

Appendix 12.9

CFD Simulation Results



Swansea Tidal Bay CFD

CFD Simulation Results

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Prepared for:
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Bay) plc**

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REVISION SCHEDULE

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TABLE OF CONTENTS

APPENDIX 12.9	1
CFD SIMULATION RESULTS	1
0.0 EXECUTIVE SUMMARY	2
1.0 INTRODUCTION	4
2.0 METHODOLOGY	5
2.1 Approach	5
2.2 Bay Area Features	6
3.0 MODELLING INPUTS DATA	7
3.1 Site Information – Wind	7
3.2 Site Information – Terrain	7
3.3 Assumptions	9
4.0 RESULTS	10
4.1 Air Velocities – Ground Level	10
4.2 Air Velocities – At 1m above Ground Level	13
4.3 Air Velocities – Vertical Sections through Studied Area	15
5.0 SUMMARY	17
6.0 APPENDIX	18
6.1 Velocity Difference Plots	18

0.0 EXECUTIVE SUMMARY

- 0.0.0.1 Sand dunes are a dynamic habitat and are maintained by a balance in the rate at which sand is transported into and transferred within the dunes. The construction of new buildings or structures nearby would affect the baseline conditions. If the change in wind speed or direction is large enough, then this could potentially affect the rate that sand is transported into the dunes, the retention of sand within the dunes and the rate that sand is lost from the dunes. Depending on the magnitude of the changes in these rates, the dunes habitat may be changed as a result.
- 0.0.0.2 The construction of the proposed eastern Lagoon wall and Swansea University Bay Campus (SUBC) would have the potential to change the localised wind patterns as well as the speed of the air flow across the immediate area. This in turn could potentially affect the adjoining Crymlyn Burrows SSSI sand dune site. As such further investigation was undertaken. However, it should be noted, that the effect of wind speed on windblown sand is one factor that fits into a complex system affecting the dynamics of transport and transference of sand within the dune system. Other factors include longshore sediment transport, deposition of sand during storm events and activities affecting the dune system (e.g. public access). Thus the report focuses on examining the changes in wind speeds across the dune system resulting from the construction of the Project.
- 0.0.0.3 URS Infrastructure & Environment (UK) Ltd were commissioned to quantify the likely physical effect of the Project on the movement of the air across the site and the adjoining Crymlyn Burrows SSSI site. This report provides quantitative information that can be used in an assessment of the likelihood of significant effects being experienced at the Crymlyn Burrows SSSI. The assessment of significance is best undertaken by an ecologist, based on the information contained in this report, in combination with their professional judgement on the other relevant processes affecting the habitat.
- 0.0.0.4 This report describes how Computational Fluid Dynamics (CFD) methods have been used to simulate air flow patterns and speeds for the current baseline conditions and with the Project in operation. It should be noted that the current baseline conditions presents the situation with no buildings present in the vicinity of the SSSI. For the future, a worst case Lagoon wall height was used at the eastern landfall. However, part of the ongoing development associated with SUBC is already under construction. As such, the study examines the scenario of the Project in operation which assumes that the SUBC development has also been fully completed.
- 0.0.0.5 The study area of the model encompasses a 10 mile area which incorporates the SUBC development and the area where the proposed eastern wall of the lagoon would run alongside Crymlyn Burrows Site of Special Scientific Interest (SSSI).
- 0.0.0.6 Consideration is limited to the likely change in wind speeds for scenarios that are representative of conditions that are most likely to illustrate the impact of the introduction of the new structures (i.e. the ongoing SUBC building development and the construction of the eastern seawall).
- 0.0.0.7 The CFD model considers the elevation of the ground and large structures on the ground level in 3 dimensions and includes representations of the presence of smaller features, such as vegetation and minor undulations, by making use of a surface roughness factor. The model has been run for the south west wind scenario. It is considered that the pattern and speed of air flow onto and across the dunes are

generally unaffected by the presence of the eastern lagoon sea wall when the wind is blowing from the north-west clockwise direction, around to the southeast direction.

- 0.0.0.8 The results of modelling for the current baseline (not including the recently developed SUBC building) and the future situation when the Project and the SUBC development have been constructed are compared and the calculated changes in wind speeds at ground level and at a height of 1m above ground level are reported graphically.
- 0.0.0.9 Overall the results indicate that there will be localised effect within 200m of the seawall and the SUBC buildings on ground level wind speeds from a south westerly direction. Beyond these areas around the new structures there would be an imperceptible change (less than 1m/s) in the ground level wind speed. At 1m above ground level, no perceptible difference is evident in wind speeds from a south westerly direction between the two modelled scenarios. As a result it is considered that unconsolidated sand particles would continue to be transferred across the Crymlyn SSSI dune area in a similar manner to the baseline scenario.

1.0 INTRODUCTION

- 1.0.0.1 The Dunes at Crymlyn Burrows SSSI are a dynamic habitat and are maintained by a balance in the rate at which sand is transported into and transferred within the dunes. Potential factors that could also affect the dynamics of the dune system include longshore sediment transport, deposition of sediment following storm events and public access. This report considers the effect of a change in the wind speed component of this complex dynamic system.
- 1.0.0.2 There is the potential for the construction of new structures as part of the Project (the eastern seawall) to change the pattern and the speed of the air flow across the Project footprint and the adjoining Crymlyn Burrows SSSI site.
- 1.0.0.3 The Crymlyn Burrows SSSI is located to the east of the lagoon wall structure, and it is possible that large changes in wind speed or direction could potentially affect the rate that sand is transported into the dunes, the retention of sand within the dunes and the rate that sand is lost from the dunes which may affect its ecological status. In addition to the eastern seawall, it is considered that the SUBC development will have an in-combination effect on wind speed and so this development has also been examined.
- 1.0.0.4 URS Infrastructure & Environment (UK) Ltd were commissioned to quantify the likely physical effect of the Project on the movement of the air across the site and the adjoining Crymlyn Burrows SSSI site. As outlined above, the study also examines the potential effects of the nearby development, mainly the SUBC. This report provides quantitative information upon which an assessment of the likelihood of a significant effect being experienced at the Crymlyn Burrows SSSI is made. The assessment of significance is best undertaken by an ecologist, based on the information contained in this report, in combination with their professional judgement on the other relevant processes affecting the habitat (see above for other factors potentially affecting the dune system).

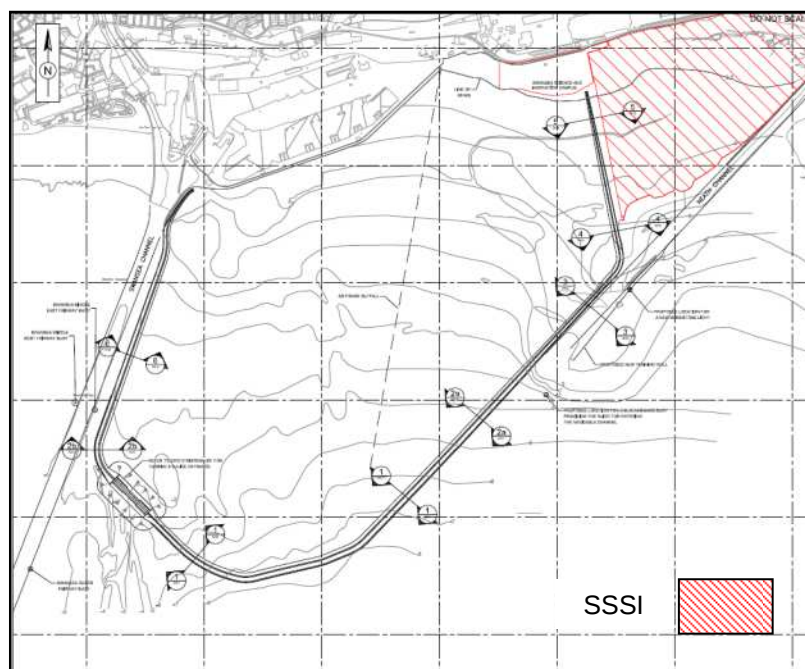


Figure 01 – Topographic map of proposed Lagoon structure and SSSI.

