Level 1 Air Quality Impact Assessment

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Crowley Engineering Pty Ltd
PO22-00125

Project Caymus Bulk Fuel Storage Facility
11 August 2022

Level 1 Air Quality Impact Assessment

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Executive summary

Crowley engaged Jacobs to undertake a 'Level 1' (screening level) air quality impact assessment for the Project Caymus Bulk Fuel Storage Facility (BFSF) as a condition of the Northern Territory Government Environmental Approval Number EP2021/008–001 (NTG, 2021). The relevant Environmental Conditions were (quote):*11.c Within 20 business days after the commencement of construction of the action, complete:*

> *(i) a Level 1 air quality impact assessment (AQIA) of the operational design of the action; and*
>
> *(ii) if required following completion of the Level 1 assessment, a Level 2 (refined dispersion modelling) AQIA for operation of the action.*

The NSW Environment Protection Authority *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (NSW 2016) sets out two levels of AQIA: Level 1 is a screening-level dispersion modelling technique using worst-case input data including the use of synthetic meteorological data covering a wide range of hypothetical meteorological conditions. The AQIA was undertaken in accordance with NSW (2016); a compliance checklist is provided in Appendix D.

The worst-case BFSF operation was determined by 'TANKS' modelling of air emissions of hydrocarbon vapours, (Volatile Organic Compounds or 'VOCs'), due to fuel-loading of four floating-roof F-35 (AVTUR) tanks and seven fixed-roof F-44 (AVCAT) tanks. The worst-case air emissions scenario was determined to be loading the fixed-roof tanks at the maximum fuel-loading rate, an equipment limitation on East Arm Wharf.

A synthetic meteorological data file was created in accordance with the Level 1 assessment requirements of NSW (2016) and used for this assessment. Additionally, sensitivity tests were conducted with other meteorological datasets; e.g., (1) an annual dataset based on hourly average meteorological observations at Darwin Airport; and (2) Ausplume's own screening-test meteorological file ('met-sample'). The Ausplume results were very similar regardless of the meteorological data used.

Ausplume was selected for the Project Caymus Level 1 'screening level' assessment; the model is specified for use in NSW (2016). Ausplume modelling was completed for 10,201 grid receptors with horizontal resolution 100 metres giving a study grid area of 14 km east-west by 10 km north-south, centred on the Project Caymus site location in East Arm District.

The NSW (2016) VOCs were assessed by comparisons of the Ausplume-predicted maximum Ground Level Concentrations (GLC) of individual toxic VOCs with relevant NSW (2016) Impact Assessment Criteria (IAC) applied at and beyond site boundaries; i.e., at all 10,201 grid receptor locations. The results for the highest maximum 1-hour average GLC for the toxic VOCs was benzene:

- benzene 1.9 $\mu g/m^3$ (6.5% of IAC - 29 $\mu g/m^3$)

The NSW (2016) odorous VOCs were assessed by comparisons of the Ausplume-predicted maximum GLCs with IAC applied at existing or future sensitive receptor locations – ten discrete (sensitive) receptor locations. The results for the highest maximum 1-hour average GLCs for the odorous VOCs was for cumene:

- cumene 0.6 $\mu g/m^3$ (2.7% of IAC - 21 $\mu g/m^3$)

All the Ausplume results were less than 7% of their IAC – none of the thousands of Ausplume results obtained for Project Caymus operations exceeded NSW impact assessment criteria.

In conclusion, the results indicate there is a low risk of air quality impact on and around East Arm Wharf and anywhere else in the Darwin region due to operations by Project Caymus.

It is not recommended to proceed to a Level 2 assessment as prescribed in NSW (2016) for these reasons:

- NSW EPA (2016) Section 2.1 states – "*It is not intended that an assessment should routinely progress through the two levels... if a Level 1 assessment conclusively demonstrates that adverse impacts will not occur, there is no need to progress to Level 2*". There were no Ausplume-predicted exceedences of NSW impact assessment criteria at any receptor. Further, all the Ausplume results were less than 7% of IAC.
- Further, the BFSF loading operation will be a unique event, occurring once to fill the fuel farm. Essentially the fuel farm will serve as a storage facility.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs was to provide an air quality assessment for Crowley in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report.

Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs's Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

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Acronyms and abbreviations

AG	Australian Government
AQIA	Air Quality Impact Assessment
BBL	Barrel – oil volume unit equivalent to 42 USG ('BBL' origin is 'blue barrel')
BFSF	Bulk Fuel Storage Facility
Crowley	Crowley Australia Pty Ltd
EPA Victoria	Environment Protection Authority Victoria
FSII	Fuel System Icing Inhibitor
GLC	Ground Level Concentration (from model results, for comparison with IAC)
IAC	Impact Assessment Criteria (NSW EPA)
kL	kiloLitre
MGA2020	Map Grid of Australia 2020 (Geoscience Australia)
ML	MegaLitre
NEPC	National Environment Protection Council
NPI	National Pollutant Inventory
NSW EPA	New South Wales Environment Protection Authority
NT EPA	Northern Territory Environment Protection Authority
t	tonne (metric; 1000 kg)
USG	U.S. Gallon
U.S.	United States of America
VOC	Volatile Organic Compound – for the purpose of this report the Australian Government NPI definition is adopted; i.e., *any chemical compound based on carbon chains or rings with a vapour pressure greater than 0.01 kiloPascal at 293.15 K (25 degrees Celsius) that participate in chemical reactions; exclusions include carbon monoxide and methane; see AG* (2009).

1. Introduction

1.1 Background

A U.S. Defence Bulk Fuel Storage Facility (BFSF) is to be located on Lot 5720 west of the Railway Terminal on East Arm District, Northern Territory, near Darwin. The jet fuel storage facility functional requirements were identified as having a minimum storage of 300 MegaLitre (ML) jet fuel comprising the capacities:

- 700,000 barrels (111.3 ML) of F-35 or 'AVTUR' jet fuel (military kerosene type) aviation turbine fuel with Fuel System Icing Inhibitor (FSII) used by land-based military gas turbine engine aircraft; and
- 1,200,000 barrels (190.8 ML) F-44 or 'AVCAT' combustible jet fuel (military high flash-point kerosene type) aviation turbine fuel with FSII used by ship borne military gas turbine engine aircraft.

1.2 Project Caymus and air quality assessment

Crowley Australia Pty Ltd (Crowley) is pursing development of the new BFSF (Project Caymus). The 300 ML-capacity BFSF will comprise eleven fuel tanks: four vertical floating-roof tanks for F-35; and seven vertical fixed-roof tanks for F-44. Crowley engaged Tetra Tech Proteus partnering with Pritchard Francis to undertake the Phase I Project Definition and Conceptual Design for the BFSF, and Pritchard Francis engaged CDM Smith to undertake the environmental approvals.

On 29th November 2021 the Northern Territory Government approved construction and operation of the BFSF and ancillary infrastructure for the transfer and storage of jet fuel – Environmental Approval Number EP2021/008 – 001.

Environmental condition 11 of the Approval is the 'approval holder must ensure there are no attributable impacts from the (BFSF) on the following environmental outcome:

- *Protect air quality and minimise emissions and their impacts on the Darwin airshed so that environmental values are maintained.*'

The NT Government Minister for Environment determined that due to the estimated emissions of Volatile Organic Compounds (VOCs) from the planned BFSF, including cumulative impacts to the regional airshed; i.e., the wider Darwin region, that there is potential for Darwin's air quality to be impacted. Accordingly, the NT EPA required Crowley conduct an air quality impact assessment (AQIA) to demonstrate the project will not have a significant air quality impact. This report describes the AQIA undertaken and results.

1.3 Scope of AQIA

Crowley requested Jacobs perform the AQIA of the operational design of the Caymus BFSF as required by the Northern Territory Environment Protection Authority (NT EPA), described in the Environmental Approval Number EP2021/008 – 001; specifically Conditions 11.c. and 11.d (Northern Territory Government, 29 November 2021):

The preceding Notice of Decision and Statement of Reasons includes these conditions (NT EPA, 14 October 2021):

- *Condition 11.c. Within 20 business days after the commencement of construction of the action, complete:*
    - *Level 1 AQIA of the operational design of the action; and*
    - *If required following completion of the Level 1 assessment, a Level 2 (refined dispersion modelling) AQIA for operation of the action.*
- *Condition 11.d. Undertake the AQIA in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (State of NSW and Environment Protection Authority [EPA] 2016 or latest version), to the satisfaction of the CEO. An AQIA report must be provided to the CEO within 20 business days of completing the AQIA.*

Exclusions from the scope of work are described in the following points:

- The assessment was based on air dispersion modelling of BFSF emissions in accordance with the NSW Environment Protection Authority *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (NSW, 2016), for the VOCs of interest. The inclusion of background VOC concentrations was outside the scope of the NSW (2016) Level 1 assessment.
- It was assumed NT EPA's intention was to focus the assessment on VOCs; i.e., to assess air quality impact due to emissions of VOCs; i.e., the assessment of emissions of 'criteria pollutants' such as nitrogen dioxide and particulate matter was outside the scope of this assessment.
- If accidental, (relatively small), leaks and spills occur their VOC emissions are expected to have a negligible effect on ambient air quality. The spills would occur over relatively short timeframes, and they are expected to be cleaned up quickly.
- An assessment for the wider Darwin region ('airshed'), was outside the scope of this assessment.

