February 2020

TALLAWARRA B OCGT

AVIATION IMPACT ASSESSMENT

Prepared for EnergyAustralia Development Pty Ltd

AVIATION PROJECTS

AVIATION PROJECTS

DOCUMENT CONTROL

Document Title: Tallawarra B OCGT - Aviation Impact Assessment

Reference: 062001-03

Release Date: 13 February 2020

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Reviewed by: P Davidyuk

Released by: K Tonkin

Revision History

Version	Description	Transmitted	Reviewed by	Date
0.3	Draft for internal review	05 December 2019	EA	09 December 2019
0.4	Draft for internal review	10 December 2019	EA reviewers	11 December 2019
0.5	Draft for external review	11 December 2019	Various	
0.6	Final Draft	11 February 2020	EA	12 February 2020
1.0	Final	13 February 2020	EA	13 February 2020
1.1	Revised Final	13 February 2020	EA	

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AVIATION PROJECTS

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GLOSSARY

AGL	above ground level
AHD	Australian height datum
AIP	aeronautical information package (Airservices Australia)
ALA	aircraft landing area
AMSL	above mean sea level
ARP	aerodrome reference point
CAAP	Civil Aviation Advisory Publication
CAR	Civil Aviation Regulations (1988)
CASA	Civil Aviation Safety Authority
CASR	Civil Aviation Safety Regulations (1998)
ERSA	En Route Supplement Australia (Airservices Australia)
FAC	facilities information chart
ICAO	International Civil Aviation Organisation
LGA	local government area
MOC	minimum obstacle clearance
MOS	Manual of Standards Part 139—Aerodromes
MSA	minimum safe altitude
OCGT	open cycle gas turbine
OLS	obstacle limitation surface(s)

UNITS OF MEASUREMENT

ft	feet	(1 ft = 0.3048 m)
km	kilometres	(1 km = 0.5399 nm)
m	metres	(1 m = 3.281 ft)
nm	nautical miles	(1 nm = 1.852 km)

EXECUTIVE SUMMARY

Aviation Projects has prepared this Aviation Impact Assessment to assess the potential risks to aviation of EnergyAustralia's proposed Open Cycle Gas Turbine (OCGT) at Tallawarra B (the project), near Shellharbour Airport in NSW. The project is required to ensure security of electricity supply in NSW upon the expected retirement of the Liddell power station in the Hunter Valley in 2022/23.

The primary purpose of this report is to address Condition 1.6 of the approval to proceed with construction of the project.

While it is clear that some stakeholders would prefer that the power station is not built due to its proximity to the airport, Australia's aviation regulatory framework requires the Civil Aviation Safety Authority (CASA) to foster 'equitable access' to airspace for all users of that airspace. A power station with thermal exhaust is an airspace user and has a right to equitable access to airspace, subject to certain legislative and regulatory requirements. In other words, it is possible for the Tallawarra B project to safely co-exist with aviation activities in and around Shellharbour Airport.

EnergyAustralia accepts that the Danger Area, as proposed in May 2019 as a mitigation for the plume, is not supported by CASA or Shellharbour Airport stakeholders. In response, EnergyAustralia has redesigned the project concept to reduce the height of the plume. This revised concept is presented for assessment in this report.

EnergyAustralia is evaluating a number of equipment options with a view to achieving a 6.1 m/s critical plume height below 1000 ft AMSL as directed by CASA and in accordance with guidance published in Advisory Circular 139-05(v 3.0) – *Plume rise assessments*. EnergyAustralia has specified a maximum 6.1 m/s critical plume height of 650 ft AMSL for the equipment being evaluated. A conservative value of 700 ft AMSL has been adopted for the purposes of this impact assessment.

This aviation impact assessment considers aviation safety in the context of the definition of safety in ICAO DOC 9859, *Safety Management Manual* (Fourth Ed):

> *The state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level.*

Of particular interest is the potential impact on lighter aircraft flying circuit operations in close proximity to the power station.

Modelling shows that the plume velocity at 1000 ft above mean sea level (AMSL) (circuit height for most general aviation activities) will be around 5.2 m/s, which falls within the definition of 'light' turbulence (which extends up until 6.1 m/s). While historical flight data shows that around 98.5% of all flights avoid the proposed plume area anyway, and it is possible in almost all circumstances for pilots to avoid over-flying the plume, at this velocity it is expected that impact on general aviation activities will be negligible.

The assessment concludes that with pragmatic and sensible mitigation, such as alerting pilots to the potential existence of the plume through education, annotation in aeronautical charts and publications and dynamic lighting on the top of the stack, the risks to aviation can be reduced to as low as reasonably practicable.

1. INTRODUCTION

1.1. Situation

EnergyAustralia Development Pty Ltd (EnergyAustralia) proposes to construct the new Tallawarra B open cycle gas turbine (OCGT) adjacent to the existing Tallawarra A combined cycle gas turbine (CCGT) at Tallawarra Power Station, which is located on the western shore of Lake Illawarra near Shellharbour in New South Wales. An overview of the site location is provided in Figure 1 (source: Google Earth), and a close up of the power station site showing the location of the proposed power station is provided in Figure 2 (source: EnergyAustralia).

Due to the velocity of the exhaust plume rise, there is potential for the exhaust plume to affect aircraft operating at or in the vicinity of the aerodrome.

In April 2019, EnergyAustralia submitted an Airspace Change Proposal to the Civil Aviation Safety Authority (CASA) for the implementation of a Danger Area over the site, as a means of mitigating the plume hazard. The equipment proposed at the time was an F Class gas turbine with a critical plume velocity of 6.1 m/s at a height of 1296 ft above mean sea level (AMSL).

CASA did not support the application for a Danger Area on the grounds that the location and proximity of the Danger Area would adversely impact aircraft operations in and around Shellharbour Airport to the extent the Office of Airspace Regulation determined the resulting risks to aviation would be unacceptable.

EnergyAustralia has subsequently undertaken additional engineering investigations with several equipment suppliers and identified a range of options to reduce the 6.1 m/s critical plume height to well below 1000 ft AMSL. These equipment options include a modified F Class machine (with exhaust diffuser) and several aero-derivative open cycle gas turbines.

1.2. Purpose and scope of task

EnergyAustralia has requested Aviation Projects to prepare an aviation impact assessment of the proposed Tallawarra B Open Cycle Gas Turbine (OCGT) power station to identify potential hazards to aviation, to undertake a thorough risk analysis and identify appropriate mitigation measures.

1.3. Methodology

The task was performed according to the method outlined below:

1. Confirm the scope and deliverables;
2. Review information and materials provided by the client;
3. Review relevant regulatory requirements and information sources;
4. Consider relevant aerodrome safeguarding aspects;
5. Assist with stakeholder consultation; and
6. Prepare an aeronautical impact assessment for submission to CASA in accordance with Advisory Circular (AC) 139-05 v3.0 *Plume rise assessments*, January 2019.

Figure 1 Tallawarra Power Station location overview

Figure 2 Location of Tallawarra B power station on site

1.4. Exclusions

In preparing the assessment, we relied on data provided by the client in relation to the characteristics of the vertical plume rise.

1.5. References

References used or consulted in the preparation of this report include:

- Airservices Australia, *Aeronautical Information Package; including AIP Book, Departure and Approach Procedures and En Route Supplement Australia,* dated 07 November 2019;
- Airservices Australia, *Designated Airspace Handbook,* dated 07 November 2019;
- Australian Transport Safety Bureau, Aviation Occurrence Statistics 2008-2017;
- Australian Transport Safety Bureau, Aviation Research Paper B2004/0010, *General aviation fatal accidents: How do they happen? A review of general aviation fatal accidents 1991 to 2000,* June 2004;
- Bureau of Meteorology, Hazardous Weather Phenomena – Turbulence;
- Civil Aviation Safety Authority, *Civil Aviation Regulations 1998 (CAR)*;
- Civil Aviation Safety Authority, *Civil Aviation Safety Regulations 1998* (CASR);
- Civil Aviation Safety Authority, *Manual of Standards Part 173 – Standards Applicable to Instrument Flight Procedure Design,* version 1.5, dated March 2016;
- Civil Aviation Safety Authority, *Manual of Standards Part 139 – Aerodromes*, version 1.14: dated January 2017;
- Civil Aviation Safety Authority, *Advisory Circular (AC) 139-8(2): Reporting of Tall Structures,* dated March 2018;
- Civil Aviation Safety Authority, *Advisory Circular (AC) 139-05(3.0): Plume Rise Assessment*, dated 03 January 2019;
- Department of Infrastructure and Regional Development, Australian Government, NASF Guideline E: *Managing the Risk of Distractions to Pilots from Lighting in the Vicinity of Airports;* and *Guideline F: Managing the Risk of Intrusions into the Protected Airspace of Airports*, dated 15 July 2012;
- Federal Aviation Administration, Airplane Flying Handbook;
- International Civil Aviation Organization (ICAO), *Doc 8168 Procedures for Air Navigation Services—Aircraft Operations (PANS-OPS)*;
- ICAO Standards and Recommended Practices, Annex 14—Aerodromes;
- OzRunways, aeronautical navigation charts, dated 07 November 2019; and
- other references as noted.

2. PLANNING CONTEXT

2.1. Conditions of approval

Tallawarra B OCGT was approved by the NSW Minister for Planning on 21 November 2010 according to Project Approval MP 07_0124 and subsequently according to Notice of Modification dated 06 April 2016. Condition 1.6 of the Administrative Conditions of Approval is the operative condition with respect to the exhaust plume analysis considered in this report:

> *1.6 Nothing in the* approval permits the construction and operation of an open cycle gas turbine plant, unless the Proponent has submitted a report to the Secretary which demonstrates that operation of an open cycle gas turbine plant *will not have an adverse impact on aviation safety*. This report must be prepared in consultation with Shellharbour City Council, and its *conclusions and recommendations must have been agreed by the Civil Aviation Safety Authority* prior to submission to the Secretary. *The report must be approved by the Secretary before the commencement of construction of an open cycle plant.*

2.2. Airport Master Plan

The *Illawarra Regional Airport Strategic and Business Plan*, prepared by Shellharbour City Council and published in or around 2015, "has been developed to provide a clear direction for Illawarra Regional Airport over the next 15 years." Note that the airport was renamed Shellharbour Airport in November 2019.

The strategic vision is set out in Section 3:

> *The overarching strategic vision of this plan is as follows:*
>
> > *i. To create, operate, maintain and manage a well-connected transport hub using existing and expanded facilities associated with Illawarra Regional Airport and adjoining road and rail facilities.*
> >
> > *ii. To offer competitive leases, pricing and services as compared with alternative airports and real estate parks.*
> >
> > *iii. To maintain at a minimum the infrastructure required for Code 2 aerodrome standards, to maintain current tenant aircraft operations eg emergency services. Code 2 means a runway capable of hosting aircraft that require between 800m & 1200m to take-off and land in all prevailing wind conditions, i.e. DHC8-300.2.*
> >
> > *iv. To achieve a positive return on Council assets by developing a mix of aeronautical and non-aeronautical business and community activities.*
> >
> > *v. To support and enable businesses, community events, tourism and economic growth in the region.*

The analysis contained herein has been prepared in consideration of this strategic vision.

3. REGULATORY CONTEXT

3.1. Civil Aviation Safety Regulations (1998) Part 139—Aerodromes

The Civil Aviation Safety Authority (CASA) regulates aviation activities in Australia. Applicable requirements include the Civil Aviation Regulations 1988 (CAR), Civil Aviation Safety Regulations 1998 (CASR) and associated Manuals of Standards (MOS) Part 139—*Aerodromes* and other guidance material.

Regulation 139.370 provides that CASA may determine that a gaseous efflux having a velocity in excess of 4.3 m/s is, or will be, a hazard to aircraft operations because of the velocity or location of the efflux. If CASA makes such a determination, it must publish in AIP or NOTAMS particulars of the hazardous object or gaseous efflux to which the determination relates; and give written notice of the determination.

The nominal 4.3 m/s velocity is used as a trigger for notification, not the velocity at which CASA will necessarily apply airspace risk control measures.

3.2. Manual of Standards Part 139–*Aerodromes*

Manual of Standards Part 139—Aerodromes (MOS 139) comprises specifications (S*tandards*) prescribed by CASA, of uniform application, determined to be necessary for the safety of air navigation. In those parts of the MOS where it is necessary to establish the context of standards to assist in their comprehension, the sense of parent regulations has been reiterated.

Chapter 7 of MOS 139 sets out the standards applicable to Obstacle Restriction and Limitation.

Section 7.1.2 establishes *Obstacle Restriction* requirements, including physical dimensions of OLS surfaces, for approach runways in Table 7.1-1: *Approach runways* and take-off runways in Table 7.1-2 *Take-off runways*.

Section 7.1.4 provides *Procedures for Aerodrome Operators to Deal with Obstacles*:

> *7.1.4.1 The aerodrome operator must monitor the OLS applicable to the aerodrome and report to CASA any infringement or potential infringement of the OLS.*
>
> *Note: Aerodrome operators need to liaise with appropriate planning authorities and companies that erect tall structures, to determine potential infringements. Every effort should be made to implement the OLS standards and limit the introduction of new obstacles.*
>
> *7.1.4.2 When a new obstacle is detected, the aerodrome operator must ensure that the information is passed on to pilots, through NOTAM, in accordance with the standards for aerodrome reporting procedures set out in Chapter 10.*
>
> *7.1.4.3 Information on any new obstacle must include:*
>
> *(a) the nature of the obstacle — for instance structure or machinery;*
>
> *(b) distance and bearing of the obstacle from the start of the take-off end of the runway, if the obstacle is within the take-off area, or the ARP;*
>
> *(c) height of the obstacle in relation to the aerodrome elevation; and*

(d) if it is a temporary obstacle — the time it is an obstacle.

The current standards have been revised and a new MOS 139 will be published with effect 22 August 2020.

Some of the dimensions relating to runway strip width and approach surface inner edge width relevant to the circumstances will change as of August 2020.

3.3. Advisory Circular 139-05 v3.0 - *Plume rise assessment*

According to the introduction contained within the relevant Advisory Circular 139-05 v3.0 - *Plume rise assessment,* Advisory Circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.

CASA has identified the need to assess the potential hazard to aviation where the vertical exit velocity from gas efflux or exhaust plume exceeds 6.1 metres per second (m/s). Relevant legislation includes the potential hazard, under Regulation 139.370 of CASR 1998 and the potential danger, under Regulation 6 of the Airspace Regulations 2007.

The purpose of Advisory Circular 139-05 v3.0 is to provide:

- *guidance to persons involved in the design, construction and operation of facilities with vertical exhaust plumes about the information required to assess the potential hazard from a plume to aircraft operations;*
- *a standard method of determining the critical plume height of a vertical exhaust plume so that impacts of a plume near aerodromes and away from aerodromes can be assessed in a consistent and reliable way; and*
- *guidance to proponents and stakeholders on the plume rise assessment process.*

The latest version of the AC 139-05 amends the original 4.3 m/s benchmark velocity parameter to 6.1 m/s in line with the Manual of Aviation Meteorology. Content and flowchart updates have been made to further clarify the process steps and roles.

If the exit velocity exceeds 6.1 m/s a Form 1247 (Application for Operational Assessment of a Proposed Plume Rise) must be submitted to CASA OAR (oar@casa.gov.au).

Step 3 of the Plume Rise Assessment Process, at para 3.1.3. states:

3.1.3 CASA will undertake the following key assessments and actions:

- *assessment of the critical plume velocity (CPV),*
- *assessment of the critical plume height (CPH),*
- *aviation stakeholder engagement, and*
- *assessment of the impact of the plume on aviation operations.*

The benchmark velocities selected by CASA to align with the Bureau of Meteorology classifications of turbulence are 6.1m/s for flight on terminal instrument flight procedures (TIFPs) and 10.6m/s for visual flight procedures. This approach protects flight on TIFPs up to the level of 'light turbulence' and protects visual flight procedures up to the level of 'moderate turbulence'. As there are many causes of turbulence prevalent in the atmosphere, pilots of smaller aircraft should assess the effects of vertical exhaust plumes in line with the current classification system[1].

A plume velocity of 6.1 m/s represents the Bureau of Meteorology's threshold between light and moderate turbulence. Any plume velocity below 6.1 m/s is classified as light turbulence. All aircraft, including light sport aircraft, certified and maintained as airworthy under Australia's regulatory framework should be capable of flight in light turbulence.

It should also be noted that the Bureau of Meteorology's definition of moderate turbulence expressly notes that the pilot remains in control at all times, in which case, regardless of the actual plume velocity that induces this effect, moderate turbulence should be tolerable for the aircraft in question.

Although a vertical exhaust plume exceeding 4.3 m/s remains a trigger for the assessment of a hazard under regulation 139.370, this benchmark velocity is not addressed in the assessment guidance in the AC 139-05. However, if a vertical exhaust plume exceeding 4.3m/s was assessed by CASA as a potential danger to aircraft flying over the area, this could warrant the declaration of a danger area under Airspace Regulation 6(4)[2].

There are currently 19 danger areas established in Australia due to high velocity exhaust plumes. Of those danger areas, D611 at Ballera is established up to FL150 and is within 260 m of the runway. D652 is established at Oakey up to 2800 ft AMSL and is located 2 nm from the threshold of runway 09. D187 at Barrow Island is established up to 1800 ft AMSL and is situated on the extended centreline at 3.7 nm from the threshold of runway 21.

Research[3] shows that there are multiple Open Cycle Gas Turbine (OCGT) plants in close proximity to aerodromes that were commissioned prior to the establishment of the Office of Airspace Regulation at CASA that are unlikely to have ever been assessed for their impact on aviation. Examples are OCGT plants at Mackay (1.5 nm from the threshold of runway 14), Bairnsdale (2.4 nm from the threshold of runway 13) and Darwin (Berrimah OCGT 1.5 nm from the threshold of runway 29 and the Channel Island OCGT south of existing D227).

The danger areas applied to these circumstances protect aircraft from a plume velocity of 6.1 m/s. If a lower critical plume velocity was to now be established, all of the existing danger areas would need to be re-evaluated, and in most cases, raised to accommodate the higher critical plume height. This may result in inadvertent impacts on instrument approach procedures at some nearby aerodromes.

Note the following conversions for metres/second to knots:

- 4.3 m/s = 8.4 kt
- 6.1 m/s = 11.9 kt
- 10.6 m/s = 20.6 kt.

[1] ICAO is moving away from derived vertical gusts to describe turbulence in favour of energy dissipation rates which are aircraft independent.

[2] The *Airspace Regulations 2007* provides under regulation 6(4): "CASA must not declare an area to be a danger area unless, in the opinion of CASA, there exists within or over the area an activity that is a potential danger to aircraft flying over the area."

[3] http://globalenergyobservatory.org/select.php?tgl=Edit

3.4. CASA guidance re plume velocity

CASA specifically directed Energy Australia, in a letter from Mr Andrew Sparrow to Mr Justin Courmidias, dated 23 July 2018, to use 6.1 m/s as the critical plume velocity for this assessment:

> *CASA has determined that due to the proximity of the power plant to the circuit area of Wollongong Airport, a plume velocity of 6.1 m/s should be used when determining the potential plume rise turbulence impact on aircraft.*

Mr Sparrow went on to say:

> *CASA recommends that the plumes …be managed through an engineering solution…to ensure the plume reduce below 6.1 m/s by 1031 ft AMSL.*

EnergyAustralia intends to ensure the 6.1 m/s critical plume height is well below 1000 ft AMSL. The assessment provided herein relies on a maximum height of 700 ft AMSL for the 6.1 m/s plume velocity.

3.5. Airspace Act (2007)

Section 12 of the Airspace Act 2007 contains overarching principles that serve as a guide as to the "Matters affecting CASA's administration and regulation of Australian-administered airspace". In performing its functions and in exercising its powers…CASA:

- must foster efficient use of airspace;
- must foster equitable access to that airspace for all users of that airspace;
- is not limited as to the matters that may be taken into account; and
- must take into account the capacity … of Australian-administered airspace to accommodate changes in its use.

The Civil Aviation Act (1988) also provides that certain other matters are triggered such as compliance with the Australian Airspace Policy Statement 2015 (AAPS). Paragraph 8 of the AAPS states that the administration of Australian administered airspace shall be in the best interests of Australia.

3.6. Airspace Regulations (2007)

The Airspace Regulations 2007 provide under Regulation 6(1) that CASA may, in writing, make a declaration designating an area of Australian territory to be a prohibited area, a restricted area or a danger area.

> 4.3.1. Regulation 6(3) provides that CASA must not declare an area to be a restricted area unless, in the opinion of CASA, it is necessary to restrict the flight of aircraft over the area to aircraft flown in accordance with specified conditions in the interests of any of the following:
>
> (a) public safety, including the safety of aircraft in flight;
>
> (b) the protection of the environment;
>
> (c) security.

4.3.2. Regulation 6(4) provides that CASA must not declare an area to be a danger area unless, in the opinion of CASA, there exists within or over the area an activity that is a potential danger to aircraft flying over the area.

3.7. Airspace context

The existing regulatory framework therefore provides for CASA to undertake an assessment of the proposed facility at Tallawarra, taking into account the capacity of Australian-administered airspace to accommodate changes in its use and to foster efficient use of that airspace, in the best interests of Australia.

3.8. Civil Aviation Advisory Publication (CAAP) 166-1(v4.2)

CAAP 166-1(v4.2) – Operations in the vicinity of non-controlled aerodromes – provides guidance with respect to CAR 166. The purpose of this CAAP is to support Common Traffic Advisory Frequency (CTAF) procedures. It provides guidance on a code of conduct (good airmanship) to allow flexibility for pilots when flying at, or in the vicinity of, non-controlled aerodromes.

CAAP 166-1(v4.2) paragraph 2.1.4 states the following:

> *2.1.4 CASA strongly recommends the use of 'standard' traffic circuit and radio broadcast procedures by radio-equipped aircraft at all non-controlled aerodromes. These procedures are described in the Aeronautical Information Publication (AIP) and Visual Flight Rules Guide (VFRG), and discussed in Section 65 of this CAAP (Standard traffic circuit procedures) and Section 7 (Radio broadcasts).*

The standard circuit consists of a series of flight paths known as *legs* when departing, arriving or when conducting circuit practice. Illustrations of the standard aerodrome traffic circuit procedures are provided in Figure 3 and Figure 4.

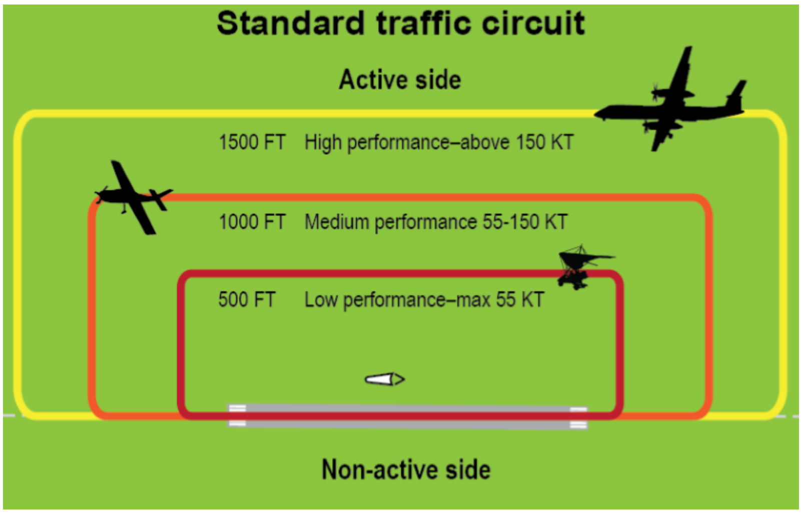


Figure 3 Lateral and vertical separation in the standard aerodrome traffic circuit

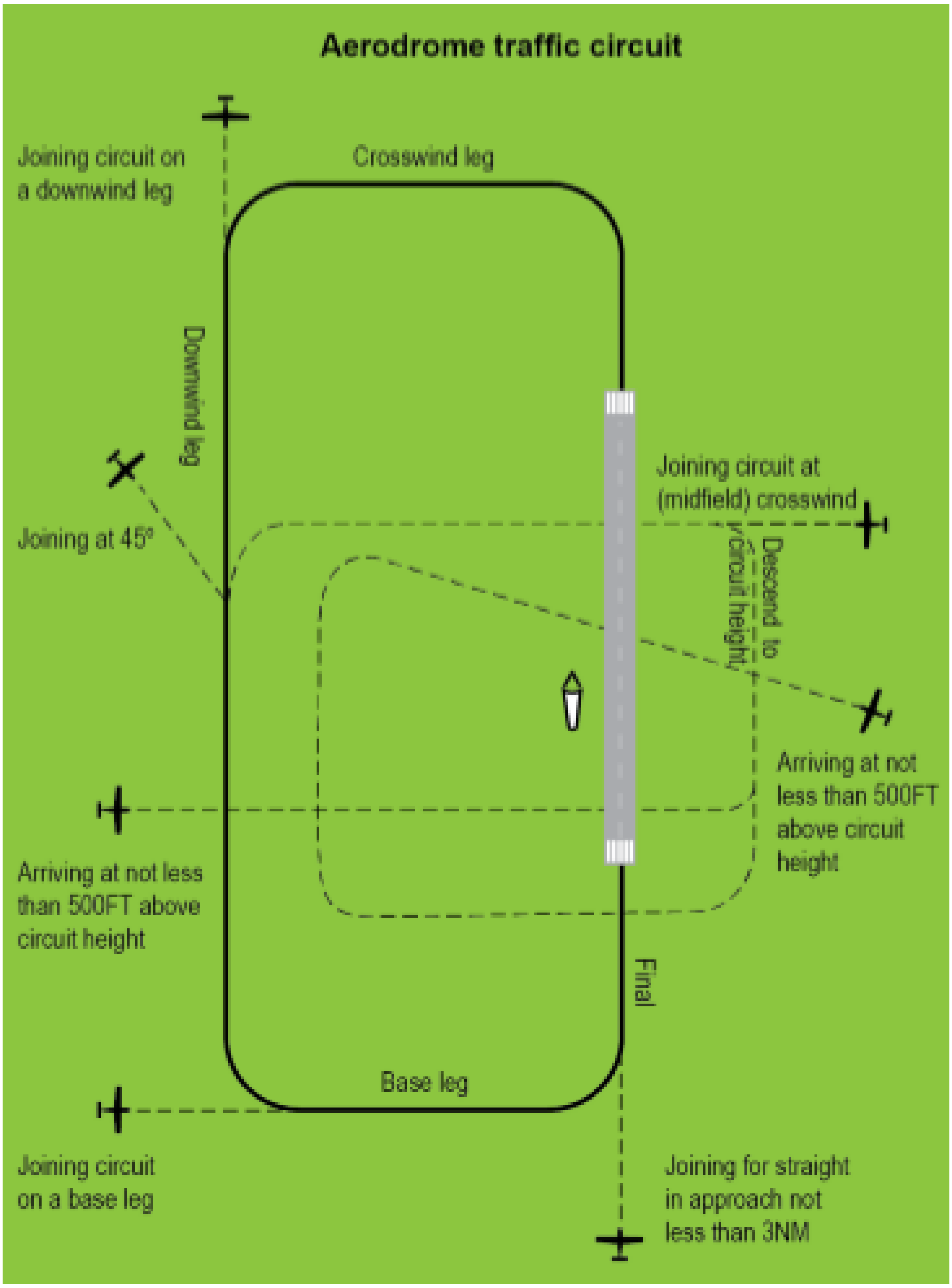


Figure 4 Aerodrome standard traffic circuit, showing arrival and joining procedures

Paragraph 5.3.1 provides guidance in relation to standard traffic circuit heights:

> *By convention, aircraft should fly the standard traffic circuit at the heights above aerodrome elevation listed in Table 1…*

Table 1 Standard circuit heights and aircraft performance

Type of aircraft	*Standard circuit speed*	*Standard circuit height*
High performance (includes jets and many turboprops)	*Above approximately 150 kt*	*1500 ft above aerodrome elevation*
Medium performance (includes most piston engine aircraft and gliders)	*Between approximately 55 kt and 150 kt*	*1000 ft above aerodrome elevation*
Low performance (trikes and ultralight aircraft)	*Approximately 55 kt maximum*	*500 ft above aerodrome elevation*

Paragraph 5.3.2 provides guidance in relation to the height required to be achieved during climb-out:

> *During initial climb-out, the turn on to crosswind should be appropriate to the performance of the aircraft but, in any case, not less than 500 ft above terrain so as to be at circuit height when turning downwind (refer paragraph 166A (2) (f) of CAR). Pilots may vary the size of the circuit depending on:*
>
> - *the performance of the aircraft.*
> - *AFM/Pilot's Operating Handbook requirements.*
> - *company SOPs.*
> - *other safety reasons.*

Paragraph 5.5.2 provides guidance in relation to the conduct of final approach:

> *Except for IFR circling operations, the turn onto final approach should be completed at least 500 ft above aerodrome elevation. This should allow sufficient time for the pilot to ensure that the runway is clear for landing. It will also allow sufficient time for the majority of aircraft to fly a stabilised approach and landing.*

3.9. Rules of flight

3.9.1. Flight under Day Visual Flight Rules (VFR)

According to Aeronautical Information Publication (AIP) the meteorological conditions required for visual flight in the applicable (class G) airspace at or below 3000 ft AMSL or 1000 ft AGL whichever is the higher are: 5000 m visibility, clear of clouds and in sight of ground or water.

Civil Aviation Regulation (1988) 157 (Low flying) prescribes the minimum height for flight. Generally speaking aircraft are restricted to a minimum height of 500 ft AGL above the highest point of the terrain and any object on it within a radius of 600 m (or 300 m for helicopters) in visual flight during the day when not in the vicinity of built up areas, or 1000 ft AGL over built up areas, such as Tallawarra and its environs.

These height restrictions do not apply if through stress of weather or any other unavoidable cause it is essential that a lower height be maintained.

Flight below these height restrictions is also permitted in certain other circumstances.

3.9.2. Night VFR

With respect to flight under the VFR at night, Civil Aviation Regulations (1988) 174B states as follows:

The pilot in command of an aircraft must not fly the aircraft at night under the V.F.R. at a height of less than 1000 feet above the highest obstacle located within 10 miles of the aircraft in flight if it is not necessary for take-off or landing.

3.9.3. IFR (Day or night)

According to CAR 178, flight under the instrument flight rules (IFR) requires an aircraft to be operated at a height clear of obstacles that is calculated according to an approved method. Obstacle lights on structures not within the vicinity of an aerodrome are effectively redundant to an aircraft being operated under the IFR.

3.10. Recreational Aviation Australia (RAAus)

Australian sport aviation operates under self-administration. Self-administering organisations operate under a series of exemptions and delegations. These sets of rules allow specialised aircraft that don't meet certification standards to operate through a series of exemptions from the regulations that apply to broader aviation activities.

