THE ODOUR UNIT

PAVILION BIOGAS PTY LTD

Pavilion Farms Fertiliser Facility – Technical Review and Air Quality & Odour Impact Assessment

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Anakie, VIC

Final Report

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Report Title: Pavilion Biogas Pty Ltd – Pavilion Farms Fertiliser Facility – Technical Review and Air Quality & Odour Impact Assessment	

EXECUTIVE SUMMARY

In December 2021, The Odour Unit Pty Ltd (**TOU**) was engaged by Ricardo Energy Environment & Planning (**Ricardo**), on behalf of Pavilion Biogas Pty Ltd (**Pavilion Biogas**), to complete a technical risk-based management review of the air quality and odour risks (the **Technical Review**) relating to the proposed Pavilion Farms Fertiliser Facility to be located at 445 Carrs Road, Anakie, Victoria (the **Proposed Fertiliser Facility**). Subsequent to completion of the Technical Review, Pavilion Biogas instructed TOU to proceed with the air and odour quality impact assessment (the **AQOIA**) for the Proposed Fertiliser Facility in May 2022.

Study Approach

The Technical Review and the AQOIA for the Proposed Fertiliser Facility approach is aimed to be consistent with achieving the outcomes of the general environmental duty (**GED**), the Environment Protection Act 2017 (**EP Act 2017**) and the Environment Protection Regulations 2021 (**EP Regulations**) in the context of air quality and odour emissions. To that end, the approach for the Technical Review and the AQOIA are framed around the requirements outlined in:

- Environment Protection Authority (**EPA VIC**) Publication 1825.1 titled *Waste and recycling – Guide to preventing harm to people and the environment* dated June 2021;
- EPA VIC Publication 1518 titled *Recommended Separation Distances for Industrial Residual Air Emissions* dated March 2013;
- EPA VIC Publication 1550 Revision 3 titled *Guideline – Construction of input meteorological data files for EPA Victoria's regulatory air pollution model AERMOD* date September 2014;
- EPA VIC Publication 1551 Revision 6 titled *Guidance notes for using the regulatory air pollution model AERMOD in Victoria* dated February 2015; and
- EPA VIC Publication 1961 titled *Guideline for Assessing and Minimising Air Pollution in Victoria* dated February 2022.

As part of this risk assessment-based approach for addressing and managing air quality and odour emissions from the Proposed Fertiliser Facility, the following has been completed as part of the Technical Review and the AQOIA:

- Site plan and layout;
- Locational analysis and context;
- Process and operational review, which facilitates in the undertaking of an operational odour analysis;
- Identification and characterisation of all potential air and odour emission risks;

- Estimation of key pollutant sources and emission rates;

- Identification and characterisation of all necessary air and odour emission risk controls and mitigation measures; and

- Expert input and review of the proposed odour management design options. This includes the building design of the Proposed Fertiliser Facility and air emissions management and control systems, where applicable.

Operational Context

It is proposed to use part of the existing Pavilion Farms premises for the operation of an agricultural facility that can produce high-grade organic fertiliser as its primary operational function. Biogas will also be generated, captured, and combusted for electrical energy and heat production as a secondary operational function. This will be achieved by utilising the biogas to fuel two combined heat & power engines (**CHPs**) that each produces 1,200 kilowatts-electrical (kWe), equivalent to a total of 21,000 MWh per annum, to be used to support the Proposed Fertiliser Facility operations, the surrounding chicken sheds, and any excess will be exported to the grid. The heat energy will be recovered to dry digestate and heat the process operations. The boiler operation (814 kW) will be supplemented by an e-boiler (250 kW) that is designed to convert the electrical power generated by the CHPs into steam or hot water, reducing and optimising fuel consumption of the boiler as part of normal operations.

The proposed operations will also involve particle size reduction of feedstock and the storage of feedstock materials and products. The concentrated digestate slurry and solid digestate will be dried for use as fertiliser that is to be sold.

Process Overview

Overall, the design objective of the Proposed Fertiliser Facility is to convert poultry litter and carbon-rich waste materials into valuable products, such as fertiliser product and biogas. To achieve this design objective, the key units of operations will be as follows:

- The Proposed Fertiliser Facility will receive, securely store and process approximately 19,700 tpa of poultry litter produced by Pavilion Farms, and 10,000 tpa of carbon-rich organic waste, typically paunch, dissolved air flotation sludge and cheese whey;

- During operations, the input feedstocks will undergo hydrolysis and particle size reduction. The reduced particle size stream will flow to primary and secondary digesters;

- The material in the digesters will produce in excess of 8,000,000 m^3 of biogas, which will be collected from the headspace of each digester;

- The biogas will fuel two CHPs, with an expected electrical energy output of approximately 21,000 MWh;

- The digestate material will be put through a press filter to separate approximately 17,000 m^3 per year of solids from the remaining 173,000 m^3 filtrate (solid digestate);

- Approximately 70% of the filtrate will be recirculated post- particle size reduction;

- The remaining 25% of the filtrate will be sent to a water treatment system, producing grey water for further recirculation and concentrated slurry to fertiliser product; and

- Provisions for the installation of a slurry dryer process to dry the solid digestate and concentrated slurry into fertiliser product. It is anticipated that 6,200 tonnes of fertiliser will be generated per annum from the dryer process.

Based on an understanding of the intended process activities at the Proposed Fertiliser Facility, an operational risk analysis was completed. Based on this risk analysis, the key sources that are likely to pose an air quality and odour emission risks, collectively or individually, are identified to be as follows (categorised as combustion and non-combustion gas emission sources):

- Solid feedstock storage bunkers (non-combustion gases emission source);

- Dried & separated product storage (non-combustion gases emission source);

- Buffer process material storage (non-combustion gases emission source);

- Slurry dryer process (non-combustion gases emission source);

- Particle size reduction process of the input feedstock and digested material(non-combustion gases emission source);

- Drying of solid digestate and concentrated slurry (non-combustion gases emission source);

- CHPs (continuous combustion gas emission source); and

- The flare and boiler exhaust stacks (transient combustion gas emission sources).

The combustion and non-combustion gas emission sources are discussed in the context of their potential impact and the required level of management to achieve the necessary regulatory air quality objectives set by Environment Protection Authority Victoria (**EPA VIC**).

Key Findings

The modelling prediction show that all Air Pollution Assessment Criteria (**APAC**) are satisfied except for short-term NO_2 prediction of 0.3 ppm (99.9%, 1 h), which exceeds the APAC of 0.12 ppm (99.9%, 1 h) at and beyond the boundary of the Proposed Fertiliser Facility. It is noted that the exceedance is largely contained within the property boundary. In the case of odour, the contour presents the baseline predicted ground level concentrations based on the following design assumptions and configurations:

- Open poultry/feedstock receival area (concrete clamps). The poultry litter will be sourced from the existing broiler farms stockpile areas in the vicinity and moved to the Proposed Fertiliser Facility as feedstock for processing. Therefore, it is presumed that the change to the existing local poultry background odour and air quality impact (particulate matter) will be negligible;

- The dryer exhaust air emission will be treated via a biofilter or equivalent odour control system with a treatment airflow capacity of 6,200 m^3/hr. Biofiltration is an established technology and proven air emissions control technology for the treatment of process air emissions in the agricultural and organic resource recovery sector;

- The liquid feedstocks/slurry vessels will be covered and fully enclosed (i.e., closed loop operational circuit). As such, there air quality impacts are anticipated to be negligible emissions;

- The dried and separate storage of product components such as the press filter cake and product from the dryer to be kept under cover in a building. As such, there will be negligible odour and particulate matter emissions on the basis the product is in a dry state and good housekeeping and management practices are followed as part of material transport and handling activities; and

- The input feedstock and digested material particle size reduction process is enclosed (i.e., closed loop operational circuit), with any displaced gas emissions captured and returned to digester.

The AQOIA notes that the CHPs contribute to over 95% of the Proposed Fertiliser Facility predicted total NOx emissions. Given the performance specification provided by the equipment supplier and emission estimation techniques for determining the combustion conversion to NO_2 and its subsequent predicted exceedance in the AQOIA. If required, this circumstance can be managed in one or more of the following manners, including but not limited to:

- Optimal operation and maintenance of the CHPs and validated performance emissions limits, resulting in a revised conversion performance; and

- If required, additional measures such as a stack extension, pre-conditioning of the biogas fuel, and/or enhanced operating conditions can be adopted to manage NO_2 emission release levels.

One or more of the above measures will ensure that human health and the environment are protected both at on-site and off-site locations of the Proposed Fertiliser Facility.

For the other key pollutants, TOU could not identify any representative sources of background air pollution monitoring data for the region surrounding Anakie. It is assumed that the key pollutants of concern have negligible background levels within a farming land use environment.

As part of best industry practice, the potential upset conditions should be examined, and remedial actions developed as part of a site-specific Air Quality & Odour Management Plan (**AQOMP**) for the Proposed Fertiliser Facility. Notwithstanding this, the locality analysis (agricultural/farming setting) and minimum separation distance from the nearest sensitive receptor (975 m) is considered appropriate to facilitate in the management of accidental release of emissions to air under upset or atypical operating conditions. This separation distance should be preserved for the long-term viability of the operations and as part of prudent practice to avoid any potential future land-use conflict.

Recommendations

Based on the findings documented in the Technical Review and AQOIA, TOU has recommended the following for the Proposed Fertiliser Facility:

1. For the proposed dryer biofilter system (or equivalent odour control system), a process monitoring system consisting of the logging of key operational parameters such as airflow, pressure, relative humidity, and temperature;

2. Development of an AQOMP. As a minimum, the details of this should include:

   a. Identification and characterisation of the key steps involved in the Proposed Fertiliser Facility activities and the associated air quality/odour emission risks;

   b. A qualitative assessment on the risk rating for each key step;

   c. An identification of the key odour management and monitoring procedures that will be adopted as part of the site activities (including proactive and reactive strategies);

   d. The reporting requirements with respect to odour as part of the normal site activities;

   e. The training and awareness programs surrounding the activities and its potential odour emissions risk and associated mitigation;

   f. An outline of a commitment to operational excellence and continuous improvement in odour management; and

   g. A trigger and response action plan to abnormal/atypical events that are beyond the normal operational settings.

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FIGURES AND TABLES

FIGURES

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LIST OF ABBREVIATIONS AND DEFINITIONS

Air Pollution Guideline	Guideline for Assessing and Minimising Air Pollution in Victoria
APAC	Air Pollution Assessment Criteria
AQOIA	the air quality and odour impact assessment
AQOMP	air quality and odour management plan
CHP	combined heat and power engine
EET	Emission Estimation Technique
EP Act 2017	Environment Protection Act 2017
EP Regulations	Environment Protection Regulations 2021
EPA VIC	Environment Protection Authority Victoria
ERS	Environmental Reference Standard
GED	General Environment Duty
LHV	Lower Heating Value
NEPM	National Environment Protection Measure (Ambient Air Quality
NPI	National Pollutant Inventory
OCS	odour control system
Pavilion Biogas	Pavilion Biogas Pty Ltd
Proposed Fertiliser Facility	The Pavilion Farms Proposed Fertiliser Facility at Carrs Road, Anakie, Victoria
Ricardo	Ricardo Energy Environment & Planning
SOER	specific odour emission rate
TAPM	The Air Pollution Model
Technical Review	the technical risk-based management review
TOU	The Odour Unit

UNITS OF MEASUREMENTS

Am^3/s	actual cubic metres per second (at stack conditions)

kWe	kilowatt-electrical
kWm	kilowatt-mechanical
L	litres
m	metre
m/s	metres per second
m^2	square metres
m^3	cubic metres
m^3/hr	cubic metres per hour
m^3/s	cubic metres per second
min	minute
mm	millimetre
MWh	megawatt-hours
Nm^3/hr	normal cubic metres per hour (at atmospheric pressure at sea level and 0°C)
°C	degrees Celsius
ou	odour unit
PM_{10}	Particulate matter, 10 microns
$PM_{2.5}$	Particulate matter, 2.5 microns
rpm	revolutions per minute
tpa	tonnes per annum

CHEMICAL NOMENCLATURE

Ar	Argon
CH_4	methane
CO_2	carbon dioxide
H_2S	hydrogen sulphide
N_2	nitrogen
NO	nitric oxide

NO_x	nitrogen oxides
SO_2	sulphur dioxide

1 INTRODUCTION

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1.1 RELEVANT BACKGROUND AND CONTEXT

TOU understands that Ricardo is currently managing and preparing the requisite environmental approvals applications on behalf of Pavilion Biogas for the Proposed Fertiliser Facility, which is proposed to be co-located with the existing broiler farms. The Proposed Fertiliser Facility will process approximately 19,700 tonnes per annum (**tpa**) of poultry litter (sourced from the broiler farms) and 10,000 tonnes per annum of other carbon rich organic waste. It will produce 6,200 tonnes of high-grade organic fertiliser as its primary function, with biogas capture and electricity generation as a secondary function. A total of 8,000,000 cubic metres (**m^3**) of biogas (60–65% methane) will be converted to approximately 21,000 megawatt hours (**MWh**) per annum of electricity. The generated power will be used to support the Proposed Fertiliser Facility operations, the surrounding chicken sheds, and any excess will be exported to the grid.

The Technical Review (referred to as **Phase 1**) is the first of two phases for the undertaking of the air quality and odour assessment study of the Proposed Fertiliser Facility, with the AQOIA (referred to as **Phase 2**) representing the undertaking of comparative dispersion modelling for air quality and odour based on the information and outcomes generated from Phase 1.

1.1.1 Supplied Information

The Technical Review and the AQOIA is based on the information supplied by Ricardo and Pavilion Biogas and combined with TOU's experience in similar anaerobic digestion facilities across Australia. It is noted that the existing conceptualisation of the anaerobic digestion process and ancillary equipment may undergo updates or modifications as part of the detailed design and engineering review process. Notwithstanding this, the design function of key equipment will remain unchanged, particularly as they relate to the operational management of air quality and odour impacts.

1.2 APPROACH

The Technical Review and the AQOIA for the Proposed Fertiliser Facility approach is aimed to be consistent with achieving the outcomes of the general environmental duty (**GED**), the Environment Protection Act 2017 (**EP Act 2017**) and the Environment Protection Regulations 2021 (**EP Regulations**) in the context of air quality and odour emissions. To that end, the approach for the Technical Review and the AQOIA are framed around the requirements outlined in:

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- Estimation of key pollutant sources and emission rates;

- Identification and characterisation of all necessary air and odour emission risk controls and mitigation measures; and

- Expert input and review of the proposed odour management design options. This includes the building design of the Proposed Fertiliser Facility and air emissions management and control systems, where applicable.

To meet the overall objective of the EP Act 2017, the aim of the Technical Review and AQOIA is to identify opportunities to reduce offensive odour as far as reasonably practicable with the use of the best available techniques and technologies applicable for a facility processing agricultural waste as a feedstock.

