Aviation Hangar Project

CFD-based Windshear and Turbulence Study

Bankstown Airport Proprietary Limited

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Making Sustainability Happen

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
R02-v3.0	15 May 2024	Dr Neihad Al-Khalidy	Dr Peter Georgiou	Dr Neihad Al-Khalidy
R02-v2.0	2 November 2023	Dr Neihad Al-Khalidy	Dr Peter Georgiou	Dr Neihad Al-Khalidy
R02-v1.0	18 October 2022	Dr Neihad Al-Khalidy	Dr Peter Georgiou	Dr Neihad Al-Khalidy

Basis of Report

This report has been prepared by SLR Consulting Australia (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Bankstown Airport Proprietary Limited (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

Executive Summary

SLR Consulting Australia Pty Ltd (SLR) has been commissioned by Bankstown Airport Propriety Limited to undertake a windshear and turbulence report for a proposed aviation facility at Bankstown Airport.

The proposed site is located at the northeastern side of the airport's runways – refer **Figure 1**.

BAL has commissioned a quantitative Computational Fluid Dynamics (CFD) modelling assessment and report on the windshear and wake turbulence effects of the proposed aviation facility development.

The assessment is conducted in accordance with the National Airports Safeguarding Framework (NASF) Guideline B, 2018 – *Managing the Risk of Building Generated Windshear and Turbulence at Airports* - specifically to address wind impacts on runways at Bankstown Airport. The NASF-B (2018) criteria are:

- The *"7-knot alongwind criterion"* - the variation in mean wind speed due to wind disturbing structures must remain below 7 kt (3.6 m/s) along the aircraft trajectory at heights below 200 ft. The speed deficit change of 7 kt must take place over a distance of at least 100 m.
- The *"6-knot crosswind criterion"* - the variation in mean wind speed due to wind disturbing structures must remain below 6 kt across the aircraft trajectory at heights below 200 ft. The speed deficit change of 6 kt must take place over a distance of at least 100 m.
- The *"4-knot turbulence criterion"* - the standard deviation of wind speed must remain below 4kt at heights below 200 ft.

The instability which building-induced wake effects can cause to an aircraft is significantly reduced once the airplane has touched down (upon landing) or is at reasonable height (200 ft off the ground prior to landing). After touch-down, the aircraft has increased stability/support from contact with the runway pavement and above 200 ft, the consequences of a drop in altitude or a change in wind bank are considerably less and the pilot has increased latitude and hence time to correct for any unforeseen induced effects on the aircraft prior to touch-down.

Bankstown Airport is situated southwest of the Sydney CBD and comprises three runways (11R/29L, 11L/29R and 11C/29C) suitable for fixed wing aircraft movements and aeronautical facilities required for substantial rotary wing movements as well. Night operations on 11C/29C comprise approximately 2.5% of all movements.

In relation to the location of the proposed development, the wind directions deemed to have the greatest potential impact on the Runways are the winds originating from north-northeast (33.5°±22.5°).

The study of the current and post-development winds has been undertaken using a quantitative CFD analysis approach. The reference approach wind speed for this study is 20 kt at 10 m height taking into account the local exposure factors by wind direction. Crosswinds at and above 20 kt for the relevant northeast wind direction for the current study have zero frequency of occurrence.

- Bureau of Meteorology (BoM) records at Bankstown Airport, covering a 23-year period from 1999-2021 inclusive, show that, from the north-northeast (33.5°±22.5°), there were 0 hours where the mean wind speed exceeded 20 kt.

Assessments in the current report were made for the worst-case condition (ie covering all possible flight landing paths), starting from an altitude band of 30 m. The wind deficit at an altitude >30 m is negligible due to the proposed building's height and runway location. Offshoot landing is not analysed due to the location of the proposed building. The relationship distance-wise of the proposed development to the nearest Runway 11L can be seen in **Figure 1**.

While SLR's measurement positions did not cover the NASF-B *"900 m before the threshold and up to 500 m along the runways from the threshold at 100 m intervals"*, SLR assessed the results at more than 50 horizontal landing intervals to capture the worst-case scenario. The results (as confirmed by previous SLR studies) show that modelling a greater number of possible landing scenarios in areas where the wake occurs (for example conducting modelling along the runway at horizontal intervals of 25 m or 50 m is more critical than presenting the results between changes -900 m to +500 m. For example, the peak turbulence may not be captured if the results are presented every 100 m, subject to geometry, runway and building orientation.

The following major conclusions have been reached based on results of simulations for the critical wind directions and assessment of Bankstown Airport BoM Weather Station data.

The current study has involved the modelling of the following built environment "scenarios":

- "Current" - the existing built environment (as of September 2022) including recently approved developments. Refer **Figure 4A**
- "Post development - Proposed" - including Current + Proposed Development. Refer **Figure 4B and Figure 5**

Existing Wind Conditions

<u>Mean Wind Speed at 10 m Height</u>

- There were 0 hours where the mean wind speed exceeded 20 kt taking into account wind directions 33.5°±22.5° over the 23-year BoM record period.
- There were 8 hours per year where the mean wind speed exceeded 15 kt taking into account wind directions over the 23-year BoM record period.

Runway 11R/29L and Runway 11L/29R operate during daylight only from 06:00 hrs to 18:00 hrs while 11C/29C operates 24 hours a day. The occurrence of the exceedance for 15 kt is reduced to 6-7 hours per year when only daylight hours are included in SLR's assessment (refer **Section 3.2.1**)

<u>Turbulence Exceedance at the Anemometer Location</u>

- There were approximately 1,600 occasions during the 23-year BoM record period (69.5 per year) where natural turbulence exceeded 4-kt taking into account ALL wind directions.
- There were 2.5 occasions per year where natural turbulence exceeded 4-kt from winds orientating from 33.5°±22.5°.

It should be noted that while many of those exceedance "occasions" occurred on different days, some occurred in consecutive hours on the same day during the passage of major windstorm events.

Future Wind Conditions (Associated with the Post-Post Development Scenario)

The following major conclusions have been reached based on results of CFD simulations for the analysed wind directions:

Windshear – Approaching Wind Speed = 20 Knot at 10m above ground

- A number of warehouses and low-rise buildings are located to the northeast side of the runways.
- The variation in the mean wind speed for the existing and post development scenarios is either below 6 kt or impacted less than 100 m at a height below 60 m. The NASF-B windshear criterion is therefore not exceeded. due to the following:
  - Shape of the building (eg the building's dimension in line with the wind is greater than its width to significantly reduce the wake behind the building).
  - Relatively low building height (13.1 m)

Wind Turbulence – Approaching Wind Speed = 20 Knot at 10m above ground

- In the CFD modelling, the trees and vegetation surrounding the site were removed primarily to reduce computational time, noting that this removal makes the model slightly conservative as the addition of vegetation would typically reduce ground level wind speeds.
- The proposed development will have a minor impact on the peak turbulence levels taking into account 33.5°±22.5° wind directions.

11L

- Current Scenario: the turbulence criterion of 4 kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at an approaching wind of approximately 13.5 kt (wind angle = 33.8°) for the most critical wind direction.
- Post Development Scenario: the turbulence criterion 4kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at approaching wind of approximately 11.9 kt for the most critical wind direction (wind angle =33.8°).

11C

- Current Scenario: the turbulence criterion of 4 kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at approaching wind of approximately 15.2 kt for the most critical wind direction (wind angle = 33.8°).
- Post Development Scenario: the turbulence criterion of 4 kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at approaching wind of approximately 15.5 kt for the most critical wind direction (wind angle = 33.8°).

Summary Results

Results of simulations for the worst case scenario are summarised below.

Scenario	Are the NASF-B Compliance Criteria Satisfied ?		Runway 11L	Runway 11C
	Cross-Wind 6 kt	Turbulence 4 kt	No of Hours per Year Turbulence Criterion Exceeded 6 am - 6 pm	No of Hours per Year Turbulence Criterion Exceeded 6 am - 6 pm
Current	Yes	No	19[1,2]	0[1]
Post Development	Yes	No	21.6[1,2]	0[1]

Note 1: The results take into account 33.8±22.5° wind directions. Refer **Table 7** and **Table 8**

Note 2: Runway 11R/29L and Runway 11L/29R operate during daylight only from 06:00 – 18:00 while 11C/29C operates 24 hours

Recommendations

To mitigate building-induced wake turbulence, it's recommended to implement operational risk mitigation measures accepted by the airport operator and CASA when winds exceed 11.9 kt from the NNE (wind angle 33.8°± 22.5°).

The addition of the proposed development has a minor impact on the peak turbulence levels, ie it increases the peak turbulence level by ~0.9 kt for the worst-case scenario, taking into account all analysed wind directions.

Building (Northwest Hangar) Update

There have been some amendments to Northwest Hanger layout since the original assessments were carried out. The changes include cutting the office space associated with the Northwest Hangar as it fell within the public safety area.

SLR is of the opinion that the changes would not result in any changes to the conclusions of the report.

Table of Contents

Tables in Text

Figures in Text

Acronyms and Abbreviations

BAL	Bankstown Airport Propriety Limited
BoM	Bureau of Meteorology
CASA	Civil Aviation Safety Authority
NASF	National Aviation Safeguarding Framework
Kt	Knot (nautical mile per hour)
SLR	SLR Consulting Australia Pty Ltd

1.0 INTRODUCTION

SLR Consulting Australia Pty Ltd (SLR) has been commissioned by Bankstown Airport Proprietary Limited (BAL) to undertake a windshear and wake turbulence study for a proposed aviation facilities at the airport.

The proposed site is located at the northeastern side of the airport's main runways – refer **Figure 1**.

BAL has commissioned a quantitative Computational Fluid Dynamics (CFD) modelling assessment and report on the potential windshear and wake turbulence effects of the proposed development.

The main operational runway at Bankstown Airport is Runway 11C/29C. The runway is 1416 m in length and 30 m in width.

Runway 11L/29R has primary and secondary operations which operate both independently and in conjunction with Bankstown's main runway.

The southern Runway 11R/29L, at 1038 m in length and 23 m wide, is only suitable for single and small twin engine light aircraft such as Cessna 172, 206 and Piper aircraft.

Simulations for worst wind directions from the north-northeast (wind angle 33.5°±22.5°) have been modelled, given the position of the proposed development relative to typical landing zone range of Runways.

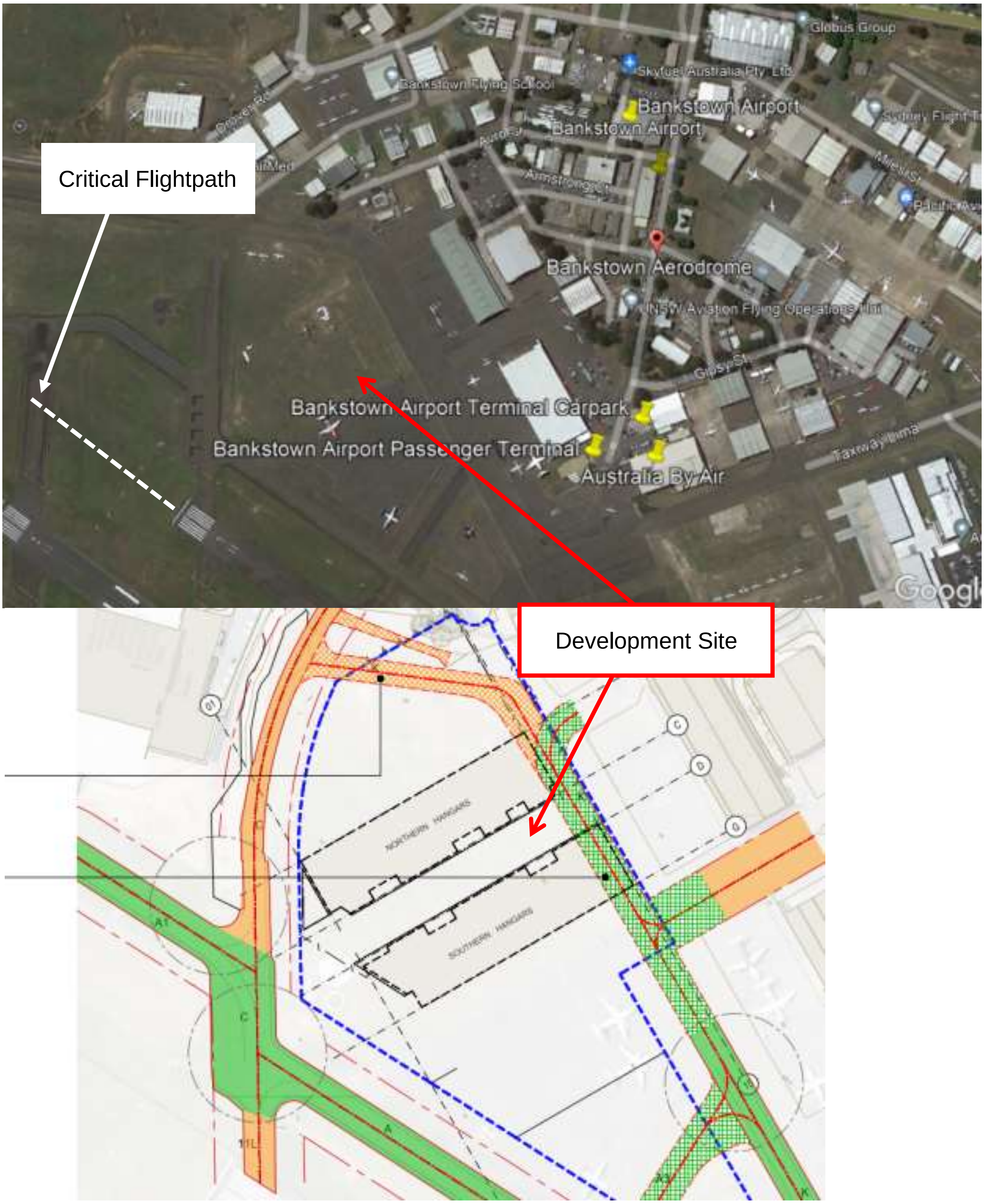
The objective of this study is to undertake a quantitative Computational Fluid Dynamics (CFD) analysis approach of current and post development for the most critical cross-wind directions.

1.1 Development Site

The design involves the development of a new aviation facility a total area of approximately 10,000 m^2 to the northeast of the runways.

- Two Hangers
- 13.15m to top of ridge on pitched roof.

Figure 1 Aerial View of Proposed Development Site



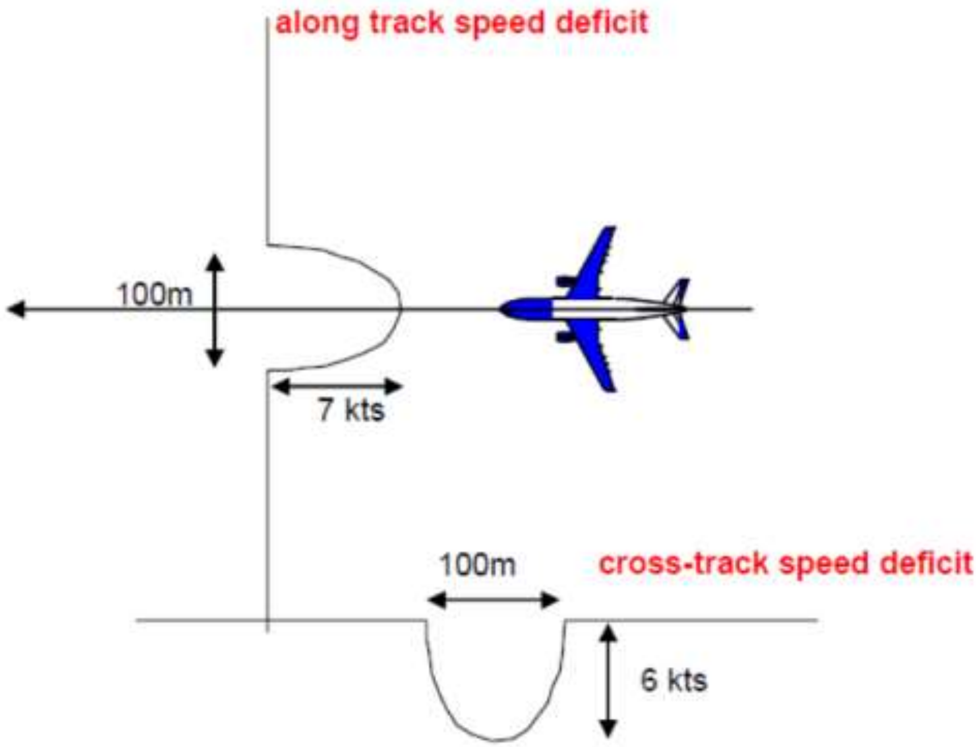
2.0 ACCEPTABILITY CRITERIA

2.1 The National Airports Safeguarding Framework (NASF) Guideline B - 2018

The assessment has been conducted in accordance with the National Airports Safeguarding Framework (NASF) Guideline B, 2018 – *Managing the Risk of Building Generated Windshear and Turbulence at Airports* specifically to address wind impacts on Bankstown Airport runways which state:

- The *"7-knot alongwind criterion"* - the variation in mean wind speed due to wind disturbing structures must remain below 7 kt (3.6 m/s) along the aircraft trajectory at heights below 200 ft. The speed deficit change of 7 kt must take place over a distance of at least 100 m.
- The *"6-knot crosswind criterion"* - the variation in mean wind speed due to wind disturbing structures must remain below 6 kt across the aircraft trajectory at heights below 200 ft. The speed deficit change of 6 kt must take place over a distance of at least 100 m.
- The *"4-knot turbulence criterion"* - the standard deviation of wind speed must remain below 4kt at heights below 200 ft.

Figure 2 NASF-B (2018) Windshear Criteria



3.0 LOCAL EXPOSURE OF THE SITE

3.1 Critical Wind Directions for the Site

Due to the relative position of proposed aviation facility to the runway direction, the cross-wind directions for the windshear and turbulence are between North (0º) and East (90º).