Recreational Aviation Australia (RAAus) is a self-administering organisation responsible for administering ultralight, recreational and light sport aircraft operations, including 3-Axis aircraft, weight shift trikes, or powered parachutes.

All RAAus aircraft currently have a maximum of two seats with a maximum take of weight (MTOW) no more than 600 kg (with pathways in place to increase this limit in the future to 760 kg or greater), and are permitted to operate during daylight hours only under the visual flight rules.

A copy of the images published by RAAus on its website to illustrate the aircraft on its register is provided at Figure 5.

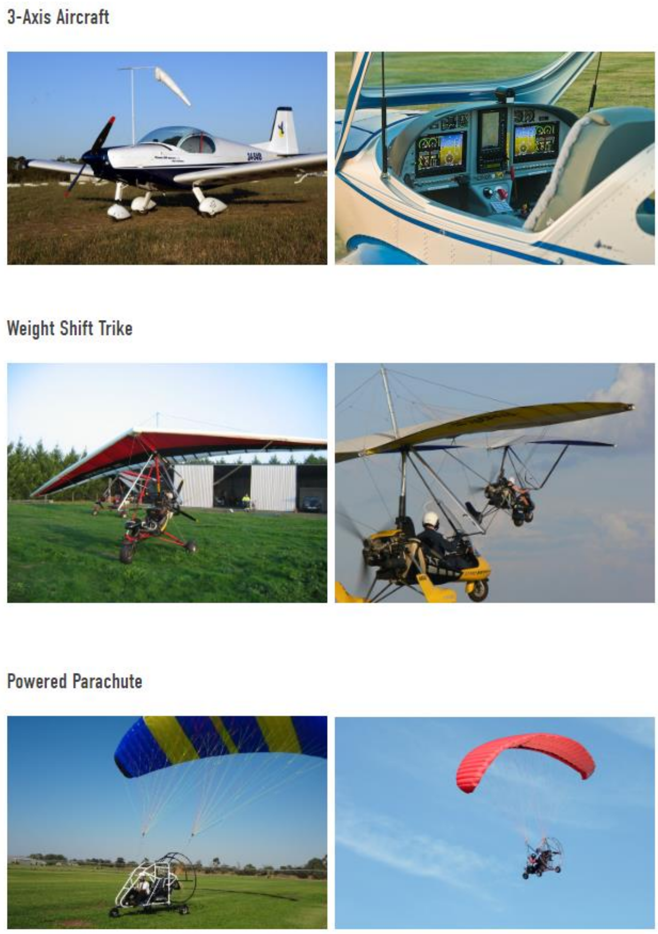


Figure 5 RAAus indicative aircraft

3.11. Airspace Risk and Safety Management Manual

The Airspace Risk and Safety Management Manual (ARASMM) is not currently available on the CASA website. However, the CASA Risk Management Framework is understood to be based on the Australian/New Zealand Standard on Risk Management – Principles and Guidelines (AS/NZS ISO 31000:2018)[4]

CASA's fundamental risk management process includes the following key stages:

1. Establish the context
2. Identify the risks
3. Assess the risks
4. Evaluate and analyse the risks (both qualitatively and quantitatively)
5. Treat the risks

The result of this process aims to reduce the risks to as low as reasonably practicable (ALARP) or to a level of risk that is acceptable or tolerable.

3.12. ICAO Safety Management Manual Ed 4

ICAO DOC 9859, Safety Management Manual (Fourth Ed) defines safety as:

> *The state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level.*

This definition forms the basis of interpreting the relevant aspect of condition of approval 1.6 relating to impact on aviation safety.

3.13. Airspace protection

NASF Guideline F: *Managing the Risk of Intrusions into the Protected Airspace of Airports* addresses the intrusions into operational airspace of airports by tall structures, such as buildings and cranes. Key considerations in the protection of visual operations includes the protection of the OLS and PANS-OPS.

NASF Guideline F sets out the details of the assessment process. NASF Guideline F is available at the website: https://www.infrastructure.gov.au/aviation/environmental/airport_safeguarding/nasf/files/6.1.3_Guideline_F.pdf

[4] https://www.iso.org/iso-31000-risk-management.html

4. POWER STATION OPERATIONS

4.1. Proposed operations

EnergyAustralia advises that due to the transition of the electricity grid to a higher percentage supply from variable sources such as wind and solar, increasingly there is a need for flexible and dispatchable sources to ensure security of supply when the wind doesn't blow and the sun doesn't shine. Gas-fired generation is ideally suited to this role in the market.

The power station is intended to be operated in response to a need to supplement base load power during periods of peak demand or when there is insufficient supply from intermittent sources such as wind and solar. For the purpose of evaluating potential impacts on flying operations, the nominal operating schedule is assumed to be for one or two hours in the morning, and three hours in the afternoon, five working days per week. The power station could, however, be operated 24 hours per day, or not at all for days at a time, according to demand.

EnergyAustralia is engaged in commercial negotiations with several equipment manufacturers for the supply of an OCGT solution that can achieve a critical plume height of 6.1 m/s at an altitude below 1000 ft AMSL (specified as a maximum of 650 ft AMSL). As these negotiations are currently underway, and the disclosure of specific plume details would invalidate probity obligations, a range of critical plume heights (which are preliminary and subject to further verification) for a modified F Class and aero-derivative machines has been provided by EnergyAustralia for the purposes of the analysis herein.

Note: In this report, 700 ft AMSL has been used as a conservative value for the 6.1 m/s critical plume height.

4.2. Plume characteristics – Modified F Class

EnergyAustralia's plume modeller Katestone has prepared a summary assessment for the modified F Class turbine. This report is provided at Annexure 1.

Refer to Table 2 for the current Tallawarra A and preliminary modified F Class data.

Table 2 Plume modelling results – modified F Class

Plume velocity	*Tallawarra A 99.9% TAPM plume height (ft AMSL)*	*Modified F Class Modified Spillane plume height (ft AMSL)*
4.3 m/s	558	2200
6.1 m/s	356	580
10.6 m/s	266	275

Preliminary plume velocities for the modified F Class machine at nominated altitudes are provided in Table 3.

Table 3 Plume velocities at nominated altitudes – modified F Class

Altitude (ft AMSL)	*Modified F Class Modified Spillane Plume velocity (m/s)*
1000	5.2
1200	5.1
1500	4.9

4.3. Plume characteristics – Aero derivatives

Katestone has prepared a summary assessment for aero-derivative turbines, in the report provided at Annexure 1.

Refer to Table 4 for the range of results for aero-derivative machines.

Table 4 Plume modelling results – Aero-derivatives

Plume velocity	*Tallawarra A 99.9% TAPM plume height (ft AMSL)*	*Aero-derivative 99.9% TAPM plume height range (ft AMSL)*
4.3 m/s	558	1300-1650
6.1 m/s	356	340-420
10.6 m/s	266	180-190

Preliminary plume velocity ranges for the various machines at nominated altitudes are provided in Table 5.

Table 5 Plume velocities at nominated altitudes – Aero-derivatives

Altitude (ft AMSL)	*Aero-derivative 99.9% TAPM Plume velocity range (m/s)*
1000	5.4-5.8
1200	4.8-5.6
1500	4.1-4.8

4.4. Wind effect on plumes

Katestone has provided the following advice in relation to the effect of wind on the plume characteristics.

In simple terms, the effect of increasing wind speed is to 'push' the plume over progressively and diminish the amount of plume rise.

The environmental lapse rate (atmospheric stability) is also important because instability encourages upward penetration whereas stability produces a restraining influence.

For example, a situation where the wind speed is low at the top of the stack and remains low up through the atmosphere, the plume would be largely unaffected by wind until plume momentum and buoyancy are reduced.

On the other hand, if the conditions are unstable and the wind speed (and accompanying turbulence) is elevated at the top of the stack and remains elevated up through the atmosphere, then the plume would be affected throughout its trajectory, resulting in a more diminished plume and lower height.

Any realistic situation of Tallawarra plumes will be a combination of the above effects.

The purpose of the TAPM plume model is to simulate these effects and predict the resulting plume heights. Five years of atmospheric data is run through the model to help inform the probabilities of plume heights.

5. AVIATION OPERATIONS

5.1. Scope of operations

Shellharbour Airport supports a wide range of aircraft operations, ranging from private flying, commercial and charter operations including sky diving, flying training, warbird and experimental aircraft displays and regular public transport. These operations are conducted in recreational and VH-registered aircraft up to Saab 340 (34 passenger seats) sized aircraft. The airport supports the occasional operation of code 3 jet aircraft.

Operations at the airport are conducted year-round, day and night.

The annual number of aircraft movements (take-offs and landings) has variously been reported as 40,000 to 45,000.

Actual Avdata records of aircraft movements at Shellharbour Airport for the period 1 June 2017 to 31 May 2019 (in line with FlightAware data) was on request at the time of writing this report.

5.2. Performance categories

An aircraft's performance category is determined according to a fixed multiple of its stall speed.

At Shellharbour Airport, the most prevalent aircraft are in performance categories A and B. Larger turboprop and most jet aircraft are performance category C and above.

5.3. Circuits

CASA does not publish the dimensions of a standard circuit. It publishes guidance on what it calls 'standard traffic circuit procedures' in CAAP 166-01(v4.2), as outlined in Section 3.8.

The Federal Aviation Administration, in The Airplane Flying Handbook, Chapter 7 – Airport Traffic Patterns, suggests that that the "downwind leg is flown approximately ½ to 1 [statute] mile out from the landing runway". 1 statute mile = 0.87 nm.

The amount of runway required for take-off can be affected by such considerations as the runway surface (e.g. dry or wet, length of grass), actual temperature, wind direction and strength, the weight of the aircraft (which can change for time to time according to the number of passengers or amount of baggage or other payload being carried), forward visibility and pilot handling.

The distance required to achieve the minimum 500 ft above ground level prior to turning onto crosswind can be affected by the aircraft's weight, engine performance, wind strength and direction and pilot handling.

The strength and direction of wind can affect aircraft tracking, which means that there is likely to be some variation in the tracks flown when performing a circuit. For this reason alone, any representation of a circuit pattern should be considered indicative only and subject to some variation according to environmental conditions and pilot handling.

In any case, for the purposes of the analysis herein, the following design parameters have been adopted for a nominal 1 nm circuit:

- 1 nm upwind to achieve at least 500 ft AGL;

- 1 nm abeam the runway for downwind spacing;
- 45° relative position from the threshold for the turn from downwind onto the base leg; and
- Roll out at 1 nm final, not below 500 ft AGL.

A larger 1.5 nm circuit has also been introduced for the purpose of analysing the proposition (which is not supported by Aviation Projects) that aircraft must overfly the power station when conducting a circuit on runway 16 or 34.

For aircraft conducting a straight-in approach, the final leg must be joined not closer than 3 nm from the threshold, and therefore is not considered a factor in potential impacts arising from the proposed power station.

5.4. Runways 08/26 circuits

Circuits on runways 08 and 26 are conducted to the north of the aerodrome, as represented in Figure 6.

Note as per the Noise Abatement Procedures published in En Route Supplement Australia (ERSA), take-offs on runway 08 and landings on runway 26 are to be avoided unless operationally required.

The power station site is approximately 2.5 nm from runway 08/26 and so aircraft conducting circuits on that runway will be well clear of the power station.

Figure 6 Runways 08/26 1 nm circuit

5.5. Runways 16/34 circuits

Circuits on runways 16 and 34 are conducted to the east of the aerodrome, as represented in Figure 7.

Figure 7 Runway 16/34 1 nm circuit

Generally, smaller low performance aircraft such as microlights and gyrocopters operating at 500 ft are likely to remain closer to the aerodrome than aircraft operating at higher circuit altitudes. This is so that they are able to glide back to the runway in the event of an engine failure. Larger, high performance aircraft such as the Saab 340 are not likely to be affected by the vertical plume due to their higher performance and the fact that they conduct circuit operations at 1500 ft.

Further, the hill just to the north west of the power station with a mast at 436 ft AMSL presents a significant hazard to aircraft operating at 500 ft above aerodrome elevation (31 ft), and there are high tension power lines and pylons in the vicinity of the power station adding to the risk of operating at low level over them.

When conducting a circuit, the aim is to place the aircraft in an optimal position for final approach and landing, with the downwind leg of a suitable length and distance parallel to the runway that may provide a chance to return to the runway in the event of an engine failure. An extended upwind and a wide and/or extended downwind, which would be required to overfly the power station, do not put the aircraft in a suitable position to account for emergency returns to the aerodrome.

Sound airmanship as demonstrated by the response from operators consulted in the course of preparing this report would keep them away from the area as much as possible.

Figure 8 provides an image looking towards the airport to the south west, with the 1.0 nm (orange) and 1.5 nm (magenta) indicative circuit ribbons (based on 1000 ft downwind altitude) and the code 2 obstacle limitation surfaces overlaid on Google Earth. The outer 1.5 nm circuit that would overfly the power station site would also require an aircraft to overfly the small hill to the west of the site. The highest obstacle on the hill is marked on aeronautical charts as a lit obstacle with a maximum overall height of 436 ft AMSL.

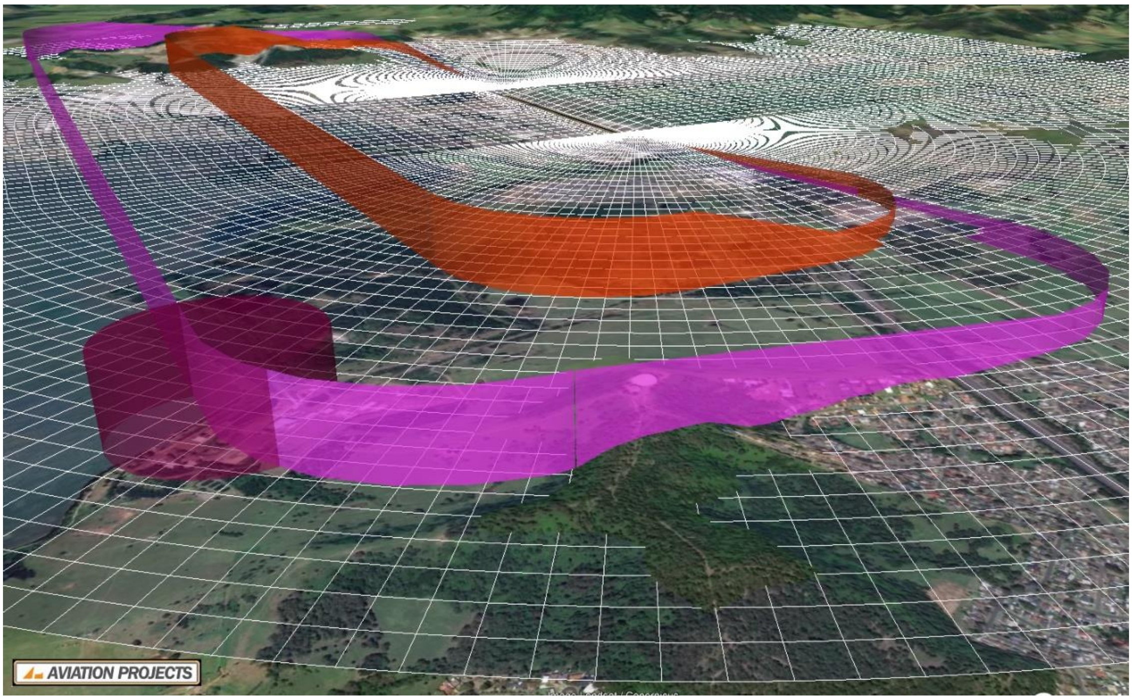


Figure 8 North western extent of circuits on runway 16/34

Figure 9 shows a view from Haywards Bay towards the power station, clearly showing the tank on the nearby hill.

Figure 9 View from Haywards Bay towards the power station looking north east

Figure 10 (day) and Figure 11 (night) show the view from Mt Warrigal towards the power station. The obstacle light on the nearby hill can be clearly seen in Figure 11.

Figure 10 View from Mt Warrigal towards power station site looking north west (day)

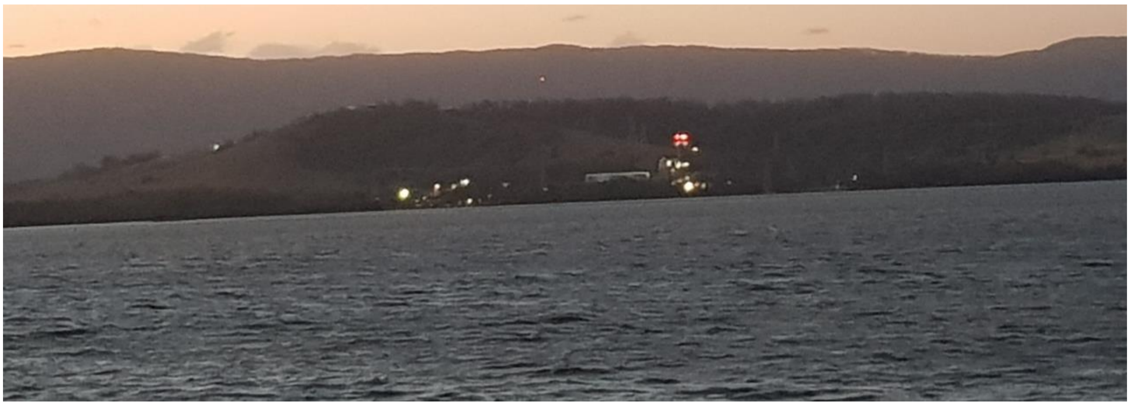


Figure 11 View from Mt Warrigal towards power station site looking north west (night)

Figure 12 provides an image looking towards the airport to the north west, with the two circuits and the code 2 obstacle limitation surfaces overlaid on Google Earth. High terrain to the south of the airport impinges on both circuits, but to a greater extent on the larger 1.5 nm circuit.

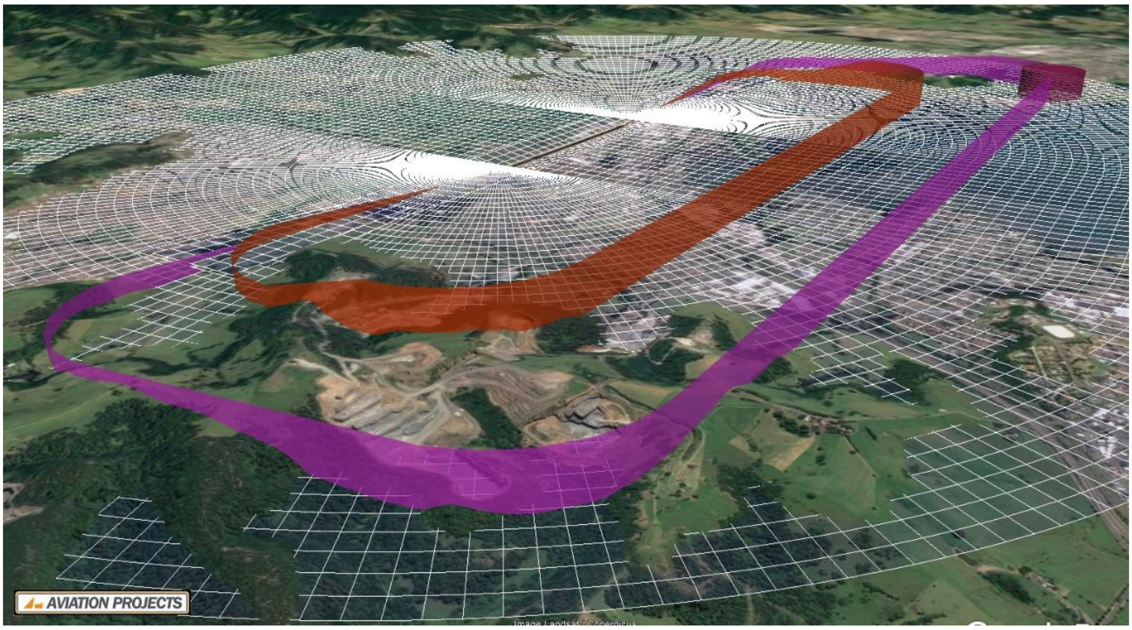


Figure 12 South western extent of circuits on runway 16/34

5.6. Discussion of general circuit operations

This discussion arises from comments regarding the likelihood of a small aircraft overflying the power station on climb out from runway 34 or downwind/base on runway 16.

On runway 34, an aircraft taking off must climb to 500 ft above aerodrome elevation before turning right onto crosswind. Overflight of the power station after the turn from upwind would involve a non-standard circuit pattern of departure for most small aircraft under most conditions.

The aircraft would continue climbing – to cruise altitude if departing the circuit, or to circuit height if remaining in the circuit. The standard circuit height is 1000 ft. Some lower performance aircraft may remain at 500 ft, but consultation with local operators revealed a preference to climb to 1000 ft in any case. It has already been demonstrated that aircraft should not be flying below approximately 1000 ft in the vicinity of the power station because of the 436 ft high mast on the hill just to the north west of the power station. Doing so would likely violate CAR 157 requirements.

Having turned crosswind, the aircraft will travel at least 1.5 nm, and in most cases, have diverged from a standard crosswind track, to arrive overhead the power station. At a speed of say 75 kt, an aircraft would need to climb at a relatively low 416 ft/min rate of climb to achieve 1000 ft circuit height overhead the power station.

If a pilot was concerned about the potential for the plume to affect aircraft controllability, it would be simply a matter of either deviating left or right to avoid the plume. If, for whatever reason, the pilot was unable to avoid overflying the plume at 1000 ft, they would likely experience conditions equivalent to momentary light turbulence, a commonplace condition encountered every day by light aircraft all around the world, without consequence. In the extremely unlikely event of aerodynamic stall or loss of control as a result of the turbulence (as suggested by AOPA in its feedback) the pilot would merely need to apply appropriate control input to address this occurrence, as they would if they had encountered similar weather-driven turbulence.

The case of a Cessna 172 at maximum weight and maximum rate of climb was cited by AOPA as a cause for concern. However, in order to overfly the station, albeit in a non-standard circuit pattern, and at that high rate of climb at slow speed, the aircraft would take around 2.3 minutes to arrive overhead the power station, and if it is climbing at max rate of around 700 fpm, would be at an altitude of at least 1600 ft AMSL, well above any plume concerns.

On runway 16, a low performance aircraft is very unlikely to overfly the power station unless for some reason it needs to widen or extend the circuit for traffic avoidance purposes. It almost certainly will not be lower than 1000 ft AMSL because of the 436 ft high mast on the hill just to the north west of the power station. In this event, some pilots may select flaps on late downwind or early base (so that the aircraft is in the approach configuration when it overflies the power station), but this would not necessarily result in the most efficient energy management solution for these low performance aircraft. In any case, if the aircraft experienced the effects of the plume, the plume would be at a velocity of well below 6.1 m/s.[5]

5.7. Equivalent situation – danger area under final segment of instrument approach

An equivalent hypothetical situation involving a vertical plume directly underneath the final segment of an instrument approach can be considered. In this situation, a danger area could be located over the plume with its vertical dimension corresponding to the 6.1 m/s critical plume height.

According to Manual of Standards Part 173—*Standards Applicable to Instrument Flight Procedure Design*, paragraph 8.1.1.6, procedures which cross or abut danger areas associated with high-velocity gas efflux must be designed so that, vertically, the upper limit of the danger area may be used, provided obstacle clearance criteria are met.

According to ICAO Doc 8168 (PANS-OPS), the obstacle clearance height applicable to the final segment of a non-precision instrument approach where the angle between the track and the extended runway centre line does not exceed 5 degrees is 75 m (246 ft) if there is a final approach fix.

An aircraft conducting such a non-precision approach, such as a Cessna 172, could potentially descend to the minimum descent altitude and overfly the plume source at a height of 246 ft above the 6.1 m/s critical plume height.

Note that an aircraft overflying the proposed power station at a height of 1000 ft AMSL will be at least 300 ft above the 6.1 m/s critical plume height (conservatively nominated as 700 ft AMSL).

[5] The link below records the typical circuit pattern of such an aircraft, illustrating the points made here. The flight is a first solo in a Jabiru 170, conducted in calm winds, on runway 16. The aircraft turns base well before Tallawarra Power Station, and it can be seen that the downwind leg is conducted on or inside the orange circuit depicted in Figure 7. The aircraft flaps are not operational, so there is no changing of configuration on downwind or base. https://youtu.be/ecaORnym6LY

5.8. Flight path analysis – FlightAware data

FlightAware provides aircraft tracking data for various commercial purposes. It receives data from a number of sources, including from terrestrial and space-based automatic dependent surveillance – broadcast (ADS-B) networks. Flight tracks within the vicinity of Shellharbour Airport from 0 – 2500 ft AMSL, for the period 01 June 2017 through to 31 May 2019 were procured from FlightAware for the purposes of further analysis.

The data files were cleaned of multiple tracks and null values, resulting in a total of 13,233 unique tracks over the two-year period.

Aircraft types captured in the data included a range of helicopters (Robinson R44, A119, Squirrel) through to fixed wing aircraft ranging from various RAAus aircraft (registration numbers available), Aquila AT01, Cessna 172, Cessna 210, Cirrus SR20 and SR22, Diamond DA40, PA28 Cherokee, Lancair IV, Lancair Legacy, GA8 Airvan, C208 Caravan, Cessna 404, Cessna 441, Beech 350 King Air, Saab 340. This is a non-exhaustive list.

Of the unique tracks, a total of 6 tracks (0.045%) entered a cylinder of 260 m radius between 0-550 ft AMSL, centred on the proposed power station site, and a total of 209 tracks (1.58%) entered a cylinder the same radius between 550 ft AMSL and 1050 ft AMSL. These 215 tracks that flew through the cylinder represent 1.62% of all flights tracked.

A total of 29 unique tracks flew through the same radius cylinder below a height of 700 ft AMSL (nominal moderate turbulence region), and 186 tracks flew through the volume between 700 – 1050 ft AMSL (light turbulence). This means a total of 13.5% of those flights tracked through the cylinder flew in the nominal moderate turbulence region applicable to the proposed power station, representing 0.22% of all flights tracked.

It is important to note that these results were in the absence of any alerting to a potential hazard that may arise from the Tallawarra B plume.

5.9. Heat maps

The FlightAware data referenced above has been analysed to produce ‘heat maps’ of the density of data points within nominated height bands, as a way of showing where aircraft are flying in the vicinity of Shellharbour Airport.

Figure 13 shows the density of data points below 1000 ft AMSL, and Figure 14 shows the relative density of data points between 1001 ft and 1500 ft AMSL, for values within 100 m radius of a nominated position. Figure 15 and Figure 16 provide the data relevant to 500 m radius circles, to present a less cluttered analysis.

This analysis shows the proposed power station is rarely overflown below 1000 ft AMSL (1.62% of all flights), and the 1 nm circuit is generally representative of the circuit pattern flown by those aircraft that were tracked by FlightAware. The 1.5 nm circuit track and the power station site are located on the outer periphery of flights tracked at or below 1000 ft AMSL.

