Hunter Power Project

Plume Rise Assessment

Rev 0

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Snowy Hydro

Environmental Impact Statement

Hunter Power Project

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Contents

List of figures

List of tables

Executive Summary

Snowy Hydro Limited (Snowy Hydro) ('the Proponent') proposes to develop a gas fired power station near Kurri Kurri, NSW ('the Proposal'). The Proposal involves the construction and operation of a power station consisting of two F-Class open cycle gas turbines, supporting balance of plant and an electrical switchyard. The Proposal would have a capacity of up to approximately 750 megawatts (MW) operating primarily on natural gas, with occasional operation on diesel (as back-up fuel) as required. Operation on diesel would occur if there were a constraint or unavailability in the natural gas network and there was a need to supply electricity to the National Electricity Market (NEM). The Proponent is seeking approval from the NSW Minister for Planning and Public Spaces under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) for the Proposal.

The main objective of the plume rise modelling investigation was to provide estimates of plume rise height, in order for the Civil Aviation Safety Authority (CASA) to determine any impact on Instrument Flight Rules (IFR). The plume rise modelling investigation has been carried out in accordance with CASA Advisory Circular titled "AC 139-05v3.0 - Plume Rise Assessments (CASA, 2019).

Modelling for a five year simulation period showed that the height at which the plume vertical velocity falls below the critical vertical velocity threshold of 6.1 m/s would not exceed 1,144 m AGL. The meteorological condition which led to this maximum result was based on the assumption that two gas turbines were operating at a time of very light winds (0.1 m/s) on a winter day, a meteorological condition which occurred for one hour in the five year simulation period. At the other meteorological conditions experienced during the five year simulation period, the corresponding maximum heights were all below 1,144 m AGL.

1. Introduction

Snowy Hydro (the Proponent) is seeking approval for the development and operation of a new gas fired power station (the Proposal) to be located at the former Kurri Kurri aluminium smelter owned by Hydro Aluminium Kurri Kurri Pty Ltd (Hydro Aluminium), located in the small suburb or Loxford, just north of Kurri Kurri in NSW. The Proponent has engaged Jacobs to prepare the environmental impact statement (EIS) and a plume rise and aviation assessment. This report represents the plume rise impact assessment component and addresses the Secretary's Environmental Assessment Requirements (SEARs) relating to hazards and risks due to future operation of the Proposal.

The Proposal involves the construction and operation of a power station and electrical switchyard, together with other associated infrastructure. The power station would have a capacity of up to approximately 750 megawatts (MW) which would be generated via two heavy duty gas turbines. Although primarily a gas fired power station, the facility would also be capable of operating on diesel (as a back-up) as required, if there were a constraint or unavailability in the natural gas network and there was a need to supply electricity to the National Electricity Market (NEM).

The Proposal would operate as a "peak load" generation facility supplying electricity at short notice when there is a requirement in the National Electricity Market. The major supporting infrastructure that is part of the Proposal would be a 132 kV electrical switchyard located within the Proposal Site. The Proposal would connect into existing 132 kV electricity transmission infrastructure located adjacent to the Proposal Site. A new gas lateral pipeline and gas receiving station will also be required and this would be developed by a third party and be subject of a separate environmental assessment and planning approval.

Other ancillary elements of the Proposal include:

- Water storage tanks and other water management infrastructure
- Fire water storage and firefighting equipment such as hydrants and pumps
- Maintenance laydown areas
- Stormwater detention basin
- Diesel fuel storage tanks and truck unloading facilities
- Site access roads and car parking
- Office/administration, amenities, workshop/storage areas.

Construction activities are anticipated to commence early 2022 and the Proposal is intended to be operational by the end of 2023, with operations potentially commencing in mid 2023.

The plume rise modelling investigation has been carried out in accordance with Civil Aviation Safety Authority (CASA) Advisory Circular titled "AC 139-05v3.0 - Plume Rise Assessments (CASA, 2019). The main objective of the modelling was to provide estimates of plume rise height, in order for CASA to determine any impact on Instrument Flight Rules (IFR).

2. Assessment Methodology

2.1 Background

The Civil Aviation Safety Authority (CASA) is the national authority which regulates Australian aviation safety. The CASA has historically established that wind gusts with vertical velocity exceeding 4.3 metres per second (m/s) may cause damage to an aircraft airframe or otherwise upset an aircraft flying at low levels. The CASA subsequently required that proponents of a facility where the vertical velocity of exhaust plumes exceeds a critical plume velocity (CPV) of 4.3 m/s or 10.6 m/s at an aerodrome Obstacle Limitation Surface (OLS), or at 110 m above ground level anywhere else, must undertake plume rise modelling to assess the potential hazard to aircraft operations. Requirements of the plume rise modelling were originally outlined in CASA's Advisory Circular (AC 139-5) titled "Guidelines for conducting plume rise assessments" (CASA, 2004).