3.2 Bankstown Airport Bureau of Meteorology Data

3.2.1 Mean Wind Speed Exceedance

SLR has analysed long-term wind records at the Bankstown Airport Bureau of Meteorology (BoM) Weather Station site. This dataset contains records at hourly intervals of:

- Mean Wind Speed – average wind speed during the 60-minute period.
- Gust Wind Speed – peak 2-3 second gust occurring (anytime) within the 60-minute period.
- Wind Direction – average wind direction during the 60-minute period.

From this dataset, SLR has derived the occurrence of the exceedance for various wind speed levels at a 10 m reference height (which is close to the proposed building height) where the angle bandwidth is ±22.5°. This covers wind directions from 0° to 360° - refer **Table 1**.

Table 1 Mean Wind Speed Exceedances (Hours/5-Year Period) versus Wind Direction (all hours of the day)

10m ht MEAN Wind Speed (kt)	Wind Direction (±22.5°)								
	N 0°	NE 45°	E 90°	SE 135°	S 180°	SW 225°	W 270°	NW 315°	ALL
5	1912	3351	2807	4429	3171	3339	2794	3022	24825
10	313	1260	1356	2848	1481	902	1125	587	9872
15	37	62	107	862	443	173	390	173	2247
20	0	0	7	115	89	10	74	26	321
25	0	0	0	12	7	0	7	1	27

Table 1 shows the following:

All Wind Directions

- There were 27 hours total (5.2 per year) where the mean wind speed exceeded 25 kt taking into account ALL wind directions.
- There were 321 hours total (64 per year) where the mean wind speed exceeded 20 kt taking into account ALL wind directions.
- There were 2,247 hours total (449 per year) where the mean wind speed exceeded 15 kt taking into account ALL wind directions.

NE ±22.5°

- There were NO hours where the mean wind speed exceeded 25 kt.
- There were NO hours where the mean wind speed exceeded 20 kt.
- There were 62 hours (12 per year) where the mean wind speed exceeded 15 kt.

It should be borne in mind that the above "hours" of exceedance do not translate into the same number of discrete hourly "windstorm events". There were a number of occasions during the passage of extreme windstorm systems, when these exceedances occurred during consecutive hours on the same day, ie associated with the same windstorm.

One such example occurred during the passage of a strong low pressure system on 29 October 2013. The wind remained above 20 kt for a continuous 6-hour period between Noon and 6:00 pm that day. Accordingly, this one "event" accounted for 6 hourly exceedances of 20 kt.

The data shown in **Table 1** has been reproduced in **Table 2**, this time as an annual exceedance probability of occurrence. The following conclusions can be reached from **Table 1** and **Table 2**.

- The probability of a 20 kt or higher mean wind speed from the NE±22.5° is 0.0%.
- The probability of exceeding 15 kt from the NE ±22.5° is approximately 0.14%, ie a 1.4 in 1000 chance of exceeding 15 kt from that direction.

Table 2 Mean Wind Speed Exceedance Probability versus Wind Direction (all hours of the day)

10m ht MEAN Wind Speed (kt)	Wind Direction (±22.5°)								
	N 0°	NE 45°	E 90°	SE 135°	S 180°	SW 225°	W 270°	NW 315°	ALL
5	4.36%	7.65%	6.41%	10.11%	7.24%	7.62%	6.38%	6.90%	56.6%
10	0.71%	2.88%	3.09%	6.50%	3.38%	2.06%	2.57%	1.34%	22.5%
15	0.08%	0.14%	0.24%	1.97%	1.01%	0.39%	0.89%	0.39%	5.13%
20	0.000%	0.000%	0.016%	0.262%	0.203%	0.023%	0.169%	0.059%	0.732%
25	0.000%	0.000%	0.000%	0.027%	0.016%	0.000%	0.016%	0.002%	0.062%

Table 3 shows the annual number of movements at Bankstown Airport in 2014. Runway 11R/29L and Runway 11L/29R operate during daylight only from 0600hr to 1800hr while 11C/29C operates 24 hours per day. As per **Table 3**, the annual number of movements in 2014 was:

- 116,240 on Runway 11R/29L.
- 32,141 on Runway 11C/29C (with 804 movements occurring at night-time).
- 47,220 on Runway 11L/29R.

Table 3 Total Number of Movements at Bankstown Airport in 2014

Category	Movements	HLS	NWS	11L	11C	11R	29L	29C	29R
Fixed Wing	79,362			23.8%	16.2%			24.3%	35.7%
Fixed Wing Training	116,240					40%	60%		
Helicopters	26,217	100%							
Rescue Helicopters	1,360			30%	10%		20%		40%
Helicopter Training	6,377		100%						
TOTAL in 2014	**229,556**								

Table 3 shows that night-time activity at Runway 11C/29C is approximately 2.5% of all movements. Accordingly, the data shown in **Table 1** and **Table 2** have been reproduced in **Table 4** and **Table 5**, this time only for daylight hours.

Table 4 Mean Wind Speed Exceedances (Hours/5-Year Period) versus Wind Direction (Daylight Hours only)

10m ht MEAN Wind Speed (kt)	Wind Direction (±22.5°)								
	N 0°	NE 45°	E 90°	SE 135°	S 180°	SW 225°	W 270°	NW 315°	ALL
5	1288	1418	1584	2396	1690	1959	1792	2087	14214
10	242	644	907	1715	950	633	736	425	6252
15	35	44	90	605	315	129	304	155	1677
20	0	0	3	85	62	8	66	25	249
25	0	0	0	7	6	0	7	1	21

Table 5 Mean Wind Speed Exceedance Probability versus Wind Direction (Daylight Hours only)

10m ht MEAN Wind Speed (kt)	Wind Direction (±22.5°)								
	N 0°	NE 45°	E 90°	SE 135°	S 180°	SW 225°	W 270°	NW 315°	ALL
5	2.94%	3.24%	3.61%	5.47%	3.86%	4.47%	4.09%	4.76%	32.4%
10	0.55%	1.47%	2.07%	3.91%	2.17%	1.44%	1.68%	0.97%	14.3%
15	0.080%	0.100%	0.205%	1.381%	0.719%	0.294%	0.694%	0.354%	3.83%
20	0.000%	0.000%	0.007%	0.194%	0.141%	0.018%	0.151%	0.057%	0.568%
25	0.000%	0.000%	0.000%	0.016%	0.014%	0.000%	0.016%	0.002%	0.048%

Table 4 and **Table 5** show the following:

ALL Wind Directions

- There were 21 hours total (4.2 per year) where the mean wind speed exceeded 25 kt.
- There were 249 hours total (50 per year) where the mean wind speed exceeded 20 kt.
- There were 1,667 hours total (333 per year) where the mean wind speed exceeded 15 kt.

NE ±22.5°

- There were NO hours where the mean wind speed exceeded 25 kt.
- There were NO hours where the mean wind speed exceeded 20 kt.
- There were 44 hours (8.8 per year) where the mean wind speed exceeded 15 kt.

With regard to the limits of the approaching wind speed, SLR has been advised that there are practical aspects of the runways becoming inoperable in high cross-winds at and above 25 kt.

3.2.2 Natural and Existing Built Environment Turbulence Exceedance

SLR's analysis of the Bankstown Airport Bureau of Meteorology (BoM) Weather Station data has yielded the annual exceedance characteristics of 4 kt turbulence shown in **Table 6** and **Figure 3**

ALL Wind Directions

- There were 66 hours per year where 4 kt turbulence was exceeded. While many of those exceedances occurred on different days, some would have occurred in consecutive hours during the passage of major windstorm events.

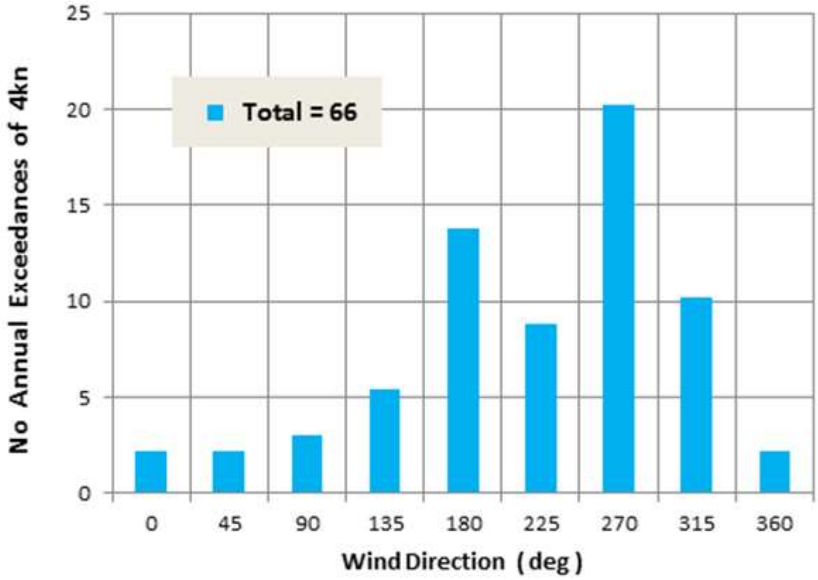
NE ±22.5°

- There were 2 hours per year where 4 kt turbulence was exceeded. Again, in any one year, these may have occurred on consecutive hours during the passage of a major windstorm event.

Table 6 4-knot Turbulence Exceedance Probability versus Wind Direction

Annual Exceedances	Wind Direction (±22.5°)								
	N 0°	NE 45°	E 90°	SE 135°	S 180°	SW 225°	W 270°	NW 315°	ALL
No / Year	2.2	2.2	3.0	5.4	13.8	8.8	20.2	10.2	65.8
%age	0.025%	0.025%	0.034%	0.062%	0.158%	0.100%	0.231%	0.116%	0.025%

Figure 3 4 knot Turbulence Exceedance Probability in 1-Year – Bankstown Airport BOM Weather Data



4.0 CFD MODELLING, ASSUMPTIONS AND ANALYSIS

SLR has modelled the proposed development and the surrounds using the Creo Parametric software package. This was then imported to ANSYS to prepare the model for solving.

The surrounding buildings and airport runways were included in the study. The model was then moved to the specialised world leading CFD software ANSYS-FLUENT for computation.

Ambient wind profiles have been created for all critical wind directions.

Wind speeds were then determined at the runways relative for the current and post development scenarios.

4.1 Modelling

A 3D model of the development area and surrounding buildings was created from sketches and 2D AutoCAD files supplied by RP Infrastructure (received 23/09/2023).

The geometry for CFD Modelling is shown in **Figure 4** to **Figure 6.** The developed model accounts for all small features of the proposed development (eg parapet, plant rooms, gaps, etc).

SLR has also reviewed the survey data for the areas of interest. The available survey data for the proposed development site has shown elevated ground at the areas of interest. All complex topographic features are also included in the current and post development scenarios (Refer **Figure 4**).

A calculation domain of 2,200 m length, 2,744 m wide and 400 m high was used for the CFD analysis.

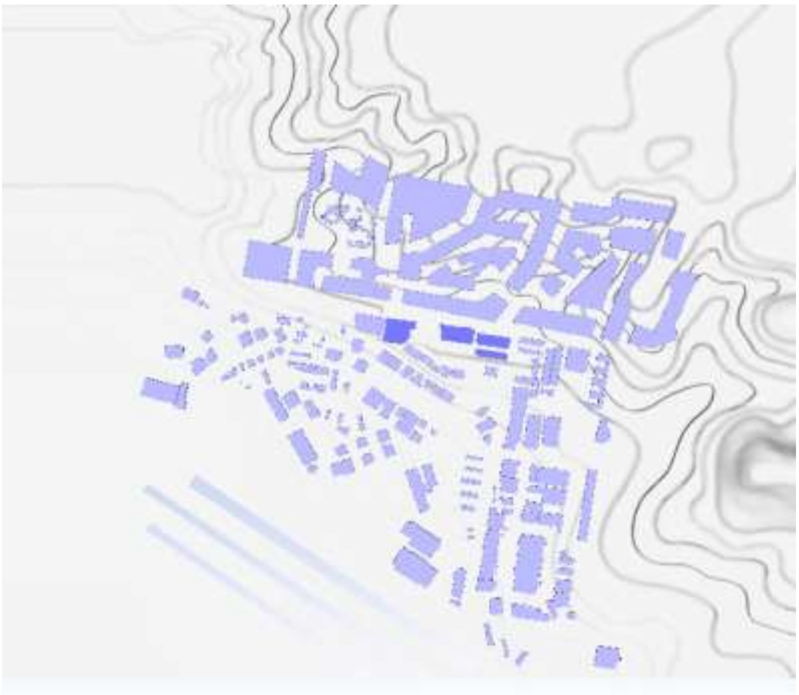
4.2 Wind Condition

The results in the following sections are presented for a reference approach wind speed of 20 kt at 10 m height taking into account the local exposure factors by wind direction.

SLR's analysis of Bankstown Airport Bureau of Meteorology (BoM) Weather Station data shows that there were 0 hours total (refer **Table 1**) where the mean wind speed exceeded 20 kt from the relevant critical wind direction of 33.5°±22.5°. The results in this study will be presented for the worst-case wind conditions.

At the upwind free boundary inlet, velocity profiles were derived from the Australian Wind Code, AS1170.2. For example, the approaching wind speed is 20 kt at 10 m height with a vertical profile determined by the surrounding terrain in accordance with the Terrain Category classification contained in the Code. The effect of terrain roughness on wind speed is then used to obtain the variation in wind speed with height.

Figure 4 Development Site and Surrounds



A: EXISTING

B: POST DEVELOPMENT

Figure 5 3D Model of the Site and Surrounds Including Modelled Site Topography

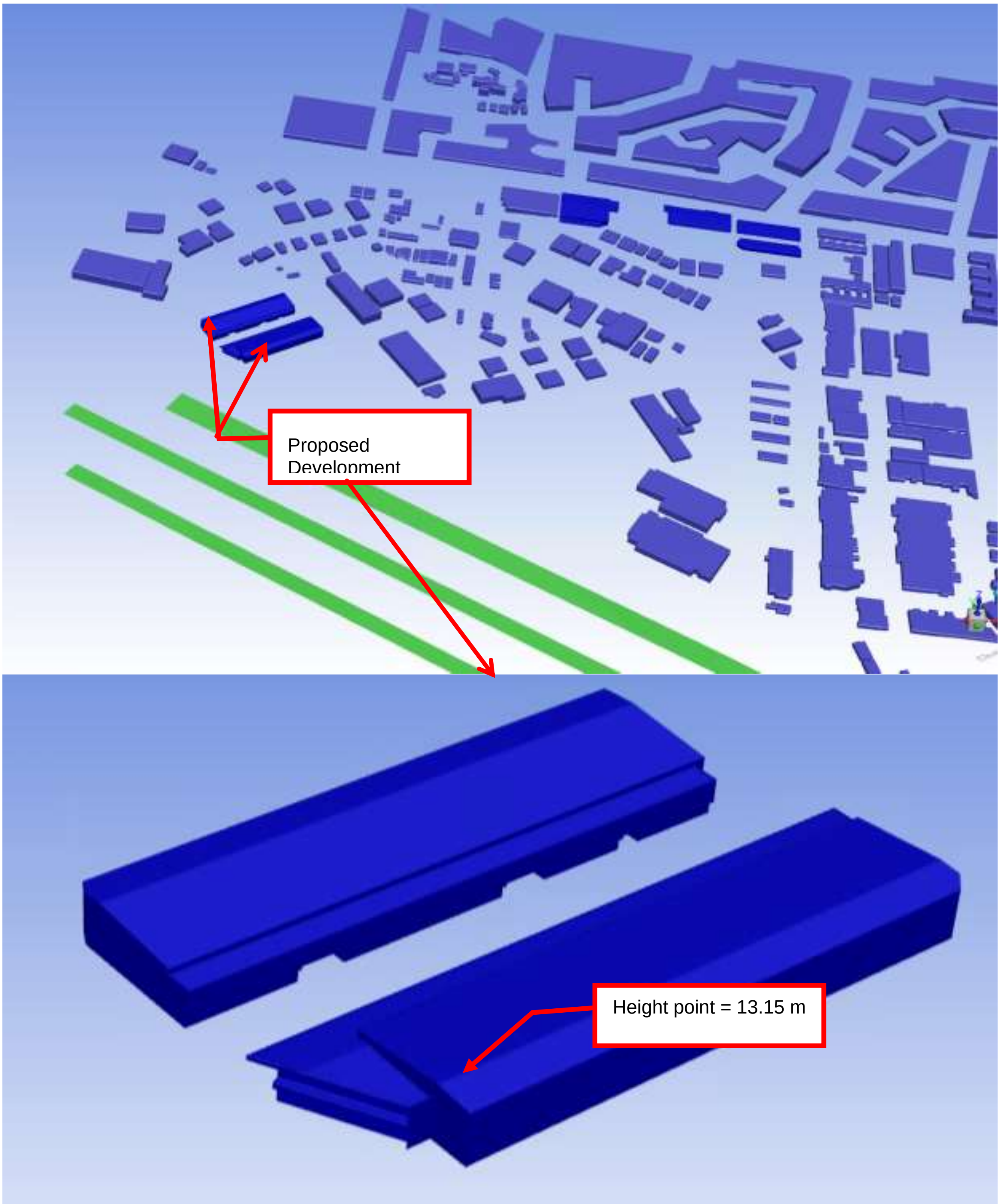
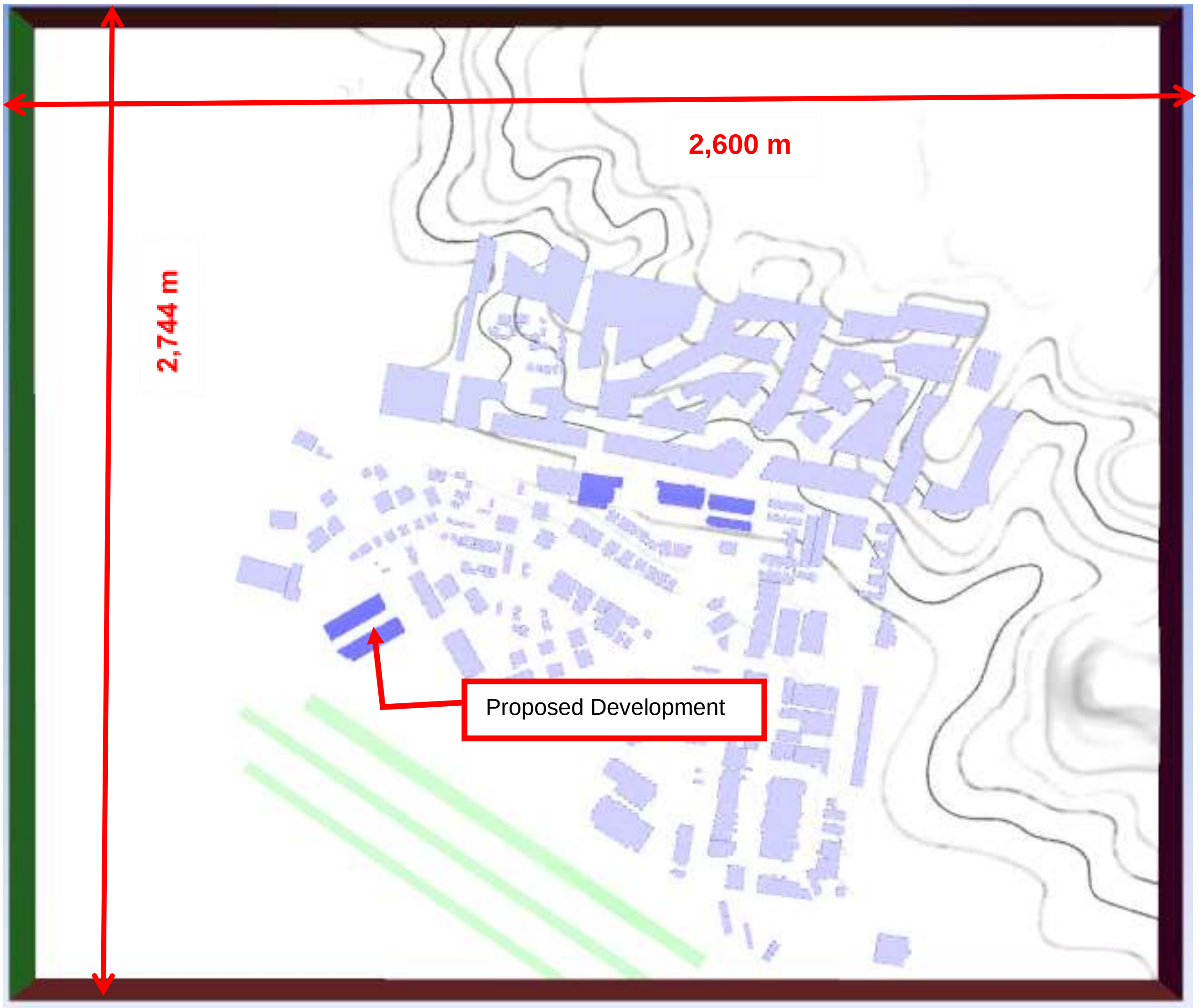


