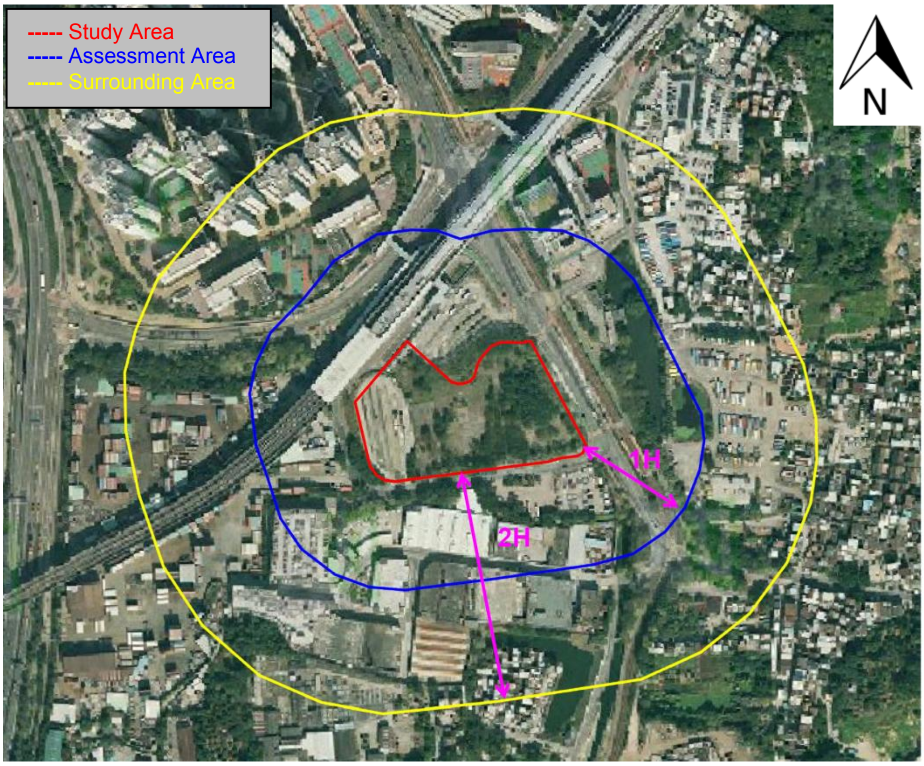


Figure 3.1 Boundaries of Study Area, Assessment Area and Surrounding Area

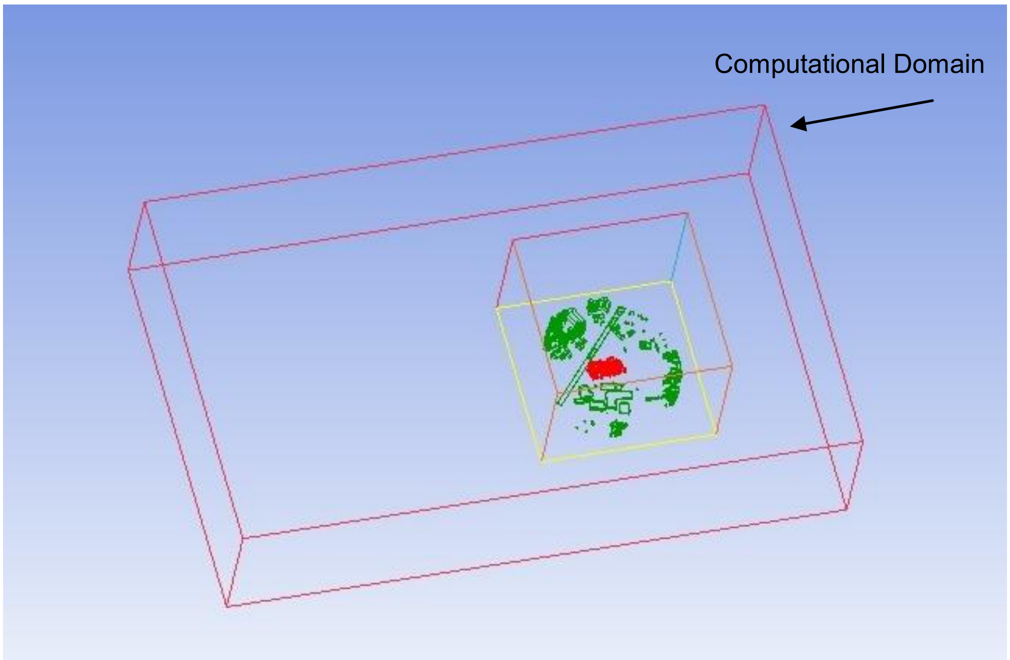


Figure 3.2 Extent of Computational Domain for CFD Model

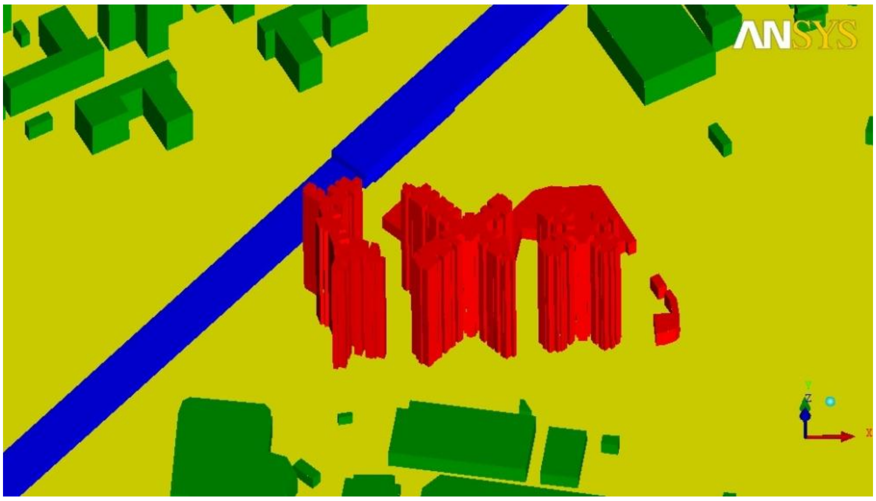


Figure 3.3 Images of 3D CFD Model (Proposed Scenario)

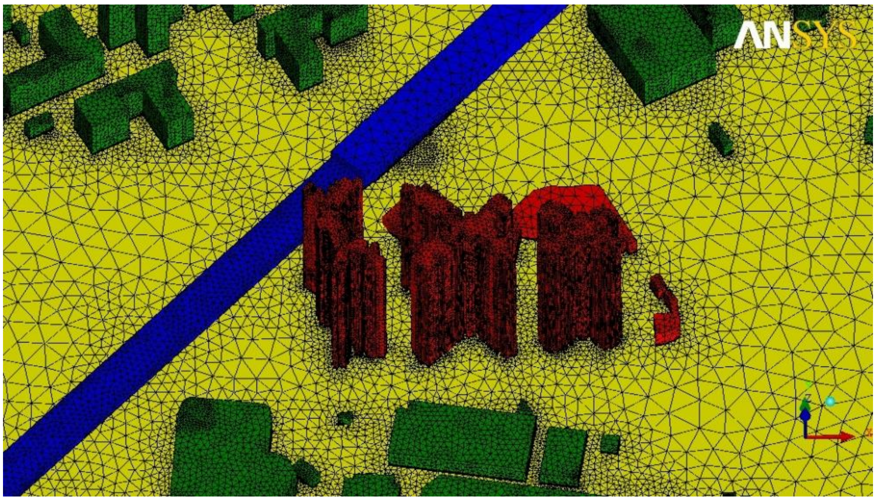


Figure 3.4(a) Images of Mesh Cells Setup in the CFD Model (Proposed Scenario)

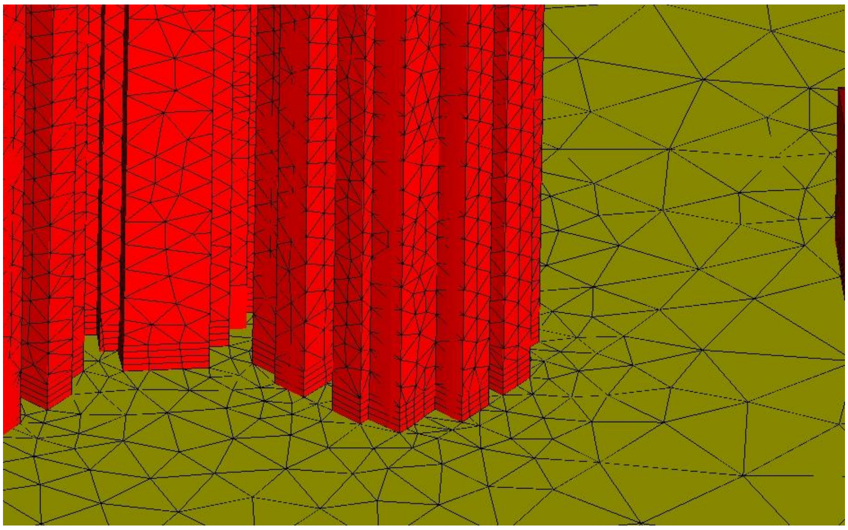


Figure 3.4(b) 4 layers of Prism Mesh Cells Setup in the CFD Model

3.2.11 Test Points: 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. Perimeter test points were selected along the boundary of the Project Area with separation distance of about 50m. Overall test points were evenly distributed over surrounding open spaces, streets, landscape deck, podium and other parts of the Assessment Area where pedestrian can or will mostly access. All test points are elevated at 2m above ground level.

3.2.12 The selected overall test points were grouped based on the land use / sensitive receivers as shown in **Figure 3.5** and summarized in **Table 3.2** for ease of discussion. There are 37 perimeter test points (with prefix "P") and 50 overall test points (with prefix "T") selected for the purpose of this AVA study.

Table 3.2 Grouping of the Test Points

Group	Description	Test Points
G1	Test points located northwest to the study area.	T1 to T15
G2	Test points located south to the study area	T16 to T39
G3	Test points located east to the study area	T40 to T50

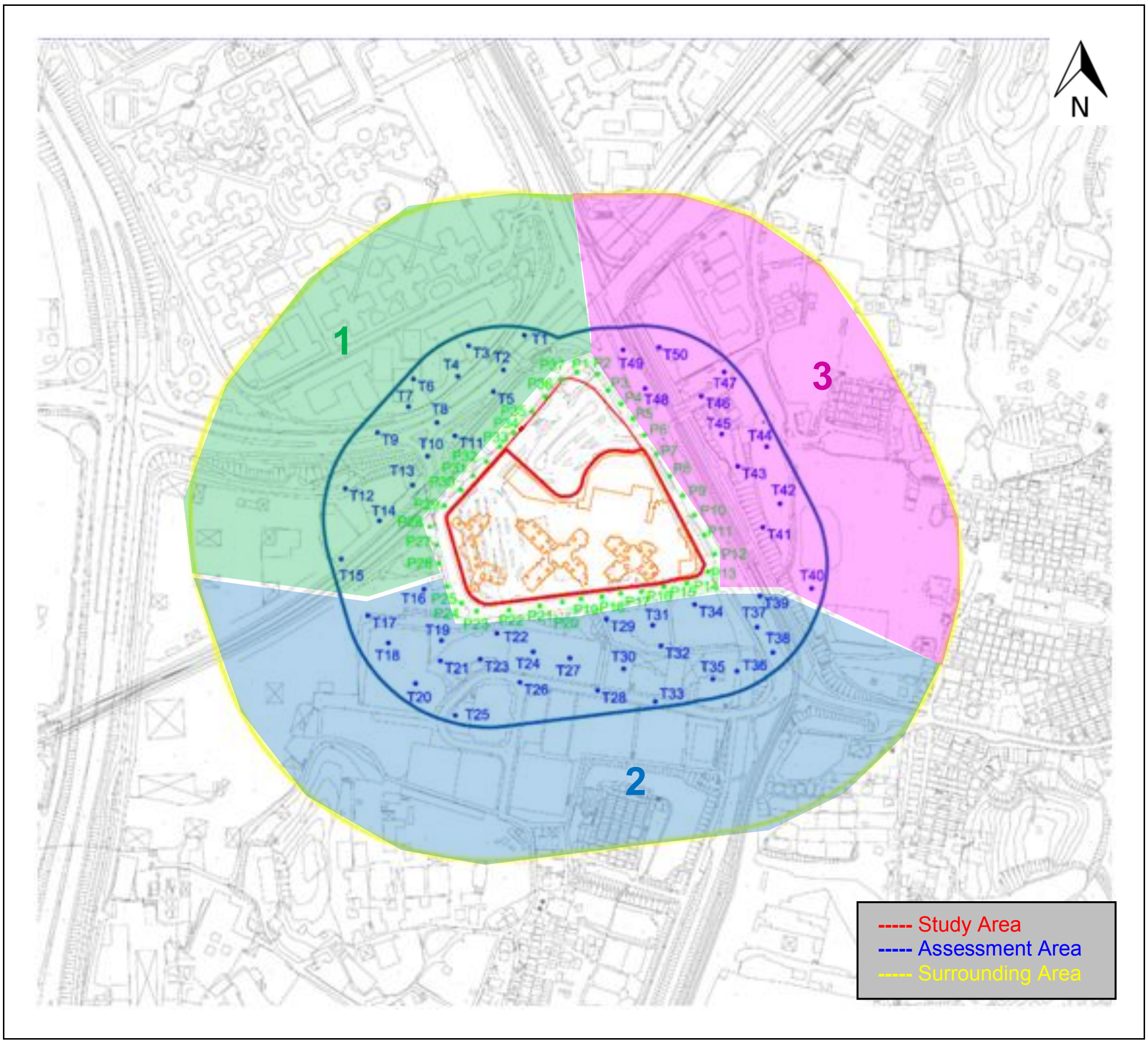


Figure 3.5 Test Points Selected for this Assessment

3.3 Wind Velocity Ratio

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

3.3.2 VR_W is the frequency weighted wind velocity ratio calculated based on the frequency of occurrence of all the 16 wind directions for the purpose of comparison.

3.3.3 For Site Air Ventilation Assessment, the Site Spatial Average Wind Velocity Ratio (SVR_W) and individual VR_W of all perimeter test points are reported. SVR_W is the average of VR_W of all perimeter test points.

3.3.4 For Local Air Ventilation Assessment, the Local Spatial Average Wind Velocity Ratio (LVR_W) of all overall test points and perimeter test points, and individual VR_W of the overall test points are reported. LVR_W is the average of all overall test points and perimeter test points.

3.3.5 The SVR_W and LVR_W are worked out so as to understand the overall impact of air ventilation on the immediate and further surroundings of the Project Area due to the proposed development.

4 KEY FINDINGS OF AVA STUDY

4.1 Local Situation

4.1.1 The local situation including the site environs, site wind environment, and site wind availability of the Subject Site are described in **Section 2** above.

4.2 Air Ventilation Issues

4.2.1 As discussed in **Section 2** above, the Subject Site is located in the Yuen Long Area. There are open grounds situated to the south of the Tin Shui Wai MTR station and Tin Shing Court. The height of the proposed Kiu Cheong Road East HOS are approximately 110mPD.

4.2.2 In accordance with the wind availability data, Kiu Cheong Road East HOS area relies heavily on easterly, north easterly and east north easterly winds for ventilation during most time in a year. Therefore, any blockage to these prevailing winds should be avoided as far as possible.

4.2.3 There are several open spaces and low-rise village houses/Temples to the east of the study area, and the building clusters to the south are mainly low-rise building and have a reasonable distance from the site. This would enhance the air ventilation performance to the subject area at the east, north east and south east wind directions and reduces blockage of the wind flow to a minimal level.

4.2.4 The scheme shown in Figure 4.1(a) was approved in Feb. 2000. It possesses two main high-rise clusters (about 110mPD in building height) constructed upon a large podium of approximately 28m in height. The northern cluster has three blocks while the southern one has five blocks. The blocks within the same cluster are closely packed together, without wind corridors.In current AVA study, this scheme approved in Feb.2000.acts as the Base Scheme is used for comparison with the Proposed Scheme as mentioned in Section 4.2.5.

4.2.5 The Proposed Scheme is decreased in the site area as compared with the Base Scheme. It possesses 3 building blocks with no podium structure and low rise retail shops located at the north of the site. The three high-rise building blocks are in same building heights and have adequate distance between each other, creating two wind corridors allowing wind to penetrate through the building clusters. **Figure 4.1(b)** shows the layout plan for the Proposed Scheme.

4.2.6 This AVA Study assessed and investigated the air ventilation performance of two design scheme options (namely the Base Scheme and the Proposed Scheme). The major difference between the Base Scheme and the Proposed Scheme is that the Base Scheme possesses a podium with eight residential blocks while the Proposed Scheme is a podium free design with sufficient separation distances between the three proposed building blocks. Furthermore, there are some low rise retail shops in the immediate vicinity of the building blocks in the Proposed Scheme.

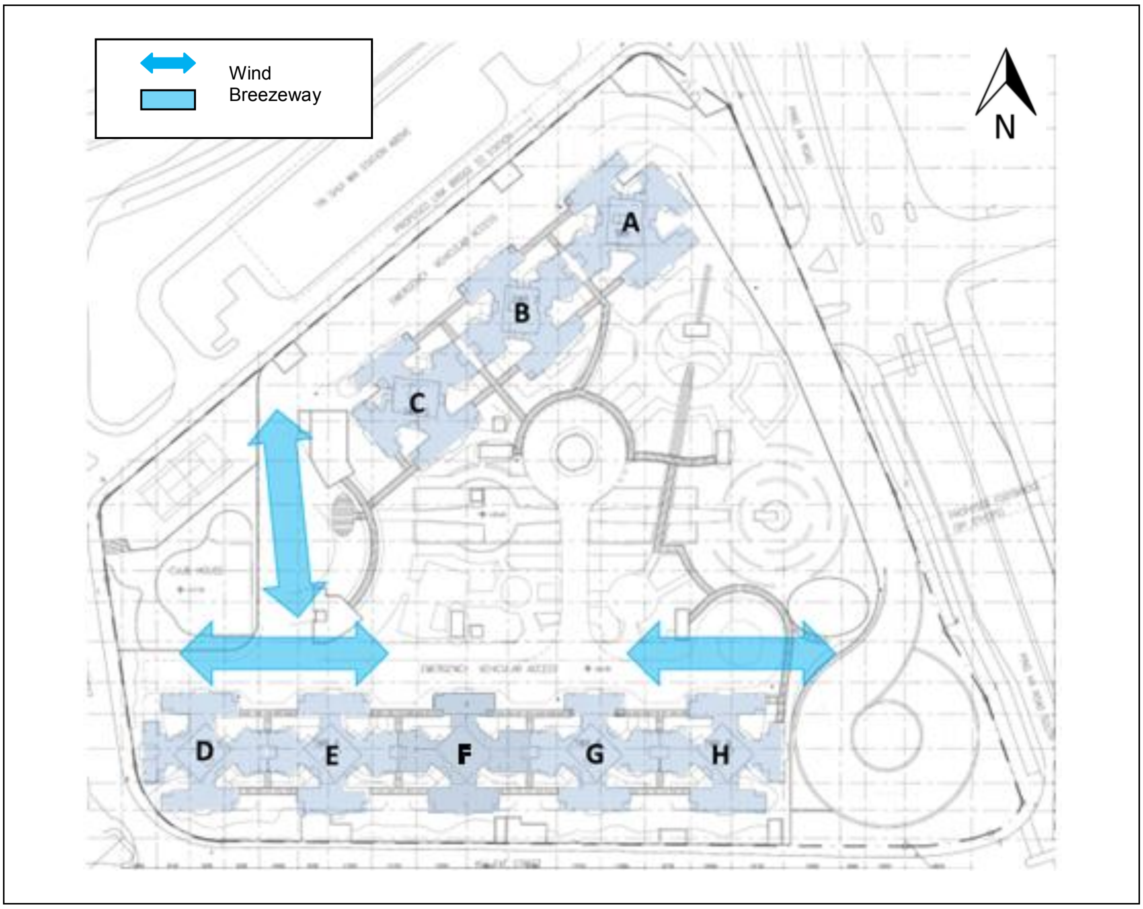


Figure 4.1(a) Layout Plan for the Base Scheme (Approved Scheme in Feb. 2000)

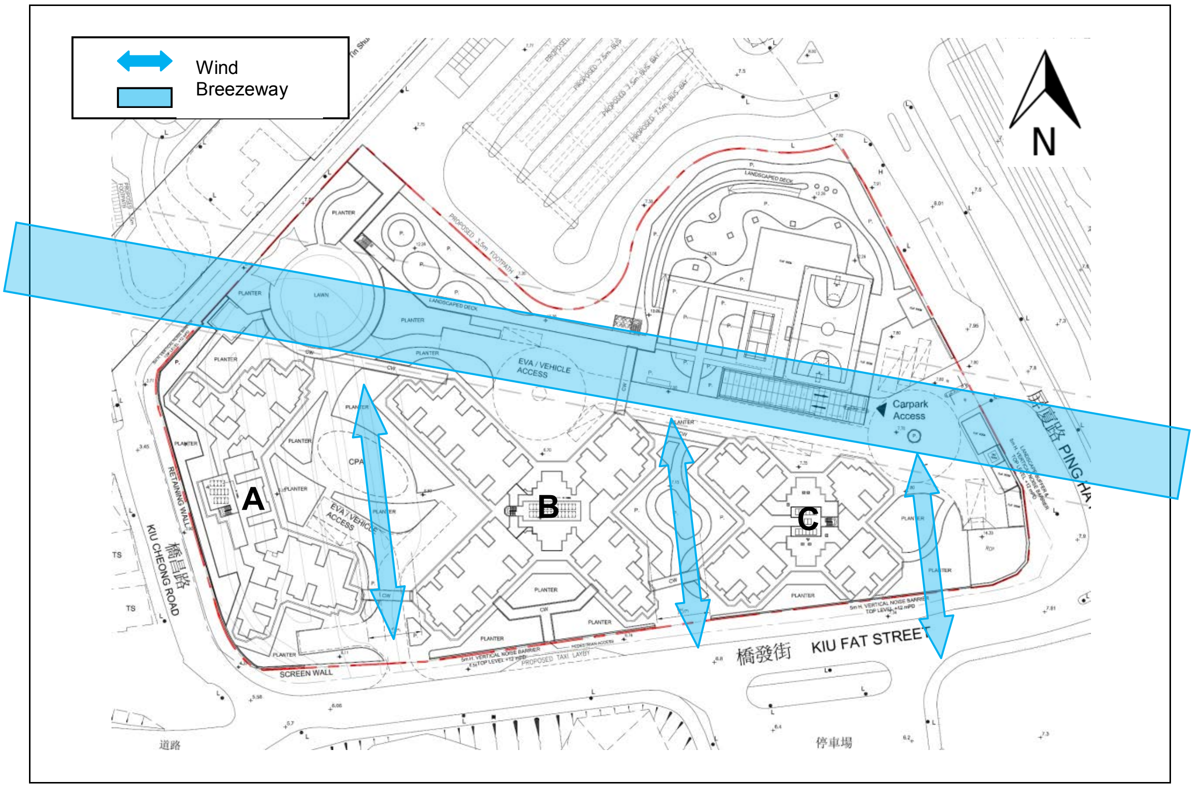


Figure 4.1(b) Layout Plan for the Proposed Scheme

4.3 Wind Velocity Ratio Results

4.3.1 A summary of the predicted wind velocity ratios for the Perimeter Test Points and the Overall Test Points as well as the SVR_W and LVR_W are presented in **Table 4.2** below. Details of the predicted wind velocity ratios are presented in **Appendix B**.

Table 4.1 Summary of Wind Velocity Ratios for Subject Site

	Wind Velocity Ratios	
	Base Scheme	Proposed Scheme
SVR_W	0.219	0.233
LVR_W	0.227	0.235

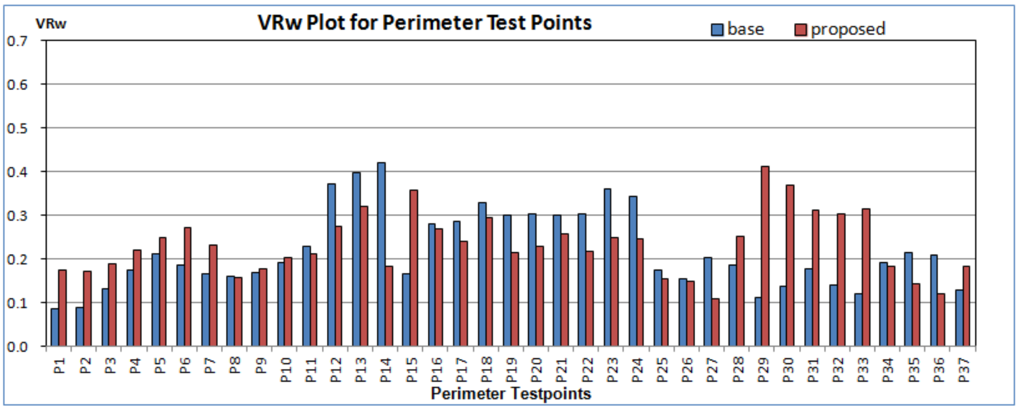
4.3.2 The results of VR_W for different groups of test points are summarized in **Table 4.2** below.

Table 4.2 Summary of Wind Velocity Ratio for Different Test Point Groups

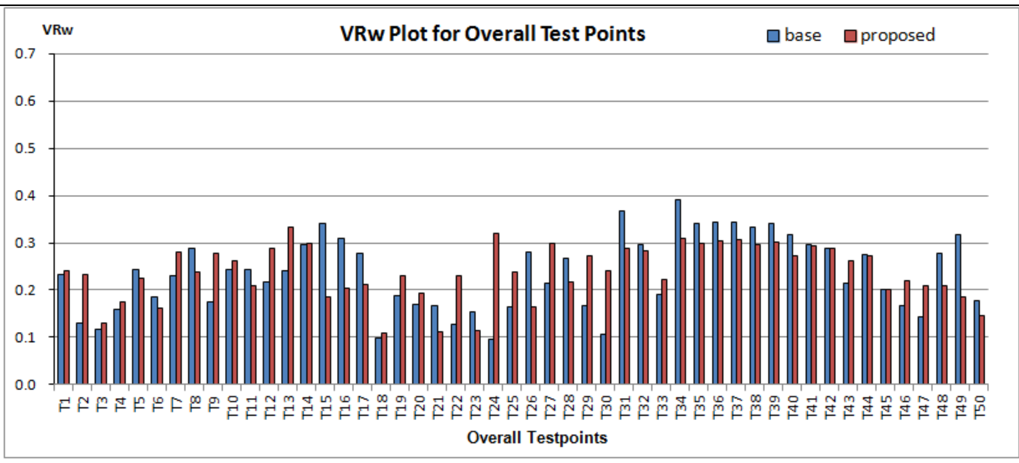
Group	Description	Test Points	Average VR_w	
			Base Scheme	Proposed Scheme
G1	Test points located northwest to the study area	T1– T15	0.223	0.236
G2	Test points located south to the study area	T16 – T39	0.239	0.240
G3	Test points located east to the study area	T40 – T50	0.231	0.233

4.3.3 The averaged VR_W result for individual test points and test point groups are also presented in the form of bar chart as shown in **Figure 4.2**. Calculation of averaged VR_w within each test group would help to get a clear picture of wind environment within each area group. The averaged VR_W result for individual test points and test points groups in the form of bar chart under the 8 wind directions are shown in **Appendix C**.

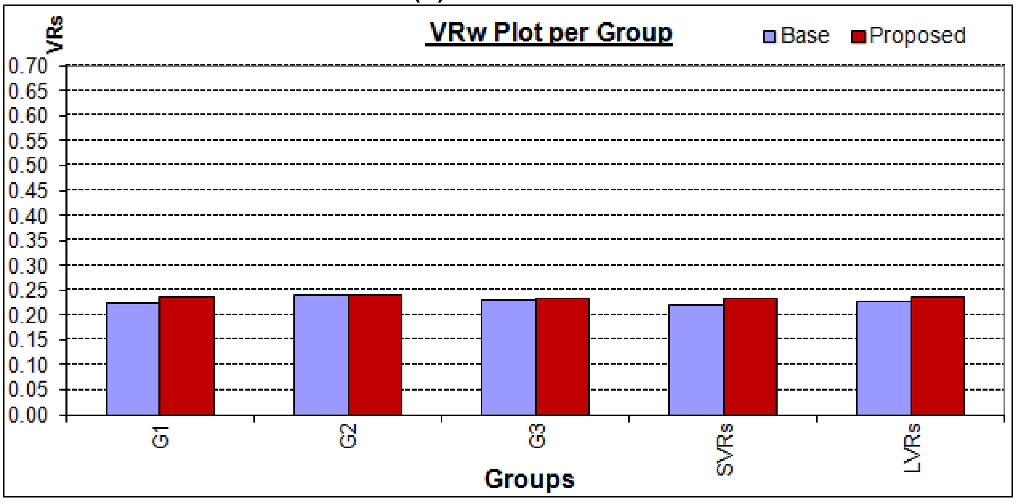
4.3.4 Contour plots of wind velocity ratio and wind velocity vector plots at 2m above the pedestrian level of assessment area under the 8 wind directions are shown in **Appendix D** and **Appendix E** respectively.



(a) Perimeter Test Points



(b) Overall Test Points



(c) Test Point Groups

Figure 4.2 Average VRw Result

4.4 Site Ventilation Assessment

4.4.1 It should be noted that the one major difference between Proposed Scheme and the Base Scheme is the elimination of the podium as well as reducing the number of buildings and the structures constructed in the region north of the proposed building clusters. The Proposed Scheme development blocks are designed and situated more to the southwards portion in which leaves more open spaces to the northern portion. This will create an even wider east western breezeway (marked in **Figure 4.1**) which will be effective in enhancing ventilation under the annual eastern prevailing wind.

4.4.2 The SVR_w indicates how the lower portion of the buildings on the project site may affect the wind environment of its immediate vicinity. The predicted SVR_w for the Base Scheme is around 0.219, while the Proposed Scheme maintains the SVR_w of 0.233 which results a slight improvement and a satisfactory pedestrian wind environment around the development site boundary. Therefore, the podium free design in the proposed development schemes would likely to improve the wind environment of its immediate vicinity.

4.4.3 The effect of the podium is most significant at the northern point of the study area. In the Base Scheme, the average VR value of the perimeter test points (P1 and P37) near this region is 0.108 which reflects a relatively worse air ventilation condition. It is improved in the Proposed Scheme which the podium is eliminated, and the average VR value in the same area obtained a value up to 0.178.

4.4.4 Perimeter test points P2 to P12 are located along Ping Ha Road which serves as a south to north direction wind corridor. For the Proposed Scheme, it maintains an average VR value of around 0.215 over all 8 wind directions, compared to that of 0.189 maintained in the Base Scheme.

4.4.5 Perimeter test points P24 to P28 are located along Kiu Cheong Road which serves as another south to north direction wind corridor. For both the Proposed Scheme and Base Scheme, it maintains an average VR value of over 0.18 over all 8 wind directions. While under SSW and SSE summer wind directions, both schemes maintains the average VR value over 0.29. The VR results imply that the Kiu Cheong Road is an effective breezeway under the summer prevailing winds.

4.4.6 Perimeter test points P13 to P23 are located along Kiu Fat Street which serves as an east to west direction wind corridor. The wind ventilation there is expected to be good and the perimeter test points P13 to P23 and both schemes maintains the average VR value of over 0.25. Under the winds from the eastern direction, both schemes maintains the average VR value over 0.28.