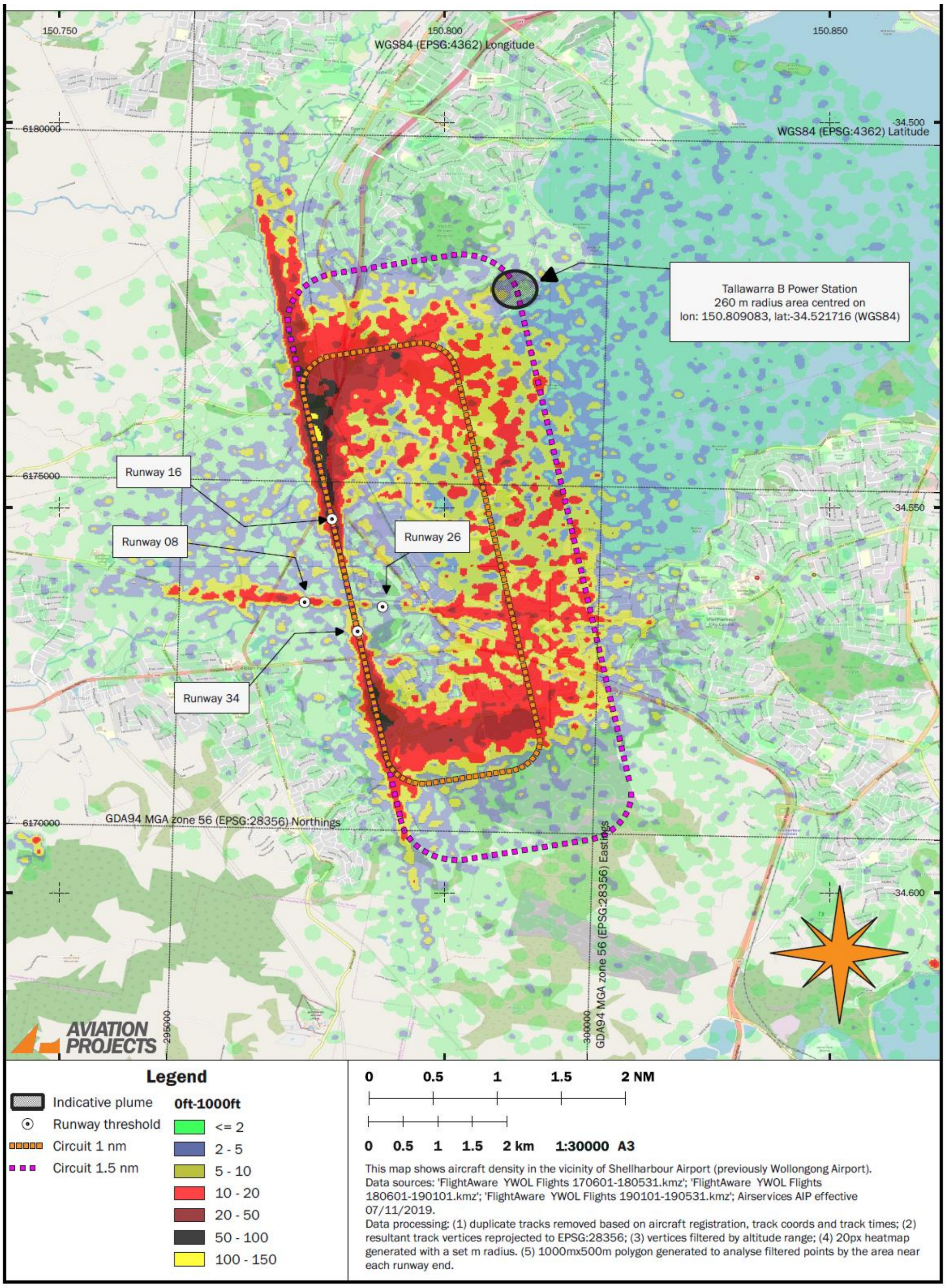


Figure 13 Heat map 0-1000 ft AMSL (100 m analysis)

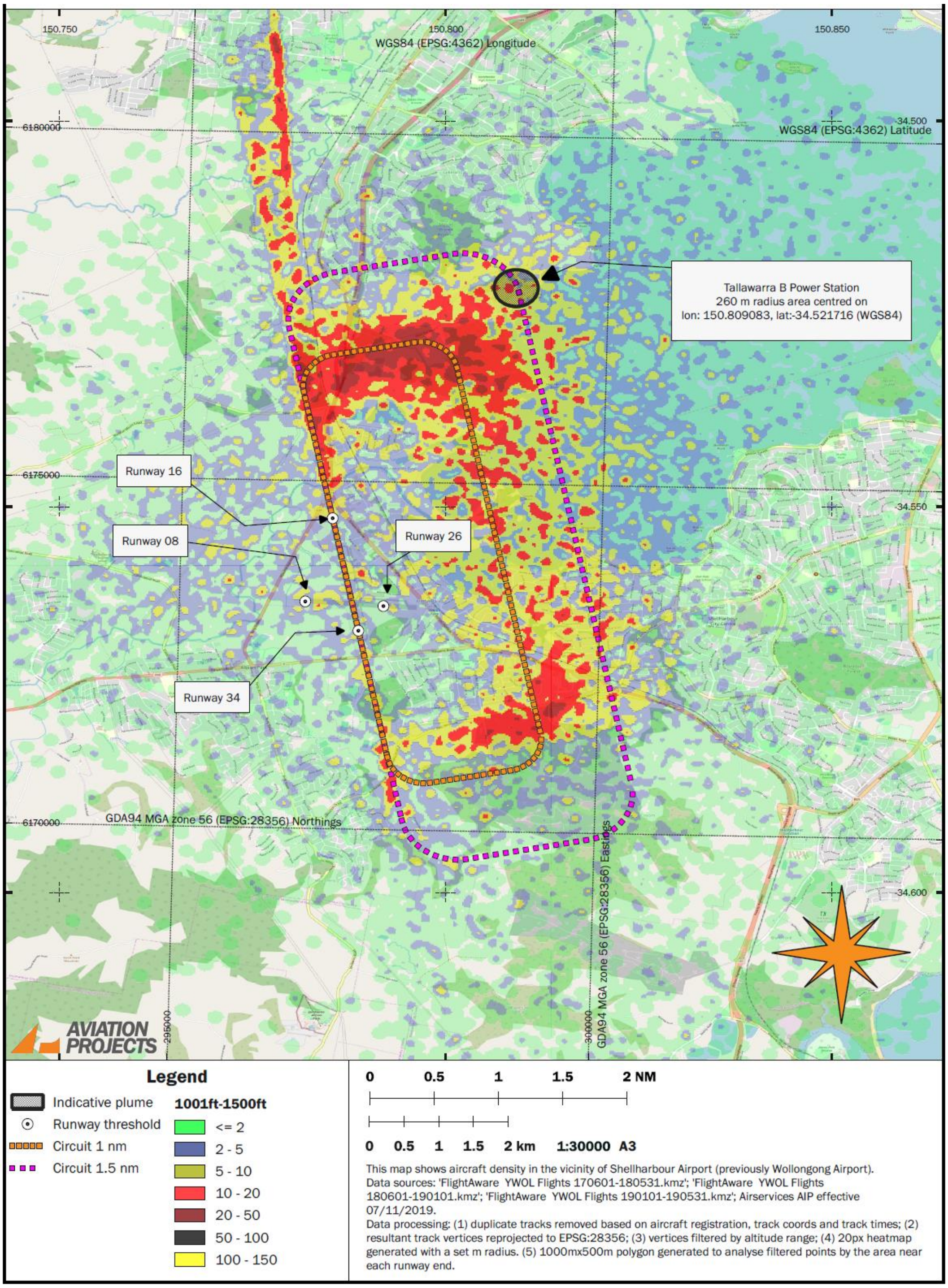


Figure 14 Heat map - 1001-1500 ft AMSL (100 m analysis)

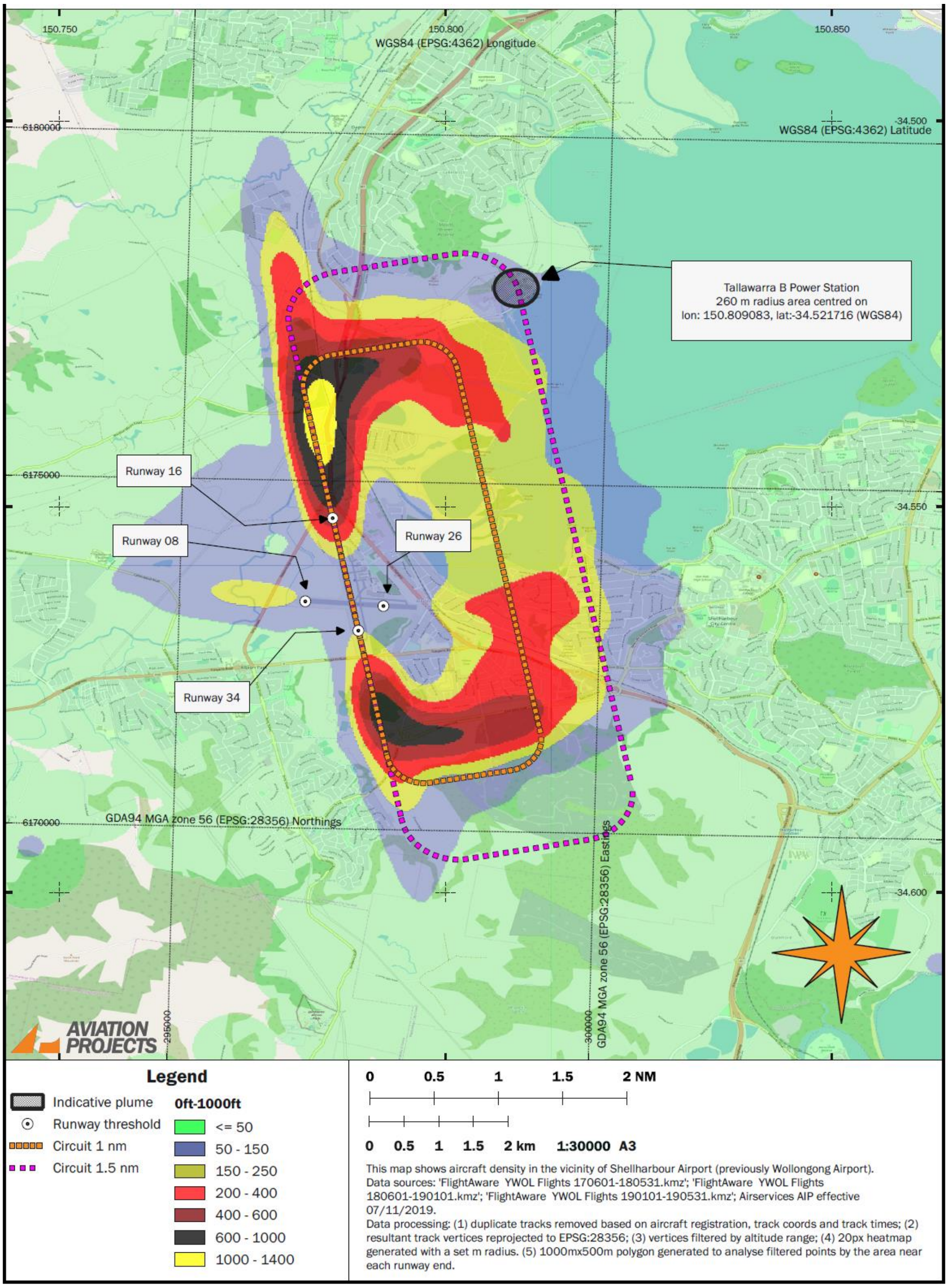


Figure 15 Heat map 0-1000 ft AMSL (500 m analysis)

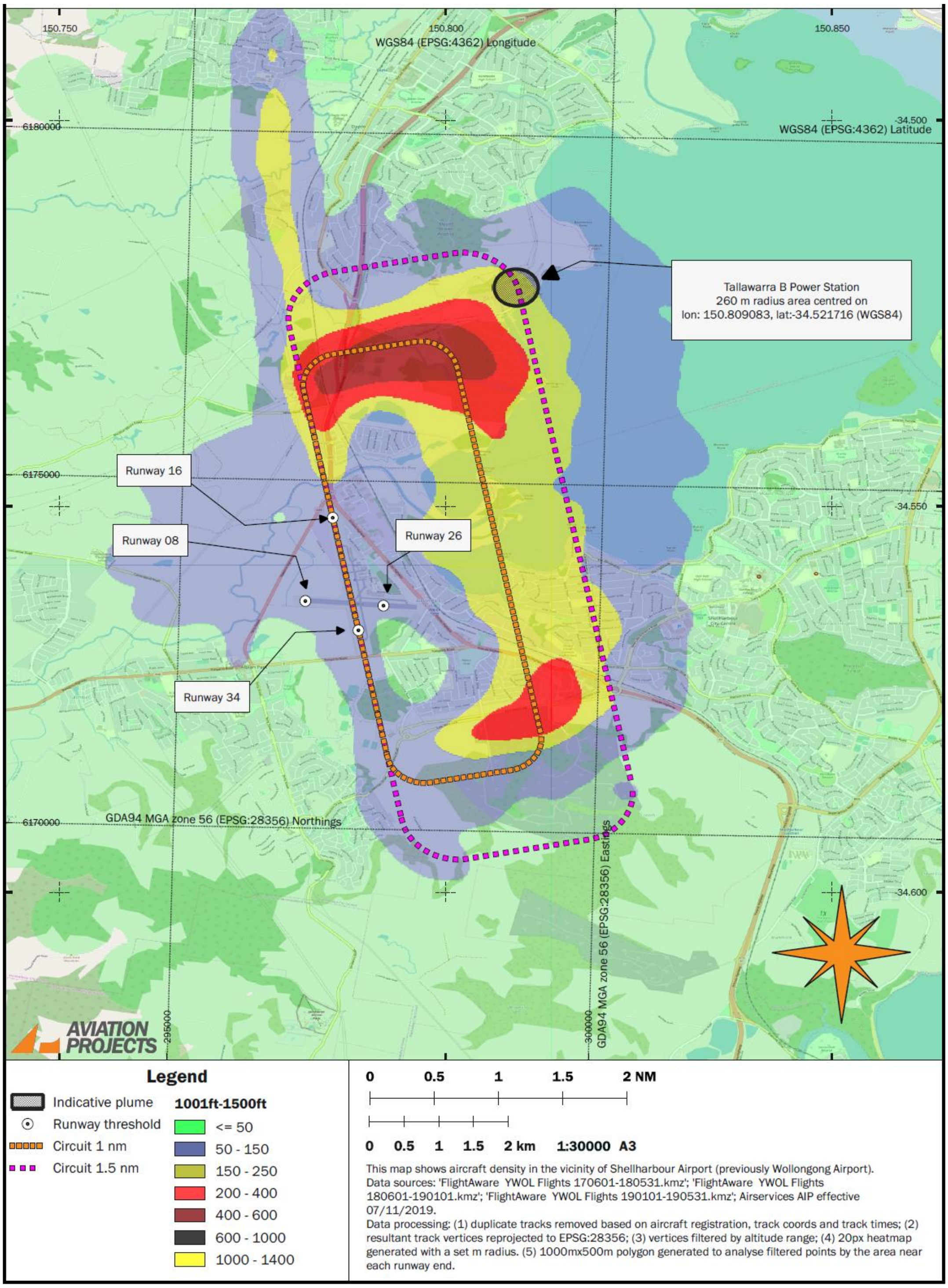


Figure 16 Heat map - 1001-1500 ft AMSL (500 m analysis)

5.10. Prevailing wind

According to Bureau of Meteorology climate data, the prevailing average wind at 9 am is westerly, and at 3 pm, is north easterly. Refer to (source: Bureau of Meteorology Climate Data Online). This means that aircraft will generally use runways 26 and 34, but any runway could be used according to the prevailing wind.

Note that the smaller aircraft that are the subject of this study are not very tolerant of excessive crosswind.

Wind roses showing historical average wind direction and speed for the period 05 June 1999 to 10 August 2019, at 9 am and 3 pm, are provided at Figure 17 (source: Bureau of Meteorology).

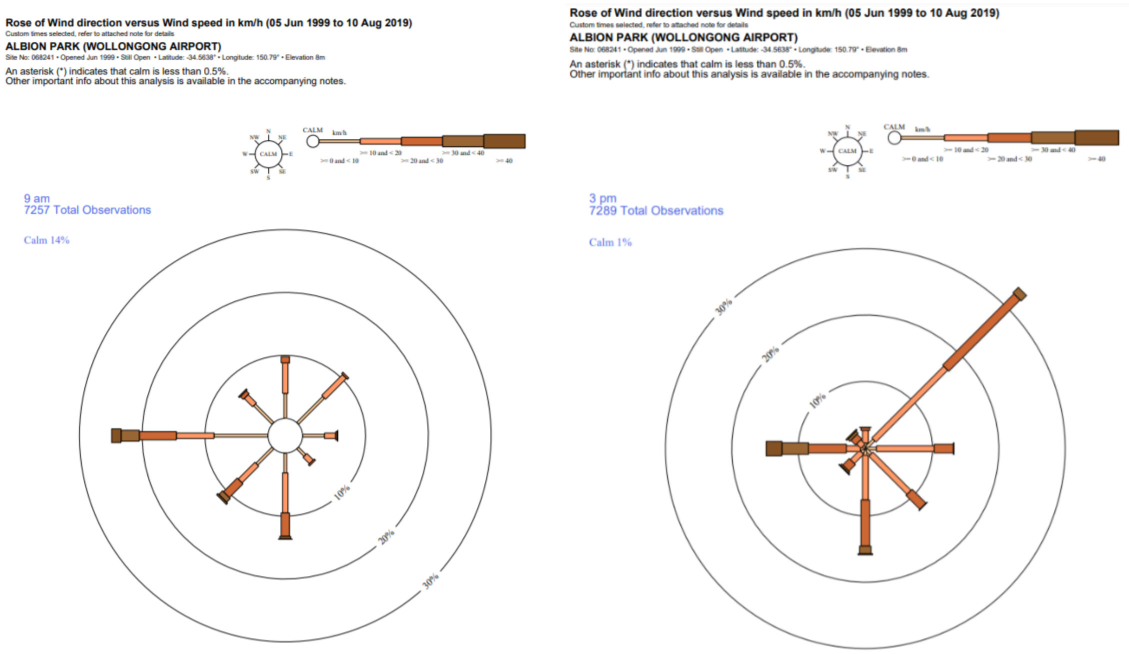


Figure 17 Wind roses at 9 am and 3pm

Analysis of Bureau of Meteorology Aerodrome Climatological Summary Model D for Albion Park (Wollongong Airport) – YWOL revealed that the wind is less than 5 kt for approximately 42.9% of the time. The summary data also demonstrates that the wind is between 26-30 kt for 0.49% of the time, 31-35 kt for 0.16% of the time and 36-40 kt for 0.03% of the time. Values greater than 40 kt were not recorded as they had occurred with a frequency of less than 0.05% in any month.

5.11. Weather conditions – day/night, visual/IMC

A summary of the major climate statistics recorded at Shellharbour Airport (Albion Park site) is provided in Table 6 (source: Bureau of Meteorology, 2019).

Table 6 Shellharbour Airport annual weather statistics

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years	
Temperature															
Mean maximum temperature (ºC)	27.1	26.4	25.3	23.3	20.7	18.1	17.8	18.8	21.3	23.1	24.0	25.6	22.6	20	1999-2019
Mean minimum temperature (ºC)	17.0	17.1	15.6	12.2	8.8	7.2	6.2	6.5	8.5	10.8	13.4	15.3	11.6	20	1999-2019
Rainfall															
Mean rainfall (mm)	74.4	135.0	124.1	72.0	53.3	93.6	47.6	52.7	42.7	65.7	83.5	66.1	909.6	18	1999-2019
Decile 5 (median) rainfall (mm)	69.2	116.0	65.2	47.3	32.6	73.8	30.6	28.8	40.2	55.6	58.1	58.6	873.8	20	1999-2019
Mean No. of days of rain ≥ 1 mm	7.7	8.4	8.1	7.0	4.5	6.5	4.6	4.3	5.0	6.6	8.2	8.0	78.9	20	1999-2019
Other daily elements	No data														
9 am conditions															
Mean 9am temperature (°C)	22.5	22.0	20.2	19.2	15.8	13.0	12.5	14.0	17.1	19.0	19.7	21.4	18.0	11	1999-2010
Mean 9am relative humidity (%)	68	74	76	68	69	73	68	61	57	58	67	66	67	11	1999-2010
Mean 9am wind speed (km/h)	11.6	9.8	8.1	10.7	12.4	13.6	14.4	15.0	15.3	14.4	12.9	12.7	12.6	11	1999-2010
3 pm conditions															
Mean 9am temperature (°C)	24.8	24.5	23.5	21.3	18.8	16.7	16.2	17.3	19.3	20.4	21.6	23.5	20.7	11	1999-2010
Mean 9am relative humidity (%)	63	67	64	61	58	57	54	49	53	58	63	61	59	11	1999-2010
Mean 9am wind speed (km/h)	21.6	20.0	18.9	17.7	17.1	17.6	18.1	21.8	22.6	20.9	20.9	21.5	19.9	11	1999-2010

5.12. Runway use

Runway 16/34 is the primary runway at Shellharbour Airport. Runway 08/26 is subject to restrictions associated with the proximity to residential areas to the east and is only available during daylight hours.

An analysis was performed of the FlightAware tracking data to determine the relative proportion of use for each runway direction. This was done by defining a 1000 m long by 500 m wide rectangle projecting along the runway centreline from the threshold of each runway and calculating the number of data points within each rectangle.

According to this analysis, runway 16/34 was used 79% of the time and runway 08/26 was used 21% of the time.

5.13. Other sources of turbulence in and around the aerodrome

Air turbulence in the vicinity of the aerodrome could be caused by mechanical turbulence created by wind flowing over nearby terrain – particularly to the west and north west, and other atmospheric conditions such as thermal instability, as would occur in thunderstorms.

5.14. Instrument landing system

Consideration has been given to the implementation of a precision instrument approach such as instrument landing system (ILS) as a means of mitigating the plume hazard. Given that current and proposed instrument approaches will not be affected by the plume, an ILS will not be necessary to mitigate the hazard to conducting instrument flight, and in any case, the obstacle environment and other restrictions to upgrading the aerodrome to precision approach requirements will prevent its implementation.

5.15. Operational restrictions

There are operational restrictions implemented at Shellharbour Airport for all four runways. These restrictions are necessary to meet noise abatement procedures due to built-up areas at Haywards Bay (north from runway 34 end) and Albion Park Rail (east from runway 34 threshold).

The restrictions currently in force at Shellharbour Airport are listed in ERSA (source: AsA, FAC YSHL-1 dated 7 November 2019).

Specifically:

- Aircraft departures from runway 34 should position crosswind to avoid flying over houses on Haywards Bay.
- For departures from runway 16 pilots should not turn onto crosswind below 700 ft.
- Pilots are advised to avoid departures from runway 08 and arrivals to runway 26 unless operationally necessary.
- Departures from runway 16 at night should be avoided unless operationally necessary.

Fly Neighbourly Practices published by SCC on its website are extracted in Figure 18.

Fly Neighbourly Practices

Shellharbour City Council and the Airport Operators have agreed to fly neighbourly practices which state that:

- Pilots use runway 08 (to the east) only when operationally necessary (due to wind direction).
- Helicopters are not allowed to overfly the residential area to the east of the airport at an altitude less than 1000ft (300m).
- Pilots to avoid flight over Haywards Bay when taking off and landing on runway 16/34.
- Air Ambulance helicopter pilot familiarisation training is restricted to practice approach and departures.
- Night training restricted to north/south runway with runway 34 preferred.
- Night circuit training to cease at 10pm local time. Further information for pilots is available on the AirServices Australia website.

Figure 18 Shellharbour City Council Fly Neighbourly Practices

5.16. RAAus Operations Manual

RAAus publishes the *RAAus Operations Manual*, as the only manual recognised by RAAus for the control of recreational aeroplane operations and related requirements. This manual and its supplements have been compiled to meet the relevant requirements of the Civil Aviation Act 1988 (CAA), Civil Aviation Regulations 1988 (CAR), Civil Aviation Safety Regulations 1998 (CASR), CAOs and relevant associated legislation such as the Transport Safety Investigation Act 2003 (TSI Act).

Section 4.01 of the manual sets out requirements applicable to *RAAus Operations at Certain Aerodromes*.

Of specific interest in terms of potential risk mitigations, the following requirements apply:

> *1. When RAAus aeroplanes are operating from an aerodrome where an FTS is based, the CFI of that FTS has the authority to control and direct RAAus aeroplane operations. Where more than one RAAus CFI operates from the same aerodrome, procedures will be mutually developed and agreed upon for control of RAAus operations.*
>
> *2. A CFI or CFIs designated in Paragraph 1 of this Section should also liaise on a regular basis with other aerodrome users to ensure the safety of air navigation.*

According to these provisions, pilots operating under RAAus requirements at Shellharbour Airport could be directed by the relevant Chief Flying Instructor(s) to avoid overflying the Tallawarra B power station below a particular height (say 1000 ft AMSL) when the power station is operating in order to avoid the potential plume hazard.

5.17. Jabiru aircraft characteristics

Jabiru Aircraft Pty Ltd (Jabiru) is an Australian-based manufacturer of two-seat recreational aircraft.

Fly Illawarra is a flying training organisation based at Shellharbour Airport that operates three Jabiru variants.

According to the Jabiru website, Jabiru aircraft (J230-D, J170-D, J160-D and J120-C) are designed to CASA accepted ASTM standards for Light Sport Aircraft under CASR Subpart 21.H.

According to ASTM 2245-18 (5.2.6 *Gust Load Factors*), an aircraft must be designed for the gust loads resulting from positive and negative gusts of 7.5 m/s nominal intensity at the design flap speed (V_f) with the flaps fully extended. Further, 5.2.3.3 *Gust Envelope* specifies that the aircraft is assumed to be subject to symmetrical vertical gusts in level flight, and limit load factors must correspond to positive and negative gusts of 15 m/s at design cruising speed (V_C) and positive and negative gusts of 7.5 m/s at design diving speed (V_D).

These requirements can be interpreted to mean that an aircraft designed and certificated to the applicable standards will be able to experience a 6.1 m/s vertical gust (which is less than 7.5 m/s) in the approach configuration (flaps down) and maintain its structural integrity.

Of the four nominated Jabiru aircraft variants, the J230-D has the longest take-off distance required of 226 m, which is less than 800 m and therefore a code 1 aircraft for the purpose of determining aerodrome reference code number.

An image of the Jabiru J230 is provided at Figure 19 (courtesy Jabiru Aircraft Pty Ltd).

Figure 19 Jabiru J-230

6. AVIATION IMPACT STATEMENT

6.1. Nearby registered/certified aerodromes

The proposed power station is site is located approximately 4.8 km to the north east of the certified Shellharbour Regional Airport aerodrome reference point. Refer to Figure 20 (source: OzRunways).

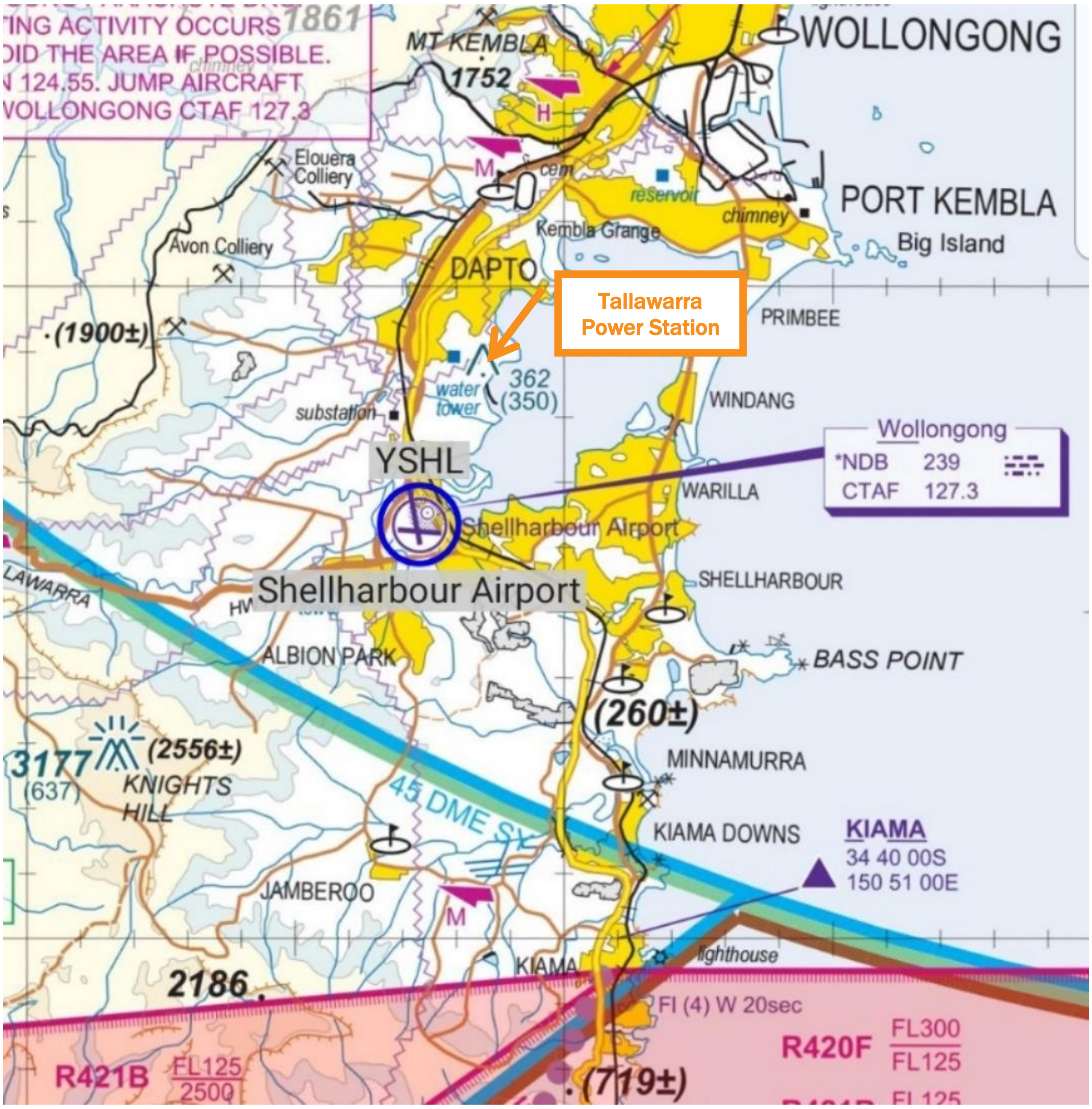


Figure 20 Proposed power station site relative to Shellharbour Airport

6.2. Shellharbour Airport

Shellharbour Airport is the nearest certified airport to the power station site, and the airport of specific interest to this impact assessment.

It has a pair of cross runways 16/34 and 08/26 with the following details:

- Runway 16/34 – 1819 m x 30 m, sealed; and
- Runway 08/26 – 1331 m x 30 m sealed.

Both runways are published as code 2, with the main runway 16/34 served by runway aligned non-precision instrument approaches and lighting for night operations. Runway 08/26 does not have instrument approaches, and is therefore a non-instrument runway, and does not have runway lighting so it can only be used during the day.

An overview of the airport infrastructure is provided in Figure 21 (source: AIP DAP).

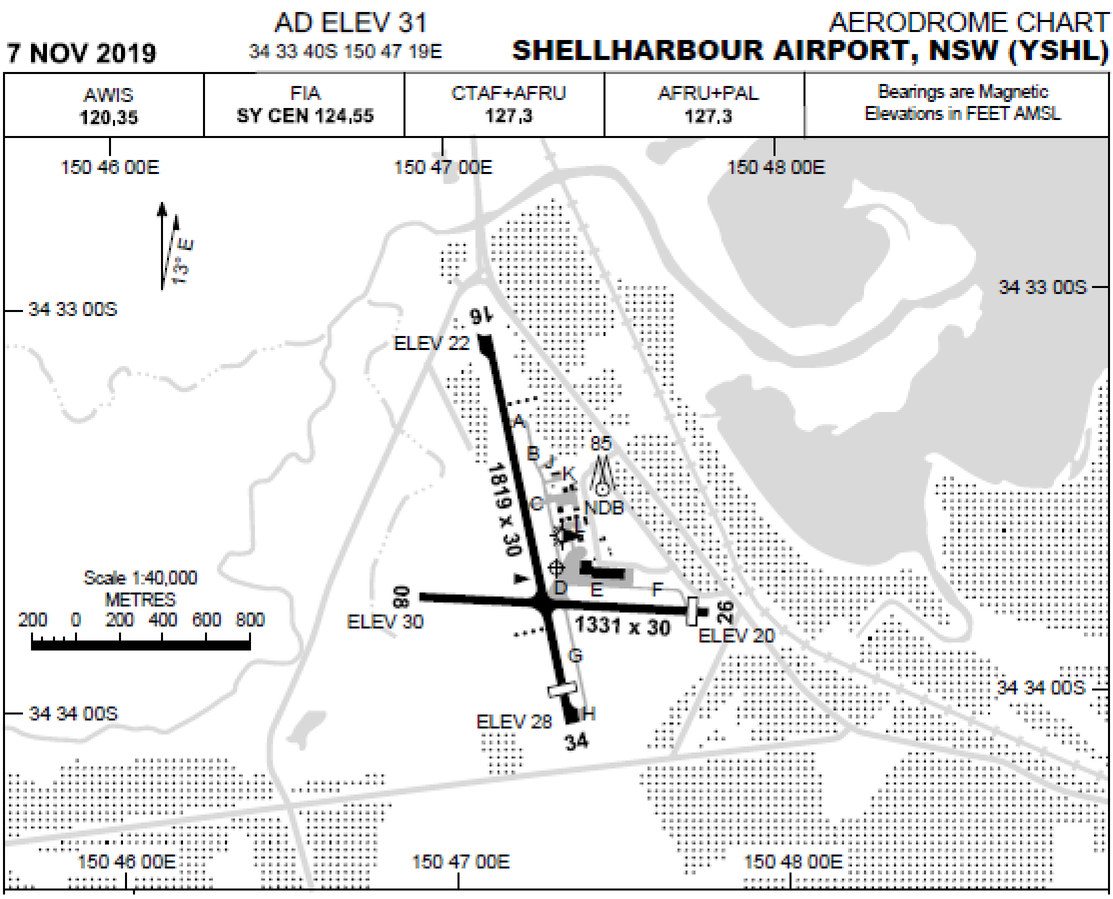


Figure 21 Shellharbour Airport (YSHL) DAP

6.3. Instrument procedures – Shellharbour Airport

A check of the AIP via the Airservices Australia website showed that Shellharbour Airport is serviced by non-precision flight procedures as per Table 7 (source: Airservices Australia), designed by Airservices Australia (AsA).