Figure 6 3D Model of the Proposed Development



4.3 Turbulence Model

For the current study, SLR used an advanced Delayed Detached Eddy Simulation (DDES) turbulence model to capture the unsteadiness arising from turbulence for a number of critical wind directions.

- The proposed DDES (hybrid modelling mythology) approach combines the benefits of Reynolds-averaged Navier–Stokes equations (or RANS equations) and LES while minimising their disadvantages
- While the RANS (Realizable k-epsilon in this study) can achieve good prediction for attached boundary layers, LES can capture unsteady motions of large eddies in separated regions.
- The DDES can also be coupled with different turbulence model (eg SST k-omega, Spalart - Allmaras, etc).

This approach is significantly more reliable than the RANS approach for the turbulence prediction. However, it is important to understand that the DDES method is substantially more computationally demanding than RANS simulations. SLR has used a very small time step in the order of 0.1 sec to provide an adequate temporal resolution of the flow as it passes through each cell at the area of the interest.

It is anticipated that the DDES may generate a more conservative turbulence data near the ground when compared to LES.

4.4 Discretization

The quality of the mesh is a critical aspect of the overall numerical simulation and it has a significant impact on the accuracy of the results and solver run time.

A mesh sensitivity assessment has been carried out for the current and post development scenarios. A procedure has been developed to adopt very fine meshes at areas of interest including site topography and analysed flight paths.

For all cases in this study, polyhedral elements with a total number of 27,071,370 nodes for the post-development scenario and 29,076,570 nodes for the current scenario were used to cover the computational domain. This is significantly higher than the number of cells typically used in RANS CFD Wind Studies.

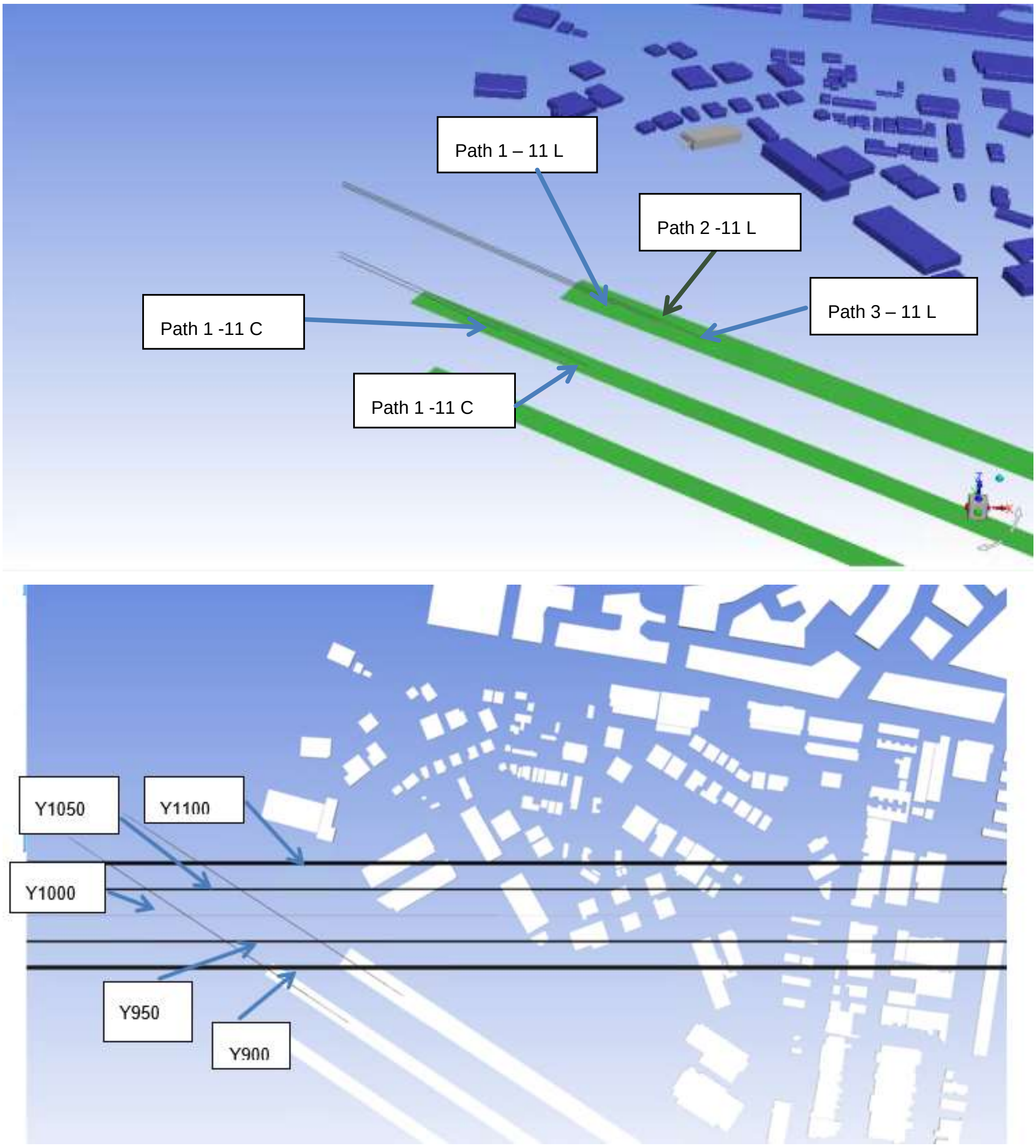
Polyhedral cells are especially beneficial for handling recirculating flows and used to provide more accurate results than even hexahedra mesh. For a hexahedral cell, there are three optimal flow directions which lead to the maximum accuracy while for a polyhedron, with 12 faces, there are six optimal directions which, together with the larger number of neighbours, lead to a more accurate solution with a lower cell count.

5.0 RESULTS AND DISCUSSION

5.1 Runway Modelling

The flight path glide angle for landing can vary between 2.7 degrees and 4 degrees, with 3 degrees considered as the average. Three critical landing scenarios per runway with an approaching angle of 3 degrees are analysed in this study – refer **Figure 7**. Offshoot landing is not analysed due to location of the proposed building.

Figure 7 Possible Landing Scenarios for a 3° Glide Landing Path



5.2 Wind Directions Analysed

Due to the relative position of buildings to the runway direction, the following wind directions for the windshear and turbulence are analysed in this study:

- Northeast Wind = 33.8^o (wind perpendicular to Runways)
- North-Northeast Wind = 33.8-22.5 = 11.3^o
- East-Northeast Wind = 33.8+22.5 = 56.3^o

5.3 Wind Angle: East-Northeast (33.5°)

5.3.1 Windshear Assessment

Figure 8 shows the velocity vector results of the CFD simulations at CFD Model RL 10m. Dark blue represents still conditions at 0 m/s and red representing the strongest wind speed. The following conclusions can be reached from the above figure:

- The CFD model captures the fluid flow characteristics in significant detail. Wind is approaching the site from the north northeast at 33.8^o as per the given boundary condition. Wind is then accelerated near the edges and stagnated and recirculated behind the buildings.
- The localised impact of the proposed development is shown in **Figure 8B**.
- There is a minor variation in wind speeds along the width of the runways.
- A comparison for the windshear shows that the proposed development will have a minor impact at the runways and that disturbance to the approaching mean wind speed is localised due to the size of the proposed building, eg building height = 13.15 m.

The cross-wind variation in mean wind speed due to wind disturbing structure must remain below 6 kt along the aircraft trajectory at a height below 200 ft (60 m). The speed change of 6 kt must take place over a distance of at least 100 m (NASF-B, 2018). The aircraft instability is significantly reduced once the airplane has touched down or is above 200 feet off the ground after take-off.

A comparison for the wind along the aircraft trajectory for the above paths is shown in **Figure 9** and **Figure 109**. The following comments are made with regards to the above graphs:

- The graphs present the results at variable height of the aircraft trajectory (3-degree glide path).
- The presentations are made for the worst-case condition, starting from an altitude band of 30 m or similar with the focus on the impacted areas. The mean wind speed deficit at an altitude >30 m is negligible due to the building's height and runway's relative locations.
- The windshear calculation is based on the normal component of the approaching wind.

The following clarifications are provided with regards to **Figure 9**:

- Runway 11L starts at position Y=935m for flight path 1 – the aircraft lands at position 885m for flight path 1-11L.
- The approaching mean wind speed at 10 m above ground is 20 kt. Wind speed increases with height. The presented results accounts for site topography and shielding from the surrounding buildings.

- Impact of the existing built environment is captured by the CFD model (Refer **Figure 9A**).
- The highest mean wind speed deficit is obtained at the wake of buildings (existing and/or proposed development).
- The mean wind speed at the ground = 0. All tested points in Figure 10 are located above ground.

The following conclusions can be reached from **Figure 9** to **Figure 10**:

- The variation in the mean wind speed for the existing and post development scenarios is either below 6 kt or impacted less than 100m at a height below 60 m. The NASF-B windshear criterion is therefore not exceeded.

Figure 8 Velocity Vector (m/s) at CFD Model RL 10 m - DDES Turbulence Model, Approaching Wind = 20 Knot, Wind Angle = 33.8°