1.3 Proposed Activities

It is proposed to use part of the existing Pavilion Farms premises for the operation of an agricultural facility that can produce high-grade organic fertiliser as its primary operational function. Biogas will also be generated, captured, and combusted for electrical energy and heat production as a secondary operational function. This will be achieved by utilising the biogas to fuel two combined heat & power engines (CHPs) that each produces 1,200 kilowatts-electrical (**kWe**), equivalent to a total of 21,000 MWh per annum, to be used to support the Proposed Fertiliser Facility operations, the surrounding chicken sheds, and any excess will be exported to the grid. The heat energy will be recovered to dry digestate and heat the process operations. The boiler operation (814 kW) will be supplemented by an e-boiler (250 kW) that is designed to convert the electrical power generated by the CHPs into steam or hot water, reducing and optimising fuel consumption of the boiler as part of normal operations.

The proposed operations will also involve particle size reduction of feedstock and the storage of feedstock materials and products. The concentrated digestate slurry and solid digestate will be dried for use as fertiliser that is to be sold.

2 SITE AND SURROUNDS

2.1 SITE LAYOUT AND PLAN

The site plans showing the locality and context, overall site works layout, and the general arrangement plan are provided in **Figure 2.1**, **Figure 2.2**, **Figure 2.3**, and **Figure 2.4**, respectively. The Proposed Fertiliser Facility will be located between Farm 1 and Farm 2, as shown in **Figure 2.2**. The site layout and elevations of the Proposed Fertiliser Facility from the northern, eastern, southern and western perspectives are shown in **Figure 2.5**, **Figure 2.6**, **Figure 2.7**, **Figure 2.8**, respectively.