2.0 METHODOLOGY

2.1 Approach

- 2.1.0.1 A Computational Fluid Dynamics (CFD) study has been carried out to simulate the wind flows across the Swansea Bay Area in order to investigate the effects of the lagoon structure on the SSSI site. The study also examines the effects of the nearby SUBC development as this is likely to have an in-combination effect on the SSSI. The computational model has been set up to cover a region 6 km in diameter including the Crymlyn Burrows SSSI and the surrounding terrain.
- 2.1.0.2 The following scenarios were considered:
- i. Baseline model (2013) – no development in the vicinity of the SSSI (does not include the recently constructed SUBC building).
 - ii. Post completion of the eastern seawall (worst case height) and SUBC development.
- 2.1.0.3 The CFD model considers the elevation of the ground and large structures on the ground level in 3 dimensions and includes representations of the presence of smaller features, such as vegetation and minor undulations, by making use of a surface roughness factor.
- 2.1.0.4 Consideration is limited to the likely change in wind speeds for scenarios that are representative of conditions that are most likely to illustrate the impact of the introduction of the new structures (i.e. the ongoing SUBC building development and the construction of the eastern seawall).
- 2.1.0.5 The model scenarios are based on conditions with winds blowing from the south west. It is considered that the pattern and speed of air flow onto and across the dunes are generally unaffected by the presence of the eastern lagoon sea wall when the wind is blowing from all directions from the north-west clockwise, around to the southeast, and wind flow from the west or south would result in the same or lesser impacts than with winds blowing from the south west. A south-westerly wind condition has been considered for the simulations as this is representative of the prevalent wind direction in the region. A sample wind speed of 8 m/s has been taken from the wind-rose (average wind speed, ABPmer document (Figure 6.6, Chapter 6 ES). This wind speed has been applied at a height of 10 m and constitutes a velocity (wind speed and direction) profile applied as the upstream boundary condition of the model.
- 2.1.0.6 Steady-state CFD simulations will thus be carried out to predict the effects of the eastern seawall and SUBC buildings on the wind speed and profile by comparing the simulation results of the wind conditions across the site for the two scenarios described above.
- 2.1.0.7 The resulting wind profiles for the new structures will then be compared at ground level, 1m above ground level, and select vertical planes using contours of velocity magnitude. The difference in the calculated velocities between the two scenarios studied will illustrate the impact of the various structures on the site and across the SSSI. This information provided by the difference in velocity can then be utilised by an ecologist to determine the potential changes to the Crymlyn SSSI sand dune system.

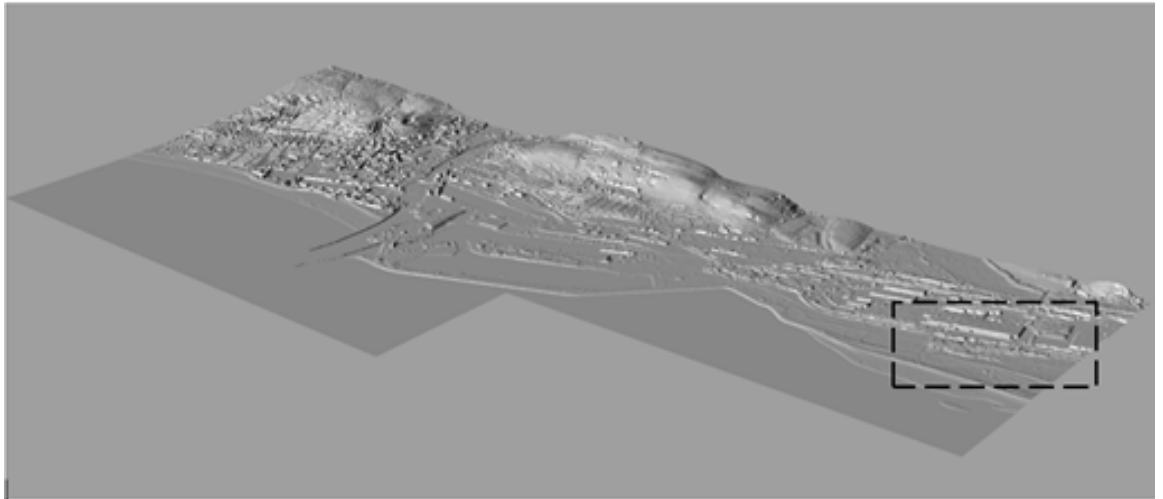


Figure 02 – 3D LiDAR model of Swansea Bay (SSSI sand dunes shown in rectangle.)

2.2 Bay Area Features

2.2.0.1 The following features are characteristic of the Swansea Bay Area considered for the CFD modelling.

- I. SSSI Area (as shown on Figure 1 of this report)
- II. SSSI Area including surrounding bay and land inland region:
 - Bay to the East, South-East, South, South-West and West
 - Land to the West, North-West, North, North-East and East
- III. Prevailing wind direction modelled – South West
- IV. The model scenario is based on a wall extending in height 9m above local mean low water sea level (MLWS).

3.0 MODELLING INPUTS DATA

3.1 Site Information – Wind

- 3.1.0.1 The location of the area studied is situated within the Swansea Bay and the weather information for this site is taken from the ABPmer document (Figure 6.6). In this document it is stated that the primary wind conditions are 'southwesterly' with an average wind speed of 8m/s.

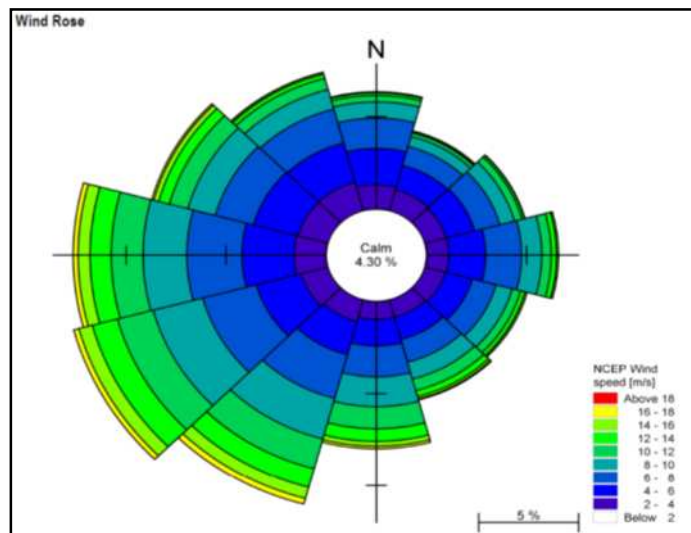


Figure 03 – Wind Rose of the local area of Swansea.

3.2 Site Information – Terrain

- 3.2.0.1 A 3km radius has been considered for the simulation which includes the SSSI site, the eastern part of the lagoon structure as well as the SUBC buildings.
- 3.2.0.2 As mentioned earlier, a baseline model (Base Case) has been setup as shown in Figures 04 and 05, assuming low tide. This assumes no development at the SUBC site.