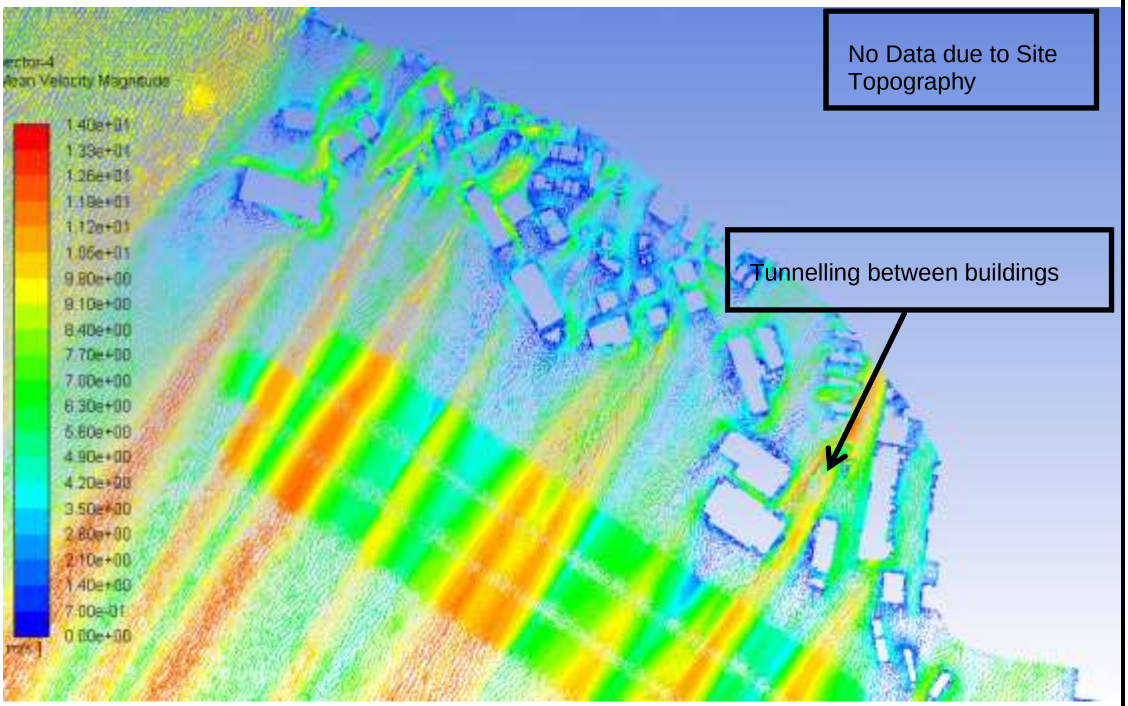
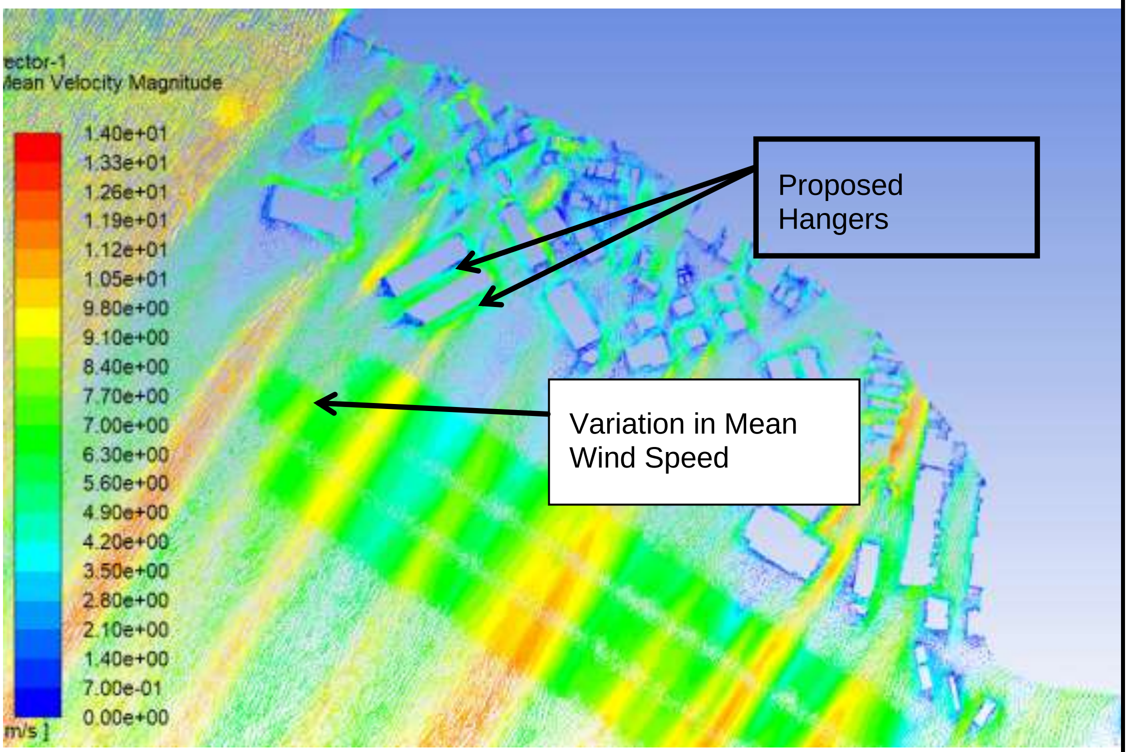
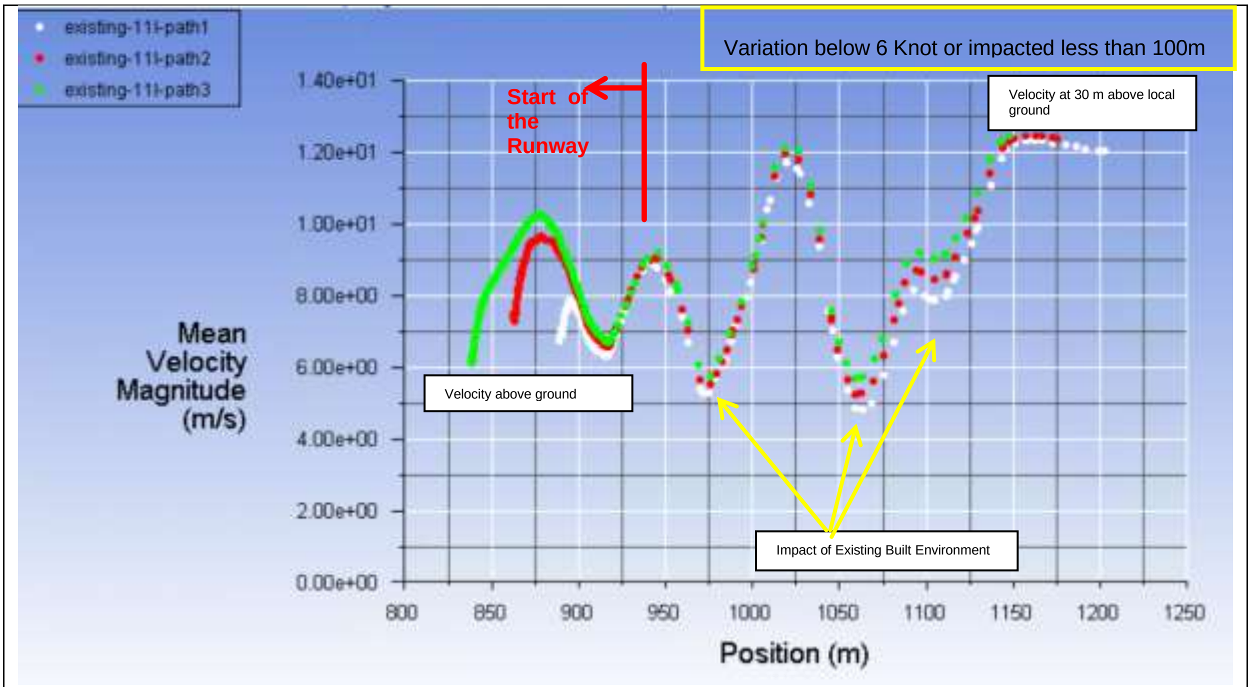
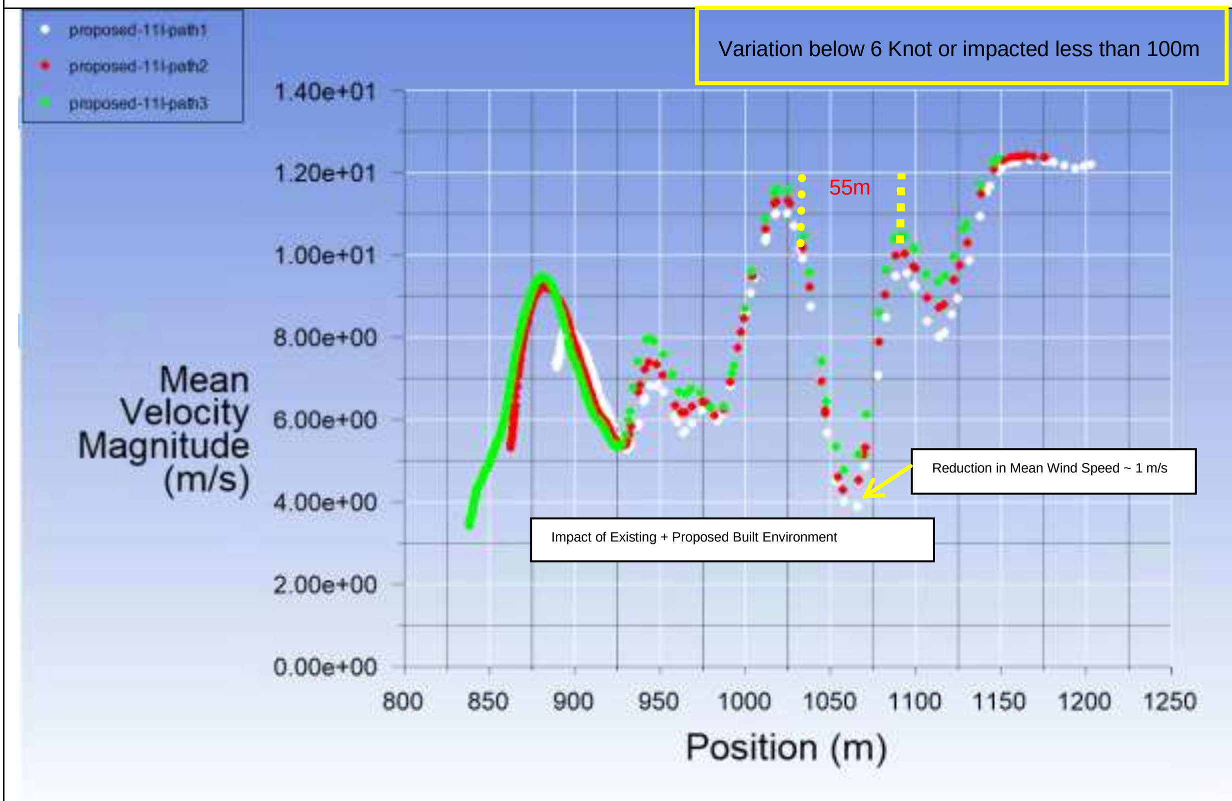
A: Current	
B: Post Development	

Figure 9 Comparison of the Normal Velocity Component (m/s) – Runway 11 L (DDES Turbulence Model, Approaching Wind = 20 Knot, Wind Angle = 33.8°)

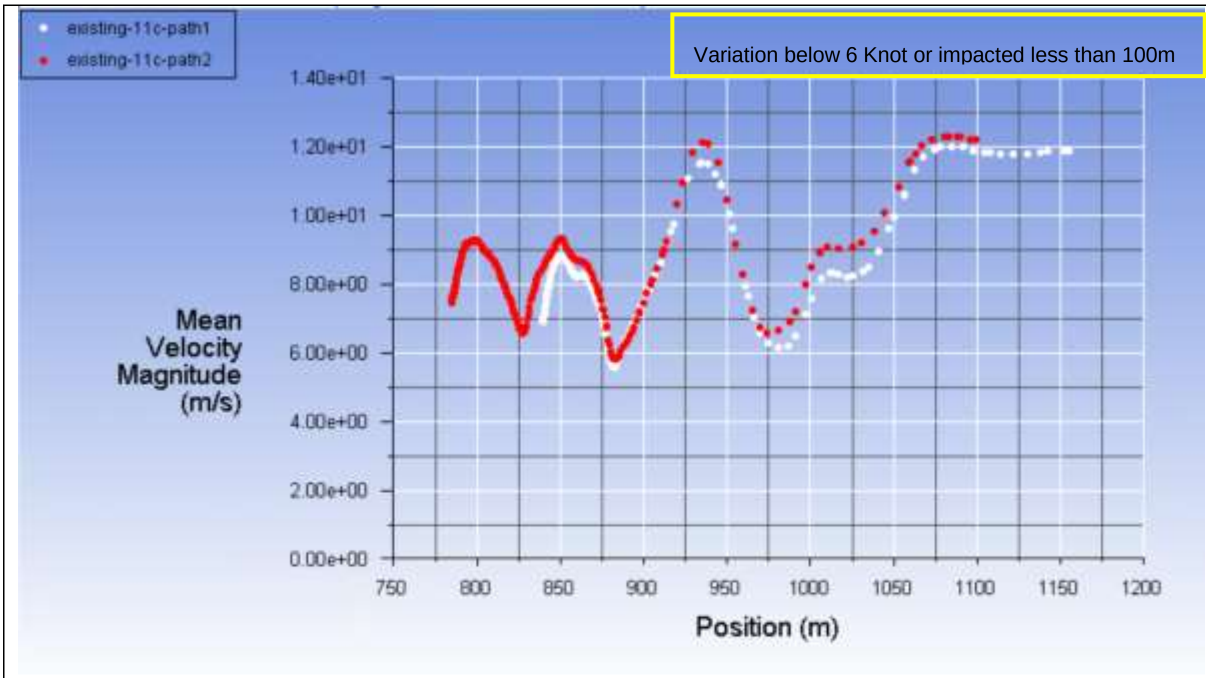


A: Current

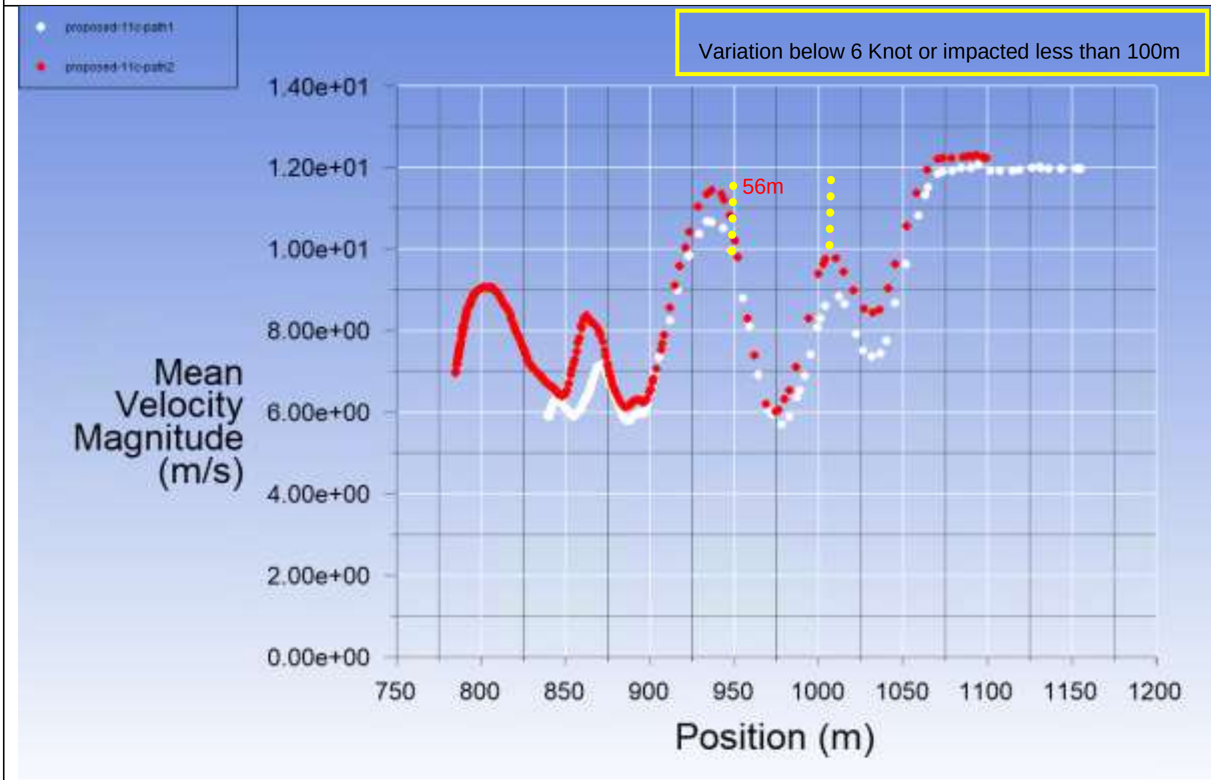


B: Post Development

Figure 10 Comparison of the Normal Velocity Component (m/s) – Runway 11C (DDES Turbulence Model, Approaching Wind = 20 Knot, Wind Angle = 33.8°)



A: Current



B: Post Development

5.3.2 Turbulence Assessment

The NASF Guideline B, 2018 adopts the NLR additional turbulence criteria:

- The "4-knot turbulence criterion" – i.e. the standard deviation of wind speed must remain below 4 kt at heights below 200ft.

The turbulence or root-mean-square (RMS or σ_V) value along the aircraft trajectory for the flight paths is predicted using the following relationship.

$$\sigma_V = \sqrt{\frac{\sum(V - \bar{V})^2}{N}}$$

where V = instantaneous wind speed

$\bar{V}$ = mean wind speed

N = no of samples

SLR assumes that the criterion is triggered if 4 kt is exceeded at any point along the aircraft trajectory for the analysed flight paths.

The results of the simulations for turbulence level are shown in **Figure 10** and **Figure 11**.

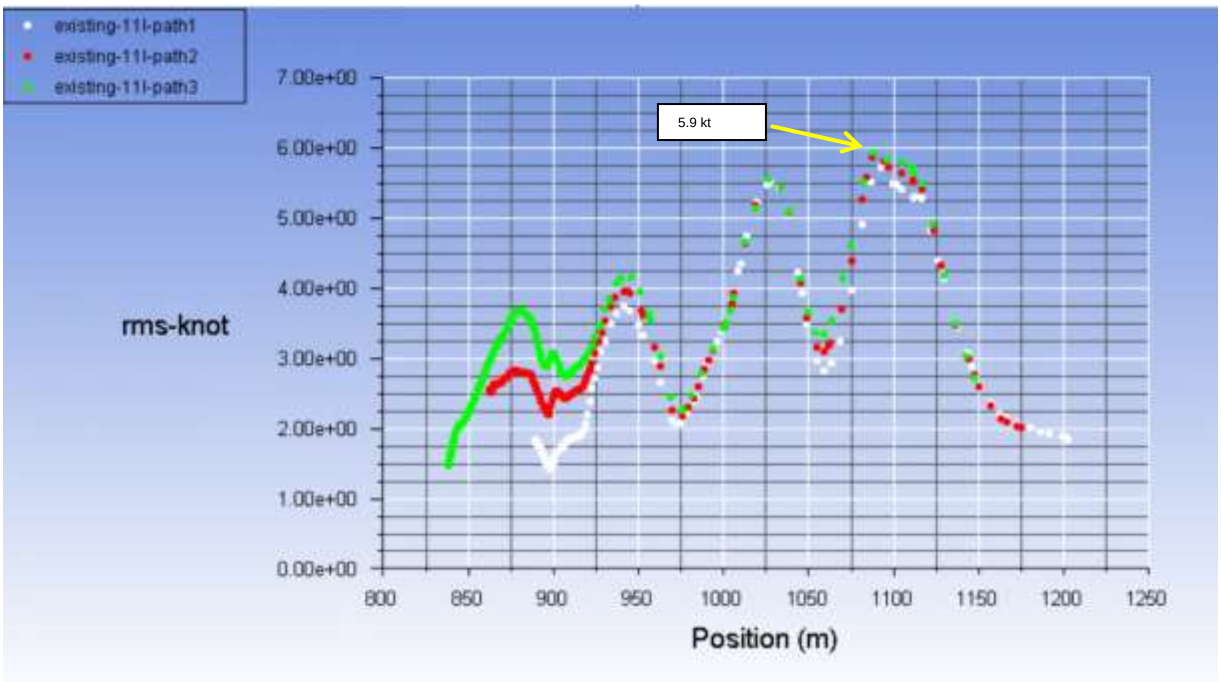
Runway 11 L

- The peak RMS (standard deviation or turbulence) is above the 4 kt for an approaching wind of 20 kt at 10 m above ground for the current and post development scenarios.
- The peak localised (instantaneous) turbulence for the existing scenario is 5.9 kt and the averaged turbulence over a distance of 100 m spanning the peak is below 4 kt.
- The location of the peak turbulence changes due to the addition of the proposed building.
- The peak localised (instantaneous) turbulence for the post development is 6.8 kt and the averaged turbulence over a distance of 100 m spanning the peak is below 4 kt.
- The peak turbulence is increased by 0.9 kt due to the addition of the proposed development.

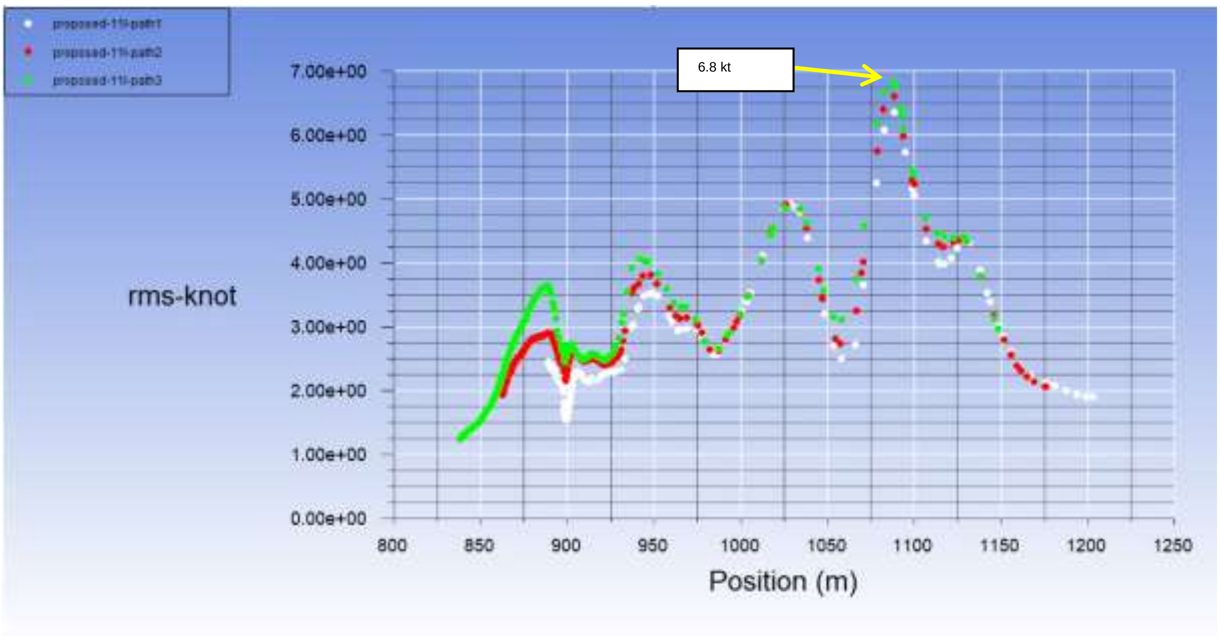
Runway 11 C

- The peak localised (instantaneous) turbulence for the existing and proposed scenarios is 5.25 kt and 5.15 kt, respectively.