Table 7 Shellharbour Airport (YSHL) aerodrome and procedure charts

Chart name (Procedure Designer)	*Effective date*
AERODROME CHART (AsA)	7 November 2019 (Am 161)
GNSS Arrival (AsA)	7 November 2019 (Am 161)
NDB-A (AsA)	7 November 2019 (Am 161)
RNAV-Z (GNSS) RWY 16 (AsA)	7 November 2019 (Am 161)
RNAV-Z (GNSS) RWY 34 (AsA)	7 November 2019 (Am 161)

The current RNAV (GNSS) approach procedures have some noteworthy features. The RNAV (GNSS) for runway 16 is copied in Figure 23 and the RNAV (GNSS) for runway 34 is copied in Figure 24 (source: Airservices Australia).

The runway 16 approach has an approach path angle of 3.7° (whereas the standard approach path angle is 3°), and there is no minimum descent altitude (circling only) for performance category C aircraft (large turboprop and jets).

The runway 34 approach also has a higher than normal approach path angle of 3.4°, and a relatively high minimum descent altitude (1340 ft AMSL).

The image at Figure 22 is an extract from the runway 16 approach that shows the power station and nearby lit mast, along with other obstacles in the vicinity of the airport. For reference, images of the power station and mast are provided at Figure 10 (day) and Figure 11 (night).

On 29 December, the following questions were asked of Airservices Australia's Chief Procedure Designer:

1. *What will be the impacts to current procedures, and if the implementation of the proposed Tallawarra B power station will prevent the introduction of further efficiencies to those procedures, including the introduction of Category C performance aircraft and potential for those aircraft to adopt straight in minima rather than circling minima:*
    a. *GNSS Arrival.*
    b. *NDB-A.*
    c. *RNAV-Z (GNSS) RWY 16.*
    d. *RNAV-Z (GNSS) RWY 34.*
2. *What will be the impacts to future procedures which may considered and how this information was calculated:*
    a. *Details regarding the introduction of Category C performance aircraft.*

b. Will the proposed power station impact future improvements to the existing RNAV procedures.

c. Will the proposed power station impact future introduction and/or efficiencies when Approaches with Vertical Guidance (APV-barometric VNAV) are introduced.

3. When will the future proposed procedures be published?

On 31 January 2020, Mr Andrew Mihu, Snr. Instrument Flight Procedure Designer at Airservices Australia replied as follows:

We have finished the assessment against the currently published YSHL instrument flight procedures and found the following.

With respect to procedures designed by Airservices in accordance with ICAO PANS-OPS and Document 9905, at a revised height of 700ft AMSL the plume rise ***will not affect*** *any sector or circling altitude, nor any instrument approach or departure procedure at Shellharbour aerodrome.*

The plume rise ***will not affect*** *the Sydney RTCC.*

Note: Procedures not designed by Airservices at Shellharbour aerodrome were not considered in this assessment.

Now with regard to your specific questions about future procedures, I still need to discuss that further with my manager Obrad and then get back to you. I did want to clarify a few things however:

With regard to the GNSS Arrivals; these procedures can only be designed to circling minima. The purpose of those types of arrivals is to allow aircraft to descent from the enroute environment down to the circling area for a circling approach.

Similarly, a straight-in MDA cannot be instated on the NDB-A approach because of the alignment of the final approach track.

With respect to Category C aircraft, they already can fly all published YSHL approaches. If you're referring to the fact that the RNAV 16 approach only has circling minima for CAT C specifically; the concept redesign of that approach did introduce S-I minima for CAT C, so that's possible.

We need to discuss future plans for introduction of revised RNAV approaches internally and get back to you on that.

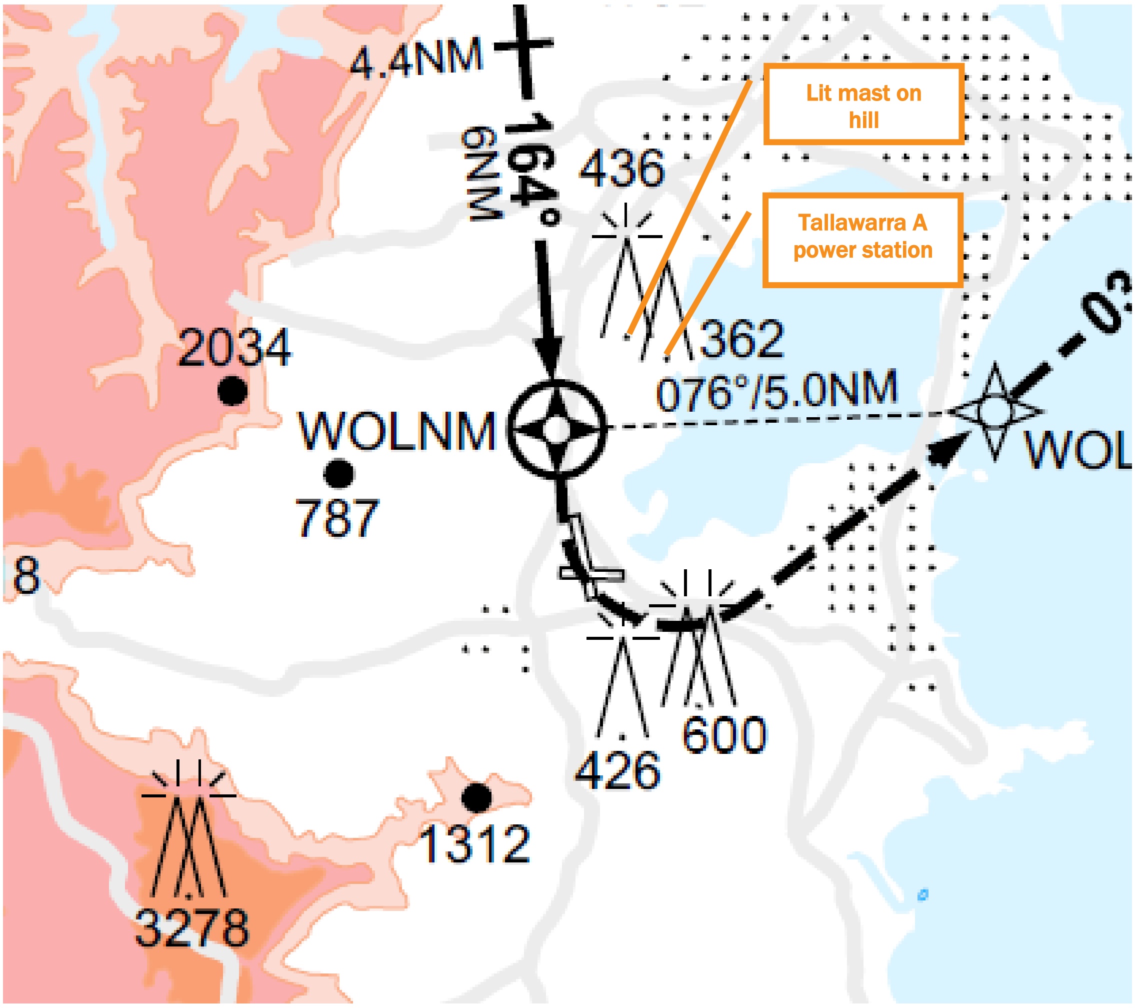


Figure 22 Extract of instrument approach procedure showing obstacles

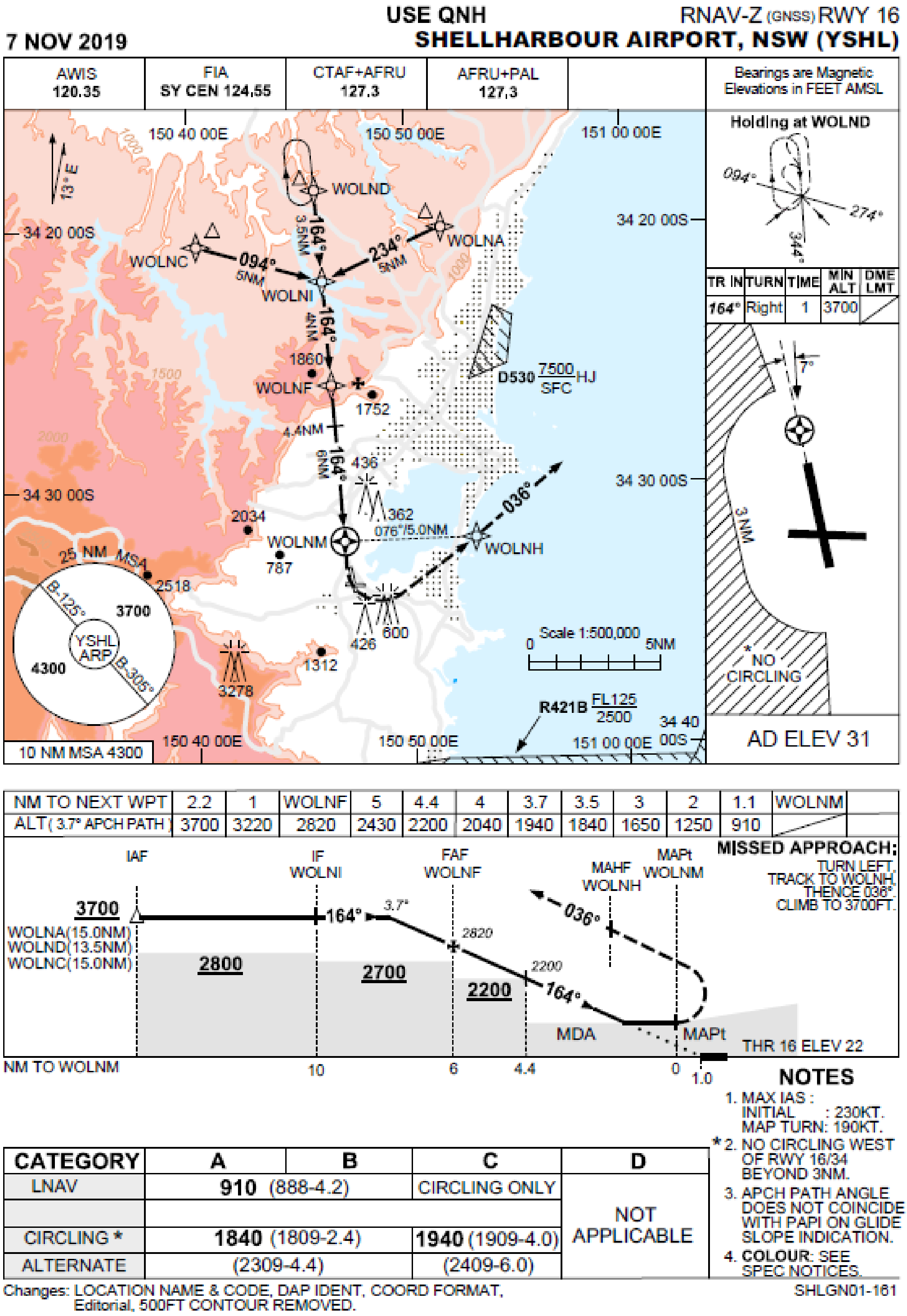


Figure 23 Extract of RNAV GNSS RWY 16

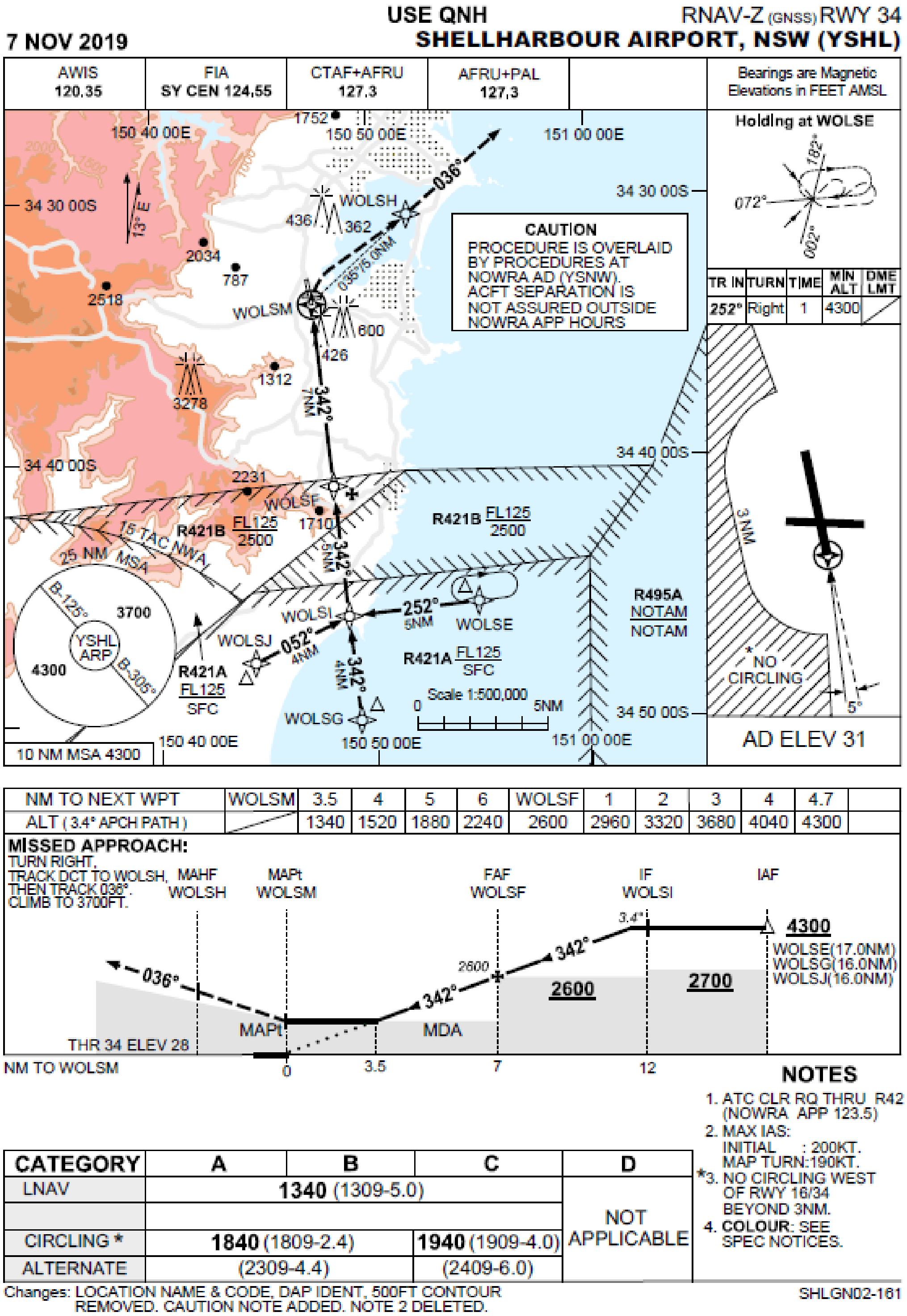


Figure 24 Extract of RNAV GNSS RWY 34

6.4. Circling areas

Circling areas provide protection for aircraft according to their performance category when manoeuvring to land from an instrument approach that is not runway aligned. Circling area parameters according to the respective aircraft performance categories are as follows:

- Category A – 1.68 nm (3.1 km) radius and 300 ft minimum obstacle clearance;
- Category B – 2.66 nm (4.9 km) radius and 300 ft minimum obstacle clearance
- Category C – 4.2 nm (7.8 km) radius and 400 ft minimum obstacle clearance; and
- Category D – 5.28 nm (9.8 km) radius and 400 ft minimum obstacle clearance.

An analysis of the modelled plume height at 6.1 m/s and potential impacts on circling area minimum obstacle clearance is provided in Table 8, which shows that the 6.1 m/s plume height will be well below the height to which vertical buffers are applied to determine the applicable circling altitude. Note that 100 ft has been deducted from the published circling altitudes in consideration of the availability of actual QNH (AIP ENR 1.5 para 5.3 refers).

Table 8 6.1 m/s plume - impact on circling areas

Performance category	*Circling altitude (ft AMSL)*	*MOC (ft AMSL)*	*Max plume height at 6.1 m/s (ft AMSL)*	*Impact*
A	1840	1540	700	Nil (beyond circling area)
B	1840	1540	700	Nil (below MOC)
C	1940	1540	700	Nil (below MOC)
D	1940	1540	700	Nil (below MOC)

Summary: The proposed power station will not affect circling altitudes.

6.5. Obstacle Limitation Surface (OLS) analysis

Obstacle limitation surfaces (OLS) are defined in MOS 139 as:

> *A series of planes associated with each runway at an aerodrome that defines the desirable limits to which objects may project into the airspace around the aerodrome so that aircraft operations at the aerodrome may be conducted safely.*

Chapter 7 of MOS 139 specifies the requirements applicable to establishing and protecting an aerodrome's OLS. The design parameters for the various surfaces of an OLS correspond to the aerodrome reference code number and scope of operations.

6.6. Code 1 non-instrument OLS

RAAus and other light aircraft have been represented as the most at risk due to the commonly held perception that they are more susceptible to the effects of turbulence.

RAAus aircraft are by virtue of the applicable regulatory framework not permitted to be heavier than 600 kg (with pathways in place to increase this limit in the future to 760 kg or greater), have more than two seats or be operated in any conditions other than under visual flight rules during the day.

Aeroplane reference field length is defined in MOS 139 as the minimum field length required for take-off at maximum certificated take-off mass, sea level, standard atmospheric conditions, still air and zero runway slope, as shown in the appropriate aeroplane flight manual prescribed by the certificating authority or equivalent data from the aeroplane manufacturer. Field length means balanced field length for aeroplanes, if applicable, or take-off distance in other cases.

Aircraft that have an aeroplane reference field length of less than 800 m are nominally aerodrome reference code number 1 for the purpose of designing an applicable OLS.

The Jabiru J230-D has a take-off distance required of 226 m.

Textron Aviation publishes a take-off distance of 497 m for the Cessna 172 Skyhawk.

Beechcraft publishes a take-off distance of 643 m for the King Air 200 (operated by RFDS and Careflight NSW).

Pilatus publishes a take-off distance of 793 m for the PC12.

All these aircraft are code 1 aircraft for the purposes of designing an OLS.

The OLS applicable to these aircraft being operated during the day on a runway not served by an instrument approach extends to a maximum distance of 2700 m. This is particularly applicable to RAAus and other similar light aircraft conducting circuits or other flying activities during the day under the visual flight rules.

Figure 25 shows the OLS applicable to these aircraft, for runway 16/34 as the most relevant runway direction, will not be impacted by the plume. It will, however, be infringed by terrain to the south.

The representative 1 nm circuit is slightly larger than the code 1 non-instrument OLS.

The representative 1.5 nm circuit that overflies the power station site is significantly larger than the code 1 non-instrument OLS and not a valid representation of these operations.

If the aerodrome was registered or certified as a code 1 non-instrument aerodrome and the Tallawarra B OCGT was proposed, it would not trigger a referral to CASA under MOS 139 Chapter 7 requirements as the plume would not penetrate the OLS.

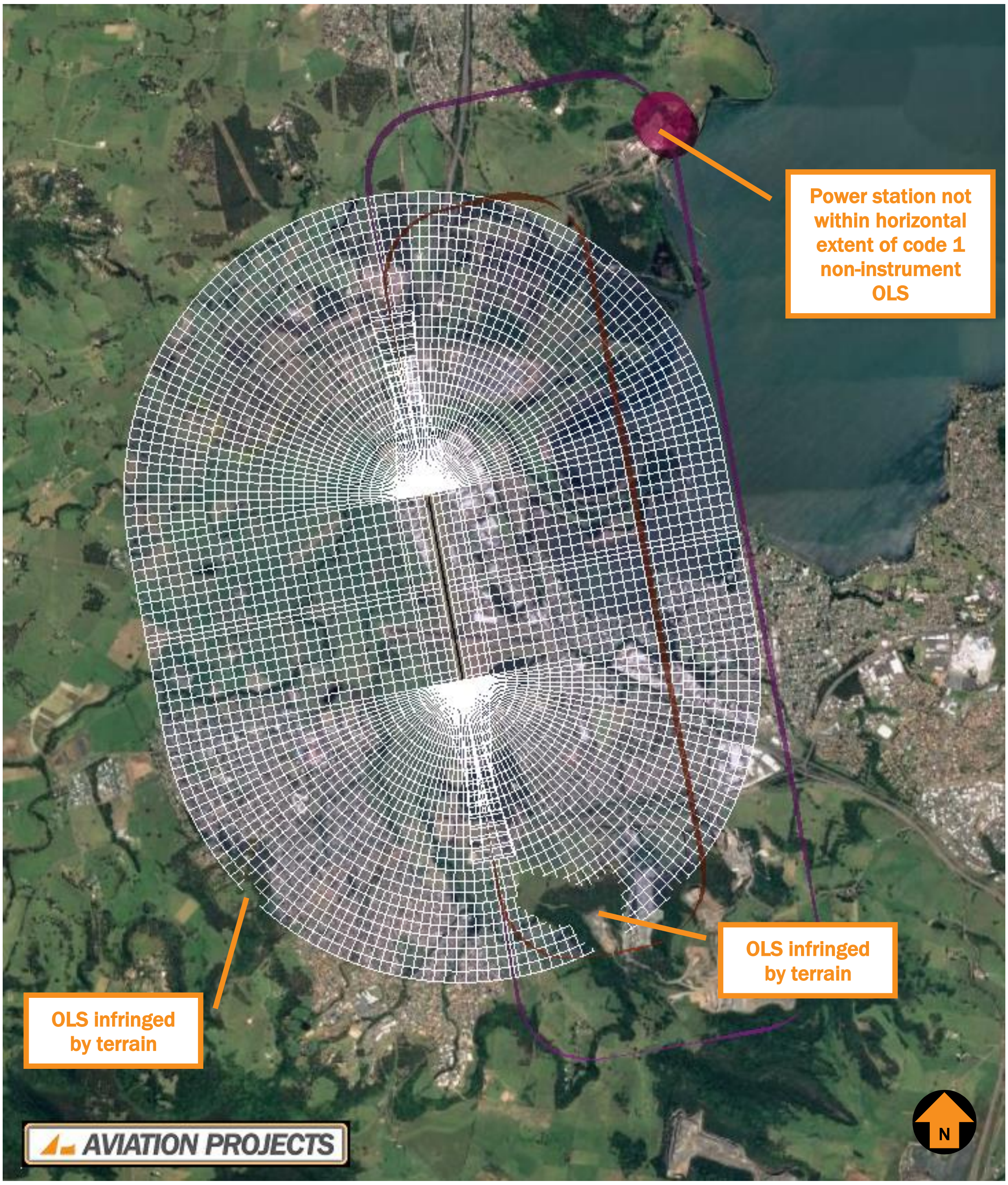


Figure 25 Code 1 non-instrument OLS - runway 16/34

6.7. Code 2 instrument non-precision OLS (current)

The operational OLS, as published in En Route Supplement Australia (ERSA), for both runways is based on code 2 requirements. Runway 16/24 is a non-precision approach runway and runway 08/26 is a non-instrument runway.

The exhaust plume will penetrate the conical surface of the current code 2 instrument non-precision OLS at a height of approximately 59.5 m AHD.

The current operational OLS is extensively infringed by terrain in all four quadrants, as can be seen in Figure 26, which shows the OLS only for runway 16/34 as the most relevant runway direction.

Although there are some obstacle lights on some of the features, the details of the terrain infringements are not published in ERSA.

A 1.5 nm circuit overflies significant terrain penetrations on the southern side of the circuit and the tank on the hill just to the north west of the power station site.

The 1.0 nm circuit overflies some of the terrain penetrations on the southern side of the circuit.

The lit mast on the hill with the tank on it just to the north west of the power station rises to 436 ft AMSL and infringes the OLS.

It is not realistic to expect that an aircraft conducting a 500 ft circuit on runway 16/34 would overfly the power station due to the significant hazard presented by this high terrain.

The current 90 m runway strip on runway 16/34 is illustrated in Figure 27.

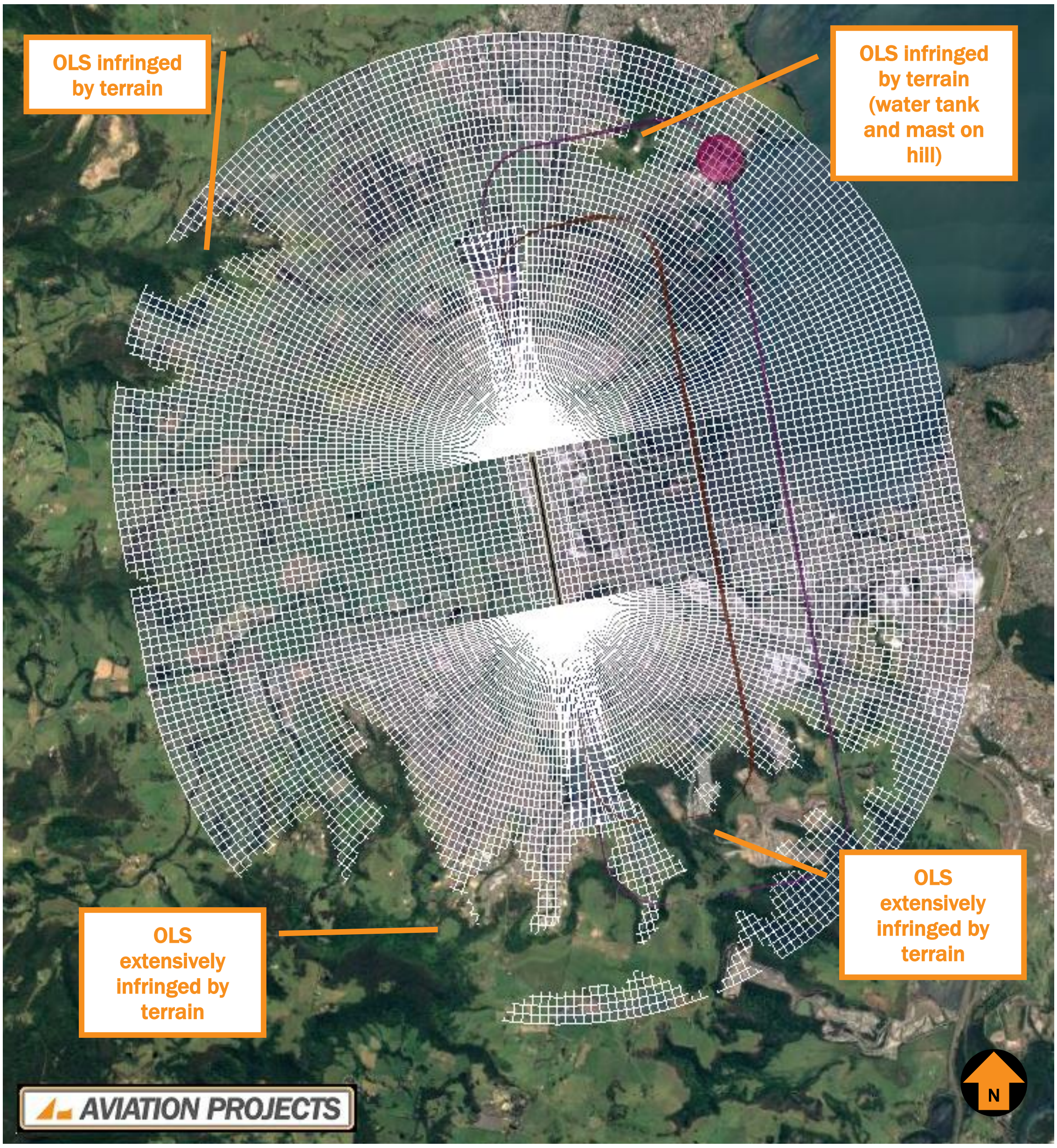


Figure 26 Code 2 instrument non-precision OLS (current) – overview runway 16/34

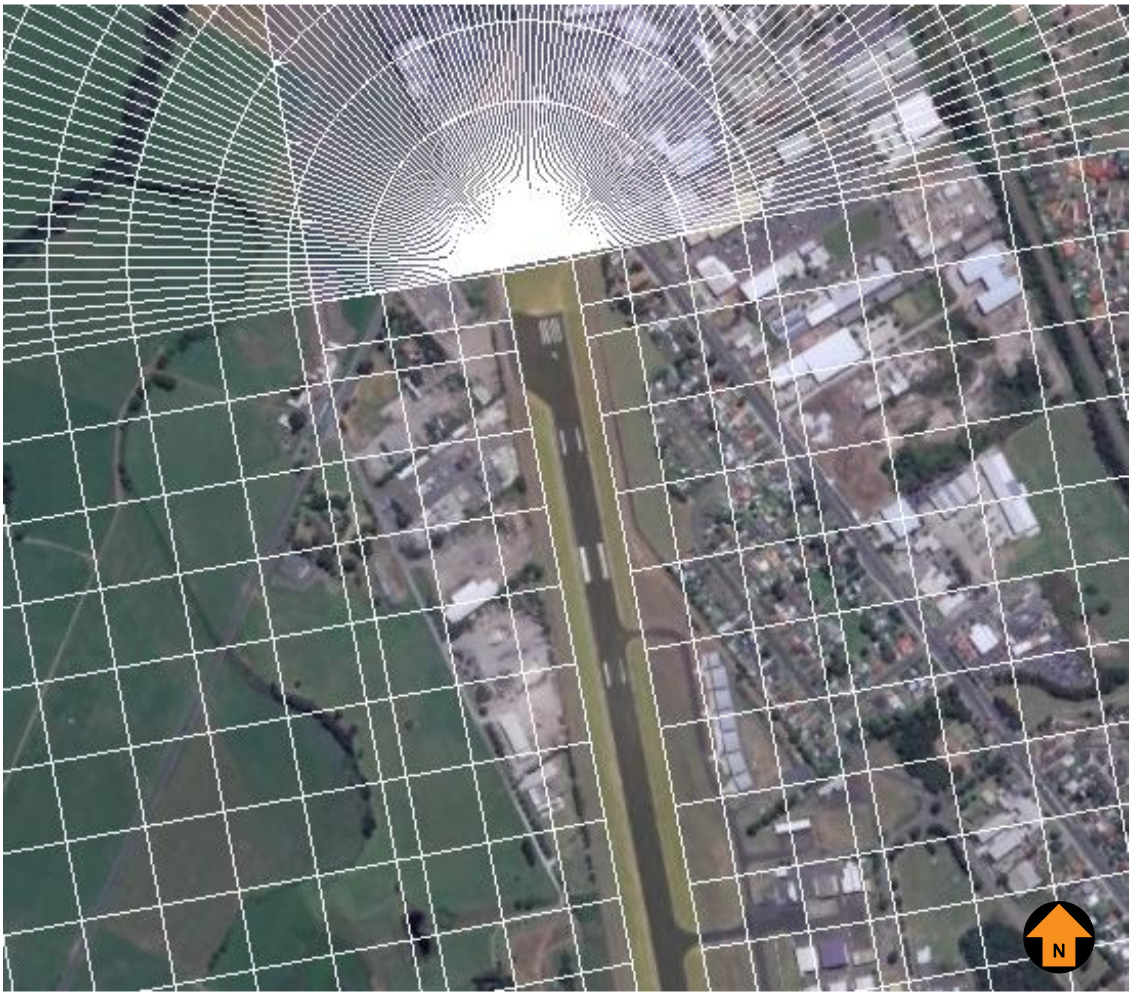


Figure 27 Code 2 instrument non-precision OLS (current) – 90 m runway strip runway 16/34

6.8. Code 2 instrument non-precision OLS (future)

In August 2020, when the revised version of MOS 139 comes into effect, new standards will apply to the design of obstacle limitation surfaces.