In summary this NSW (2016) Level 1 AQIA assessed the VOC emissions expected from sources associated with filling the BFSF; i.e., filling of floating-roof tanks with F-35 ('AVTUR'), and the filling of fixed-roof tanks with F-44 ('AVCAT'), with the focus on the worst-case air emissions scenario, filling the fixed-roof tanks.

The report also provides recommendations on whether a Level 2 AQIA may be required, as per the second point of Condition 11.c, with the ultimate conclusion that a Level 2 AQIA is not necessary.

2. Project Description

2.1 Overview

The air quality study area for the Level 1 AQIA for Project Caymus is shown in Figure 2-1 (see also Appendix A). The study area was designed to capture the key discrete (sensitive) receptors for the modelling study and other industrial sources of air pollution considered in the cumulative impact assessment.

Figure 2-1 Project Caymus air quality study area

- Base map aligned to grid north (base map image: Google Earth).
- Co-ordinate system Map Grid of Australia 2020; co-ordinates labelled in metres.
- Plotted points: Discrete (sensitive) receptor locations (blue); to decode abbreviations see Section 2.5. Industrial facilities (yellow) with abbreviations: ‘PC’ =Project Caymus; ‘VT’ = Vopak Terminal; ‘DLNG’ = Darwin LNG (plant). INPEX plant location also plotted.

Details about the Ausplume model study grid are provided in Section 0.

2.2 Site Plan

A Project Caymus site plan and elevation are provided in Appendix B. The site is located on East Arm District shown by ‘PC’ in the centre of Figure 2-1, between the existing Vopak Terminal (VT) and Darwin Rail Terminal (DRT).

2.3 Site Activities

There will be very little site activity most of the time. Fuel ships will be unloaded at Wharf 4 at the East Arm port facility approximately four times per year. Fuel will be delivered via ship to the BFSF along a pre-existing pipeline rack and easement. Fuel will be delivered via shore pumps located at the storage facility (CDM

Smith, 2021). After the initial terminal fill, the expectation is that the terminal will receive about 120 ML/annum (4 ships).

The maximum BFSF fuel loading rate will be 1,400 m^3/hr, which was a key input for this AQIA; i.e., part of the assessment of the worst-case operating scenario. Other site activities such as tank truck on/off loading were considered to be minor relative to the main activity for assessment which is high-rate fuel loading to the BFSF.

2.4 Air Emissions Inventory

2.4.1 Overview

The purpose of this section is to set out the air (VOC) emissions estimates used as input to the AQIA for the Caymus Project. Other significant sources of VOC emissions in the study area were identified.

2.4.2 Fuel tank air emissions

A fuel tank fitted with a vent, usually on top-centre, will emit fuel vapours (VOCs) as it is being filled with fuel, as the air space within decreases. The vented emissions occur at ambient temperature, and relatively slowly, so the buoyancy of the emissions is expected to be zero. A diagram of a Crowley fixed-roof tank vent is provided in Figure 2-2.

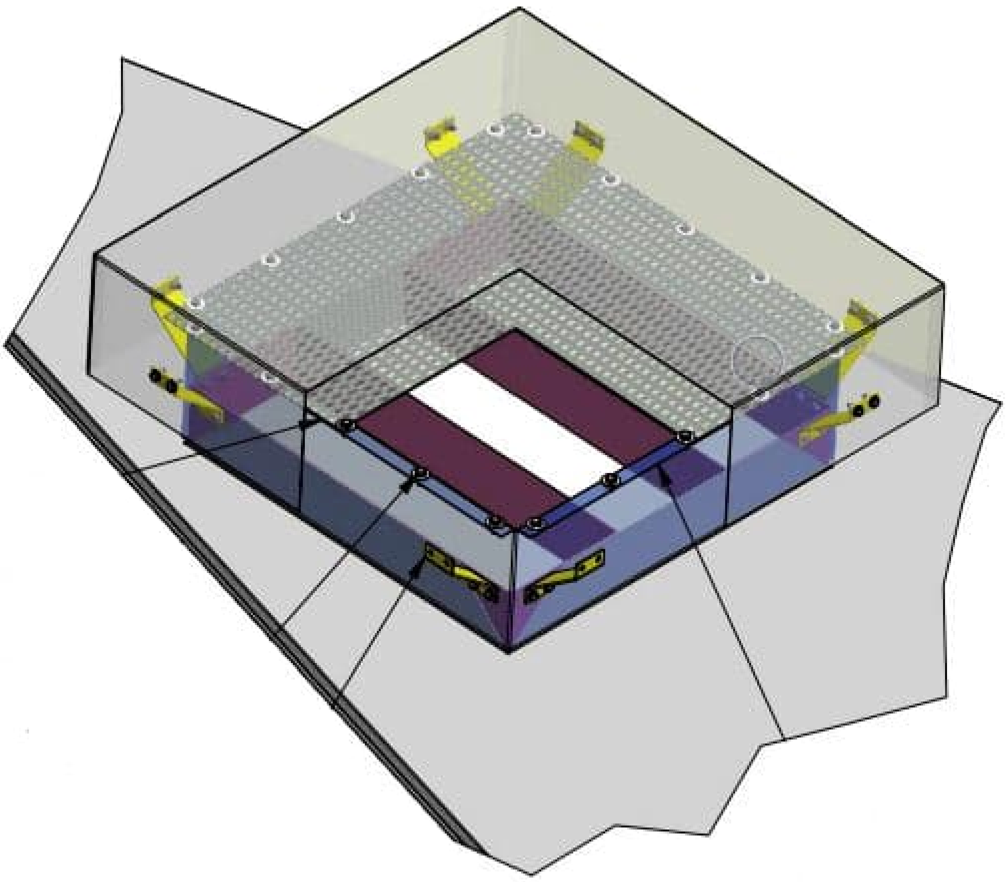

Figure 2-2 Project Caymus vertical fixed-roof tank – single roof vent with cover

In Australia, the rate of VOCs released may be calculated using National Pollutant Inventory (NPI) methods. However, for this assessment, more accurate modelling was completed using the U.S. EPA 'TANKS' model. The Australian Government (AG) NPI Emissions Estimation Technique Manual for Fuel and Organic Liquid Storage (AG, 2012), was used to speciate the TANKS results into individual species, such as benzene. The speciation compared well with the speciation calculated directly from TANKS.

The seven vertical fixed-roof F-44 tanks of Project Caymus are geodesic dome rooves with VOCs vented from the top vents and the rims, the latter comprising intersections of roof joints and shells. The four floating-roof F-35 tanks are equipped with full contact floating rooves with no fuel surface areas venting to internal tank spaces.

2.4.3 Air emissions scenarios and estimates

Analysis of the NSW (2016) impact assessment criteria, the TANKS model outputs, and the proposed Caymus fuel loading operations, led to use of the maximum BFSF fuel-loading rate in the Ausplume model to determine maximum 1-hour average VOC Ground Level Concentrations (GLCs) for assessment. The maximum fuel loading rate was a limitation of the East Arm wharf facilities, not a Caymus limitation.

Air emissions parameters and estimates for the BFSF Floating-Roof tank fuel-loading scenario are provided in Table 2-1, and similarly for the Fixed-Roof tank fuel-loading scenario in Table 2-2.

Table 2-1 BFSF maximum F-35 fuel-loading scenario: four Floating-Roof tanks

Assessment parameter	Value	Notes
Turnover (conservative, high)	Single turnover	Single filling event
Working volume per tank (input to TANKS program)	7,386,300 27,960	USG per tank, or kL per tank[1.]
No. of floating-roof tanks	4	
Fuel farm "working capacity", and conservative (high) fuel movement for assessment	29,545,200 111,840 703,457	USG, or kL[1.], or BBL[2.]
Floating-roof tank scenario, annual venting		
Standing loss time (no working losses by TANKS)	8760	hours of emissions (hours in one year)
Fuel density	0.837	t/kL
TANKS model result: standing (and total) losses	27.65	kg TVOC per annum
Calculated TVOC emission rate	0.0032	kg/h
Calculated TVOC emission rate	0.001	g/s – annual average emission rate
Conclusion:	Negligible TVOC emission rate for assessment	

1. Conversion factor 3.785412 L/USG
2. Conversion factor 42 USG/BBL

Table 2-2 BFSF maximum F-44 fuel-loading scenario: seven Fixed-Roof tanks

Assessment parameter	Value	Notes
Turnover (conservative, high)	Single turnover	Single filling event
Working volume per tank (input to TANKS program)	7,386,300 27,960	USG per tank, or kL per tank[1.]