Figure 11 RMS (Standard Deviation) Value in Knot across the Aircraft Trajectory at Runway 11L – DDES Turbulence Model (Approaching Wind = 20 Knot at 10 m above Ground, Wind Angle =33.8°)

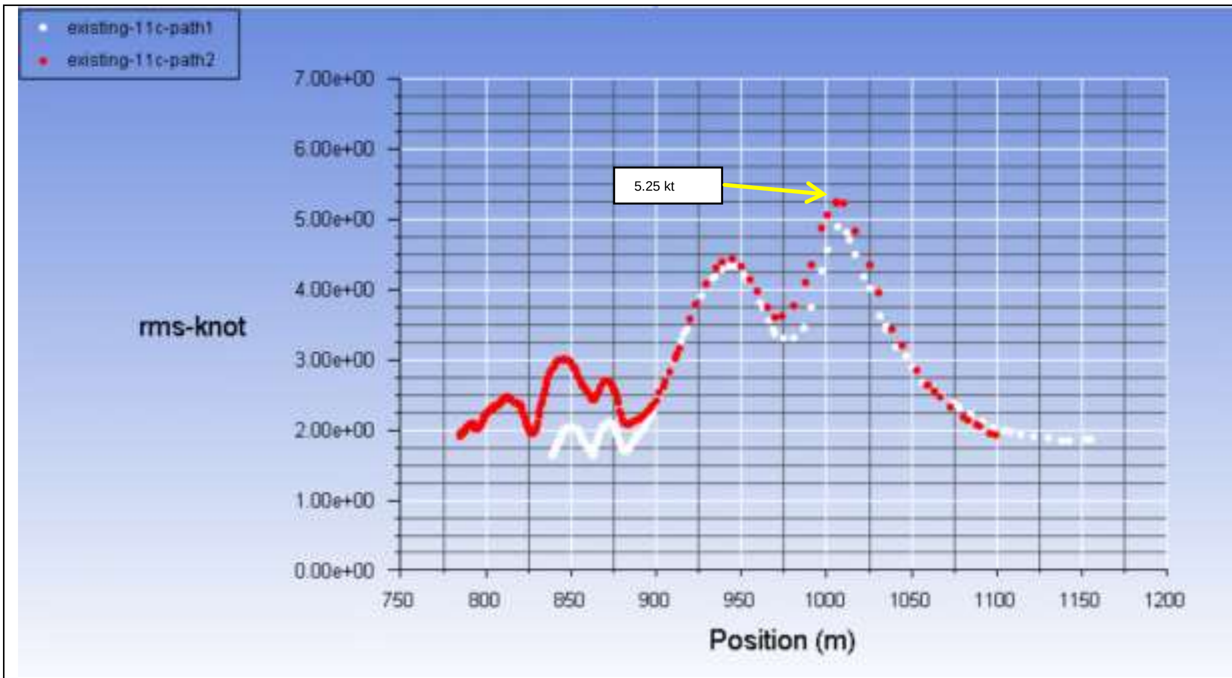


A: Current

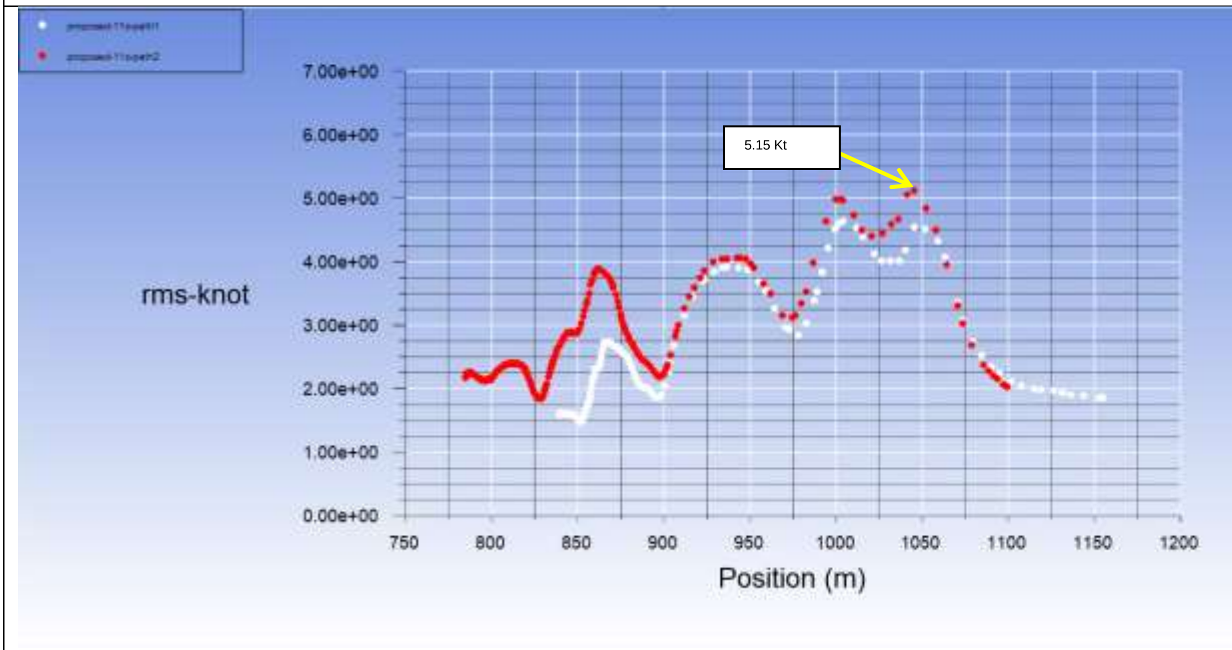


B: Post Development

Figure 12 RMS (Standard Deviation) Value in Knot Across the Aircraft Trajectory for Runway 11C– DDES Turbulence Model (Approaching Wind = 20 Knot at 10 m above Ground, Wind Angle =33.8°)



A: Current



B: Post Development

5.4 Wind Angle: North-Northeast(11.3°)

Figure 13 shows the wind speeds on 0-14 m/s colour coded scales.

- The CFD model captures the fluid flow characteristics in significant detail. Wind is approaching the site from the NNE at 11.3º as per the given boundary condition. Wind is then accelerated near the edges and stagnated and recirculated behind the buildings.
- There is approximately 2 m/s reduction in the mean speed at 11 L Runway.
- The localised wake behind the proposed facility is shown in **Figure 13B**.

5.4.1 Windshear Assessment

A comparison for the wind along the aircraft trajectory for the flight paths in **Figure 8** is shown in **Figure 14** and **Figure 15**. The following conclusions can be reached from the above figures:

- The variation in the mean wind speed for the existing and post development scenarios is either below 6 kt or impacted less than 100m at a height below 60 m. The NASF-B windshear criterion is therefore not exceeded.

5.4.2 Turbulence Assessment

The turbulence or root-mean-square (RMS) value along the aircraft trajectory for the flight paths in **Figure 8** are shown in **Figure 16** and **Figure 17**.

Runway 11 L

- The peak RMS (standard deviation or turbulence) is above the 4 kt for an approaching wind of 20 kt at 10 m above ground for the current and post development scenarios.
- The localised (instantaneous) turbulence for the existing and post development condition is 5.25kt.
- The averaged turbulence over a distance of 100 m spanning the peak is below 4 kt.

Runway 11 C

- The peak RMS (standard deviation or turbulence) is above the 4 kt for an approaching wind of 20 kt at 10 m above ground for the current and post development scenarios.
- The localised (instantaneous) turbulence for the existing scenario is 4.35 kt and the averaged turbulence over a distance of 100 m spanning the peak is below 4 kt
- The localised (instantaneous) turbulence for the post development is 4.25 kt and the averaged turbulence over a distance of 100 m spanning the peak is below 4 kt
- The peak turbulence is slightly reduced by 0.1 kt at the most impacted are due to the edition of the proposed development.

Figure 13 Velocity Vector (m/s) at RL 10 m - DDES Turbulence Model, Approaching Wind = 20 Knot, Wind Angle = 11.3°

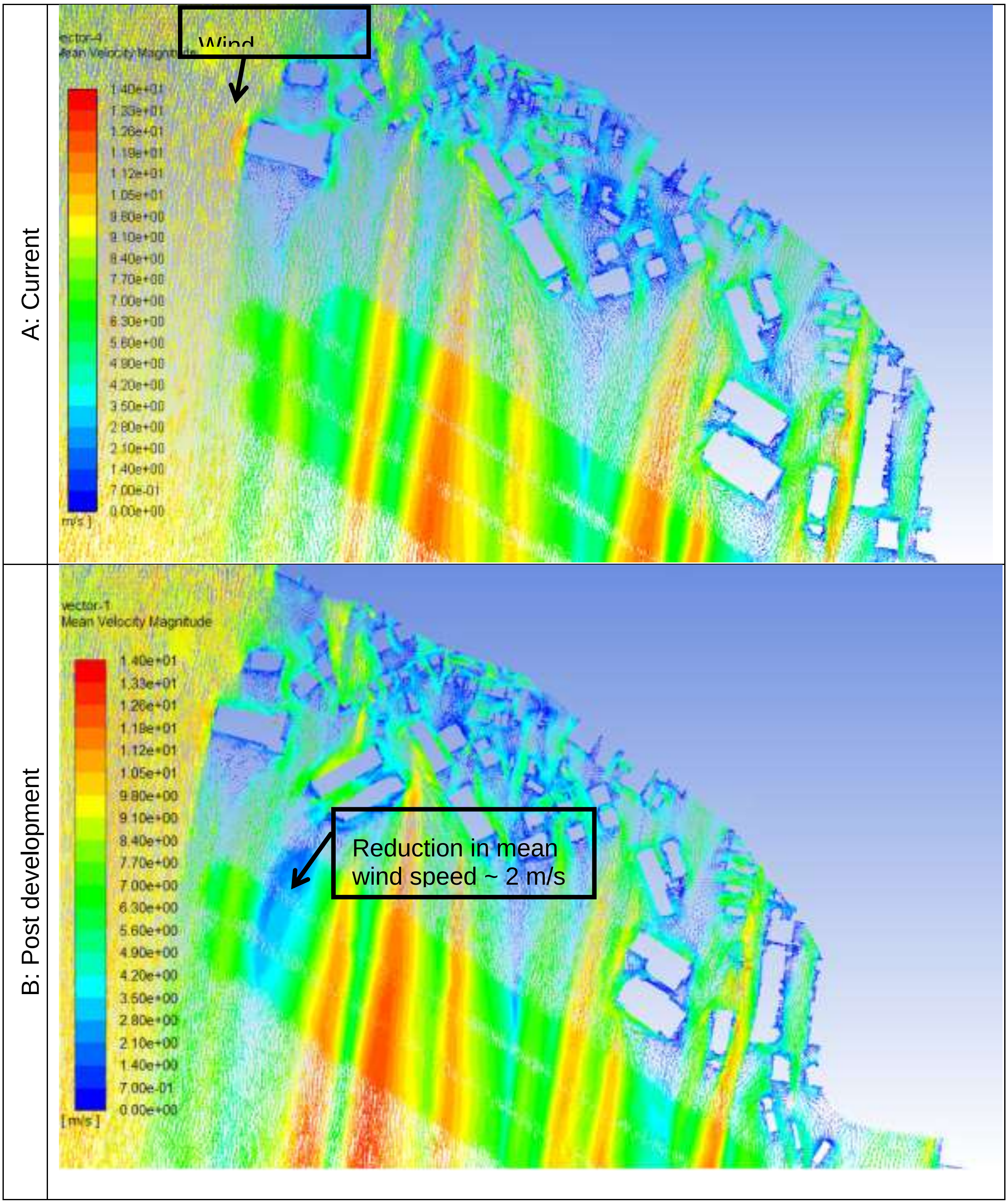
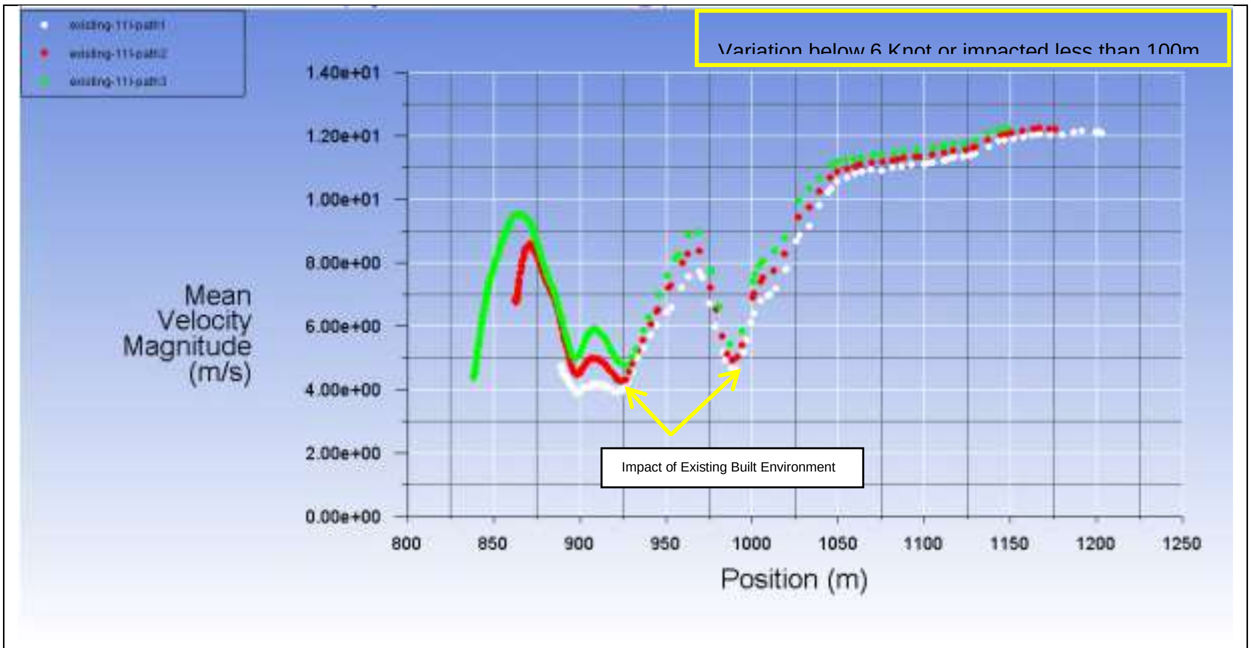
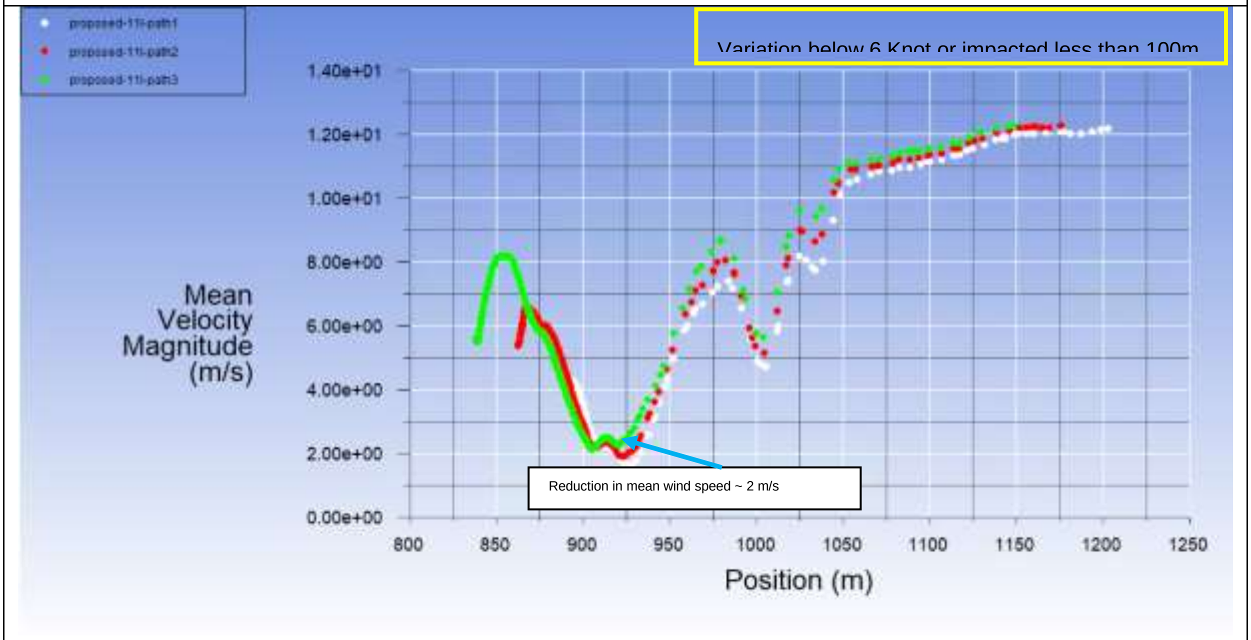


Figure 14 Comparison of the Normal Velocity Component (m/s) – Runway 11 L (DDES Turbulence Model, Approaching Wind = 20 Knot, Wind Angle = 11.3°)