4.5 Local Air Ventilation Assessment

4.5.1 Design of the Proposed Scheme has eliminated the podium and redesigned multiple blocks in the base scheme to one cluster containing three proposed building blocks with large wings and sufficient separation distances in between. Therefore, improvement in wind performance can be seen within the study area and at locations north to the project site.

4.5.2 The averaged wind velocity ratio of Group 1 test points reflects the wind environment of the area to the northwest of the Subject Site. Within the area of Group 1 test points; there is Tin Shui Wai MTR station. The averaged VR_w for Group 1 test points is 0.223 and 0.236 for the Base Scheme and the Proposed Scheme respectively and is considered as satisfactory in terms of air venilation.

4.5.3 The average wind velocity ratio of Group 2 test points reflects the wind environment of the area to the south of the Subject Site. As the averaged VR_w for Group 2 test points is 0.239 and 0.240 for the Base Scheme and the Proposed Scheme respectively, the two schemes are considered comparable in terms of wind environment in this area.

4.5.4 Local test points T19 and T21 to T23 are located between the building of Brown Motor Ltd. and the Lai Tak Group Buildings at the west end of the Kiu Wong Street. Averaged Wind Velocity Ratios of these test points have value of around 0.16 for both the Base Scheme and the Proposed Scheme. The relatively low value of wind velocity ratio is due to the fact that this area is surrounded by these building clusters (Brown Motor Ltd. and the Lai Tak Group Buildings) and the buildings south of them, which formed a trapping zone.

4.5.5 The average wind velocity ratio of Group 3 test points reflects the wind environment of the area to the east of the Subject Site. There are several open grounds and clusters low rise village buildings in or near this region and the region is not expected to have severe wind environment since both schemes achieved a VR value of over 0.23.

4.5.6 Under the prevailing dominate wind directions, which include NE, ENE, E, and ESE, it is noticed that there are areas with good wind performance. These places include: areas northeast to the Lai Tak Building near the cross section of Ping Ha Road and Kiu Hong Road (test points T34 to T37), as well as the open area between study site and the Hang Tai Tseun Village, these two areas both maintain average VR value of greater than 0.248 in the Proposed Scheme. On the contrary, there are relatively low VR areas under these wind directions and are listed below:

- Area between Block C and the building to its east since it is in the shadow region of the building to its east under eastern quadrant winds. It is recommended to leave some gaps between the small buildings to its east to create wind corridor.
- Area southwest to the Subject Site, since it is located on the downwind side of the study area under the eastern quadrant winds. However, it should be noted that the VR value in this area in the Proposed Scheme maintains 0.160 which is significantly

lower than the average VR over the whole assessment area, which is 0.236 under these 4 wind directions.

4.5.7 Under the prevailing south quadrant wind directions SE, SSE and SSW, it is noticed that there are locations with relatively good wind performance. These places are mainly the open area east of the subject site, the average VR value in the region could reach up to 0.34. On the contrary, there are relatively low velocity ratio areas and are listed below:

- Area northwest to Block A since it is located in the shadow zone of the blocks under these wind directions.
- East portion of the Kiu Wong Road, since it is under the shadow region of the buildings south to the street.

5 SUMMARY AND CONCLUSIONS

5.1.1 This AVA Study Report aims at assessing the characteristics of the wind availability of the site, providing a general pattern and a quantitative estimate of wind performance at the pedestrian level under different wind directions and investigating the effectiveness of ventilation for two developments namely the Base Scheme and the Proposed Scheme for the Kiu Cheong Road East HOS .

5.1.2 During the assessment of Proposed Scheme, the following design merits from air ventilation perspective was found:

- The podium free design which would results a much better air ventilation conditions in the whole subject area.
- Minimizing the number of blocks and clusters, which would results better air ventilation to the immediate vicinity of the study area.

5.1.3 From the finding of this AVA Study, the SVR_W for Base Scheme ranges from 0.177 to 0.244 under the NNE, NE, ENE, E, ESE, SE, SSE and SSW winds which amount to about 80% of time in a year, while that of the Proposed Scheme range from 0.144 to 0.319. The Proposed Scheme performs better than the Base Scheme in terms of air ventilation performance.

5.1.4 The LVR_W for the Base Schemes ranges from 0.206 to 0.259 under the same 8 wind directions stated above, while that of the Proposed Scheme ranges from 0.193 to 0.265. A conclusion of Proposed Scheme is slightly better than Base Scheme in terms of air ventilation performance can be made.

5.1.5 To conclude, the Proposed Scheme has incorporated a number of ventilation improvement measures during the scheme design stage and the CFD modelling results show that it is able to maintain a relatively good wind performance at the pedestrian level within the study area and around its immediate vicinity.

APPENDICES

Appendix A - Wind Probability Table (obtained from Planning Department)

Square (14,36) V Infinity (m/s)	Wind direction Sum	N 0.033	NNE 0.088	NE 0.133	ENE 0.17	E 0.126	ESE 0.098	SE 0.068	SSE 0.063	S 0.04	SSW 0.057	SW 0.051	WSW 0.027	W 0.014	WNW 0.009	NW 0.011	NNW 0.013
0_to_1	0.021	0	0.002	0.001	0.001	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001
1_to_2	0.052	0.003	0.002	0.004	0.004	0.004	0.005	0.006	0.004	0.006	0.005	0.003	0.001	0.002	0.001	0.003	0.002
2_to_3	0.072	0.005	0.004	0.005	0.007	0.009	0.007	0.006	0.005	0.005	0.004	0.003	0.002	0.002	0.002	0.003	0.003
3_to_4	0.082	0.004	0.007	0.012	0.008	0.011	0.009	0.006	0.003	0.003	0.005	0.003	0.003	0.002	0.001	0.002	0.003
4_to_5	0.093	0.005	0.007	0.013	0.014	0.009	0.01	0.005	0.005	0.003	0.005	0.005	0.005	0.003	0.001	0.001	0.002
5_to_6	0.095	0.005	0.008	0.009	0.012	0.01	0.012	0.007	0.007	0.004	0.005	0.007	0.005	0.002	0.001	0	0
6_to_7	0.097	0.002	0.005	0.014	0.015	0.01	0.012	0.008	0.008	0.004	0.005	0.007	0.005	0.001	0.001	0	0
7_to_8	0.085	0.001	0.003	0.012	0.013	0.013	0.01	0.008	0.007	0.004	0.005	0.005	0.002	0.001	0	0	0
8_to_9	0.077	0.001	0.005	0.01	0.011	0.012	0.009	0.005	0.007	0.002	0.005	0.008	0.001	0	0	0	0
9_to_10	0.072	0.001	0.007	0.009	0.016	0.011	0.007	0.005	0.006	0.001	0.005	0.005	0	0	0	0	0
10_to_11	0.061	0.001	0.007	0.009	0.016	0.008	0.005	0.003	0.003	0.002	0.005	0.001	0	0	0	0	0.001
11_to_12	0.054	0.001	0.006	0.009	0.015	0.01	0.004	0.002	0.002	0.002	0.003	0	0	0	0	0	0
12_to_13	0.039	0	0.003	0.008	0.012	0.008	0.003	0.001	0.002	0.001	0.002	0.001	0	0	0	0	0
13_to_14	0.029	0	0.004	0.004	0.009	0.004	0.002	0.001	0.001	0	0.002	0.001	0	0	0	0	0
14_to_15	0.021	0	0.004	0.006	0.005	0.003	0	0	0.001	0	0	0	0	0	0	0	0
15_to_16	0.014	0.001	0.005	0.003	0.003	0.001	0	0	0	0	0	0	0	0	0	0	0
16_to_17	0.012	0	0.005	0.002	0.002	0	0	0	0	0.001	0	0	0	0	0	0	0
17_to_18	0.008	0	0.003	0.002	0.001	0	0	0	0	0	0	0	0	0	0	0	0
18_to_19	0.006	0.001	0.001	0.001	0.002	0	0	0	0	0	0	0	0	0	0	0	0
19_to_20	0.004	0	0	0	0.002	0	0.001	0	0	0	0	0	0	0	0	0	0
20_to_21	0.003	0	0	0	0.001	0	0.001	0	0	0	0	0	0	0	0	0	0
21_to_22	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22_to_23	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23_to_24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average Wind Speed at 596m, m/s		5.32	9.10	8.21	8.82	7.50	6.81	5.73	6.66	5.59	6.75	6.25	4.57	3.86	3.00	2.23	3.15

Selected wind directions	Probabilty of wind occurrence
NNE	8.8%
NE	13.3%
ENE	17.0%
E	12.6%
ESE	9.8%
SE	6.8%
SSW	5.7%
SSE	6.3%
Sum	80.3%

Appendix B - Details of the Predicted Wind Velocity Ratio (VR_W)

Test Point	Base								VR_w
	NNE	NE	ENE	E	ESE	SE	SSE	SSW	
Wind speed at infinity	**9.100**	**8.200**	**8.800**	**7.500**	**7.000**	**5.700**	**6.700**	**6.700**	
Wind probability	**0.088**	**0.133**	**0.170**	**0.126**	**0.098**	**0.068**	**0.063**	**0.057**	**0.803**
P1	0.029	0.087	0.111	0.108	0.095	0.088	0.044	0.087	0.086
P2	0.011	0.067	0.095	0.124	0.137	0.127	0.088	0.029	0.088
P3	0.014	0.071	0.130	0.185	0.220	0.205	0.146	0.089	0.131
P4	0.028	0.072	0.166	0.242	0.299	0.283	0.225	0.102	0.173
P5	0.065	0.067	0.204	0.287	0.373	0.347	0.322	0.068	0.211
P6	0.099	0.045	0.175	0.232	0.327	0.300	0.339	0.023	0.185
P7	0.130	0.038	0.126	0.181	0.285	0.259	0.355	0.102	0.167
P8	0.173	0.091	0.045	0.143	0.267	0.231	0.347	0.207	0.159
P9	0.214	0.137	0.032	0.113	0.257	0.249	0.356	0.255	0.169
P10	0.269	0.196	0.106	0.064	0.239	0.286	0.324	0.261	0.191
P11	0.354	0.301	0.214	0.027	0.209	0.305	0.276	0.247	0.228
P12	0.501	0.511	0.438	0.193	0.175	0.442	0.496	0.167	0.372
P13	0.487	0.566	0.551	0.319	0.038	0.336	0.534	0.140	0.398
P14	0.307	0.463	0.573	0.440	0.161	0.213	0.544	0.573	0.421
P15	0.153	0.167	0.135	0.125	0.149	0.069	0.268	0.426	0.167
P16	0.215	0.343	0.371	0.239	0.230	0.057	0.236	0.479	0.281
P17	0.195	0.325	0.416	0.288	0.275	0.041	0.137	0.415	0.285
P18	0.191	0.365	0.502	0.382	0.329	0.100	0.067	0.380	0.328
P19	0.039	0.314	0.458	0.401	0.378	0.167	0.043	0.305	0.301
P20	0.046	0.291	0.435	0.415	0.409	0.225	0.108	0.239	0.304
P21	0.061	0.237	0.377	0.428	0.452	0.308	0.205	0.152	0.301
P22	0.025	0.145	0.308	0.457	0.551	0.467	0.383	0.050	0.304
P23	0.083	0.052	0.273	0.482	0.662	0.652	0.631	0.337	0.360
P24	0.166	0.121	0.173	0.387	0.598	0.627	0.646	0.448	0.344
P25	0.235	0.206	0.101	0.101	0.075	0.195	0.316	0.373	0.174
P26	0.267	0.234	0.112	0.079	0.041	0.087	0.159	0.345	0.153
P27	0.315	0.293	0.038	0.126	0.168	0.292	0.204	0.462	0.204
P28	0.308	0.240	0.110	0.089	0.101	0.272	0.078	0.482	0.186
P29	0.072	0.027	0.185	0.070	0.147	0.156	0.060	0.189	0.111
P30	0.100	0.068	0.159	0.142	0.160	0.175	0.240	0.073	0.136
P31	0.235	0.175	0.161	0.123	0.201	0.182	0.271	0.115	0.177
P32	0.255	0.206	0.101	0.066	0.117	0.100	0.151	0.156	0.139
P33	0.242	0.193	0.041	0.088	0.063	0.041	0.127	0.267	0.121
P34	0.226	0.294	0.151	0.219	0.093	0.186	0.104	0.235	0.191
P35	0.184	0.293	0.266	0.243	0.147	0.267	0.066	0.084	0.214
P36	0.139	0.269	0.301	0.225	0.150	0.250	0.043	0.104	0.209
P37	0.104	0.148	0.173	0.126	0.109	0.059	0.102	0.152	0.129
Average SVR	**0.177**	**0.209**	**0.225**	**0.215**	**0.235**	**0.234**	**0.244**	**0.233**	**0.219**
P_{Min}	0.011	0.027	0.032	0.027	0.038	0.041	0.043	0.023	0.086
P_{Max}	0.501	0.566	0.573	0.482	0.662	0.652	0.646	0.573	0.421

Appendix B - Details of the Predicted Wind Velocity Ratio (VR_W)

	Base								
Test Point	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**	**SSW**	
Wind speed at infinity	**9.100**	**8.200**	**8.800**	**7.500**	**7.000**	**5.700**	**6.700**	**6.700**	**VR_w**
Wind probability	**0.088**	**0.133**	**0.170**	**0.126**	**0.098**	**0.068**	**0.063**	**0.057**	**0.803**
T1	0.340	0.273	0.185	0.210	0.234	0.251	0.260	0.139	0.234
T2	0.281	0.064	0.113	0.084	0.057	0.047	0.121	0.448	0.130
T3	0.078	0.080	0.086	0.153	0.204	0.078	0.115	0.175	0.116
T4	0.197	0.085	0.170	0.160	0.107	0.131	0.189	0.352	0.160
T5	0.318	0.275	0.263	0.249	0.184	0.119	0.078	0.413	0.243
T6	0.100	0.047	0.176	0.234	0.329	0.304	0.343	0.022	0.186
T7	0.259	0.088	0.166	0.293	0.337	0.204	0.239	0.396	0.229
T8	0.346	0.236	0.416	0.196	0.215	0.214	0.281	0.365	0.288
T9	0.317	0.144	0.218	0.051	0.094	0.090	0.260	0.310	0.174
T10	0.304	0.299	0.279	0.154	0.259	0.059	0.125	0.451	0.244
T11	0.280	0.259	0.178	0.265	0.188	0.226	0.276	0.383	0.243
T12	0.334	0.172	0.234	0.036	0.198	0.220	0.410	0.293	0.216
T13	0.317	0.315	0.343	0.050	0.096	0.235	0.164	0.419	0.241
T14	0.254	0.209	0.269	0.175	0.379	0.407	0.547	0.370	0.296
T15	0.284	0.236	0.260	0.299	0.526	0.610	0.346	0.388	0.342
T16	0.291	0.275	0.076	0.280	0.455	0.536	0.576	0.373	0.310
T17	0.396	0.356	0.142	0.290	0.375	0.376	0.148	0.158	0.278
T18	0.093	0.079	0.096	0.055	0.097	0.144	0.205	0.087	0.098
T19	0.054	0.064	0.182	0.261	0.262	0.258	0.303	0.229	0.189
T20	0.080	0.137	0.181	0.212	0.208	0.220	0.188	0.109	0.169
T21	0.049	0.063	0.185	0.172	0.209	0.306	0.273	0.168	0.166
T22	0.086	0.075	0.099	0.104	0.101	0.286	0.302	0.131	0.128
T23	0.142	0.094	0.139	0.176	0.221	0.194	0.177	0.144	0.155
T24	0.043	0.097	0.052	0.055	0.095	0.257	0.228	0.069	0.096
T25	0.136	0.127	0.132	0.184	0.238	0.284	0.189	0.066	0.165
T26	0.329	0.394	0.275	0.215	0.256	0.334	0.245	0.130	0.281
T27	0.016	0.198	0.319	0.273	0.256	0.173	0.077	0.243	0.214
T28	0.333	0.250	0.273	0.265	0.241	0.257	0.212	0.324	0.268
T29	0.052	0.106	0.203	0.234	0.243	0.150	0.058	0.257	0.168
T30	0.077	0.105	0.094	0.093	0.147	0.094	0.093	0.202	0.107
T31	0.344	0.445	0.537	0.429	0.253	0.012	0.197	0.408	0.368
T32	0.291	0.347	0.404	0.346	0.241	0.018	0.180	0.309	0.296
T33	0.143	0.209	0.328	0.180	0.049	0.127	0.073	0.281	0.190
T34	0.413	0.494	0.472	0.323	0.176	0.249	0.396	0.564	0.391
T35	0.404	0.416	0.434	0.316	0.244	0.134	0.312	0.285	0.340
T36	0.432	0.421	0.430	0.305	0.246	0.203	0.250	0.292	0.343
T37	0.414	0.402	0.401	0.287	0.218	0.236	0.316	0.422	0.343
T38	0.412	0.397	0.400	0.280	0.232	0.228	0.274	0.335	0.332
T39	0.416	0.395	0.367	0.265	0.202	0.265	0.368	0.499	0.341
T40	0.362	0.343	0.339	0.236	0.193	0.258	0.325	0.407	0.305
T41	0.334	0.309	0.245	0.216	0.248	0.349	0.436	0.257	0.285
T42	0.354	0.276	0.209	0.216	0.252	0.340	0.391	0.330	0.276
T43	0.109	0.109	0.167	0.176	0.265	0.387	0.483	0.108	0.203
T44	0.320	0.301	0.186	0.201	0.251	0.356	0.403	0.226	0.264
T45	0.049	0.072	0.152	0.231	0.276	0.343	0.399	0.122	0.188
T46	0.072	0.188	0.122	0.048	0.134	0.270	0.377	0.220	0.156
T47	0.110	0.008	0.181	0.234	0.043	0.020	0.280	0.185	0.130
T48	0.115	0.147	0.215	0.307	0.387	0.450	0.510	0.132	0.265
T49	0.070	0.300	0.360	0.318	0.344	0.416	0.444	0.124	0.304
T50	0.023	0.215	0.238	0.070	0.158	0.174	0.037	0.424	0.166
Average LVR	**0.206**	**0.215**	**0.233**	**0.212**	**0.229**	**0.236**	**0.259**	**0.255**	**0.227**
T_{Min}	0.016	0.008	0.052	0.036	0.043	0.012	0.037	0.022	0.096
T_{Max}	0.432	0.494	0.537	0.429	0.526	0.610	0.576	0.564	0.391

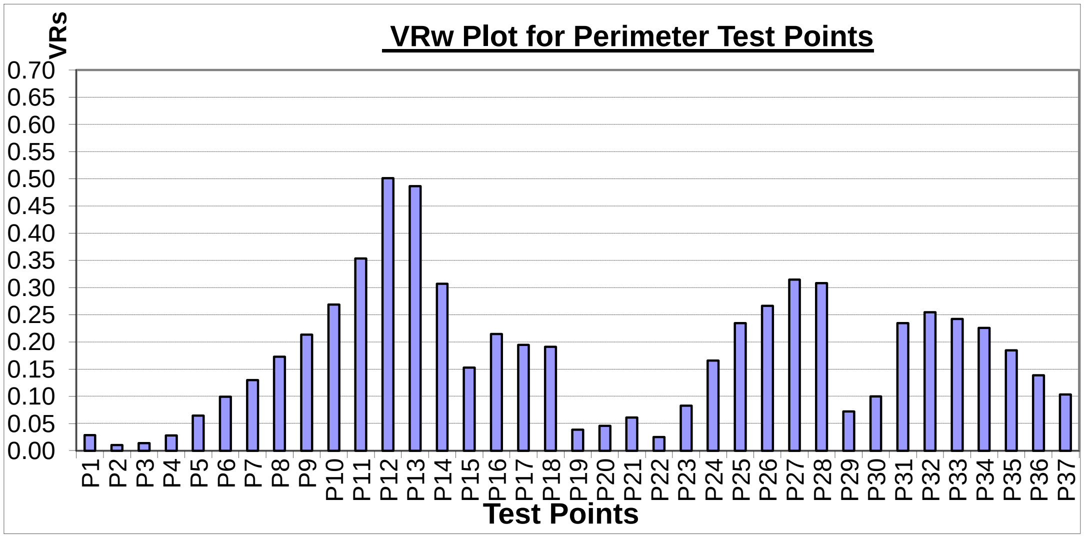
Appendix B - Details of the Predicted Wind Velocity Ratio (VR_W)

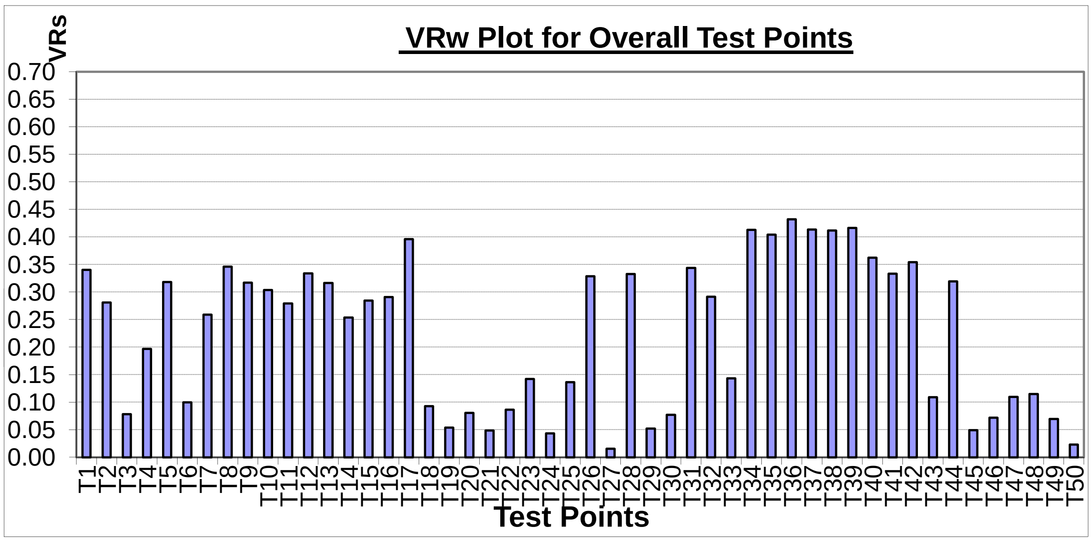
	proposed								
Test Point	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**	**SSW**	
Wind speed at infinity	**9.100**	**8.200**	**8.800**	**7.500**	**7.000**	**5.700**	**6.700**	**6.700**	**VR_w**
Wind probability	**0.088**	**0.133**	**0.170**	**0.126**	**0.098**	**0.068**	**0.063**	**0.057**	**0.803**
P1	0.096	0.067	0.256	0.174	0.136	0.347	0.266	0.052	0.174
P2	0.050	0.135	0.209	0.185	0.125	0.323	0.286	0.079	0.172
P3	0.056	0.186	0.179	0.149	0.236	0.365	0.301	0.092	0.189
P4	0.084	0.205	0.190	0.232	0.303	0.388	0.309	0.085	0.220
P5	0.118	0.210	0.235	0.306	0.339	0.397	0.300	0.073	0.250
P6	0.137	0.177	0.293	0.363	0.379	0.419	0.287	0.073	0.273
P7	0.095	0.087	0.252	0.310	0.365	0.396	0.259	0.107	0.233
P8	0.041	0.036	0.127	0.205	0.290	0.331	0.224	0.108	0.158
P9	0.101	0.060	0.134	0.210	0.281	0.359	0.283	0.111	0.178
P10	0.172	0.166	0.165	0.235	0.266	0.351	0.225	0.074	0.204
P11	0.259	0.251	0.130	0.166	0.231	0.358	0.290	0.080	0.211
P12	0.330	0.340	0.210	0.175	0.185	0.332	0.396	0.416	0.276
P13	0.375	0.416	0.297	0.229	0.130	0.286	0.418	0.530	0.320
P14	0.084	0.117	0.139	0.181	0.139	0.112	0.382	0.560	0.183
P15	0.345	0.372	0.475	0.386	0.149	0.121	0.426	0.514	0.359
P16	0.047	0.092	0.355	0.400	0.268	0.207	0.348	0.474	0.270
P17	0.065	0.148	0.201	0.332	0.352	0.351	0.270	0.252	0.239
P18	0.327	0.354	0.208	0.349	0.325	0.290	0.175	0.345	0.296
P19	0.122	0.053	0.142	0.392	0.282	0.174	0.269	0.432	0.215
P20	0.062	0.146	0.115	0.407	0.322	0.281	0.291	0.327	0.229
P21	0.133	0.165	0.117	0.393	0.364	0.412	0.397	0.255	0.257
P22	0.066	0.033	0.127	0.400	0.422	0.351	0.319	0.125	0.218
P23	0.041	0.160	0.136	0.370	0.416	0.383	0.391	0.239	0.249
P24	0.064	0.149	0.075	0.337	0.439	0.433	0.482	0.255	0.247
P25	0.076	0.089	0.104	0.097	0.220	0.231	0.394	0.217	0.153
P26	0.043	0.131	0.126	0.142	0.149	0.181	0.251	0.264	0.148
P27	0.021	0.136	0.044	0.054	0.081	0.246	0.131	0.343	0.109
P28	0.142	0.142	0.285	0.281	0.369	0.239	0.125	0.450	0.251
P29	0.356	0.454	0.504	0.433	0.397	0.319	0.126	0.519	0.411
P30	0.367	0.464	0.446	0.370	0.403	0.310	0.033	0.298	0.369
P31	0.321	0.400	0.292	0.295	0.421	0.331	0.144	0.153	0.312
P32	0.185	0.277	0.331	0.373	0.424	0.338	0.222	0.156	0.304
P33	0.197	0.328	0.344	0.367	0.404	0.394	0.096	0.256	0.315
P34	0.042	0.116	0.226	0.119	0.305	0.438	0.154	0.077	0.183
P35	0.080	0.028	0.185	0.057	0.211	0.391	0.197	0.111	0.144
P36	0.116	0.044	0.130	0.115	0.114	0.269	0.190	0.020	0.119
P37	0.100	0.162	0.253	0.105	0.213	0.363	0.180	0.042	0.182
Average SVR	**0.144**	**0.186**	**0.217**	**0.262**	**0.283**	**0.319**	**0.266**	**0.231**	**0.233**
P_{Min}	0.021	0.028	0.044	0.054	0.081	0.112	0.033	0.020	0.109
P_{Max}	0.375	0.464	0.504	0.433	0.439	0.438	0.482	0.560	0.411

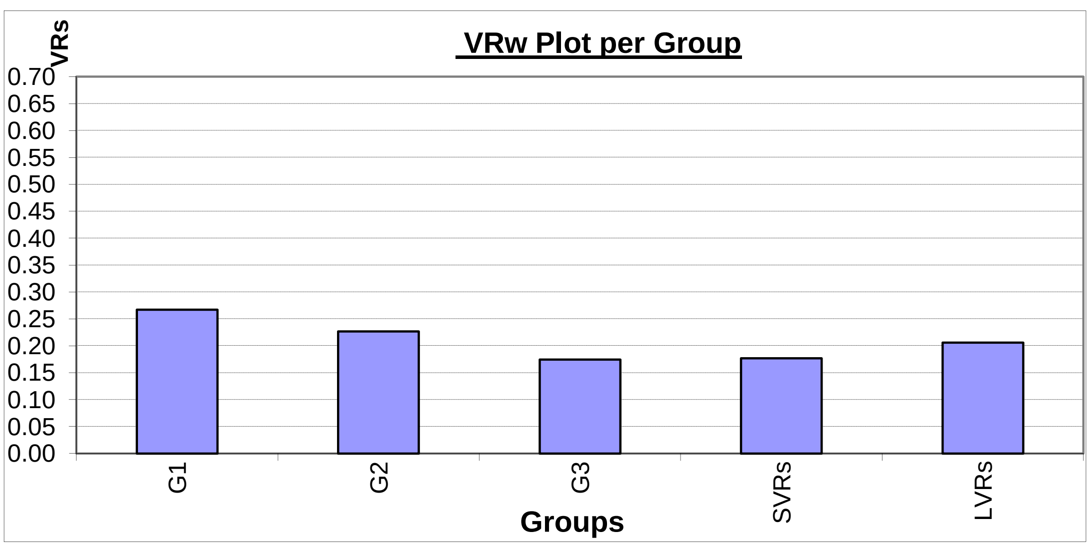
Appendix B - Details of the Predicted Wind Velocity Ratio (VR_W)

	proposed								
Test Point	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**	**SSW**	
Wind speed at infinity	**9.100**	**8.200**	**8.800**	**7.500**	**7.000**	**5.700**	**6.700**	**6.700**	**VR_w**
Wind probability	**0.088**	**0.133**	**0.170**	**0.126**	**0.098**	**0.068**	**0.063**	**0.057**	**0.803**
T1	0.279	0.250	0.170	0.236	0.246	0.273	0.204	0.365	0.241
T2	0.305	0.330	0.129	0.282	0.191	0.130	0.054	0.464	0.232
T3	0.094	0.093	0.116	0.185	0.194	0.173	0.040	0.143	0.131
T4	0.294	0.082	0.248	0.103	0.108	0.116	0.079	0.442	0.176
T5	0.283	0.178	0.231	0.271	0.178	0.233	0.045	0.387	0.225
T6	0.128	0.047	0.107	0.223	0.283	0.263	0.190	0.137	0.161
T7	0.317	0.128	0.351	0.291	0.351	0.331	0.109	0.363	0.281
T8	0.321	0.202	0.271	0.198	0.207	0.264	0.140	0.317	0.239
T9	0.354	0.241	0.302	0.302	0.255	0.205	0.197	0.310	0.277
T10	0.285	0.351	0.281	0.227	0.183	0.241	0.132	0.355	0.263
T11	0.211	0.172	0.247	0.195	0.138	0.276	0.101	0.366	0.209
T12	0.344	0.401	0.327	0.224	0.182	0.110	0.339	0.282	0.287
T13	0.373	0.464	0.362	0.391	0.188	0.195	0.155	0.352	0.333
T14	0.266	0.301	0.427	0.349	0.131	0.123	0.390	0.231	0.298
T15	0.144	0.109	0.104	0.167	0.167	0.322	0.429	0.315	0.186
T16	0.071	0.208	0.200	0.150	0.194	0.330	0.453	0.138	0.205
T17	0.038	0.254	0.162	0.094	0.360	0.393	0.390	0.107	0.211
T18	0.082	0.127	0.120	0.107	0.110	0.133	0.106	0.060	0.110
T19	0.128	0.045	0.166	0.328	0.323	0.387	0.447	0.205	0.230
T20	0.157	0.111	0.167	0.275	0.285	0.289	0.169	0.086	0.193
T21	0.051	0.032	0.140	0.173	0.104	0.199	0.144	0.064	0.113
T22	0.034	0.114	0.238	0.318	0.371	0.326	0.297	0.135	0.229
T23	0.119	0.055	0.105	0.122	0.123	0.136	0.210	0.105	0.114
T24	0.128	0.215	0.422	0.413	0.374	0.417	0.296	0.151	0.319
T25	0.243	0.361	0.247	0.173	0.178	0.282	0.221	0.104	0.237
T26	0.186	0.200	0.142	0.108	0.136	0.268	0.229	0.086	0.164
T27	0.206	0.167	0.327	0.497	0.408	0.305	0.213	0.117	0.299
T28	0.294	0.392	0.263	0.115	0.093	0.078	0.112	0.257	0.216
T29	0.110	0.098	0.368	0.433	0.294	0.192	0.215	0.409	0.273
T30	0.205	0.322	0.293	0.286	0.208	0.135	0.155	0.116	0.241
T31	0.258	0.334	0.349	0.338	0.249	0.073	0.183	0.347	0.287
T32	0.297	0.357	0.294	0.316	0.230	0.110	0.215	0.343	0.283
T33	0.228	0.303	0.273	0.265	0.181	0.135	0.090	0.098	0.223
T34	0.384	0.414	0.291	0.261	0.178	0.226	0.280	0.465	0.310
T35	0.408	0.386	0.341	0.256	0.231	0.146	0.278	0.193	0.298
T36	0.435	0.392	0.344	0.244	0.220	0.218	0.225	0.220	0.303
T37	0.431	0.379	0.332	0.229	0.190	0.232	0.276	0.355	0.306
T38	0.411	0.384	0.337	0.226	0.187	0.222	0.216	0.299	0.296
T39	0.425	0.363	0.299	0.219	0.198	0.229	0.284	0.420	0.301
T40	0.338	0.339	0.301	0.195	0.164	0.195	0.272	0.371	0.272
T41	0.396	0.290	0.217	0.291	0.205	0.269	0.366	0.479	0.294
T42	0.384	0.258	0.219	0.287	0.209	0.296	0.342	0.476	0.288
T43	0.236	0.294	0.208	0.259	0.238	0.313	0.384	0.251	0.263
T44	0.353	0.307	0.158	0.252	0.200	0.333	0.351	0.419	0.273
T45	0.071	0.076	0.241	0.305	0.248	0.294	0.317	0.038	0.202
T46	0.147	0.267	0.264	0.294	0.195	0.082	0.227	0.119	0.220
T47	0.059	0.229	0.274	0.329	0.145	0.135	0.203	0.134	0.209
T48	0.074	0.175	0.242	0.160	0.233	0.358	0.386	0.083	0.209
T49	0.059	0.101	0.266	0.247	0.180	0.124	0.353	0.082	0.185
T50	0.054	0.102	0.175	0.175	0.124	0.091	0.386	0.075	0.146
Average LVR	**0.193**	**0.215**	**0.236**	**0.254**	**0.242**	**0.265**	**0.250**	**0.239**	**0.235**
T_{Min}	0.034	0.032	0.104	0.094	0.093	0.073	0.040	0.038	0.110
T_{Max}	0.435	0.464	0.427	0.497	0.408	0.417	0.453	0.479	0.333