The current non-conforming OLS will need to be grandfathered in its current state (noting that there are extensive penetrations of the OLS currently published in ERSA, plus all the terrain infringements that are not published). Refer to Figure 28, which shows the OLS only for runway 16/34 as the most relevant runway direction.

Under the new standards, the runway strip and inner edge width for the approach surface for code 2 instrument non-precision runways will increase to 140 m.

The widened runway strip will induce infringements of the transitional surface at the north western end of the airport, including fencing, trees, buildings etc, and will worsen other existing infringements. Figure 29 illustates this situation.

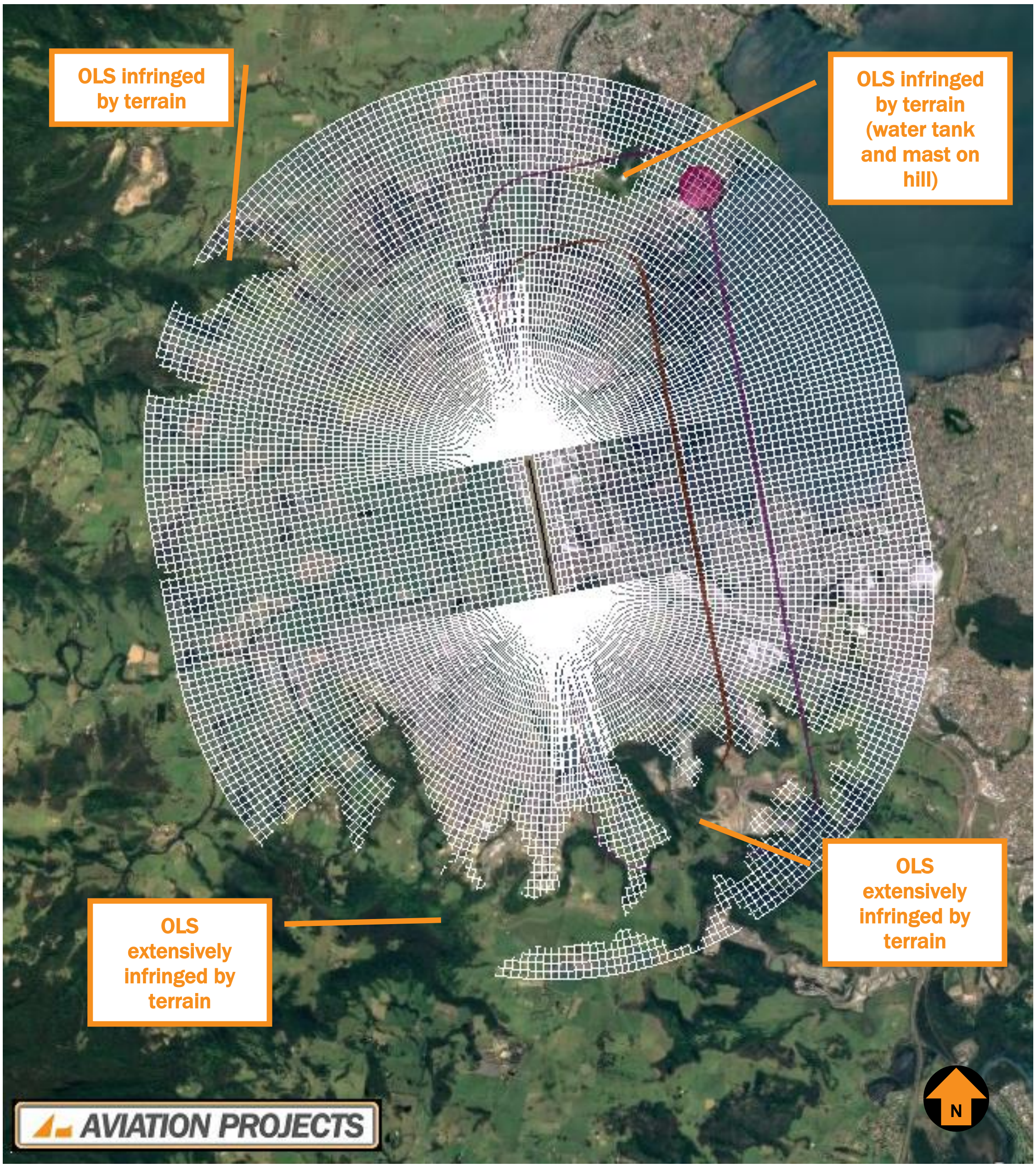


Figure 28 Code 2 instrument non-precision OLS (future) – overview runway 16/34

Figure 29 Code 2 instrument non-precision OLS (future) – 140 m runway strip runway 16/34

6.9. Code 3 instrument non-precision OLS (current)

Shellharbour City Council has expressed an intention to upgrade Shellharbour Airport to code 3 standards.

The Saab 340 being operated to the airport by Fly Corporate is a code 3 aircraft, although the current OLS is published according to code 2 requirements.

Under current standards, the runway strip and approach surface inner edge would need to be widened to 150 m to meet code 3 requirements.

The outer extremities of the approach surface at each end of runway 16/34 will be cut off by high terrain.

The first and second sections of the approach surface for runway 34 would be cut-off by terrain. The only way to resolve the approach surface infringement would be to displace the threshold of runway 34.

A widened runway strip on runway 16/34 will induce additional infringements of the transitional surface at the north western end of the airport site, by fencing, trees, buildings etc and worsen other existing infringements.

Figure 30, which shows the OLS only for runway 16/34 as the most relevant runway direction, Figure 31 and Figure 32 illustrate this situation.

Increasing the aerodrome reference code from 2 to 3 is not practically achievable under current standards, and consequently the exhaust plume will not be the most significant constraint to a future upgrade of the aerodrome reference code/scope of operations.

Figure 30 Code 3 instrument non-precision OLS (current) – overview runway 16/34

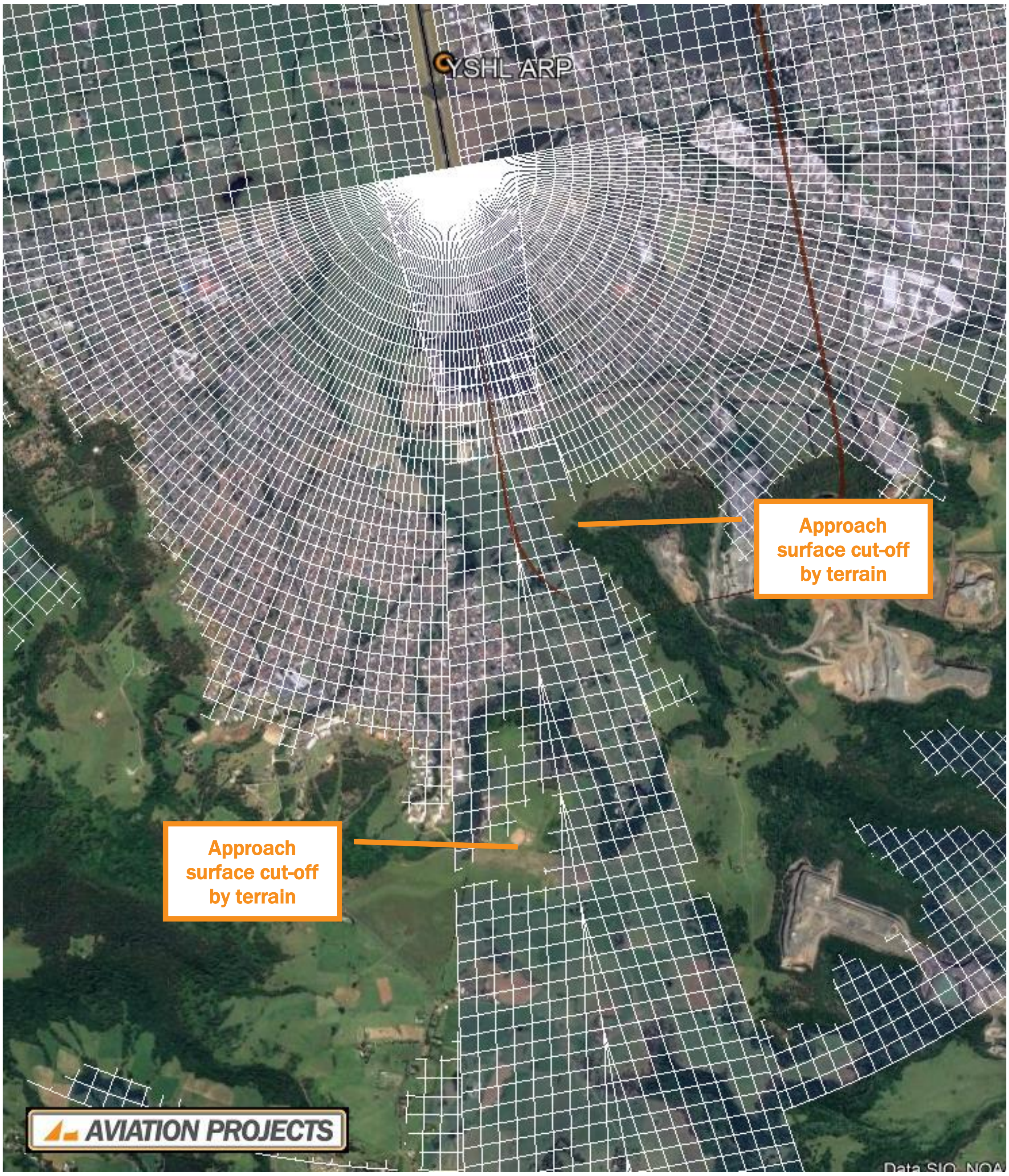


Figure 31 Code 3 instrument non-precision OLS (current) – approach surface runway 34

Figure 32 Code 3 instrument non-precision OLS (current) – 150 m runway strip runway 16/34

6.10. Code 3 instrument non-precision OLS (future)

Under the new standards due to take effect in August 2020, the runway strip and approach surface inner edge must be 280 m wide (rather than the current 150 m) for a code 3 non-precision runway, and the gradient of the first section of the approach surface must be 2% (rather than the current 3.33%).

Under these new requirements, the outer extremities of the approach surface at each end of runway 16/34 will be cut off by high terrain (Figure 33), and because of the lower gradient of the first section, the southern surface (along with other surfaces) would be cut-off by terrain (Figure 34). The only way to resolve the approach surface infringement would be to displace the threshold of runway 34.

This would also render invalid substantial elements of airside infrastructure, such as hangars and the parallel taxiway, require removal of trees, buildings and fencing and other obstructions on the western side, relocation/diversion of the Princes Highway and removal of houses on the north eastern end (or shortening of the runway). Figure 35 illustrates this situation.

Increasing the aerodrome reference code from 2 to 3 is not practically achievable under future standards.

Therefore, on the basis of this analysis, we can conclude that the exhaust plume will not be the most significant constraint to a future upgrade of the aerodrome reference code/scope of operations.

Figure 33 Code 3 instrument non-precision OLS (future) – overview runway 16/34

Figure 34 Code 3 instrument non-precision OLS (future) – approach surface runway 34

Figure 35 Code 3 instrument non-precision OLS (future) – 280 m runway strip runway 16/34

6.11. Nearby aircraft landing areas

There are no aircraft landing areas in close proximity to the power station.

6.12. Air routes and LSALT

The power station (including the exhaust stack) are lower than close-by terrain and will not affect air routes or lowest safe altitudes.

6.13. Airspace

The proposed power station is located outside controlled airspace (wholly within Class G airspace), and is not located in any Prohibited, Restricted and Danger areas. Class C airspace commences at 7500 ft AMSL overhead the site. Figure 36 refers (source: OzRunways, Sydney VNC).

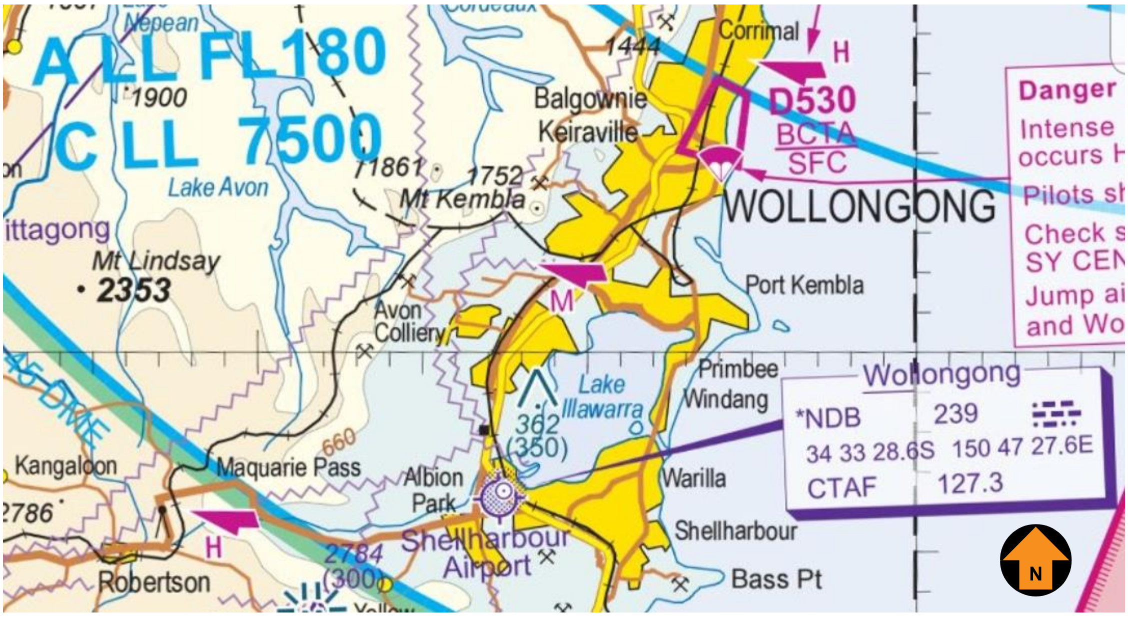


Figure 36 Surrounding airspace

The power station will not impact on controlled and designated airspace.

6.14. Aviation facilities

The power station will not impact on any aviation facilities.

6.15. Radar and surveillance facilities

The power station will not impact on any radars or other surveillance facilities.

7. ACCIDENT DATA

This section considers, using available aviation accident data, the likelihood of a loss of control that leads to a fatal accident - due to turbulence, whether caused by man-made plume or weather effects.

7.1. ATSB Occurrence Database

A search of the ATSB Occurrence Database with the parameters listed below revealed one fatal accident (AO-2008-069) resulting from weather – Turbulence / Windshear / Microburst, in which an aircraft conducting low-level baiting operations likely suffered a loss of control during strong gusty conditions from which recovery was not possible before the aircraft struck the ground.

The conditions at the location of the accident were likely to have included significant turbulence. The following extract from the ATSB Transport Safety Report (AO-2008-069) discusses the conditions at the time:

> *A Bureau of Meteorology (BoM) post-occurrence report stated that, at the time of the accident, the estimated surface winds across the general area would most likely have been from the west-south-west at about 15 to 20 kts, with gusts of between 25 and 30 kts. The BoM report also stated that:*
>
> > *Based on the available meteorological information and the terrain at the incident location, terrain induced wind flows (waves or down slope winds) or turbulence may have been present at the time of the accident.*
>
> *and that:*
>
> > *The incident location lies within a valley, it is possible that mountain waves may have occurred, including breaking waves, and also down slope winds in the vicinity. It is also reasonable to expect that the likelihood of encountering these phenomena would have been significantly greater at low altitude and close to the terrain.*
>
> *Anemometer equipment was located at the property that was being baited, and the property owner reported advising the pilot via ultra high frequency (UHF) radio that the indicated wind speed at the time was about 30 kts.*

The parameters searched in the ATSB Occurrence Database were validated via a telephone call to the ATSB, and noted as follows:

- Date range: From 02 March 1989 to 01 March 2019 (30 years);
- Location – all;
- Occurrence Category – all;
- Occurrence type: Environment – Weather – Turbulence / Windshear / Microburst, unforecast weather, weather - other, lightning strike; and
- Aircraft and Airspace: Aircraft Type: Aeroplane, Motor-Glider, Gyrocopter, Powered Weight Shift.

7.2. ATSB Review of general aviation fatal accidents 1991 to 2000

The ATSB produced Aviation Research Paper B2004/0010, *General aviation fatal accidents: How do they happen? A review of general aviation fatal accidents 1991 to 2000.*

This paper notes there were 215 fatal accidents and 413 associated fatalities in the period 1991-2000 inclusive.

It also noted the general aviation fatal accident rate ranged between 0.9-1.5 fatal accidents per 100,000 hours flown ($0.9\text{-}1.5 \times 10^{-5}$ per hour flown), with a general downward trend (in 2000 the rate was 0.9 per 100,000 hours flown and the three year central moving average was 1.1 per 100,000 hours flown). Over the 10-year period there were 1.2 fatal accidents per 100,000 hours flown.

According to the ATSB's *Aviation Occurrence Statistics 2008-2017*, the All General Aviation fatal accident rate for the more recent 10-year period was 1.19 per 100,000 hours flown. The accident rate for RPT and charter operations is much lower than that of general aviation.

According to the research paper:

> *The majority of fatal accidents (82%) fell into three main groups:*
>
> - *controlled flight into terrain*
> - *managed flight into terrain*
> - *uncontrolled flight into terrain.*
>
> *For the purpose of this report these accident types were defined as:*
>
> - *Controlled flight into terrain (CFIT) - an event where an aircraft collided with obstacles, objects or terrain during powered, controlled flight with little or no awareness on the part of the pilot of the impending impact.*
> - *Managed flight into terrain (MFIT) – an event where an aircraft collided with obstacles, objects or terrain while being flown under limited control or reduced performance, with insufficient height/performance to reach a designated landing area.*
> - *Uncontrolled flight into terrain (UFIT) - an event where an aircraft collided with obstacles, objects or terrain after control of the aircraft was lost in-flight (includes cases where the pilot became incapacitated) but the aircraft structure did not change prior to impact.*
>
> *UFIT fatal accidents were the most prevalent of the fatal accident types (46 per cent), followed by CFITs (30 per cent) and MFITs (6 per cent).*
>
> *The vast majority of low-level UFIT fatal accidents (approximately 90 per cent) could be described as accidents where the pilot's control inputs (or lack of inputs) initiated a loss of control. In almost a quarter of these cases, turbulence or windshear may have also contributed to the loss of control. In contrast, UFIT fatal accidents during 'normal' operations were more likely to have had an initiating factor such as a loss of engine power, loss of reference to the external environment, aircraft system or airframe problem, pilot incapacitation etc., with around 20 per cent being primarily the result of pilot action or inaction.*

CFIT accidents are by definition not relevant to this assessment as we are specifically interested in operations in which controlled flight is lost.

Of the 13 MFIT accidents, six were ditchings due to mechanical failure, loss of power or fuel starvation, three were tree strikes resulting from loss of power over terrain unsuitable for forced landings, one was a loss of power in the circuit area, and three were fuel exhaustion events. None of these is relevant to this assessment.

We are particularly interested in UFIT accidents during 'normal' operations, as they represent the operations of concern to this assessment.

Paragraph 4.4.2.3 records UFIT fatal accidents initiated from a loss of control in turbulence or icing conditions.

It notes there were 10 fatal accidents where weather conditions (other than operating in IMC) were a factor in the accident. All were in aeroplanes (not helicopters). Three were charter, two were other aerial work and five were private/business. Notably, none of these fatal accidents involved flying training.

Two of these accidents occurred while the aircraft were flying in icing conditions. The cause of these accidents is not relevant to the subject of this assessment.

The other eight accidents occurred in conditions of turbulence or windshear:

- Two aircraft which were close to the maximum permissible take-off weights, encountered windshear on take-off and the pilot's control inputs did not keep the aircraft under controlled flight.
    - The power station is not close enough to Shellharbour Airport to affect aircraft during take-off, so these accidents are not relevant to this assessment;
- Two aircraft, one of which was overweight, were being operated in turbulent conditions and at the limit of the aircraft's operating envelope when control of the aircraft was lost.
    - These two accidents may be relevant to this assessment, on the premise that an aircraft may be at the limit of its operating envelope and experiences the effects of the plume and control of the aircraft is lost. Note however, that the plume will only affect an aircraft for a short period of time (up to approximately three seconds), after which it will experience the prevailing conditions again;
- In the four remaining accidents, the pilot's control inputs were not appropriate to keep the aircraft under controlled flight in the wind conditions.
    - These four accidents may be relevant to this assessment, on the premise that an aircraft experiences the effects of the plume and the pilot does not apply appropriate control inputs. Note however, that the plume will only affect an aircraft for a short period of time (up to approximately three seconds), after which it will experience the prevailing conditions again.

In summary, up to six of the 215 fatal accidents in the 10-year period 1991-2000 may be relevant to the circumstances. An investigation of the actual circumstances involved in these accidents (which were not disclosed) may reveal a lack of relevance.

Factoring the 1991-2000 general aviation fatal accident rate (1.2 fatal accidents per 100,000 hours flown) by this ratio derives an average 0.033 general aviation fatal accidents per 100,000 hours flown where weather conditions (other than operating in IMC) were a factor in the accident. This rate can be written as 0.33×10^{-6} per hour flown.

7.3. RAAus accident data

On 07 February 2020, Recreational Aviation Australia provided a spreadsheet with data from its Occurrence Management System related to accidents involving windshear or turbulence. It was noted that data has only been collected since the end of October 2015.

RAAus specifically noted that there are no reported events due to man-made/generated turbulence i.e. plumes.

Of the 41 recorded events, five were fatal.

One occurred during take-off.

Once involved an Airborne XT 912:

> *Evidence supports findings that environmental factors contributed to the cause of the accident to the extent that the presence of convective turbulence adversely influenced the pilots' ability to control at a time where the Coroner found it likely they were flying too low on the presence of these factors.*

One involved an Airborne Windsports Edge X912 while on approach to an airport.

One involved a Jabiru J170 (ATSB: AO-2016-112):

> *On 7 September 2016, the pilot of a Jabiru J170-C aircraft, registered 24-5215, approached to land, or perform a 'touch-and-go' manoeuvre, on runway 09 at Yarram aerodrome, Victoria, as part of a solo training flight. The pilot mishandled the landing attempt and lifted off to perform a go-around. The aircraft was observed at 50 to 100 ft above the aerodrome in a left wing down 30° angle of bank prior to it entering a steep descent consistent with an aerodynamic stall. The aircraft collided with the terrain and the pilot was fatally injured.*

One involved a Slipstream Industries Revelation conducting a climbing turn close to the ground at an aerodrome.

Four of these accidents occurred during the conduct of a take-off or landing approach, and the other one involving the Airborne Edge Trike XT912 was within the circuit area in the presence of what is described as a dust devil.

The circumstances of these five fatal accidents are different to the circumstances applicable to this assessment because of the following reasons:

1. The power station will be a known hazard to which pilots will be alerted through various, appropriate means, so they will be able to plan to avoid it under most circumstances;
2. Smaller aircraft will almost certainly not be overflying the power station in the course of conducting standard circuits, regardless of whether or not they have been alerted to the hazard, because of its distance from Shellharbour Airport; and
3. If aircraft do overfly the power station, it will likely be at or above 1000 ft, at which the vertical velocity of the plume will be below 6.1 m/s, engendering conditions equivalent to momentary light turbulence, a commonplace condition encountered by light aircraft around the world, without consequence.

8. STAKEHOLDER CONSULTATION

Energy Australia acknowledges the importance of stakeholder consultation and has committed to ensuring that its engagement with the community and consultation with stakeholders will continue through the life of the project, with a dedicated Community Relations Lead (CRL) located at Tallawarra Power Station.

This section records the consultation that was undertaken to inform the development of this report.

8.1. Aircraft Owners and Pilots Association of Australia

Feedback from the Aircraft Owners and Pilots Association of Australia (AOPA) regarding the draft AIA was received from Mr Benjamin Morgan on 24 January 2020. The submission included a cover letter and a number of supporting documents. Table 9 summarises the issues and subsequent responses.

A summary of AOPA's correspondence, including links to download the various attachments, was posted on AOPA's website on 04 February 2020. The draft AIA was not included in the set of documents available for download.

Table 9 AOPA response 31 January 2020 (specific recommendations)

Item	*Issue*	*Response*
1	CASA to determine the appropriate Critical Plume Velocity for the correct assessment of risk to the safety of aviation, taking into account the Visual Flight Rules (VFR) aircraft affected by the plume, their location in the circuit, and the aircraft aerodynamic situation.	This recommendation was directed at CASA. Additional discussion incorporated in Section 5 and specifically in Section 5.6.
2	CASA to determine the appropriate Critical Plume Height(s) for the assessment taking into account Visual Flight Rules (VFR) aircraft affected by the plume, their location in the circuit, and the aircraft aerodynamic situation.	This recommendation was directed at CASA. Additional discussion incorporated in Section 5 and specifically in Section 5.6.
3	Energy Australia to present a transparent plume rise assessment with clarity of specifically what is being assessed and how it is being assessed.	Refer to the detailed discussion provided by Katestone at Annexure 1.
4	Energy Australia to validate the model output data used for the assessment, against the Shellharbour historical BOM data. Energy Australia to report an assessment of the accuracy of that data as part of the assessment.	Refer to the detailed discussion provided by Katestone at Annexure 1.
5	Energy Australia to reconcile any difference between assessment findings and those presented by Jacobs in their technical memo on peaking power plant engineering modifications.	The Jacobs memo did not contemplate the engineering solution now being adopted, so this reconciliation is not applicable.

Item	*Issue*	*Response*
6	EnergyAustralia to conduct a valid risk assessment.	Additional data and analysis incorporated throughout the assessment and summarised in more detail at Section 11.

8.2. Australian Flying

On 24 January 2020, *Australian Flying* published an article on its website entitled *Gas Plume could stall Light Aircraft: AOPA*, based on a summary of the AOPA submission. The publisher did not seek EnergyAustralia's point of view for the article.

On 30 January 2020, EnergyAustralia's perspective was published on the *Australian Flying* website in a new article entitled *Tallawarra B can work: Energy Australia.*

8.3. Fly Illawarra

Fly Illawarra operates a number of RAAus-registered aircraft for the purposes of private hire and pilot training, including three Jabiru variants, a Pipistrel Alpha trainer and an Evektor SportStar Plus.

A telephone conversation was conducted with a Mr Bruce Robbins who is a senior instructor of Fly Illawarra.

Mr Robbins advised as follows:

- The organisation operates 3-axis aircraft registered with RAAus;
- The typical circuit is approximately ¾ - 1 nm abeam the runway and is rarely flown wider than that;
- Most circuits are conducted at 1000 ft AMSL, although sometimes low-level circuits are conducted as part of the applicable flying training syllabus, at 500 ft or 800 ft AMSL;
- Generally runway 16/34 is used in summer and 08/26 is used in winter, although he has observed a longer 'winter' season characterised by westerly winds this year requiring the use of runway 26 for longer than usual; and
- Flying operations are conducted under the visual flight rules, during the day only and do not involve aerobatics.

8.4. Fly Corporate

During the course of preparing the ACP (in June 2019), a summary response to concerns relating to departure procedures on runway 34, and instrument approach procedures to both runways 16 and 34 was sent to Fly Corporate's Manager Flight Operations.

Further follow-up telephone calls were left but at the time of writing no response has been received.

Fly Corporate has a company departure procedure on runway 34 – Runway heading to 2.5 nm from YWOL ARP then turn right 080°.

Figure 37 indicates a notional 0.2 nm area of interest around the site. It also shows the perfect situation of tracking runway centreline until intersecting 2.5 nm from the ARP, then turning right through a 0.25 nm radius turn onto 080°. Also modelled are gross tracking errors of 15° either side of centreline, which amounts to about 0.5 nm off track at the 2.5 nm distance from the ARP, then turning right onto 080°.

In all cases the departure procedure track is clear of the area of interest.

Airservices Australia has subsequently advised that there would be no impact to current instrument approach procedures. Refer to Section 6.3 for further details.

Figure 37 Fly Corporate company departure procedure analysis

8.5. Five Point Aviation/Southern Biplanes

Five Point Aviation is a flying school based at Shellharbour Airport, which operates a number of light aircraft including C172, CAP10, Citabria and Cessna 208. Southern Biplanes is an associated business operating aerobatics flights in Pitts Special, Stearman, Tiger Moth aircraft.

A face to face meeting was conducted with the Chief Pilot, Mr Chris Clark.

Mr Clark mentioned the following considerations:

- Standard circuit height is 1000 ft AMSL for most aircraft, and higher (1500 ft AMSL) for higher performance aircraft;
- Low level circuits are generally not conducted;
- The normal circuit does not usually involve overflying the power station; and
- It would be preferable if the Tallawarra B power station was not constructed, but it could be accommodated through consideration of potential impacts and adjustment of operating procedures as appropriate.

8.6. Recreational Aviation Australia

The following questions were asked of Mr Jared Smith of RAAus via email on 04 November 2019:

1. *Does RAAus consider 0.5 g (for a vertical gust) to be the lower limit of severe turbulence (rather than 1.0 g as per the BoM classification)?*
2. *Should the pilot of an RAAus aircraft be capable of maintaining control of the aircraft while experiencing a 0.5 – 0.99 g vertical gust (i.e. moderate turbulence), and if not, under what circumstances?*
3. *Should an RAAus aircraft be able to maintain structural integrity while experiencing a 0.5 – 0.99 g vertical gust (i.e. moderate turbulence), and if not, under what circumstances?*
4. *Is there a standard circuit size/dimension for RAAus aircraft, and if so, please provide details.*

On 05 December 2019, Mr Smith advised that RAAus had not been able to fully consult with Light Sport Aircraft manufacturers to the detail required to put forward a formalised response regarding the gust loads.

In response to question 4, Mr Smith advised that there is no standard circuit size for RAAus aircraft.

Mr Smith also advised that there are currently 765 members operating in and around the Shellharbour Airport area with proportionally 250 + aircraft registered with members in and around the area. These aircraft operate into and out of the airport either as private flights or flight training based at the airport.