Assessment parameter	Value	Notes
No. of fixed-roof tanks	7	
Fuel farm "working capacity", and conservative (high) fuel movement for assessment	51,704,100 195,721 1,231,050	USG, or kL[1.], or BBL[2.]
Floating-roof tank scenario, East Arm Wharf maximum fuel loading rate 1,400 kL/h		
Time to load AVCAT tanks	139.8	hours to load
Fuel density	0.837	t/kL
Fuel loading rate (t/h)	1,172	t/h
Total working losses (calculated by TANKS model)	1,330	kg TVOC
Calculated TVOC emission rate (worst-case VOC emissions scenario for input to Ausplume)	9.51 2.64	kg/h, or g/s

3. Conversion factor 3.785412 L/USG
4. Conversion factor 42 USG/BBL

The speciation of the TVOC emissions estimates into benzene etc. used the NEPC (2012) emissions factors for jet kerosene, but equivalently could have been done using the TANKS outputs directly (data comparisons confirmed this). The speciation results and calculated species emission rates are provided in Table 2-3, by emission rate (g/s).

Table 2-3 Speciation of TVOC emissions results

VOC species	Emission rate, floating roof tank (g/s)	Emission rate, fixed-roof tank (g/s)
Benzene	3.0×10^{-6}	0.019
Cumene	12×10^{-6}	0.008
Cyclohexane	9.7×10^{-6}	0.065
Ethylbenzene	2.3×10^{-6}	0.003
n-Hexane	48×10^{-6}	0.390
Toluene	0.96×10^{-6}	0.003
Xylenes	8.3×10^{-6}	0.009
TVOC	880×10^{-6}	2.64

2.4.4 Other VOC sources

Existing sources of hydrocarbon (VOC) emissions were determined by an analysis of the National Pollutant Inventory (NPI). Road vehicle traffic emissions in the larger urban centres such as Darwin and Palmerston, are widespread over a large area. The main industrial sources of VOCs are listed in Table 2-4; inspection of their distances from the BFSF shows that only the Vopak Terminal, which is a petroleum products and sulfuric acid import and distribution terminal, has some potential to add detectable amounts of VOCs to those of Project Caymus. However, it is unlikely both facilities would be filled (therefore emitting), at the same time and therefore there is a low risk of potential cumulative effects.

Table 2-4 Other main VOC sources in Darwin region in relation to Project Caymus

Industrial VOC source	Approximate vector from Project Caymus BFSF
Vopak Terminal	400 metres SW
INPEX Ichthys plant	5.2 km SSE
INPEX, 2 tanks	7.0 km SSE
Darwin LNG plant	6.5 km SW
Channel Island Power Station (CIPS) 279MW	9.7 km SSW
Weddell Power Station (WPS) 129 MW	12.4 km SSE

2.5 Sensitive Receptors

The sensitive ('discrete') receptors located closest to the proposal site were identified in the study area by inspection of vertical imagery; these are listed in Table 2-5. Some of the points are representative of sensitive areas; e.g., urban areas, and are approximately the closest urban points to the BFSF.

Table 2-5 Project Caymus nearest sensitive receptors (air quality impact assessment)

Easting (m)	Northing (m)	Sensitive receptor	Labels used this report
707516	8623398	Hidden Valley (racecourse)	Hidden Valley
713400	8620800	Durack (north)	Durack N
701000	8620700	Darwin Waterfront Lagoon	Darwin Waterfront Lagoon
708555	8620655	Arnhem Land Progress Aboriginal (ALPA) Corporation & car park	ALPA
708350	8620350	Northline & car park	NL
706950	8620350	Darwin Rail Terminal & car park	DRT
707770	8619180	East Arm Boat Ramp & car park	EABR
713400	8619180	Elrundie	Elrundie
712250	8617600	Marlow Lagoon, Bridle Rd.	Marlow Lagoon
706933	8621191	Bleesers Creek (nominal boat location)	Bleesers Ck

3. Local Air Environment

3.1 Overview

Meteorological data are important for air quality impact assessment; parameters important for predicting the dispersion of air pollutants towards sensitive receptors include: wind speed and direction, temperature, humidity, and rainfall. This section provides a brief description of Darwin's climatological data as it pertains to this assessment, and details about the meteorological data used as input to Ausplume.

3.2 Darwin Climatology

Hourly average meteorological observations were obtained from the Bureau of Meteorology (BoM) Darwin Airport monitoring station #014015, for a five-year period (2014-2018). This station is located 5.65 km north-northwest of the Project Caymus site. The observations were considered representative of East Arm District for the purpose of this assessment.

Darwin has a tropical climate that can be divided into a warmer wet season from November to March inclusive, and a cooler dry season from April to October. Temperature varies little over the course of a year, typically ranging between 31°C and 33°C. Typically, humidity varies between 70-80% during the wet season. Monthly rainfall totals vary between more than approximately 400 mm in January, to almost none over June-August.

Wind roses were created from the hourly average wind speed and wind direction observations from BoM Darwin Airport. Annual wind roses for 2014-2018 are provided in Appendix C.1, and seasonal wind roses for the same years in Appendix C.2. The wind rose 'spokes' show wind direction 'blowing from'. Inspection of these wind roses shows (using the traditional southern seasons as divisions):

- Summer winds are dominated by W to WNW winds.
- Autumn winds are dominated by easterly winds.
- Winter winds are dominated by winds in the SE sector.
- Spring winds are dominated by winds in the NW sector.

3.3 Meteorological Data for Assessment

This NSW (2016) Level 1 air quality impact assessment was conducted using synthetic worst-case meteorological data. NSW (2016) provides instructions for the data file construction including combinations of wind speed and stability class, temperature, and mixing layer height; further details are provided in Appendix D.

Darwin's ambient temperature varies only a little by season, and ambient temperature variations are relatively unimportant for volume sources. Wind speed was varied incrementally between the minimum wind speed for Ausplume, 0.5 m/s, and 20 m/s. Wind direction was cycled around the points of the compass in increments of 5 degrees.

Atmospheric stability parameter was varied throughout the range from most unstable ('A' class stability), to most stable ('F' class stability). Mixing layer heights for a rural location were calculated in accordance with the NSW (2016) procedures and set in the input file, ranging from 61 metres up to 5000 metres in height (capped). The completed Level 1 screening meteorological file contained a total of 4,752 hourly records.

Also, an annual meteorological dataset of meteorological parameters was created from BoM observations at Darwin Airport (Jacobs, 2022). This file contained 8,760 records of hourly average meteorological data. The use of this more detailed meteorological file was outside the scope of the Level 1 assessment specified for Project Caymus; the data were used for additional sensitivity testing and for quality control purposes.

3.4 Background VOC levels

The *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*, (NSW 2016), does not require background levels of individual VOCs to be included as part of a Level 1 (screening) air quality impact assessment. However, in general, background levels of VOCs are low, and they are expected to be reasonably low for sensitive receptors surrounding East Arm Wharf for most of the time. For example, in rural areas, generally VOCs may be detectable at levels of a fraction of 1 part per billion by volume (ppb) (NEPC, 2021).

For Darwin, NEPC (2021) stated that a 9-month monitoring program was completed in February 2006 as part of a program to establish baseline conditions for Darwin. These results showed that concentrations of benzene, toluene and xylenes, were well below NEPM investigation levels. No further (monitoring) activities were conducted in 2018-2019.

New information about VOC levels is expected to become available soon; NEPC (2021) stated that a “number of companies have indicated that they will be undertaking air toxics monitoring at the NT EPA air quality monitoring stations as part of their environment protection licence requirements.”

4. Modelling Methodology

4.1 Overview

A NSW (2016) Level 1 air quality impact assessment was undertaken in accordance with NT Government instructions (Section 1.3). The Ausplume model was selected for use for this Level 1 'screening level' assessment. This section sets out the NSW (2016) Level 1 AQIA requirements, and the Ausplume methodology and parameters used.