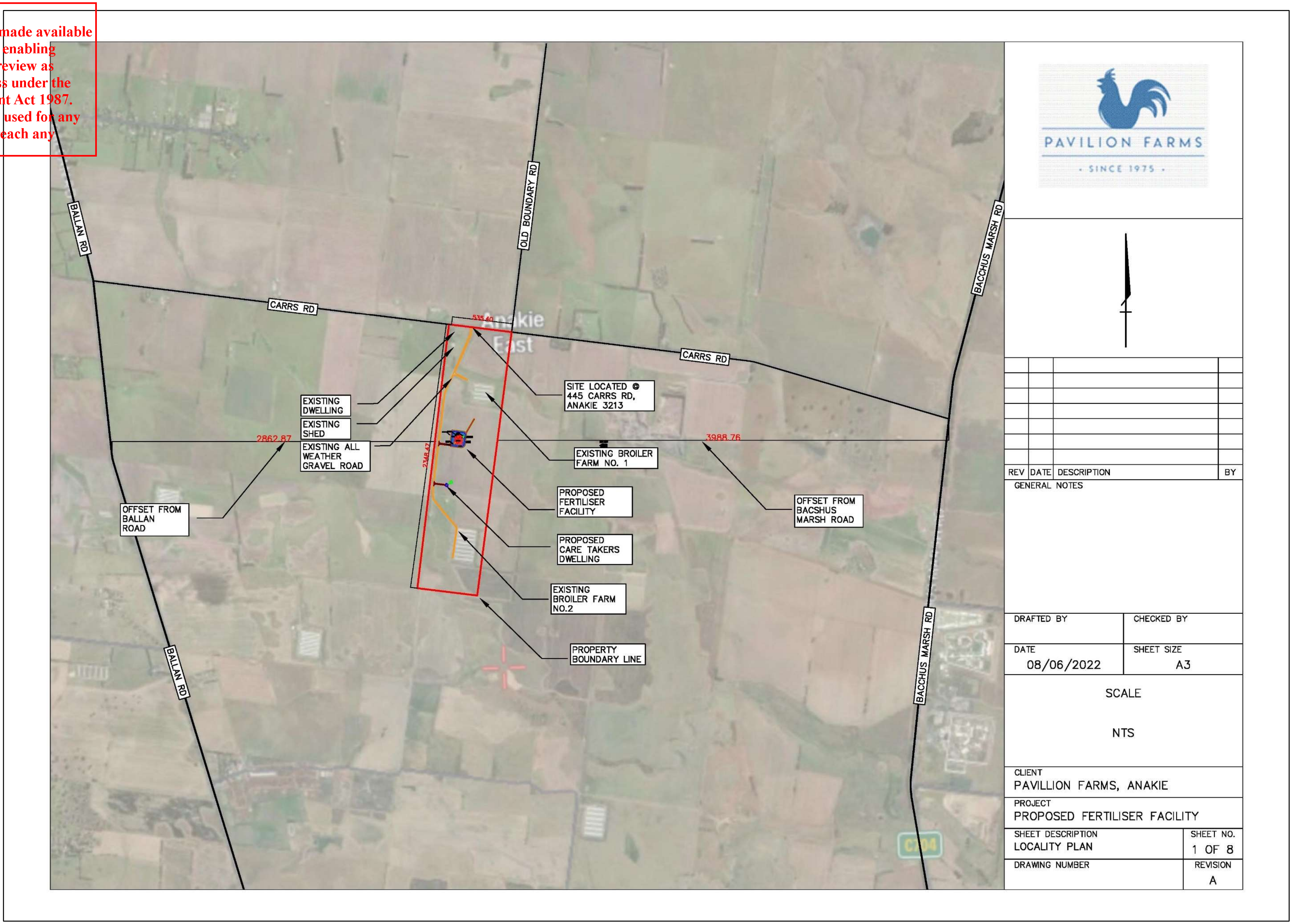


Figure 2.1 – Locality Plan of the Proposed Fertiliser Facility

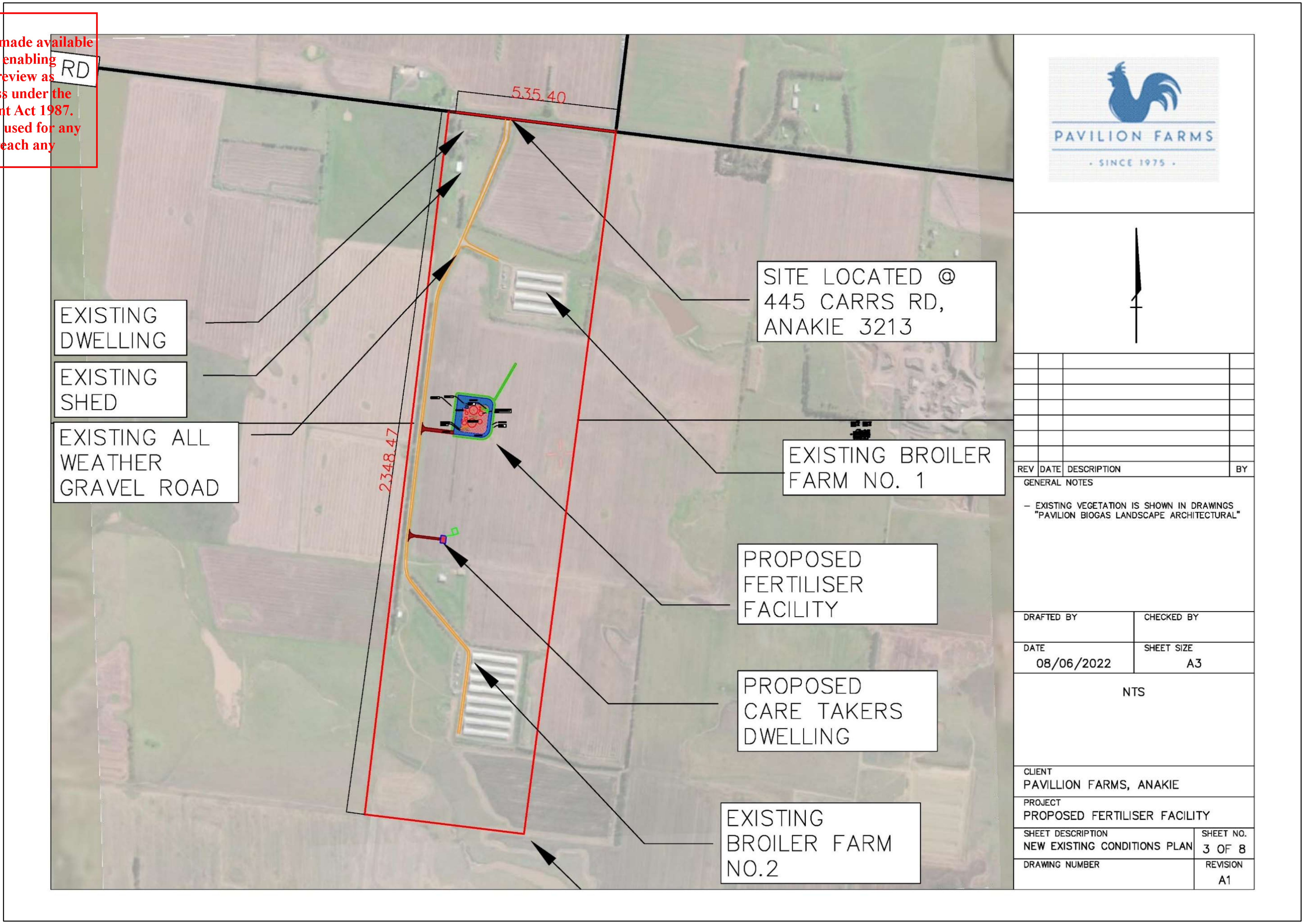


Figure 2.2 – Overall site works layout of the Proposed Fertiliser Facility

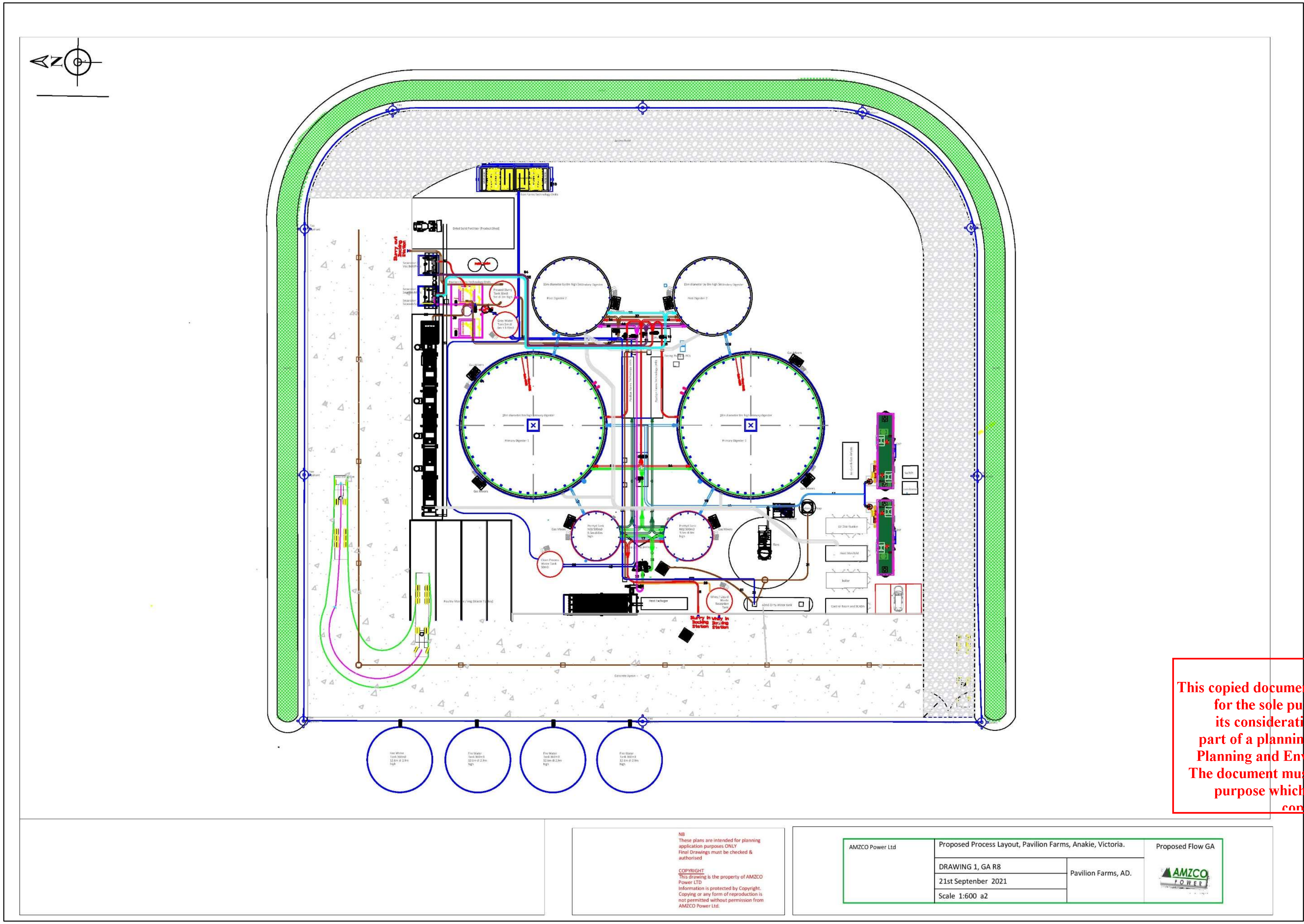


Figure 2.3 – Overall site layout of the Proposed Fertiliser Facility

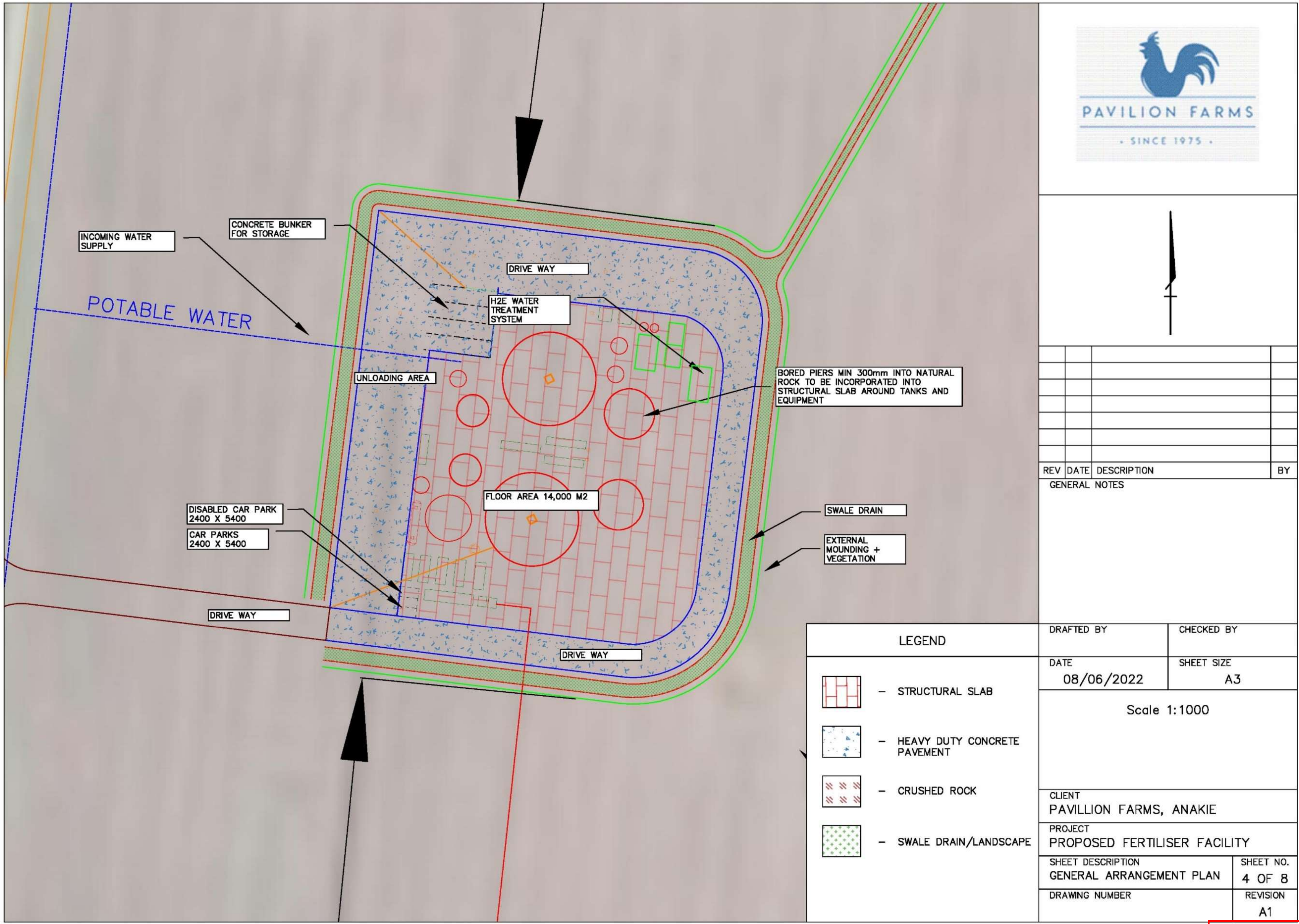


Figure 2.4 – General arrangement plan of the Proposed Fertiliser Facility

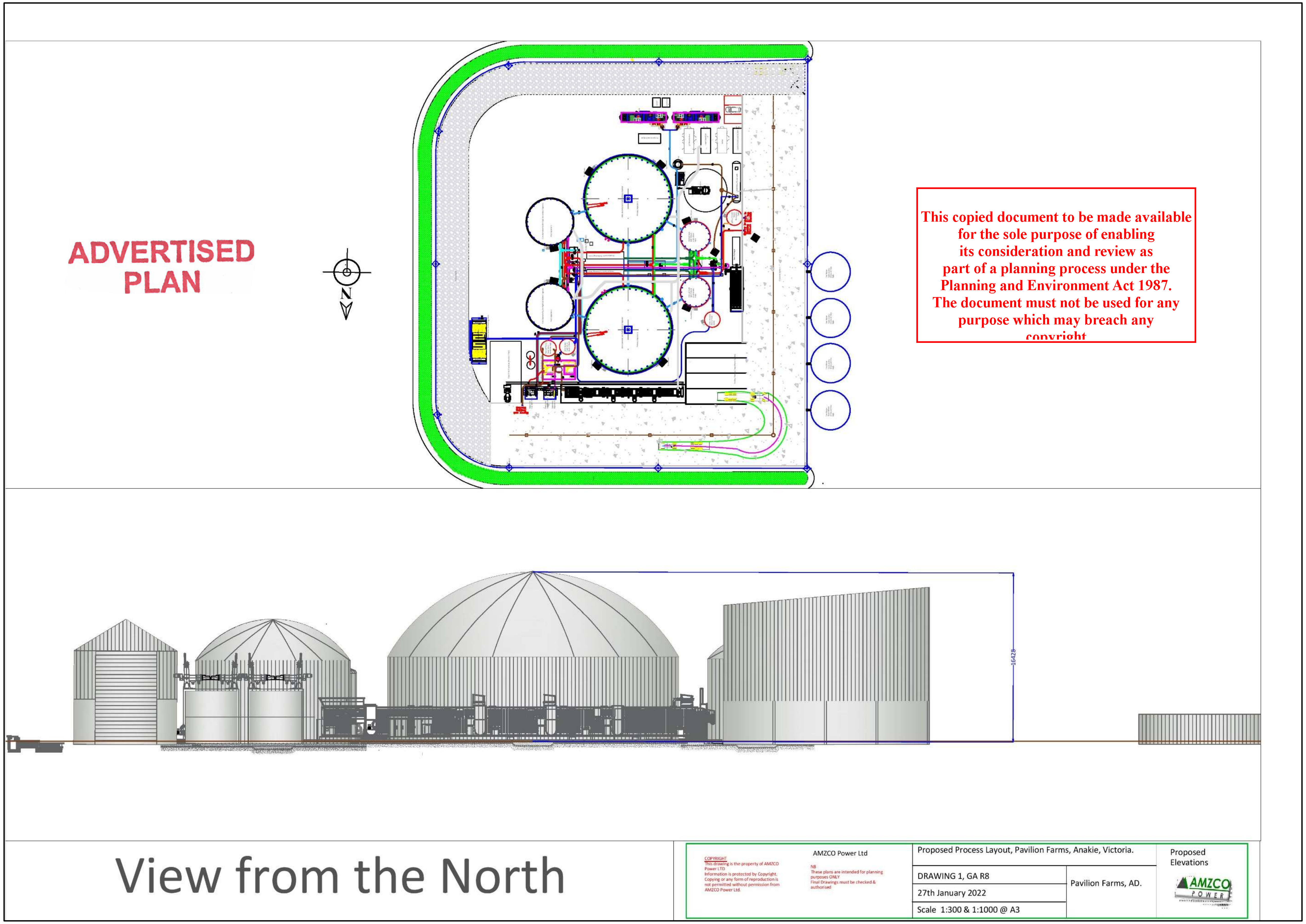


Figure 2.5 – Site layout and elevation: Northern perspective of the Proposed Fertiliser Facility

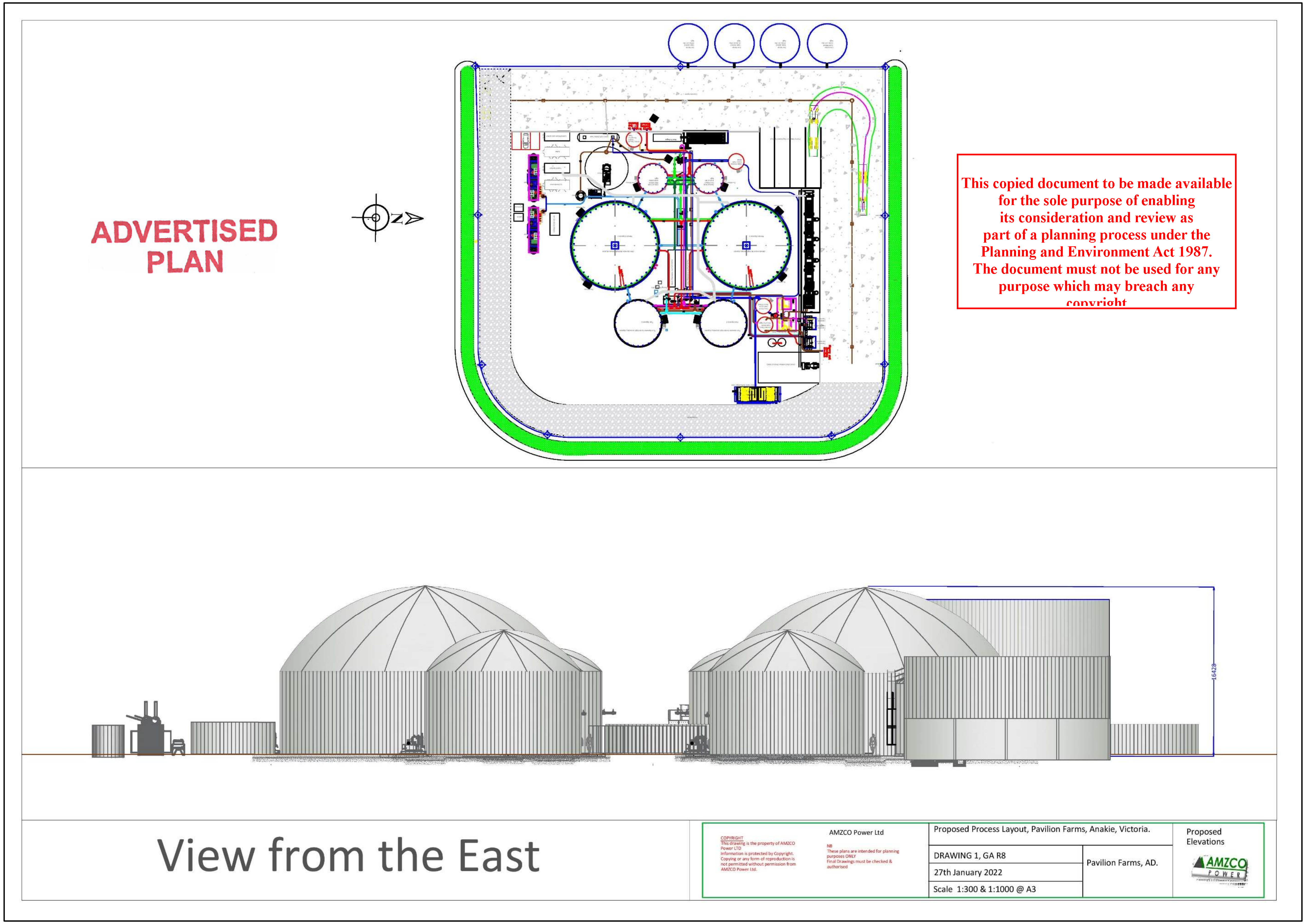


Figure 2.6 – Site layout and elevation: Eastern perspective of the Proposed Fertiliser Facility

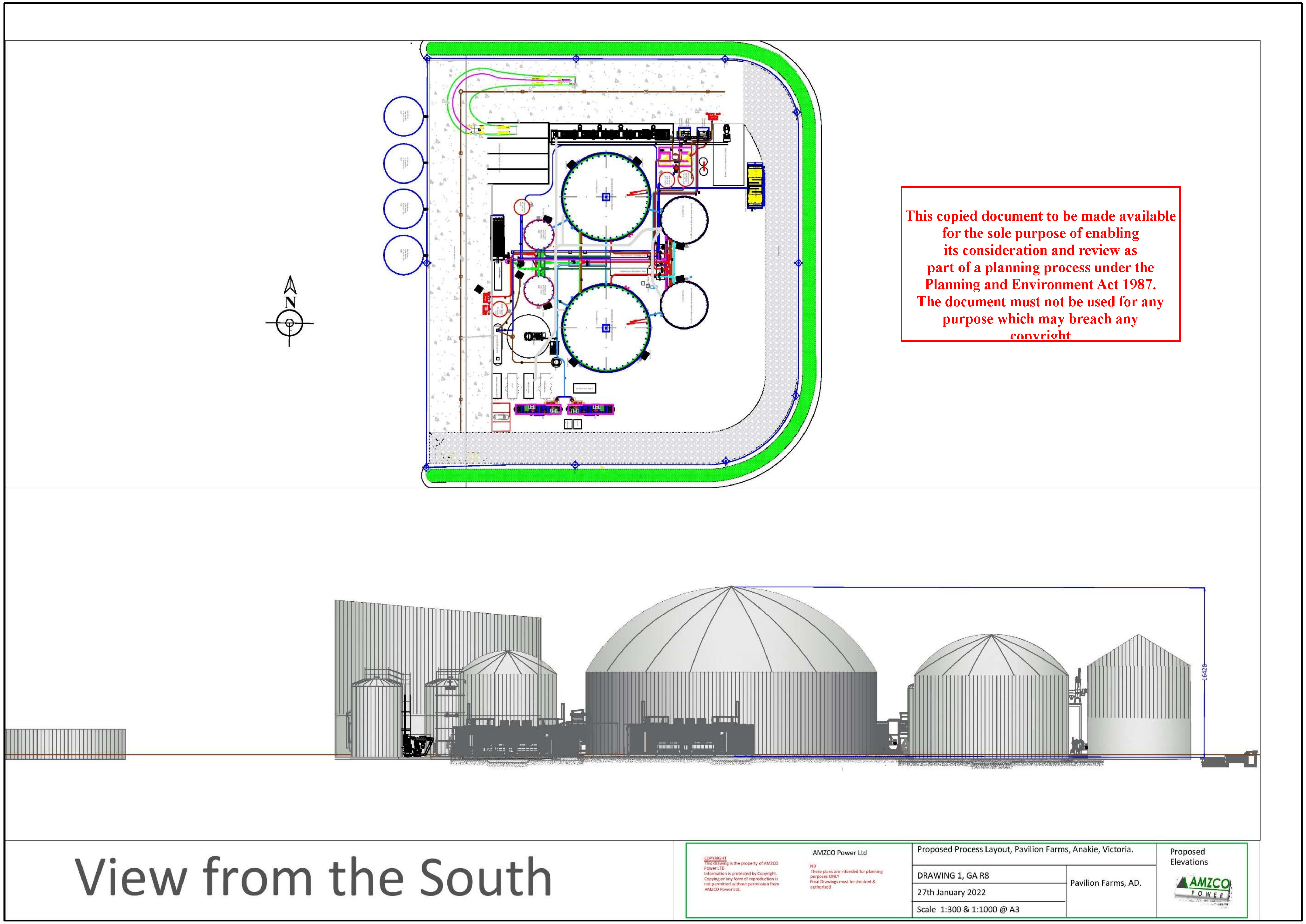


Figure 2.7 – Site layout and elevation: Southern perspective of the Proposed Fertiliser Facility