A further request for clarification was sent on 28 November 2019:

> *Further to our telephone conversation just now in relation to the subject, one of the stakeholders at Shellharbour Airport is circulating the following observation:*

> *"RA Aus advise on their website that their 3 axis aircraft experience the onset of severe turbulence at 6.1 metres per second. This is in keeping with the ASTM design standard for gust load limits."*

Would you please advise if this is correct, and if so, where I will find it on your website.

Mr Smith replied on 06 December 2019:

I have searched our current website and have not found any reference to the observation mentioned below. However, after speaking with stakeholders at Shellharbour airport the information may have come from a previous version of our website where we hosted a number of technical documents. I am trying to source these from our developer.

On 28 January 2020, a follow-up email was sent to Mr Smith, requesting a response to the first three questions of the original email sent 04 November 2019.

On 31 January 2020, in its monthly newsletter, RAAus included an article on the subject entitled *Tallawarra Power Station consultation*. The article essentially repeated the AOPA summary and provided a link to the Australian Flying article *Tallawarra B can work: Energy Australia.* The article also provided a link to the member portal, on which it had placed all the AOPA documents, but not the draft Aviation Impact Assessment.

It suggested that a meeting that was held on 30 January 2020 had been attended by representatives of EnergyAustralia, when in fact no representatives of EnergyAustralia attended that meeting.

RAAus then went on to ask members to review the data and provide responses to EnergyAustralia (Mr Julian Turecek) directly using suggested content for the email, by 14 February 2020. At the time of submission (13 February 2020), Mr Turecek had received no submissions.

On 07 February 2020, Mr Smith advised:

Unfortunately I am not able to supply further information regarding your points below without the consultation of an aeronautical engineer. I understand your office has requested further data regarding weather related incidents which has been compiled and sent.

On 07 February 2020, Ms Janelle Wayling, Safety Coordinator, sent a spreadsheet with data from RAAus' Occurrence Management System related to accidents involving windshear or turbulence.

8.7. Shellharbour City Council

A summary of engagement activities involving Shellharbour City Council up to the submission of the Airspace Change Proposal in April 2019 is contained within that submission. Subsequent to CASA's decision to not support that application, EnergyAustralia has continued to engage with Shellharbour City Council.

Meetings were held with the Council Executive on 25 July 2019 and 16 September 2019.

Additional meetings were held with the Airport Manager on 17 September 2019 and 22 October 2019.

A meeting was held with representatives of Shellharbour City Council on 24 October 2019, at which the parties expressed their respective positions on the issues to be resolved.

A meeting was then held with representatives of Shellharbour City Council and the Shellharbour Airport User Group (Mr John Cleary) on 27 November 2019.

At this meeting, concern was primarily directed towards the potential impact of the plume on 3-axis light sport aircraft (RAAus) and smaller VH-registered aircraft, particularly in relation to the critical plume velocity for these aircraft (which it was suggested is less than for other aircraft).

It was accepted that the onset of moderate turbulence is the appropriate determining factor for critical plume height and velocity.

Preliminary questions in response to the Draft Aviation Impact Assessment were sent by Mr Joel Sinclair from Shellharbour City Council on 18 December 2019. Table 10 summarises the issues and relevant responses. Items 1-4 were provided on 23 January 2020, and Airservices Australia's response to Item 5 was forwarded on receipt on 31 January 2020.

Table 10 Preliminary questions – 18 December 2019

Item	*Issue*	*Response*
1	Exact location of the proposed Open Cycle Gas Turbine in latitude and longitude	34°31'18.27''S, 150°48'32.45''E
2	Exact location of current Gas Turbines at Tallawarra	34°31'21.55''S, 150°48'30.45''E
3	Is the intention to build single or multiple stacks? Subject to the answer, please response to the below as appropriate: a) For single stacks i) Stack exit velocity (m/s). ii) Stack exit temperature (degrees Celsius). iii) Stack radius (m). iv) Stack height (m AGL). b) For multiple stacks i) Stack separation distance (m). ii) Stack exit velocity (m/s). iii) Stack exit temperature (degrees Celsius). iv) Stack radius (m). v) v. Stack height (m AGL).	a) Single stack - exact details of exit velocity and radius can only be provided when OEM and engineering solution is finalised. ii. Stack exit temperature (degrees Celsius). [approx.650°C] iii. Stack radius (m). [approx. 3.5m] iv. Stack height (m AGL). [approx. 40m] b) Multiple stacks - still awaiting submissions from the aero-derivative suppliers.
4	Modelling refers to the use of 5 years of weather data, confirm the timeframes used in months and years	1 January 2014 till 31 December 2018
5	Impacts on the Instrument Flight Procedures are unclear, confirm the following: a) Exact impacts to current procedures, and if the implementation of the proposed Open Cycle Gas Turbine will prevent the introduction of further efficiencies to those procedures, including the introduction of Category C performance aircraft and potential for those aircraft to adopt straight in minima rather than circling minima:	Refer to Section 6.3.

Item	Issue	Response
	i) GNSS Arrival. ii) NDB-A. iii) RNAV-Z (GNSS) RWY 16. iv) RNAV-Z (GNSS) RWY 34. b) Exact impacts of future procedures which may considered and how this information was calculated: i) Details regarding the introduction of Category C performance aircraft. ii) Will the proposed Open Cycle Gas Turbine impact future improvements to the existing RNAV procedures. iii) Will the proposed Open Cycle Gas Turbine impact future introduction and/or efficiencies when Approaches with Vertical Guidance (APV-barometric VNAV) are introduced.	

Formal feedback in response to the Draft Aviation Impact Assessment was sent by Mr Joel Sinclair, Manager Airport from Shellharbour City Council on 29 January 2020. Table 11 summarises the issues and relevant responses.

Table 11 Formal response – 29 January 2020

Item	Issue	Response
1	Insufficient technical information available to determine where there is no adverse impact to aviation safety	Additional technical information on the plume source was provided on 23 January 2020. The final engineering solution will be validated through CFD modelling.
2	AIA fails to identify how proposed CPV impacts common aircraft types frequenting Shellharbour Airport	The assessment has been prepared in accordance with specific direction from CASA regarding the use of 6.1 m/s critical plume velocity, and the guidance published in AC 139-05 v3.0.
3	Insufficient detail on potential impacts on instrument flight procedures	Refer to Section 6.3.
4	Risk assessment not sufficiently rigorous	The risk assessment has been updated. Refer to Section 11.

Item	*Issue*	*Response*
Section 3.3	Regarding CASR 139.70 Regarding Danger Area	CASR 139.370 provides CASA with a right to determine whether a 4.3m/s plume is a hazard to aircraft operations. It is a trigger for notification, not the velocity at which CASA will necessarily apply control measures.
Section 4.1	Hours of plant operation	Although it is unlikely that the power station will operate continuously for extended periods, the risk assessment now assumes worst case continuous operation for assessing exposure to the plume hazard.
Section 4.2	Regarding plume heights and velocities	Refer to the detailed discussion provided by Katestone at **Annexure 1**.
Section 5.1	Regarding aircraft movements	45,000 annual movements as verbally advised by Shellharbour Council, was used in the absence of more definitive data. A follow up request was sent to the Manager Airport on 30 January 2020, requesting official data from Shellharbour Council. On 10 February 2020, The Manager Airport advised the data would be provided on 17 February 2020. To the extent that the new data materially affects the analysis, summary or conclusions, an addendum to this report may be prepared and submitted.
Section 5.5	Regarding circuit pattern	The analysis shows the extent of indicative circuit patterns and some of the difficulties in adopting a single shape and size for the various aircraft types. Adopting a single generic circuit pattern diminishes the validity of the assessment. Moreover, Tallawarra can be in the general 'circuit area' without necessitating that every single flight overflies the station.
Section 5.6	Regarding FlightAware data; SAAB340s	Acknowledging its shortcomings, Flight Aware data is the only source of 'truth' available. Flights above 1050 ft will be below the CPV. An indicative list of aircraft types has been provided in Section 5.8.
Section 5.12	Regarding impact on IFR procedures	Refer to Section 6.3.
Section 6.3	Regarding IFR procedures	Refer to Section 6.3.

Item	*Issue*	*Response*
Section 6.6, 6.7 and 6.8	Regarding future airport plans to Code 3	The analysis clearly shows that the power station will not be the most significant constraint to future upgrade of the aerodrome. If exemptions are acceptable for these significant issues, then so should a safety case be acceptable for the power station.
Section 7	Regarding ATSB data accuracy Regarding RAAus accident data	ATSB data was validated by speaking with an ATSB representative and re-checking the searched criteria. Refer to Section 7.1. Additional analysis of fatal general aviation accidents produced by ATSB was reviewed and summarised in Section 7.2. RAAus data was sought and provided. Refer to Section 7.3.
Section 9.2	Regarding use of coloured smoke	Coloured smoke is not a standard obstacle marking solution. Obstacle lighting requirements in MOS 139 Chapter 9 allow for various options in consideration of visual impact to the surrounding community.
Section 11	Regarding risk assessment	The risk assessment has been updated. Refer to Section 11.

8.8. TrikeFan Services

TrikeFan Services operates microlights from Shellharbour Airport. A telephone conversation was conducted with the owner, Mr Tony Dennis.

Mr Dennis mentioned the following considerations:

- Microlights weigh up to approximately 450 kg and have relatively low wing loading, so they're quite susceptible to the effects of turbulence and strong winds;
- Circuits are generally flown at 1000 ft AMSL, but sometimes lower, and are generally closer than most other aircraft;
- The aircraft he operates are certificated to applicable standards by the manufacturers;
- The aircraft he operates do not generally overfly the power station;
- Flying is normally conducted in the mornings and afternoons (day only);
- He checks to see if the creek near the power station is running to determine whether or not the current Tallawarra A power station is operating (as the water is used in the combined cycle process); and

- A flashing light on the Tallawarra B power station when it is operating would be a good way to alert pilots to the potential plume hazard, noting that it should be shielded to prevent visual amenity impact to surrounding residents.

8.9. Wollongong City Council

A meeting with Wollongong City Council Executive was held on 20 September 2019.

A copy of the draft Aviation Impact Assessment was provided to the Wollongong City Council Executive on 12 December 2019. No feedback was received.

9. HAZARD LIGHTING AND MARKING

9.1. Civil Aviation Safety Authority

In considering the need for aviation hazard lighting, an analysis of the regulatory context was undertaken.

Chapter 8 of MOS 139 specifies the standards for markings, including standards applicable to Obstacle Marking. The applicable requirements are extracted below:

> *8.10.2 Marking of Obstacles*
>
> *8.10.2.6 Masts, poles and towers must be marked in contrasting bands with the darker colour at the top. The bands must be perpendicular to the longest dimension and have a width approximately 1/7 of the longest dimension.*

Chapter 9 sets out the standards applicable to visual aids provided by aerodrome lighting. The applicable requirements are extracted below:

> *9.4.1 General*
>
> *9.4.1.1 Under the Civil Aviation Regulations, CASA may determine that an object or a proposed object which intrudes into navigable airspace requires, or will be required to be provided with, obstacle lighting. Responsibility for the provision and maintenance of obstacle lighting on a building or structure rests with the owner of the building or structure. Within the limits of the obstacle limitation surfaces of an aerodrome, responsibility for the provision and maintenance of obstacle lighting on natural terrain or vegetation, where determined necessary for aircraft operations at the aerodrome, rests with the aerodrome operator.*
>
> *.....*
>
> *9.4.1.3 Owners of tall buildings or structures below the obstacle limitation surfaces, or less than 110 m above ground level, may, of their own volition, provide obstacle lighting to indicate the presence of such buildings or structures at night. To ensure consistency and avoid any confusion to pilots, the obstacle lighting provided needs to conform with the standards specified in this Chapter.*

Section 9.4.2 provides guidance on types of obstacle lighting and their use:

> *9.4.2.1 Three types of lights are used for lighting obstacles. These are low intensity, medium intensity and high intensity lights, or a combination of such lights.*
>
> *9.4.2.3 Medium intensity obstacle lights are to be used either alone or in combination with low intensity lights, where:*
>
> *(a) the object is an extensive one;*
>
> *(b) the top of the object is 45 m or more above the surrounding ground;*
>
> *(c) CASA determines that early warning to pilots of the presence of the object is desirable.*
>
> *9.4.2.4 There are three types of medium intensity obstacle lights:*

(a) Flashing white light. Likely to be unsuitable for use in environmentally sensitive locations, and near built-up areas. May be used in lieu of obstacle markings during the day to indicate temporary obstacles in the vicinity of an aerodrome, for example construction cranes, etc. and are not to be used in other applications without specific CASA agreement.

(b) Flashing red light, also known as a hazard beacon. Is suitable for all applications, and is extensively used to mark terrain obstacles such as high ground.

(c) Steady red light. May be used where there is opposition to the use of a flashing red light, for example in environmentally sensitive locations.

9.4.2.5 High intensity obstacle lights are flashing white lights used on obstacles that are in excess of 150 m in height. As high intensity obstacle lights have a significant environmental impact on people and animals, it is necessary to consult with interested parties about their use. High intensity obstacle lights may also be used during the day, in lieu of obstacle marking, on obstacles that are in excess of 150m in height, or are difficult to be seen from the air because of their skeletal nature, such as towers with overhead wires and cables spanning across roads, valleys or waterways.

Section 9.4.3 provides guidance on location of obstacle lights:

9.4.3.1 One or more obstacle lights are to be located as close as practicable to the top of the object. The top lights are to be arranged so as to at least indicate the points or edges of the object highest above the obstacle limitation surface.

9.4.3.2 In the case of a chimney or other structure of like function, the top lights are to be placed sufficiently below the top (nominally 1.5 m to 3 m) so as to minimise contamination by smoke, etc.

....

9.4.3.8 The number and arrangement of lights at each level to be marked is to be such that the obstacle is indicated from every angle of azimuth. Where a light is shielded in any direction by an adjacent object, the light so shielded may be omitted but additional lights may be required in such a way so as to retain the general definition of the obstacle.

9.4.3.9 Illustrations of typical lighting of obstacles are shown below…

Section 9.4.6 and 9.4.7 provide guidance on characteristics of low and medium intensity lights and are copied below:

9.4.7 Characteristics of Medium Intensity Obstacle Lights

9.4.7.1 Medium intensity obstacle lights are to be flashing or steady red lights or flashing white lights, visible in all directions in azimuth.

9.4.7.2 The frequency of flashes is to be between 20 and 60 flashes per minute.

9.4.7.3 The peak effective intensity is to be 2,000 ± 25% cd with a vertical distribution as follows:

(a) vertical beam spread is to be 3° minimum (beam spread is defined as the angle between two directions in a plane for which the intensity is equal to 50% of the lower tolerance value of the peak intensity);

(b) at -1° elevation, the intensity is to be 50% minimum and 75% maximum of lower tolerance value of the peak intensity; and

(c) at 0° elevation, the intensity is to be 100% minimum of the lower tolerance value of the peak intensity.

9.4.7.4 Where the flashing white light is used in lieu of obstacle marking during the day to indicate temporary obstacles in the vicinity of an aerodrome, in accordance with Paragraph 9.4.2.4(a), the peak effective intensity is to be increased to 20,000 ± 25% cd when the background luminance is 50 cd/m² or greater.

9.2. Lighting/marking recommendations

The proposed Tallawarra B OCGT power station development comprises a 40 m AGL exhaust gas stack at a maximum height of 45 m AHD (to be confirmed subject to selected equipment and engineering mitigation solution).

Based on the design of the development, existing stack's marking and lighting arrangements and analysis of relevant marking/lighting regulatory context, it is concluded that the exhaust gas stack of the proposed Tallawarra B OCGT should be marked and lit in accordance with the requirements set out in MOS 139. Specifically:

- the top of the stack should be marked in accordance with sub section 8.10.2.6;
- top lights are to be placed sufficiently below the top in accordance with sub section 9.4.3.2;
- the number and arrangement of lights during the day and at night should be in accordance with sub section 9.4.3.8
- flashing white medium intensity lights should be provided during the day in accordance with sub section 9.4.2.4 (a) and 9.4.7 (paragraphs 9.4.7.1 - 9.47.4); and
- flashing red medium intensity lights should be provided at night in accordance with sub section 9.4.2.4 (b), and 9.4.7 (paragraphs 9.4.7.1 - 9.47.4).

The obstacle lights should be activated when the Tallawarra B OCGT power station is operating.

10. POTENTIAL MITIGATIONS

A number of potential mitigations to the plume hazard are proposed in this section, as a means of alerting pilots and assisting their pre-planned and in-flight avoidance of the hazard.

10.1. Alerting through AIP – ERSA, aeronautical charts

Pilots can be alerted to the hazard through information published in the various elements of the Aeronautical Information Package (AIP) published by Airservices Australia. The various documents and proposed changes are listed below:

- ERSA FAC – a note could be included in Local Traffic Regulations to the effect that aircraft should avoid overflying the power station below 1000 ft when it is operating; and
- Aeronautical charts – a plume symbol could be placed over the power station site - refer to Figure 38 which shows the plume symbol near Laverton in Victoria (source: OzRunways).

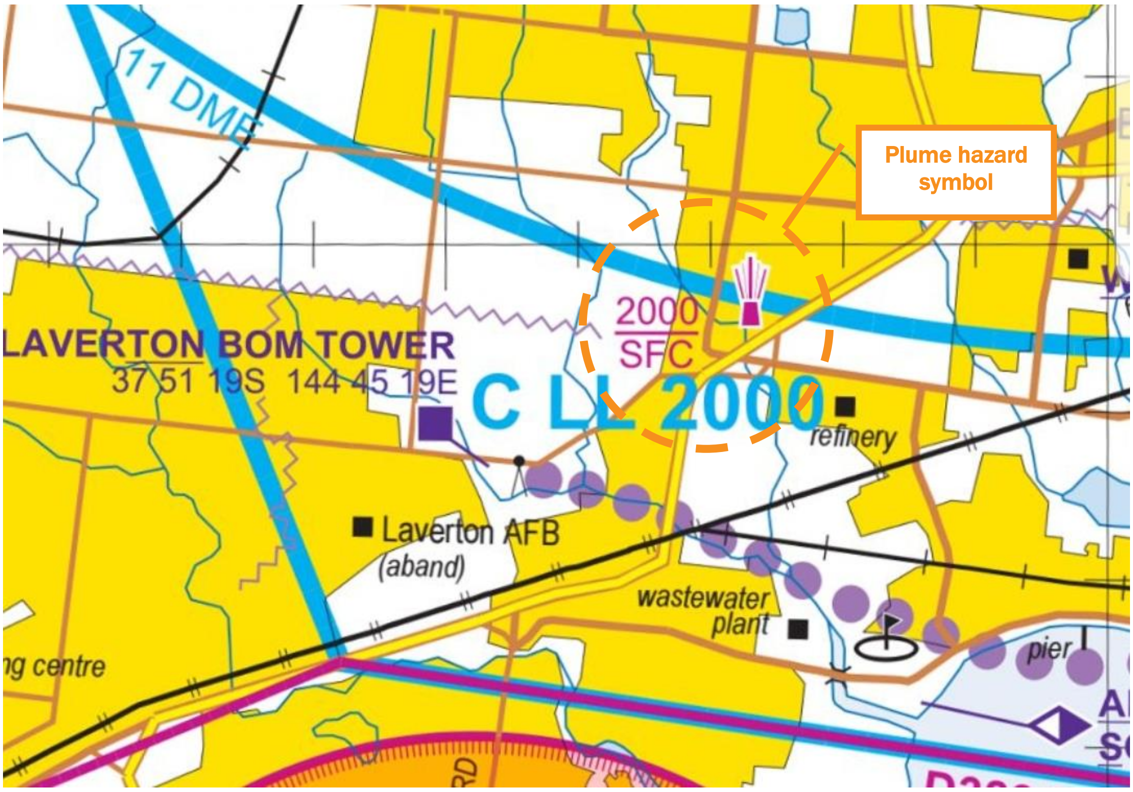


Figure 38 Plume symbol on aeronautical chart

10.2. Alerting through marking and lighting

As a means of alerting pilots to the potential hazard associated with the plume, it is proposed to mark the chimney stack and provide medium intensity flashing white lights on the exhaust stack during the day and medium intensity flashing red lights on the exhaust stack at night, to be activated when the power station is operating.

10.3. Pilot awareness and operating procedures

Locally based pilots and aircraft operators including flying schools should be made aware of the potential hazard via the airport safety committee and/or user group forums, and the broader pilot community via RAPAC, well in advance of first operations of the power station. With adequate notice, these locally based operators should be able to review their operating procedures and amend them accordingly.

10.4. Shut down on certain high activity days

EnergyAustralia has indicated that it is prepared to not operate Tallawarra B OCGT on days when significant flying activities are planned to be conducted at Shellharbour Airport. Such days might include the Wings over Illawarra, a two-day airshow event which occurs in May each year.

10.5. Electronic Flight Bag (EFB) applications

A number of commercially available electronic flight bag (EFB) applications are used by pilots in Australia. At least one of these applications can indicate hazards such as a vertical plume at relatively short notice. EFB providers should be encouraged to make this facility available, specifically in relation to the Tallawarra B plume hazard.

11. RISK ASSESSMENT

A risk management framework is comprised of likelihood and consequence descriptors, a matrix used to derive a level of risk, and actions required of management according to the level of risk.

The risk assessment set out herein is based on the framework contained within Form 1589 published by CASA.

The intention is to satisfy the relevant aspect of condition of approval 1.6 relating to impact on aviation safety, in demonstrating an acceptable level of safety for the proposed development, in accordance with the definition of safety as per ICAO DOC 9859, Safety Management Manual (Fourth Ed):

> *The state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level.*

Doc 9589 is intended to provide States (including Australia) with guidance on the development and implementation of a State safety programme (SSP), in accordance with the International Standards and Recommended Practices (SARPs), and is therefore adopted as the primary reference for aviation safety risk management in the context of this assessment.

The risk matrix in Form 1589 reflects the Risk Assessment Matrix contained at Appendix C of CASA's Risk Management Framework (the version available for the purposes of this report is Version 3.1 – Jan 2017).

The Event Classification Risk relevant to the subject is Operational – Aviation Safety.

11.1. Likelihood

Likelihood is defined in ISO 31000:2018 *Risk management — Guidelines* as the chance of something happening.

Likelihood descriptors used in this assessment are provided in Table 12 (source: CASA Form 1589).

Table 12 Likelihood Descriptors

No	*Descriptor*	*Numerical*	*Historical*
0	Extremely Rare	< 1 in 100,000	Could only occur under specific conditions and extraordinary circumstances
1	Rare	1 in 10,000 – 100,000	May occur in exceptional circumstances
2	Unlikely	1 in 1,000 – 10,000	Could occur but considered unlikely or doubtful
3	Possible	1 in 100 – 1,000	Might occur at some time in the future
4	Likely	1 in 10 – 100	Will probably occur
5	Almost Certain	>1 in 10	Is expected to occur in most circumstances

11.2. Consequence

Consequence is defined as the outcome of an event affecting objectives, which in this case is the safe and efficient operation of aircraft.

Consequence descriptors used in this report are provided in Table 13 (source: CASA Form 1589).

Table 13 Consequence Descriptors

No	Descriptor	Aviation Safety
0	Insignificant	Not having aviation safety implications
1	Minor	Associated with minor breaches of aviation safety regulations
2	Moderate	Major issues of compliance with aviation safety regulations but would not in itself lead to a safety incident.
3	Major	Major issue of compliance with aviation safety regulations and leading to potential for unsafe aviation operations.
4	Severe	Potential for aviation safety incident/s involving multiple life threatening injuries, or fatality with 1 or 2 persons
5	Catastrophic	Potential for multiple fatal aviation safety occurrences causing multiple fatalities (3 or more).

11.3. Risk matrix

The risk matrix, which correlates likelihood and consequence to determine a level of risk, used for this assessment is shown in Table 14 (source: CASA Form 1589).

Table 14 Risk Matrix

Likelihood	Numerical	Historical			Insignificant 0	Minor 1	Moderate 2	Major 3	Severe 4	Catastrophic 5
	>1 in 10	Is expected to occur in most circumstances	Almost Certain	5	5	6	7	8	9	10
	1 in 10 – 100	Will probably occur	Likely	4	4	5	6	7	8	9
	1 in 100 – 1000	Might occur at some time in the future	Possible	3	3	4	5	6	7	8
	1 in 1000 – 10000	Could occur but considered unlikely or doubtful	Unlikely	2	2	3	4	5	6	7
	1 in 10000 - 100000	May occur in exceptional circumstances	Rare	1	1	2	3	4	5	6
	< 1 in 100000	Could only occur under specific conditions and extraordinary circumstances	Extremely Rare	0	0	1	2	3	4	5

11.4. Actions required

Actions required according to the derived level of risk are shown in Table 15 (source: CASA Form 1589).

Table 15 Actions Required

>7	Extreme Risk	Detailed treatment plan required
6,7	High Risk	Needs senior management attention and treatment plan as appropriate
4,5	Medium risk	Manager level attention and monitoring as appropriate
<4	Low Risk	Manage by local procedures

11.5. Risk Identification

The primary risk being assessed is that an aircraft experiencing the effects of a vertical plume could suffer an aerodynamic stall or aircraft upset from which its pilot may not be able to recover. Alternatively, the aircraft may suffer a structural failure from which recovery is not possible.

The level of risk has been assessed according to the consequences applicable to two distinct aircraft operations – those by recreational type aircraft with up to two seats operating during the day under visual flight rules, and larger aircraft.

11.6. Risk Analysis, Evaluation and Treatment

For the purpose of considering applicable consequences, the concept of worst credible effect has been used. Untreated risk is first evaluated, then, if the resulting level of risk is unacceptable, further treatments are identified to reduce the level of risk to an acceptable level.

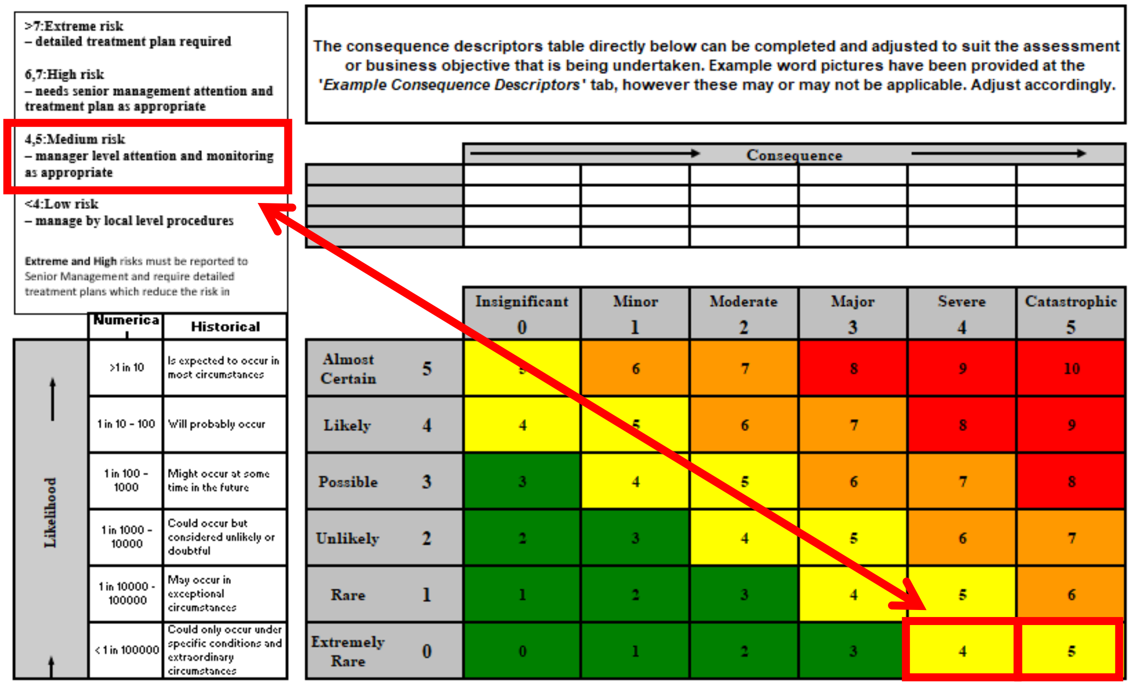
Relevant consequence descriptors are defined as follows:

- Severe - Potential for aviation safety incident/s involving multiple life-threatening injuries, or fatality with 1 or 2 persons (This consequence is strictly applicable to RAAus operations due to the aircraft not being permitted to have more than two seats); and
- Catastrophic - Potential for multiple fatal aviation safety occurrences causing multiple fatalities (3 or more).

It should be noted that the lowest possible level of risk for a Catastrophic consequence is 5 (Medium Risk), and for a Severe consequence is 4 (Medium Risk).

Medium Risk is defined as – manager level attention and monitoring as appropriate.

This can be seen in the risk matrix copied from Form 1589 in Figure 39.



Numerical	Historical	Likelihood		Insignificant 0	Minor 1	Moderate 2	Major 3	Severe 4	Catastrophic 5
>1 in 10	Is expected to occur in most circumstances	Almost Certain	5	5	6	7	8	9	10
1 in 10 - 100	Will probably occur	Likely	4	4	5	6	7	8	9
1 in 100 - 1000	Might occur at some time in the future	Possible	3	3	4	5	6	7	8
1 in 1000 - 10000	Could occur but considered unlikely or doubtful	Unlikely	2	2	3	4	5	6	7
1 in 10000 - 100000	May occur in exceptional circumstances	Rare	1	1	2	3	4	5	6
< 1 in 100000	Could only occur under specific conditions and extraordinary circumstances	Extremely Rare	0	0	1	2	3	4	5

Figure 39 Form 1589 risk matrix

According to the methodology published in CASA's Risk Management Framework, a risk rating of <6 indicates that positive or negative risks are negligible, or so small that no risk treatment measures are needed.

In any case, the likelihood of the consequence that derives the lowest practicable level of risk is defined as <1:100,000 – Could only occur under specific conditions and extraordinary circumstances.

For the level of aviation safety risk associated with the Tallawarra B power station to be as low as practicable within the nominated framework, it must be shown that the likelihood of a severe/catastrophic consequence as applicable is less than 1:100,000.

To recap some relevant data:

- Annual movements = 22,500 (half of total movements to represent the number of flights);
- FlightAware tracked flights = 13,233 (two years), average = 6,617/year;
- FlightAware tracked flights through indicative plume = 107.5/year (1.62%);
- Proportion of flights (1.62%) tracked through indicative plume in moderate turbulence region (based on a conservative 6.1 m/s critical plume height of 700 ft AMSL) = 13.5%;
- Proportion of operations on Runway 16/34 = 79%;
- Likelihood of a catastrophic failure or loss of control leading to a fatal accident if an aircraft flies through an area of turbulence is 0.33×10^{-6} (as per the analysis in Section 7.2) - this likelihood is well below the threshold for the lowest practicable risk in CASA's risk matrix (1:100,000).