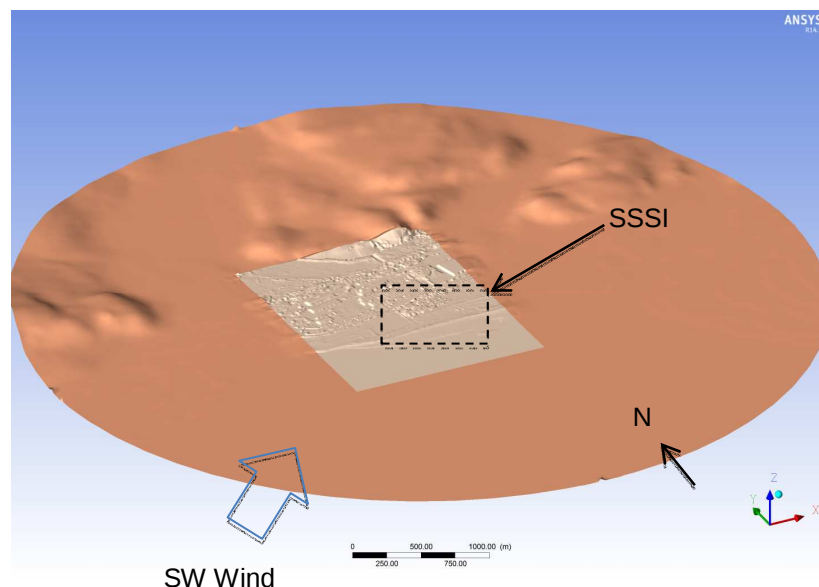


Figure 04 – 3D image of 3km Model of Swansea Bay Base Case

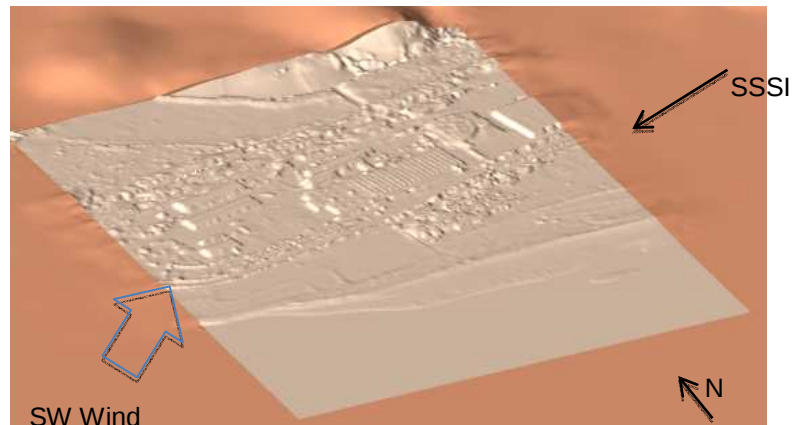


Figure 05 – 3D image of Model of Swansea Bay Base Case of SSSI and surroundings.

- 3.2.0.3 Figures 06 and 07 illustrate the second case setup model (Case 1) which includes the SUBC development as well as the eastern seawall.
- 3.2.0.4 The wind condition applied for the scenarios was the prevailing south-westerly wind.

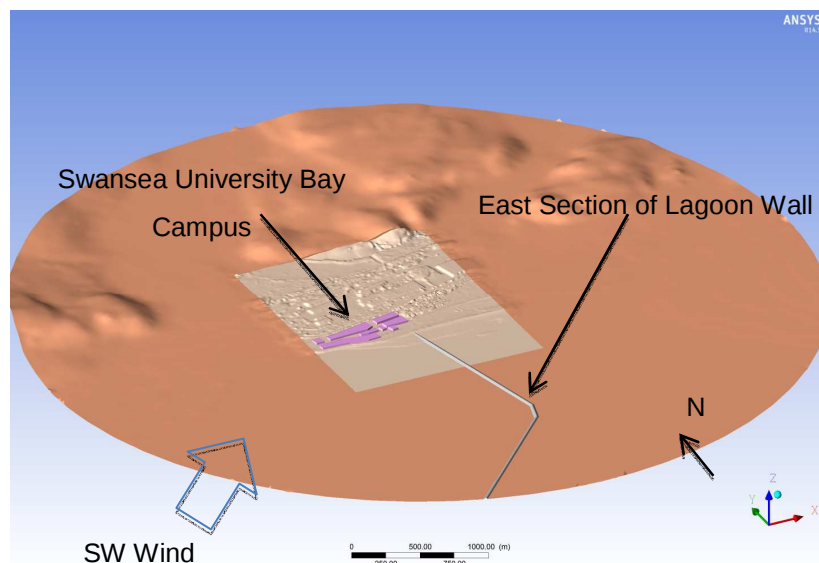


Figure 06 – 3D Model of Case 1; Swansea Bay Base with proposed campus and Lagoon wall

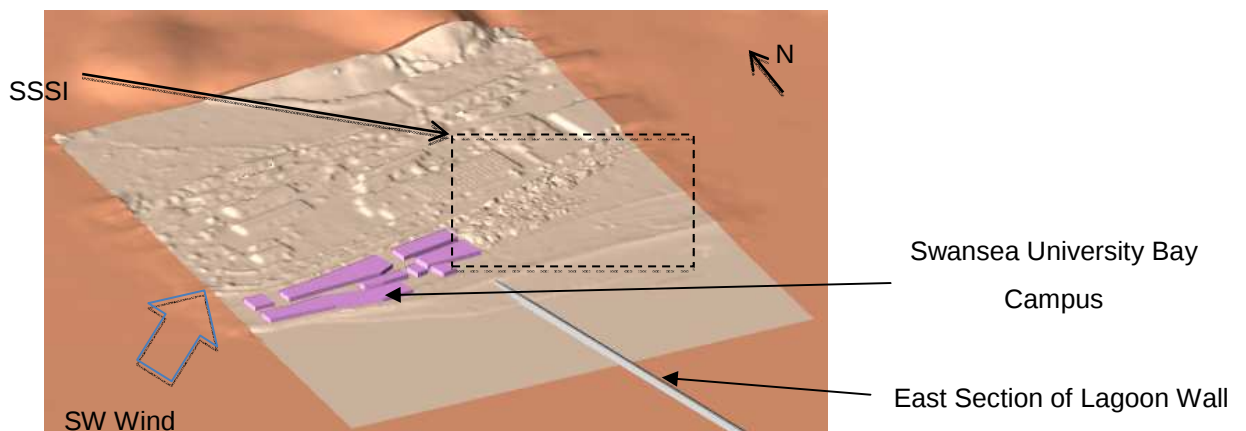


Figure 07 – 3D Model of Case 1; Swansea Bay Base of SSSI and surroundings with proposed campus and Lagoon wall.

3.3 Assumptions

- 3.3.0.1 The main assumptions taken into account for this study are that the steady-state CFD simulation will be sufficient for the purposes of this analysis, i.e. predicting the airflow pattern and sand transportation by way of comparing the velocity profiles
- 3.3.0.2 In addition, the calm sea conditions will be used along with the Mean Low Water Spring (MLWS) tide level.

4.0 RESULTS

- 4.0.0.1 The CFD simulations are reported graphically using a scale that reports values to 0.7m/s so that the changes in wind speed can be visualised. In reading these illustrations care should be taken to recognise the uncertainties associated with any form of atmospheric modelling. In discussing the predicted impacts, values for wind speed are reported to the nearest whole metre per second.
- 4.0.0.2 The simulation results for the baseline model (assuming no development at the SUBC site) (Base case) shown in the following sections demonstrate that when the winds are blowing into the study area from the south west, they remain at speeds of 8 m/s or higher across the southern edge of the dunes and then decrease to speeds of 3 m/s as the surface of the ground becomes higher and less even. In the main body of the dunes wind speeds are 3 to 4 m/s lower than at the southern edge of the dunes.
- 4.0.0.3 The results for the wind speeds at ground level are shown in Figures 08 – 11 and for the wind speeds at 1m above ground level, in Figures 12 - 14. The results indicate that the worst case scenario is for wind speeds from the south-westerly direction at ground level. There is little difference from the baseline scenario when examining wind speeds at 1m above ground level. The results for wind speeds at ground level are discussed in more detail below.
- 4.0.0.4 The introduction of the lagoon wall (case 1) reduces wind speeds at ground level over land to the western and eastern face of the seawall and increases the wind speed directly above the wall. On the western side of the seawall, the wind speed drops to between 5-6 m/s within a distance of 50 m away from the wall. Directly above the seawall, the speed is increased to 12 m/s. On the eastern side of the seawall wind speeds are predicted to be approximately 4.5 – 6 m/s within 100m of the wall. Between 100 – 200m to the east of the seawall speeds increase to approximately 6-7.5 m/s. At the western edge of the dunes, the wind speed is predicted to be between 6-7 m/s and it is considered likely that with this limited reduction in wind speed unconsolidated sand particles would continue to be transferred across the dune in a similar manner to the baseline scenario. The results suggest that the seawall causes a very localised effect (within a 200m boundary to the east of the seawall) on wind speeds.
- 4.0.0.5 Wind speeds to the east of the SUBC buildings fall to approximately 2 – 3 m/s, with recirculation taking place within 50 – 100 m and as a result, approximately 200 – 300 m further east of the SUBC buildings, the wind speeds pick up again and the general difference in wind speeds when compared to the base case are about 1 – 2 m/s
- 4.0.0.6 Vertical sections through the studied areas (lagoon sea wall and SUBC buildings) are shown in Figures 13 – 14.