4.2 Tank venting: source type

Tank fuel must be protected from evaporation and water ingress, so the vents are capped or covered. For Project Caymus, the fixed-roof tanks have one vent approximately centrally located on each tank roof (Figure 2-2); also, venting can occur around the rims of the tanks. When air emissions occur from these vents they are not vertically upwards, but directed outwards and downwards from the roof and rim. These emissions occur at near-ambient temperatures. As such, fuel tank venting was modelled as a 'volume source'. The dimensions of the tank, or tanks, are used to estimate the initial mixing of the VOCs into the building wake-affected air passing over the tank(s).

It is noted 'point source' air dispersion algorithms were developed based on plume behaviour from stacks usually involving hot (buoyant), plumes injected vertically into the atmosphere. This is a different physical situation from the downwards and sideways venting of hydrocarbon vapours from a fuel tank, which occur at near-ambient temperatures (Section 2.4.2).

As the BFSF fuel tanks were modelled as volume sources, building wake effects algorithms were not included in the calculations. Instead, wake effects were included implicitly due to the modelled emissions from a volume source being spread out in a similar way to a building wake. This meant the modelled emissions were drawn immediately down to ground-level in the modelling – a conservative step in the assessment.

For these reasons the Crowley fuel tank vent releases were modelled as volume sources – tank vents cannot, (and should not), be modelled as point sources.

4.3 Worst Case Air Emissions Scenario

The worst-case fuel-loading operation was assessed; i.e., loading of the BFSF from a ship. Of the two tank types, modelling with 'TANKS' software showed that emissions from filling a fixed-roof tank (F-35 fuel) would be significantly higher than filling a floating-roof tank (F-44 fuel). Hence the worst-case scenario was filling a fixed-roof tank with F-44 fuel at the maximum rate, which was included in the assessment. During this operation, fuel vapours would be emitted from the BFSF tanks as they are filled, while insignificant vapour emissions would occur at the ship with ambient air being drawn into the ship's fuel tanks as their levels decrease. This strengthens the worst-case emissions case because the source of the emitted vapours; i.e. the fuel tank being filled, is closest to the nearest sensitive receptors in the East Arm District.

4.4 NSW (2016) Level 1 AQIA requirements

This section sets out the NSW (2016) Level 1 assessment requirements in relation to Condition 11.d of the Environmental Approval (preceding section). NSW (2016) sets out two levels of impact assessment: Level 1 is a screening-level dispersion modelling technique using worst-case input data. The requirement for Level 1 assessments is to use synthetic, worst-case meteorological data.

The main input parameters were hourly average wind speed and direction, and temperature. Other required hourly parameters calculated from this dataset were atmospheric stability class and mixing layer height (hourly); see Section 3.3.

Ausplume was selected for this Level 1 'screening level' assessment given the model is specified for use in NSW (2016). While improved Gaussian models such as Aermod are now available, Ausplume has been used successfully for detailed air quality assessment for many sites in Australia for over two decades and is suitable for a Level 1 (screening) assessment of the BFSF VOC 'volume' source.

The NSW (2016) air quality impact assessment criteria used for assessment are applied to model results at different receptor locations depending on whether they are toxic pollutants (risk of human health impact), or odorous (risk of amenity impact):

- NSW (2016) Table 7.2a lists Principal Toxic air pollutants and Table 7.2b lists Individual Toxic air pollutants.
  - The relevant Project Caymus substances for assessment are benzene, cyclohexane, ethylbenzene and n-hexane.
  - The Impact Assessment Criteria (IAC) for these pollutants are applied as follows:
    - at and beyond (site) boundaries,
    - incremental (not cumulative) calculated concentrations are assessed, and
    - the modelled GLC maxima results are assessed by comparisons with the corresponding IAC.
- NSW (2016) Table 7.4a lists Individual Odorous air pollutants.
  - The relevant Project Caymus substances for assessment: cumene, toluene and xylenes.
  - The Impact Assessment Criteria (IAC) for these pollutants are applied as follows:
    - at existing or future sensitive receptors,
    - incremental (not cumulative) calculated concentrations are assessed, and
    - the modelled GLC maxima results are assessed by comparisons with the corresponding IAC.

The NSW (2016) IAC identified for assessment of Project Caymus operations are detailed in Table 4-1.

Table 4-1 NSW (2016) impact assessment criteria for assessment

NSW (2016) Table	Substance	Receptor type for assessment	IAC ($\mu g/m^3$)
7.2a	Benzene	Grid	29
7.4a	Cumene	Discrete (sensitive)	21
7.2b	Cyclohexane	Grid	19000
7.2b	Ethylbenzene	Grid	8000
7.2b	n-Hexane	Grid	3200
7.4a	Toluene	Discrete (sensitive)	360
7.4a	Xylenes	Discrete (sensitive)	190

It is noted the NSW (2016) criterion for benzene (29 $\mu g/m^3$, a maximum 1-hour average), is very similar to the Victoria Government's *State Environment Protection Policy (Air Quality Management) 2001* design criterion (53 $\mu g/m^3$, a 99.9th percentile 3-minute average). However, EPA Victoria updated its assessment criteria for VOCs in February of this year – the new benzene criterion is 580 $\mu g/m^3$ (a maximum 1-hour average). This indicates the risk of human health impact due to airborne benzene is lower than indicated by the Victorian 2001 policy, and the NSW (2016) criterion.

4.5 Ausplume inputs

The Ausplume input parameters and settings are detailed in Table 4-2. The 10,201 grid receptors with 100-metre horizontal resolution are plotted on the base map in Figure 4-1 (grid receptors plotted as white points).

Table 4-2 Ausplume input parameters and settings

Parameter	Settings / details
Input meteorological data file	Screening test meteorological file created in accordance with NSW (2016) methods; for more details see Appendix D.
Met. obs. site parameters	Surface roughness 0.1 metres (m); anemometer mast height 10 m.
Surface roughness, study area	0.4 m to reflect turbulence effects by buildings in East Arm District. This is considered to be a conservative (low) estimate for surface roughness, because a less conservative 'industrial' surface roughness (0.8m) could be justified for this site.
Source location	E. 706,600 m; N. 8,620,200 m – the northern-most fixed-roof tank nearest to the closest sensitive receptor (Darwin Rail Terminal); this was a conservative step in the assessment.
Source characteristics	'Volume' source: horizontal spread 10 m (25% of tank width) and vertical spread 10 m (25% of tank heights) representing emissions from a fixed-roof tank dispersing north-east prior to reaching the nearest sensitive receptor (Darwin Railway Terminal), located approximately 380 m ENE of the northernmost fixed-roof tank. Use of a smaller initial horizontal spread (10 metres) was considered to be conservative, reflecting the spread for one fuel tank only i.e., the fixed-roof fuel tank closest to Darwin Railway Terminal. Source height 40 m above ground level; i.e., tank vent height, but use of the volume source spread the emissions down to ground-level at the source.
Cartesian study area and grid receptors	101 grid points (east-west) x 101 grid points (north-south). Horizontal resolution 100m; total 10,201 grid points (Figure 4-1). Grid receptor heights 1.5m above ground level.
Discrete receptors	10 discrete receptors at 2.0m above ground level (for details see Section 2.5).
Horizontal & vertical dispersion curves for sources <100m high	Pasquill Gifford curves – adjusted for roughness: horizontal & vertical.
Temperature gradients	Ausplume defaults for wind speed category vs. stability category
Upper bounds for wind speed categories	Ausplume defaults: 1.54, 3.09, 5.14, 8.23, 10.80, >10.80 m/s
Wind profile exponents	Irwin rural exponent scheme
Miscellaneous parameters	Default decay coefficient (0.0); sigma theta (wind direction) averaging period 60 min., no stability class adjustments.