The CASA 2019 plume rise assessment guidelines, detailed in (AC-139-5) advises the critical plume velocity threshold as 4.3 to 6.1 m/s to reflect the latest information on potential hazards to aviation (CASA, 2019). In this latest 2019 Advisory Circular, CASA does not specify a specific CPV, rather it simply states that it will assess the circumstances and decide upon an appropriate CPV as it may decide to adopt a lower CPV for certain types of aircraft. To address this requirement, this plume rise assessment and an associated aviation assessment (Strategic Airspace, 2021) has considered worst-case operation scenario of the power station, in terms of plume rise, and five years of meteorological conditions to determine risk to aircraft in the vicinity of the Proposal Site.

The Proposal is seeking approval for a Capacity Factor[1] of up to 10 per cent on natural gas and up to two per cent on diesel (providing a combined Capacity Factor of 12 per cent) in any given year. However, it is expected that likely operations would result in a Capacity Factor of two per cent in any given year.

2.2 Study Requirements

Plume rise assessments to meet the requirements of the CASA are based around the use of the CSIRO's prognostic model known as TAPM (The Air Pollution Model). TAPM is a prognostic model which has the ability to generate meteorological data for any location in the world based on synoptic information determined from global weather models such as the Global Forecast System (GFS).

The requirements of CASA, when conducting plume rise modelling and assessment, can be summarised as follows:

- Modelling using TAPM version 2.0 or higher
- At least five years of continuous meteorological data modelled
- Horizontal displacement of the plume centreline evaluated as a function of height
- Plume spread about the centreline evaluated as a function of height
- Consideration of "average" and "peak" vertical plume velocities for each height
- Wind speed evaluated as a function of height
- Probability of vertical velocity exceeding the CPV threshold of 6.1 or 10.6 m/s.

[1] The Capacity Factor is the proportion of actual energy generated per year (expressed as MWh) compared with the total energy that could have been produced if operating at full load for every hour of the year (expressed as MWh).

3. Plume Rise Modelling

TAPM (version 4.0.5) modelling was undertaken in accordance with the CASA requirements outlined above. The simulation period was 2015 to 2019 inclusive. Table 3.1 provides a summary of TAPM inputs and settings for this assessment.

Table 3.1: Summary of TAPM modelling parameters

Parameter	Value(s)
TAPM version	4.0.5
Number of grids (spacing)	3 (30 km, 10 km, 3 km)
Number of grid points	25 x 25 x 25
Simulation period	Jan 2015 to Dec 2019 inclusive
Terrain information	AUSLIG 9 second DEM data
Centre of analysis	32°47'S, 151°29'E (MGA 357967 mE, 6371714 mN)
Local data assimilation	None
Mode	Meteorology and pollution mode

The gas turbine exhaust stack emission characteristics used in the modelling are shown in Table 3.2. These stack emission characteristics are based on gas fired generation as this will be the primary fuel used for the power station. The assessment also used the stack emission characteristics from the F Class open cycle gas turbine (OCGT) model which would have resulted in the most adverse (that is, highest) plume rise results, in comparison to the turbine models that could potentially be selected for the Proposal.

Table 3.2 also shows that operation on gas would result in a slightly higher stack exit temperature, and consequently higher plume buoyancy and potential plume height compared to operation on diesel fuel, and thus operation on gas was considered to be more conservative for use in the modelling and assessment.

Table 3.2: Stack emission characteristics used in the modelling

Parameter	2 x OCGT operating on gas	
Stack ID	OCGT unit1	OCGT unit2
Easting (m)	357,520	357,510
Northing (m)	6,371,471	6,371,402
Stack height (m)	36	36
Approximate base elevation (m)	14	14
Estimated stack tip diameter (m)	9.8	9.8
Stack exit temperature (°C)	635 (524 using diesel)	635 (524 using diesel)
Stack exit velocity (m/s)	25 (22 using diesel)	25 (22 using diesel)

For emissions from multiple stacks there is the possibility that merged, overlapping hot plumes may interact with one another, resulting in a single, higher buoyancy plume. This process is referred to as buoyancy enhancement.

The buoyancy enhancement factor (N_E) is defined (Hibberd *et al*, 2005) as follows:

Equation 1

$$N_E = \left[\frac{n+S}{1+S}\right]$$

Where *n* is the number of stacks and *S* is a dimensionless separation factor, defined as:

Equation 2

$$S = 6 \times \left[\frac{(n-1).\Delta s}{n^{\frac{1}{3}}.\Delta z}\right]^{\frac{3}{2}}$$

Where Δs is the stack separation and Δz is the rise of an individual plume. It should be noted that this approach is relevant to stack emissions of similar physical and emission characteristics, such as a group of gas turbine stacks separated by equal distances.

To determine relevant buoyancy enhancement factors, TAPM was run twice in pollution mode. The first run was used to predict the final rise of an individual plume. The second run included two adjacent plumes with the same emissions characteristics, with the calculated buoyancy enhancement, and was used for the final analysis. The "like" stack emissions in this instance were the two OCGT exhaust stack sources.