Risk ID:	1. RAAus and other small two-seat aircraft catastrophic failure or loss of control

Discussion

An aircraft experiencing the effects of a vertical plume could suffer an aerodynamic stall or aircraft upset from which its pilot may not be able to recover. Alternatively, the aircraft may suffer a structural failure from which recovery is not possible.

RAAus aircraft currently have a maximum of two seats and are permitted to operate during daylight hours only under the visual flight rules.

Generally, they must be designed for the gust loads resulting from positive and negative gusts of 7.5 m/s nominal intensity at the design flap speed (V_f) with the flaps fully extended.

RAAus and other small aircraft are code 1 aircraft for the purposes of designing an OLS.

The OLS applicable to these aircraft being operated during the day on a runway not served by an instrument approach extends to a maximum distance of 2700 m. This is particularly applicable to RAAus and other similar light aircraft conducting circuits or other flying activities during the day under the visual flight rules.

The power station is located beyond the extent of a code 1 non-instrument OLS, so if the aerodrome was registered or certified as a code 1 non-instrument aerodrome and the Tallawarra B OCGT was proposed, it would not trigger a referral to CASA under MOS 139 Chapter 7 requirements as the plume would not penetrate the OLS.

Generally, pilots of light sport aircraft are advised to remain within gliding distance of a runway, although this is not a strict requirement.

Almost all circuits conducted by RAAus aircraft at Shellharbour Airport are at 1000 ft AMSL, although some circuits may be conducted at lower altitudes (in which case they would be closer to the airport than the power station).

There is a hill just to the north west of the power station with a mast at 436 ft AMSL which presents a significant hazard to aircraft operating at 500 ft above aerodrome elevation (31 ft), and there are high tension power lines and pylons in the vicinity of the power station adding to the risk of operating at low level over them.

The 6.1 m/s critical plume height after engineering mitigation will be not higher than 700 ft AMSL.

Based on current expectations and subject to validation following CFD modelling, the modified F Class plume will have an indicative vertical velocity of 5.2 m/s at 1000 ft AMSL.

Consequence

If an RAAus aircraft suffered a catastrophic structural failure or loss of control, the worst credible effect would be up to two fatalities and damage beyond repair. This would be a Severe consequence.

Consequence	Severe

Untreated Likelihood

Very few RAAus aircraft will overfly the power station in the course of normal operations.

If they do, it will almost certainly be at 1000 ft AMSL or above, and not climbing or in the approach configuration due to the power station's distance from the runway.

Based on Katestone analysis of the unmitigated F Class machine, the plume at 6.1 m/s extends downwind for an average of 94.2 m.

An aircraft flying at 60 kt is travelling at 30.9 m/s, which means it would be in the unmitigated F Class 99.9th percentile 6.1 m/s plume for a maximum of 3.1 seconds. An aircraft flying at 75 kt is travelling at 38.6 m/s. That would equate to a maximum of 2.4 seconds exposure to that plume. Pilots are taught how to recover from a stall condition during their training. Up to six of the 215 fatal general aviation accidents in the 10-year period 1991-2000 may be relevant to the circumstances. None of the accidents involved flying training. An investigation of the actual circumstances involved in these accidents (which were not disclosed) may reveal a lack of relevance. Factoring the 1991-2000 general aviation fatal accident rate (1.2 fatal accidents per 100,000 hours flown) by this ratio (6/215) derives an average 0.033 general aviation fatal accidents per 100,000 hours flown where weather conditions (other than operating in IMC) were a factor in the accident. This rate can be written as 0.33×10^{-6} per hour flown. RAAus has no reported loss of control events due to man-made/generated turbulence i.e. plumes since records began in late 2015. The circumstances of five fatal accidents recorded by RAAus are different to the circumstances applicable to this assessment because of the following reasons: 1. The power station will be a known hazard to which pilots will be alerted through various, appropriate means, so they will be able to plan to avoid it under most circumstances; 2. Smaller aircraft will almost certainly not be overflying the power station in the course of conducting standard circuits, regardless of whether or not they have been alerted to the hazard, because of its distance from Shellharbour Airport; and 3. If aircraft do overfly the power station, it will likely be at or above 1000 ft, at which the vertical velocity of the plume will be below 6.1 m/s, engendering conditions equivalent to momentary light turbulence, a commonplace condition encountered by light aircraft around the world, without consequence. It is assessed that an RAAus aircraft experiencing the effects of a vertical plume suffers an aerodynamic stall or aircraft upset from which its pilot may not be able to recover, or an aircraft suffers a structural failure from which recovery is not possible may occur in exceptional circumstances, which is classified as Rare. Note regarding likelihood: While the data available suggests the likelihood of the nominated consequence is much less than 1 in 100,000, a conservative approach has been taken to assigning the untreated likelihood to enable a numerical appreciation of the benefits of the suggested mitigations.

Untreated Likelihood	Rare

Current Treatments

- The power station will be located beyond the extent of the OLS applicable to these aircraft.
- The power station will be located beyond the extent of a normal circuit for these aircraft.
- Most aircraft will operate at a circuit height of 1000 ft AMSL which is well above the 6.1 m/s plume height (expected to be 5.2 m/s at 1000 ft AMSL).
- Aircraft are unlikely to fly over the power station site at heights below 1000 ft AMSL due to the proximity of the 436 ft AMSL mast obstacle on the hill just to the north west of the site.

Level of Risk The level of risk associated with a Rare likelihood of a Severe consequence is 5.	
Current Level of Risk	5 – Medium
Risk Decision A risk level of 5 is classified as Medium risk – manager level attention and monitoring appropriate. There are other risk treatments available that may reduce the likelihood of a severe consequence even further.	
Risk Decision	Acceptable with monitoring, but consider additional treatments
Proposed Treatments The following treatments, discussed in detail in Section 10 which can be implemented at little cost will provide an additional level of safety: • Alerting through AIP – ERSA, aeronautical charts • Alerting through marking and lighting • Pilot awareness and operating procedures • Shut down on certain high activity days • Electronic Flight Bag (EFB) applications	
Likelihood after Treatment	Extremely Rare
Residual Risk With the additional recommended treatments, the likelihood that an aircraft experiencing the effects of a vertical plume suffers an aerodynamic stall or aircraft upset from which its pilot may not be able to recover, or an aircraft suffers a structural failure from which recovery is not possible will be Extremely Rare and the consequence remains Severe, resulting in an overall risk level of 4 – Medium. In the circumstances, the level of risk under the proposed treatment plan is considered as low as reasonably practicable (ALARP).	
Residual Risk	4 - Medium

Risk ID:	2. Larger aircraft catastrophic failure or loss of control

Discussion

An aircraft experiencing the effects of a vertical plume could suffer an aerodynamic stall or aircraft upset from which its pilot may not be able to recover. Alternatively, the aircraft may suffer a structural failure from which recovery is not possible.

Aircraft other than RAAus or other small aircraft have greater than two seats and may be operating under the visual flight rules or instrument flight rules.

Larger aircraft may be up to code 3 for the purposes of designing an OLS, noting that the aerodrome is currently published as code 2.

Larger aircraft will be more tolerant of the vertical plume.

Smaller aircraft, such as Cessna 172, will be less tolerant of the vertical gust than a larger aircraft.

Almost all circuits conducted by these aircraft at Shellharbour Airport will be at or above 1000 ft AMSL (1500 ft AMSL for higher performance code 2 and 3 aircraft), although some circuits may be conducted at lower altitudes (in which case they may be closer to the airport than the power station).

There is a hill just to the north west of the power station with a mast at 436 ft AMSL which presents a significant hazard to aircraft operating at 500 ft above aerodrome elevation (31 ft), and there are high tension power lines and pylons in the vicinity of the power station adding to the risk of operating at low level over them.

The 6.1 m/s critical plume height after engineering mitigation will be not higher than 700 ft AMSL.

Based on current expectations and subject to validation following CFD modelling, the plume will have an indicative vertical velocity of 5.2 m/s at 1000 ft AMSL.

Airservices Australia has advised the nominal 6.1 m/s plume at 700 ft AMSL will not affect any sector or circling altitude, nor any instrument approach or departure procedure at Shellharbour Airport.

Consequence

If a larger aircraft suffered a catastrophic structural failure or loss of control, the worst credible effect would be three or more fatalities and damage beyond repair. This would be a Catastrophic consequence.

Consequence	Catastrophic

Untreated Likelihood

Very few smaller aircraft will overfly the power station in the course of normal operations. If they do, it will almost certainly be at 1000 ft AMSL or above, and not climbing or in the approach configuration due to the power station's distance from the runway.

Larger aircraft will fly a wider and/or higher circuit.

Based on Katestone analysis of the unmitigated F Class machine, the plume at 6.1 m/s extends downwind for an average of 94.2 m.

An aircraft flying at 60 kt is travelling at 30.9 m/s, which means it would be in the unmitigated F Class 99.9th percentile 6.1 m/s plume for a maximum of 3.1 seconds.

An aircraft flying at 75 kt is travelling at 38.6 m/s. That would equate to a maximum of 2.4 seconds exposure to that plume.

An aircraft flying at 90 kt is travelling at 46.3 m/s. That would equate to 2.0 seconds of exposure to that plume.

Pilots are taught how to recover from a stall condition during their training. Up to six of the 215 fatal general aviation accidents in the 10-year period 1991-2000 may be relevant to the circumstances. None of the accidents involved flying training. An investigation of the actual circumstances involved in these accidents (which were not disclosed) may reveal a lack of relevance. Factoring the 1991-2000 general aviation fatal accident rate (1.2 fatal accidents per 100,000 hours flown) by this ratio (6/215) derives an average 0.033 general aviation fatal accidents per 100,000 hours flown where weather conditions (other than operating in IMC) were a factor in the accident. This rate can be written as 0.33×10^{-6} per hour flown. It is assessed that a larger aircraft experiencing the effects of a vertical plume suffers an aerodynamic stall or aircraft upset from which its pilot may not be able to recover, or an aircraft suffers a structural failure from which recovery is not possible may occur in exceptional circumstances, which is classified as Rare. Note regarding likelihood: While the data available suggests the likelihood of the nominated consequence is much less than 1 in 100,000, a conservative approach has been taken to assigning the untreated likelihood to enable a numerical appreciation of the benefits of the suggested mitigations.	
Untreated Likelihood	Rare
Current Treatments • Most aircraft will operate at a circuit height of 1000 ft AMSL (1500 ft AMSL for high performance code 2 and 3 aircraft) which is well above the 6.1 m/s plume height (expected to be 5.2 m/s at 1000 ft AMSL). • Aircraft are unlikely to fly over the power station site at heights below 1000 ft AMSL due to the proximity of the 436 ft AMSL mast obstacle on the hill just to the north west of the site.	
Level of Risk The level of risk associated with a Rare likelihood of a Catastrophic consequence is 6.	
Current Level of Risk	6 - High
Risk Decision A risk level of 6 is classified as High risk – needs senior management attention and treatment plan as appropriate.	
Risk Decision	Prepare treatment plan
Proposed Treatments The following treatments, discussed in detail in Section 10 which can be implemented at little cost will provide an additional level of safety: • Alerting through AIP – ERSA, aeronautical charts • Alerting through marking and lighting • Pilot awareness and operating procedures • Shut down on certain high activity days	

• Electronic Flight Bag (EFB) applications	
Likelihood after Treatment	Extremely Rare
Residual Risk With the additional recommended treatments, the likelihood that an aircraft experiencing the effects of a vertical plume suffers an aerodynamic stall or aircraft upset from which its pilot may not be able to recover, or an aircraft suffers a structural failure from which recovery is not possible will be Extremely Rare and the consequence remains Catastrophic, resulting in an overall risk level of 5 – Medium. In the circumstances, the level of risk under the proposed treatment plan is considered as low as reasonably practicable (ALARP).	
Residual Risk	5 - Medium

12. SUMMARY

The intention of this aviation impact assessment is to satisfy the relevant aspect of condition of approval 1.6 relating to impact on aviation safety, in demonstrating an acceptable level of safety for the proposed development, in accordance with the definition of safety as per ICAO DOC 9859, Safety Management Manual (Fourth Ed):

> *The state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level.*

EnergyAustralia is evaluating a number of equipment options with a view to achieving a 6.1 m/s critical plume height below 1000 ft AMSL as directed by CASA and in accordance with guidance published in Advisory Circular 139-05(v 3.0) – *Plume rise assessments*. EnergyAustralia has specified a maximum 6.1 m/s critical plume height of 650 ft AMSL for the equipment being evaluated. A conservative value of 700 ft AMSL has been adopted for the purposes of this impact assessment.

The benchmark velocities selected by CASA to align with the Bureau of Meteorology classifications of turbulence are 6.1m/s for flight on terminal instrument flight procedures (TIFPs) and 10.6m/s for visual flight procedures. This approach protects flight on TIFPs up to the level of 'light turbulence' and protects visual flight procedures up to the level of 'moderate turbulence'.

A plume velocity of 6.1 m/s represents the Bureau of Meteorology's threshold between light and moderate turbulence. Any plume velocity below 6.1 m/s is classified as light turbulence. All aircraft, including light sport aircraft, certified and maintained as airworthy under Australia's regulatory framework should be capable of flight in light turbulence, even if in the approach configuration.

It should also be noted that the Bureau of Meteorology's definition of moderate turbulence expressly notes that the pilot remains in control at all times, in which case, regardless of the actual plume velocity that induces this effect, moderate turbulence should be tolerable for the aircraft in question.

Preliminary advice from EnergyAustralia is that the plume velocity at 1000 ft AMSL over the site for the range of machines under evaluation will be 5.2 m/s (modified F Class) and 5.4 – 5.8 m/s (Aero-derivative).

It is generally accepted that smaller aircraft, and particularly those with a lower wing loading, are more susceptible to the effects of turbulence. RAAus aircraft strongly represent this stakeholder group, although there are a number of VH-registered types with similar aerodynamic properties that will be similarly affected.

A representative 1.0 nm circuit has been demonstrated through technical analysis and stakeholder consultation as conservatively applicable to the aircraft operations of greatest concern. There is little evidence that aircraft must overfly the power station when conducting circuits on runway 16/34, which is used approximately 79% of the time, and if they did, would be unlikely to be below 1000 ft AMSL due to high terrain to the north west of the site. It is acknowledged that there may be occasions when aircraft may have to overfly the site (at or above 1000 ft AMSL) to avoid conflicting with other traffic in the circuit or on departure.

The power station is located outside the horizontal extent of the OLS applicable to these smaller aircraft, and beyond the dimensions of a circuit pattern generally applicable to their operations, which is mostly flown at 1000 ft AMSL, although lower circuits are sometimes flown to achieve training requirements.

Analysis of FlightAware tracking data revealed that approximately 1.6% of aircraft that were tracked over a two-year period flew through an indicative plume volume to 1050 ft AMSL over the site. These flights were conducted in the absence of any alerting to the potential plume hazard under consideration.

The current code 2 instrument non-precision OLS is extensively penetrated by terrain (including the hill with mast on it just to the north west of the power station site) and numerous trees as published in En Route Supplement Australia. The nominal exhaust plume would penetrate the conical surface of the current OLS.

Limitations associated with the current airport site and surrounding obstacles including terrain will prevent the airport from achieving compliance with current and future code 3 requirements related to runway strip width and obstacle limitation surfaces, among others. These limitations are more significant impediments to increasing the airport's scope of operations than Tallawarra B power station's exhaust plume.

Current terminal instrument flight procedures will not be impacted by the exhaust plume with characteristics as proposed.

The primary risk being assessed is that an aircraft experiencing the effects of a vertical plume could suffer an aerodynamic stall or aircraft upset from which its pilot may not be able to recover. Alternatively, the aircraft may suffer a structural failure from which recovery is not possible. The level of risk has been assessed according to the consequences applicable to two distinct aircraft operations – those by recreational type aircraft with up to two seats operating during the day under visual flight rules, and larger aircraft. It should be noted that the lowest possible level of risk for the smaller aircraft for the worst credible consequence (Severe) is 4 (Medium Risk), and for the larger aircraft, based on a Catastrophic consequence is 5 (Medium Risk).

For the smaller aircraft, with the additional recommended treatments, the likelihood that an aircraft experiencing the effects of a vertical plume suffers an aerodynamic stall or aircraft upset from which its pilot may not be able to recover, or an aircraft suffers a structural failure from which recovery is not possible will be Extremely Rare and the consequence remains Severe, resulting in an overall risk level of 4 – Medium. For the larger aircraft, with the additional recommended treatments, the likelihood will be Extremely Rare and the consequence remains Catastrophic, resulting in an overall risk level of 5 – Medium.

In the circumstances, the level of risk under the proposed treatment plan is considered as low as reasonably practicable (ALARP).

The likelihood of a catastrophic failure or loss of control leading to a fatal accident, if an aircraft flies through an area of moderate turbulence associated with the exhaust plume with characteristics as proposed, is well below the threshold for the lowest practicable risk in CASA's risk matrix (1:100,000) and therefore the level of risk is acceptable.

13. CONCLUSION

In light of the foregoing assessment, with plume characteristics as proposed, specifically a critical plume velocity of 6.1 m/s at or below 700 ft AMSL, Aviation Projects has concluded that there will be an acceptable level of aviation safety risk associated with the Tallawarra B OCGT, reduced to as low as reasonably practicable if the mitigations proposed herein are implemented.

14. RECOMMENDATIONS

As a result of this assessment, it is recommended that the mitigations proposed in Section 10 are implemented.

ANNEXURE 1 - KATESTONE ANALYSIS

Find following this page a copy of the Katestone report –

- Tallawarra B Power Station - Plume Rise Assessment Report, February 2020

Tallawarra B Power Station - Plume Rise Assessment Report

Prepared for:

EnergyAustralia

February 2020

Final

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Document Control

Deliverable #:	D19025-23
Title:	Tallawarra B Power Station - Plume Rise Assessment Report
Version:	1.1 (Final)
Client:	EnergyAustralia
Document reference:	D19025-23 Tallawarra B Power Station - Plume Rise Study for Aviation Assessment_v1.1_Final.docx
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Approved by:	Natalie Shaw
	 13/02/2020

Disclaimer

https://katestone.global/report-disclaimer/

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Glossary

Term	Definition
$\mu g/m^3$	micrograms per cubic metre
°C	degrees Celsius
km	kilometre
km/h	kilometre per hour
m	metre
m/s	metres per second
m^2	square metres
m^3	cubic metres
m^3/s	cubic metres per second
Abbreviations	**Definition**
AC	Advisory Circular
AHD	Australian Height Datum
CASA	Australian Government Civil Aviation Safety Authority
Critical Plume Height	The height at which the average in-plume vertical velocity is less than 4.3 m/s, 6.1 m/s or 10.6 m/s
EA	EnergyAustralia
TAPM	The Air Pollution Model

EXECUTIVE SUMMARY

Katestone Environmental Pty Ltd (Katestone) has been commissioned by EnergyAustralia, to undertake a plume rise assessment of the Tallawarra B Power Station, a proposed 300-400 MW open cycle gas turbine power station to be located to the south of Wollongong in NSW. Large exhaust plumes have the potential to impact aviation operations near operations and require plume rise assessments to be completed.

This plume rise assessment has been conducted to determine the impact of the exhaust plume from the Tallawarra B Power Station by using a plume rise model to determine plume heights. The critical plume height assessment criteria for the Tallawarra B Power Station has been set by the Australian Civil Aviation Safety Authority's (CASA) at 1,000 ft for a 6.1 m/s critical plume velocity.

The plume rise modelling shows that the Tallawarra B Power Station can achieve the CASA 1,000 ft target height for the 6.1 m/s critical plume velocity with either an F Class turbine fitted with a stack top diffuser or by using smaller aeroderivative engines. The F Class turbine with a stack top plume diffuser is the preferred option for Tallawarra B Power Station.

The stack top plume diffuser device is installed on top of the vertical stack and divides it into a number of smaller stacks, of equal area, that are angled away from the vertical and each other. Plume modelling of the stack top diffuser shows that the plume height for the 6.1 m/s critical plume velocity is 580 ft, below the CASA target height of 1,000 ft. The critical plume velocity for the Tallawarra B Power Station stack with the stack top diffuser device at 1,000 ft is 5.2 m/s.

1. INTRODUCTION

Katestone Environmental Pty Ltd (Katestone) has been commissioned by EnergyAustralia, to undertake a plume rise assessment of the Tallawarra B Power Station, a proposed 300 - 400 MW open cycle gas turbine power station to be located to the south of Wollongong in NSW.

The site of the proposed Tallawarra B Power Station is on land adjacent to EnergyAustralia's existing Tallawarra A Power Station, which is approximately 4.5 km northeast of Illawarra Regional Airport (Shellharbour Airport), as shown in Figure 1.

The Australian Civil Aviation Safety Authority (CASA) requires assessment of the potential hazard to aviation posed by vertical industrial exhaust plumes in proximity to airports. Plume rise assessments are required to be conducted in accordance with CASA's Advisory Circular (AC) 139-05v3.0 *Plume rise assessments* (CASA, 2019).

The AC applies to:

- *Proponents of facilities generating a gas efflux or exhaust plume that may have a vertical exit velocity exceeding 6.1 metres per second (m/s)*
- *Aerodrome operators*
- *The Civil Aviation Safety Authority (CASA).*

The purpose of the AC is to provide:

- *guidance to persons involved in the design, construction and operation of facilities with vertical exhaust plumes about the information required to assess the potential hazard from a plume to aircraft operations*
- *a standard method of determining the critical plume height of a vertical exhaust plume so that impacts of a plume near aerodromes and away from aerodromes can be assessed in a consistent and reliable way*
- *guidance to proponents and stakeholders on the plume rise assessment process.*

Accordingly, Katestone has prepared a plume rise assessment of the Tallawarra B Power Station. The objective of the plume rise assessment is to determine the potential height and extent of the proposed Tallawarra B Power Station exhaust plume to assist with the determination of risk to aviation using Shellharbour Airport.

Figure 1 **Location of Tallawarra Power Station and Shellharbour Airport**

2. STUDY METHODOLOGY

2.1 Background

Potential hazards that could affect the safety of aircraft include tall visible or invisible obstructions. Visible obstructions include structures such as tall stacks or communication towers. Invisible obstructions include vertical industrial exhaust plumes that are of high velocity and buoyancy.

Industrial facilities are primarily designed to ensure that exhaust plumes released from the facility adequately disperse in the atmosphere and do not result in high concentrations of exhaust gases at ground-level. Typically, industrial facilities release exhaust gases vertically into the atmosphere from stacks. The higher the flow and temperature of the release, the more buoyant the exhaust plume and the higher it can rise. Whilst this will lead to better dispersion of exhaust gases in the atmosphere prior to reaching ground-level, it also results in invisible exhaust plumes that have a potential to affect aviation when located in proximity to airports.

2.2 Advisory Circular 139-5(3)

To assess the potential hazard to aviation from industrial exhaust plumes, CASA developed AC 139-5(3) *Plume Rise Assessments* (CASA, 2019). The AC details a methodology for a plume rise assessment. In particular, it requires proponents of a facility that generates vertical plumes with vertical velocities greater than 6.1 metres per second to provide details to CASA via completion of Form 1247 (*Application for Operational Assessment of a Proposed Plume Rise)*.

Previous versions of the AC (2004 and 2012) used a vertical velocity threshold of 4.3 m/s. Whereas, AC 139-5(3) applies a vertical velocity threshold of 6.1 m/s.

Form 1247 collects information about a vertical plume that CASA uses to determine the risk posed by the plume velocity for aircraft utilising nearby aerodromes and flight paths. Mitigation measures may be required to reduce the potential risk posed to aviation activities.

CASA makes an assessment of the critical plume height by use of its screening tool. If the information provided by the proponent in Form 1247 does not fall within the parameters suitable for use in the screening tool, or the situation is too complex with multiple stacks with vertical plumes, CASA will request that the proponent undertakes a detailed plume rise assessment. CASA does not provide the screening tool for external use.

EnergyAustralia has received correspondence from CASA that the critical plume height for Tallawarra B should not exceed 1,000 ft for the 6.1 m/s critical plume velocity. This is the target value considered in this assessment.

2.3 Plume Rise Assessment Method

2.3.1 Overview of plume models

There are a variety of methods that have been developed for determining the behaviour of a plume or plumes as they rise through the atmosphere. The physics of plume evolution is complex and the governing equations (even in their simplest forms) cannot be solved as they do not form a closed system. In order to arrive at a system of equations that can be solved, either by analytical or numerical methods, assumptions are required to reduce the number of variables. The set of equations which describe plume evolution are known as “plume rise models”. Different assumptions result in different plume rise models.

Plume rise models have been developed by Glendening (1984), Spillane (1980), Ooms (1981) and Shatzmann (1978). A modified set of Glendening’s plume rise model equations is used in the TAPM model.

Validation studies of plume rise models have been carried out and reported in the literature. The results of one comprehensive study can be found in the MITRE report (Gouldey et. Al, 2012). Overall, it found the Spillane and TAPM models perform favourably for single and multiple plumes when compared to observations.

An alternative approach to using plume rise models is to use Computational Fluid Dynamics (CFD) modelling. In a CDF model the spatial domain of interest is subdivided into a 3-dimensional grid or mesh and differential equations (resulting from the application of conservation of momentum, mass, energy and vorticity) are numerically solved at each grid node.

CFD models, similar to plume rise models, require a number of assumptions to close the system so that a tractable set of equations result. The CFD approach is particularly useful for modelling small scale flows around obstacles such as buildings and stacks.

2.3.2 Tallawarra B Plume Rise Methodology

To assist EnergyAustralia to characterise the vertical plume(s) associated with potential gas turbine configurations of Tallawarra B Power Station, Katestone has undertaken plume rise modelling following the methodology detailed in the AC. That is, plume rise modelling has been conducted for five consecutive years of hourly simulated meteorological conditions using The Air Pollution Model (TAPM) (Version 4).

TAPM was used to model the exhaust plume of the Tallawarra B Power Station to determine the plume height, vertical velocity and horizontal extent downwind after discharge over five years of hourly meteorological conditions. This provides an assessment of the plume heights against meteorological conditions experienced at the site. Other plume models do not have the ability to consider a three-dimensional wind field and are usually run using a calm wind scenario. Whilst this might be a worst-case, it is not representative of conditions at site.

The TAPM plume rise data was then statistically analysed, and a range of hourly percentiles of plume height, vertical velocity and downwind distance were determined. The AC requires the assessment of plume conditions to be conducted using the 99.9th percentile statistic of hourly TAPM model results.

To ensure that the TAPM model adequately predicts the meteorological conditions at the site, the meteorological conditions that have been simulated using TAPM were compared to measurements of wind speed, wind direction and temperature collected by the Bureau of Meteorology's automatic weather station at Albion Park (Shellharbour Airport). The comparison is presented in Section 3.

Additional plume modelling of the proposed Tallawarra B Power Station configuration was required to describe the exhaust plume generated by the proposed stack top diffuser device as it cannot be undertaken in TAPM due to the complexity of the exhaust release. The additional plume modelling was conducted by a third party using an adapted plume rise model from the Spillane set of equations and has been described by Katestone in Section 6.

2.3.3 TAPM configuration

For the TAPM modelling component of the work, five continuous years of meteorological conditions have been modelled in accordance with the AC. The five continuous years are 2014 to 2018.

The TAPM input parameters and settings were as follows:

- Mother domain of 30 km resolution with 3 nested daughter grids of 10 km, 3 km and 1 km resolutions
- 30 x 30 grid points for all four modelling domains resulting in a 30 x 30 km grid at 1 km resolution
- 25 vertical levels; from the surface up to an altitude of 8000 metres above ground level
- The four domains were all centred at a location close to the Tallawarra B Power Station location, with the centre having latitude 34°31.5' and longitude 150°47'.

- Default TAPM terrain data
- The default TAPM land use data was edited based on aerial photography to match current land use in the region
- Default databases for synoptic analyses and sea surface temperature were used
- Default options selected for advanced meteorological inputs
- TAPM was run for five continuous years beginning on 1 January 2014.

3. METEOROLOGICAL ANALYSIS

3.1 BoM Albion Park

The closest automatic weather station to the Tallawarra B Power Station is operated by the BoM at Albion Park, adjacent to Shellharbour Airport. The meteorological station is approximately 4.5km to the south-southwest of the proposes power station. Hourly average wind speed, wind direction and ambient temperature data from the Albion Park meteorological station was purchased from the BoM covering the period of TAPM modelling.

Wind roses of the BoM Albion Park data for 2014 to 2018 are shown in Figure 2 and a summary of the data is presented in Table 1. The wind roses show predominantly westerly winds (west-southwest to west-northwest) with winds occasionally from the northeast. Wind speeds are also strongest from the west (west-southwest to west-northwest) and south.

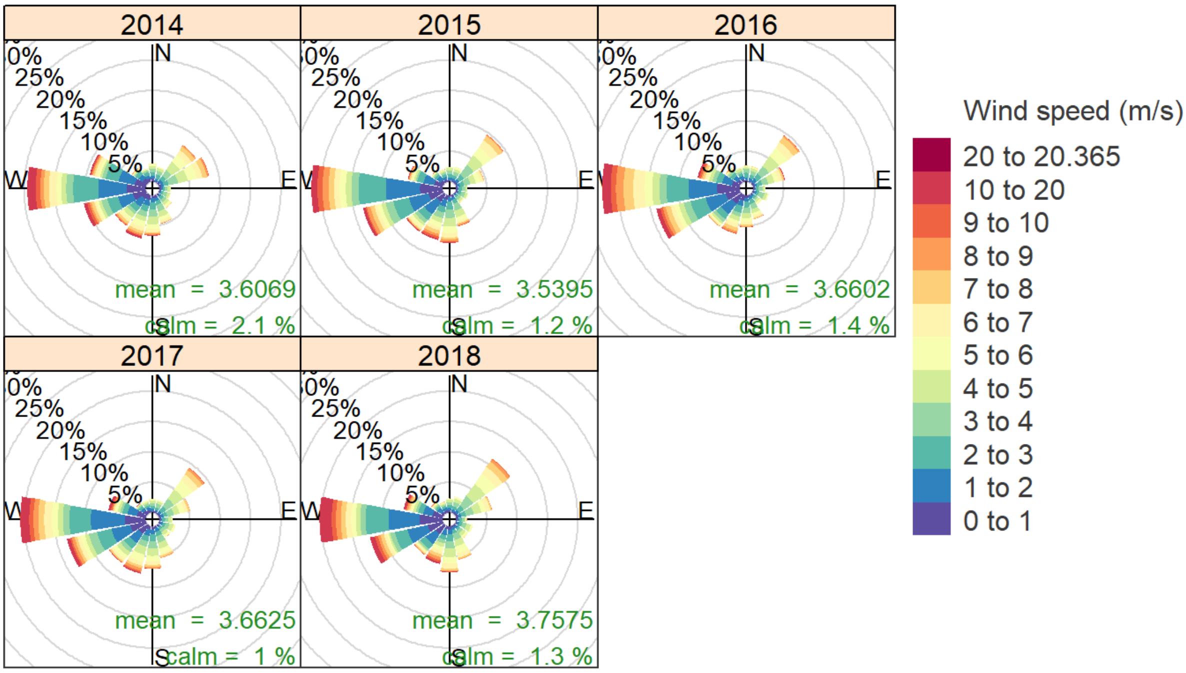

Figure 2 **Annual wind roses at Bom Albion Park from 2014- 2018**

Table 1 **Summary of BoM Albion Park hourly average data from 2014 - 2018**

Parameter	Year				
	2014	2015	2016	2017	2018
Mean wind speed (m/s)	3.61	3.54	3.66	3.66	3.74
Median wind speed (m/s)	2.99	2.94	3.03	3.15	3.06
Maximum wind speed (m/s)	20.36	15.89	17.12	17.12	16.85
Mean temperature (°C)	17.10	16.86	17.56	17.17	16.63
Minimum temperature (°C)	-0.27	0.57	1.06	0.26	-0.44
Maximum temperature (°C)	34.14	41.41	38.42	39.50	40.72
Mean relative humidity (%)	75.22	76.43	72.66	72.93	73.07
Minimum relative humidity (%)	14.58	10.60	14.13	10.83	9.28
Maximum relative humidity (%)	100.00	100.00	100.00	100.00	100.00

3.2 TAPM

Five consecutive years of hourly meteorological data was simulated using the TAPM model. Data was extracted from the model simulation at a point indicative of the BoM Albion Park meteorological station.