4.1 Air Velocities – Ground Level

- 4.1.0.1 The air velocities at the ground level for the Base Case and Case 1 are shown in the following Figures.
- i. **Base Case:** Existing Area including SSSI site
 - ii. **Case 1:** Existing Area including SSSI site, proposed Lagoon eastern seawall and SUBC buildings.

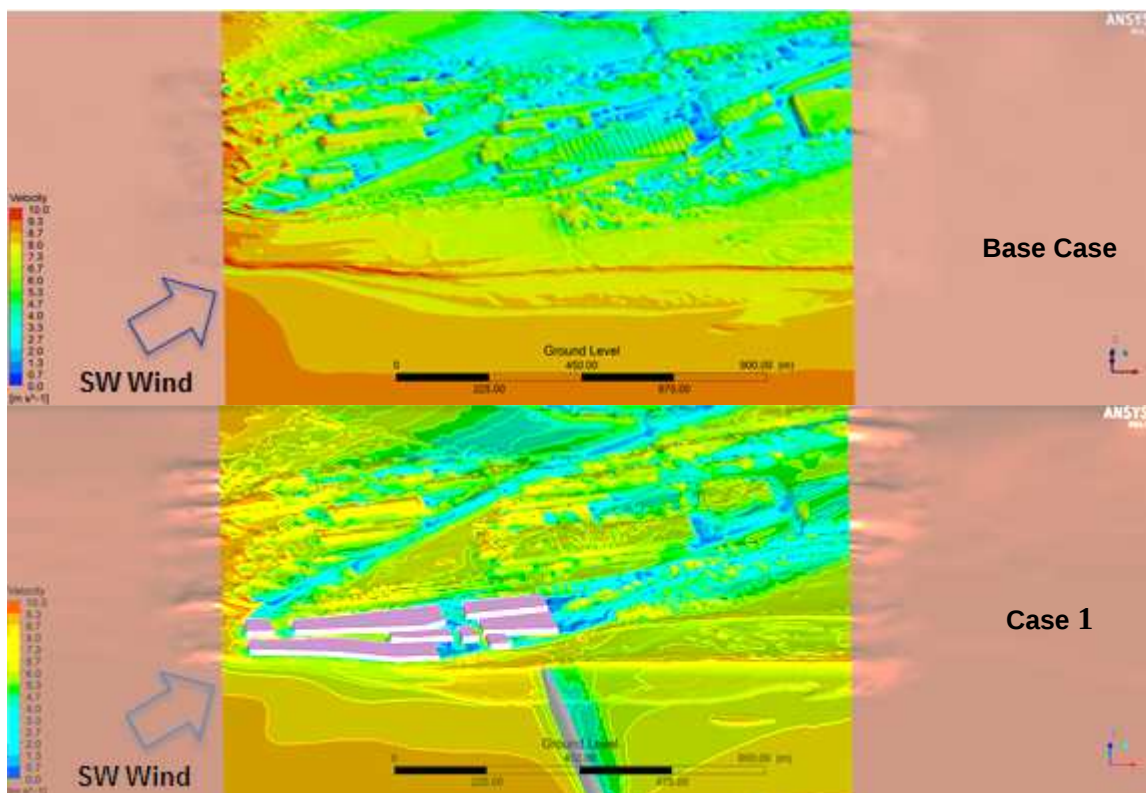


Figure 08 – CFD Results of Air velocity at ground level.