Statistics on the final rise of individual plumes, after modelling all stack emissions with no buoyancy enhancement, are shown below in Table 3.3. Buoyancy enhancement for the two sources has been determined.

The data from Table 3.3 show that the maximum final plume rise of individual plumes will be approximately 1,556 m above ground-level. The final rise is the height above ground at which the vertical velocity falls to zero. The buoyancy enhancement factor (BEF) of 1.96 was determined from the maximum final rise of individual plumes, which is a conservative approach.

Table 3.3: Final rise of individual plumes and buoyancy enhancement factors

Configuration	Statistics for final rise of individual plumes (metres above ground)		Buoyancy enhancement of stack configuration
	Maximum	Average	
2 x OCGT	1,556	550	1.96

TAPM has a limitation in that only one value of the BEF can be used for the entire model simulation. In reality, the BEF will vary from hour to hour, due to variations in meteorology.

4. Model Results

The TAPM output from the five year simulation period included gradual plume rise data for every hour in the five year simulation period and for each stack. These plume rise data included vertical velocity, plume height, plume radius and plume dimensions from the time of release to the time of final plume height. Statistics were generated from this data file by interpolating to selected heights above ground.

An analysis of plume rise data was undertaken to determine the heights at which the plume vertical velocity exceeded the velocities of 4.3, 6.1 and 10.6 m/s. Results for 4.3, 6.1 and 10.6 m/s are provided for completeness and to allow an assessment to occur if the CPV is to vary depending on the aircraft type(s) likely to be encountered at the nearby airports. Results for one and two gas turbine units are also provided for comparison and completeness purposes with the two gas turbine units representing worst-case in terms of plume rise.

Results of this analysis for various percentile bands are shown in Table 4.1 and can be seen in Figure 4.1 to Figure 4.6. Over the five year modelling period the height at which the plume vertical velocity falls below the critical plume velocity threshold of 6.1 m/s would not exceed 1,144 m AGL, for 2 x OCGT units. The conditions which led to this maximum result coincided with very light winds (0.1 m/s) on a winter day, a condition which only occurred for one hour in the five year simulation period. At the other meteorological conditions experienced during the five year simulation period, the corresponding maximum heights were all below 1,144 m AGL.

Table 4.1: Height at which plume vertical velocity falls below 4.3, 6.1 and 10.6 m/s

Percent exceedance	Equivalent number of hours of exceedance per year	Height at which plume vertical velocity falls below 4.3 m/s (m AGL)		Height at which plume vertical velocity falls below 6.1 m/s (m AGL)		Height at which plume vertical velocity falls below 10.6 m/s (m AGL)	
		1 x OCGT	2 x OCGT	1 x OCGT	2 x OCGT	1 x OCGT	2 x OCGT
0%	0	1,237	1,509	736	**1,144**	148	291
0.05%	4	1,009	1,316	560	938	135	255
0.10%	9	929	1,258	528	853	124	239
0.20%	18	823	1,162	462	766	123	225
0.30%	26	770	1,096	427	718	112	214
0.50%	44	689	1,024	389	656	110	201
1%	88	581	888	330	557	99	177
2%	175	464	743	272	456	87	155
3%	263	404	650	240	402	86	140
4%	350	361	587	219	361	75	132
5%	438	332	540	202	332	74	124
6%	526	310	502	190	312	74	115
7%	613	291	474	180	294	73	112
8%	701	278	449	170	280	73	110
9%	788	265	428	164	267	63	101
10%	876	254	410	158	256	63	99
20%	1,752	188	298	121	190	61	85
30%	2,628	158	245	104	159	60	74

Percent exceedance	Equivalent number of hours of exceedance per year	Height at which plume vertical velocity falls below 4.3 m/s (m AGL)		Height at which plume vertical velocity falls below 6.1 m/s (m AGL)		Height at which plume vertical velocity falls below 10.6 m/s (m AGL)	
		1 x OCGT	2 x OCGT	1 x OCGT	2 x OCGT	1 x OCGT	2 x OCGT
40%	3,504	140	212	95	141	50	62
50%	4,380	127	191	86	126	50	61
60%	5,256	116	175	79	115	50	61
70%	6,132	108	161	77	106	49	60
80%	7,008	100	147	70	99	49	50
90%	7,884	92	133	62	87	48	49
100%	8,760	61	82	46	53	46	47

Table 4.2 shows the frequency of time that the plume vertical velocity was predicted to fall below 4.3, 6.1 and 10.6 m/s for a range of heights above local ground-level. This form of presenting the results has been prescribed by the CASA and shows how often the plume vertical velocities exceed thresholds at specific heights during the five year simulation period. As an example, from Table 4.2, the modelling shows that the frequency of the plume vertical velocity, generated by 2 x OCGT units, exceeding 6.1 m/s at 1,000 m AGL is 0.03%, or approximately 3 hours in a year.