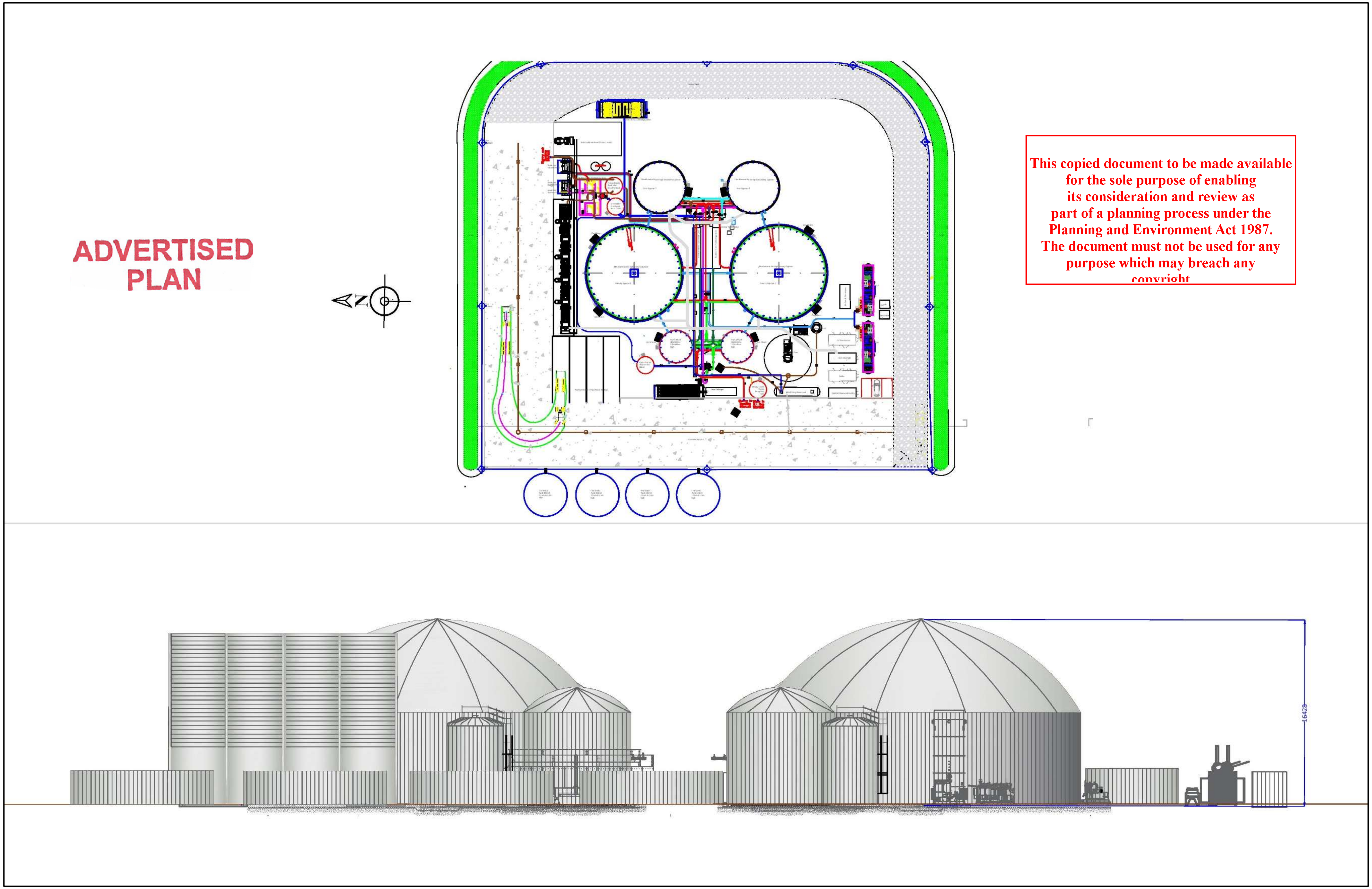


Figure 2.8 – Site layout and elevation: Western perspective of the Proposed Fertiliser Facility

2.2 LOCATIONAL ANALYSIS AND CONTEXT

The location of the Proposed Fertiliser Facility is zoned as a farming zone, as are its surrounds, as indicated on the VicPlan map shown in **Figure 2.9**.

2.2.1 Local Wind Analysis

A visualisation analysis of the local wind data is provided in **Figure 2.10**, which shows that predominant winds originating from the west south-west to north-west sectors (WSW to NW occur approximately 43% of the time. The winds from the northern sectors are also common, occurring approximately 12% of the time. In relation to wind speed, 60% of winds are in the range of 2 – 6 m/s, while calm winds occur approximately 1% of the time. Strong wind speeds (> 8 m/s) are infrequent, occurring around 3% of the time. The effect of wind and other meteorological conditions on air pollutant dispersion has been assessed in detail with air pollution modelling in **Section 5**.

2.2.2 Topography

The Proposed Fertiliser Facility is located approximately 100 metres (**m**) above sea level on moderate terrain. There is a broad ridge sloping gently from northwest to southeast with a relatively steeper downslope commencing approximately 1,500 m east of the Proposed Fertiliser Facility. **Figure 2.11** is a satellite image that depicts the location and topography of the existing Pavilion Farms premises and its surrounds. The effect of topography and land cover on air pollutant dispersion has been assessed in detail with air pollution modelling in **Section 5**.

2.2.3 Nearest Receptors

Figure 2.12 depicts the distance from the Proposed Fertiliser Facility to the two nearest residential receptors. The nearest residential receptor is approximately 954 m northwards of the Proposed Fertiliser Facility location with the next nearest receptor approximately 1,108 m to the northeast. This distance is sensible from a land use planning perspective in the context of the Proposed Fertiliser Facility. At the time of writing this report, all three of these receptors are zoned for farming use. The predicted air quality impact on the nearest receptors has been assessed in **Section 5**.

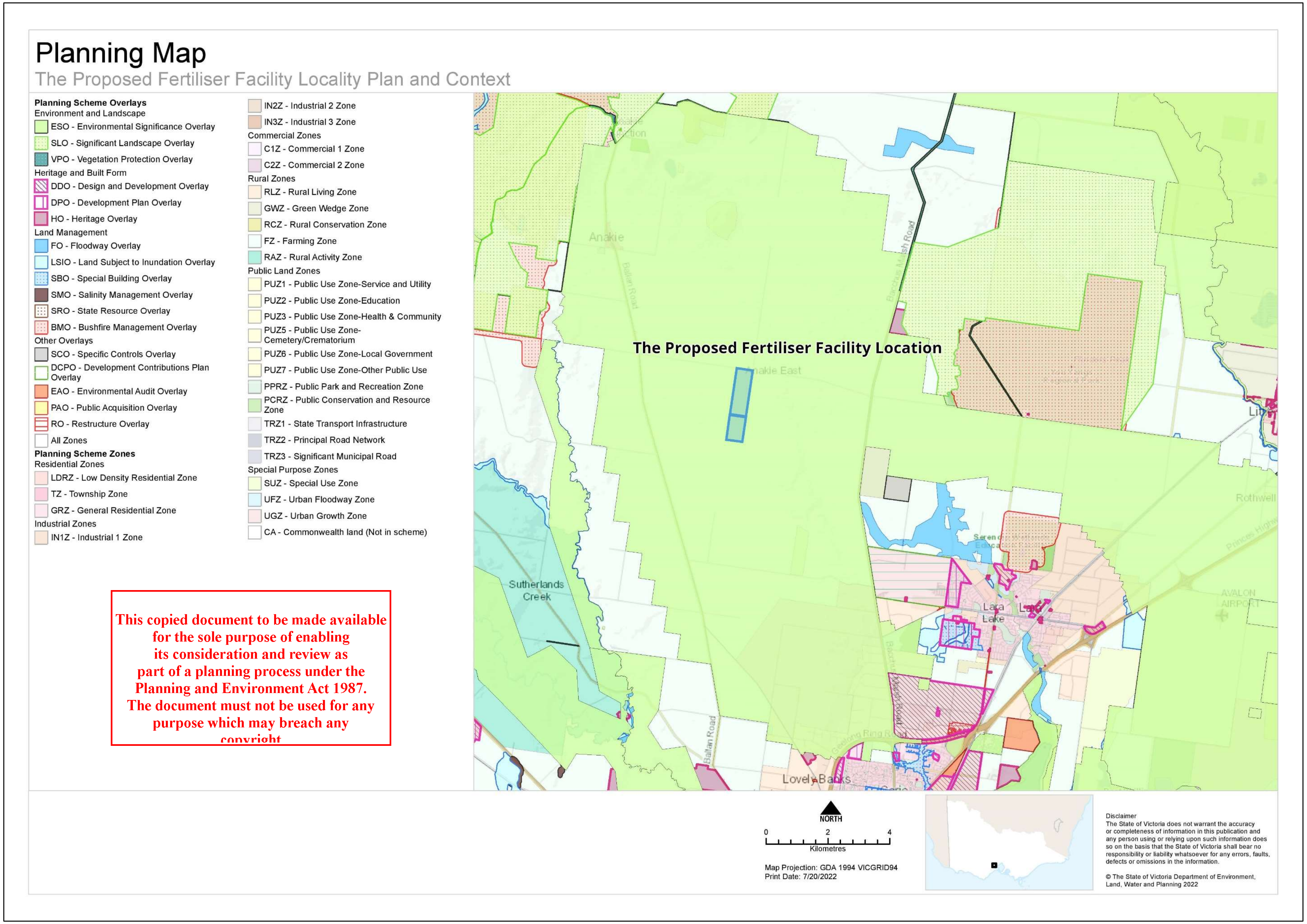


Figure 2.9 – Map of the site location and surrounds for the Proposed Fertiliser Facility (1:100,000). **Source**: VicPlan, Accessed 20 July 2022

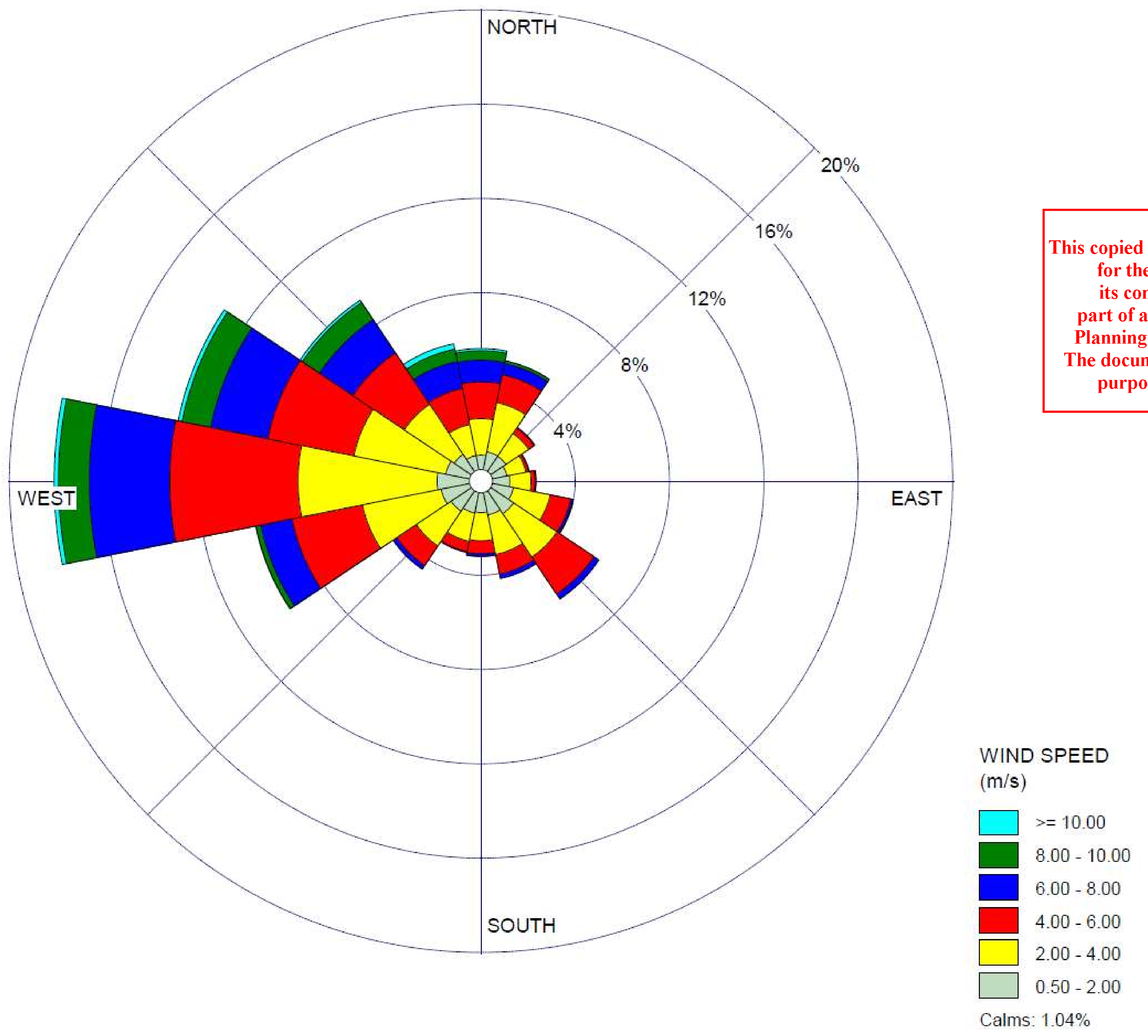


Figure 2.10 – Summary of wind distribution at site location

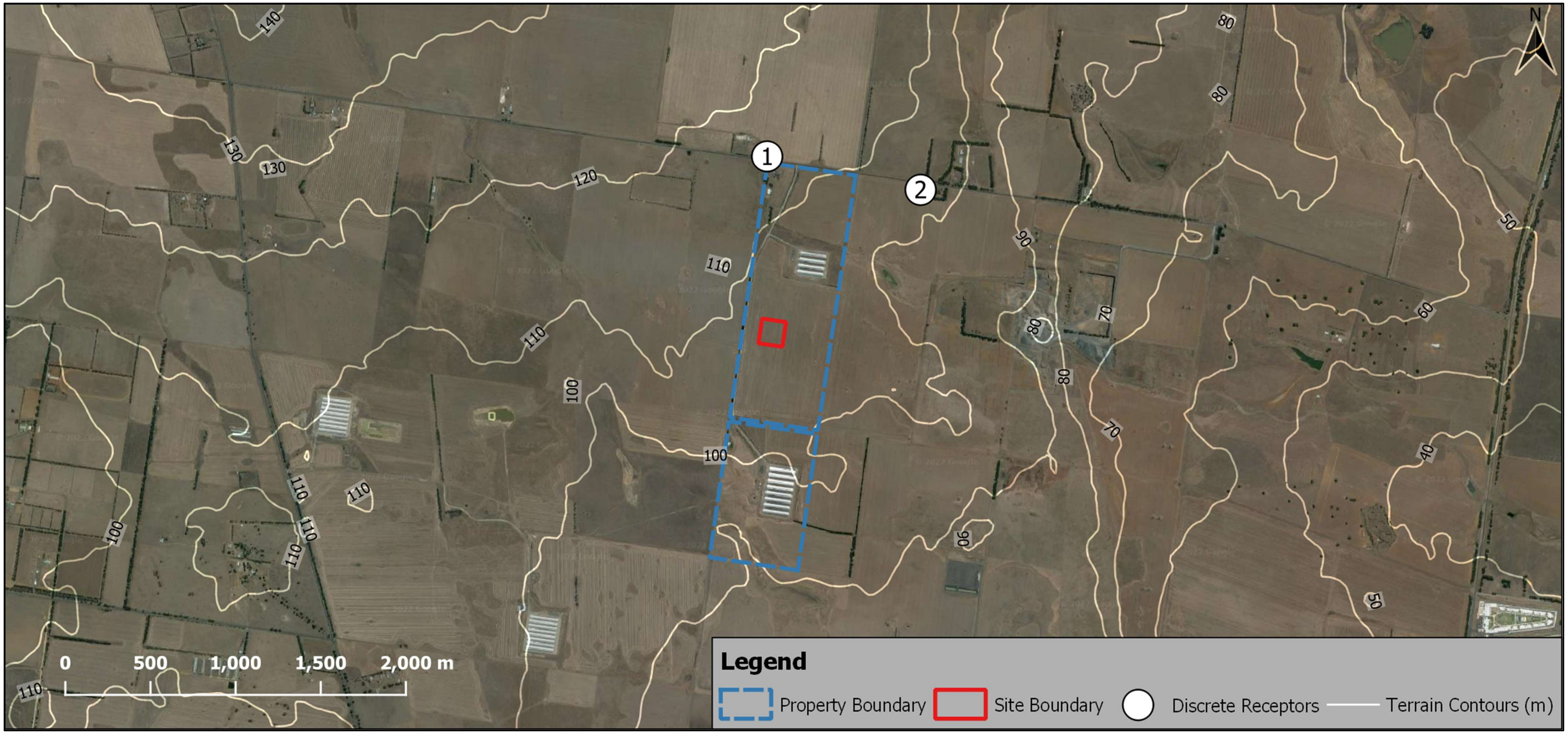


Figure 2.11 – Satellite image and topography for the Proposed Fertiliser Facility