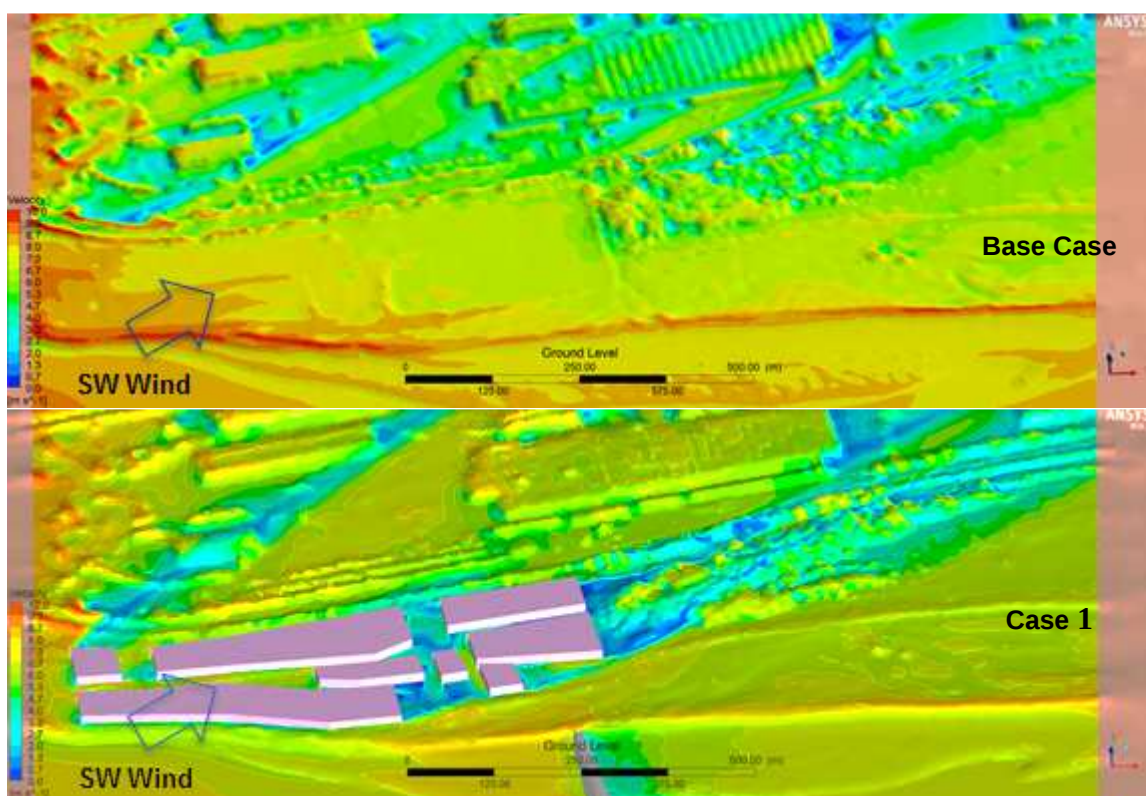


Figure 09 – CFD Results of Air Velocity at ground level *emphasising SSSI site.*

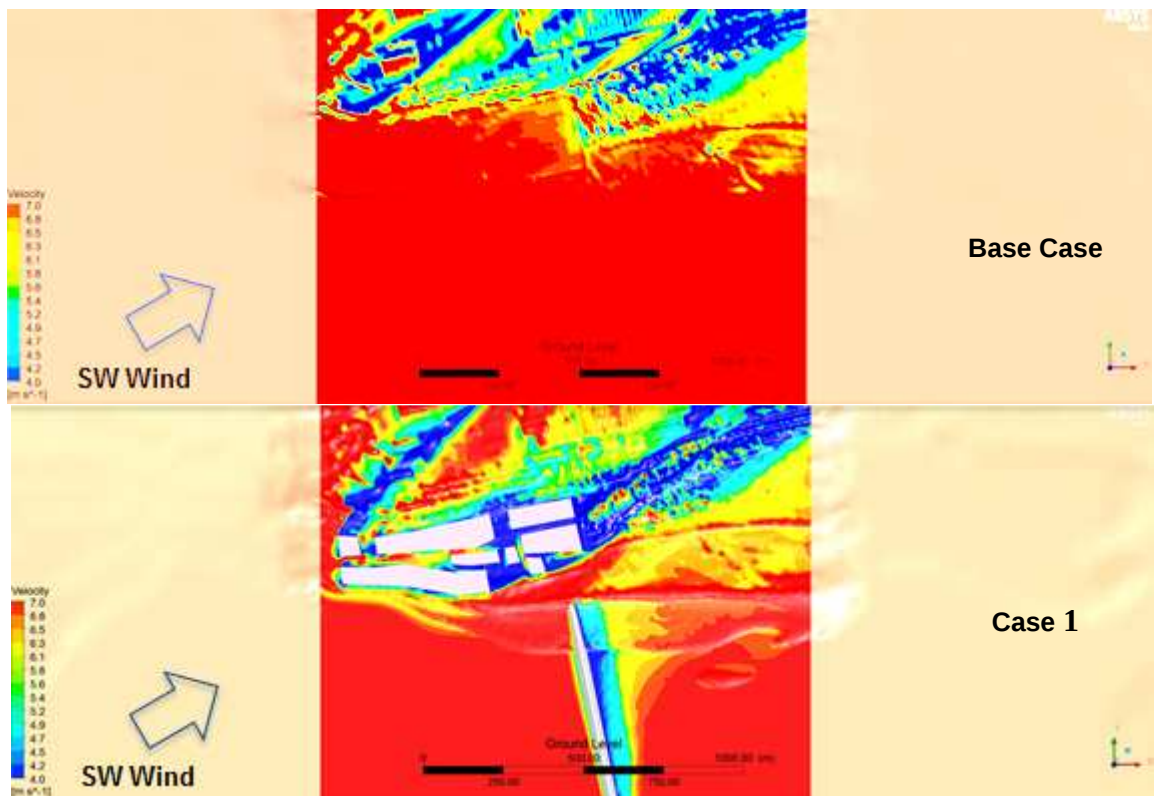


Figure 10 – CFD Results of Air Velocity at ground level, with **reduced velocity scale**.

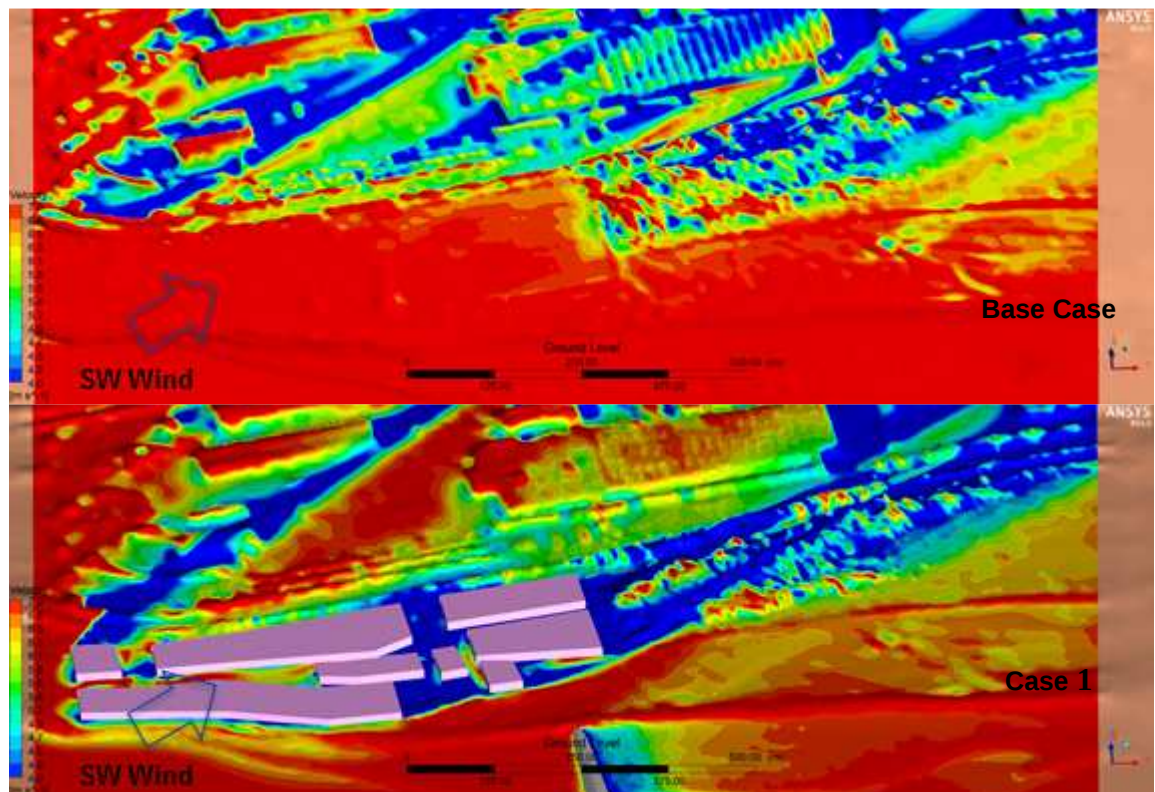


Figure 11 – CFD Results of Air Velocity at ground level, emphasising SSSI site and with **reduced velocity scale**.

4.2 Air Velocities – At 1m above Ground Level

4.2.0.1 The air velocities at 1m above the ground level for the Base case and Case 1 are shown in the following Figures.

- i. **Base Case:** Existing Area including SSSI site
- ii. **Case 1:** Existing Area including SSSI site, proposed Lagoon wall and SUBC buildings.

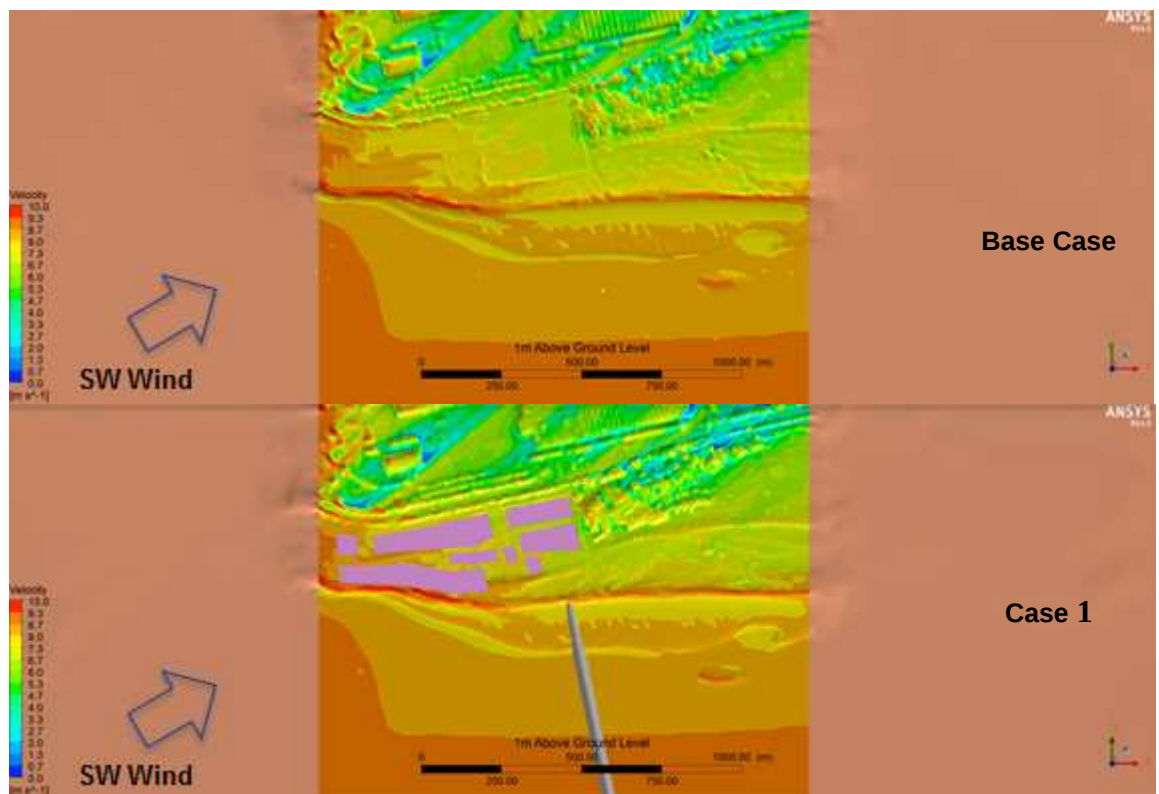


Figure 12 – CFD Results of Air velocity at 1m above ground level.