Table 4.2: Frequency of plume vertical velocity exceeding 4.3, 6.1 and 10.6 m/s in height bands

Height above ground level (m AGL)	Frequency of plume vertical velocity exceeding 4.3 m/s at each height (%)		Frequency of plume vertical velocity exceeding 6.1 m/s at each height (%)		Frequency of plume vertical velocity exceeding 10.6 m/s at each height (%)	
	1 x OCGT	2 x OCGT	1 x OCGT	2 x OCGT	1 x OCGT	2 x OCGT
50	100.00%	100.00%	99.95%	100.00%	34.01%	71.67%
100	79.72%	99.26%	34.14%	79.07%	0.72%	9.16%
150	33.55%	77.25%	11.22%	34.10%	0.00%	2.28%
200	17.48%	45.06%	5.09%	17.94%	0.00%	0.51%
300	6.51%	19.56%	1.39%	6.62%	0.00%	0.00%
400	3.06%	10.51%	0.43%	3.02%	0.00%	0.00%
500	1.58%	6.05%	0.15%	1.48%	0.00%	0.00%
600	0.89%	3.74%	0.03%	0.73%	0.00%	0.00%
800	0.26%	1.55%	0.00%	0.14%	0.00%	0.00%
1000	0.05%	0.55%	0.00%	0.03%	0.00%	0.00%
1200	0.00%	0.14%	0.00%	0.00%	0.00%	0.00%
1400	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
1600	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1800	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Figure 4.1 to Figure 4.6 provide graphical representations of the modelling results including the hourly plume radius, displacement from source and height at which the plume vertical velocity has fallen below thresholds. The plume radius, displacement and height values decrease when considering the increasing thresholds from 4.3 to 6.1 to 10.6 m/s. In addition, the graphs provide an indication of the frequency that the vertical velocity thresholds will reach particular heights, to accompany the statistics from Table 4.1 above.