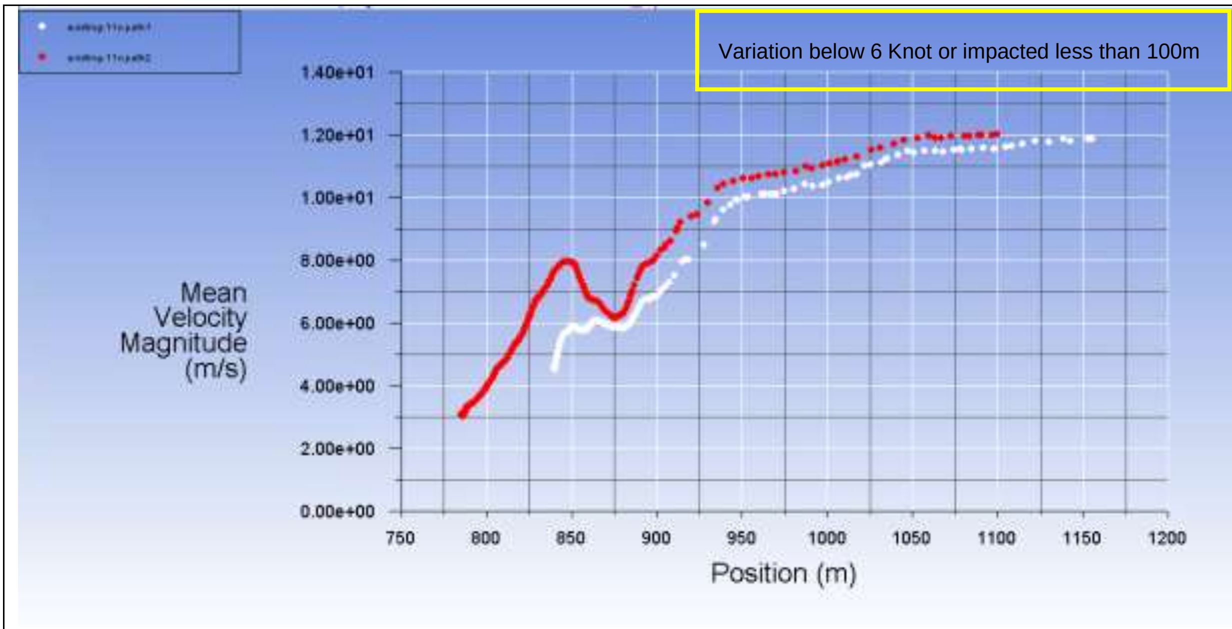


A: Current

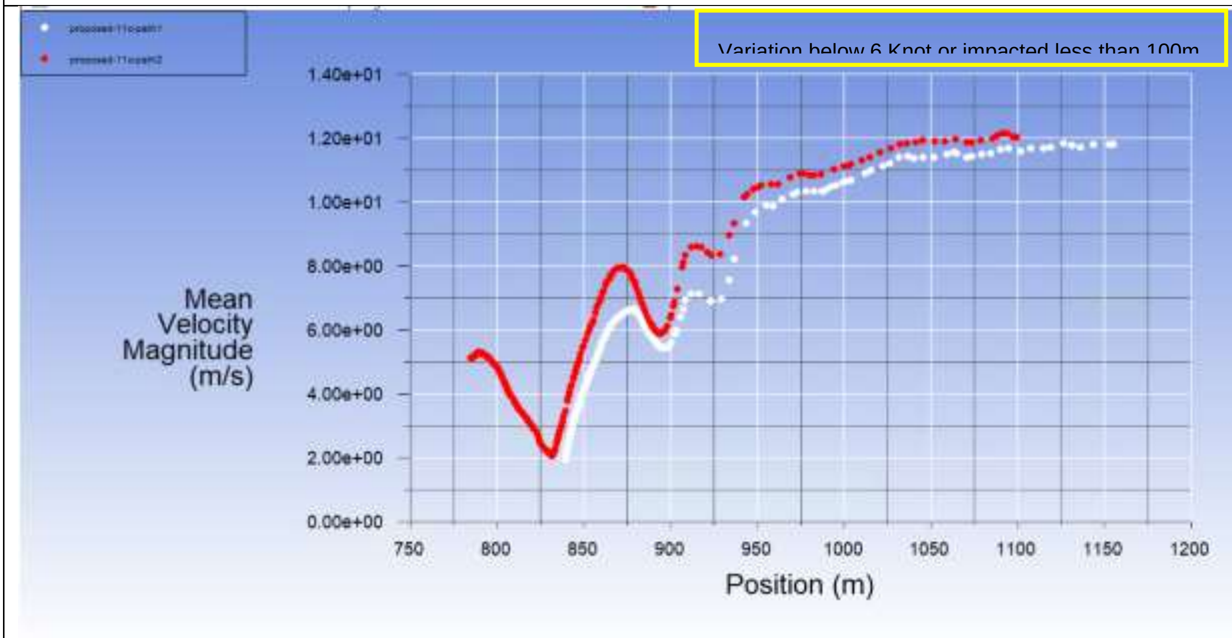


B: Post Development

Figure 15 Comparison of the Normal Velocity Magnitude (m/s) – Runway 11C – (DDES Turbulence Model, Approaching Wind = 20 Knot, Wind Angle = 11.3°)

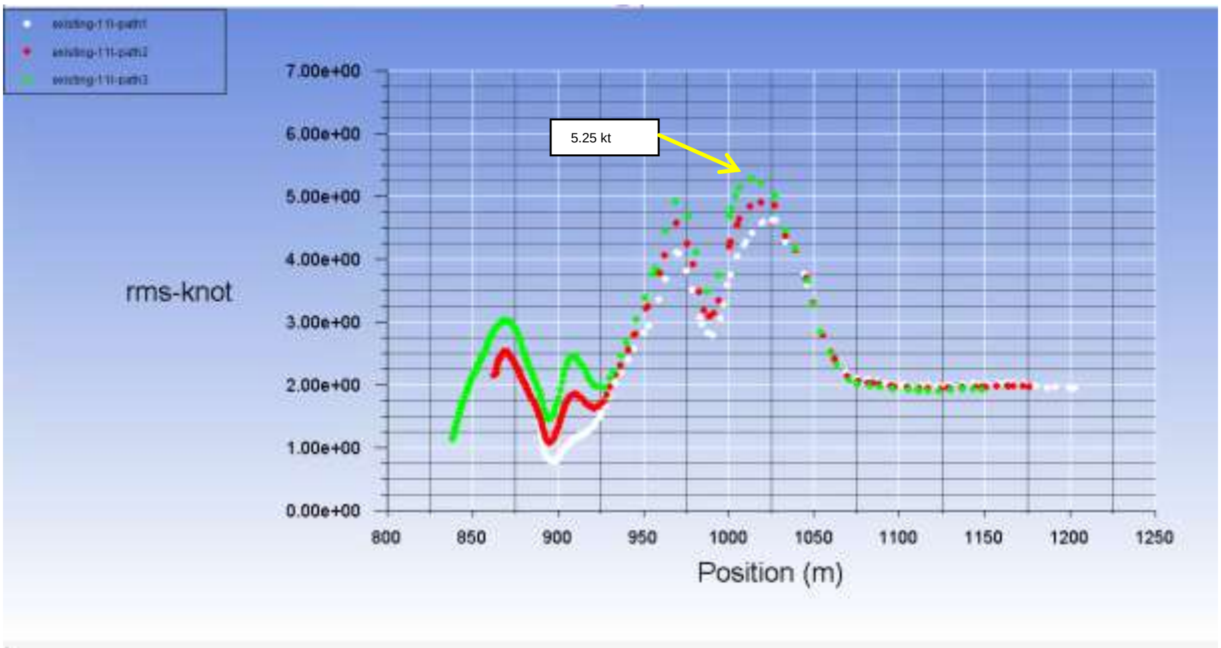


A: Current

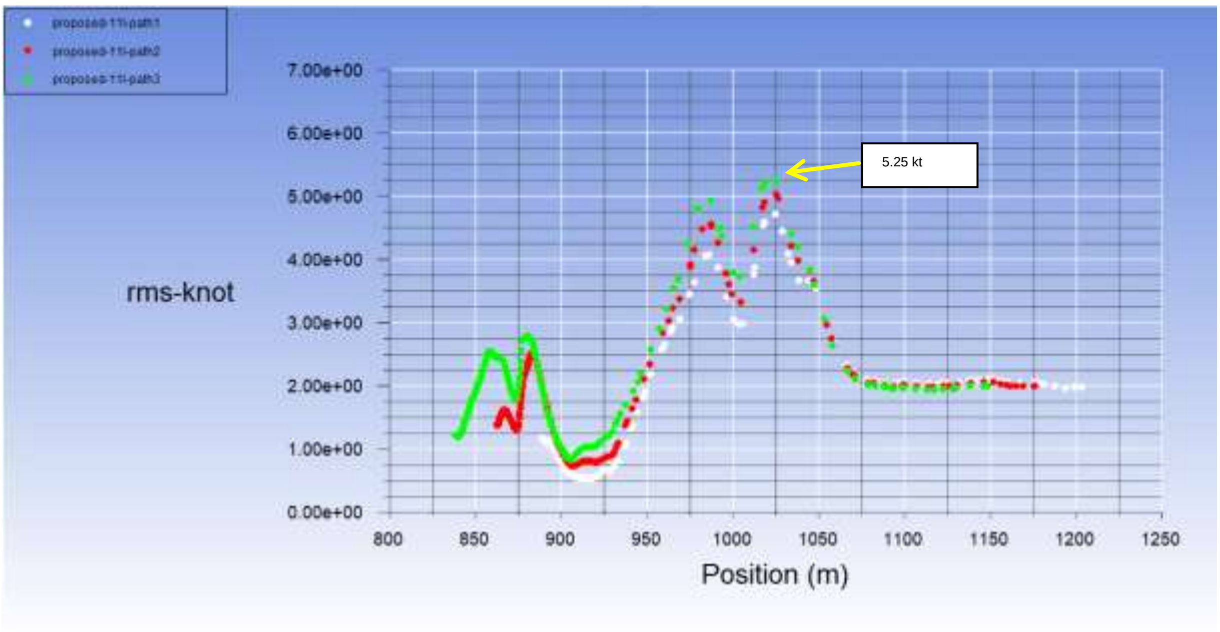


B: Post Development

Figure 16 RMS (Standard Deviation) Value in Knot across the Aircraft Trajectory at 11 L Runway – DES Turbulence Model (Approaching Wind = 20 Knot at 10 m above Ground, Wind Angle =11.3°)

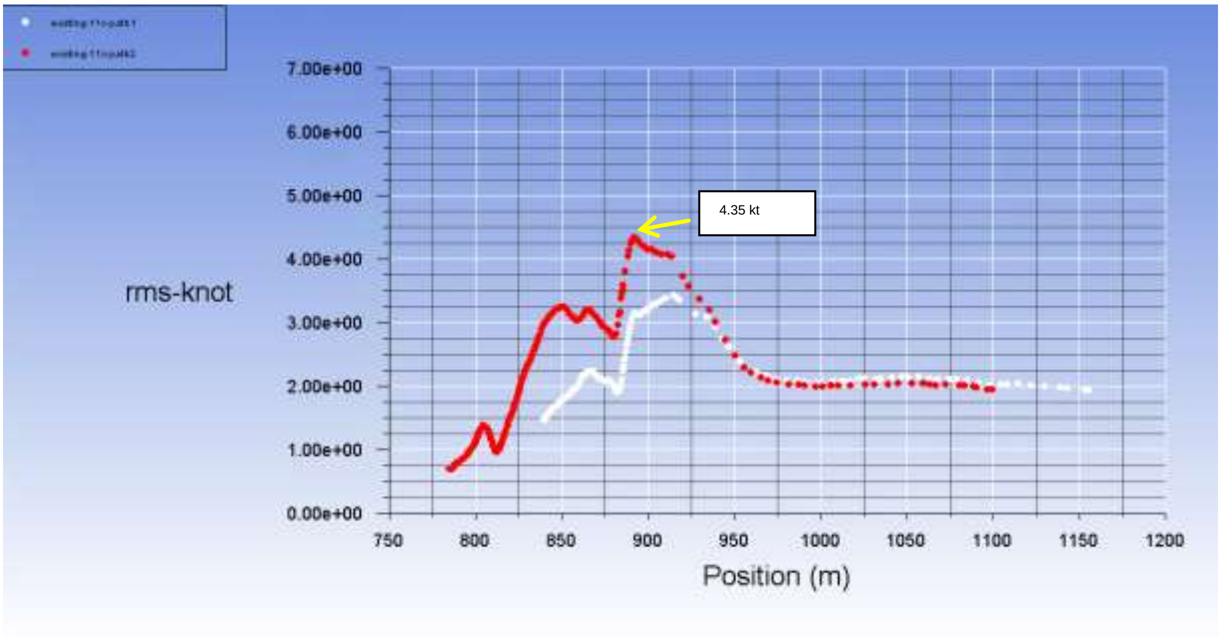


A: Current

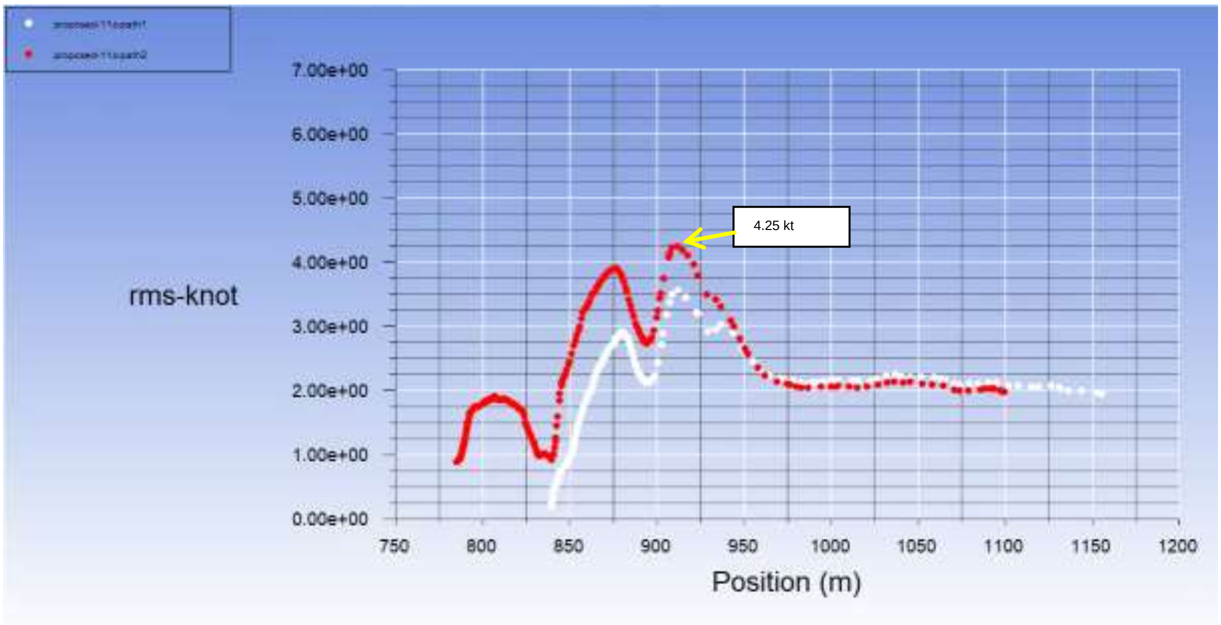


B: Post Development

Figure 17 RMS (Standard Deviation) Value in Knot across the Aircraft Trajectory at 11 C Runway – DES Turbulence Model (Approaching Wind = 20 Knot at 10 m above Ground, Wind Angle =11.3°)



A: Current



A: Post Development

5.5 Wind Angle: East Northeast (56.3°)

Figure 18 shows the wind speeds on 0-14 m/s colour coded scales.

- The CFD model captures the fluid flow characteristics in significant detail. Wind is approaching the site from the northeast at 56.3^o as per the given boundary condition. Wind is then accelerated near the edges and stagnated and recirculated behind the buildings.
- There is a minor variation in wind speeds along the width of the runways.
- The localised wake behind the proposed development is shown in **Figure 18B**.

5.5.1 Windshear Assessment

A comparison for the wind along the aircraft trajectory for the flight paths in **Figure 8** is shown in **Figure 19** and **Figure 20**. The following conclusions can be reached from the above figures:

- The variation in the mean wind speed for the existing and post development built environment scenarios is either less than 6 kt along all analysed aircraft trajectories at a height below 60 m or the variations occurs below 100 m.