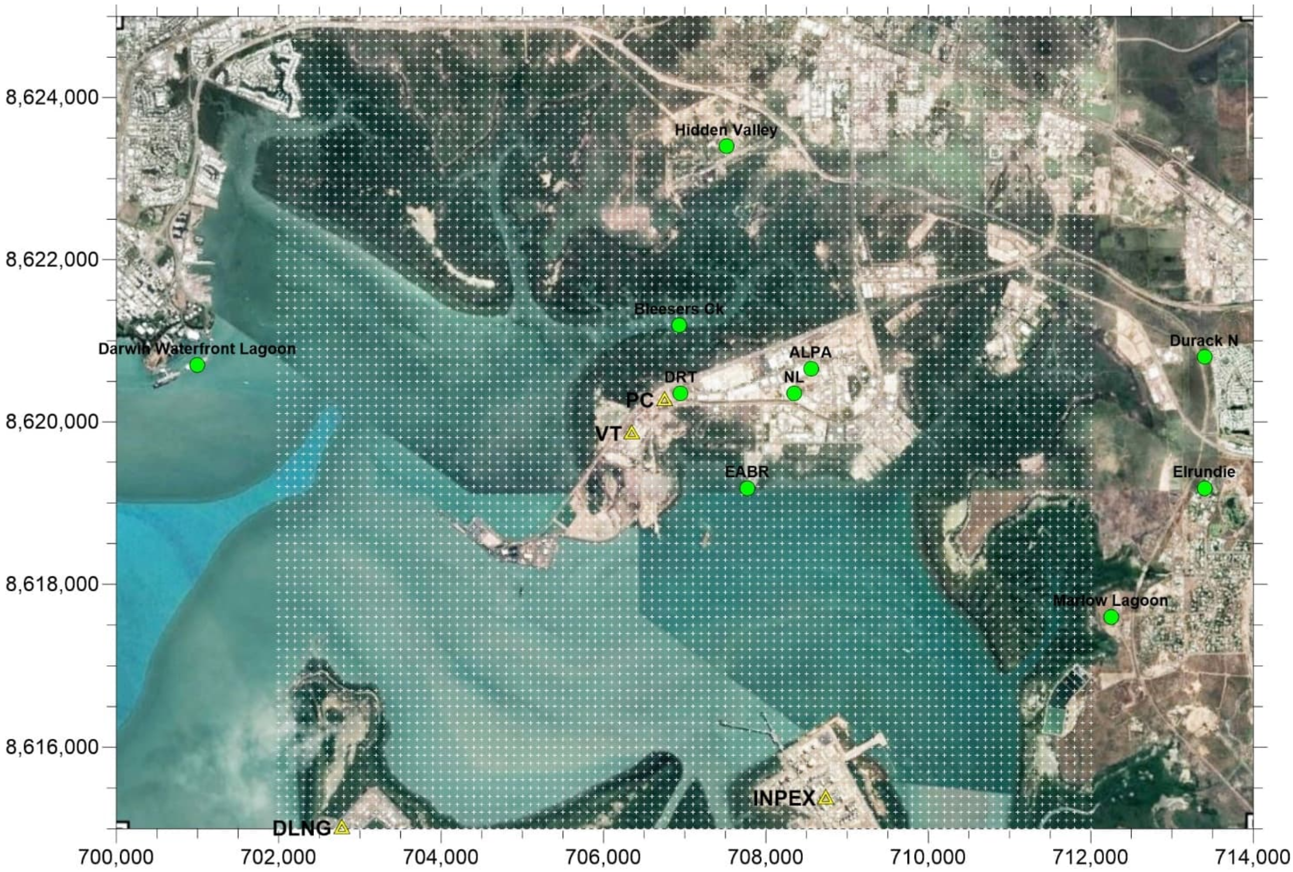

Figure 4-1 Project Caymus air quality study area with 10,201 grid receptors (white points)

4.6 Geographical parameters

The AQIA study area centred on East Arm District is relatively flat, so no topographical data (land elevations) were included in the assessment. Surface roughness selected in Ausplume for the study area was 0.4 metres, which equates to a land type of 'residential' or 'rolling rural'. This was considered to be a conservative step in the assessment; i.e., model results will be overestimated slightly, because the fuel farm and other infrastructure on East Arm would cause turbulence near ground level with a surface roughness probably closer to 0.8 metres (land type 'commercial' or 'industrial').

5. Ausplume results

5.1 Overview

This section provides the key Ausplume results enabling completion of the Level 1 assessment in accordance with NSW (2016). The NSW (2016) IAC are variously applied depending on the type of pollutant and IAC; i.e., toxic or odorous; see Section 4.4. Toxicity-based IAC are relevant for GLC results for the grid receptors anywhere on the study grid, and odour-based IAC are relevant only for the discrete receptors representing sensitive receptor locations.

5.2 Summary of Key Ausplume Results

This section provides the key Ausplume results for GLCs for the 10,201 grid receptors and 10 discrete (sensitive) receptors, for maximum 1-hour average GLC ($\mu g/m^3$), for comparisons with the impact assessment criteria.

VOC emissions for the F-35 fuel-loading scenario for the Floating-Roof tanks were found to be insignificant, with no predicted 'working losses' (during fuel-loading), and the 'standing losses' (annual venting) were insignificant due to the fuel being well-covered by the floating rooves at all times (Table 2-3).

VOC emissions for the F-44 fuel-loading scenario for the Fixed-Roof tanks were found to be significant during the loading period (working losses only; see Table 2-3). The standing losses were insignificant over the loading period, which was estimated to be just a few days. Hence the worst-case operating scenario for assessment was filling the seven Fixed-Roof tanks over the fuel-loading period. Ausplume results are provided for the worst-case VOC emissions scenario; i.e., filling of the seven fixed-roof tanks with F-44 fuel over a period of days. As a conservative step in the assessment, the volume source was assumed to be in the position of the fixed-roof tank closest to the nearest sensitive receptor (Darwin Railway Terminal). Any VOC emissions that may occur from the floating-roof tanks during the same period would be negligible.

The maximum results for all receptors are compared with relevant Level 1 impact assessment criteria in Table 5-1. All the results are less than 7% of the IAC, and (obviously) there were no predicted exceedences of criteria.

Table 5-1 Summary of maximum receptor results – maximum 1-hour average GLCs

VOC	MER (g/s)	Receptor for assessment	Max. 1h GLC ($\mu g/m^3$)	IAC ($\mu g/m^3$)	Result as fraction of IAC
Benzene	0.019	Grid	1.9	29	6.5%
Cumene	0.008	Discrete	0.6	21	2.7%
Cyclohexane	0.065	Grid	6.3	19000	0.0%
Ethylbenzene	0.003	Grid	0.3	8000	0.0%
n-Hexane	0.390	Grid	38.0	3200	1.2%
Toluene	0.003	Discrete	0.2	360	0.1%
Xylenes	0.009	Discrete	0.6	190	0.3%

Additionally, sensitivity tests were conducted with other meteorological datasets; e.g., (1) an annual dataset based on hourly average meteorological observations at Darwin Airport (8,760 hourly records); and (2) Ausplume's own screening-test meteorological file ('met-sample'). The Ausplume results were very similar regardless of the meteorological data used.

5.3 Electronic files

The Ausplume input and output files, and the processed results, include various statistical results for thousands of receptors covering the study area. The Ausplume input files and the results as electronic files will be delivered with this report; these comprise: Ausplume input files with the input unitary VOC emission rate (1 g/s), a spreadsheet showing the conversion of the model results for each substance, and Ausplume output files (all text files).

6. Conclusion

Crowley engaged Jacobs to undertake a Level 1 AQIA of the Project Caymus BFSF as a condition of the Environmental Approval Number EP2021/008 – 001.

The AQIA was undertaken in accordance with NSW (2016); a compliance checklist is provided in Appendix D.

The focus of the AQIA was the worst-case BFSF air emissions scenario, which was identified by a repeat of the TANKS modelling; i.e., loading by ship of the fixed-roof F-44 fuel tanks using the wharf's maximum fuel-loading rate. During this operation, fuel vapours will be emitted from the BFSF tanks as they are filled, while insignificant vapour emissions would occur at the ship with ambient air being drawn into the ship's fuel tanks, as their levels decrease.

The assessment was undertaken in accordance with the Level 1 assessment methodology set out in NSW (2016). Level 1 is a screening-level dispersion modelling technique using worst-case input data, and synthetic worst-case meteorological data. The main meteorological input parameters were hourly average wind speed and direction, atmospheric stability class, and mixing layer height. A number of meteorological datasets were used as input – the use of different data had only small effects on the results. The use of another meteorological dataset would not have changed the outcome of the assessment.

The NSW (2016) VOCs were assessed by comparisons of the maximum GLCs predicted by Ausplume with IAC for toxic air pollutants applied at and beyond site boundaries; i.e., at all 10,201 grid receptor locations.

All the Ausplume results were less than 7% of their IAC – none of the thousands of Ausplume results obtained for Project Caymus operations exceeded NSW impact assessment criteria.

In conclusion the results indicate there is a low risk of air quality impact anywhere in the Darwin region due to operations by Project Caymus.

It is not recommended to proceed to a more detailed (Level 2) assessment for these reasons:

- NSW EPA (2016) Section 2.1 states – "*It is not intended that an assessment should routinely progress through the two levels… if a Level 1 assessment conclusively demonstrates that adverse impacts will not occur, there is no need to progress to Level 2*". There were no Ausplume-predicted exceedences of NSW impact assessment criteria at any receptor including no exceedences at the nearest sensitive receptor, Darwin Rail Terminal.
- Further, the BFSF loading operation will be a unique event, occurring once to fill the fuel farm. Essentially the fuel farm will serve as a storage facility.