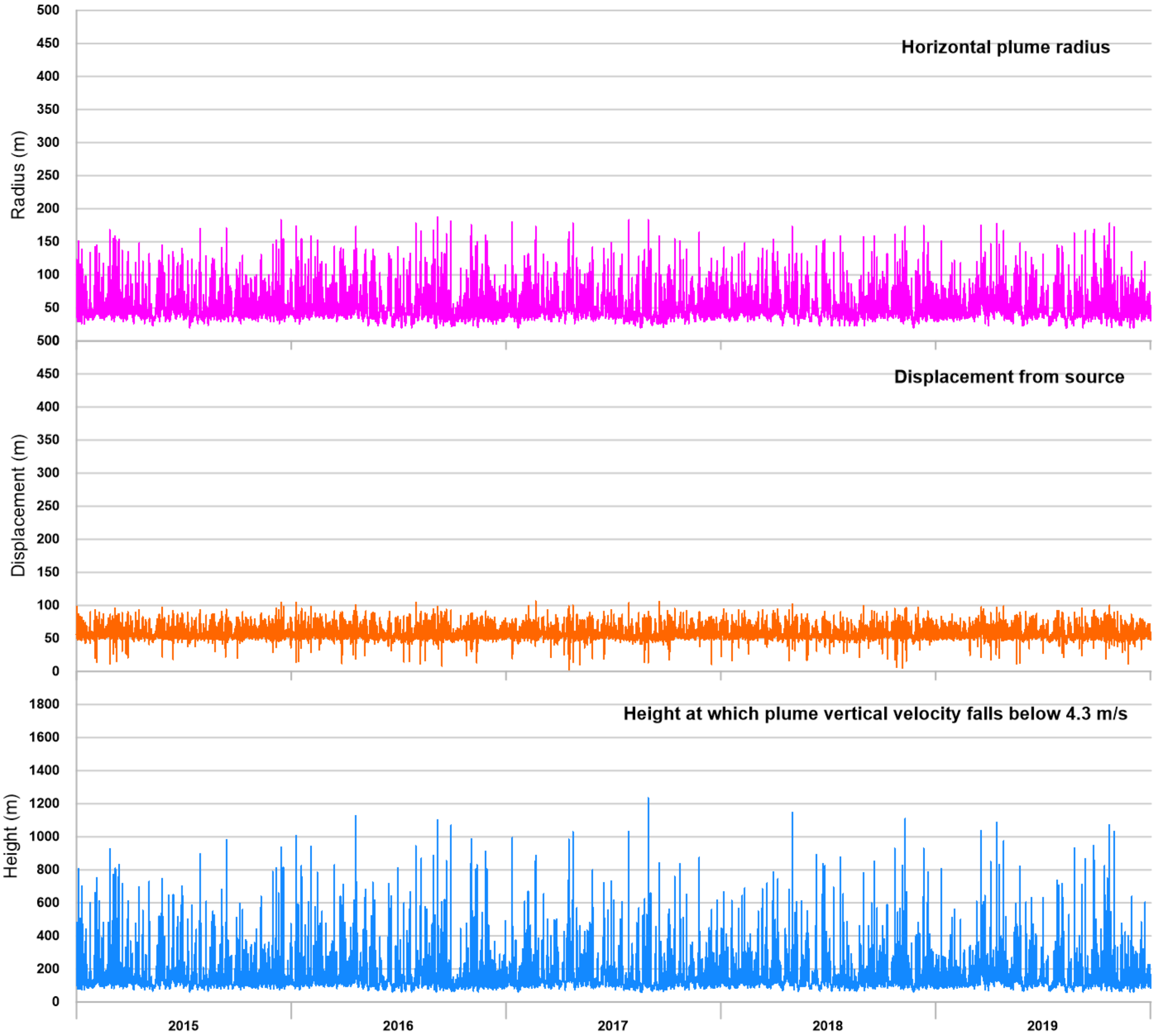

Figure 4.1: Height at which plume vertical velocity falls below 4.3 m/s for 1 x OCGT unit

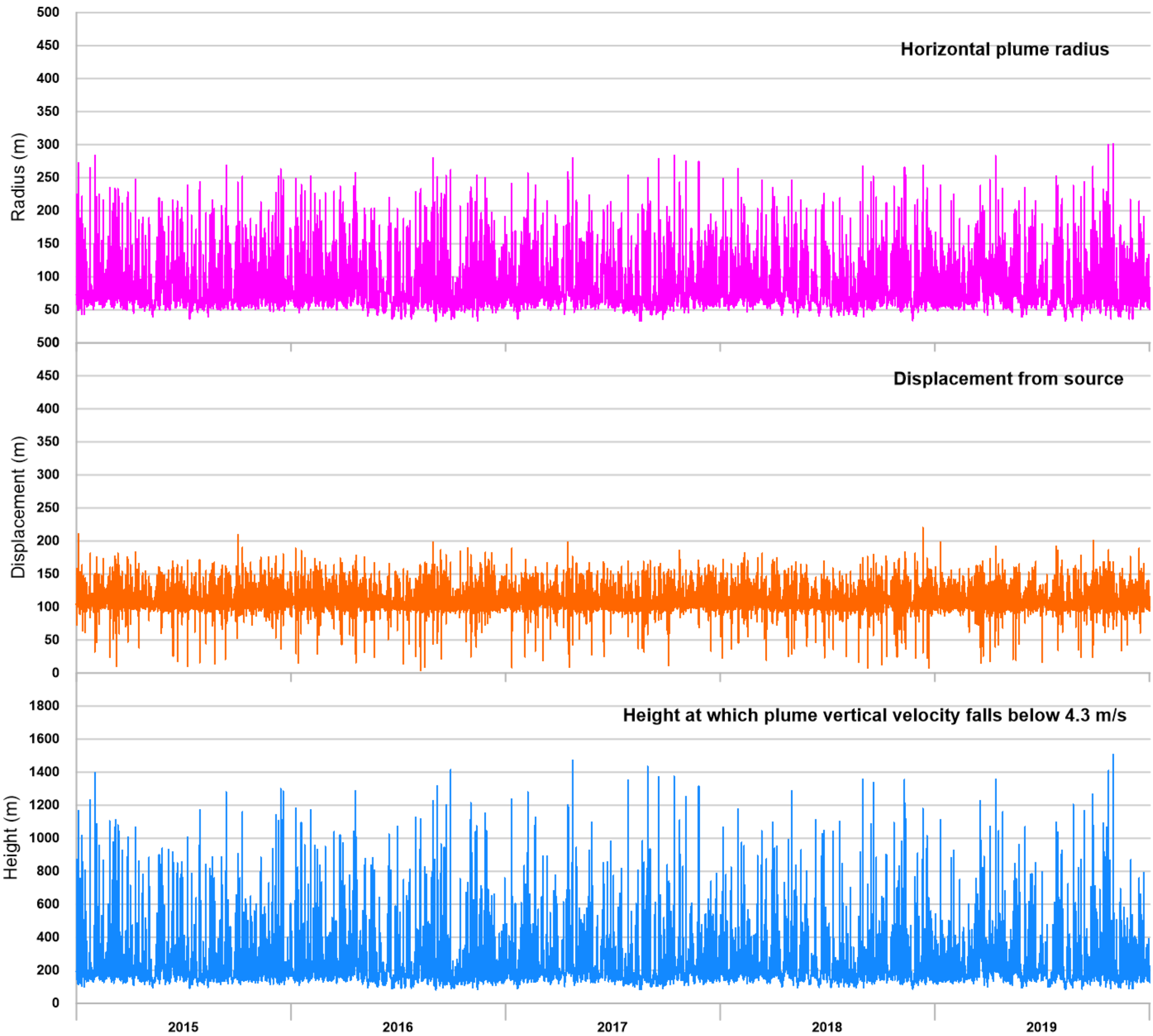

Figure 4.2: Height at which plume vertical velocity falls below 4.3 m/s for 2 x OCGT units