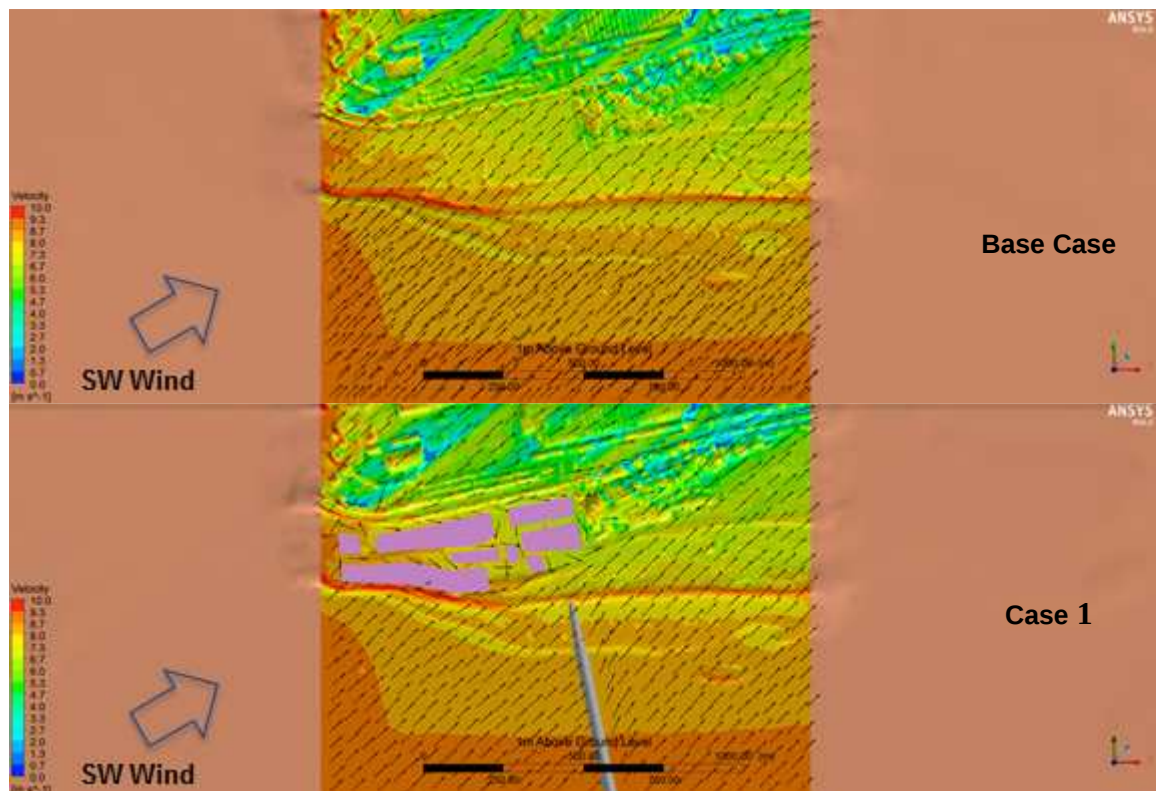


Figure 13 – CFD Results of Air velocity at 1m above ground level, including velocity vectors.

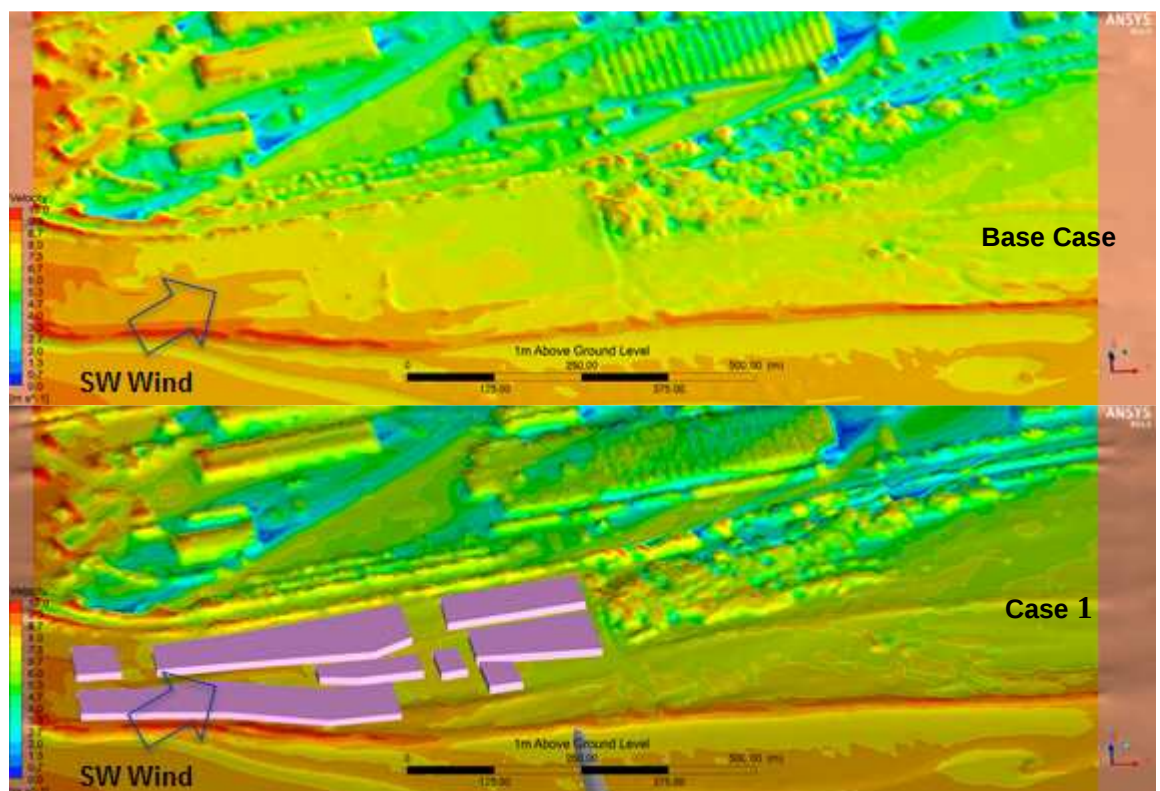


Figure 14 – CFD Results of Air Velocity at 1m above ground level **emphasising SSSI site.**

4.3 Air Velocities – Vertical Sections through Studied Area

4.3.0.1 The air velocities at a vertical section through the studied area for the Base case and Case 1 are shown in the following Figures.