5.5.2 Turbulence Assessment

The turbulence or root-mean-square (RMS) value along the aircraft trajectory for the flight paths in **Figure 8** are shown in **Figure 21** to **Figure 22.** The following conclusions can be achieved from the above figure:

Runway 11 L

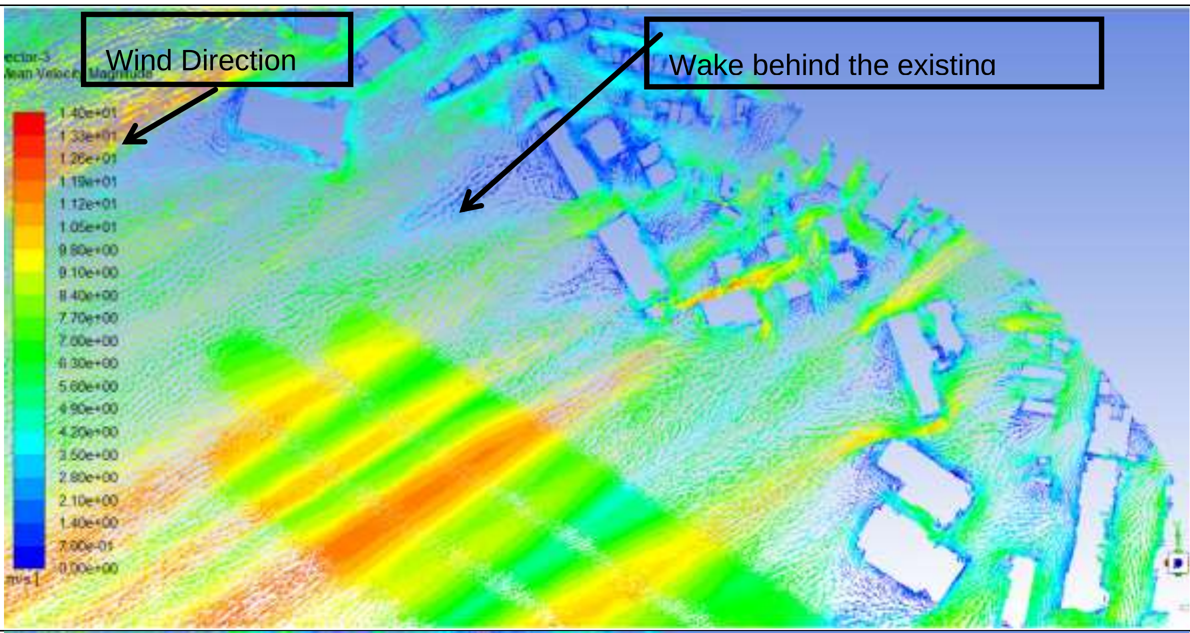
- The localised (instantaneous) turbulence for the existing and post development scenarios is 5.9 kt.

Runway 11 C

- The localised (instantaneous) turbulence for the existing scenario is 4.75 kt.
- The localised (instantaneous) turbulence for the post development is 4.50 kt.
- The peak turbulence is reduced by 0.25 kt at the most impacted are due to the edition of the proposed development.

Figure 18 Velocity Vector (m/s) at RL 10m - DDES Turbulence Model, Approaching Wind = 20 Knot, Wind Angle = 56.3°

A: Current



B: Post development

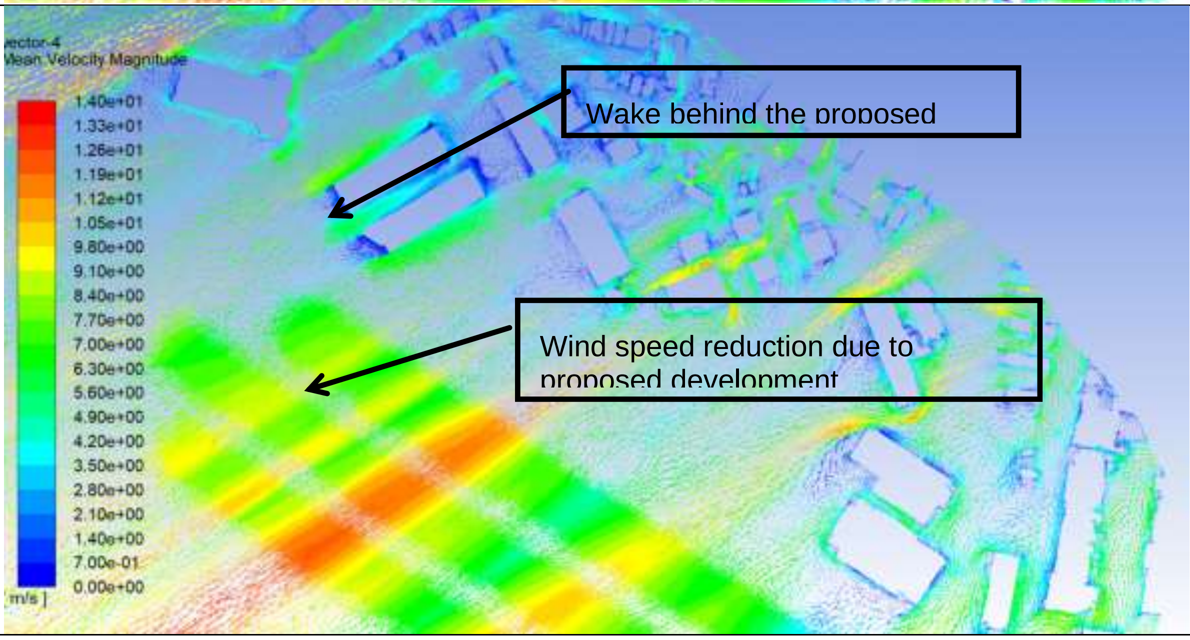
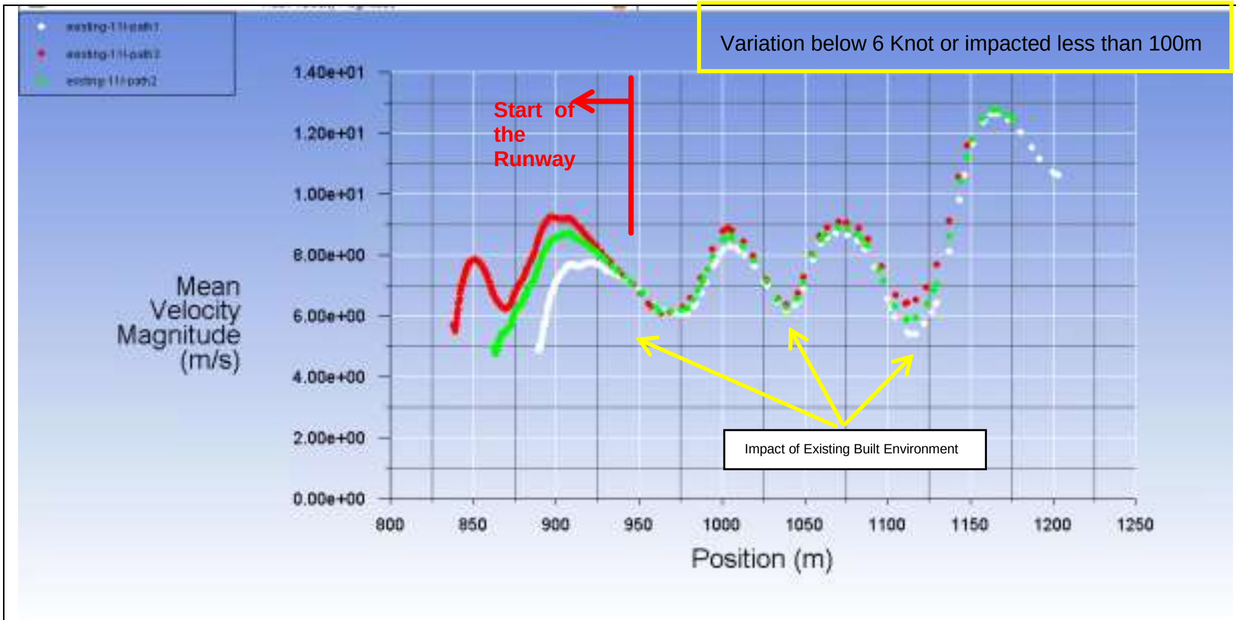
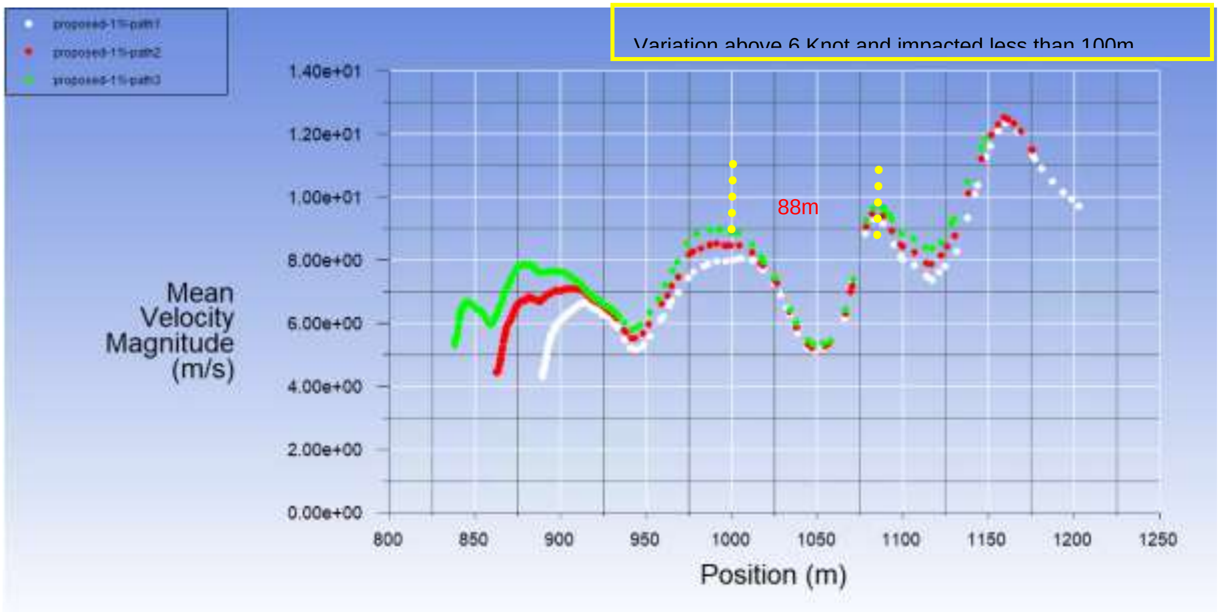


Figure 19 Comparison of the Normal Velocity Component (m/s) – Runway 11 L (DDES Turbulence Model, Approaching Wind = 20 Knot, Wind Angle = 56.3°)

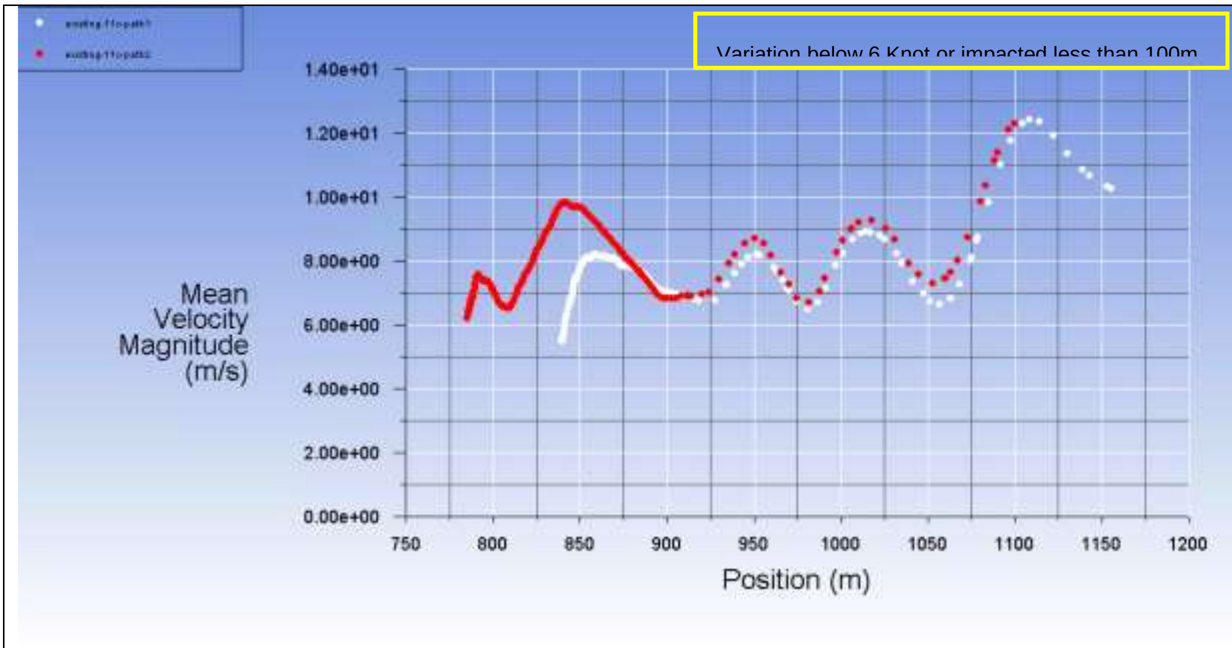


A: Current

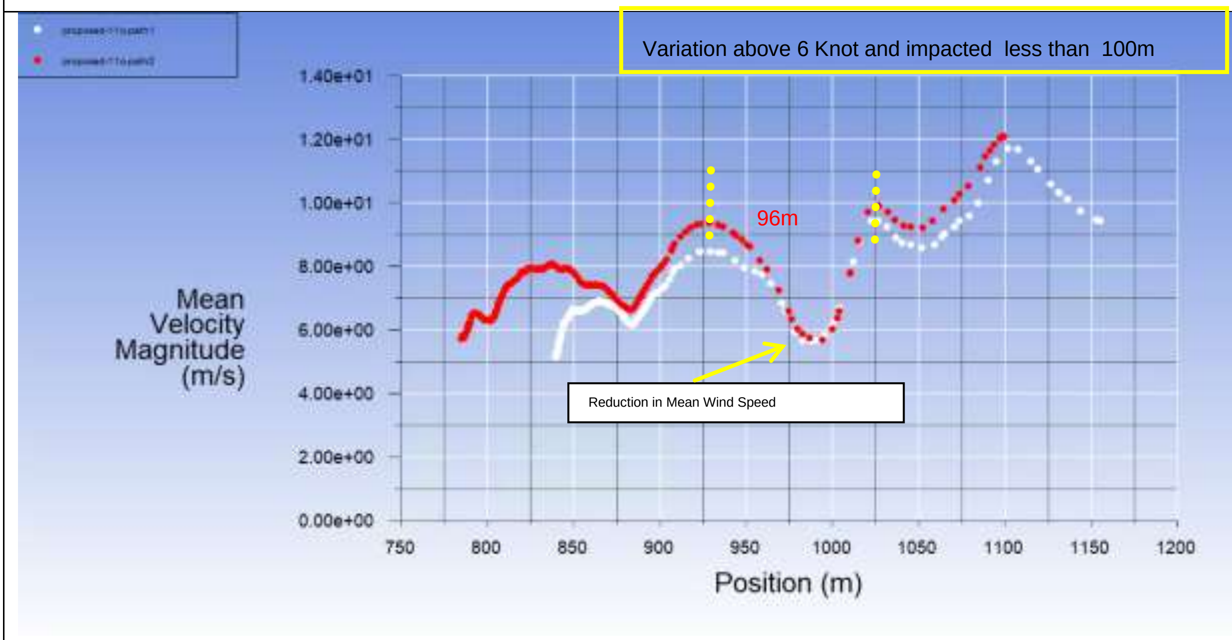


B: Post Development

Figure 20 Comparison of the Normal Velocity Component (m/s) – Runway 11 C (DDES Turbulence Model, Approaching Wind = 20 Knot, Wind Angle = 56.3°)

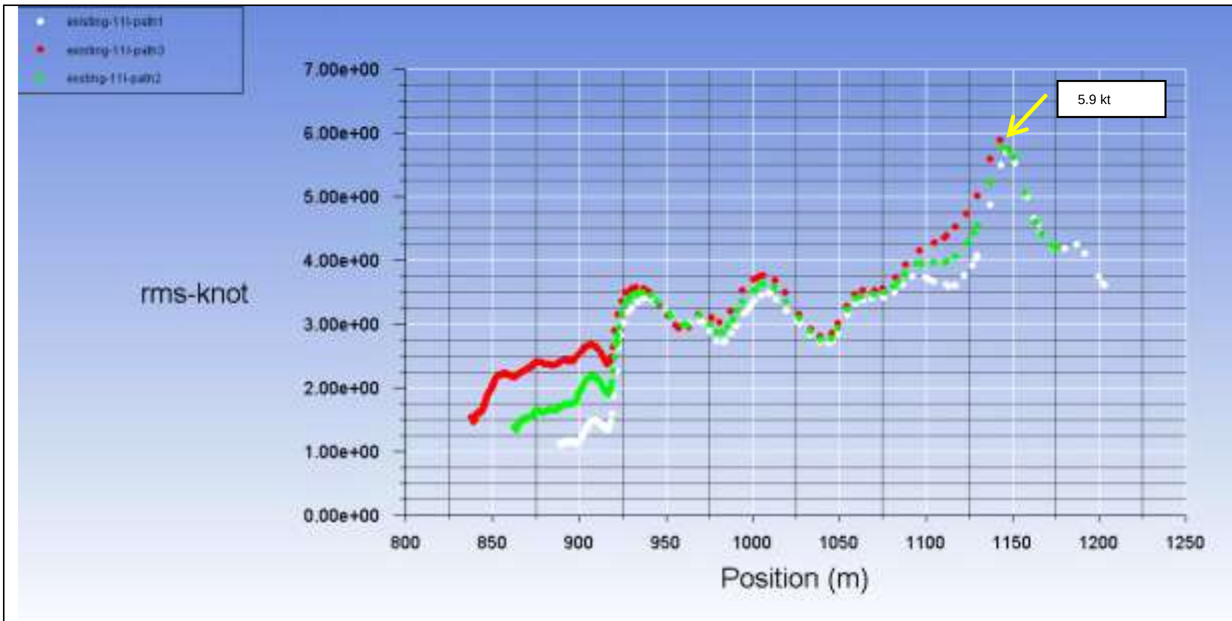


A: Current

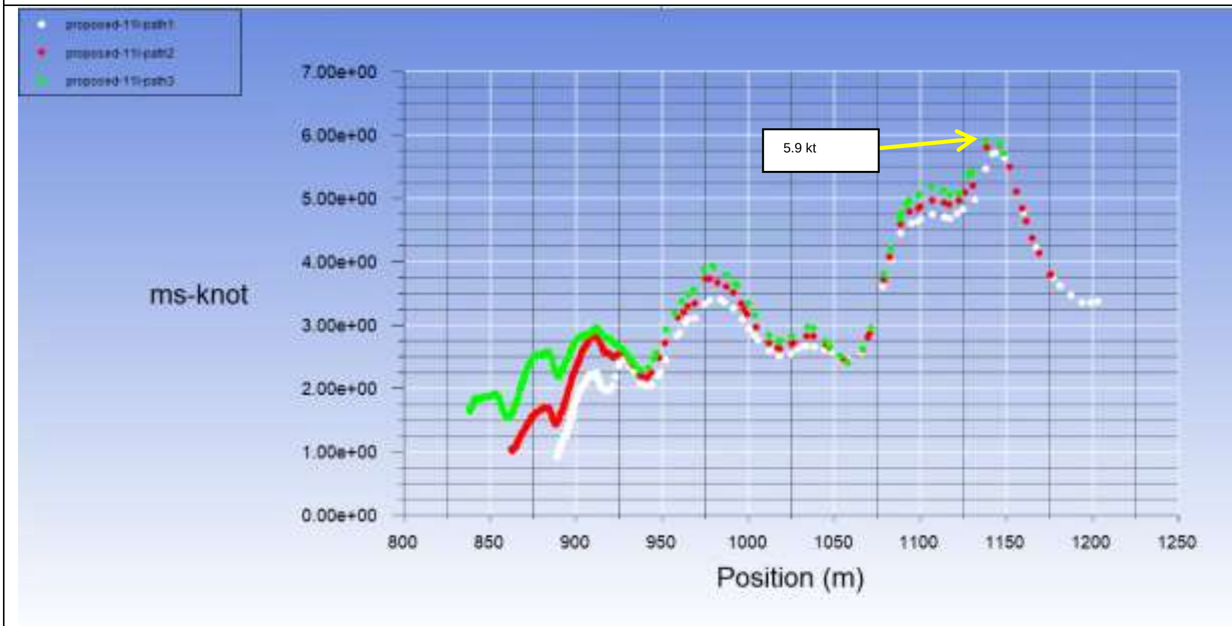


B: Post Development

Figure 21 RMS (Standard Deviation) Value in Knot across the Aircraft Trajectory at Runway 11 L– DES Turbulence Model (Approaching Wind = 20 Knot at 10 m above Ground, Wind Angle = 56.3°)