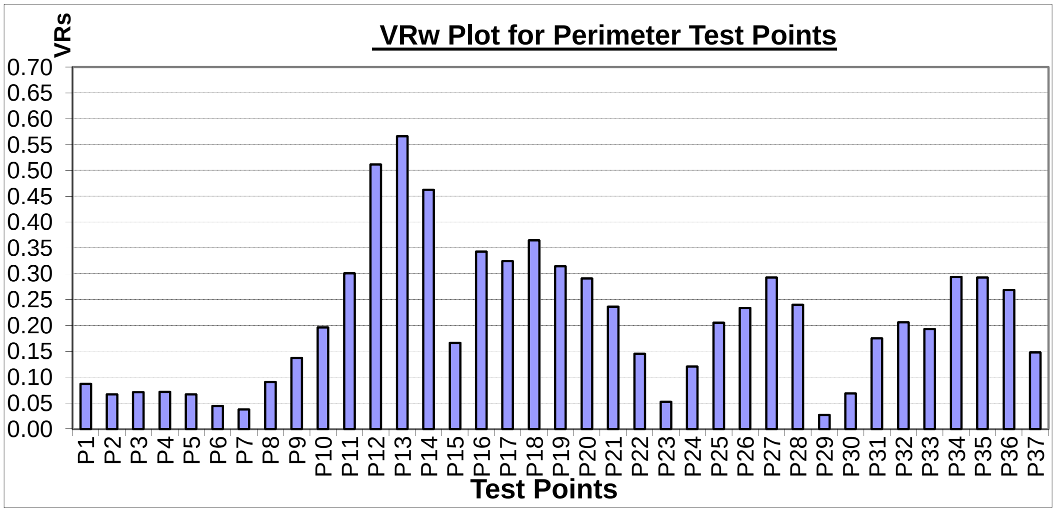
Appendix C - VRs Plot at 2m above Ground in NNE Wind Direction (Base)

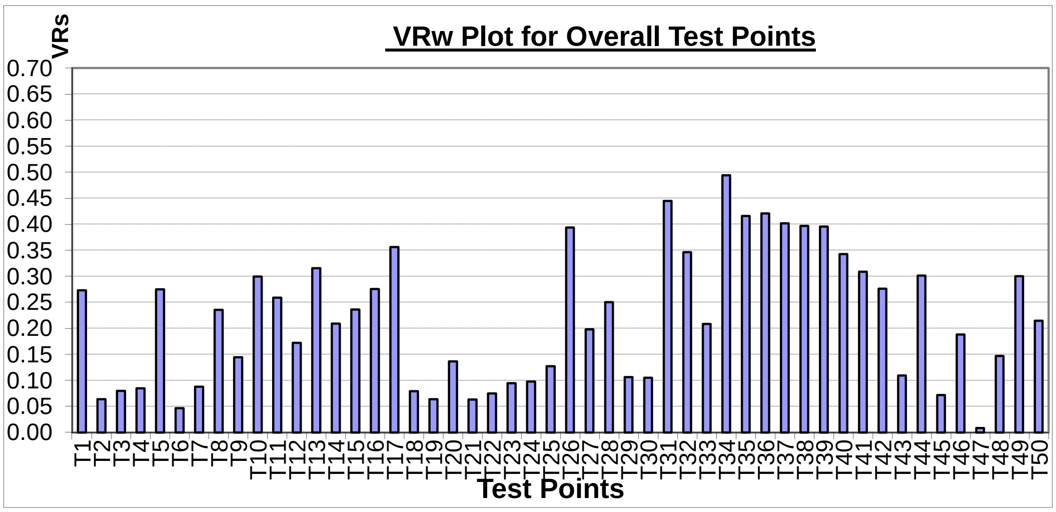


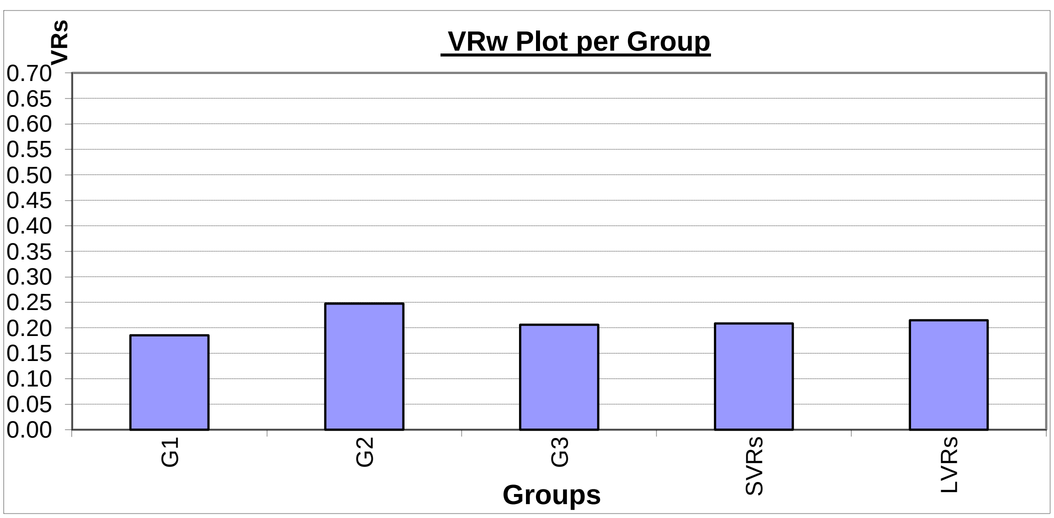




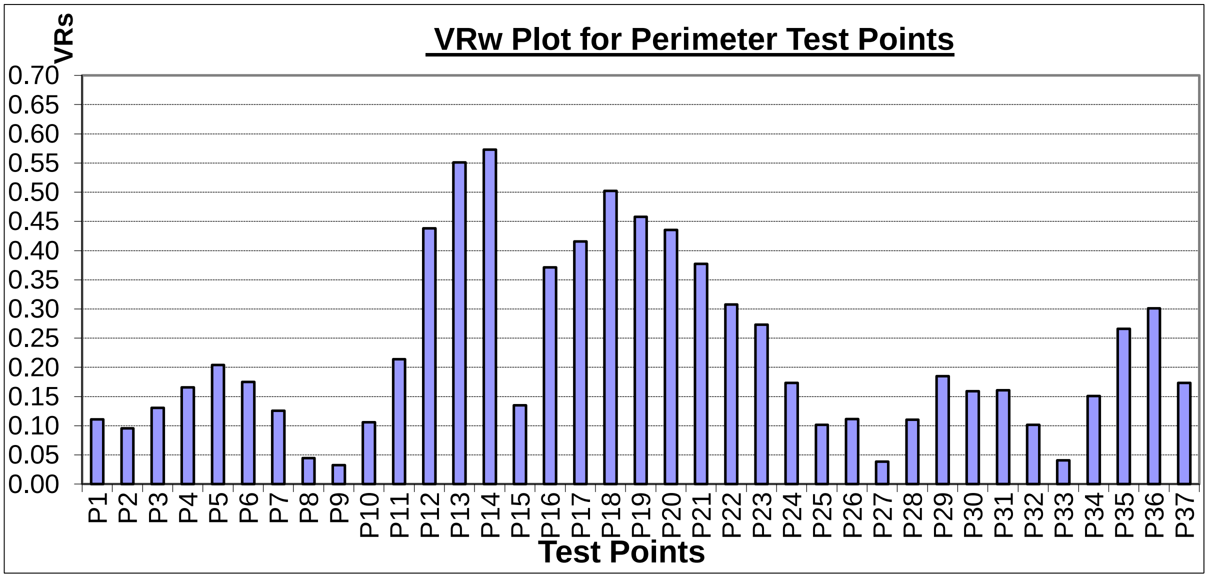
Appendix C - VRs Plot at 2m above Ground in NE Wind Direction (Base)

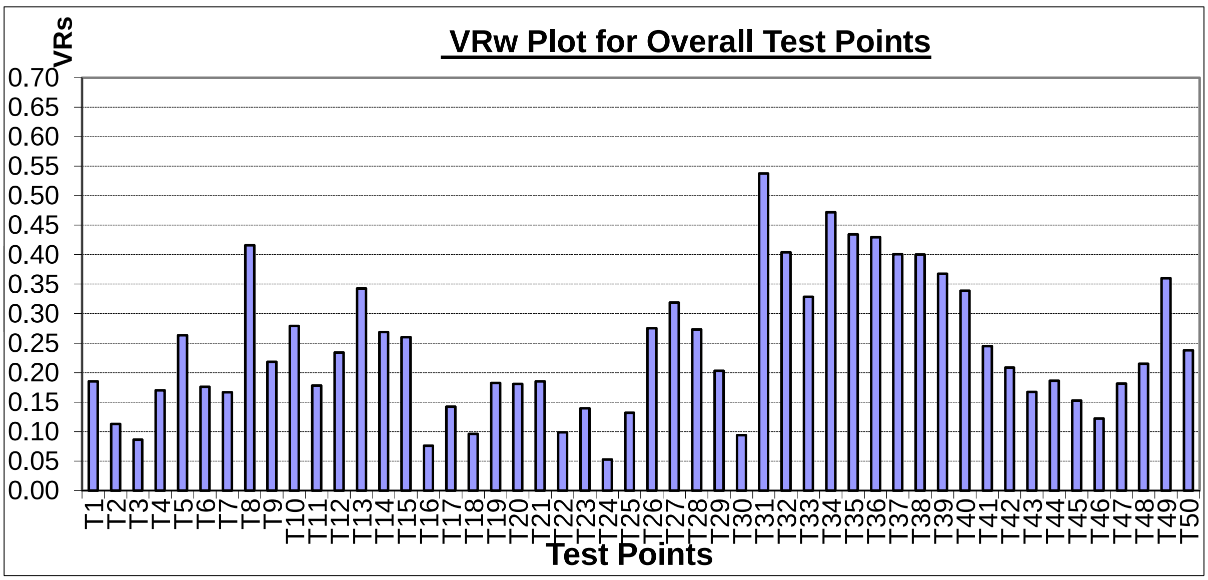


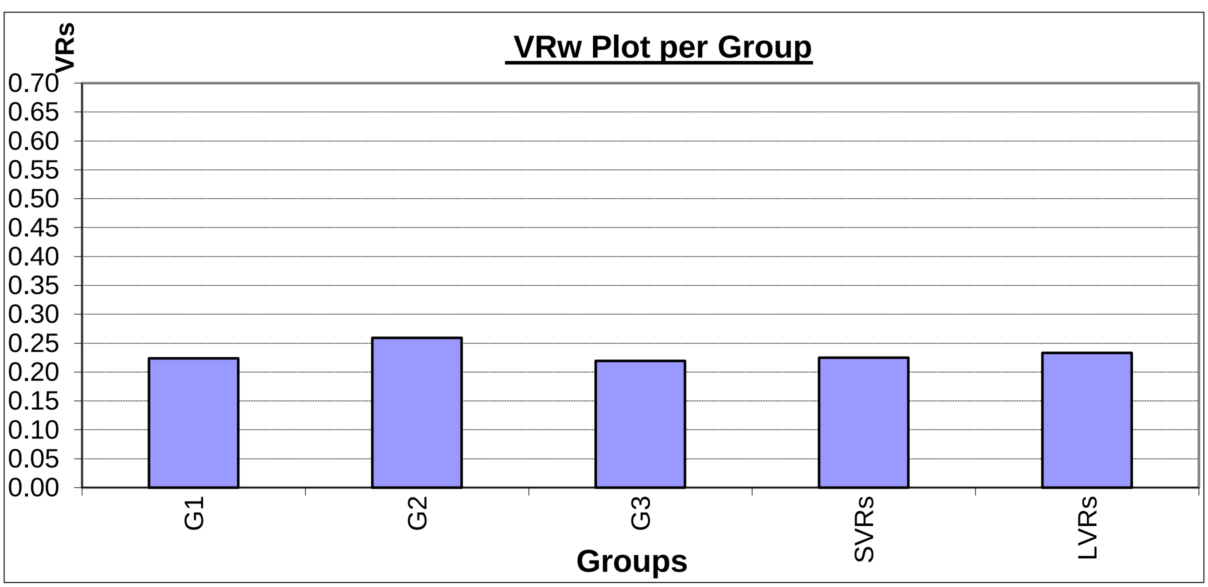




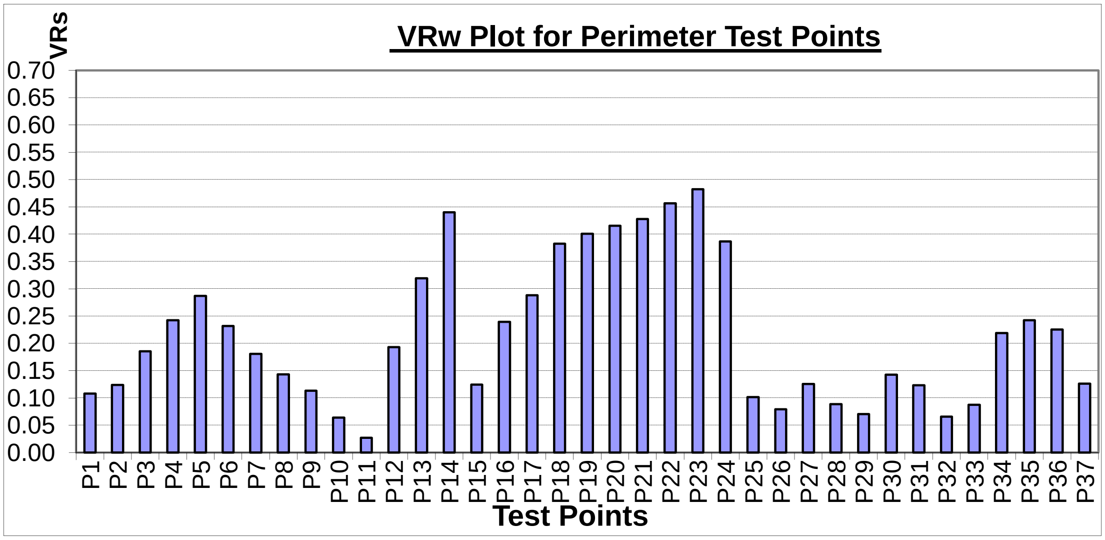
Appendix C - VRs Plot at 2m above Ground in ENE Wind Direction (Base)

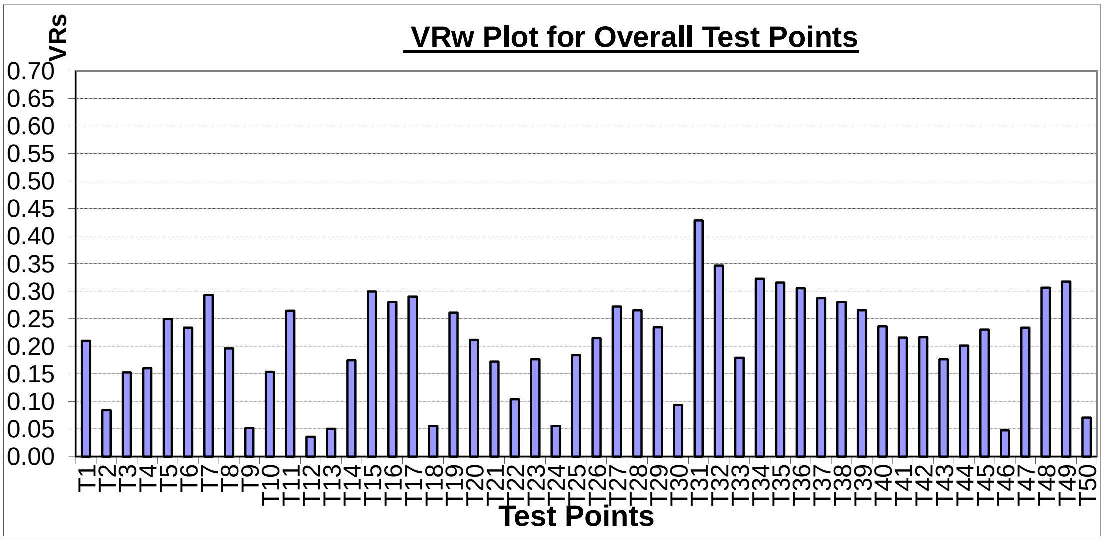


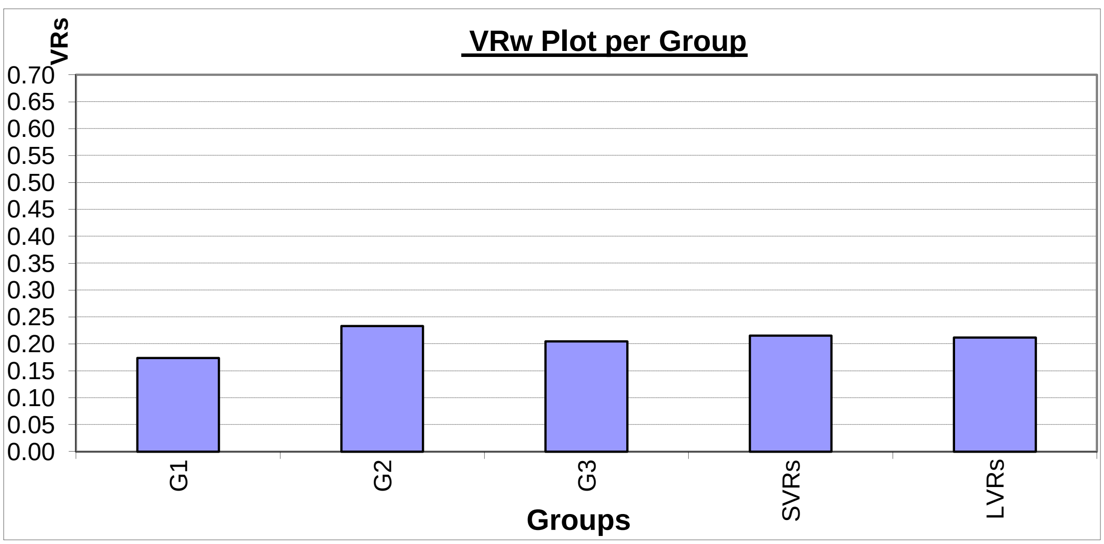




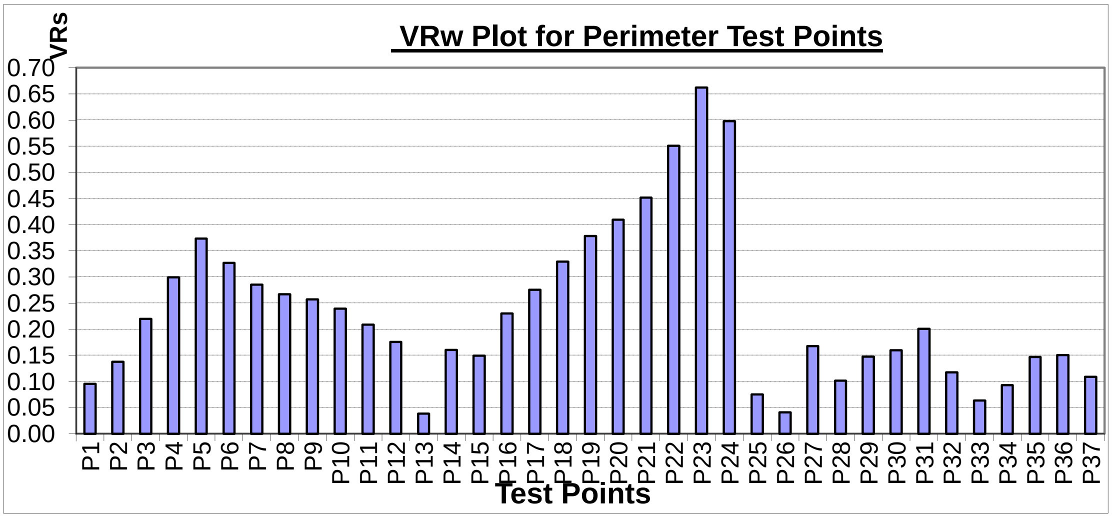
Appendix C - VRs Plot at 2m above Ground in E Wind Direction (Base)

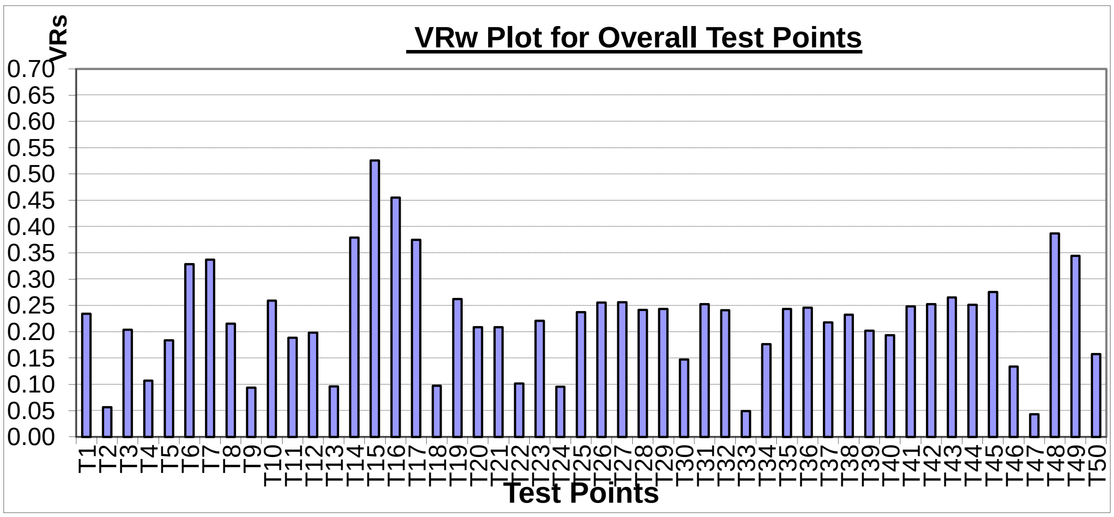


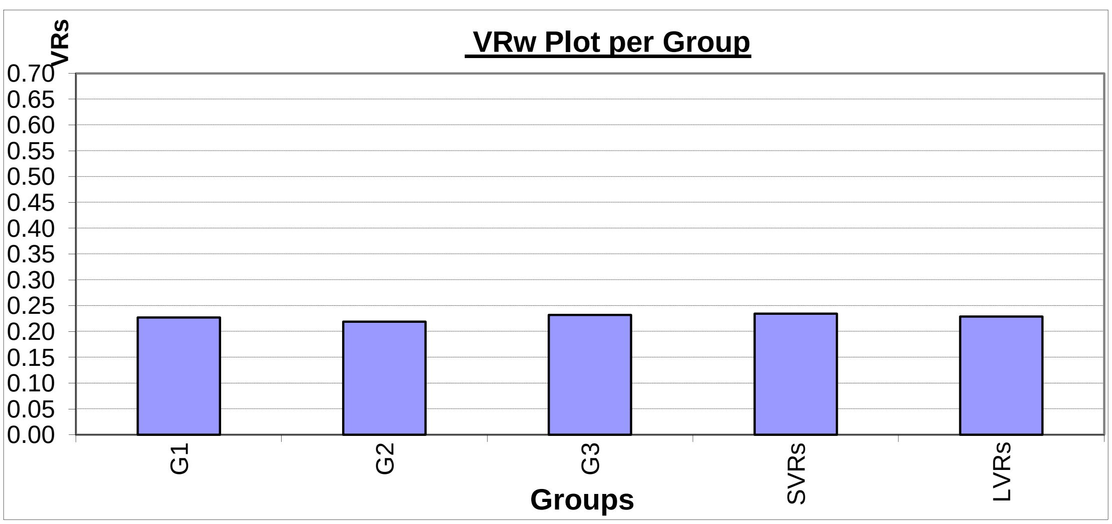




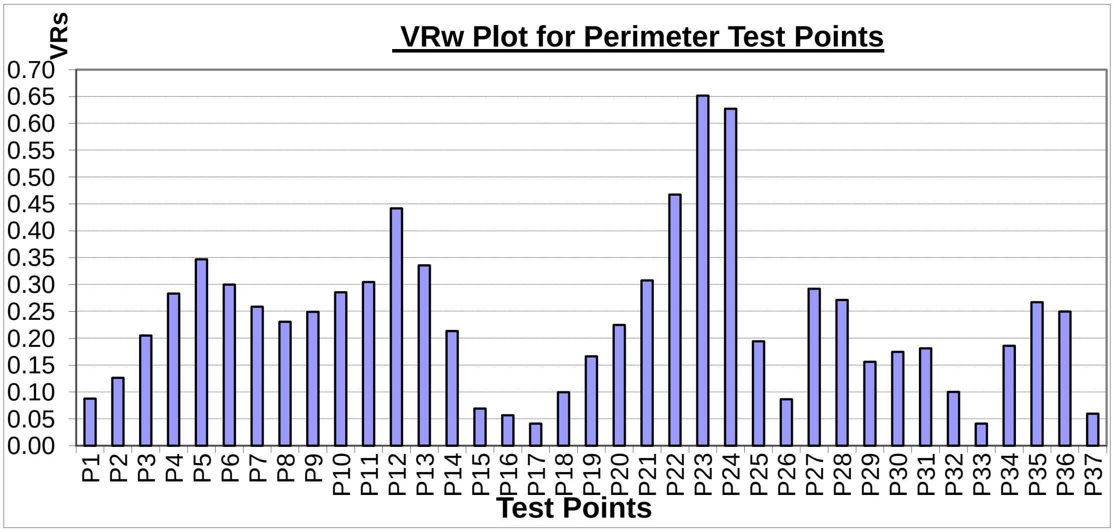
Appendix C - VRs Plot at 2m above Ground in ESE Wind Direction (Base)

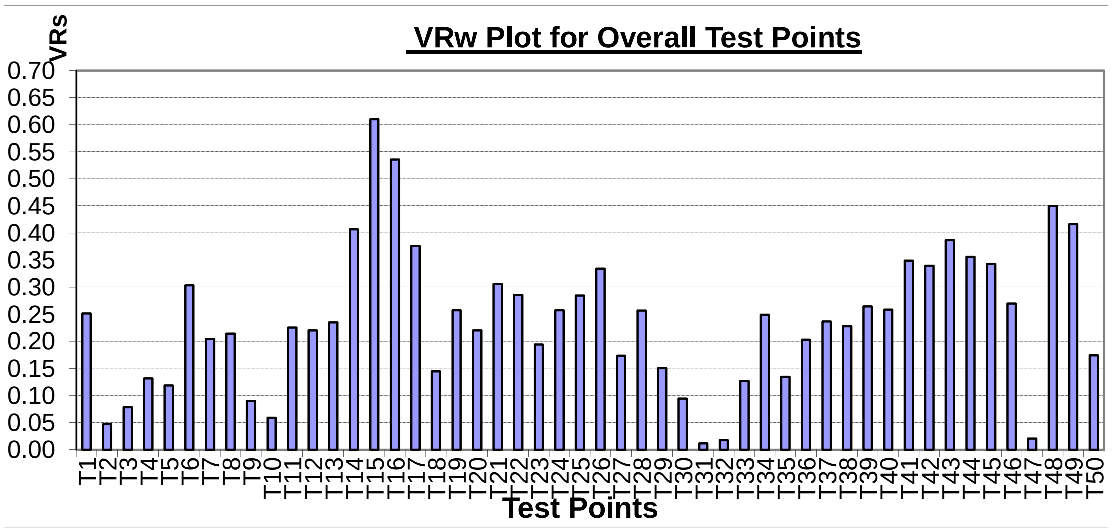


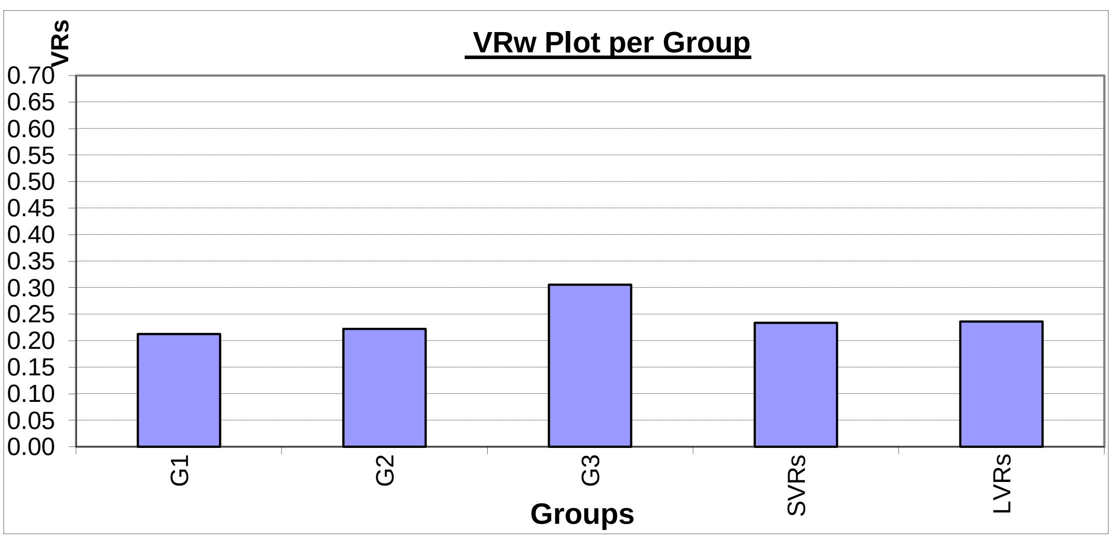




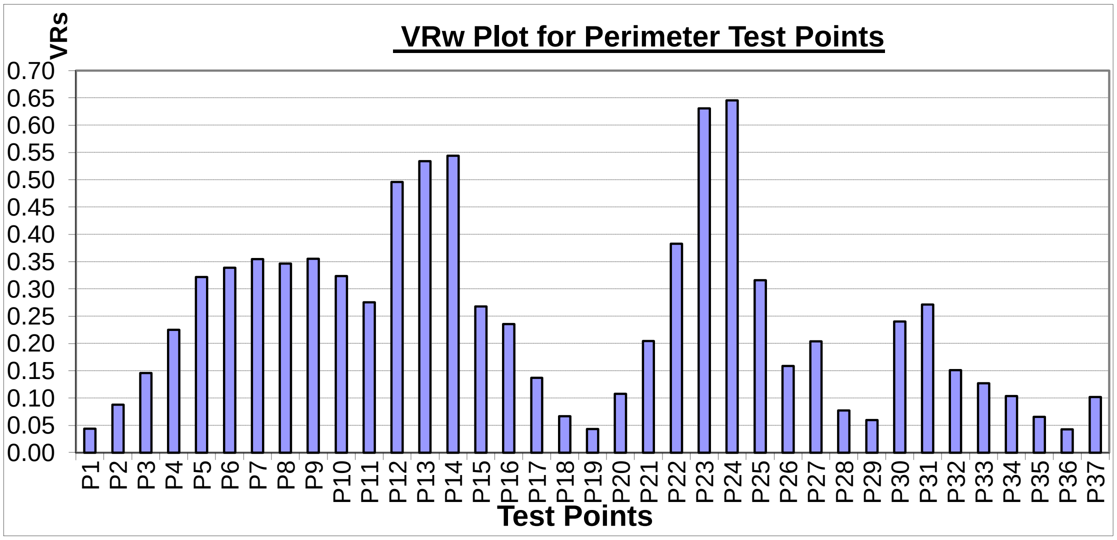
Appendix C - VRs Plot at 2m above Ground in SE Wind Direction (Base)