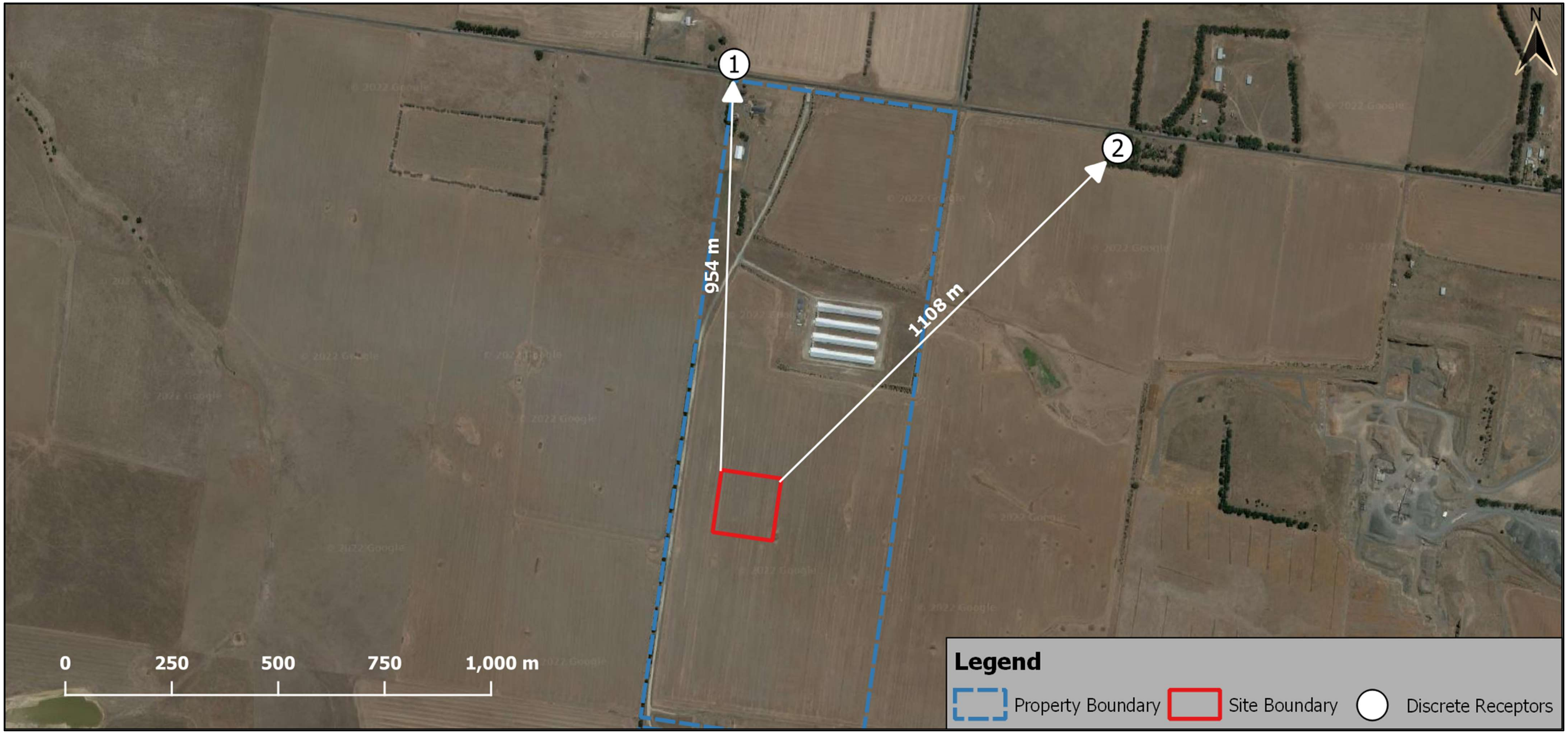


Figure 2.12 – An aerial image of the Proposed Fertiliser Facility and its distance to the nearest receptors

3 PROCESS AND OPERATIONAL REVIEW

The following section documents a detailed review of the intended activities at the Proposed Fertiliser Facility, enabling an operational risk assessment to be undertaken as documented in **Section 4**.

3.1 PROCESS OVERVIEW

The principle of operation at the Proposed Fertiliser Facility is the adoption of anaerobic digestion reactors designed to promote the biological breakdown of organic materials in the absence of oxygen. In the process, biogas containing methane (**CH_4**), carbon dioxide (**CO_2**) and other trace gases are produced. This biogas will be used as a fuel to generate electrical and heat energy via on-site CHPs. To that end, a mass balance of the process at the Proposed Fertiliser Facility is shown in **Figure 3.1**. Overall, the design objective of the Proposed Fertiliser Facility is to convert poultry litter and carbon-rich waste materials into valuable products, such as fertiliser product and biogas. To achieve this design objective, the key units of operations will be as follows:

- The Proposed Fertiliser Facility will receive, securely store and process approximately 19,700 tpa of poultry litter produced by Pavilion Farms, and 10,000 tpa of carbon-rich organic waste, typically paunch, dissolved air flotation sludge and cheese whey;
- During operations, the input feedstocks will undergo hydrolysis and particle size reduction. The reduced particle size stream will flow to primary and secondary digesters;
- The material in the digesters will produce in excess of 8,000,000 m^3 of biogas, which will be collected from the headspace of each digester;
- The biogas will fuel two CHPs, with an expected electrical energy output of approximately 21,000 MWh;
- The digestate material will be put through a press filter to separate approximately 17,000 m^3 per year of solids from the remaining 173,000 m^3 filtrate (solid digestate);
- Approximately 70% of the filtrate will be recirculated post- particle size reduction;
- The remaining 25% of the filtrate will be sent to a water treatment system, producing grey water for further recirculation and concentrated slurry to fertiliser product; and
- Provisions for the installation of a slurry dryer process (as shown in **Figure 3.2**) to dry the solid digestate and concentrated slurry into fertiliser product. It is anticipated that 6,200 tonnes of fertiliser will be generated per annum from the dryer process. It is noted that the slurry dryer process is not shown in the mass balance schematic shown in **Figure 3.1**. Pavilion Farms have advised that there will be no digestate lagoon as shown in **Figure 3.1**. As such, this detail should be

disregarded in reviewing the process flow diagram shown in **Figure 3.1** (noting that this will be updated as part of the detailed design and engineering review process).

The provision of the redacted **Figure 3.1** and **Figure 3.2** can be considered on a commercial-in-confidence basis with permission of Pavilion Farms.

3.2 Biogas Equipment Specifications

The fate of the biogas generated from the digesters will be used for electricity and heat production. This will be achieved via CHPs, with excess biogas thermally oxidised via a flare system. Based on this arrangement, the intended equipment specification for the CHPs and flare systems at the Proposed Fertiliser Facility will be as follows:

- **CHPs:** Perkins 4016-61 TRS2.
  - Engine flywheel power: 912 kWm (Natural Gas)
  - Swept volume: 61.1 L.
  - Electrical system: 400 Volts, 3-Phase, 50 Hertz.
  - Alternator model: LSA50.2L8
  - In constant operation except for start-up and emergency events.

- **Flare Stack:** Model UF10-1500.
  - 1,500 Nm^3/hr.
  - 1,000 °C at 0.3 seconds retention time.
  - Achieve at least 98% destruction efficiency with good operation.
  - Forecast to operate less than 5% of the total operational time.
- **Boiler**: 814 kW model
  - Start-up and emergency use only.
  - Forecast to operate less than 5% of the total operational time.

3.3 Identification of Relevant Air Pollutants

Based on the operational understanding as documented in **Section 3.1** and **Section 3.2**, the activities at the Proposed Fertiliser Facility consist primarily of mechanical particle size reduction, anaerobic digestion, mechanical separation of solid and liquid components, slurry drying, and storage of raw feedstock and fertiliser product. The primary air pollutant that is likely to be associated with these processes is odour. Other than odour, the secondary air pollutants that are likely to be associated with the CHPs and flare systems (i.e., combustible gases) are as follows:

- Carbon Monoxide (**CO**);
- Nitrogen Oxides (**NO_x**));
- Sulphur Dioxide (**SO_2**); and
- Particles as $PM_{2.5}$ and PM_{10}.

The air quality objectives for the above parameters are assessed as part of comparative dispersion modelling documented in **Section 5** of the AQOIA. However, it is well established that the combustion of renewable fuels (such as biogas from an anaerobic digestion process) in equipment such as CHPs and flare systems result in atmospheric emissions of substances. The volume and nature of emissions depend on several factors, including fuel composition and consumption, equipment design and operation, as well as pollution control devices.

For the Proposed Fertiliser Facility, the composition of biogas to be used is expected to be CH_4, CO_2, hydrogen sulphide (**H_2S**), balance gases such as Nitrogen (**N_2**) and Argon (**Ar**). There are other contaminants that may affect efficient combustion performance and emissions discharge to air from the CHPs and flare systems. As such, the performance specifications may be subject to variations upon completion of the detailed design process for Proposed Fertiliser Facility. Notwithstanding this, given that purpose-built equipment will be incorporated and designed to process renewable fuels (biogas) and with regard to the minimum separation distance of 975 m (as identified in the locational analysis documented in **Section 2.2**), air quality impacts from the proposed CHPs and flare system stacks are unlikely to adversely affect the local airshed (refer to **Section 5.7** for more details).

Figure Redacted
Commercial-in-Confidence

Figure 3.1 - Mass balance and process flow of the key operations at the Proposed Fertiliser Facility (note: there will be no digestate lagoon)

Figure Redacted

Commercial-in-Confidence

Figure 3.2 – P&ID of the key operations at the Proposed Fertiliser Facility

4 OPERATIONAL RISK ASSESSMENT

This section comprises an operational review to identify and characterise the air quality and odour risks associated with the Proposed Fertiliser Facility. The operational risk assessment conducted for the Proposed Fertiliser Facility enabled for an identification of critical air quality and odour risk points based on an understanding of the process activity and the odour generation mechanisms and related transport/release pathways to atmosphere. It is based on the process overview conducted in **Section 3**. From this information, an appropriate risk rating is assigned. The risk rating guidance schedule are provided in **Table 4.1** and **Table 4.2**.

Table 4.1 – Risk criteria table adopted for the Technical Review			
Consequence	**Health, Environment and Amenity**	**Likelihood**	**Description**
Severe	▪ Specific health & environment criteria (i.e., APAC) are significantly exceeded ▪ Permanent loss of amenity	Almost Certain	The risk event is expected to occur in most circumstances.
Major	▪ Specific health & environment criteria are exceeded ▪ High-level impact to amenity	Likely	The risk event will probably occur in most circumstances.
Moderate	▪ Specific health & environment criteria are at risk of not being met ▪ Mid-level impact to amenity	Possible	The risk event could occur at some time.
Minor	▪ Specific health & environment criteria are likely to be met ▪ Low-level impact to amenity	Unlikely	The risk event will probably not occur in most circumstances.
Slight	▪ Specific health & environment criteria are comfortably met ▪ Minimal impacts to amenity	Rare	The risk event may only occur in exceptional circumstances.

Table 4.2 – Risk rating matrix adopted for the Technical Review					
Likelihood	**Consequence**				
	Slight	**Minor**	**Moderate**	**Major**	**Severe**
Almost Certain	Medium	High	High	Extreme	Extreme
Likely	Medium	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	Extreme
Unlikely	Low	Medium	Medium	Medium	High
Rare	Low	Low	Medium	Medium	High

4.1 Solid Feedstock Receival

The operational risk assessment outcome for the solid feedstock receival activity at the Proposed Fertiliser Facility is outlined in **Table 4.3**.

Table 4.3 – Solid feedstock receival operational risk analysis	
Description	The delivery of food waste, paunch, and poultry litter by truck into the waste tipping bay. There will be variability in the quality based on composition, storage time and climatic conditions. This will be affected by wet weather, which will impact the odour risk rating of this material.
Uncontrolled impact consequence	Major – high-level impact to amenity.
Uncontrolled impact likelihood	Likely – an impact event will probably occur in most circumstances.
Uncontrolled risk rating	High
Proposed control measures	Sited within Farming Zone. Poultry litter sourced from farms within vicinity for processing. The change to existing local poultry background odour and air quality impact (particulate matter) anticipated to be negligible. Maintain in dry and friable state.
Residual consequence	Moderate – mid-level impact to amenity.
Residual likelihood	Possible – the risk event could occur at some time.
Residual risk rating	Medium

4.2 Liquid Feedstock Receival

The operational risk assessment outcome for the liquid feedstock receival activity at the Proposed Fertiliser Facility is outlined in **Table 4.5**.

Table 4.4 – Liquid feedstock receival operational risk analysis	
Description	The delivery of carbon-rich organic waste liquid feedstock (dissolved air flotation sludge and cheese whey) to be received by tanker trucks into tank vessels.
Uncontrolled impact consequence	Moderate to amenity
Uncontrolled impact likelihood	Unlikely, depending on the quality of liquid feedstock and meteorological conditions prevailing at the time.
Uncontrolled risk rating	Medium
Proposed control measures	Liquid feedstock vessels will be designed as a fixed cone roof tank and contained within a closed loop system.
Residual consequence	Minor – Low-level impact to amenity
Residual likelihood	Rare – The risk event may only occur in exceptional circumstances.
Residual risk rating	Low

4.3 Particle Size Reduction Process

The Proposed Fertiliser Facility will consist of a particle size reduction process, which is designed to facilitate in particle size reduction and enhance biological degradation and nutrient uptake in the digesters. As such, particle size reduction of the input feedstock and filtrate from the press filter (recirculated post-particle size reduction) will be undertaken as part of normal operations. The operational risk assessment of the particle size reduction process for these material flows are considered in **Section 4.3.1** and **Section 4.3.2**, respectively.