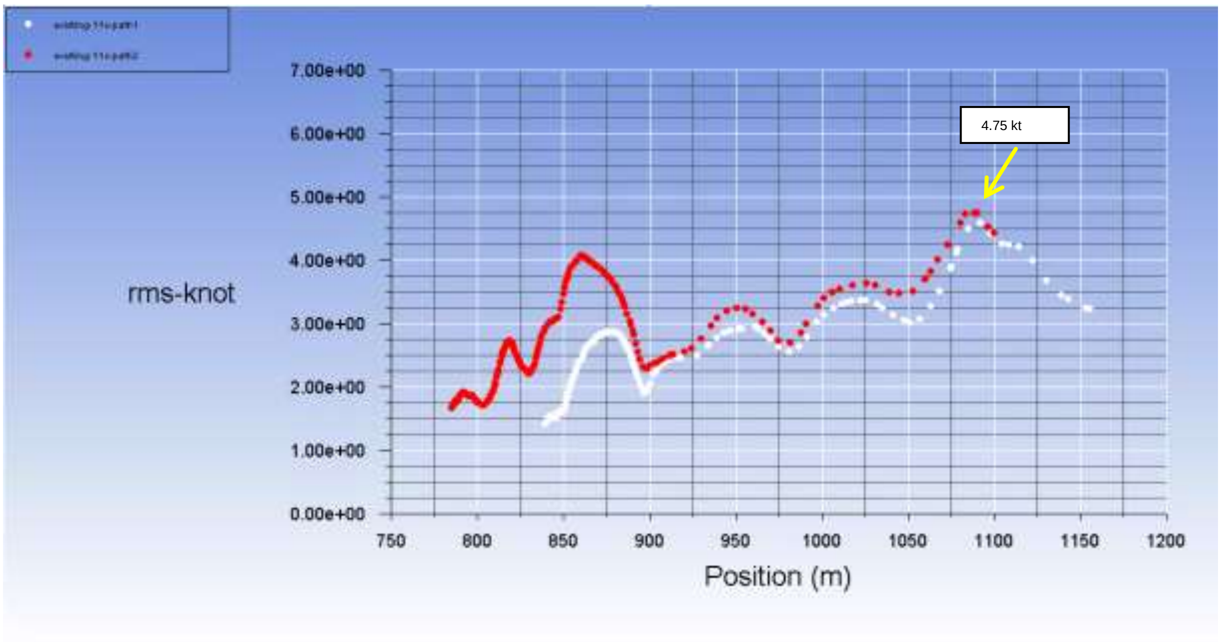


A: Current

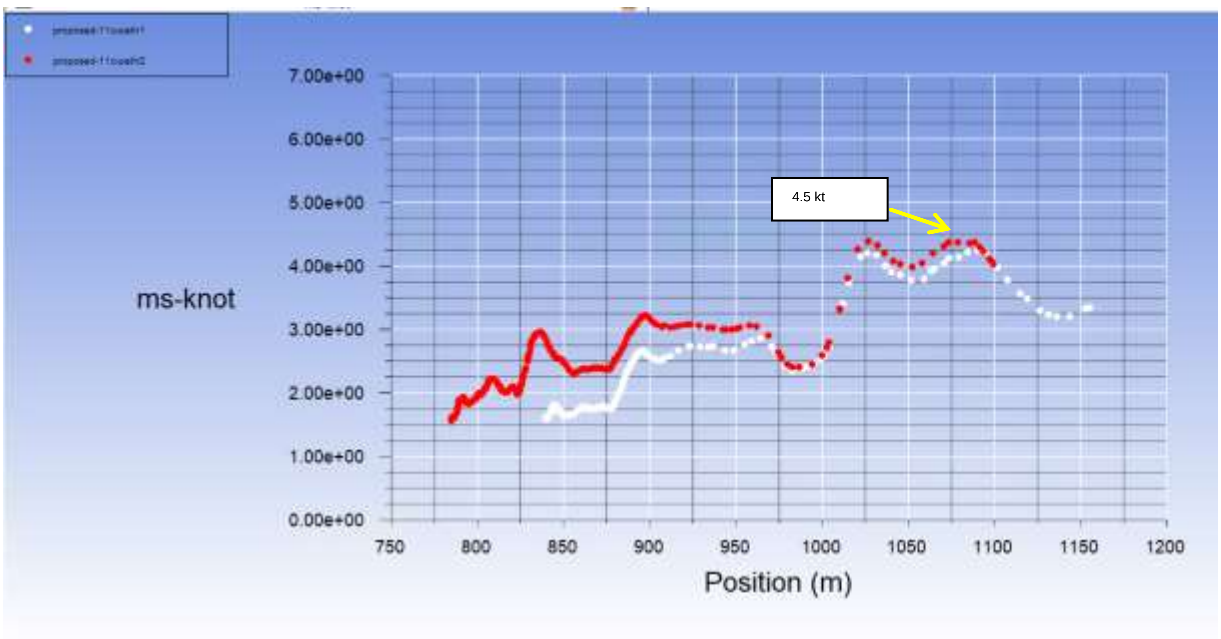


B: Post Development

Figure 22 RMS (Standard Deviation) Value in Knot across the Aircraft Trajectory at Runway 11C – DES Turbulence Model (Approaching Wind = 20 Knot at 10 m above Ground, Wind Angle = 56.3°)



A: Current



B: Post Development

5.6 Summary Results of Simulations

The trees and vegetation to the north were removed primarily to reduce computational time, noting that this removal makes the model more conservative as the addition of vegetation would typically reduce ground level wind speeds.

The following major conclusions are made from the simulations:

- The disturbance to the approaching mean wind speed for the post development scenario is localised due to the following:
    - Shape of the buildings (eg the building's dimension in line with the wind is greater than its width to significantly reduce the wake behind the building).
    - Relatively low buildings height (the highest point is 13.15 m above finished floor level).

5.6.1 Windshear – Approaching Wind Speed = 20 kt at 10m above Ground

- Current Scenario: The variation in the mean wind speed is either below 6 kt or impacted less than 100 m at a height below 60 m.
- Post Development Scenario: The variation in the mean wind is either below 6 kt or impacted less than 100 m at a height below 60 m.
    - The proposed facility will have a localised impact on the existing shears due to shape, low height and distance to the runways.

5.6.2 Turbulence - Approaching Wind Speed = 20 kt at 10m above Ground

Results of simulations are detailed in **Section 5** of this study and summarised for critical flightpaths in **Table 7** and **Table 8**:

11L

- Current Scenario: the turbulence criterion of 4 kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at an approaching wind of approximately 13.5 kt (wind angle = 33.8^{o}) for the most critical wind direction.
- Post Development Scenario: the turbulence criterion 4kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at approaching wind of approximately 11.9 kt for the most critical wind direction (wind angle =33.8^{o}).

11C

- Current Scenario: the turbulence criterion of 4 kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at approaching wind of approximately 15.2 kt for the most critical wind direction (wind angle = 33.8^{o}).
- Post Development Scenario – design Modification 2: the turbulence criterion of 4 kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at approaching wind of approximately 15.5 kt for the most critical wind direction (wind angle = 33.8^{o}).

Table 7 Predicted Turbulence vs Approaching Cross-wind (ALL flight Paths) - Runway 11 L

Built Environmnet Scenario	Wind Angle	Approach Wind for 4 kt Turbulence[1]	No of Hours 4 kt Exceeded[2]	No of Hours 4 kt Exceeded[3]
Turbulence - Existing	11.3°	15.2 kt	0.1	0.1
	33.8°	13.5 kt	7	6
	56.3°	13.5 kt	16	13
Turbulence - Proposed	11.3°	15.2 kt	0.1	0.1
	33.8°	11.9 kt	11	8.5
	56.3°	13.5 kt	16	13

Note 1: Instantaneous turbulence at the most impacted location. The averaged turbulence for the current and post development scenarios over a distance of 100 m spanning the peak is less than 4 kt for all analysed scenarios.

Note 2: The number of hours per annum that a 4kt turbulence exceedance occurs is based on the mean wind speeds data recorded during the period 2001-2020 at BoM Station 66137 during the period 1999-2021.

Note 3: Runway 11L operates during the daytime (6:00s am to 6:00 pm) ONLY. Number of exceeded hours are approximated.

Table 8 Predicted Turbulence vs Approaching Cross-wind (NNE Wind) for the Worst Case Scenario – Runway 11 C

Built Environmnet Scenario	Wind Angle	16.8 kt	16.3 kt
		Approach Wind for 4 kt Turbulence	No of Hours 4 kt Exceeded
Turbulence - Existing	11.3°	18.4 kt	0
	33.8°	15.2 kt	0
	56.3°	17.0 kt	0
Turbulence - Proposed	11.3°	18.8 kt	0
	33.8°	15.5 kt	0
	56.3°	17.7 kt	0

Note 1: The number of hours per annum that a 4kt turbulence exceedance occurs is based on the mean wind speeds data recorded during the period 2001-2020 at BoM Station 66137 during the period 1999-2021.

6.0 Mitigation Option for the current and Post Development structures

Section 5 provided guidance as to the areas where the windshear and/or turbulence acceptability criterion had the potential to be exceeded.

- The variation in the mean wind speed for both existing and post development is either below 6 kt or impacted less than 100 m at a height below 60 m. The NASF B windshear criterion is not triggered.
- Highest turbulence levels are obtained upstream the threshold.
- Peak (instantaneous) turbulence levels are increased at Runway 11L by a modest amount for the perpendicular wind 33.8º and the changes at 11C are negligible.
  - Wind angle 33.8º – Perpendicular Wind
    - 0.9 kt for 11L
    - -0.1 kt for 11C
  - Wind angle 11.3º
    - 0.0 kt for 11L
    - -0.1 kt for 11C
  - Wind angle 56.3˚
    - 0.0 kt for 11L
    - -0.25 kt for 11C

With regards to the nearest 11L/29R operations, the following comments are made:

- Runway 11L/29R is used for originating take off, full stop landing and "touch and go".
- The actual number of movements on 11R/29L was 116,240 in 2014. 60% of the movements occurred on 29 L and 40% of the movements occurred on 11R.
- Runway 11R/29L is used during daytime only (6:00 am to 6:00 pm).
- Runway 11R/29L and Runway 11L/29R can be operated simultaneously but Runway 11C/29C is only operated singularly.
- Maintenance operation and runways closure for grass cutting are undertaken 8 times per year. The runway may be closed for 4 hours each time. An alternative runway is used during the maintenance operation as per the air traffic control direction.
- Other operational restrictions published in The En-route Supplement Australia (ERSA) are mostly related to noise abatement.

To mitigate building-induced wake turbulence, it's recommended to implement operational risk mitigation measures accepted by the airport operator and CASA when winds exceed 11.9 kt from the NNE (wind angle 33.8°± 22.5°).

7.0 Conclusions

The following major conclusions have been reached based on results of simulations for the critical wind directions and assessment of Bankstown Airport BoM Weather Station data.

The current study has involved the modelling of the following built environment “scenarios”:

- “Current” - the existing built environment (as of September 2022) including recently approved developments. Refer **Figure 4A**
- “Post development - Proposed” - including Current + Proposed Development. Refer **Figure 4B and Figure 5**

Existing Wind Conditions

Mean Wind Speed at 10 m Height

- There were 0 hours where the mean wind speed exceeded 20 kt taking into account wind directions 33.5°±22.5° over the 23-year BoM record period.
- There were 8 hours per year where the mean wind speed exceeded 15 kt taking into account wind directions over the 23-year BoM record period.

Runway 11R/29L and Runway 11L/29R operate during daylight only from 06:00 hrs to 18:00 hrs while 11C/29C operates 24 hours a day. The occurrence of the exceedance for 15 kt is reduced to 6-7 hours per year when only daylight hours are included in SLR’s assessment (refer **Section 3.2.1**)

Turbulence Exceedance at the Anemometer Location

- There were approximately 1,600 occasions during the 23-year BoM record period (69.5 per year) where natural turbulence exceeded 4-kt taking into account ALL wind directions.
- There were 2.5 occasions per year where natural turbulence exceeded 4-kt from winds orientating from 33.5°±22.5°.

It should be noted that while many of those exceedance “occasions” occurred on different days, some occurred in consecutive hours on the same day during the passage of major windstorm events.

Future Wind Conditions (Associated with the Post-Post Development Scenario)

The following major conclusions have been reached based on results of CFD simulations for the analysed wind directions:

Windshear – Approaching Wind Speed = 20 Knot at 10m above ground

- A number of warehouses and low-rise buildings are located to the northeast side of the runways.
- The variation in the mean wind speed for the existing and post development scenarios is either below 6 kt or impacted less than 100 m at a height below 60 m. The NASF-B windshear criterion is therefore not exceeded. due to the following:
  - Shape of the building (eg the building’s dimension in line with the wind is greater than its width to significantly reduce the wake behind the building).
  - Relatively low building height (13.1 m)

Wind Turbulence – Approaching Wind Speed = 20 Knot at 10m above ground

- In the CFD modelling, the trees and vegetation surrounding the site were removed primarily to reduce computational time, noting that this removal makes the model slightly conservative as the addition of vegetation would typically reduce ground level wind speeds.
- The proposed development will have a minor impact on the peak turbulence levels taking into account 33.5°±22.5° wind directions.

11L

- Current Scenario: the turbulence criterion of 4 kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at an approaching wind of approximately 13.5 kt (wind angle = 33.8°) for the most critical wind direction.
- Post Development Scenario: the turbulence criterion 4kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at approaching wind of approximately 11.9 kt for the most critical wind direction (wind angle =33.8°).

11C

- Current Scenario: the turbulence criterion of 4 kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at approaching wind of approximately 15.2 kt for the most critical wind direction (wind angle = 33.8°).
- Post Development Scenario: the turbulence criterion of 4 kt across the aircraft trajectory at heights below 60 m (200ft) is triggered at approaching wind of approximately 15.5 kt for the most critical wind direction (wind angle = 33.8°).

Summary Results

Results of simulations for the worst-case scenario are summarised below.

Scenario	Are the NASF-B Compliance Criteria Satisfied ?		Runway 11L	Runway 11C
	Cross-Wind 6 kt	Turbulence 4 kt	No of Hours per Year Turbulence Criterion Exceeded 6 am - 6 pm	No of Hours per Year Turbulence Criterion Exceeded 6 am - 6 pm
Current	Yes	No	19[1,2]	0[1]
Post Development	Yes	No	21.6[1,2]	0[1]

Note 1: The results take into account 33.8±22.5° wind directions. Refer **Table 7** and **Table 8**

Note 2: Runway 11R/29L and Runway 11L/29R operate during daylight only from 06:00 – 18:00 while 11C/29C operates 24 hours

Recommendations

To mitigate building-induced wake turbulence, it's recommended to implement operational risk mitigation measures accepted by the airport operator and CASA when winds exceed 11.9 kt from the NNE (wind angle 33.8°± 22.5°).

The addition of the proposed development has a minor impact on the peak turbulence levels, ie it increases the peak turbulence level by ~0.9 kt for the worst-case scenario, taking into account all analysed wind directions.

Building (Northwest Hangar) Update

There have been some amendments to Northwest Hanger layout since the original assessments were carried out. The changes include cutting the office space associated with the Northwest Hangar as it fell within the public safety area.

SLR is of the opinion that the changes would not result in any changes to the conclusions of the report.

8.0 Feedback

At SLR, we are committed to delivering professional quality service to our clients. We are constantly looking for ways to improve the quality of our deliverables and our service to our clients. Client feedback is a valuable tool in helping us prioritise services and resources according to our client needs.

To achieve this, your feedback on the team's performance, deliverables and service are valuable and SLR welcome all feedback via https://www.slrconsulting.com/en/feedback. We recognise the value of your time and we will make a $10 donation to our 2023 Charity Partner - Lifeline, for every completed form.