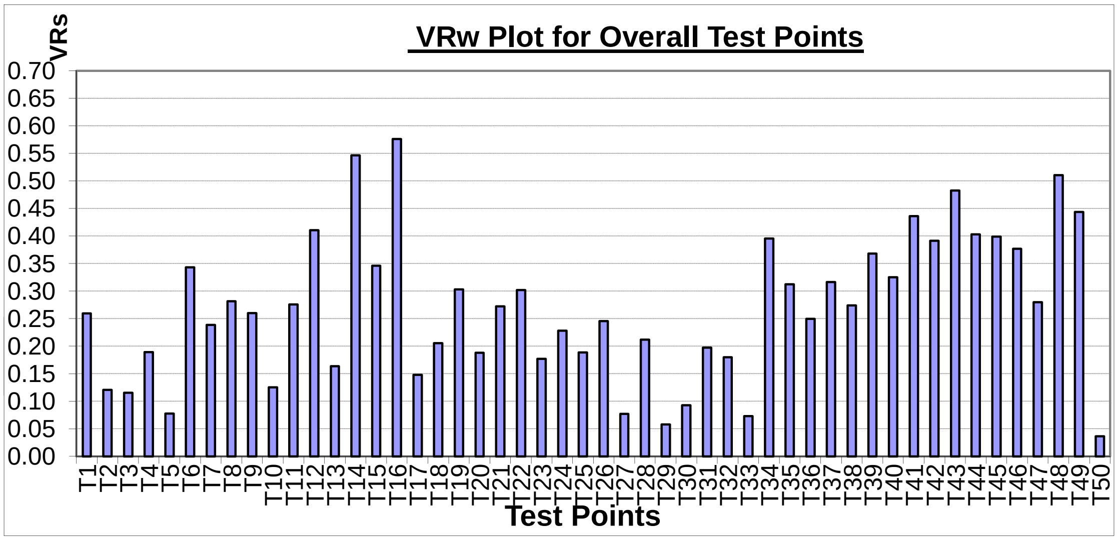


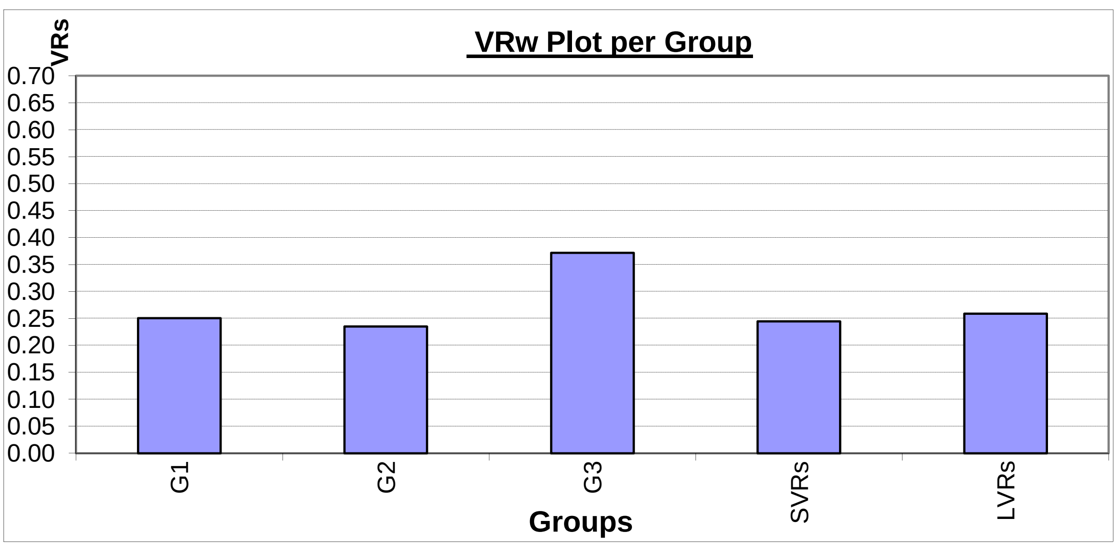




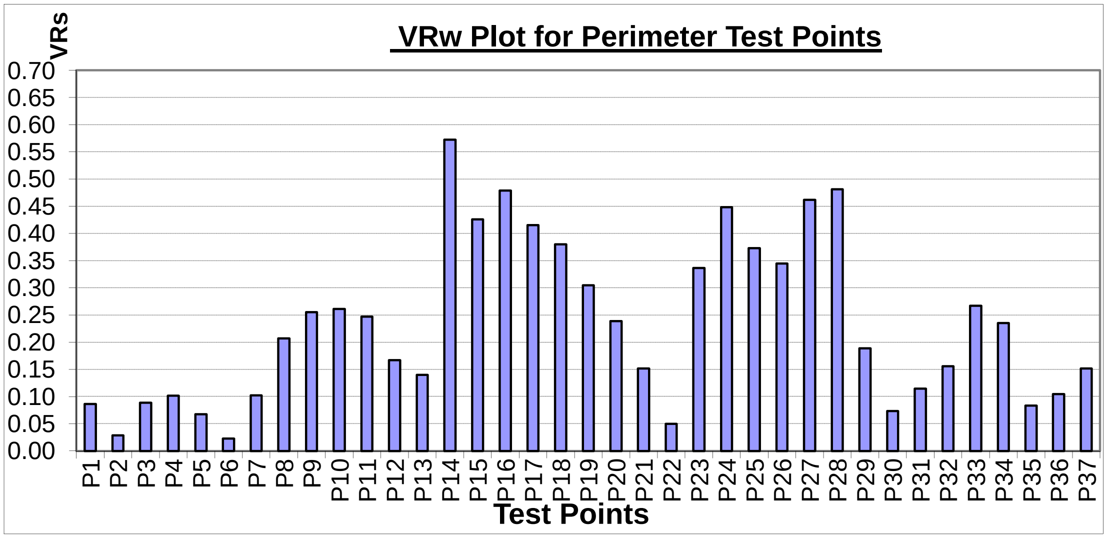
Appendix C - VRs Plot at 2m above Ground in SSE Wind Direction (Base)

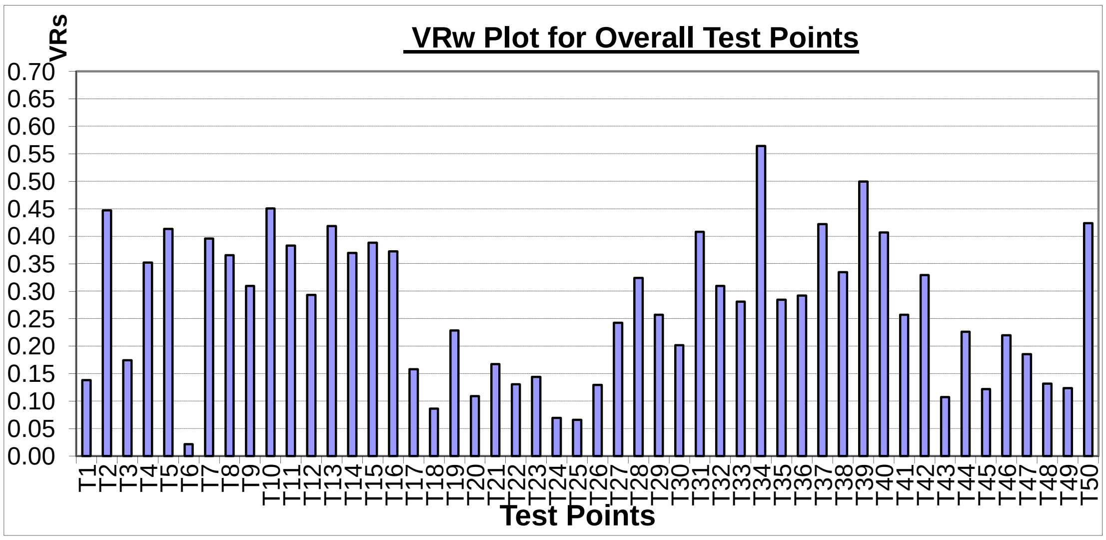


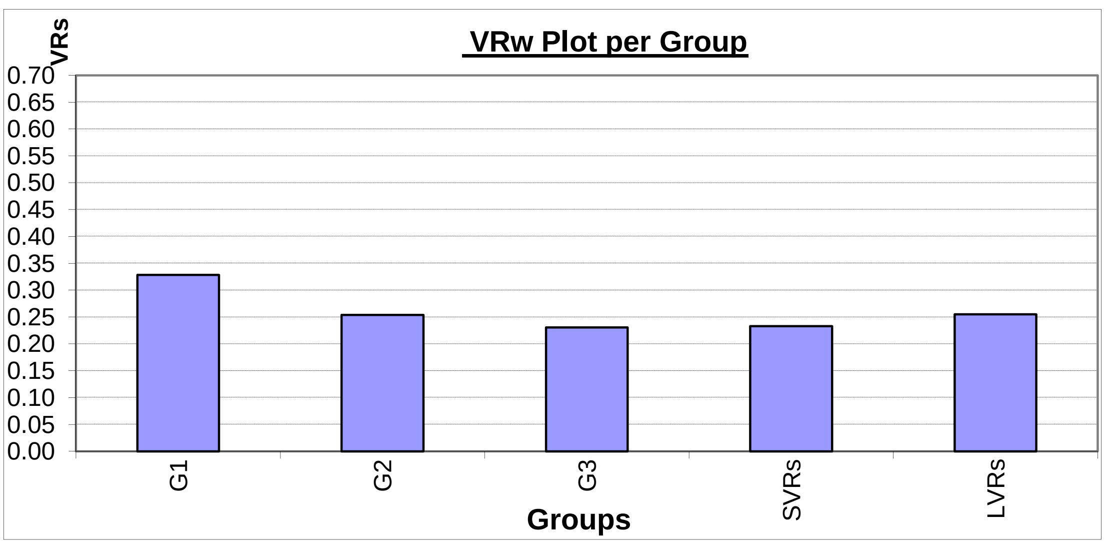




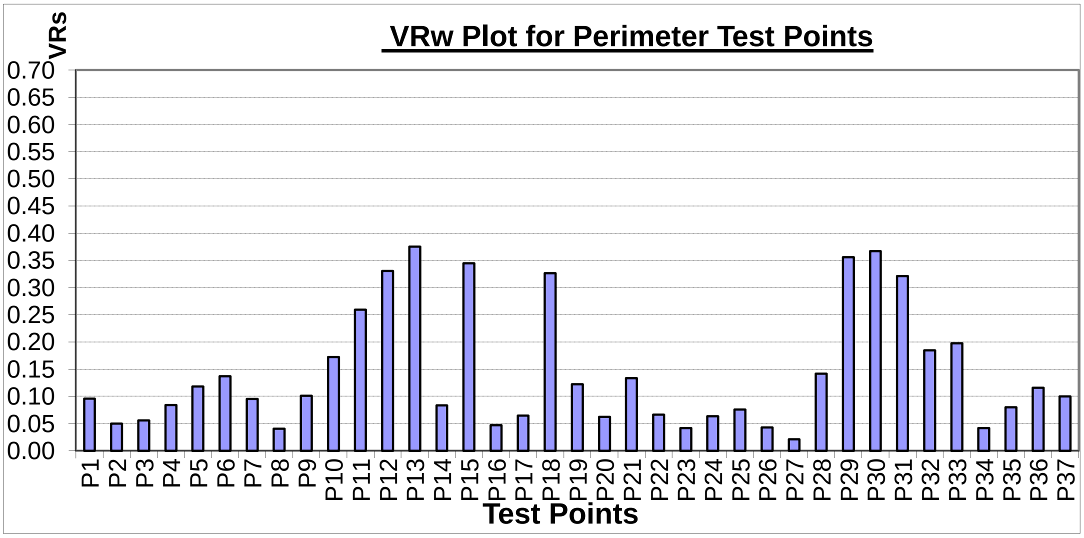
Appendix C - VRs Plot at 2m above Ground in SSW Wind Direction (Base)

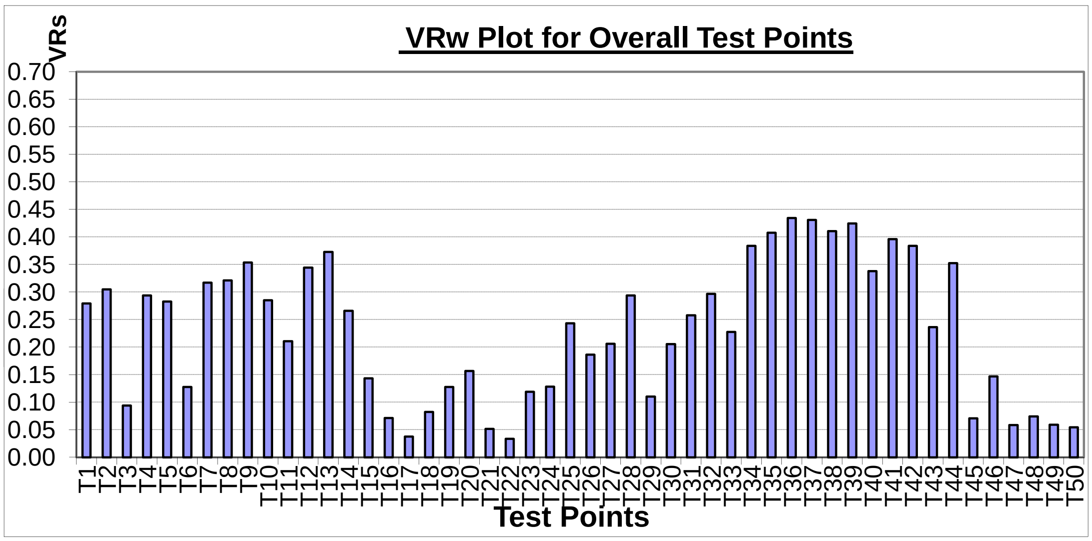


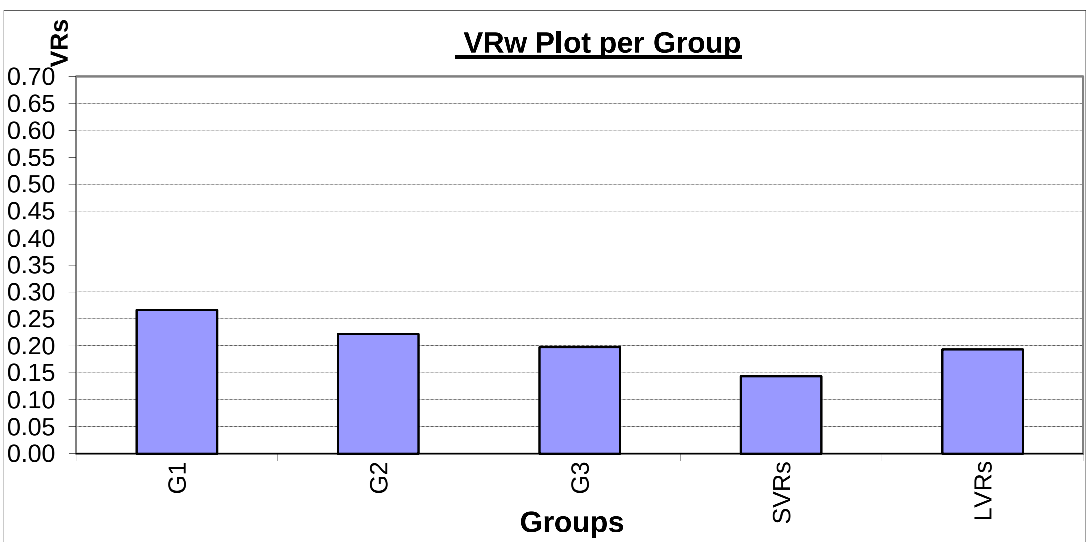




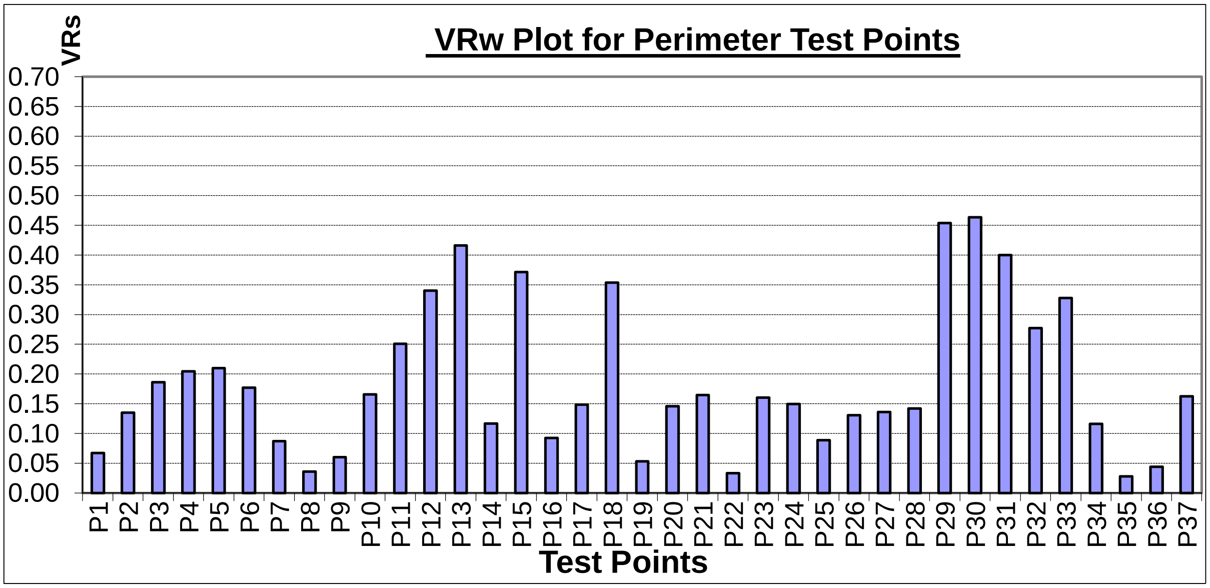
Appendix C - VRs Plot at 2m above Ground in NNE Wind Direction (Proposed)

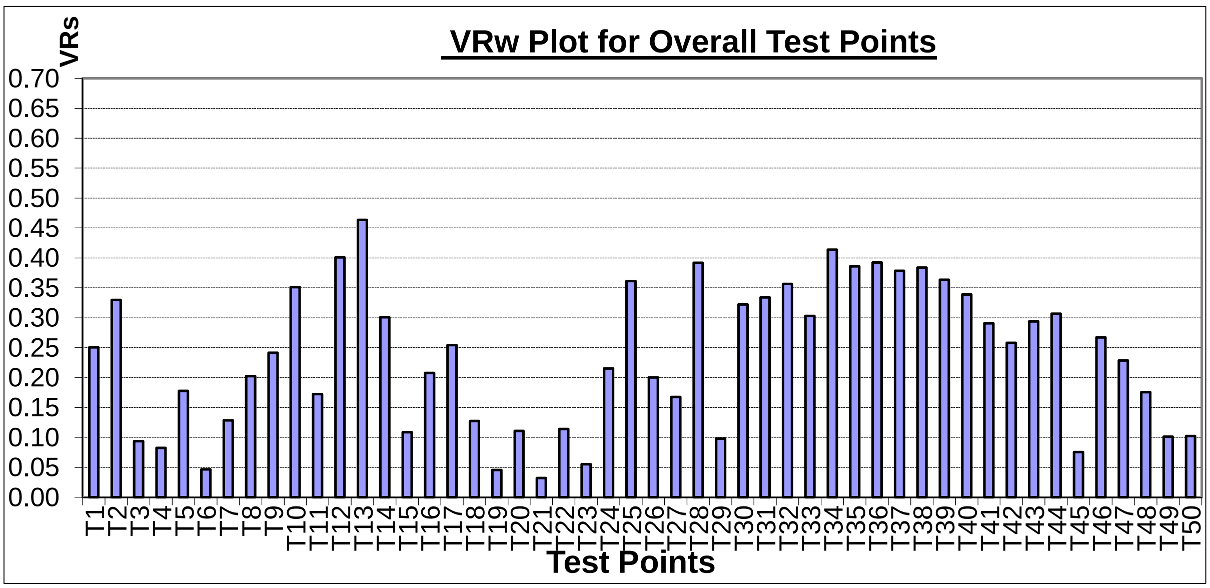


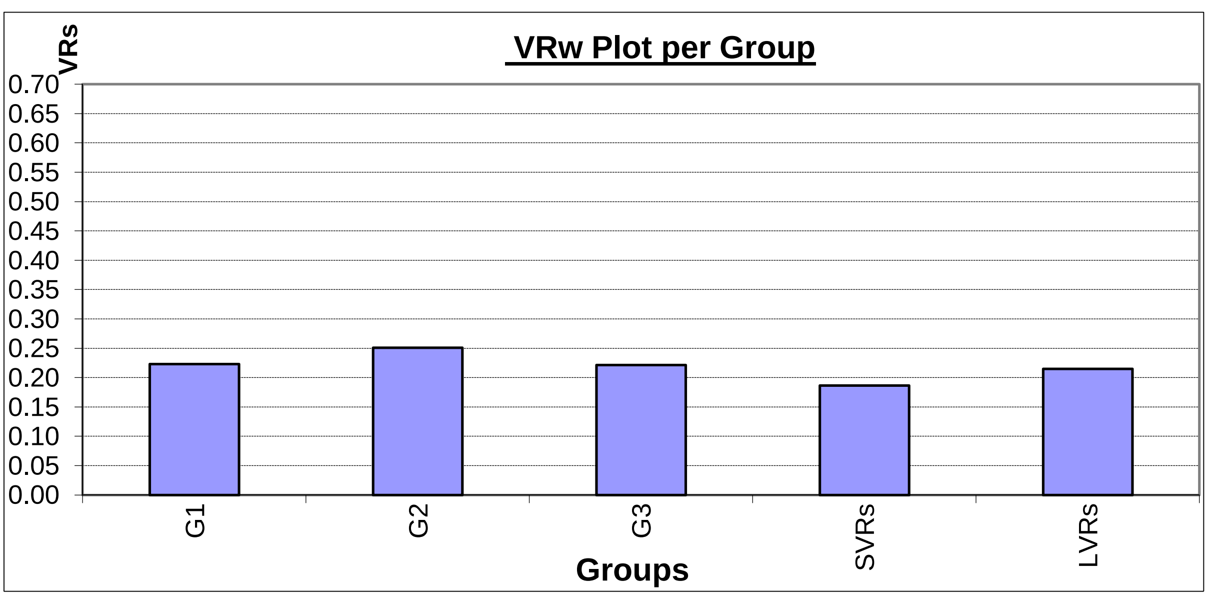




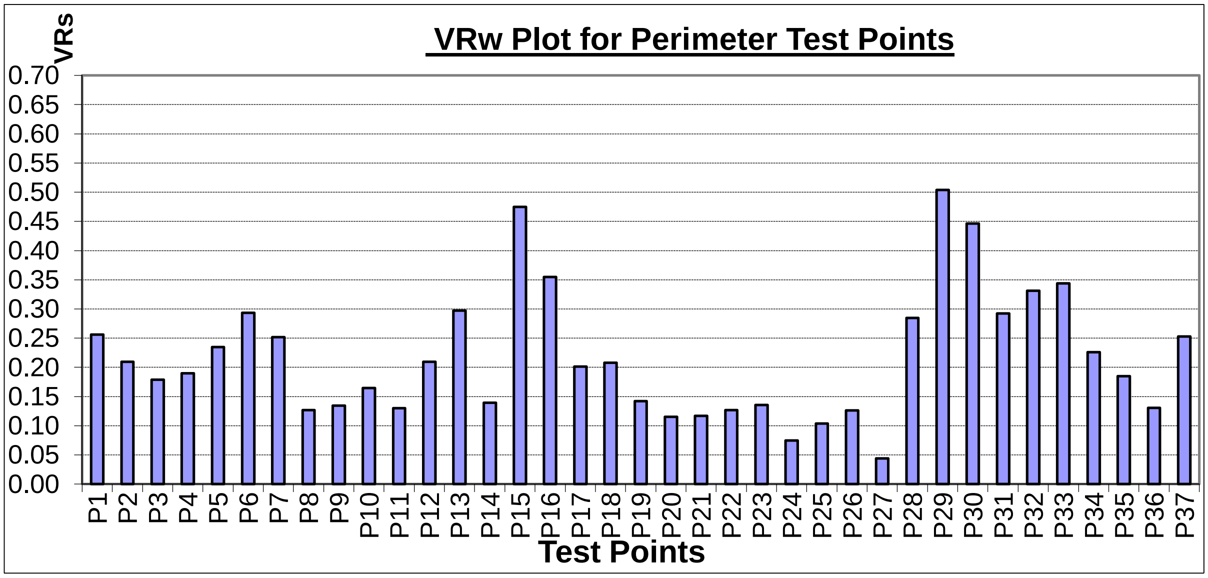
Appendix C - VRs Plot at 2m above Ground in NE Wind Direction (Proposed)

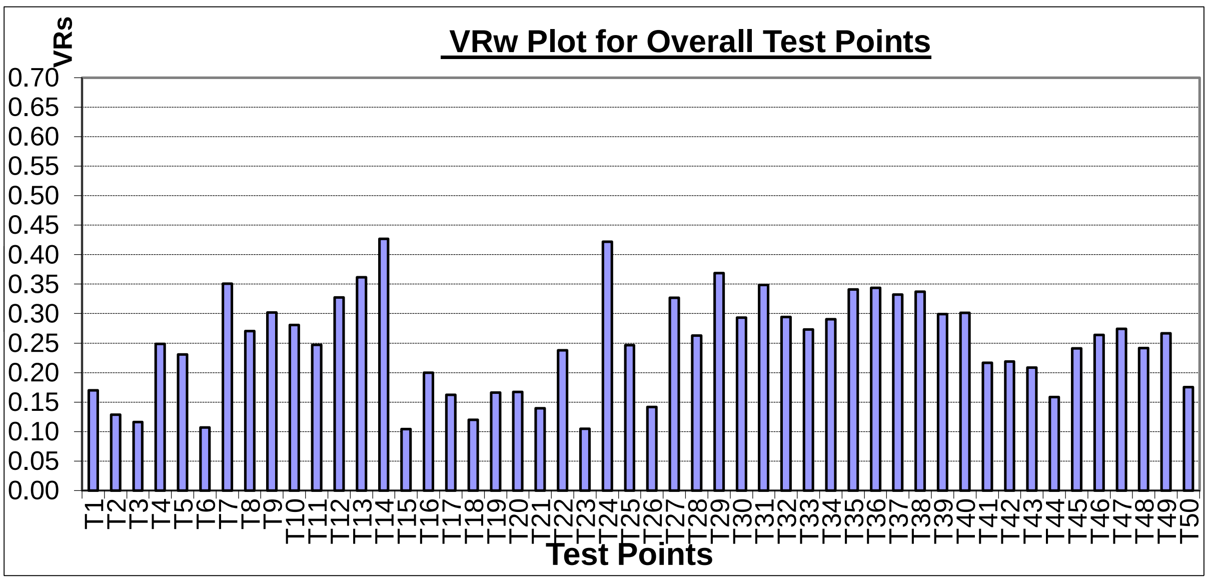


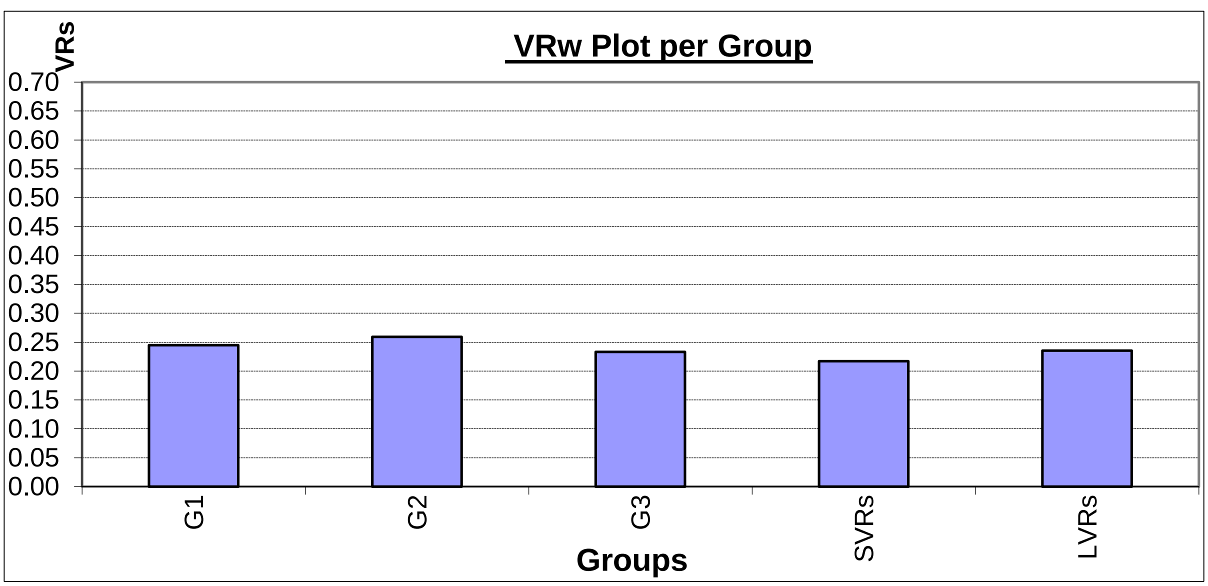




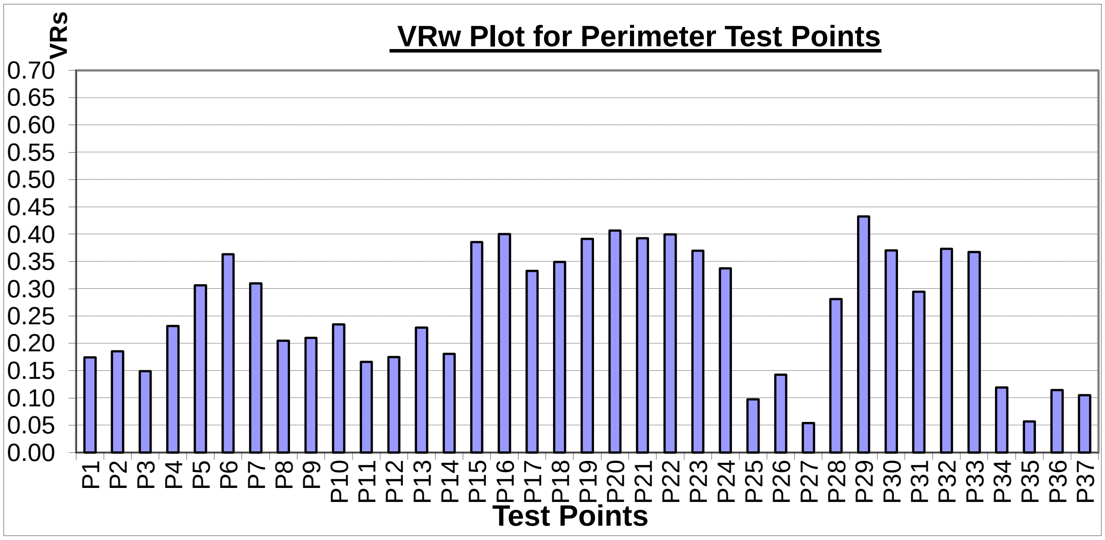
Appendix C - VRs Plot at 2m above Ground in ENE Wind Direction (Proposed)