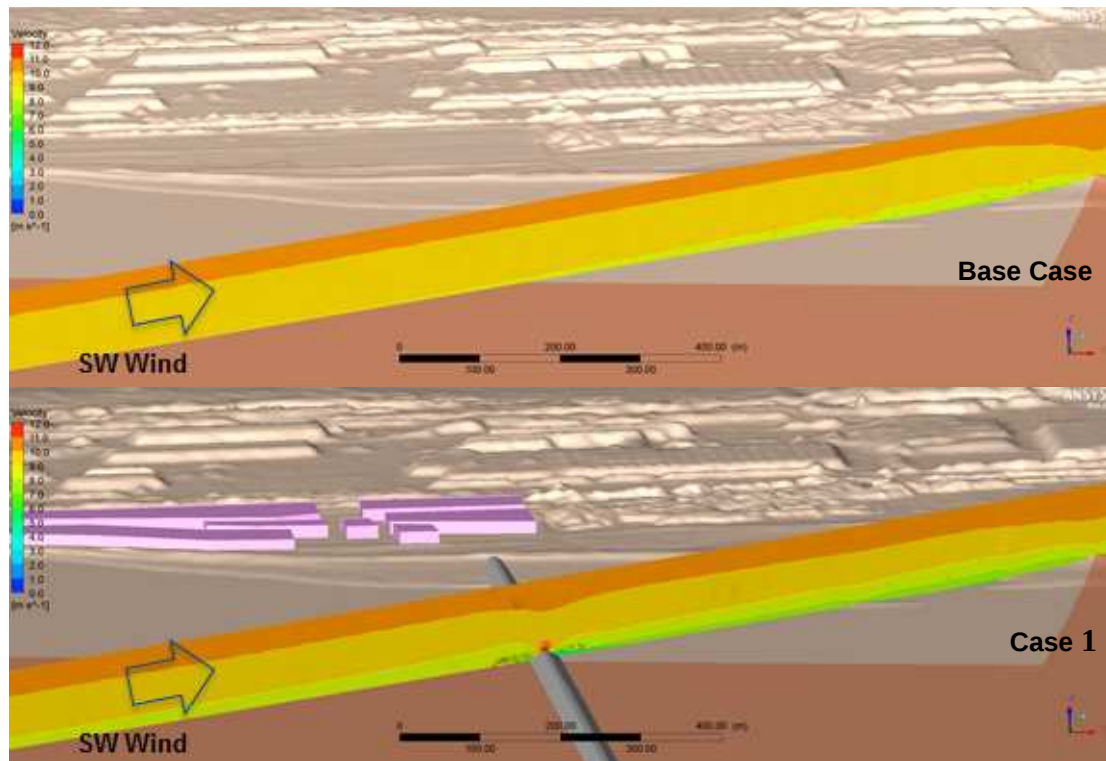
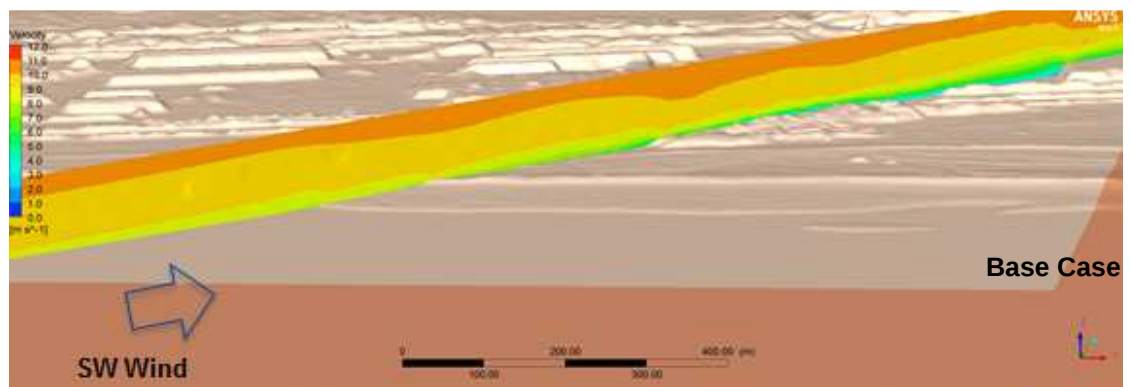


Figure 15 – CFD Results of Air Velocity at a vertical plane through the Lagoon Wall.



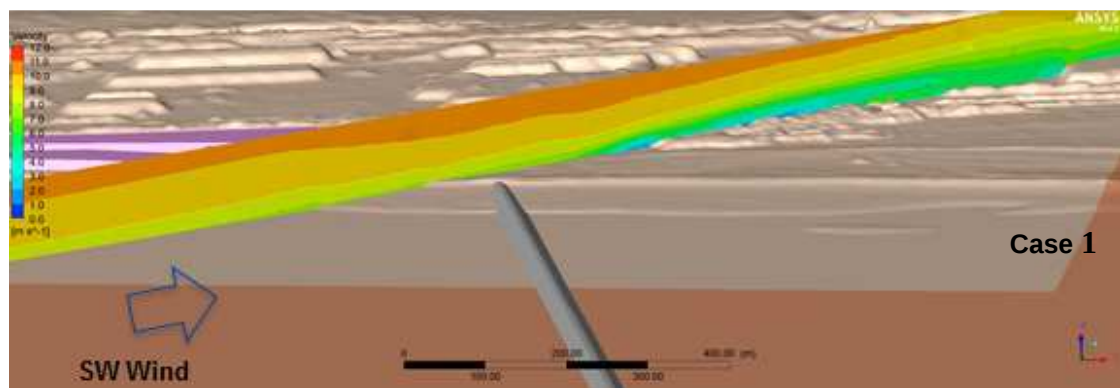


Figure 16 – CFD Results of Air Velocity at a vertical plane between the Lagoon Wall and the proposed campus, running through the Sand dunes.

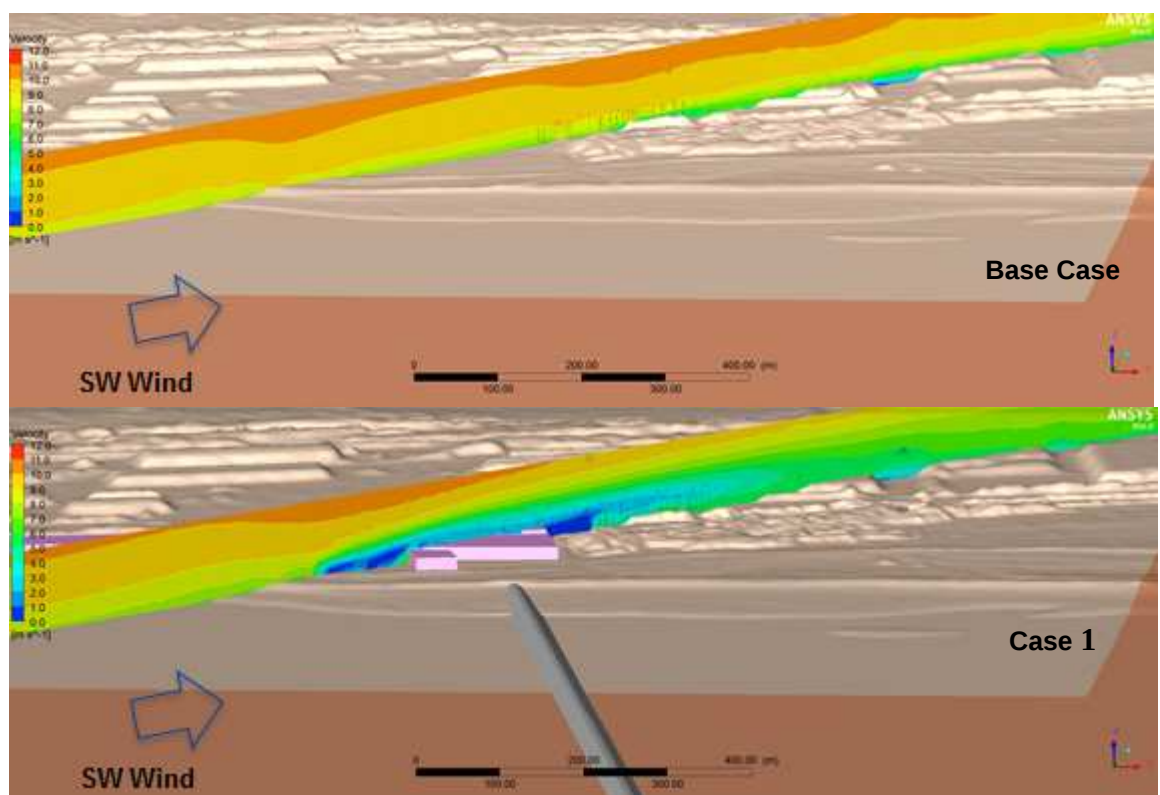


Figure 17 – CFD Results of Air Velocity at a vertical plane through the proposed University campus.