7. References

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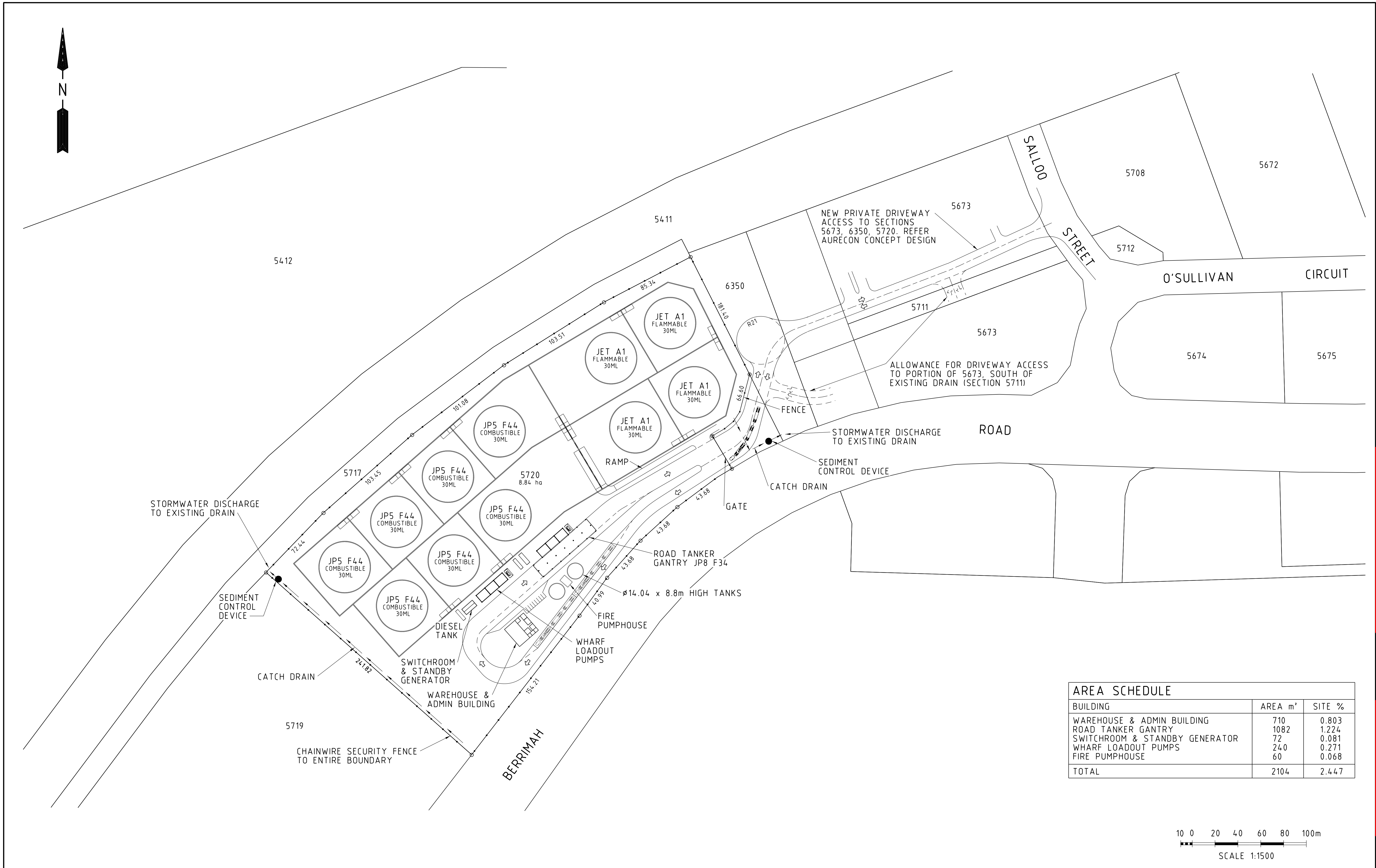
VG (2001) Victoria Government, *State Environment Protection Policy (Air Quality Management)*, Victoria Government Gazette, No. S 240, 21 December 2001.

Appendix A. Darwin Air Quality Study Area

8,624,000
8,622,000
8,620,000
8,618,000
8,616,000
700,000
702,000
704,000
706,000
708,000
710,000
712,000
714,000
Hidden Valley
Bleesers Ck
Darwin Waterfront Lagoon
Durack N
ALPA
DRT
NL
PC
VT
EABR
Elrundie
Marlow Lagoon
INPEX
DLNG

Appendix B. Project Caymus Site Plan and Elevation



AREA SCHEDULE

BUILDING	AREA m²	SITE %
WAREHOUSE & ADMIN BUILDING	710	0.803
ROAD TANKER GANTRY	1082	1.224
SWITCHROOM & STANDBY GENERATOR	72	0.081
WHARF LOADOUT PUMPS	240	0.271
FIRE PUMPHOUSE	60	0.068
TOTAL	2104	2.447

TT - PROTEUS DRG No. 267440-XA-006

REV	DRN	DATE	DESCRIPTION	DCHK	DESN
B	TML	05.10.21	ISSUED FOR INFORMATION		
A	TML	30.09.21	ISSUED FOR INFORMATION		

No	REF. DRG. No.	TITLE

CLIENT

CROWLEY
People Who Know

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	BY	DATE
DRN	T. LEE	30.09.21
DCHK		
DESN		
ECHK		
APP		

TITLE
CROWLEY GOVERNMENT SERVICES
PROJECT CAYMUS
JET FUEL
ALTERNATE OVERALL SITE PLAN

SCALE 1:1500 | A1 | DRG. No. 2129-7000-ARC-SKT-0006 | REV. B

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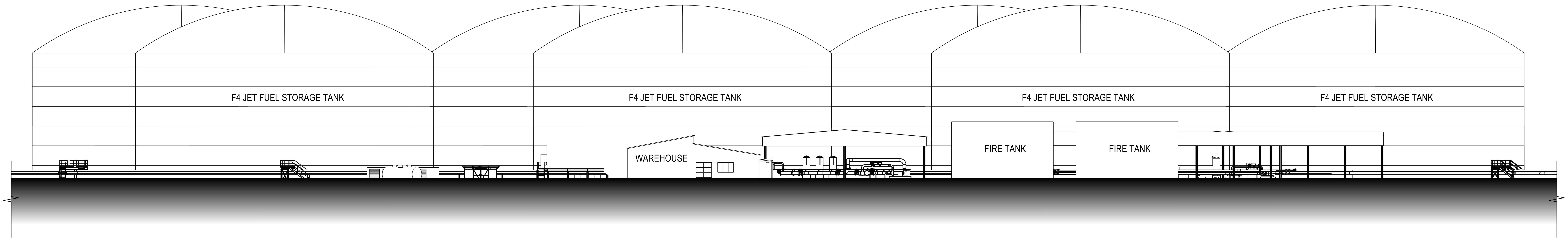

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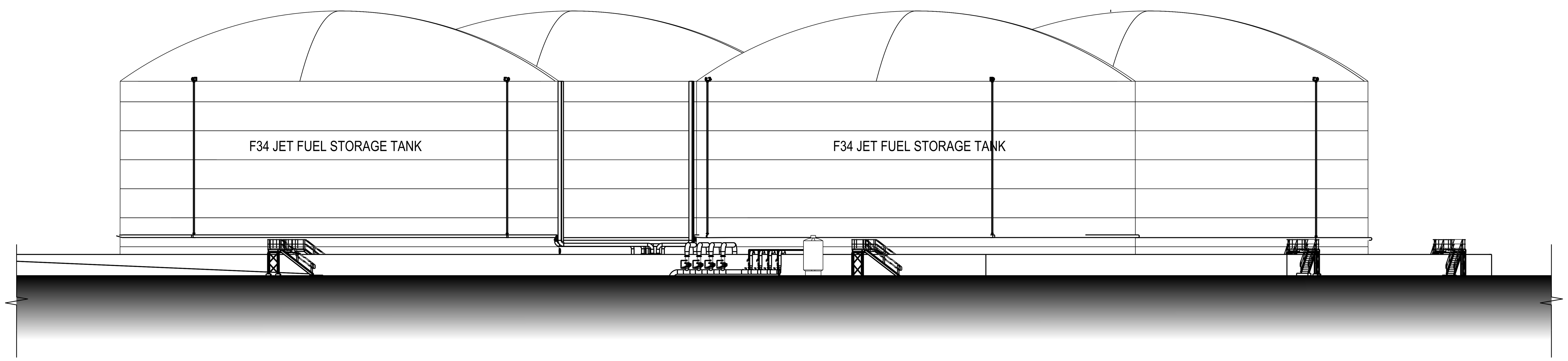

SITE ELEVATION

TETRA TECH PROTEUS
CLIENT REVIEW
CONCEPT ONLY
SIGN: .... DATE ....