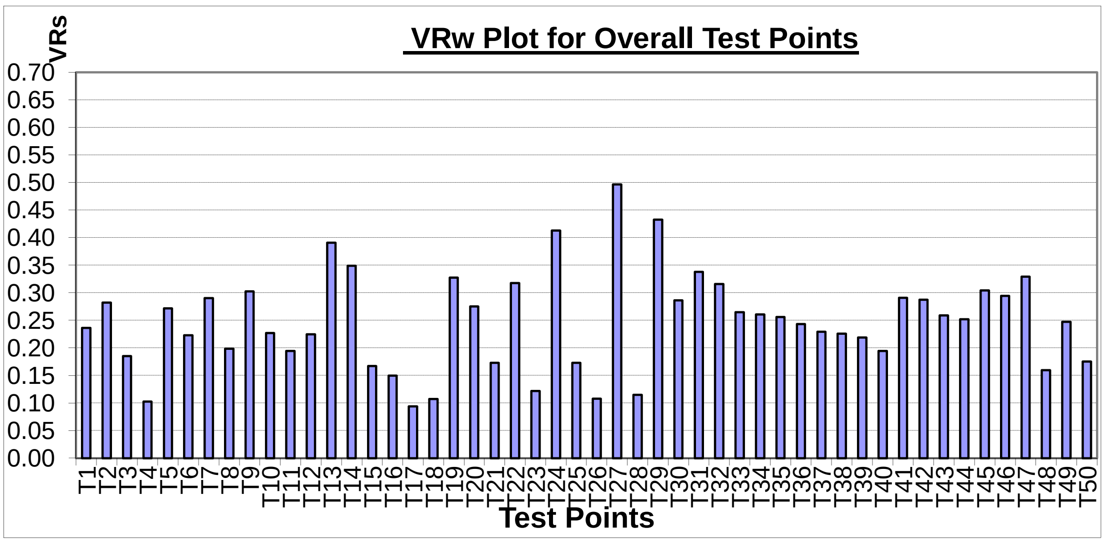


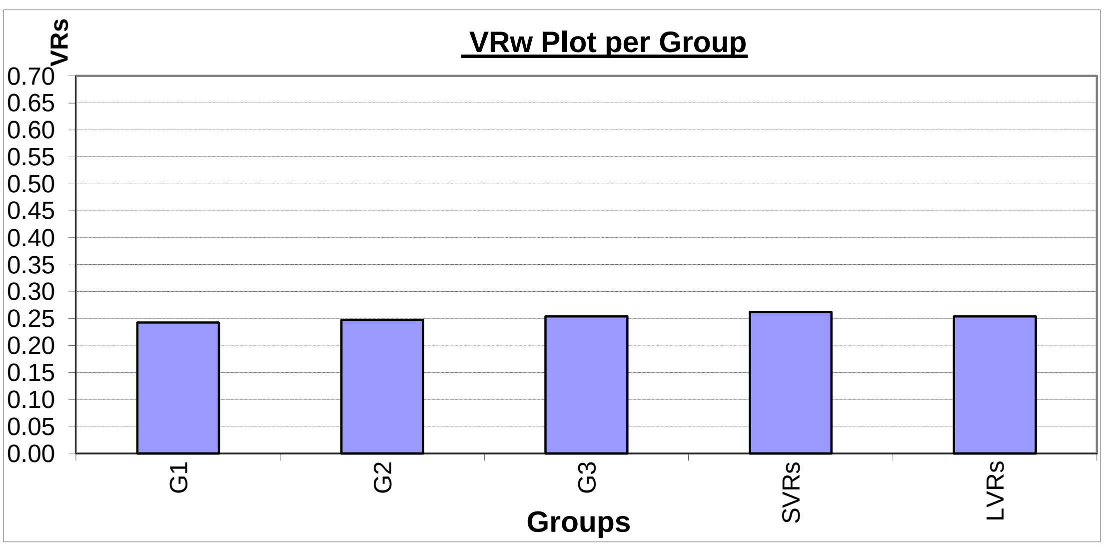




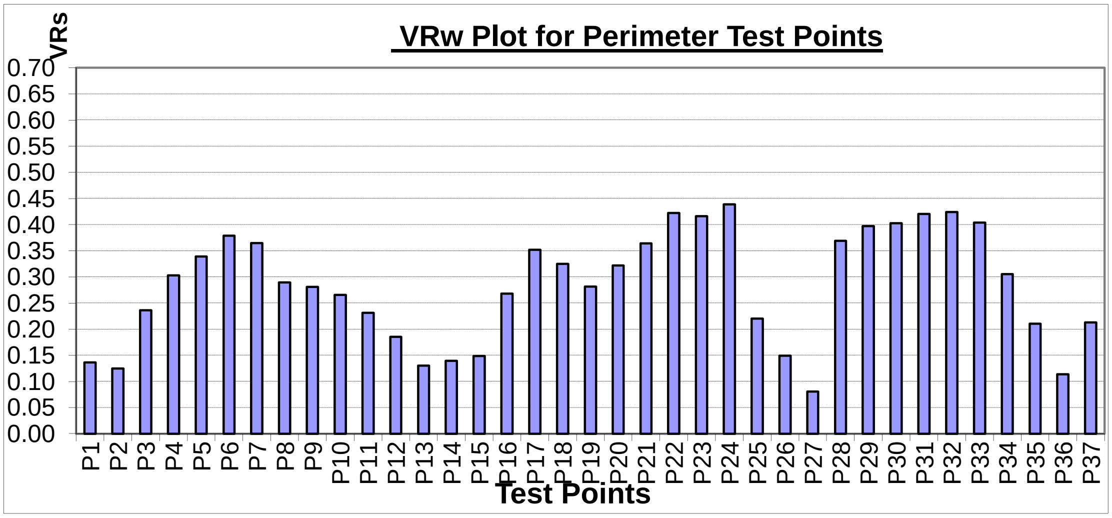
Appendix C - VRs Plot at 2m above Ground in E Wind Direction (Proposed).

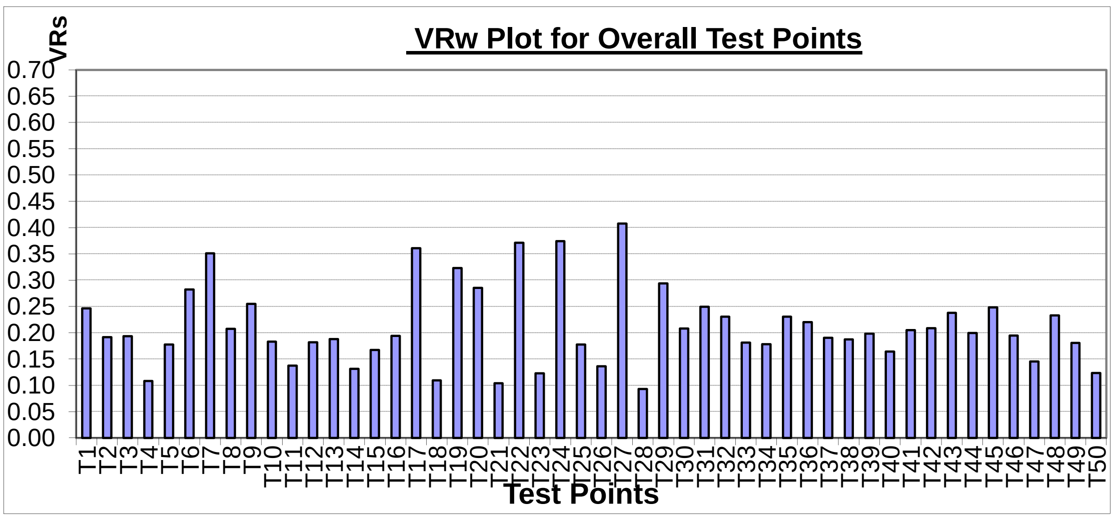


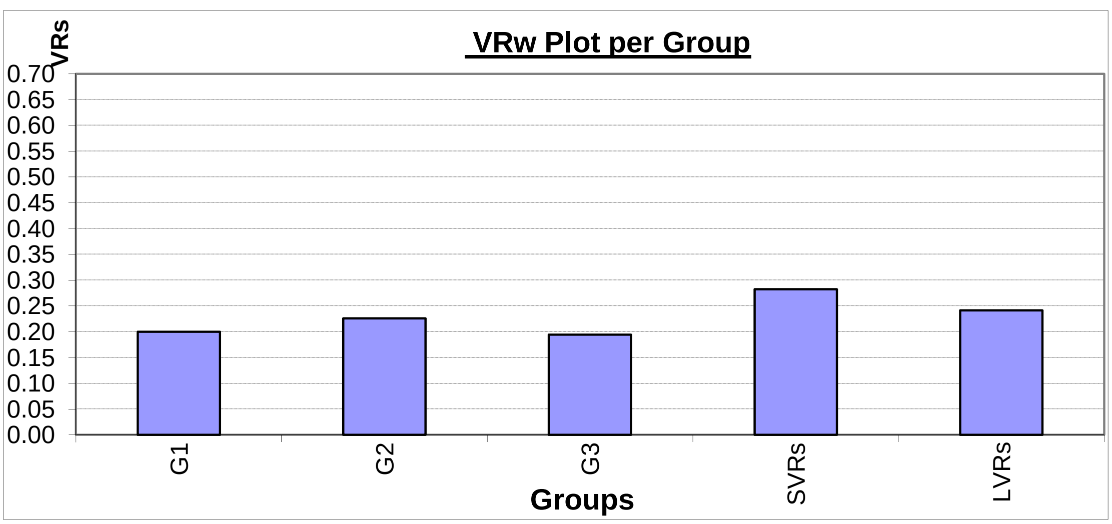




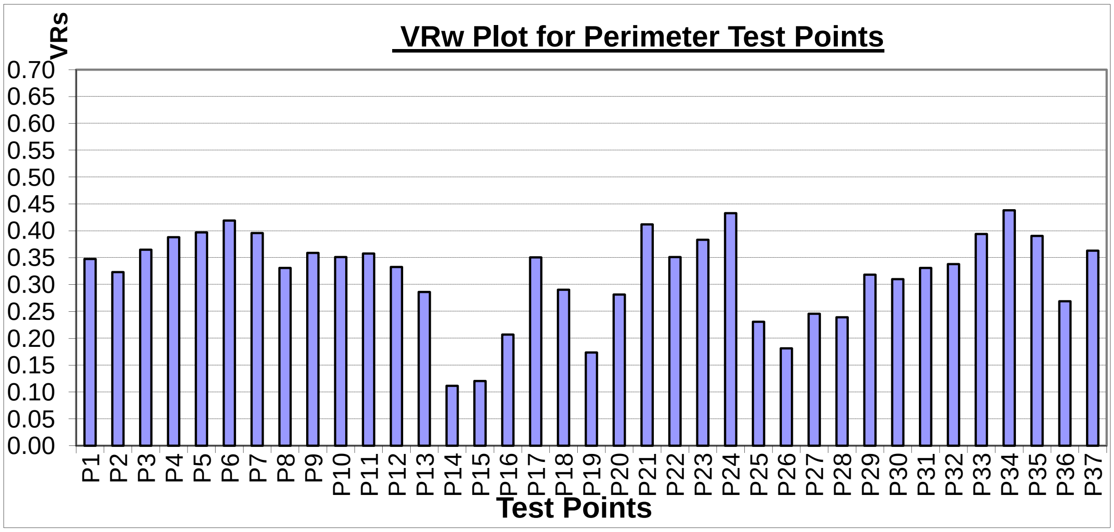
Appendix C - VRs Plot at 2m above Ground in ESE Wind Direction (Proposed)

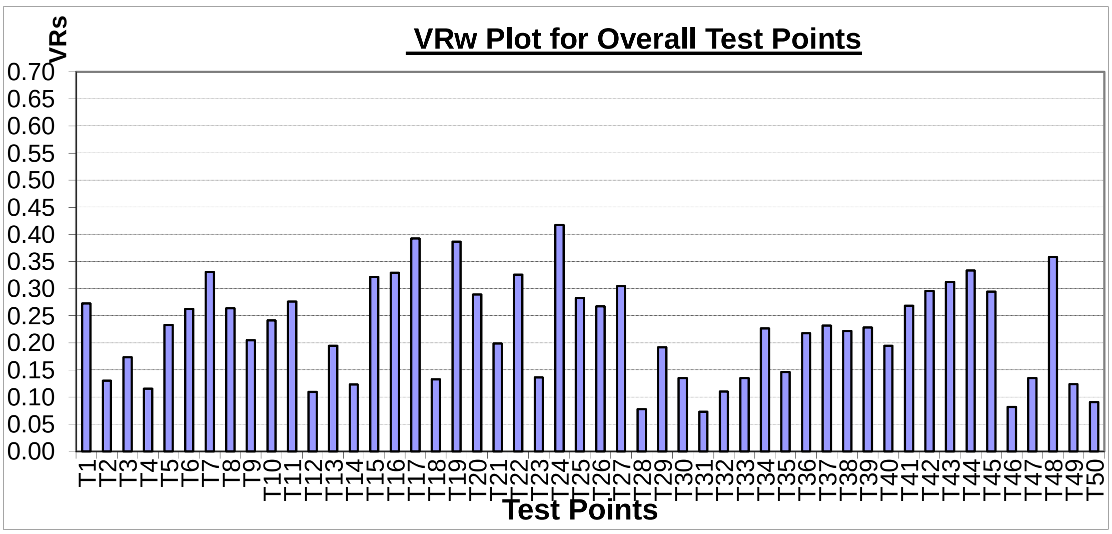


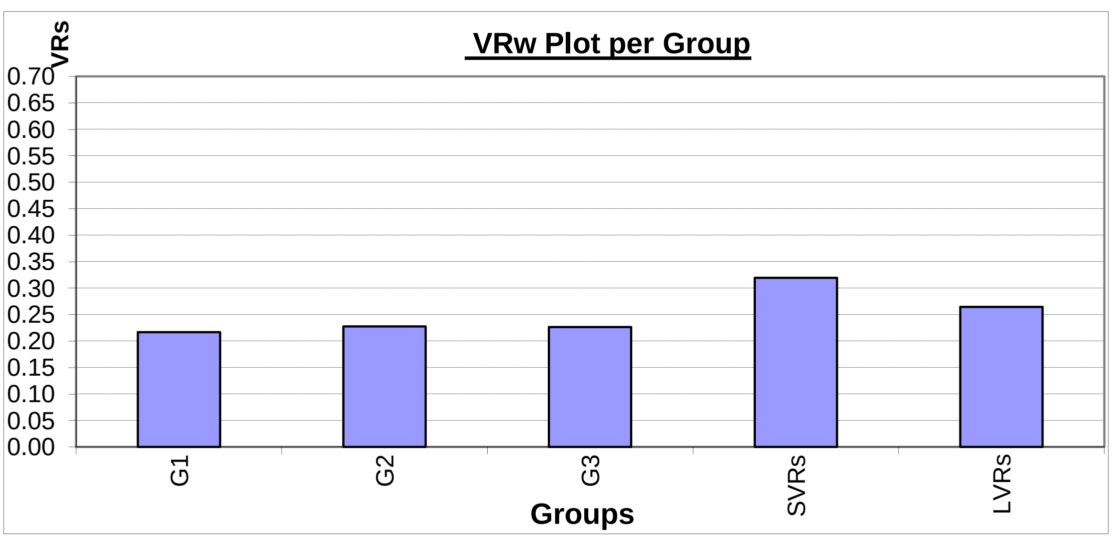




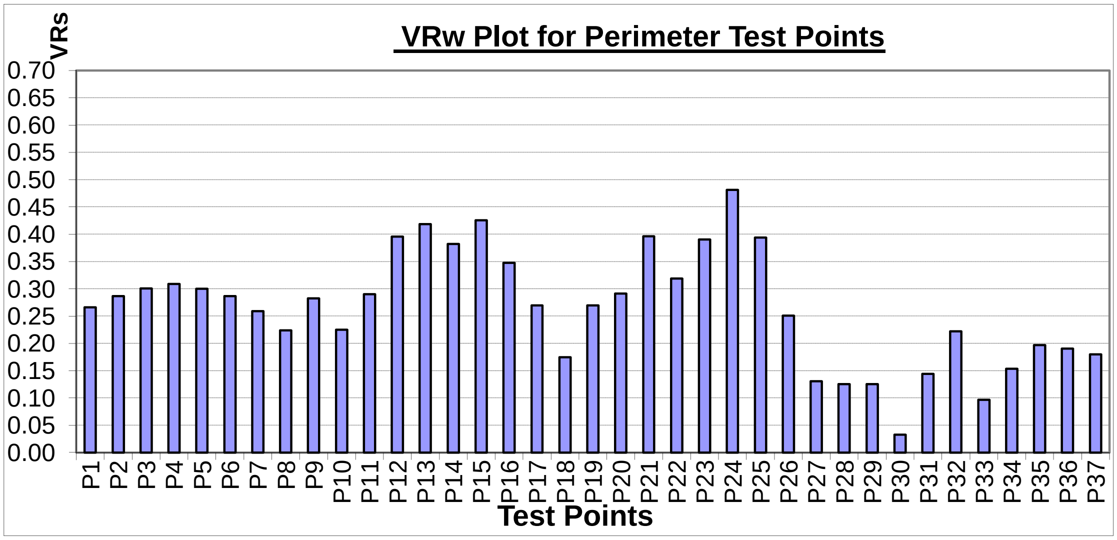
Appendix C - VRs Plot at 2m above Ground in SE Wind Direction (Proposed)

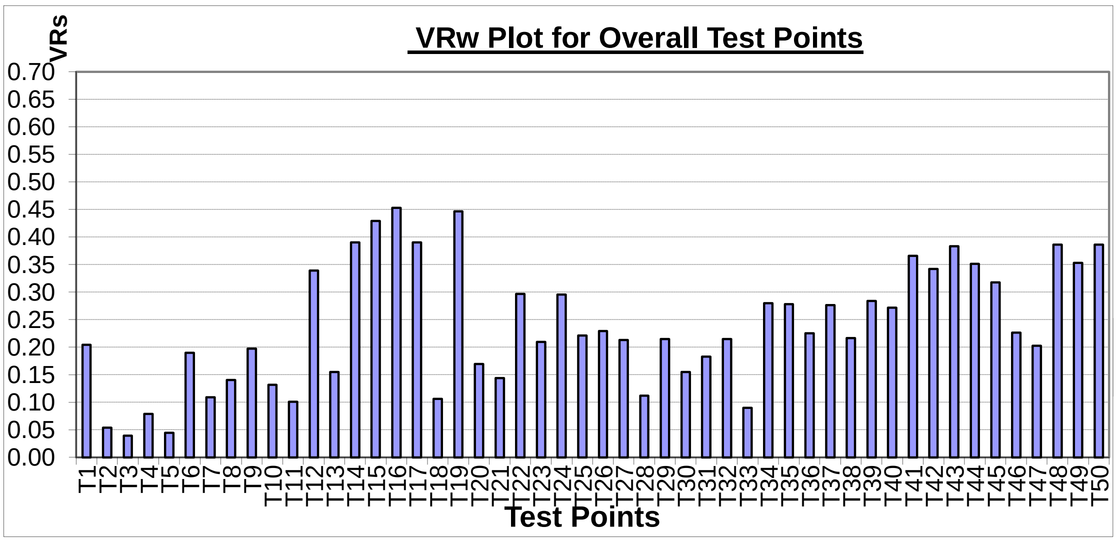


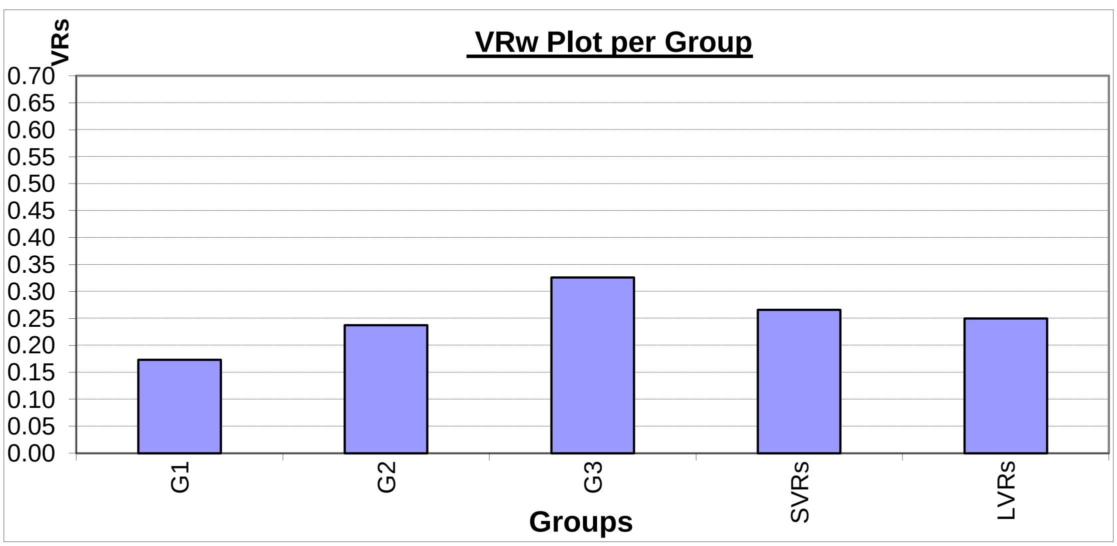




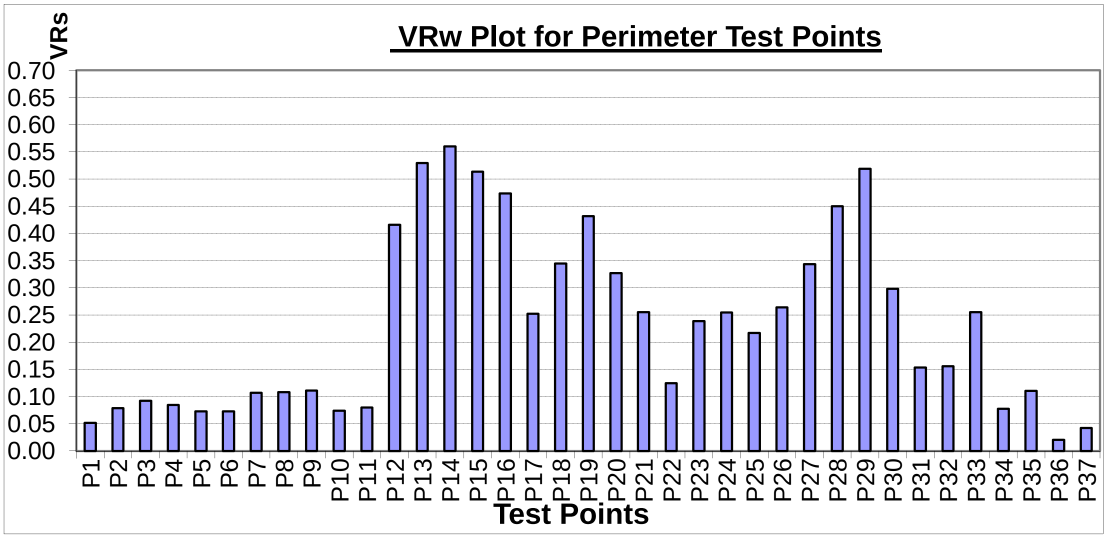
Appendix C - VRs Plot at 2m above Ground in SSE Wind Direction (Proposed)

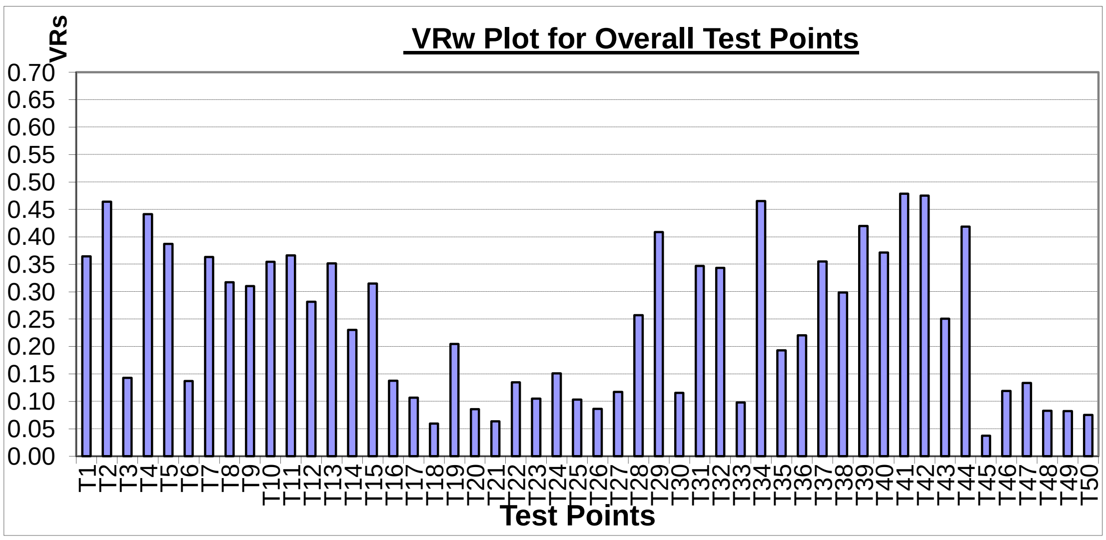


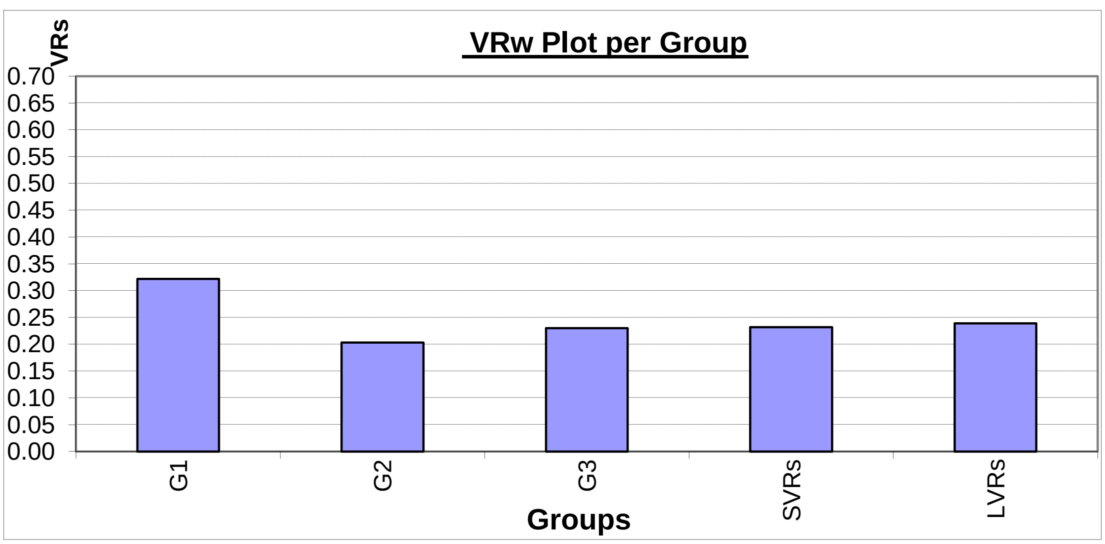




Appendix C - VRs Plot at 2m above Ground in SSW Wind Direction (Proposed)