5.0 SUMMARY

- 5.0.0.1 The simulation results illustrate that the lagoon eastern seawall will have a localised effect on wind speeds from a South westerly direction within a maximum distance of 200m east of the new structure at ground level. Wind speeds will be reduced by a maximum of 5 m/s from the 8 m/s baseline scenario within this distance. After 200m, wind speeds pick up to approximately 6-8 m/s.
- 5.0.0.2 The SUBC buildings will also have an impact on wind speeds from a south westerly direction within approximately 200 m east of the new structures (with the wind speeds commonly reduced from the 8 m/s baseline by 5-6 m/s) at ground level. Within 200-300m further east, wind speeds will have picked up to 5-7 m/s.
- 5.0.0.3 The two structures (the eastern seawall and the SUBC buildings) will therefore have only localised effects on the wind speed from a south westerly direction at ground level. Out of the wake of the new structures, wind speeds flowing over the Crymlyn Burrows SSSI from a south westerly direction at ground level will experience a reduction of within 1 – 2 m/s from the baseline scenario of 8 m/s.
- 5.0.0.4 Since the CFD modelling exercise started the Project design has continued to develop and the inclusion of a beach area on the western side of the Lagoon wall is being proposed. The level of the sand would be built up in a gentle slope to the level of the wall on the western side. This would serve to decrease the potential magnitude of any decrease in wind speeds when the wind was blowing from the west or south west, in the area close to the western side of the wall. Sand is likely to be blown by the wind over the wall towards the dunes. However, this will depend on the gradient of the slope of the built up sand.
- 5.0.0.5 Overall with a worst case lagoon wall height the results indicate that there will be localised impacts within 200m of the seawall and the SUBC buildings on ground level wind speeds from a south westerly direction. Beyond these areas around the new structures there would be an imperceptible change (about 1 m/s) in the ground level wind speed. At 1m above ground level, no perceptible difference is evident in wind speeds from a south westerly direction between the two modelled scenarios. As a result it is considered that unconsolidated sand particles would continue to be transferred across the Crymlyn SSSI dune area in a similar manner to the baseline scenario.

6.0 APPENDIX

6.1 Velocity Difference Plots

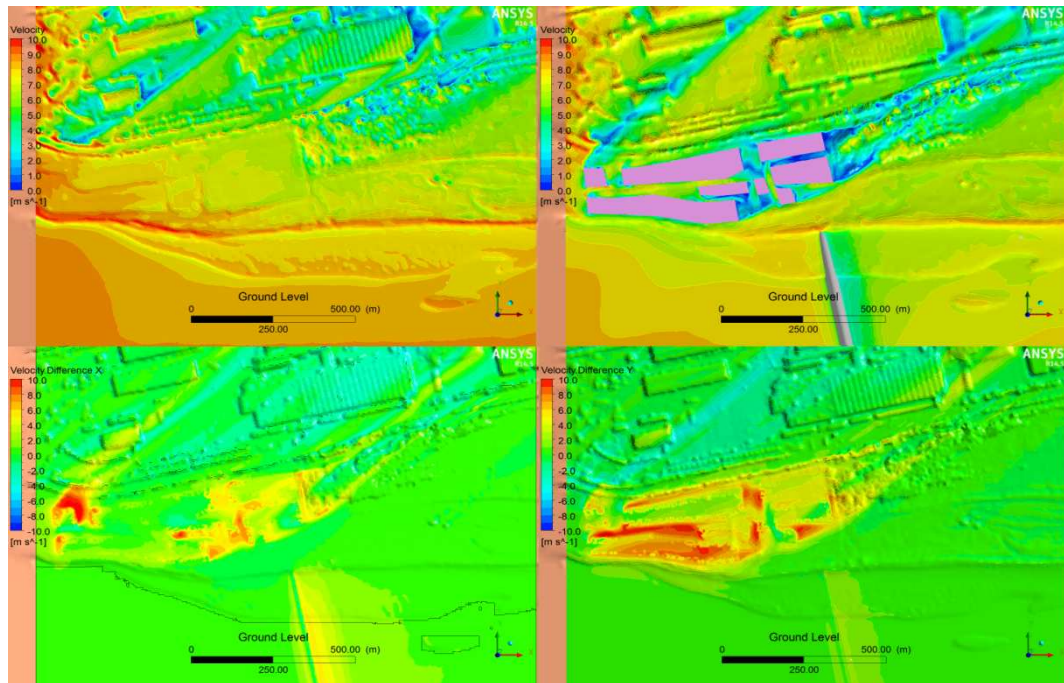


Figure 18 – CFD Results of Air velocity at ground level. (X-difference shown on bottom LHS, Y-difference shown on bottom RHS – negative indicated change in direction)

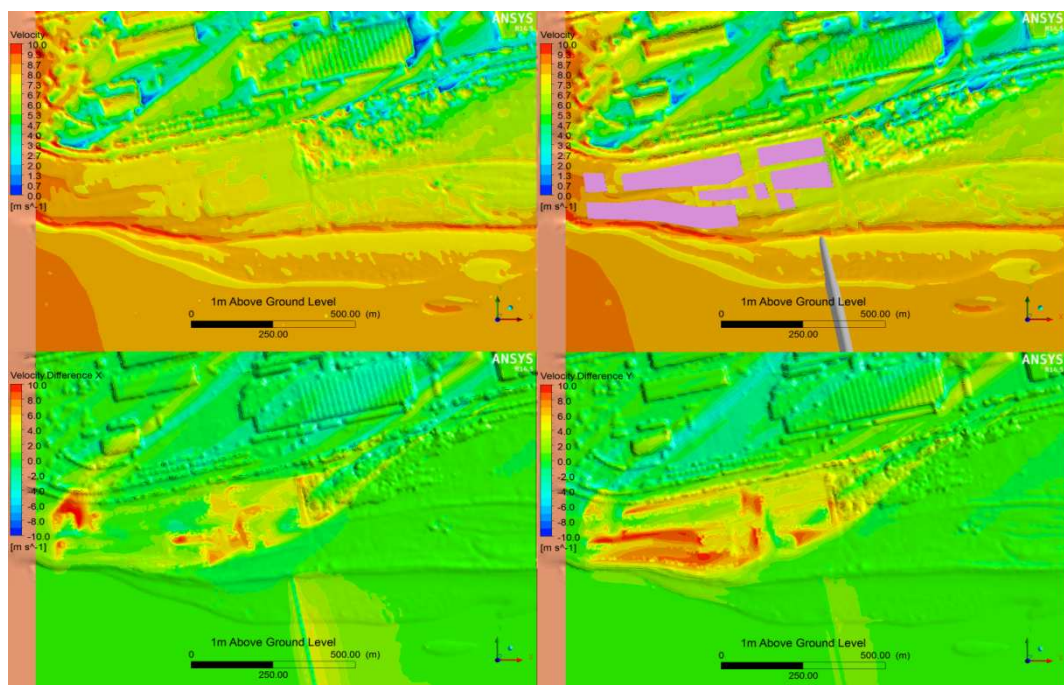


Figure 19 – CFD Results of Air velocity difference at 1m above ground level (X-difference shown on bottom LHS, Y-difference shown on bottom RHS – negative indicated change in direction)