TTP DOCUMENT CODE: 267440-DA-004

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			A	KGN	10.12.21	ISSUED FOR CLIENT REVIEW		ZG

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CROWLEY GOVERNMENT SERVICES
PROJECT CAYMUS
JET FUEL
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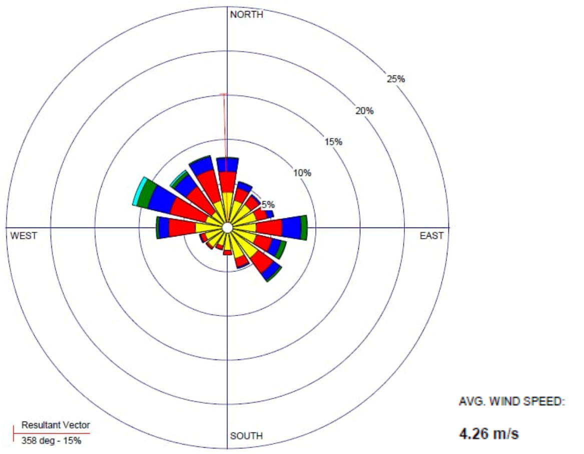
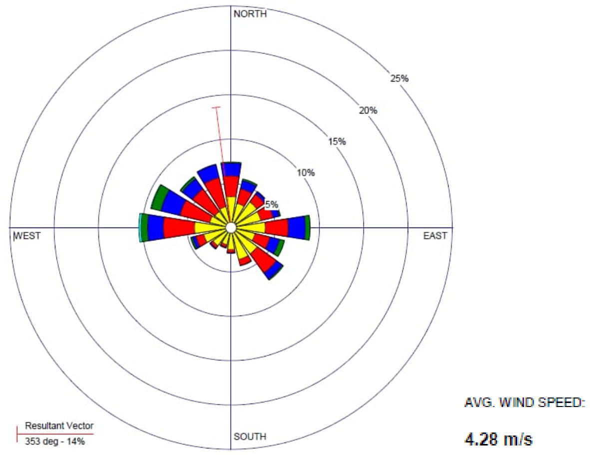
Appendix C. Wind Roses – Darwin Airport

C.1 Annual wind roses 2014-2018

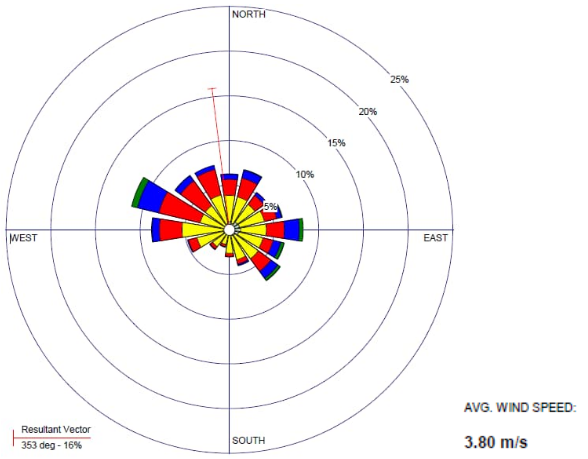
2014



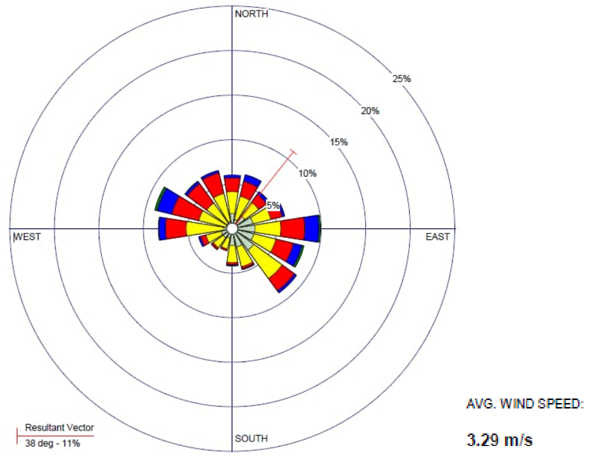
2015



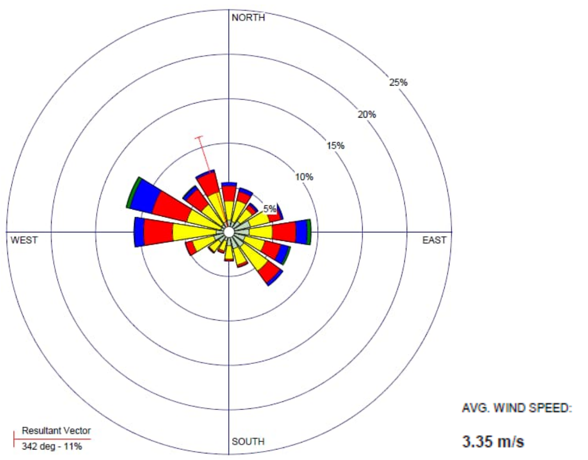
2016



2017



2018

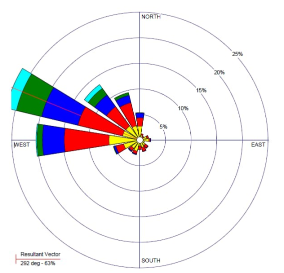
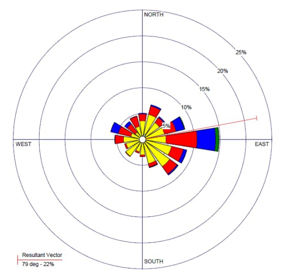
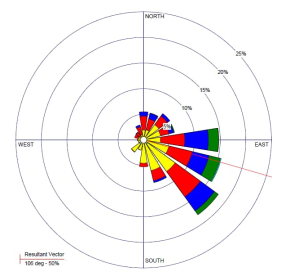
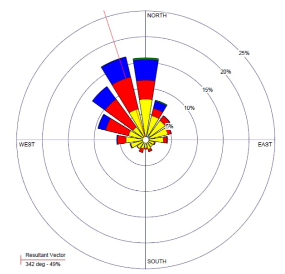
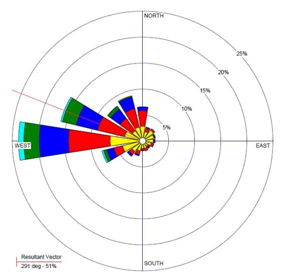
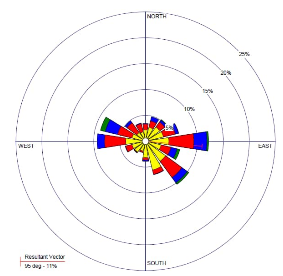
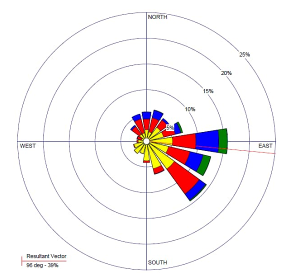
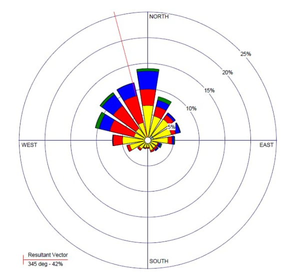
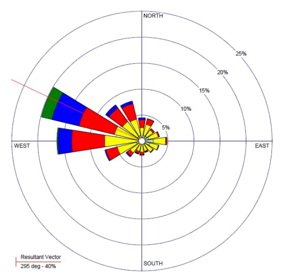
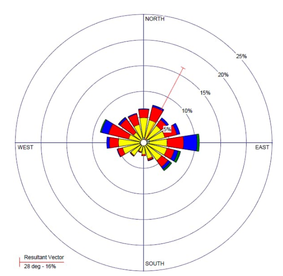
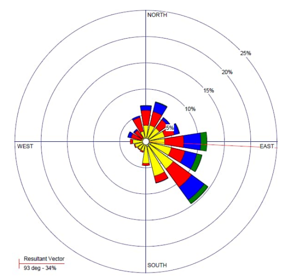
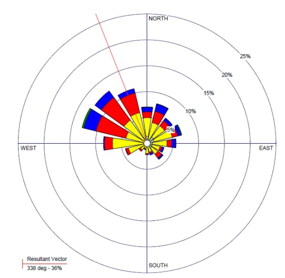
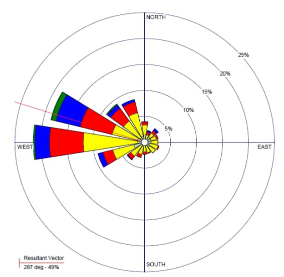
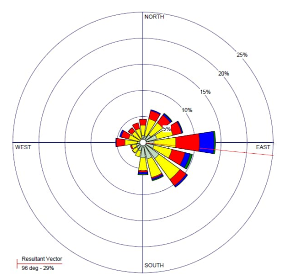
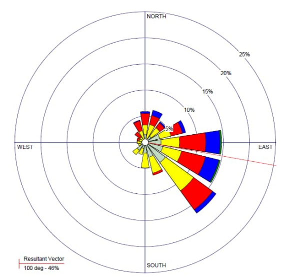
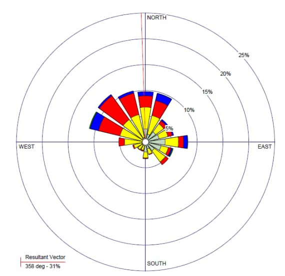
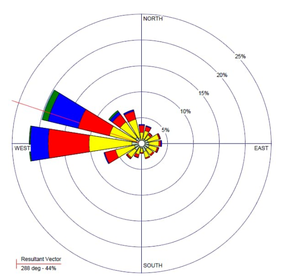
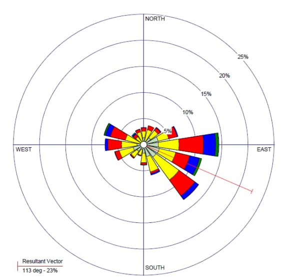
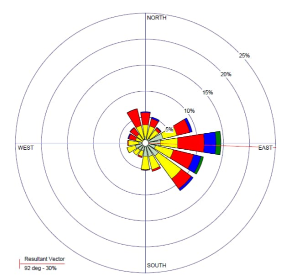
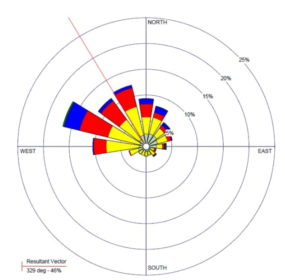