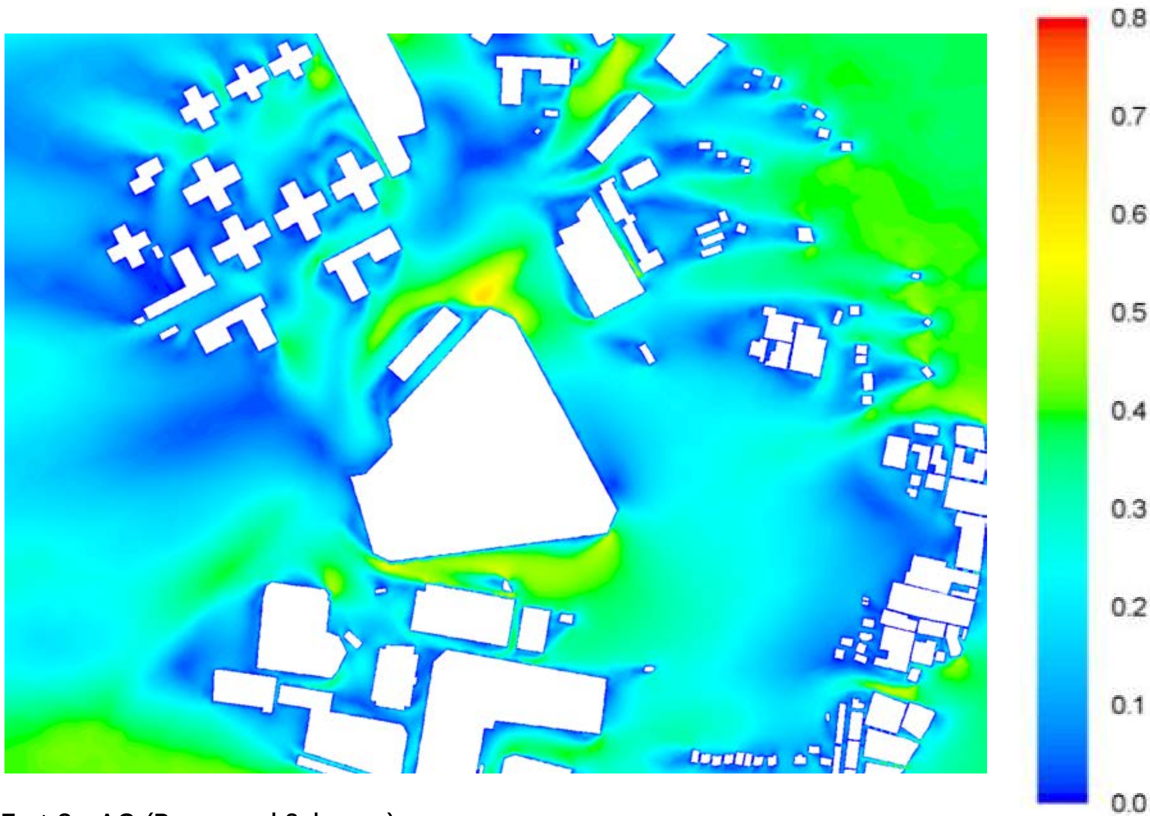




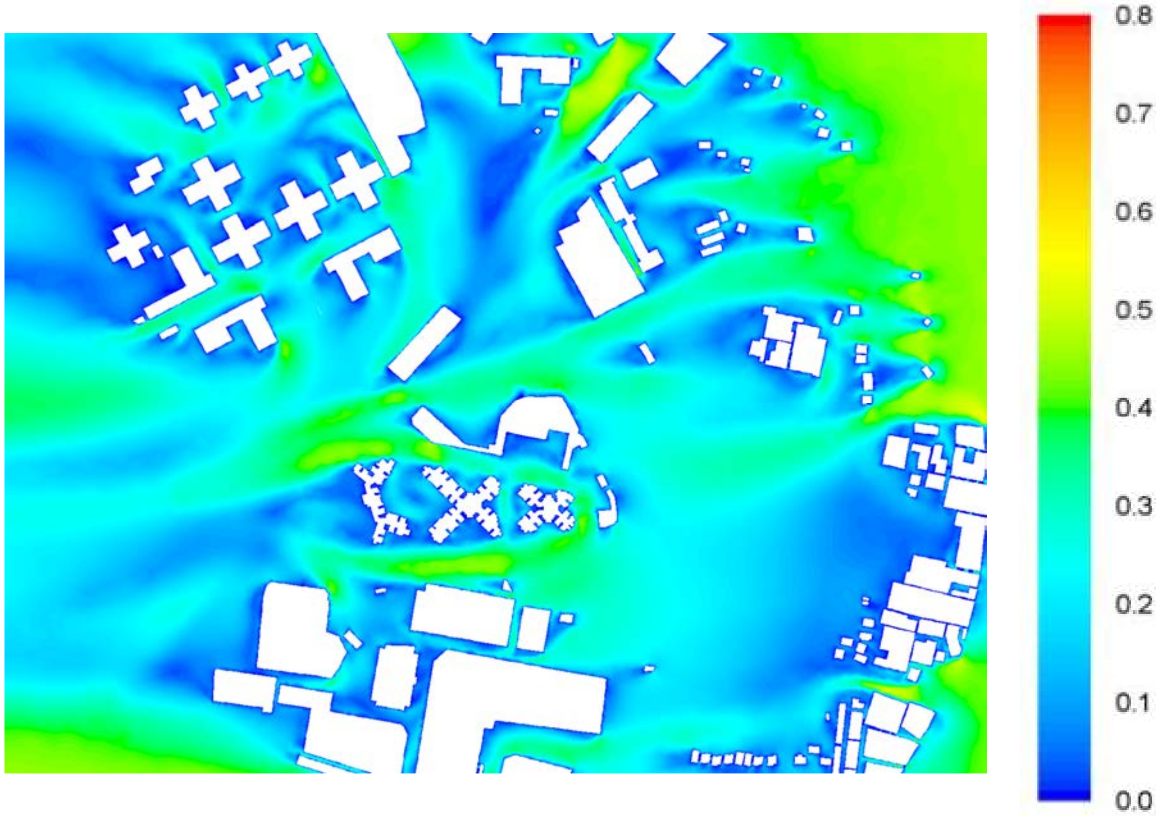


Appendix D – Wind Velocity Ratio Contour Plots

E at 2mAG (Base Scheme)

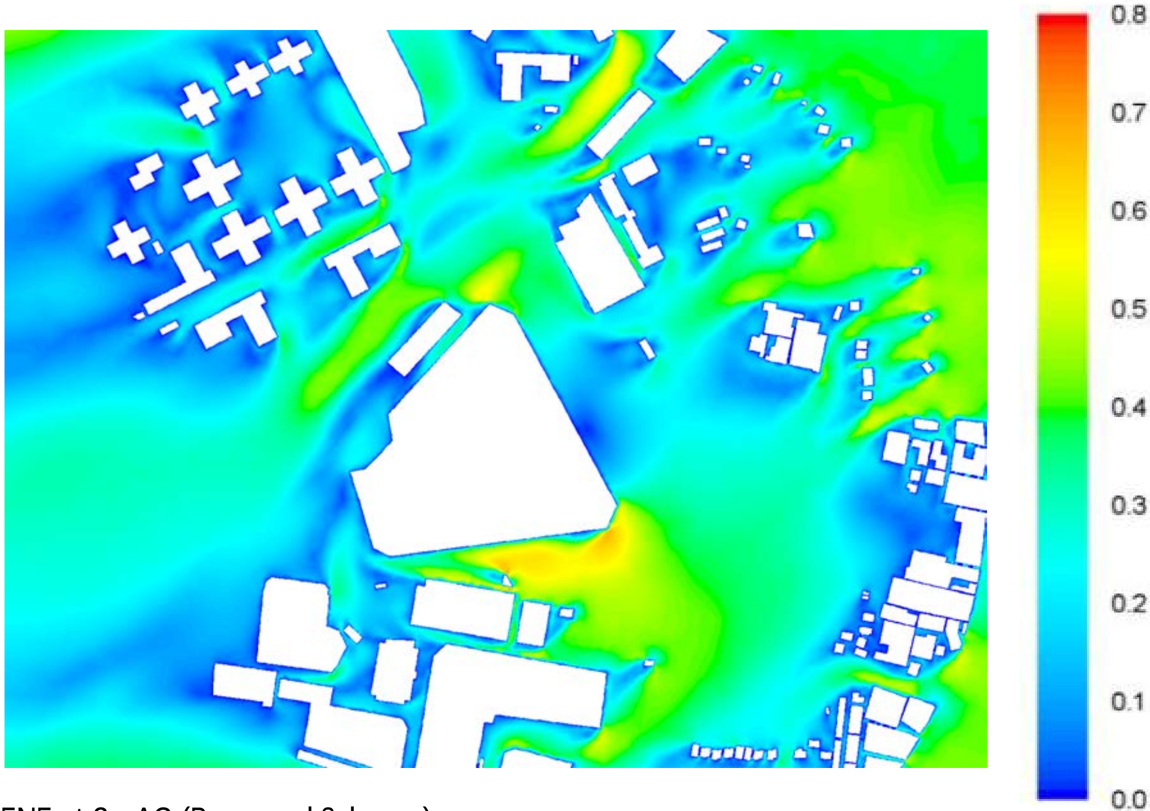


E at 2mAG (Proposed Scheme)

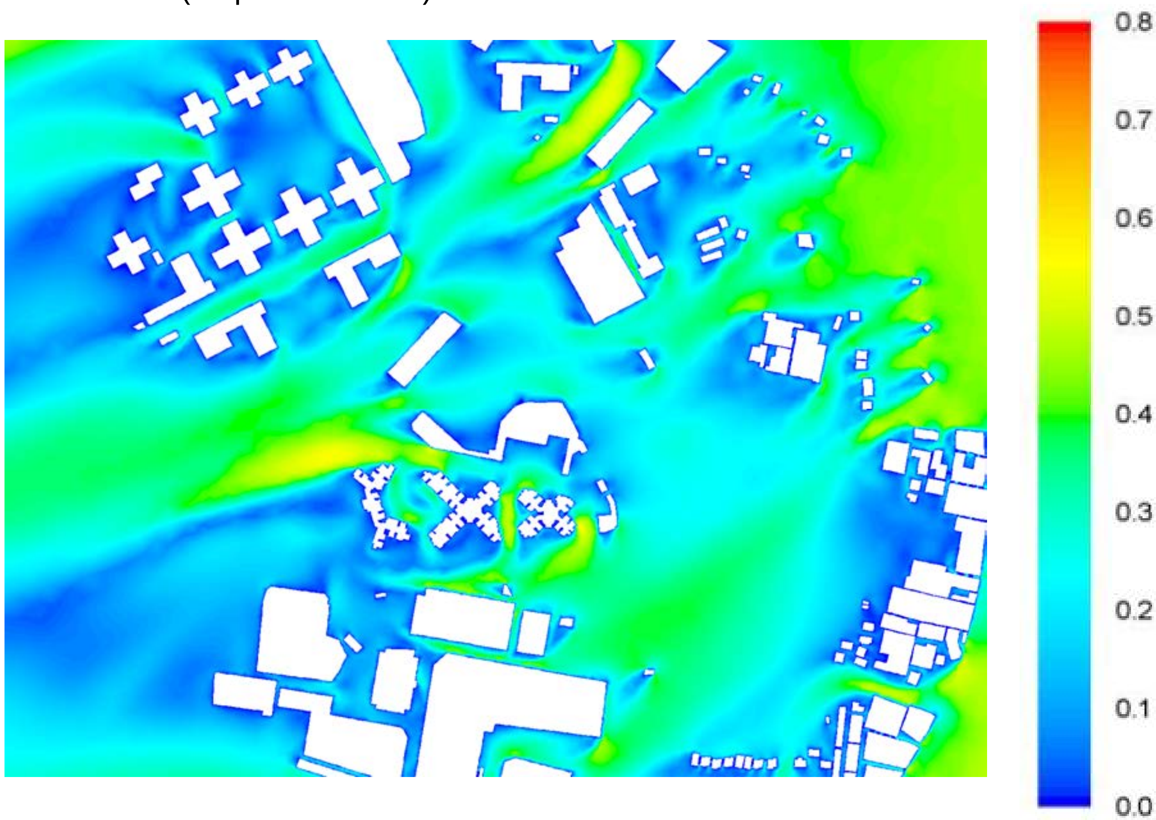


Appendix D – Wind Velocity Ratio Contour Plots

ENE at 2mAG (Base Scheme)

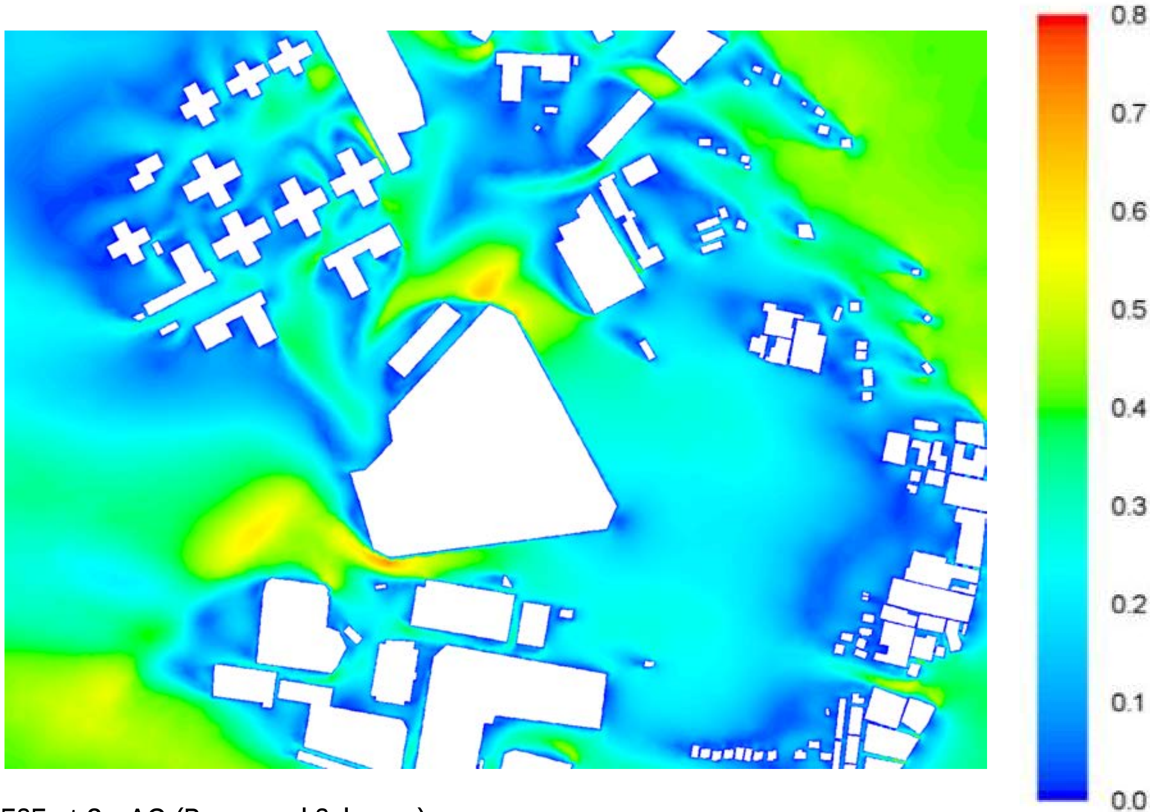


ENE at 2mAG (Proposed Scheme)

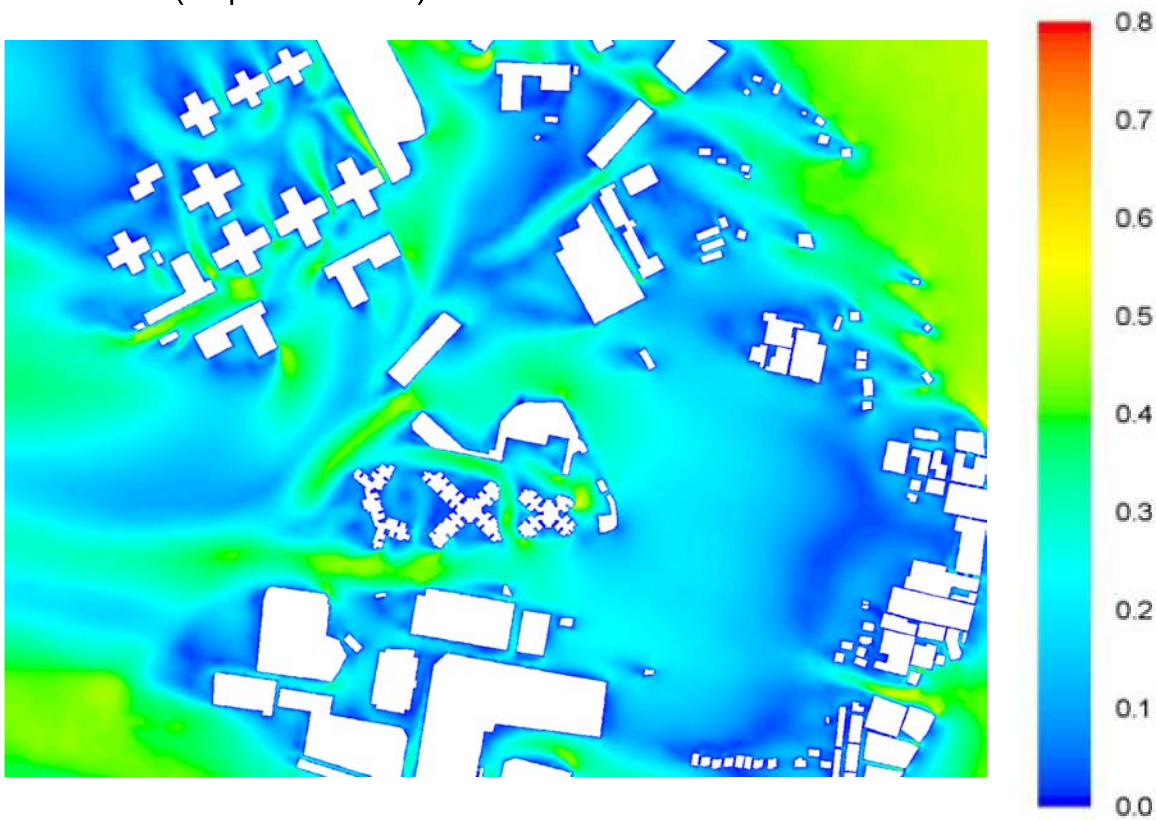


Appendix D – Wind Velocity Ratio Contour Plots

ESE at 2mAG (Base Scheme)

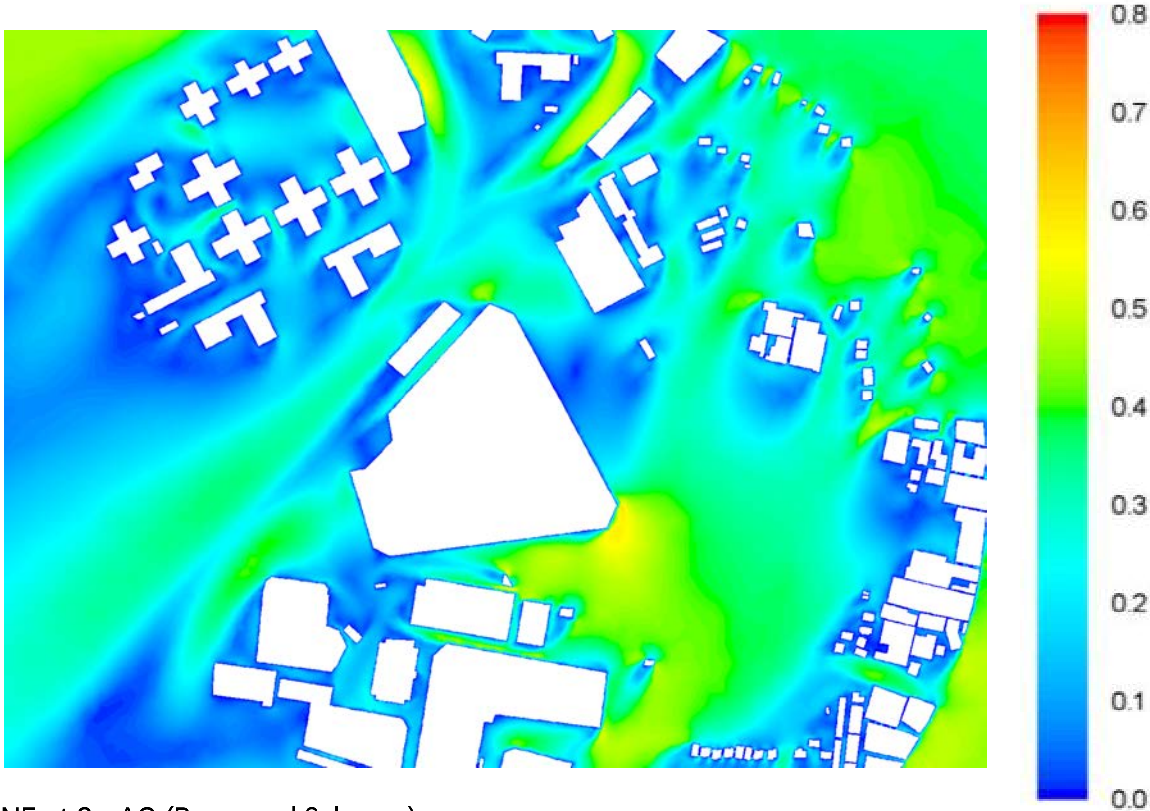


ESE at 2mAG (Proposed Scheme)

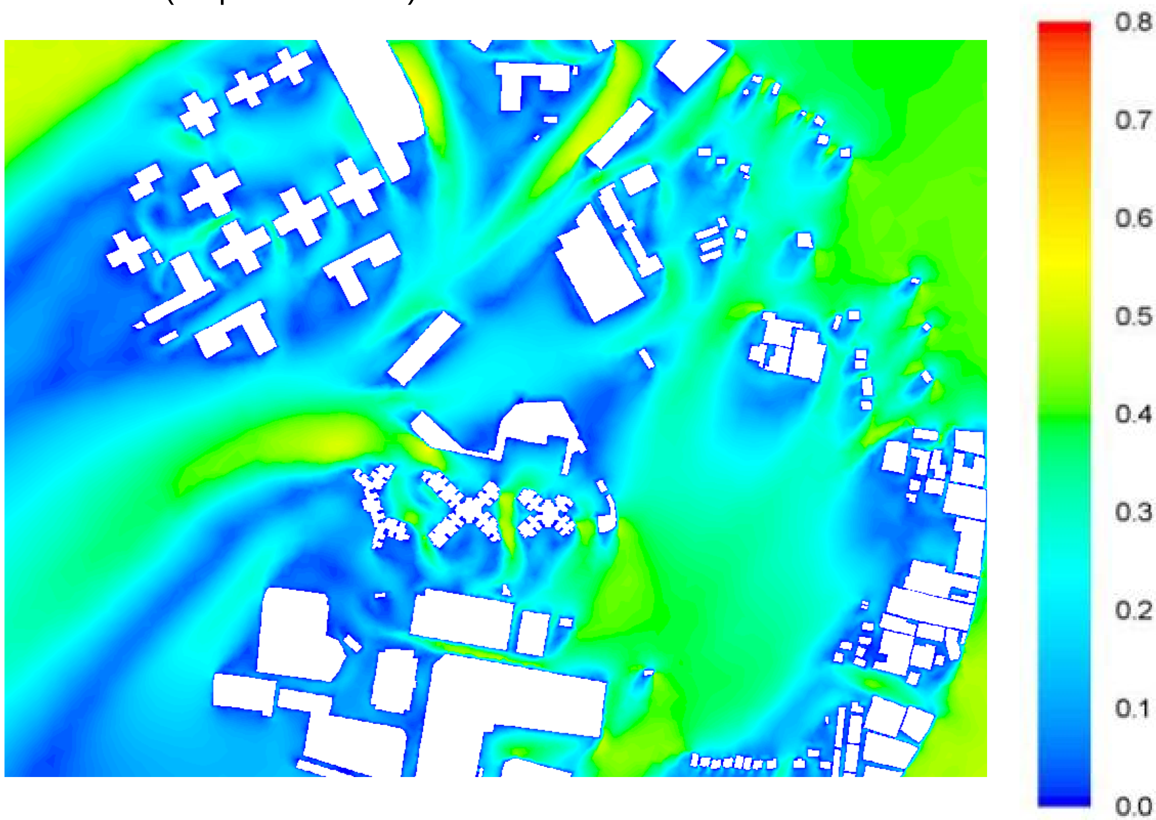


Appendix D – Wind Velocity Ratio Contour Plots

NE at 2mAG (Base Scheme)

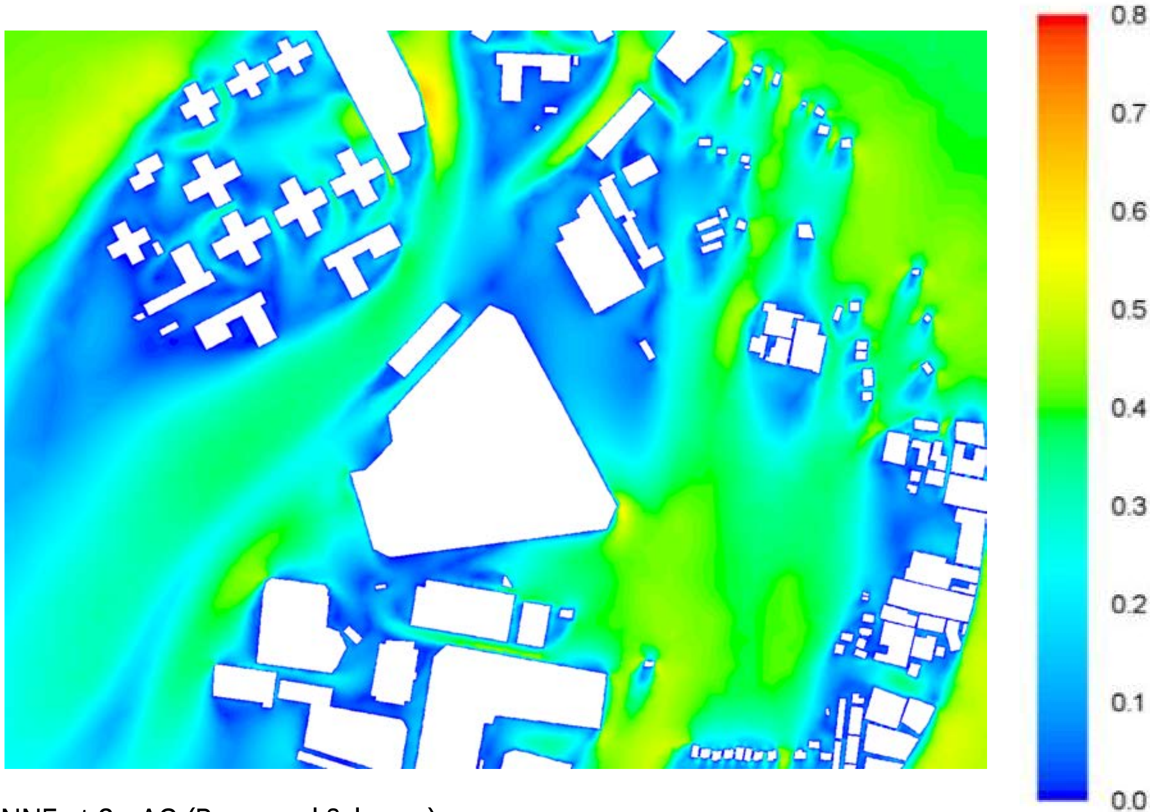


NE at 2mAG (Proposed Scheme)

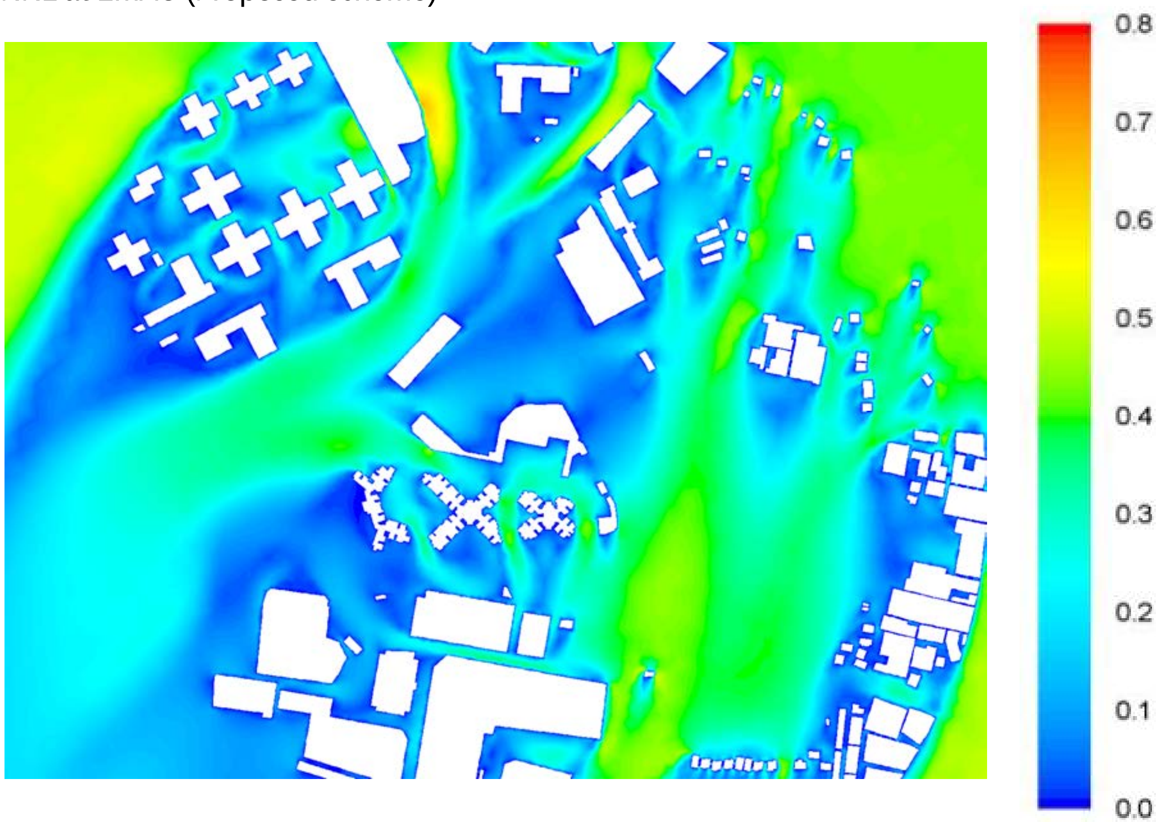


Appendix D – Wind Velocity Ratio Contour Plots

NNE at 2mAG (Base Scheme)

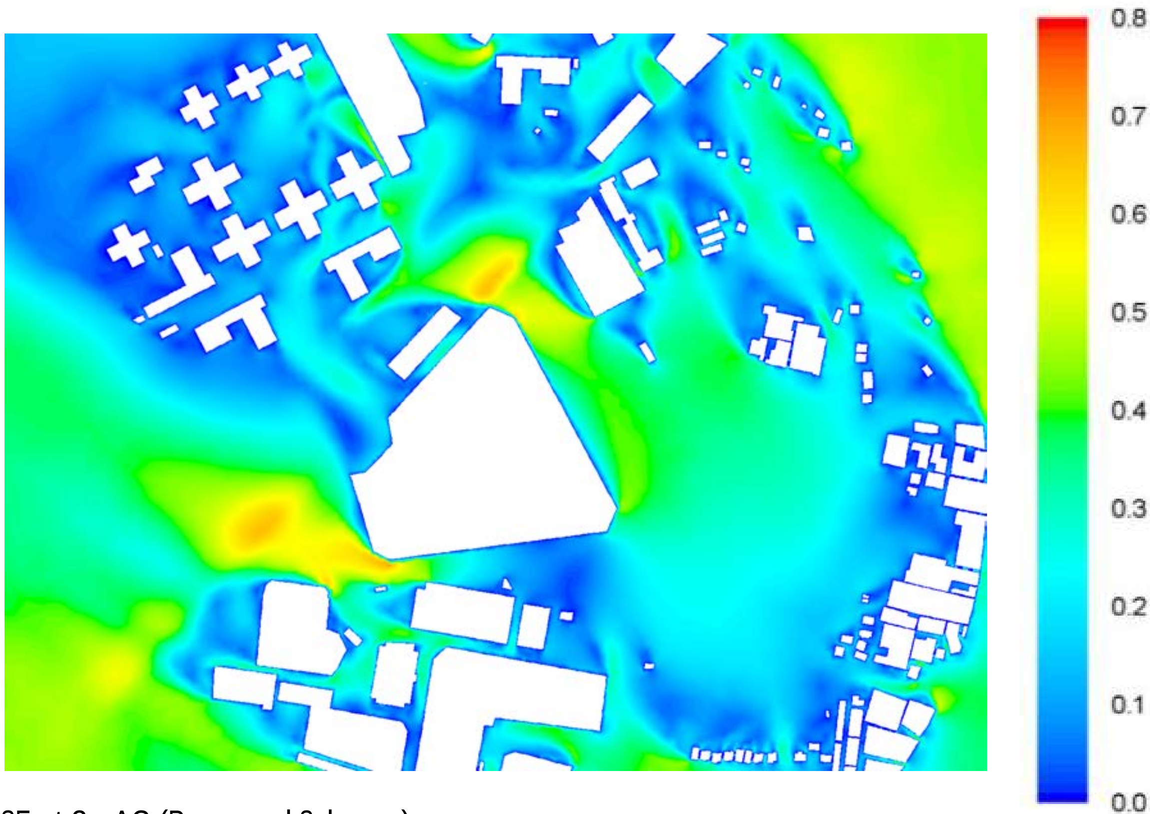


NNE at 2mAG (Proposed Scheme)