Wind roses have been constructed using the TAPM data for the 2014 to 2018 period and these are shown in Figure 3 and a summary of the data is presented in Table 2. The wind roses are similar to those constructed from the Albion Park data, showing predominant wind from the west (west-southwest to west-northwest)) as well as from the northeast. Wind speeds are also strongest when winds occur from the west (west-southwest to west-northwest).

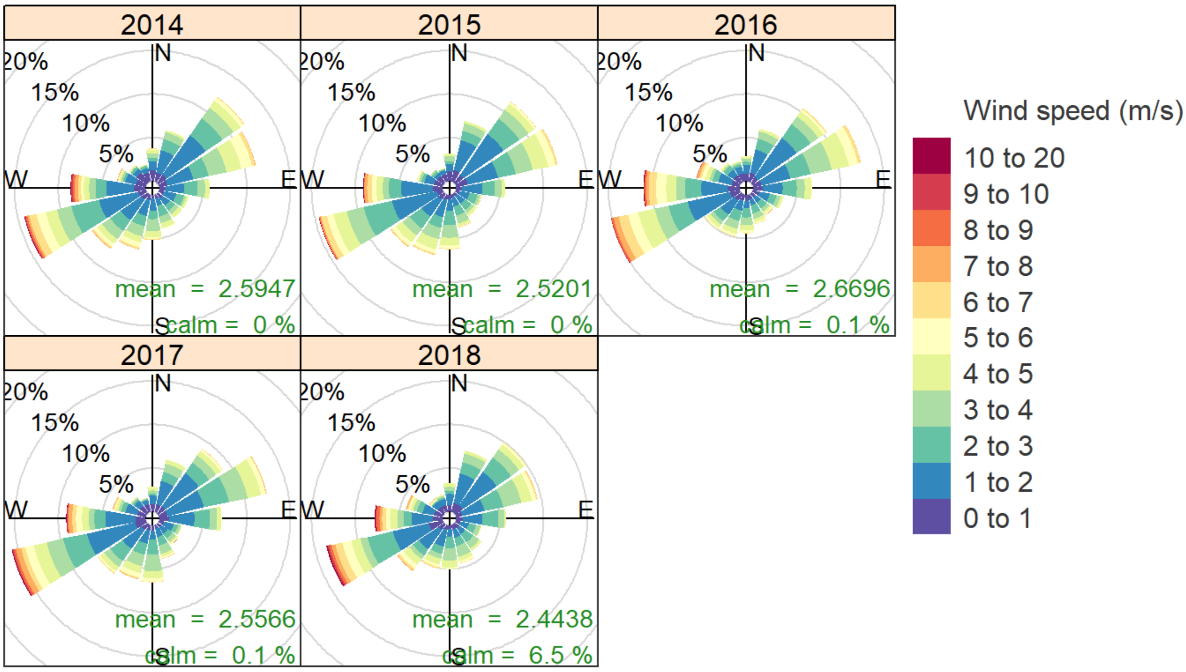

Figure 3 Annual wind roses extracted from TAPM for 2014 - 2018

Table 2 Summary of TAPM hourly average data from 2014 - 2018

Parameter	Year				
	2014	2015	2016	2017	2018
Mean wind speed (m/s)	2.59	2.51	2.66	2.58	2.63
Median wind speed (m/s)	2.10	2.10	2.10	2.10	2.10
Maximum wind speed (m/s)	10.50	11.60	11.10	11.70	12.30
Mean temperature (°C)	18.37	17.95	18.62	18.22	17.97
Minimum temperature (°C)	7.10	5.70	6.60	7.20	6.40
Maximum temperature (°C)	39.40	37.00	37.30	38.80	38.10
Mean relative humidity (%)	68.52	68.90	65.59	67.26	67.51
Minimum relative humidity (%)	14.10	8.50	11.70	9.90	17.10
Maximum relative humidity (%)	99.80	100.00	100.00	100.00	100.00

3.3 BoM vs TAPM Comparison

Data from the BoM Albion Park meteorological station have been compared to the data extracted from the TAPM meteorological model for the period from 2014 to 2018. Various statistical measures have been used to compare the measurements and modelled data, as follows:

- Statistical tests have been applied to compare BoM Albion Park observations against the TAPM simulations. Key tests include:
  - Index of Agreement (IOA) – IOA takes the value between 0 and 1, with 1 indicating perfect agreement. IOA is the ratio of the total root mean square error (RMSE) to the sum of two differences, i.e. the difference between each TAPM prediction and the observed mean, and the difference between each observation and observed mean. An IOA greater than 0.7 indicates good performance of the model in simulating observations.
  - Skill measures (SE, SV and SR) – Skill measure statistics are given in terms of a score, rather than in absolute terms. A model's skill can be measured by the difference in the standard deviation of the modelled and observed values.
    - Skill_E (SE) is indicative of how much of the standard deviation in the observations is predicted to be due to random/natural processes (unsystematic) in the atmospheric boundary layer. i.e., turbulence/chaos. For good model performance, the value for SE should be less than one.

- Skill_V (SV) is ratio of the standard deviation of the model predictions to the standard deviation of the observations. For good model performance, the value for SV should be close to one.

- Skill_R (SR) takes into account systematic and unsystematic errors in relation to the observed standard deviation. For good model performance, the value for SE should be less than one.Frequency distributions of wind speed (Figure 4), U and V components of wind direction (Figure 5 and Figure 6) and temperature (Figure 7) are shown for the BoM Albion Park observations and the TAPM predictions for each modelled year (2014-2018)

The statistical test results are shown in Table 3 and shows the following:

- IOA values are greater than 0.7 for wind speed, U and V wind components and temperature indicating the model performs adequality in simulating observations
- Skill values indicate good model performance for wind speed, U and V wind components and temperature

The wind speed distribution figures show that TAPM slightly overpredicts the frequency of lighter winds and slightly underpredicts the frequency of strong winds compared to the observations. The U and V wind components and the temperature show good agreement between modelled and observed values.

Table 3 Statistical tests for TAPM model performance evaluation against BoM Albion Park observations from 2014 – 2018

Statistic Test	Wind Speed	U Wind Component	V Wind Component	Temperature	Target
IOA	0.75	0.83	0.83	0.92	0.7
SE	0.44	0.45	0.44	0.40	<1
SV	0.62	0.70	0.68	0.87	1
SR	0.81	0.68	0.66	0.51	<1
RMSE	2.18	2.39	1.76	2.84	-

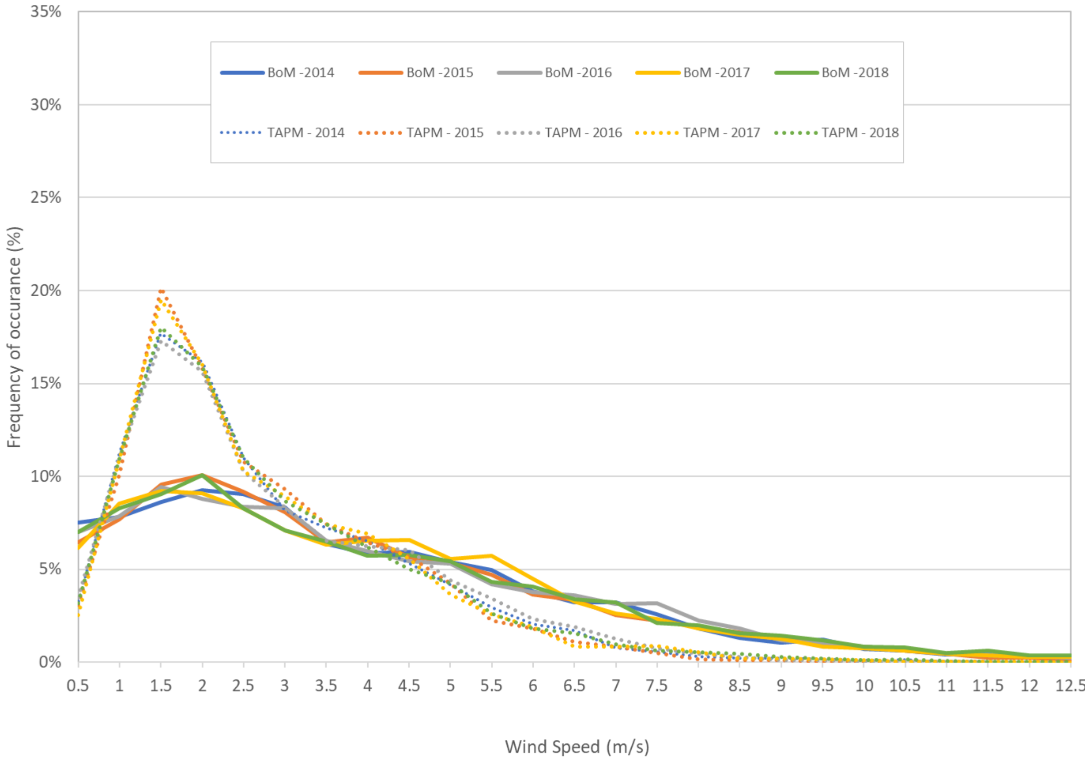

Figure 4 Frequency distribution of wind speed at BoM Albion Park versus TAPM for 2014 - 2018

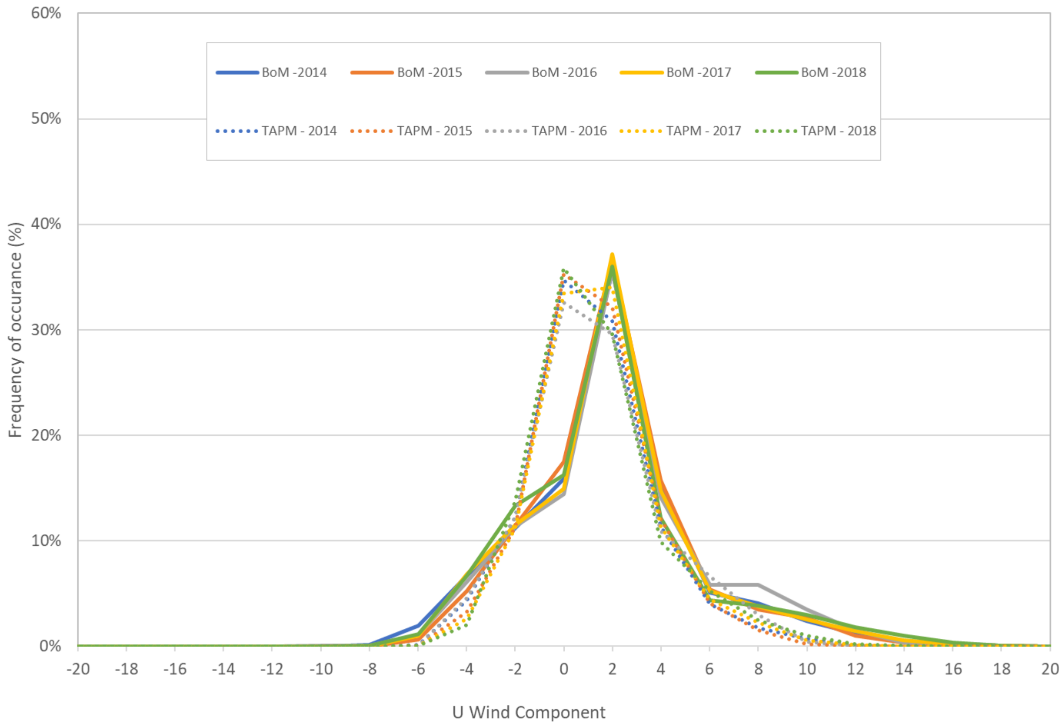

Figure 5 Frequency distribution of U component of winds at BoM Albion Park versus TAPM for 2014 - 2018

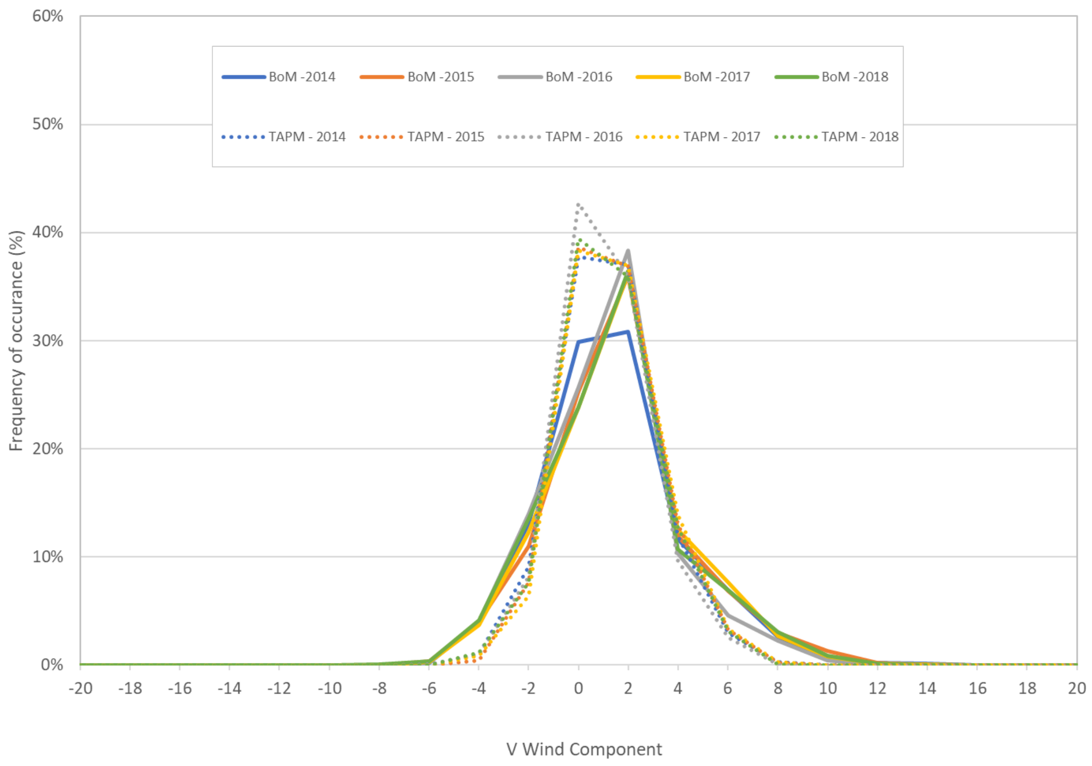

Figure 6 Frequency distribution of V component of winds at BoM Albion Park versus TAPM for 2014 - 2018

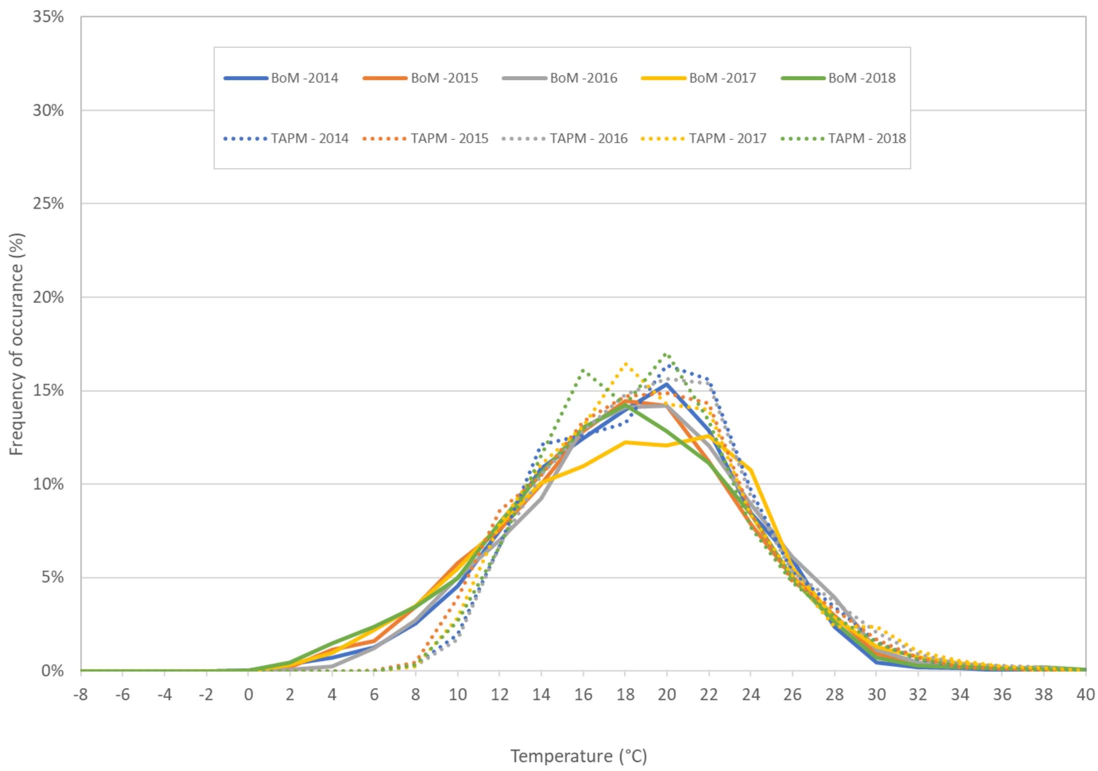

Figure 7 Frequency distribution of temperature at BoM Albion Park versus TAPM for 2014 – 2018

4. MODELLING INPUTS

The preferred option for the proposed Tallawarra B Power Station is an F Class gas turbine. Stack characteristics and release parameters for a typical F Class gas turbine are detailed in Table 4. These characteristics have been used as inputs in the plume rise modelling.

Table 4 Stack characteristics and exhaust release parameters for a typical F Class unit

Parameter	Units	Typical F Class unit
Stack X coordinate	m (UTM, Z56, S)	298,895
Stack Y coordinate	m (UTM, Z56, S)	9,177,812
Nominal plant capacity	MW	350
Stack height (above grade)	m	46.05
Number of stacks	#	1
Stack diameter	m	6.75
Exit velocity	m/s	52.55
Exit temperature	°C	643
Volume flow (actual)	m^3/s	1,853
Hours of operation (per year)	#	8760

5. UNMITIGATED PLUME RISE RESULTS

A summary of the 99.9th percentile critical plume heights and extents for typical F Class turbines (unmitigated) from the TAPM modelling are shown in Table 5 and Table 6. Table 5 also shows the maximum plume heights for reference.

The target critical plume height identified by CASA is 1,000 ft for the critical plume velocity of 6.1 m/s (assessed against the 6.1 m/s critical threshold velocity). The modelling shows plume heights that are above the 1,000 ft target critical plume height. Accordingly, to achieve better than the 1,000 ft target plume height, further design was conducted that included mitigation measures. The plume modelling results for this are discussed in detail in Section 6.

Table 5 Summary of critical plume heights for a typical F Class configuration (unmitigated design)

Percentile	Critical threshold velocity	Critical Plume Height (feet above ground level)				
		2014	2015	2016	2017	2018
99.9th	4.3 m/s	2,076	2,304	2,211	2,169	2,227
	6.1 m/s	1,364	1,303	1,421	1,306	1,309
	10.6 m/s	411	382	414	414	414
Maximum	4.3 m/s	2400	2644	2798	2698	2714
	6.1 m/s	1601	1726	1745	1951	1582
	10.6 m/s	1601	1726	1745	1951	1582

Table 6 Summary of critical plume extents for a typical F Class configuration (unmitigated design)

Percentile	Critical threshold velocity	Critical Plume Extent (downwind distance in metres)				
		2014	2015	2016	2017	2018
99.9th	4.3 m/s	209.6	215.6	206.1	212.8	214.8
	6.1 m/s	92.0	93.2	97.3	96.2	92.5
	10.6 m/s	24.6	22.7	22.4	22.4	22.4

6. MITIGATED PLUME RISE RESULTS

Mitigation measures that result in achieving better than the 1,000 ft target critical plume height for Tallawarra B Power Station include a stack top plume diffuser or use of alternative engine types.

Plume rise modelling results for each of these mitigation measures are provided in the following sections. It should be noted that two different plume rise models have been used but both provide a conservative assessment of plumes generated by the Tallawarra B Power Station.

6.1 Stack Top Plume Diffuser

A stack top plume diffuser is proposed for the Tallawarra B Power Station F Class turbine. EnergyAustralia is currently in the middle of a tender process with a number of bidders to supply the F Class gas turbine (and diffuser) on an Engineer/Procure/Construct (EPC) basis, so has an obligation to ensure that no confidential information that might favour any one bidder over another is released during the tender process.

Notwithstanding this, details on the plume heights from a stack top diffuser device have been provided by one of the EPC bidders using a conservative plume rise model and is described in the following paragraphs.

The diffuser device is installed on top of the vertical stack and divides it into a number of smaller stacks, of equal area, that are angled away from the vertical and each other. Plume modelling has been undertaking using the Spillane plume model for both an unmitigated F Class turbine case and with the stack top diffuser as the TAPM model cannot replicate the release from the stack top diffuser. The following methodology was adopted:

- Calm wind conditions assumed in Spillane model to generate worst case plume heights
- Adaptation of Spillane plume merging equation that considers plumes are merged where they first touch rather than when they cross the centreline of adjacent plumes (see Figure 8 below). This is conservative as plumes would merge sooner.
- To deal with angled stacks (Spillane requires a vertical stack) it was assumed each plume travels on the same angled trajectory until the plume changes from a turbulent jet to a buoyant plume, defined as where the momentum forces and buoyancy forces are equal.

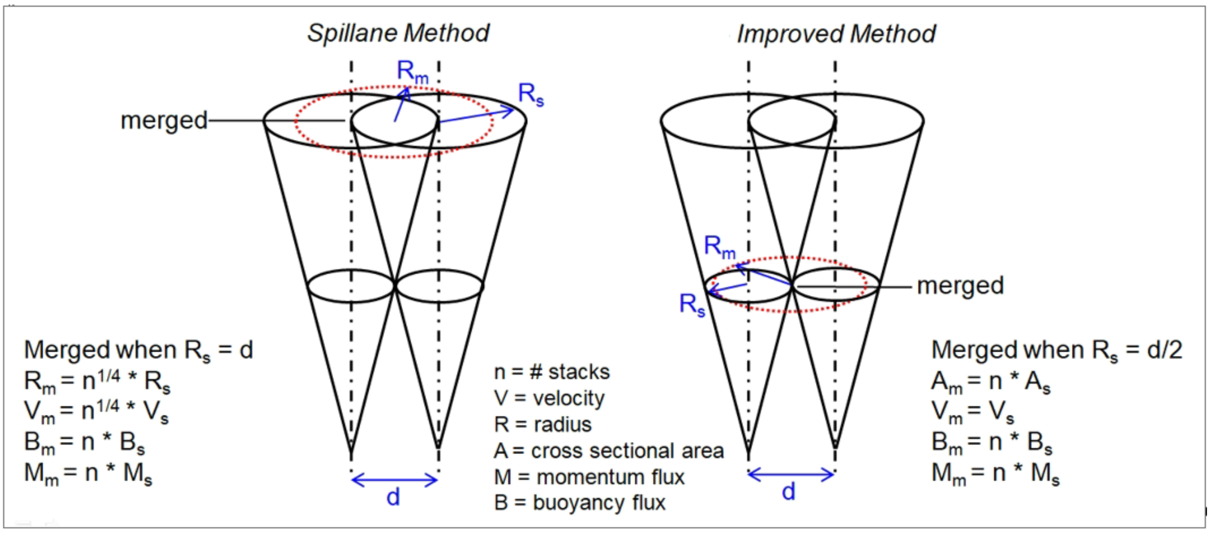

Figure 8 Adaptation of Spillane plume merging equations

The results of the Spillane plume modelling for the unmitigated F Class turbine (red line) and with the stack top diffuser (blue line) are shown graphically in Figure 9 and in Table 7 for the 4.3, 6.1 and 10.6 m/s critical threshold velocities.

The results show the following:

- Plume heights for the 6.1 m/s critical plume velocity reduce to about one third of the height attained without the diffuser (Figure 9 and Table 7), as follows:
    - Unmitigated F Class (red line) – 1,980 ft
    - Stack top diffuser (blue line) – 580 ft
- Accordingly, the CASA target height of 1,000 ft for the 6.1 m/s plume velocity is achieved by the stack top diffuser plume.
- The plume velocity from the stack top diffuser device at various heights (blue line on Figure 9) are:
    - At 1,000 ft the critical plume velocity is 5.2 m/s
    - At 1,200 ft the critical plume velocity is 5.1 m/s
    - At 1,500 ft the critical plume velocity is 4.9 m/s

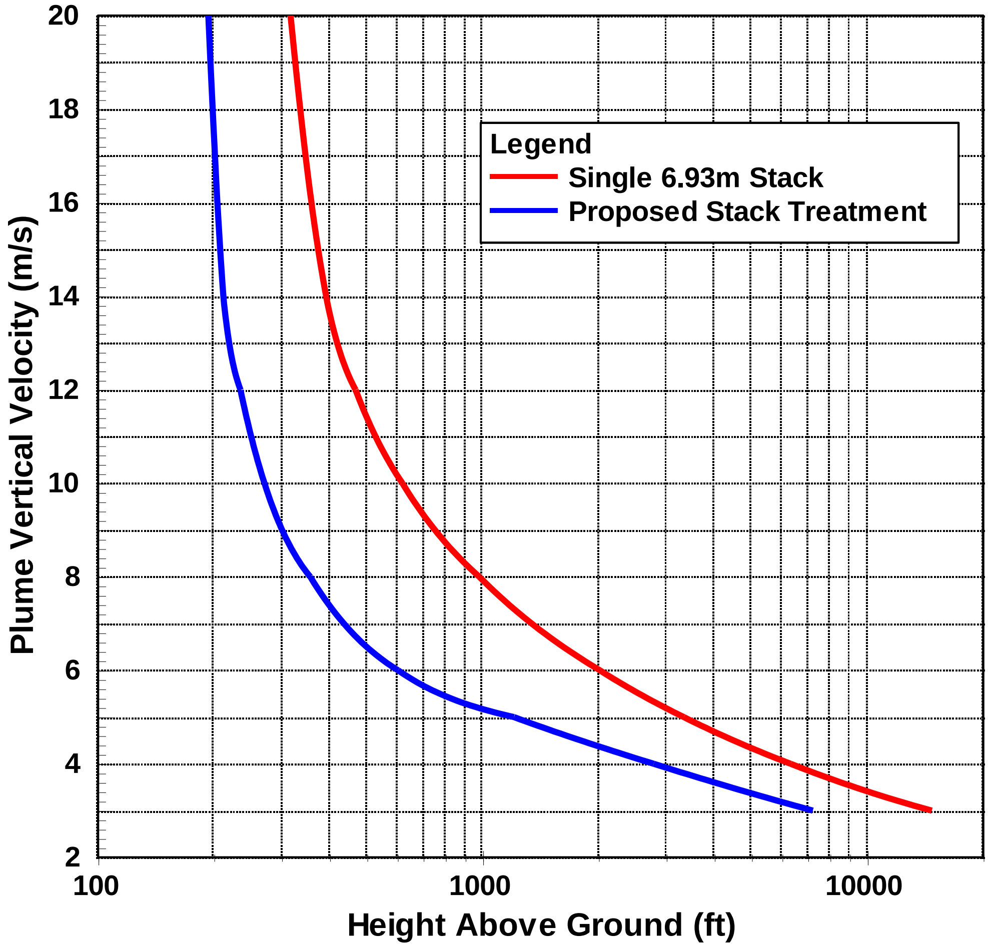

Figure 9 **Predicted plume vertical velocity vs height above ground for the unmitigated F Class stack (red line) and the proposed stack top diffuser (blue line) using the Spillane plume model**

Table 7 **Summary of critical plume heights from the stack top plume device using the Spillane plume model**

Critical threshold velocity	Critical Plume Height (feet above ground level)	
	Unmitigated F Class turbine (red line)	Stack top diffuser (blue line)
4.3 m/s	5,400	2,200
6.1 m/s	1,980	580
10.6 m/s	550	275

6.2 Aeroderivative Engines

A secondary option for the Tallawarra B Power Station that can achieve the CASA 1,000 ft plume height is to use aeroderivative engines that are smaller in size, both in output and exhaust plume, than a typical F Class turbine. Katestone has investigated a number of aeroderivative engine configurations at the Tallawarra B Power Station site following the TAPM plume modelling methodology described previously.

The results of the TAPM plume modelling for a range of aeroderivative engines (including different suppliers) are detailed in Table 8 and Table 9.

The results show the following:

- 99.9^{th} percentile plume heights for the 6.1 m/s critical plume velocity range from 340 ft – 420 ft and well below the 1,000 ft target height.
- The plume velocities from the aeroderivative engines at various heights are
    - At 1,000 ft the critical plume velocities range from 5.4 – 5.8 m/s
    - At 1,200 ft the critical plume velocities range from 4.8 – 5.6 m/s
    - At 1,500 ft the critical plume velocities range from 4.1 -4.8 m/s.

Table 8 **Summary of critical plume heights for a range of aeroderivative configurations at Tallawarra B Power Station**

Percentile	Critical threshold velocity	Critical Plume Height (feet above ground level)
99.9^{th}	4.3 m/s	1,300 – 1,650
	6.1 m/s	340 - 420
	10.6 m/s	180 - 190

Table 9 **Summary of plume velocity for a range of aeroderivative configurations at Tallawarra B Power Station**

Plume Height (ft)	Plume Velocity (m/s)
1,000	5.4 – 5.8
1,200	4.8 – 5.6
1,500	4.1 – 4.8

7. REFERENCES

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