Figure 4.3: Height at which plume vertical velocity falls below 6.1 m/s for 1 x OCGT unit

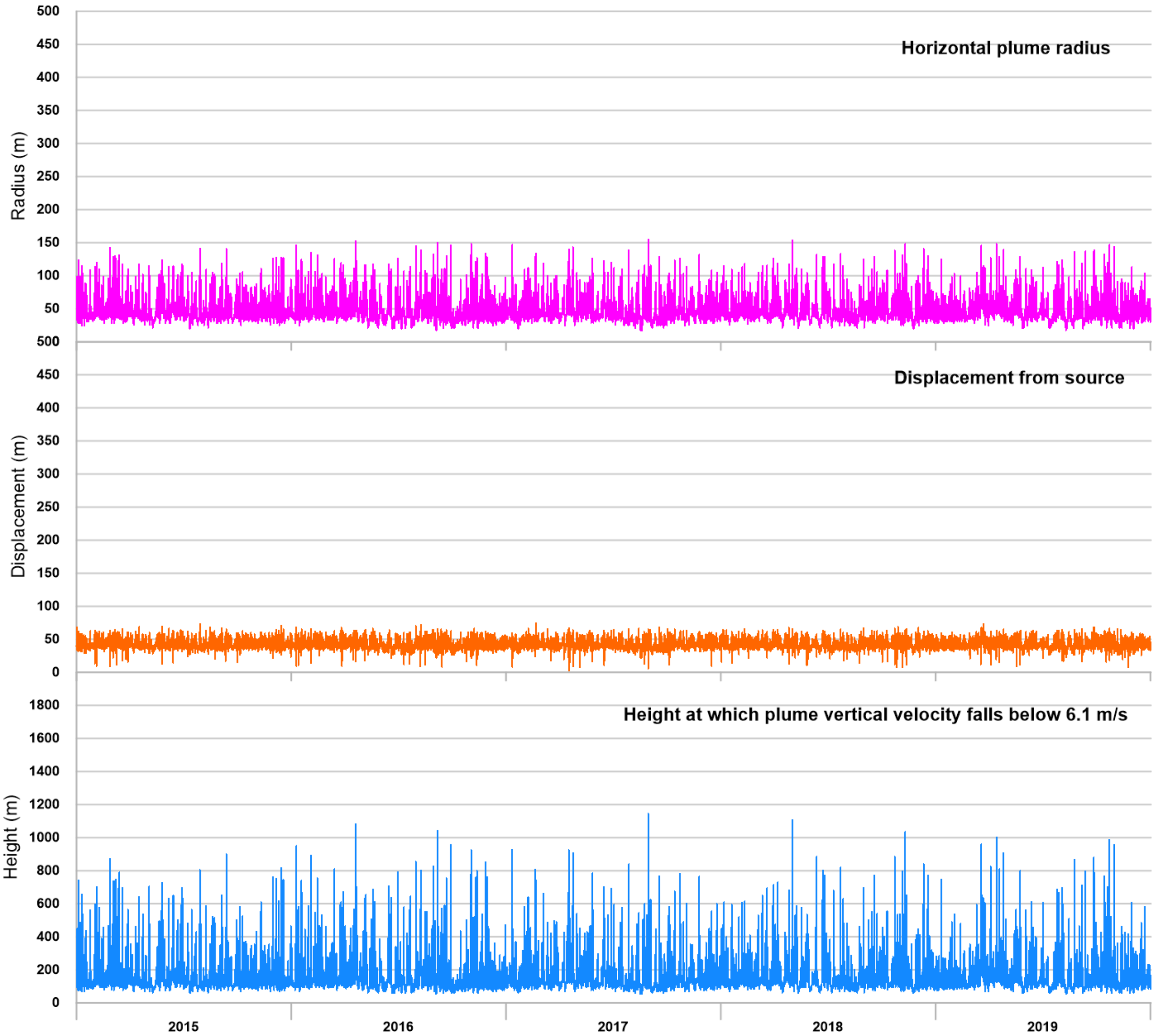

Figure 4.4: Height at which plume vertical velocity falls below 6.1 m/s for 2 x OCGT units