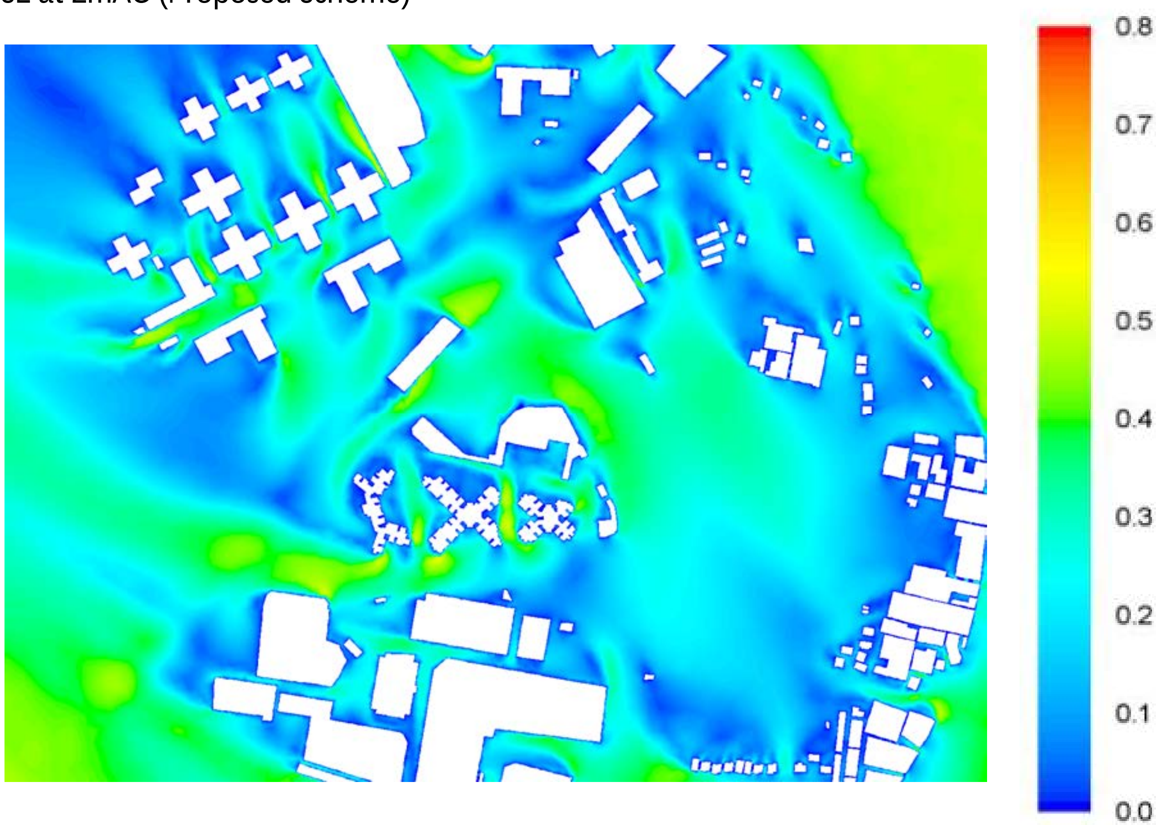


Appendix D – Wind Velocity Ratio Contour Plots

SE at 2mAG (Base Scheme)

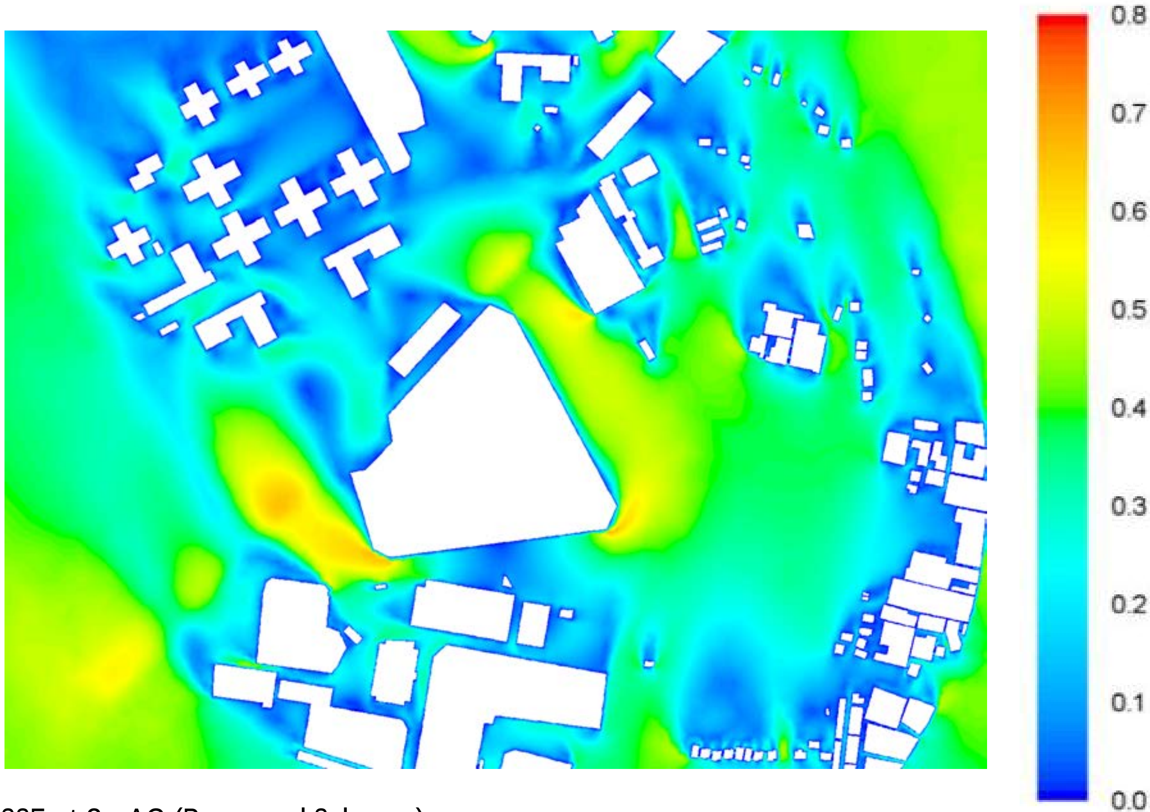


SE at 2mAG (Proposed Scheme)

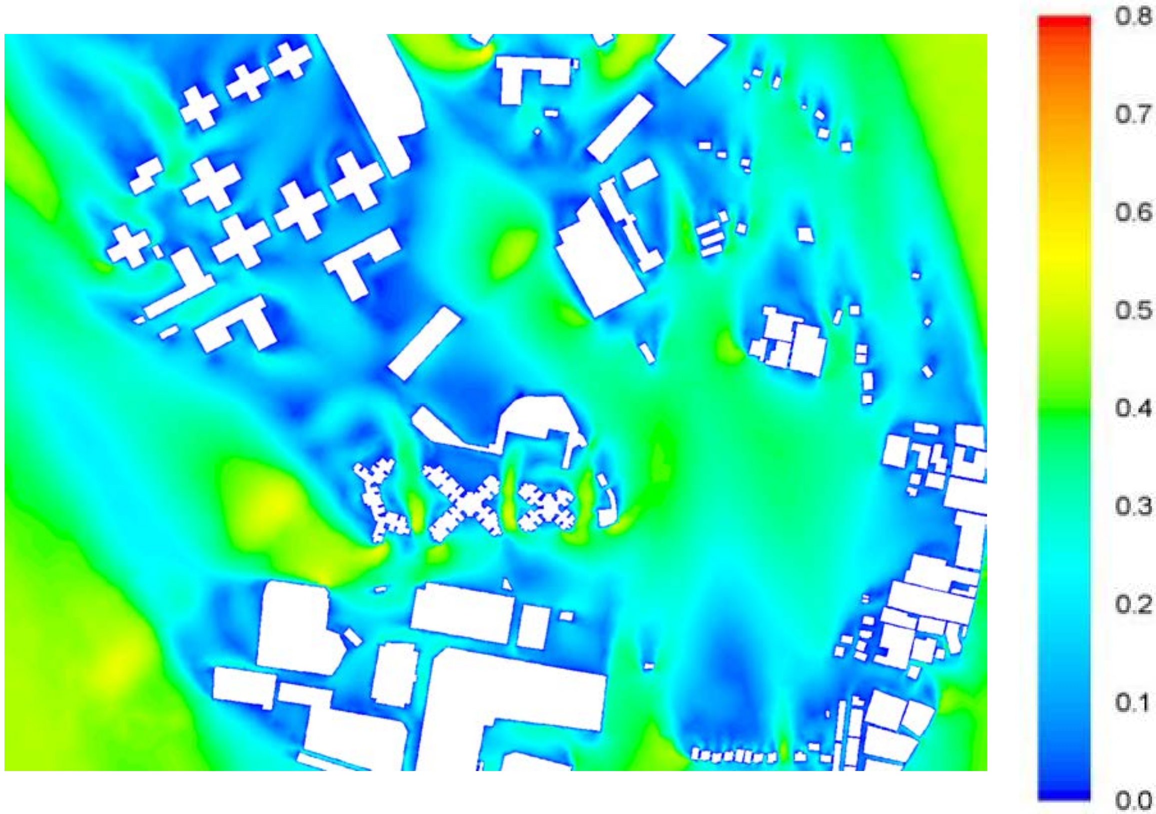


Appendix D – Wind Velocity Ratio Contour Plots

SSE at 2mAG (Base Scheme)

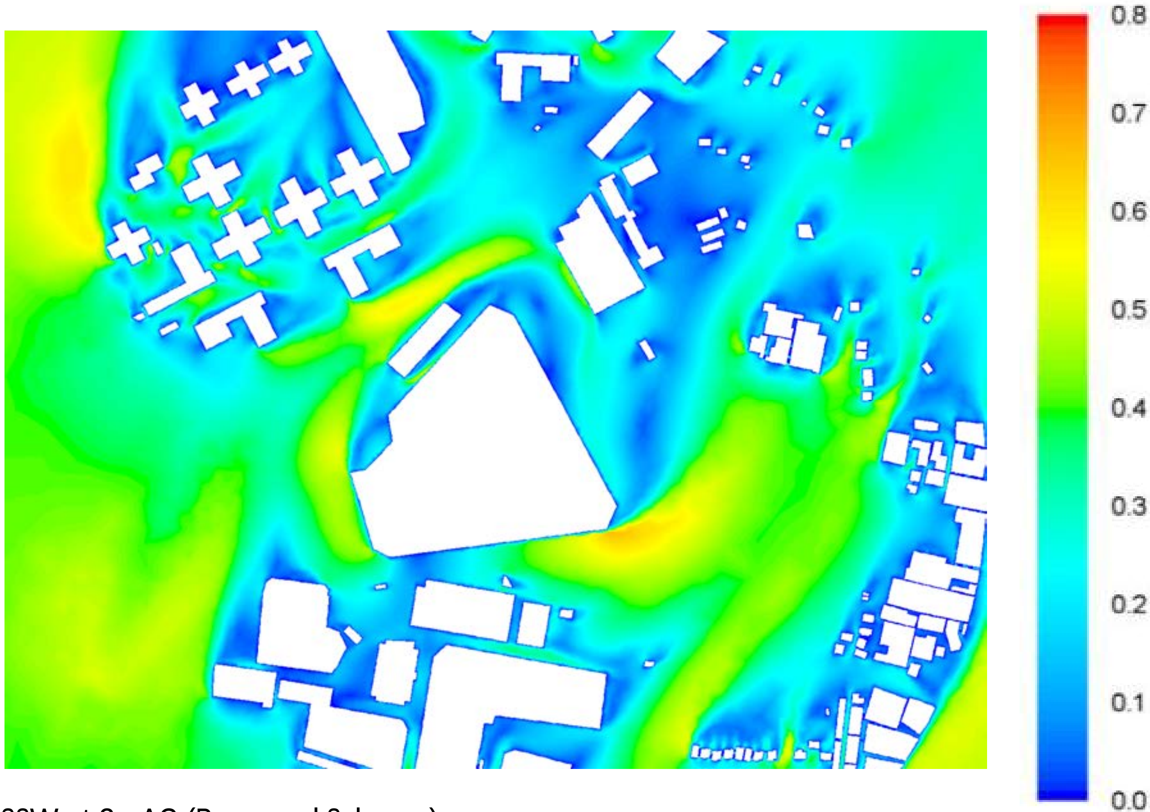


SSE at 2mAG (Proposed Scheme)

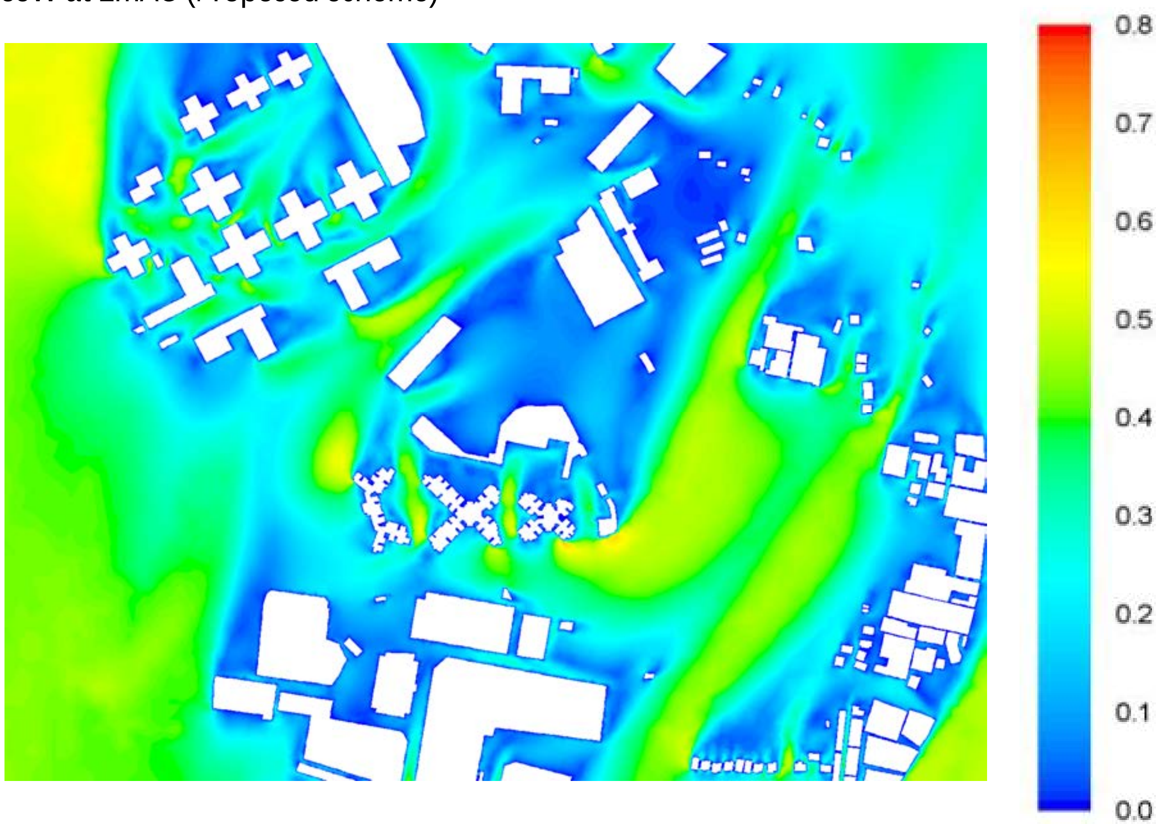


Appendix D – Wind Velocity Ratio Contour Plots

SSW at 2mAG (Base Scheme)

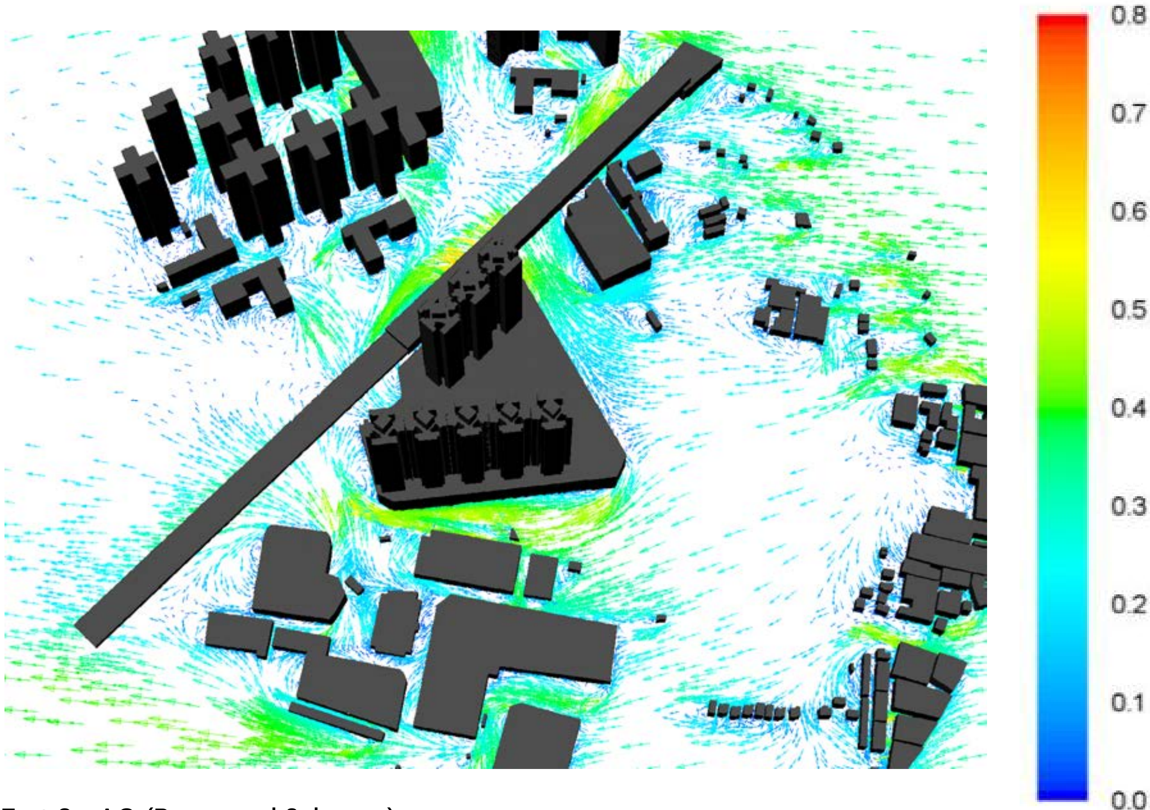


SSW at 2mAG (Proposed Scheme)

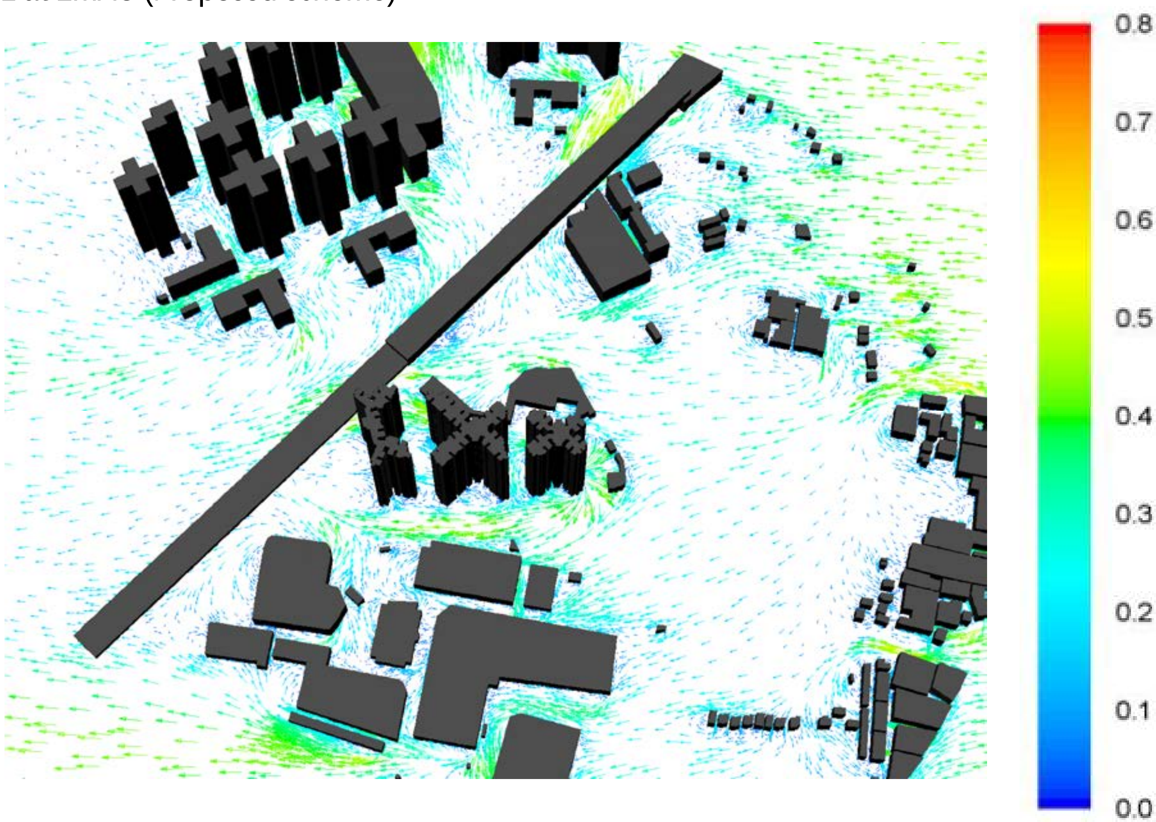


Appendix E – Wind Velocity Ratio Vector Plots

E at 2mAG (Base Scheme)

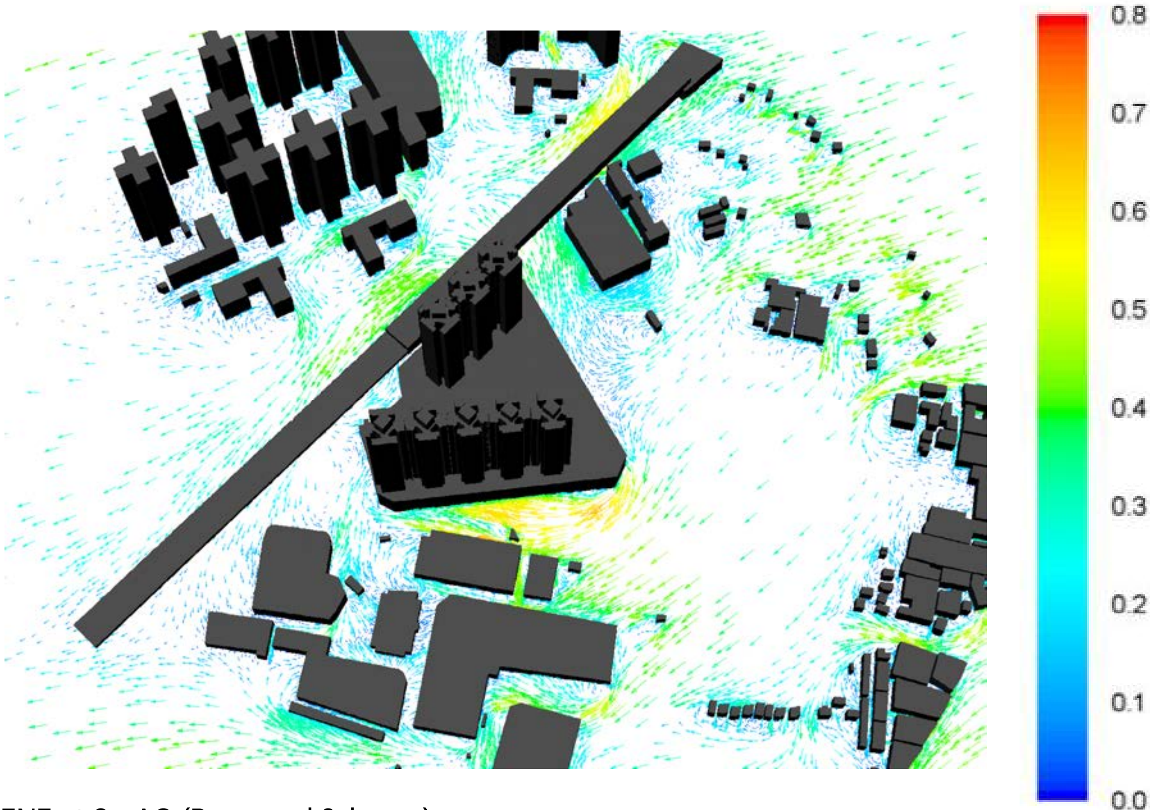


E at 2mAG (Proposed Scheme)

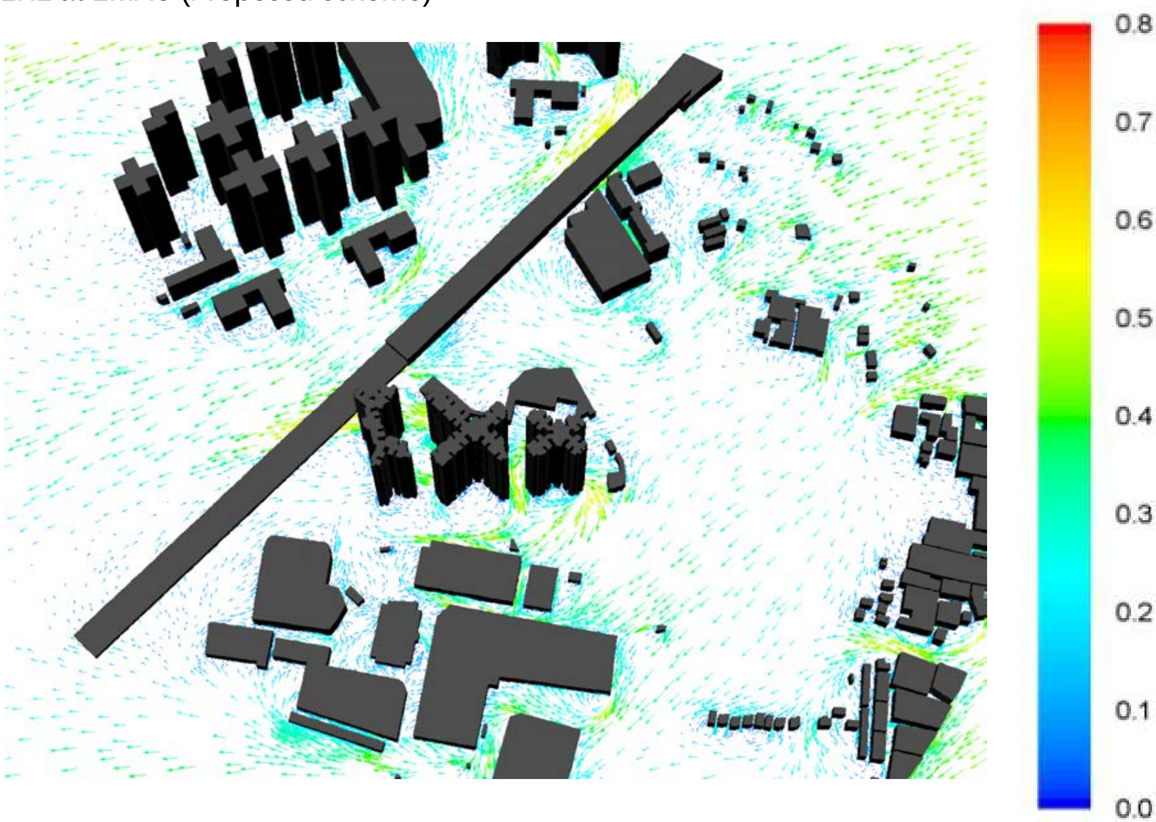


Appendix E – Wind Velocity Ratio Vector Plots

ENE at 2mAG (Base Scheme)

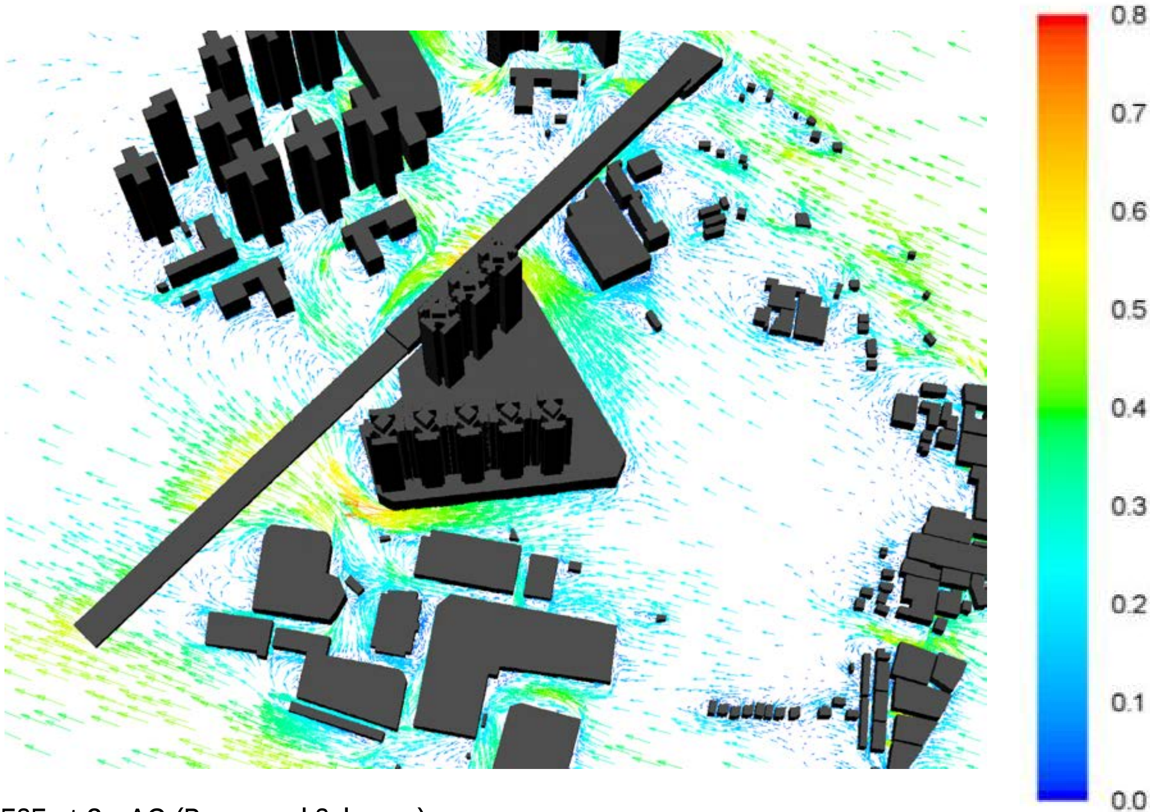


ENE at 2mAG (Proposed Scheme)