Legend:

WIND SPEED (m/s)

- >= 10.00
- 8.00 - 10.00
- 6.00 - 8.00
- 4.00 - 6.00
- 2.00 - 4.00
- 0.10 - 2.00

C.2 Seasonal wind roses 2014-2018

	Summer	Autumn	Winter	Spring
2014				
2015				
2016				
2017				
2018				

Appendix D. Compliance with EPA (2016)

This Appendix provides a checklist confirming the AQIA Level 1 assessment was undertaken in accordance with NSW (2016).

Table D-1 EPA (2016) Compliance Check

Item #	NSW 2016 Section	NSW (2016) Requirement	Compliance? (Y/N)	Notes
1	4.1	*4.1 Minimum data requirements. The meteorological data used in the dispersion modelling is one factor that determines the level of assessment. Level 1 impact assessments are conducted using 'synthetic' worst-case meteorological data. Table 4.1 lists the wind speed and stability class combinations that need to be included in the synthetic worst-case meteorological data file.*	Y	A synthetic worst-case meteorological data file was used. The meteorological data file used for the final round of modelling was compliant with the requirements for wind-speed and stability class set out in Table 4.1, and used the EPA's sub-sections for calculating Mixing Layer Height (MLH).
2	4.3.1	*Table 4.1 lists the minimum wind speed and stability class combinations that must be included in a Level 1 meteorological data file.*	Y	Exceeded requirement – the combination of F-Class Stability and wind speed =3.5 m/s was included in the meteorological data file, but not a requirement.
3	4.3.2	*For Level 1 impact assessments, the maximum and minimum ambient temperatures that are representative of the site must be included in the Level 1 meteorological data file to account for the range in possible plume rise. Higher ambient temperatures will result in the lowest plume rise and hence the largest impacts.*	N/A	Plume rise is only relevant for stacks and chimneys (point sources), not emissions from fuel tanks (volume sources), which emit at or near ambient temperature. To confirm this, Ausplume modelling sensitivity tests were undertaken using meteorological data files using two different ambient temperatures: 15 ºC and 25 ºC – the results were equivalent (ambient temperature had no effect on the volume source results).
4	4.3.3 Mixing height, and 4.3.4 Monin-Obukhov length	*For Level 1 impact assessments, the mixing height for neutral and unstable conditions (classes A–D) can be calculated using an estimate of the mechanically driven mixing height. The mechanical mixing height, h, can be calculated as follows:* *Equation 4.1: Mechanical mixing height for stability classes A–D* *Equation 4.2: Mechanical mixing height for stability classes E and F*	Y	These procedures were followed to create the meteorological file for use in Ausplume for the Caymus AQIA.

Item #	NSW 2016 Section	NSW (2016) Requirement	Compliance? (Y/N)	Notes
		Equation 4.3: Monin–Obukhov length		
5	4.3.5, Surface friction velocity	*The surface friction velocity, u*, is a measure of mechanical turbulence and is directly related to the surface roughness. The parameter, u*, can be calculated using the procedure presented below (Businger and Fleagle 1980; McRae 1981).* *Condition 1: Wind speed = 0* *Condition 2: Unstable conditions* *Condition 3: Neutral conditions* *Condition 4: Stable conditions*	Y	These procedures were followed to create the meteorological file for use in Ausplume for the Caymus AQIA.
6	4.3.6 Coriolis parameter	*The coriolis parameter accounts for variation in wind direction with height (wind shear) at different latitudes and can be calculated in accordance with well-established techniques.*	Y	The Coriolis parameter was calculated using a latitude for the East Arm Wharf site: 12.474 decimal degrees.
7	5.1.1 Accounting for background concentrations	*For impact assessments of sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), $PM_{2.5}$, PM_{10}, total suspended particulates (TSP), deposited dust, lead (Pb), carbon monoxide (CO) and hydrogen fluoride (HF), the existing background concentrations of the pollutants in the vicinity of the proposal should be included in the assessment…*	Y	The estimates for background are only to be included for the criteria and other pollutants listed. In any case background levels of the hydrocarbon (VOC) substances assessed for Project Caymus are expected to be very low most of the time; e.g., <10 parts per billion (<10 ppb) is typical for background VOC concentrations (NEPC, 2021).
8	6.2 Approved dispersion models	*AUSPLUME v. 6.0 or later is the approved dispersion model for use in most simple, near-field applications in NSW, where coastal effects and complex terrain are of no concern.*	Y	While Ausplume would not be used for a Level 2 assessment where coastal effects are of concern, the model was considered to be more than adequate for use as a Level 1 (screening test) model for the Project Caymus volume sources (downwards and side-ways emissions from tanks). Coastal effects such as sea breezes and modification of the mixing layer vertical structure along the coastline would be insignificant for these tank emissions – noting that the purpose of the screening-level

Item #	NSW 2016 Section	NSW (2016) Requirement	Compliance? (Y/N)	Notes
				meteorological data file was to test all worst-case meteorological conditions near ground-level.
9	7.2.2 Application of impact assessment criteria	*The impact assessment criteria for individual toxic air pollutants in Tables 7.2a and 7.2b must be applied as follows:* *1. At and beyond the boundary of the facility.* *2. The incremental impact (predicted impacts due to the pollutant source alone) for each pollutant must be reported in concentration units consistent with the criteria (mg/m^3 or ppm), for an averaging period of 1 hour and as the: a. 100th percentile of dispersion model predictions for Level 1 impact assessments…*	Y	Ausplume-predicted maximum 1-hour average GLC ($\mu g/m^3$) for individual toxic air pollutants were determined for all grid and discrete (sensitive) receptor locations and assessed by comparisons with their criteria.
10	7.4.2 Application of impact assessment criteria	*The impact assessment criteria for individual odorous air pollutants in Tables 7.4a and 7.4b must be applied as follows:* *1. At the nearest existing or likely future off-site sensitive receptor.* *2. The incremental impact must be reported in concentration units consistent with the impact assessment criteria ($\mu g/m^3$) for an averaging period of 1 hour… and as the… 100th percentile of dispersion model predictions for Level 1 impact assessments…*	Y	Ausplume-predicted maximum 1-hour average GLC ($\mu g/m^3$) for individual odorous air pollutants were determined for all discrete (sensitive) receptor locations and assessed by comparisons with their criteria.
11	9 Impact assessment report	*An air quality impact assessment report must clearly document the methodology and result of the assessment. The EPA's minimum requirements regarding the information contained within an impact assessment report…*	Y	This impact assessment report complies with section 9 clearly documenting the methodology and results of the assessment.
12	9.4.1 Level 1 meteorological data	*A description of the techniques used to prepare the meteorological data in a format for use in the dispersion modelling.* *The meteorological data used in the dispersion modelling supplied in a Microsoft Windows-compatible format*	Y	Descriptions of techniques provided in preceding rows of this table and in the main text. The meteorological data file used as input to the dispersion modelling supplied as a text file able to be read by Microsoft Windows-compatible software.