4.3.1 Input Feedstock Particle Size Reduction

The operational risk assessment outcome for feedstock particle size reduction activity at the Proposed Fertiliser Facility is outlined in **Table 4.5**.

Table 4.5 – Feedstock particle size reduction operational risk analysis	
Description	Poultry litter/organic waste feedstock mixture at an estimated 29,700 tpa (81 tonnes per day). The particle size reduction will result in particle size reduction and could concurrently release biogas/odorous emission generation. It is understood that particle size reduction will occur of the feedstock mixture and biogas generation will be minimal from any recirculated process loop.
Uncontrolled impact consequence	Moderate – A mid-level impact to amenity.
Uncontrolled impact likelihood	Likely – an impact event will probably occur in most circumstances.
Uncontrolled risk rating	High
Proposed control measures	The particle size reduction process is enclosed, with any displaced gas emissions captured and returned to digester.
Residual consequence	Moderate – A mid-level impact to amenity
Residual likelihood	Rare – may only occur in exceptional circumstances.
Residual risk rating	Medium

4.3.2 Primary and Secondary Digestion

The operational risk assessment outcome for primary and secondary digestion is outlined in **Table 4.6**.

Table 4.6 – Primary and secondary digestion operational risk analysis	
Description	The generation of biogas from digestion processes. Excess biogas can be generated.
Uncontrolled impact consequence	Major – high-level impact to amenity.
Uncontrolled impact likelihood	Likely – an impact event will probably occur in most circumstances.
Uncontrolled risk rating	High
Proposed control measures	The excess biogas is combusted or flared, with any fugitive gas emissions release captured and returned to digester.

Table 4.7 (continued) – Primary and secondary digestion operational risk analysis	
Residual consequence	Major – high-level impact to amenity.
Residual likelihood	Rare – may only occur in exceptional circumstances.
Residual risk rating	Medium

4.4 Combined Heat and Power Engine Exhaust

The operational risk assessment outcome for CHPs activity at the Proposed Fertiliser Facility is outlined in **Table 4.8**.

Table 4.8 – CHPs engine exhaust stacks operational risk analysis	
Description	CHPs combustion of biogas, oxidising its inlet fuel constituents, potentially producing CO, SO_2 and NO_X.
Uncontrolled impact consequence	Major – Short term nitrogen dioxide (**NO_2**) (1 hour) APAC exceeded (refer to AQOIA in **Section 5**).
Uncontrolled impact likelihood	Likely – an impact event will probably occur in most circumstances (refer to AQOIA in **Section 5**).
Uncontrolled risk rating	High
Proposed control measures	Optimal operation and maintenance of the CHPs. If required, additional measures such as a stack extension, pre-conditioning of the biogas fuel, and/or enhanced operating conditions can be adopted to manage NO_2 emission release levels.
Residual consequence	Minor – Short term NO_2 (1 hour) APAC is likely to be met.
Residual likelihood	Unlikely – The risk event will probably not occur in most circumstances.
Residual risk rating	Medium

4.5 Flare and Boiler Systems

The operational risk assessment outcome for the flare and boiler activity at the Proposed Fertiliser Facility is outlined in **Table 4.9**.

Table 4.9 – Flare and boiler systems operational risk analysis	
Description	The combustion of biogas for transient use (up to approximately 5% of the time in the calendar year) including start-up and emergencies, potentially producing CO, SO_2 and NO_X.
Uncontrolled impact consequence	Slight – Minimal combustion emissions contribution relative to CHPs, and minimal impact to amenity.
Uncontrolled impact likelihood	Rare – may only occur in exceptional circumstances.
Uncontrolled risk rating	Low

Table 4.8 (continued) – Flare and boiler systems operational risk analysis	
Proposed control measures	None, other than optimal operation and maintenance of the optimal operation and maintenance of the flare and boiler systems.
Residual consequence	Slight – Minimal combustion emissions contribution relative to CHPs, and minimal impact to amenity.
Residual likelihood	Rare – may only occur in exceptional circumstances.
Residual risk rating	Low

4.6 Solid Digestate and Concentrated Slurry Drying

The operational risk assessment outcome from the drying of digestate and concentrated slurry drying at the Proposed Fertiliser Facility is outlined in **Table 4.10**.

Table 4.10 – Drying of digestate and concentrated slurry operational risk analysis	
Description	Drying of the solid digestate and concentrated slurry. The drying process in particular will liberate a large quantity of odorous compounds and particulates.
Uncontrolled impact consequence	Major – high-level impact to amenity
Uncontrolled impact likelihood	Likely – an impact event will likely occur in most circumstances.
Uncontrolled risk rating	High
Proposed control measures	A biofilter or an equivalent odour control system to treat 6,200 m^3/h of exhaust air to 500 ou or less
Residual consequence	Slight – minimal impact to amenity
Residual likelihood	Unlikely – will probably not occur in most circumstances.
Residual risk rating	Low

4.7 Dried & Separated Product Storage

The operational risk assessment outcome from the storage of dried product at the Proposed Fertiliser Facility is outlined in **Table 4.11**.

Table 4.11 – Dried & separated product operational risk analysis	
Description	Dried & separated storage of product components, such as the press filter cake and product from the dryer may lead to odour emission depending on storage and climatical conditions. This will be affected by wet weather, which will impact the odour risk rating of this material.
Uncontrolled impact consequence	Moderate – mid-level impact to amenity
Uncontrolled impact likelihood	Likely – an impact event will probably occur in most circumstances.
Uncontrolled risk rating	High

Table 4.10 (continued) – Dried & separated product operational risk analysis	
Proposed control measures	The dried and separate storage of product components such as the press filter cake and product from the dryer to be kept under cover and maintained in dry and friable state.
Residual consequence	Slight – minimal impact to amenity
Residual likelihood	Unlikely – will probably not occur in most circumstances.
Residual risk rating	Low

4.8 BUFFER PROCESS MATERIAL STORAGE

The operational risk assessment outcome from the buffer process material storage of filtrate/concentrated slurry and dirty water components is outlined in **Table 4.11**.

Table 4.12 – Buffer process material storage of filtrate/concentrated slurry and dirty water operational risk analysis	
Description	The buffer storage of filtrate/concentrated slurry and dirty water vessels have the potential to release odour as the volume levels fluctuate.
Uncontrolled impact consequence	Moderate – mid-level impact to amenity
Uncontrolled impact likelihood	Likely – an impact event will probably occur in most circumstances.
Uncontrolled risk rating	High
Proposed control measures	The buffer storage of filtrate/concentrated slurry and dirty water vessels will be part of a closed loop system, with minimal atmospheric release points.
Residual consequence	Slight – minimal impact to amenity
Residual likelihood	Unlikely – will probably not occur in most circumstances.
Residual risk rating	Low

5 AIR POLLUTION MODELLING

5.1 OVERVIEW

The potential impacts due to the Proposed Fertiliser Facility operations of were assessed based on air pollution modelling that incorporates source characteristics, emission rates, local meteorology, and geographical features in the surrounding environment. According to *Guideline for Assessing and Minimising Air Pollution in Victoria,* air pollution modelling is a Level 2 assessment tool that complements the initial Level 1 assessment (i.e., the Operational Risk Assessment in **Section 4**).

The air pollution modelling has been conducted using the United Stated Environmental Protection Agency (**USEPA**) approved model AERMOD (USEPA, 2018b). The AERMOD atmospheric dispersion model is a steady-state Gaussian plume model in wide use within Australia and is suitable for use in most simple, near-field applications.

5.2 AIR POLLUTION ASSESSMENT CRITERIA

EPA VIC APAC outlined in *Guideline for Assessing and Minimising Air Pollution in Victoria* (the **Air Pollution Guideline**) are risk-based concentrations used to assess unacceptable risk to the receiving environment. For criteria pollutants, the relevant objectives specified in the Environmental Reference Standard (**ERS**) are adopted by the Air Pollution Guideline. The ERS generally adopts the objectives in the National Environment Protection Measure (Ambient Air Quality) (**NEPM AAQ**) with some modifications and additions. APAC are not intended to be used as compliance thresholds but as another tool to help the duty holder minimise risks so far as reasonably practicable to the receiving environment.

There are two categories of APAC:

- **Health-based:** protective of public health; and
- **Environmental**: protective of other environmental values.

An exceedance indicates an unacceptable risk to human health or the receiving environment. As a result, modelling assumptions could be refined and/or further mitigation measures considered.

The APAC adopted for the Proposed Fertiliser Facility AQOIA are shown in **Table 5.1**. The averaging time for the APAC adopted in the AQOIA are as follows:

- one hour or less are reported at the 99.9th percentile, otherwise it is reported at the 100th percentile;
- less than 24 hours are applied at or beyond the boundary of the Proposed Fertiliser Facility; and
- 24 hours or greater are applied at discrete sensitive locations.

Table 5.1 – APAC adopted for the AQOIA					
Indicator	**Category**	**Hazard / Endpoint**	**Objective (ppm)**	**Averaging Period (Percentile)**	**Maximum Exceedance Limit**
CO	Health-based	Criteria pollutant (ERS)	9.0	8 hours (100%)	1 day a year
NO_2	Health-based	Criteria pollutant (ERS)	0.12	1 hour (99.9%)	1 day a year
			0.03	1 year (100%)	None.
	Environmental	Terrestrial vegetation	0.02	1 year (100%)	N/A
SO_2	Health-based	Criteria pollutant (ERS)	0.20	1 hour (99.9%)	1 day a year
			0.08	1 day (100%)	1 day a year
			0.02	1 year (100%)	None.
	Environmental	Agricultural crops	0.01	1 year (100%)	N/A
		Natural vegetation	0.008	1 year (100%)	N/A
Odour	An air environment that is free from offensive odours from commercial, industrial, trade and domestic activities (ERS)			3 min [1.] (99.9%)	N/A

Table Notes:
[1] State of knowledge: 3 min averaging previously used for general odour design criteria in *State Environment Protection Policy (Air Quality Management) 2001*.

5.3 Meteorology

A meteorological dataset for five years from 1 January 2017 to 31 December 2021 was prepared by Air Quality Support (**AQS**) with data generated by The Air Pollution Model (**TAPM**) for the region and processed using the AERMET meteorological processor. The meteorological dataset is suitable to use as direct input to the AERMOD dispersion model. The AQS memorandum *Meteorological Dataset – Carrs Rd Anakie VIC* summarising the methodology and assumptions used for the generation of the dataset is provided in **Appendix A**.

5.4 Background Air Pollution

The poultry litter will be sourced from the existing broiler farms stockpile areas in the vicinity and moved to the Proposed Fertiliser Facility as feedstock for processing. Therefore, it is presumed that the change to the poultry background odour will be negligible in the vicinity of the Proposed Fertiliser Facility.

For the other key pollutants, TOU could not identify any representative sources of background air pollution monitoring data for the region surrounding Anakie. It is assumed that the key pollutants of concern have negligible background levels within a farming land use environment.

5.5 EMISSIONS ESTIMATION

5.5.1 Dryer Exhaust Biofilter System

For the AQOIA, it is assumed that the dryer exhaust air emission will be treated via a biofilter system with an estimated footprint area of approximately 25 m^2 (equivalent to a 40-foot shipping container) with a derived airflow of 6,200 m^3/h at 75 °C. The target performance of the biofilter is calculated to be 775 ou.m^3/s based on a treated odour concentration of 500 ou and a cooled air flow rate of 5,580 m^3/h at 40°C.

5.5.2 Solid Feedstock Bunkers

The solid feedstock bunkers will receive poultry litter and carbon-rich organic waste. A total of four 20 m by 5 m bunkers are proposed with combined footprint area of 400 m^2. It was assumed that the bunkers will be filled completely with poultry litter. A specific odour emission rate (**SOER**) was derived from odour monitoring conducted at Anakie Broiler Farm on 11 May 2018 organised by GHD and reported as odour emission rate (**OER**) per 1,000 birds in *Anakie Broiler Farm Odour Monitoring - Summary of Odour Monitoring* (Asimakis, 2018). The derivation of bunker SOER is provided in **Table 5.2**. It is assumed that the derived SOER is representative of dry and friable poultry litter. It is noted that uncovered poultry litter will be impacted by wet weather events, which could increase the emission results – this is not considered in the AQOIA.

Table 5.2 – Derived SOER for Solid Feedstock Bunkers

OER per 1000 birds	Total birds	Total OER (ou.m^3/s)	Shed area (m^2)	Derived SOER (ou.m^3/m^2.s)
530	42,500	22,525	2,850	7.9
500	42,500	21,250	2,850	7.5
510	42,500	21,675	2,850	7.6
500	42,500	21,250	2,850	7.5
640	42,500	27,200	2,850	9.5
Mean SOER				**8.0**

5.5.3 Biogas Flare

The biogas flare will burn off the excess methane and biogas of the Proposed Fertiliser Facility. The characterisation of the flare in the dispersion modelling are based on methods defined in the USEPA-approved SCREEN3 method (USEPA, 1992 and USEPA,1995), which considers the heat generated from the flame tip. The following assumptions were applied in the AQOIA for the Proposed Fertiliser Facility:

- It will be in constant operation. In practice, it will operate very rarely (as per the advice provided by Pavilion Farms, it is expected to operate less than 5% of the time). However, it is not possible to know the exact future times and durations the flare will be operating. This conservative assumption will ensure that all possible meteorological hours that the flare could operate under are examined by the modelling;

- Exhaust gas or plume temperature (post-combustion) is 1,000 °C (1,273 K);

- Exhaust gas exit velocity is 20 m/s;

- The biogas flare will be specified to best available technology and techniques to the effect that it will operate in a smokeless condition;

- The effective height of the flare stack (i.e. the height of the flare tip) is calculated to account for the flare combustion zone and the initial plume rise characteristics; and

- The effective diameter is calculated to match the effects of flare combustion zone and the initial plume rise characteristics assuming the plume is bent over by the wind by 45° from the vertical.