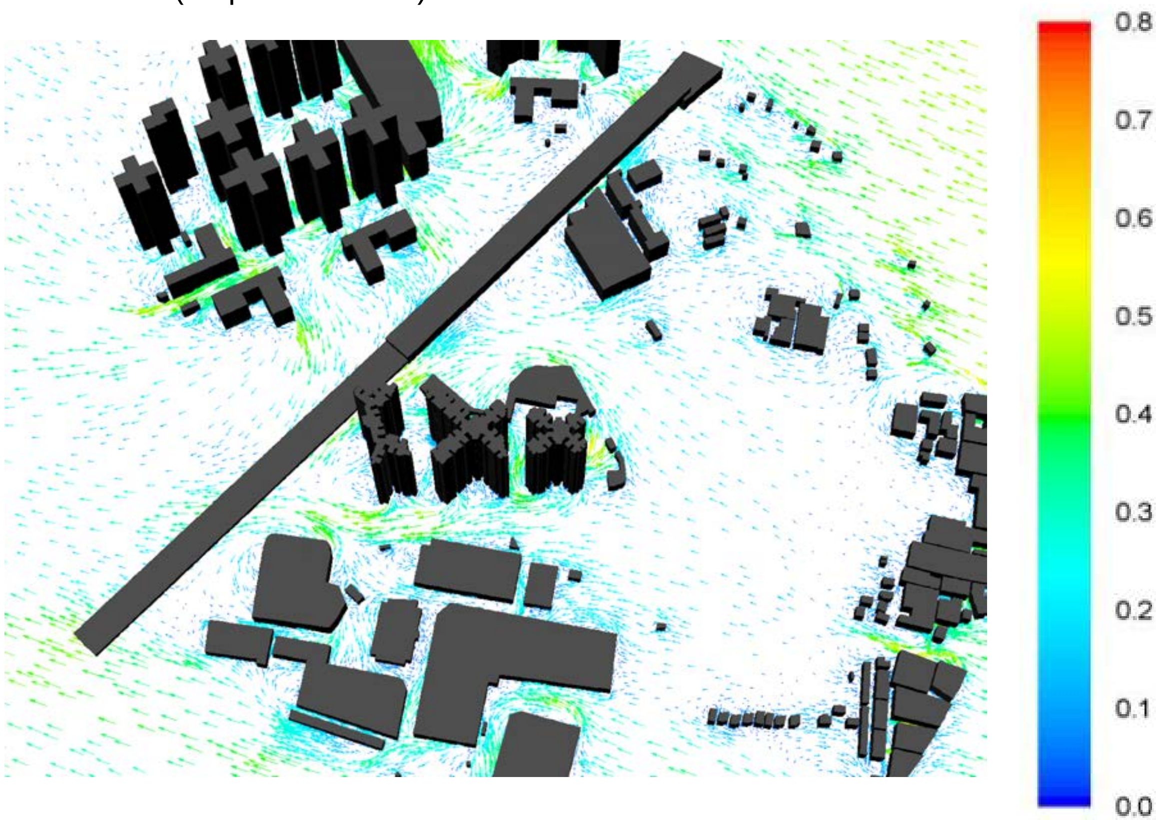


Appendix E – Wind Velocity Ratio Vector Plots

ESE at 2mAG (Base Scheme)

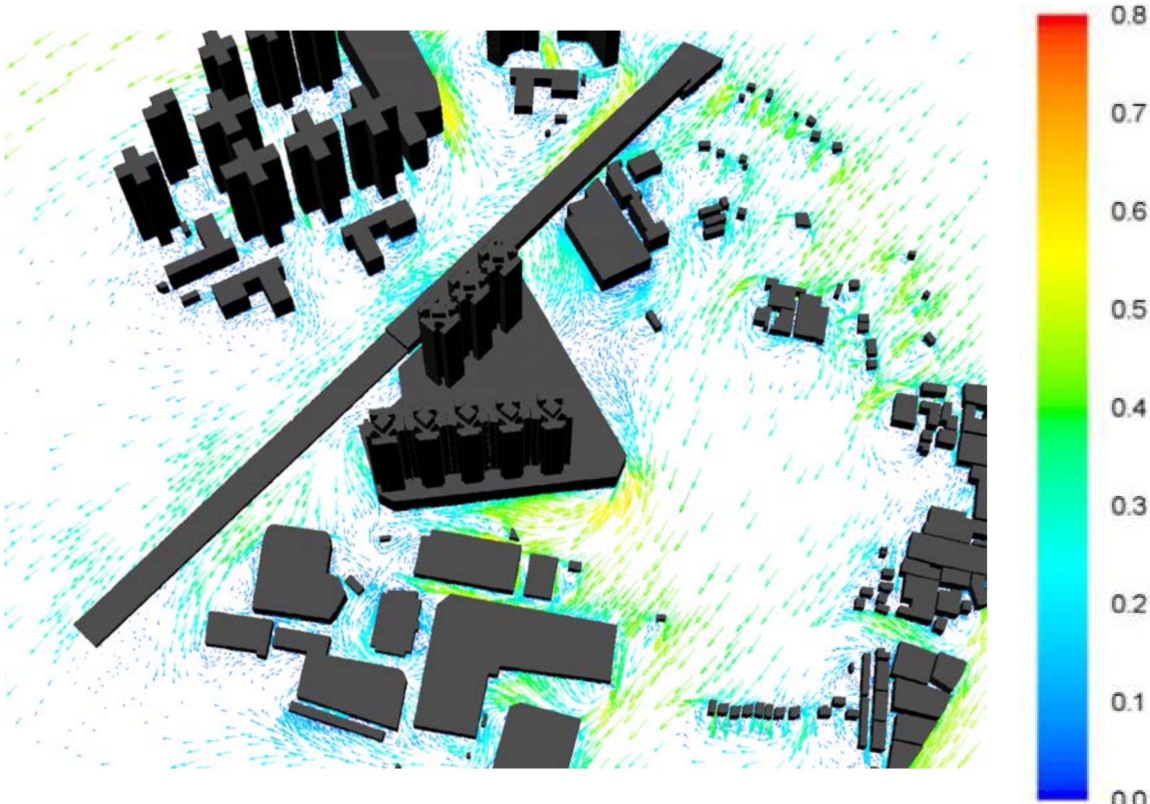


ESE at 2mAG (Proposed Scheme)

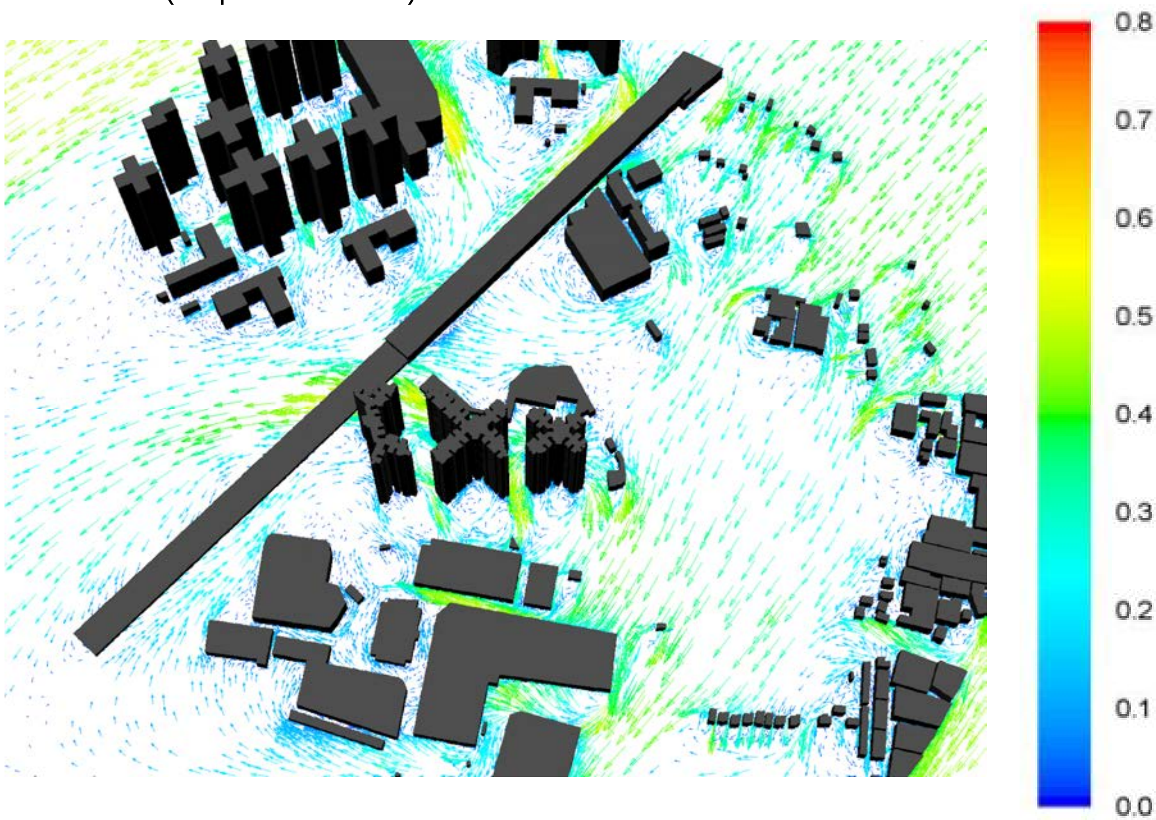


Appendix E – Wind Velocity Ratio Vector Plots

NE at 2mAG (Base Scheme)

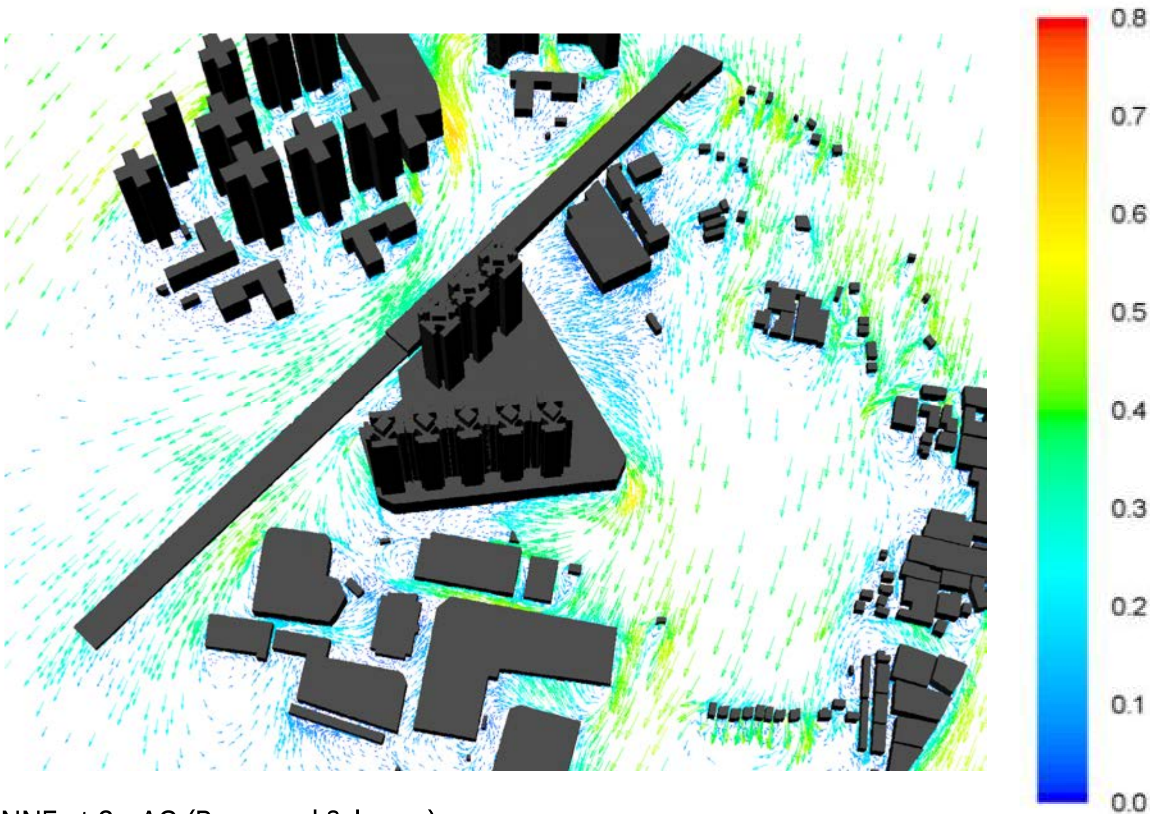


NE at 2mAG (Proposed Scheme)

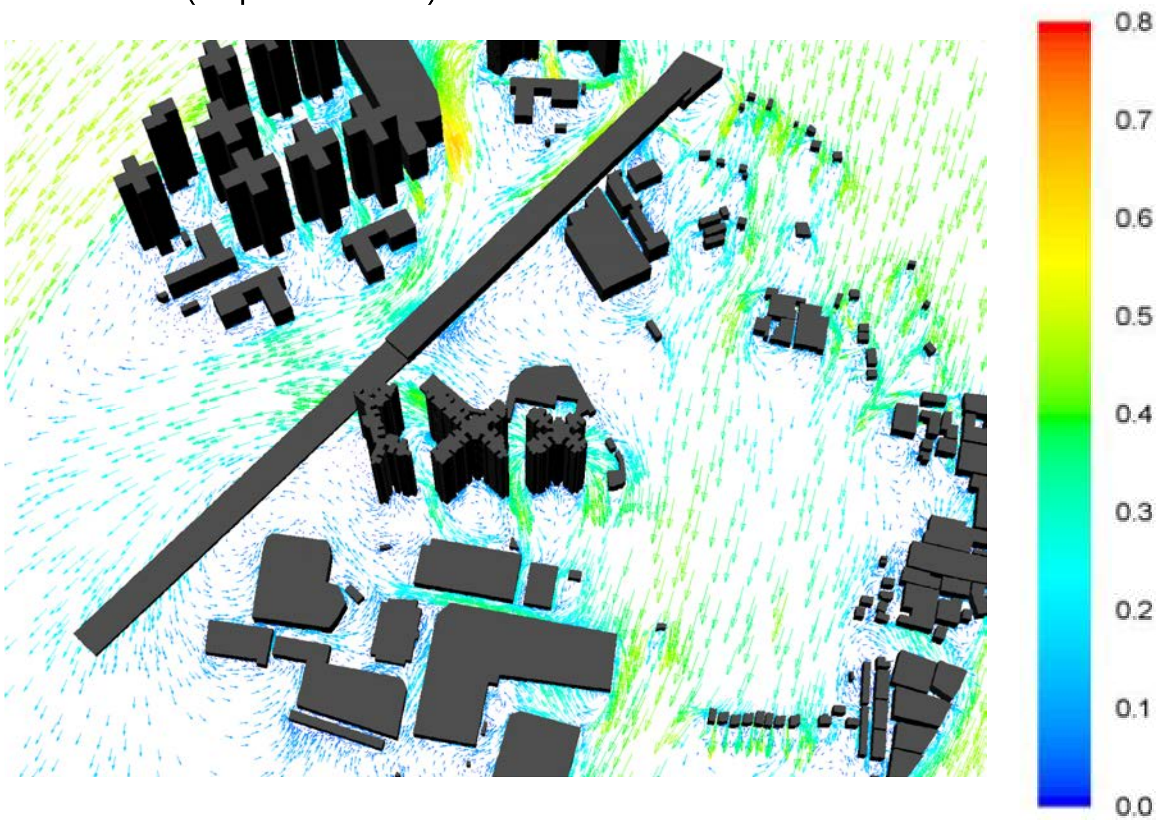


Appendix E – Wind Velocity Ratio Vector Plots

NNE at 2mAG (Base Scheme)

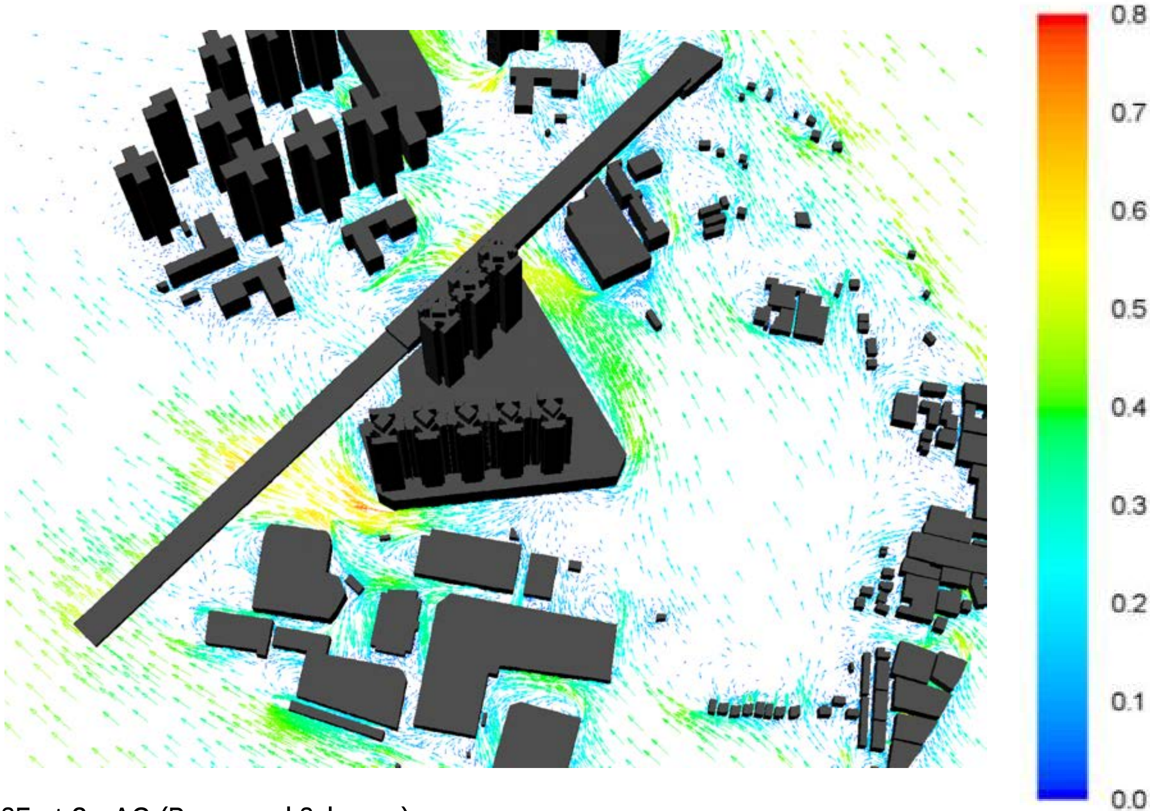


NNE at 2mAG (Proposed Scheme)

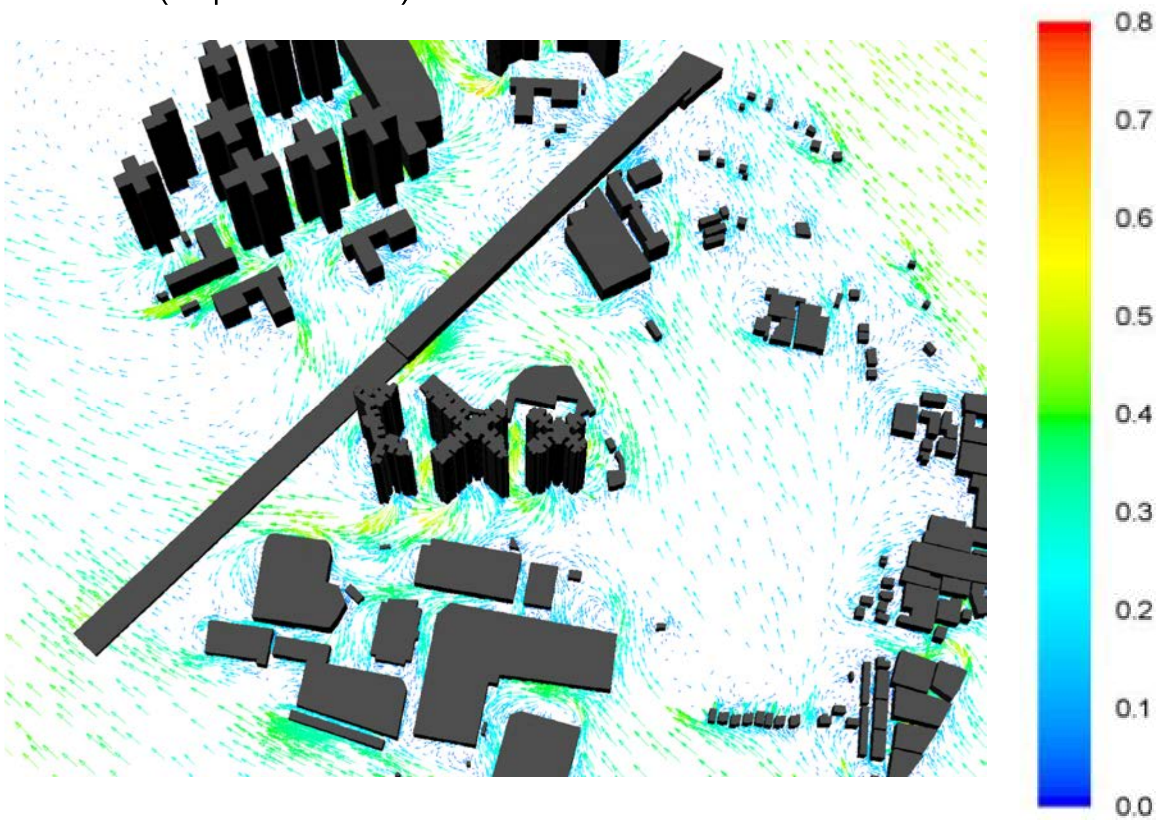


Appendix E – Wind Velocity Ratio Vector Plots

SE at 2mAG (Base Scheme)

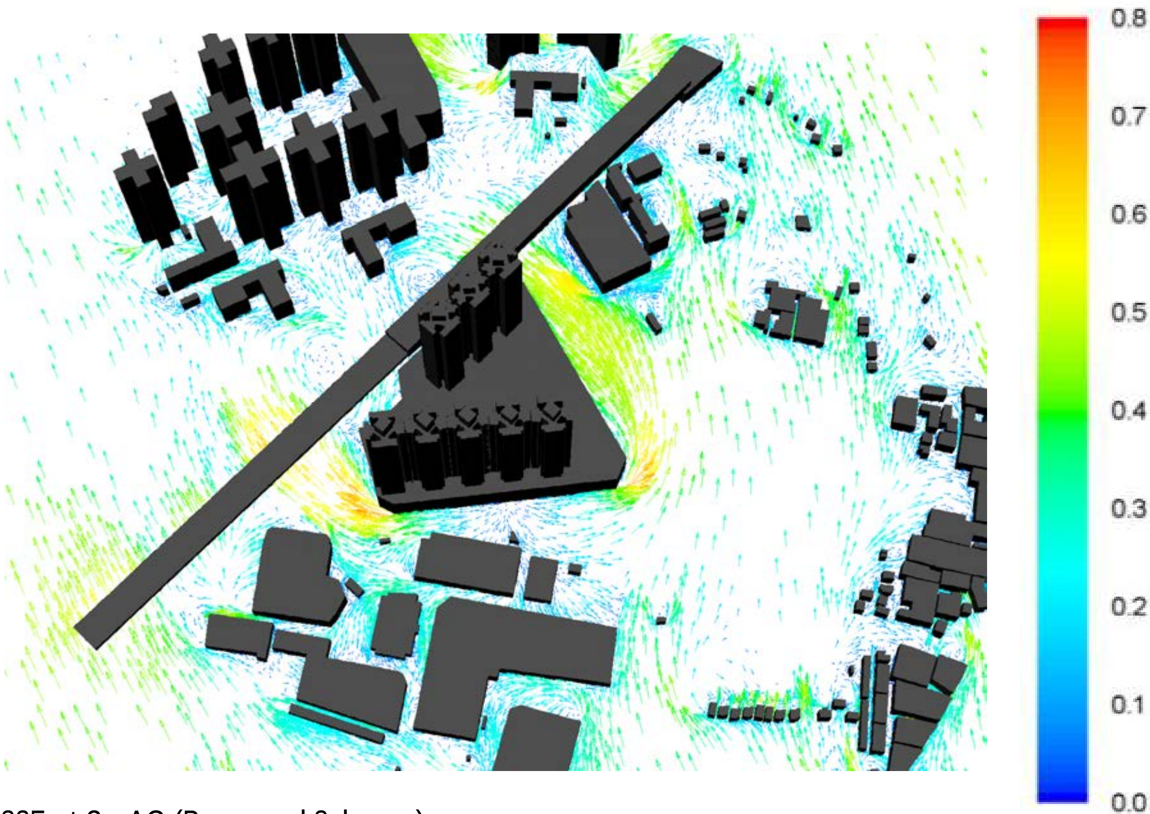


SE at 2mAG (Proposed Scheme)

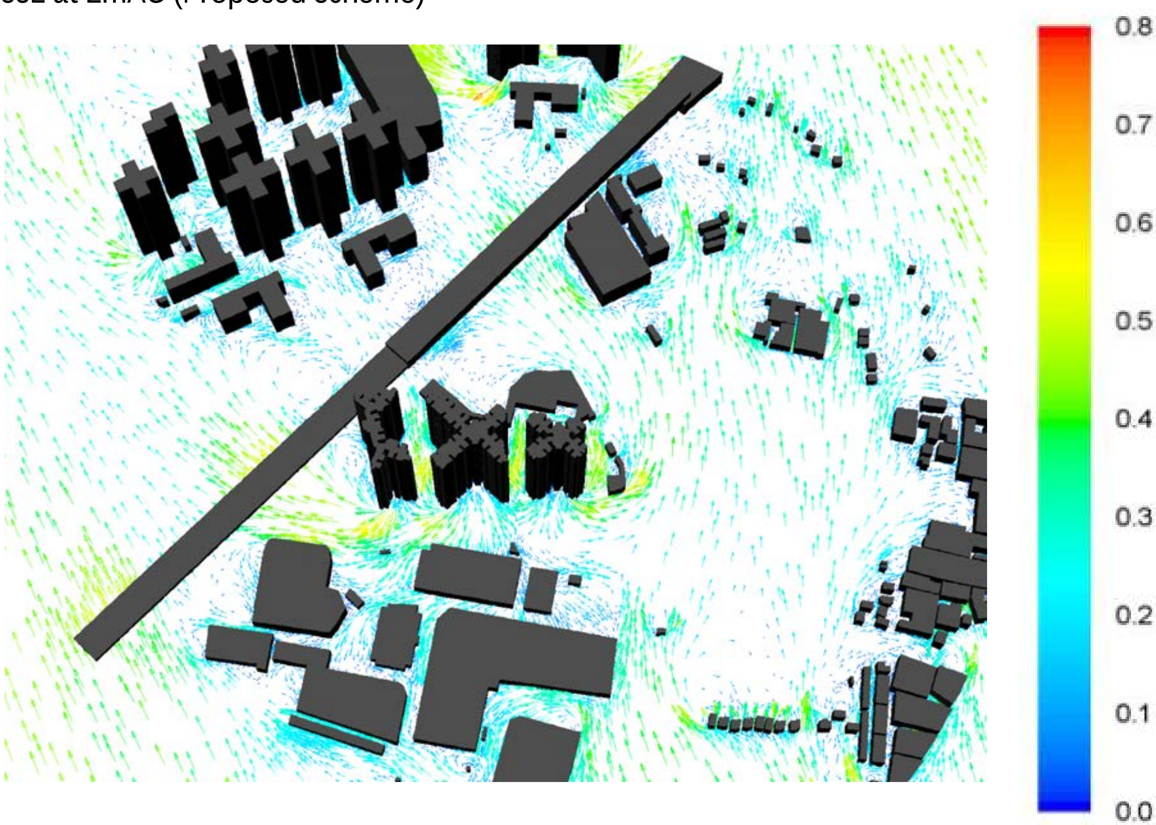


Appendix E – Wind Velocity Ratio Vector Plots

SSE at 2mAG (Base Scheme)

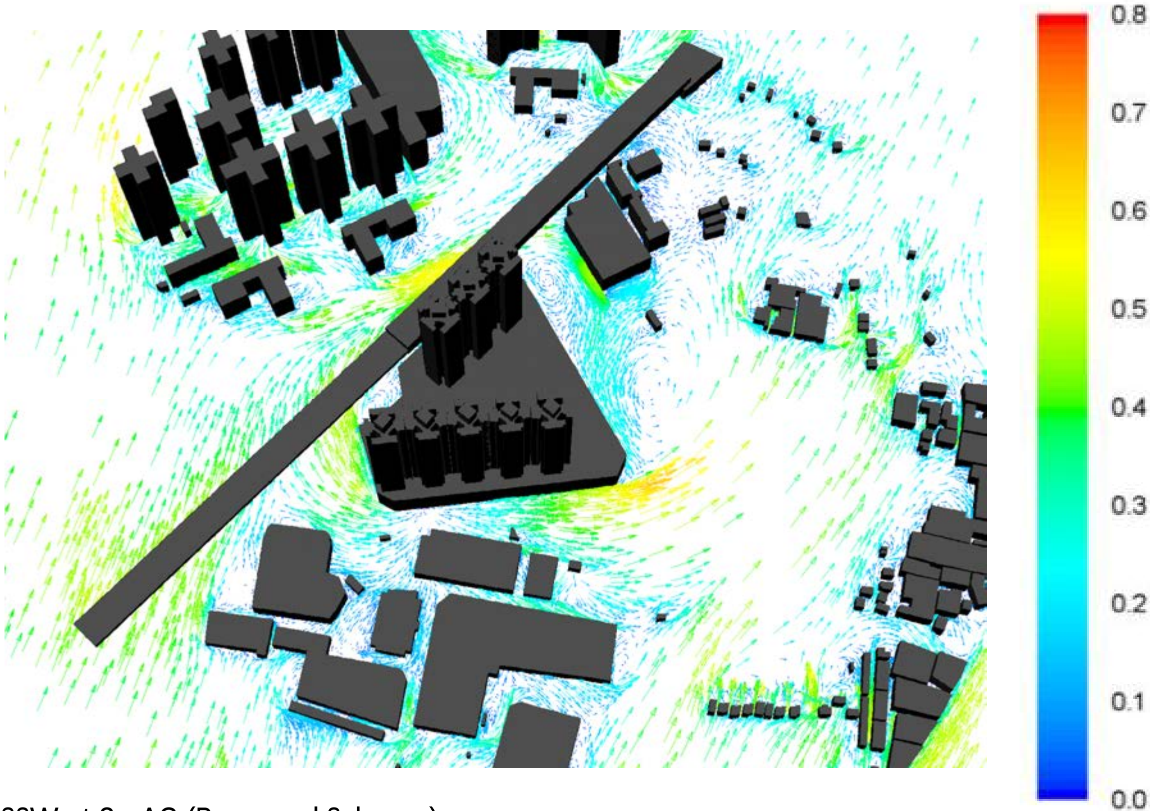


SSE at 2mAG (Proposed Scheme)



Appendix E – Wind Velocity Ratio Vector Plots

SSW at 2mAG (Base Scheme)



SSW at 2mAG (Proposed Scheme)