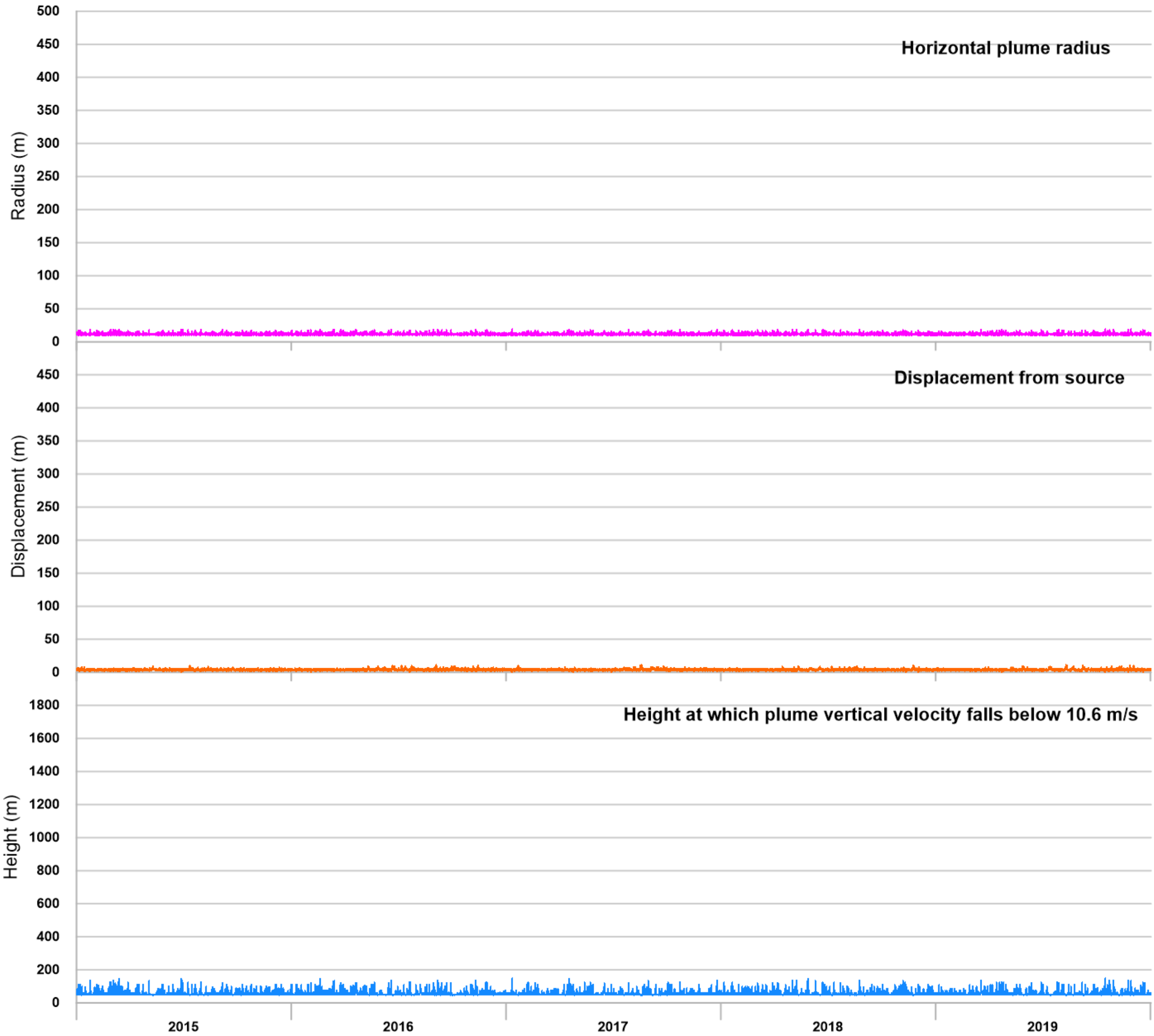

Figure 4.5: Height at which plume vertical velocity falls below 10.6 m/s for 1 x OCGT unit