The effective flare stack height was determined from the actual physical stack tip height to the top of the combustion zone and the flare flame. The effective stack height was calculated using the following equation based on the US EPA SCREEN3 approach:

$$h_{eff} = h_{nom} + 0.00456\left(\frac{q_{out} * 10^6 * H_r}{4..1868}\right)^{0.0478}$$

Where:

h_{eff}	Effective stack height in meters
h_{nom}	Nominal stack height in meters
q_{out}	Peak energy out in MJ/s
H_r	Heat generated in J/s (SCREEN3 default value of 0.45 J/s)

The effective stack diameter was calculated using the equation detailed in the SAEP-340, dependent on the net heating value for the flares. The effective diameter accounts for the assumption that the flame may be bent over to a 45° angle, providing for a potential worst-case plume extent of the flare. The effective diameter for the flare was calculated using the following equation:

$$D = \sqrt{(10^6 q_n)}$$

Where:

D	effective diameter (m)
q_n	$q\left[1 - 0.048\sqrt{MW}\right]$
q	gross heat release in cal/sec
MW	Molecular weight of the feed gas

The composition of the biogas is detailed in **Table 5.3**, while the operations data used to estimate emissions from emergency flare operations are detailed in **Table 5.5**. The emission rates were estimated using recognised and accepted methods of emissions estimation, which includes emission factors and emission rates published in the USEPA AP42 emission handbooks for Industrial Flares (US EPA, 2018). The emission factors are detailed in **Table 5.6**. The USEPA AP42 document does not include an emissions factor for SO_2, which will only occur if the feed gas contains sulphur and/or sulphur compounds, including H_2S. A mass balance approach was used to estimate SO_2

emissions, assuming all the sulphur present is oxidised and emission through the combustion process. The molecular weights of the relevant compounds are detailed in **Table 5.4**.

Table 5.3 – Supplied feed gas composition by Pavilion Farms				
Parameter	**Volumetric Composition (%)**	**Molecular Weight (g/mol)**	**LHV Net heating value (BTU/lb)**	**LHV contribution (kJ/kg)**
CH_4	60	16.04	21,540	12,920
CO_2	39	44.01	-	-
Oxygen (O_2)	0.5	32.0	-	-
Argon (Ar) [1]	0.245	39.95	-	-
Nitrogen (N_2) [1]	0.245	28.02	-	-
H_2S	0.01	34.08	6,550	1

Table Notes:
[1] Argon and nitrogen are available in trace amounts, assumed to be equally proportional in volume contribution

Table 5.4 – Molecular weight of compounds used in emissions estimation		
Substances	**Units**	**Emission Factor**
sulphur	g/mol	32.1
H_2S	g/mol	34.1
SO_2	g/mol	64.1

Table 5.5 – Supplied operational data for biogas flare operations		
Parameter	**Units**	**Value**
Biogas volume flow rate	m³/h m³/s	1,250 0.35
Gas molecular weight	g/mol	27.1
Gas density [1]	kg/m³	1.21
Lower Heating Value (LHV) [1]	MJ/m³	16
Energy out	MJ/s	5.4
Nominal stack height	m	8.5
Effective stack height [2]	m	11.1
Effective diameter [2]	m	1.1
Exit velocity [2]	m/s	20
Stack temperature [2]	°C K	1,000 1,273
Emission rates:		
NO_X	g/s	0.159
CO	g/s	0.724
SO_2	g/s	0.099

Table Notes:
[1] Estimated based on the gas composition detailed in **Table 5.3** in Section 5 of the AQOIA.
[2] Effective stack dimensions consider the heat generated from the flame, estimated using USEPA-approved SCREEN3 method (USEPA, 1992 and USEPA,1995)
[3] NO_X and CO emission rates estimated based on emission factors detailed in USEPA AP42 Chapter 13.2.5 (USEPA, 2018), detailed in Table 5.6.
[4] SO_2 emission rates estimated using a mass balance approach based on the molecular weight of sulphur and relative contribution to molecular weight of H_2S and SO_2.

Table 5.6 – Proposed Fertiliser Facility: Emission factors for industrial flares		
Substances	**Units**	**Emission Factor**
NO_X	lb/10^6 BTU	0.068
	g/GJ	29.2
CO	lb/10^6 BTU	0.31
	g/GJ	133.3
PM	µg/L	0 [1]

Table Notes:
[1] Particulate matter emission factor is based on soot emissions defined in USEPA AP 42 Chapter 13.5 Table 13.5-1, which range from 0 to 274 µg/L. Smokeless flares have a demission factor of 0 µg/L.

5.5.4 CHP Generators

The operating parameters used in the dispersion modelling study are summarised in **Table 5.7**. The emission rate of NO_X and CO are from data contained within the technical specifications of the CHP generators, detailed in **Table 5.7**. SO_2 emission rates were estimated using a mass balance approach based on the molecular weight of sulphur and relative contribution to the molecular weight of H_2S and SO_2 in the feed gas composition as detailed in **Table 5.3**. Molecular weights of the relevant compounds are detailed in **Table 5.4**.

Table 5.7 – Proposed Fertiliser Facility: Operational data for the CHP generators		
Parameter	**Units**	**P4016-TRS2**
Assumed operations	days/year hours/day	365 24
Efficiency	%	96
Engine capacity	kW	1,042
Output	MWh GJ	9,128 32,861
Actual flow rate [1]	m³/min	207
Exit velocity [2]	m/s	15
Stack temperature	°C	468
Stack diameter [2]	m	0.54
Stack height	m	5
NO_X limit	mg/Nm³	480
CO limit	mg/Nm³	870
Normalised flow rate	Nm³/hr	30,874
Derived emission rates		
NO_X [3]	g/s	4.117
CO [4]	g/s	7.461
SO_2 [5]	g/s	0.0183

Table Notes:
[1] At STP, standard temperature assumed to be 25°C.
[2] Assumed based on similar studies.
[3] Estimated based on NO_X emissions data provided by the manufacturer.
[4] Estimated based on CO emissions data provided by the manufacturer.
[5] SO_2 emission rates estimated using a mass balance approach based on the molecular weight of sulphur and relative contribution to molecular weight of H_2S and SO_2, as detailed in **Table 5.4**.

5.5.5 Boiler Operations

The operating parameters of the boiler are summarised in **Table 5.8**. The emissions of NO_X, and CO and SO_2 are based on emission factors detailed in the National Pollutant Inventory (**NPI**) Emission Estimation Technique (**EET**) Manual for combustion in boilers (AG, 2011). These are detailed in **Table 5.9**.

SO_2 emission rates were estimated using a mass balance approach based on the molecular weight of sulphur and relative contribution to the molecular weight of H_2S and SO_2 in the feed gas composition as detailed in **Table 5.3**. Molecular weights of the relevant compounds are detailed in **Table 5.4**.

It is conservatively assumed the boiler will be in constant operation. In practice, it will operate only on start-up and emergency less than 5% of the time (as per the advice by Pavilion Farms). However, it is not possible to know the exact future times and durations the boiler will be operating. The assumption will ensure that all possible meteorological hours that the boiler could operate under are examined by the modelling.

It is assumed that the e-boiler does not have an emission release to air given its inherent design function.

Table 5.8 – Operational data for the boiler

Parameter	**Units**	**Boiler**
Assumed operations	days/year hours/day	365 24
Efficiency	%	100
Engine capacity	kW	812
Output	MWh GJ	7,110 25,600
Actual flow rate	m^3/hr	4,700
Exit velocity [1]	m/s	10
Stack temperature [1]	°C	70
Stack height [1]	m	5
Stack diameter [1]	m	0.33
Emission rates:		
NO_X [2]	g/s	0.067
CO [2]	g/s	0.010
SO_2 [3]	g/s	0.0148

Table Notes:
[1] Assumed based on similar studies.
[2] Estimated based on NO_X limit as provided by the manufacturer.
[3] SO_2 emission rates estimated using a mass balance approach based on the molecular weight of sulphur and relative contribution to molecular weight of H_2S and SO_2, as detailed in Table 5.3.

Table 5.9 – Emission factors for natural gas combustion – boiler

Substances	**Units**	**Emission Factor**
NO_X	kg/GJ	8.28E-02
CO	kg/GJ	1.17E-02

5.6 Key Modelling Configurations

The key features of the AERMOD model used to simulate dispersion attributed to the operation of the proposed boiler system at the Proposed Fertiliser Facility include:

- modelling period of five years from 1 January 2017 to 31 December 2021;
- model domain covered an area of approximately 5 km x 5 km (101 x 101 grids at 50-m grid spacing);
- model domain centred on the proposed site;
- biofilter, flare, CHP and boiler modelled as point sources;
- solid feedstock bunkers modelled using volume source approximation as adjacent volume sources;
- building wake effects were accounted for using Building Profile Input Program (**BPIP**) Prime algorithms; and
- AERMOD processed in rural mode and pollutant concentrations predicted on identified sensitive receptors and uniform gridded receptors.

5.6.1 Volume Source Approximation of Area Sources

AERMOD concentration predictions for area sources in the current approved version are likely to be overestimated under very light wind conditions. As per *Section 6.2* of the *AERMOD Implementation Guide (2022)* and EPA Victoria's recommendation in Publication 1551, TOU has adopted the interim US EPA approach for cases when the key receptors are sufficiently distant from the source.

5.6.2 Modelled Source Parameters

The source parameters used in characterising the biofilter are detailed in **Table 5.10**, for the flare, CHP & boiler in **Table 5.11**, and the solid feedstock bunkers in **Table 5.12**. The source locations and illustration of the major structures and point sources in BPIP configuration are presented in **Figure 5.1** and **Figure 5.2,** respectively.

Table 5.10 – Source parameters for dispersion modelling of the biofilter

Parameter	Units	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
Type	-	Point	Point	Point	Point	Point
Easting *	m	262989.4	262991.6	262993.9	262996.1	262998.3
Northing *	m	5795266.3	5795266	5795265.7	5795265.5	5795265.2
Elevation	m	109.37	109.33	109.28	109.24	109.2
Stack height	m	2.6	2.6	2.6	2.6	2.6
Stack diameter	m	2.54	2.54	2.54	2.54	2.54
Exit velocity	m/s	0.0611	0.0611	0.0611	0.0611	0.0611
Stack temp	K	313.15	313.15	313.15	313.15	313.15

* WGS84 UTM Zone 55S

Table 5.11 – Source parameters for dispersion modelling of flare, CHP & boiler					
Parameter	**Units**	**CHP 1**	**CHP 2**	**Flare**	**Boiler**
Type	-	Point	Point	Point	Point
Easting *	m	262938.5	262967.7	262944.3	262937.3
Northing *	m	5795178	5795174.4	5795200.8	5795185.8
Elevation	m	107.02	107.8	106.88	106.72
Stack height	m	5	5	11.1	5
Stack diameter	m	0.54	0.54	0.99	1.00
Exit velocity	m/s	15	15	20	10
Stack temp	K	741.15	741.15	1,273	343.15

* WGS84 UTM Zone 55S

Table 5.12 – Source parameters for dispersion modelling of solid feedstock bunkers					
Parameter	**Units**	**Bunker 1a**	**Bunker 1b**	**Bunker 1c**	**Bunker 1d**
Type	-	Volume	Volume	Volume	Volume
Easting *	m	262956.8	262951.8	262946.8	262941.9
Northing *	m	5795266.7	5795267.3	5795267.9	5795268.5
Elevation	m	108.78	108.64	108.53	108.45
Release height	m	1	1	1	1
Sigma Y	m	2.326	2.326	2.326	2.326
Sigma Z	m	0.93	0.93	0.93	0.93
Parameter	**Units**	**Bunker 2a**	**Bunker 2b**	**Bunker 2c**	**Bunker 2d**
Type	-	Volume	Volume	Volume	Volume
Easting *	m	262956.2	262951.2	262946.2	262941.3
Northing *	m	5795261.7	5795262.3	5795262.9	5795263.5
Elevation	m	108.6	108.45	108.38	108.32
Release height	m	1	1	1	1
Sigma Y	m	2.326	2.326	2.326	2.326
Sigma Z	m	0.93	0.93	0.93	0.93
Parameter	**Units**	**Bunker 3a**	**Bunker 3b**	**Bunker 3c**	**Bunker 3d**
Type	-	Volume	Volume	Volume	Volume
Easting *	m	262955.6	262950.6	262945.6	262940.7
Northing *	m	5795256.7	5795257.3	5795257.9	5795258.6
Elevation	m	108.41	108.26	108.22	108.2
Release height	m	1	1	1	1
Sigma Y	m	2.326	2.326	2.326	2.326
Sigma Z	m	0.93	0.93	0.93	0.93
Parameter	**Units**	**Bunker 4a**	**Bunker 4b**	**Bunker 4c**	**Bunker 4d**
Type	-	Volume	Volume	Volume	Volume
Easting *	m	262954.9	262950	262945	262940.1
Northing *	m	5795251.8	5795252.4	5795253	5795253.6
Elevation	m	108.22	108.08	108.08	108.08
Release height	m	1	1	1	1
Sigma Y	m	2.326	2.326	2.326	2.326
Sigma Z	m	0.93	0.93	0.93	0.93