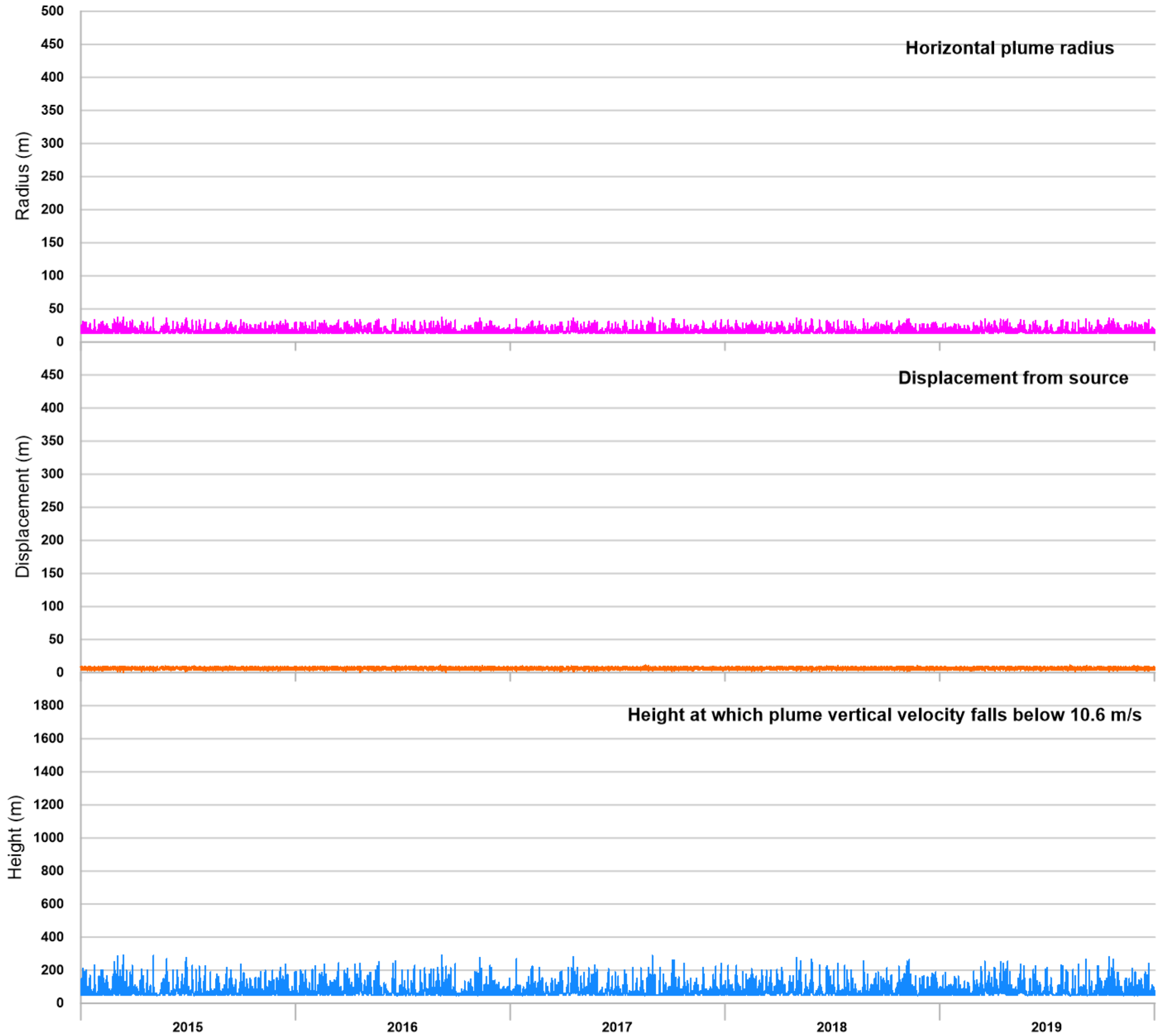

Figure 4.6: Height at which plume vertical velocity falls below 10.6 m/s for 2 x OCGT units

Table 4.3 includes additional statistics from the modelling and specifically, the maximum and median plume horizontal radius for the heights at which the plume vertical velocity falls below each threshold. These statistics have been included to address the requirements of all potential stakeholders. The data show a decrease in the maximum radius from 301 to 37 m for the 4.3 to 10.6 m/s thresholds. The radii for the 2 x OCGT scenarios include consideration of plume merging.

Table 4.3: Radius statistics

Statistic	Plume horizontal radius for the height at which plume vertical velocity falls below 4.3 m/s (m)		Plume horizontal radius for the height at which plume vertical velocity falls below 6.1 m/s (m)		Plume horizontal radius for the height at which plume vertical velocity falls below 10.6 m/s (m)	
	1 x OCGT	2 x OCGT	1 x OCGT	2 x OCGT	1 x OCGT	2 x OCGT
Maximum	187	301	93	155	19	37
Median	45	75	26	43	11	16

As the gas turbine and exhaust stack for the Proposal have not yet been selected, certain parameters including the exhaust stack exit diameter (and hence velocity) and height may be subject to minor changes from the values adopted in this assessment. As a result, a sensitivity analysis was conducted which used a 9 m taller exhaust stack (45 m height), along with a stack exit velocity of 50 m/s (twice that used in this assessment), to determine the effects on the plume rise from the Proposal's two exhaust stacks. The analysis indicated that the maximum height at which the plume vertical velocity fell below the vertical velocity thresholds of 4.3 m/s, 6.1 m/s and 10.6 m/s was not more than 10 m higher for each case. Thus, based on the modelling conducted, it was determined that the difference in plume height as a result of an increased stack exit velocity (from that adopted in this assessment) should not result in a significant change.

5. Conclusions

Plume rise modelling was conducted using TAPM in accordance with the requirements of CASA and results were presented such that the regions of space where the vertical plume velocity exceeded 4.3, 6.1 and 10.6 m/s could be determined.

Modelling for a five year simulation period showed that the height at which the plume vertical velocity falls below the critical vertical velocity threshold of 6.1 m/s would not exceed 1,144 m AGL, for 2 x OCGT units. The conditions which led to this maximum result were based on the assumption that two gas turbines were operating at a time of very light winds (0.1 m/s) on a winter day, a meteorological condition which occurred for one hour in the five year simulation period. The modelling also showed that the frequency of the plume vertical velocity exceeding 6.1 m/s at 1,000 m AGL is 0.03% (or approximately 3 hours in a year) and 0% at 1,200 m AGL for 2 x OCGT units operating.

6. References

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