* WGS84 UTM Zone 55S

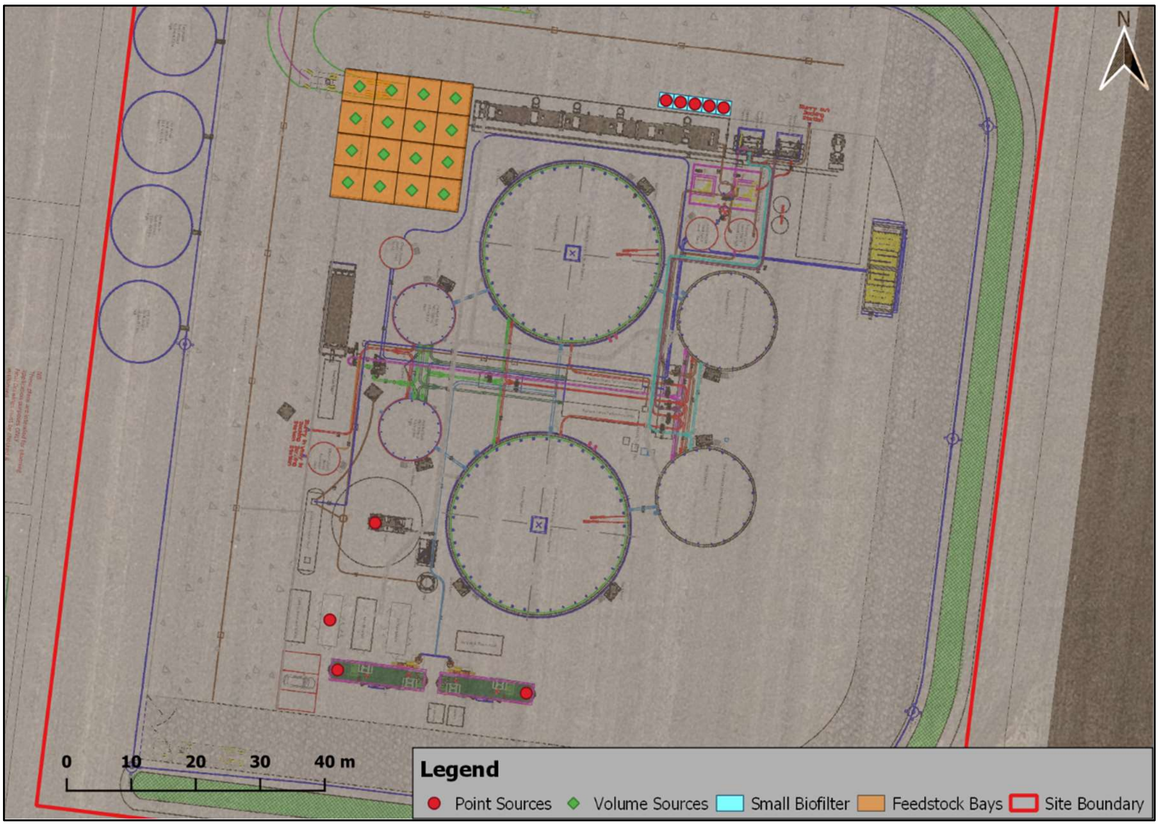


Figure 5.1 – Modelled source locations

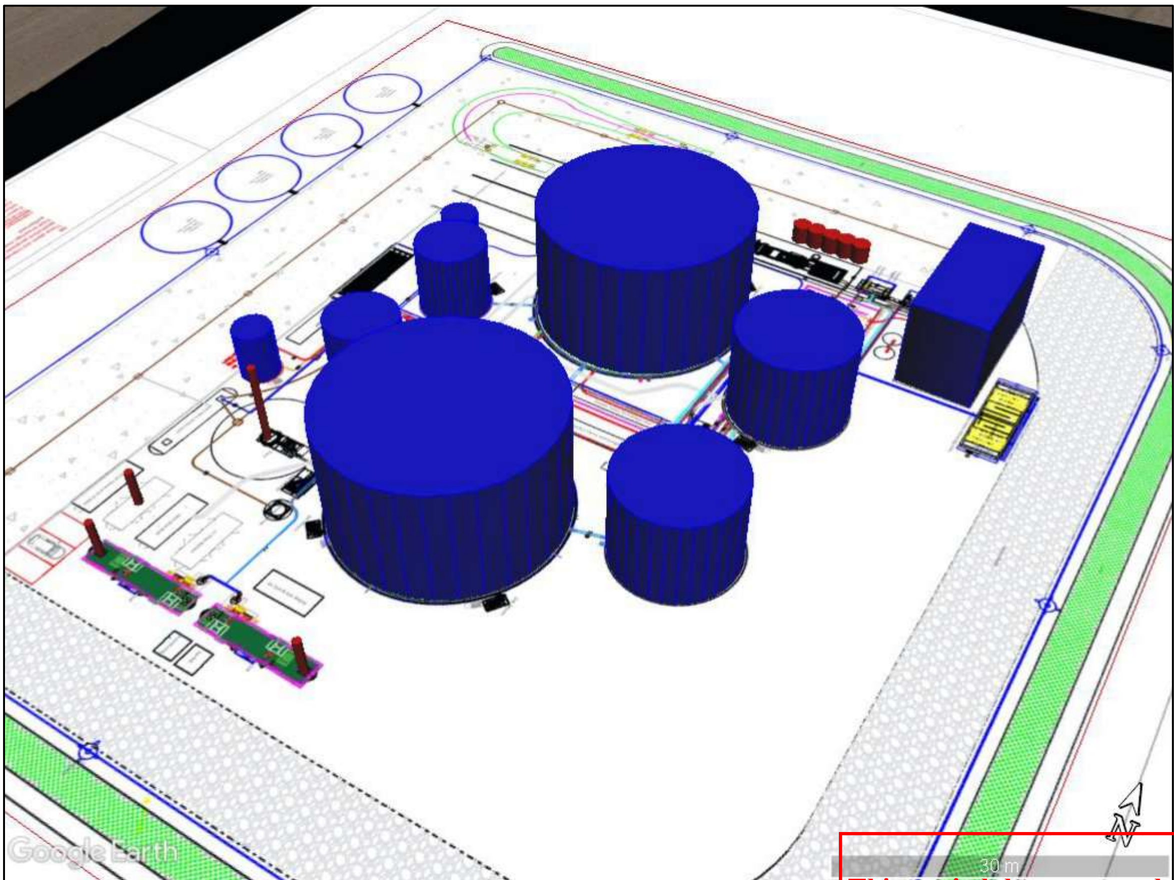


Figure 5.2 – BPIP configuration of major structures and point sources

5.6.3 Discrete Receptor Parameters

The modelled discrete receptor and site boundary receptor locations and parameters are provided in **Table 5.13** and **Figure 5.3**. The site boundary receptors were spaced at 25 m intervals.

Table 5.13 – Discrete receptor locations and parameters

Location	ID	Easting* (m)	Northing* (m)
420 Carrs Road Anakie 3213	1	262918.5	5796258.1
345 Carrs Road Anakie 3213	2	263824.4	5796080.3

* WGS84 UTM Zone 55S

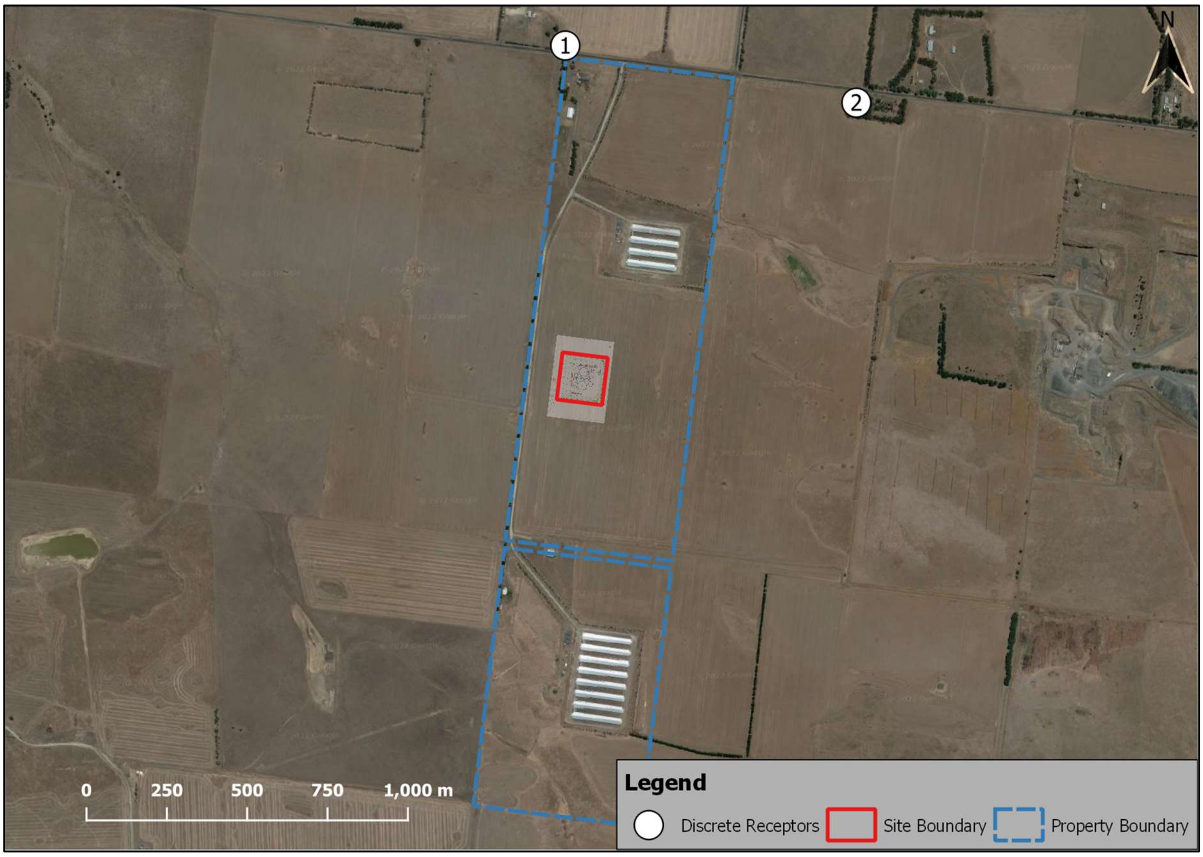


Figure 5.3 – Location of discrete receptors and site boundary receptors

5.6.4 Conversion of Nitric Oxide to Nitrogen Dioxide

The formation of oxides of nitrogen, including nitrogen dioxide, is a multi-step process that depends on the atmospheric conditions at the time of emissions. After release from the stack, nitric oxide (**NO**) gradually oxidises to form NO_2. The degree and extent of conversion is determined by several factors, which include:

- initial combustion conditions at the source and the fuel being burned;
- ambient concentration of nitrogen oxides and nitrogen dioxide in the plume at combustion;
- presence of sunlight;

- presence of other atmospheric substances such as ozone and volatile organic compounds;
- distance and duration of plume transport; and
- dispersion conditions.

A study by Bofinger et al. (1986) estimated that a NO to NO_2 conversion rate of 25% to 40% can occur within the first 10 km of plume travel, based on measurements around power stations. The elevated background levels of hydrocarbons, which may originate from bushfires, may increase the conversion rate to 50% within the first 30 km of plume transport.

For the AQOIA at the Proposed Fertiliser Facility, a conversion factor of 30%, based on empirical values, was applied (Katestone, 2017). This conversion rate is still considered relatively conservative, considering the low background levels of ozone and other reactive pollutants in the region. Furthermore, the short distance between the sources and the receptors translate to a shorter conversion period.

5.6.5 Extrapolation to 3-minute Averages

The ground-level concentrations of pollutants are predicted for every hour of modelling. For the assessment of pollutants where the criteria are for averaging periods less than one hour, concentrations are extrapolated using the power law equation (Turner, 1970). This approach is consistent with the method defined in the model guidance document for AERMOD (EPA VIC, 2015). In equation form, the power law equation is defined as:

$$C_t = C_r \left(\frac{r}{t}\right)^p$$

where:

C_t	Concentration predicted at extrapolated period
C_r	Concentration at reference period
t	Period for extrapolation (3-minutes)
r	Reference period (1-hour)
p	profile exponent (0.2)

5.7 MODELLING PREDICTION RESULTS

The predicted concentrations at the modelled discrete and site boundary receptors compared with the corresponding APAC is provided in **Table 5.14**. The model contour plots are presented as follows:

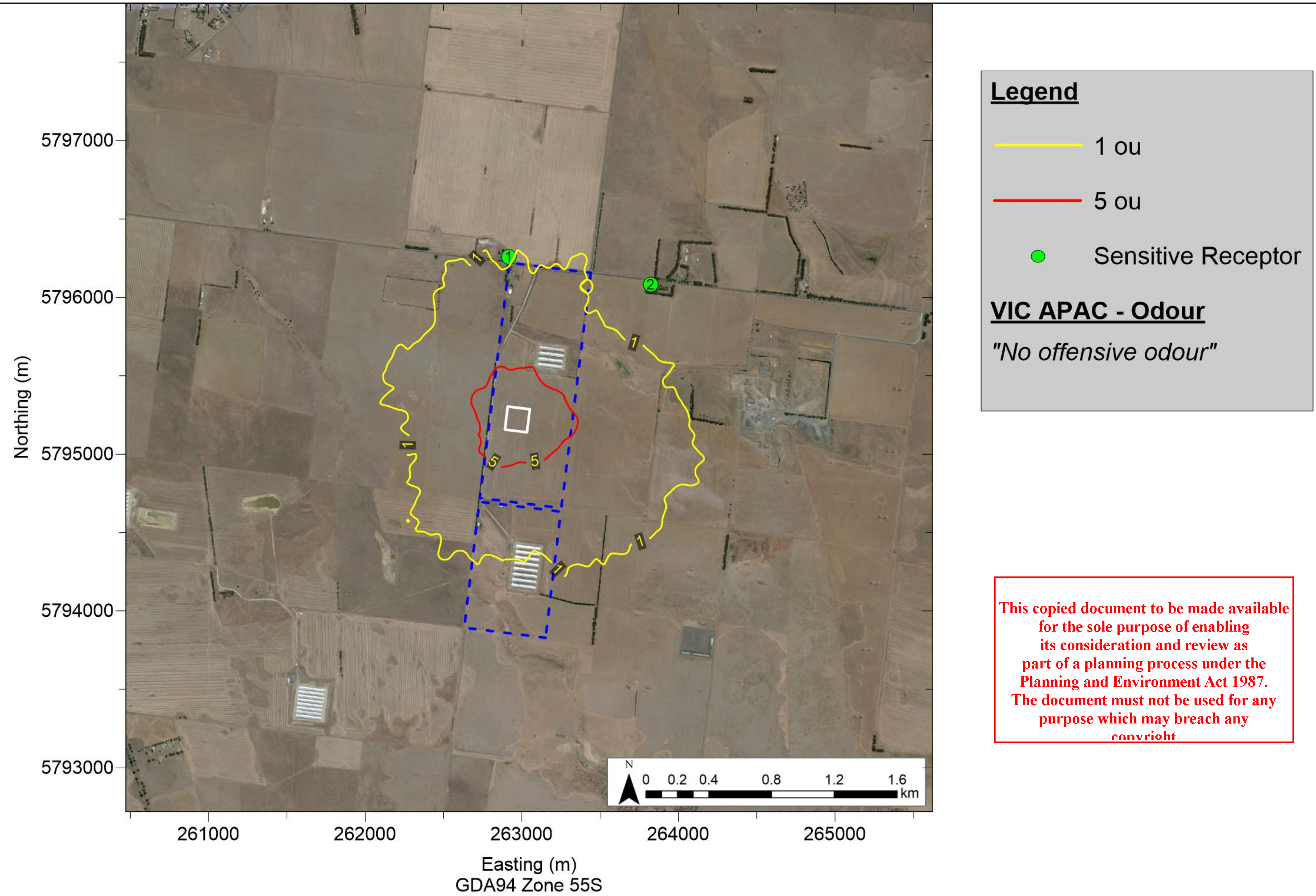
- **Figure 5.4** – Predicted Odour Impact (99.9%, 3 min);
- **Figure 5.5** – Predicted CO Impact (100%, 8 h);
- **Figure 5.6** – Predicted NO2 Impact (99.9%, 1 h);
- **Figure 5.7** – Predicted NO2 Impact (100%, 1 y);
- **Figure 5.8** – Predicted SO2 Impact (99.9%, 1 h);

- **Figure 5.9** – Predicted SO2 Impact (100%, 1 d); and
- **Figure 5.10** – Predicted SO2 Impact (100%, 1 y).

The modelling prediction show that all APAC are satisfied except for short-term NO_2 prediction of 0.3 ppm (99.9%, 1 h), which exceeds the APAC of 0.12 ppm (99.9%, 1 h) at and beyond the boundary of the Proposed Fertiliser Facility. It is noted that the exceedance is largely contained within the property boundary. In the case of odour, the contour presents the baseline predicted ground level concentrations based on the design assumptions and configurations documented in **Section 6.1.2.2**.

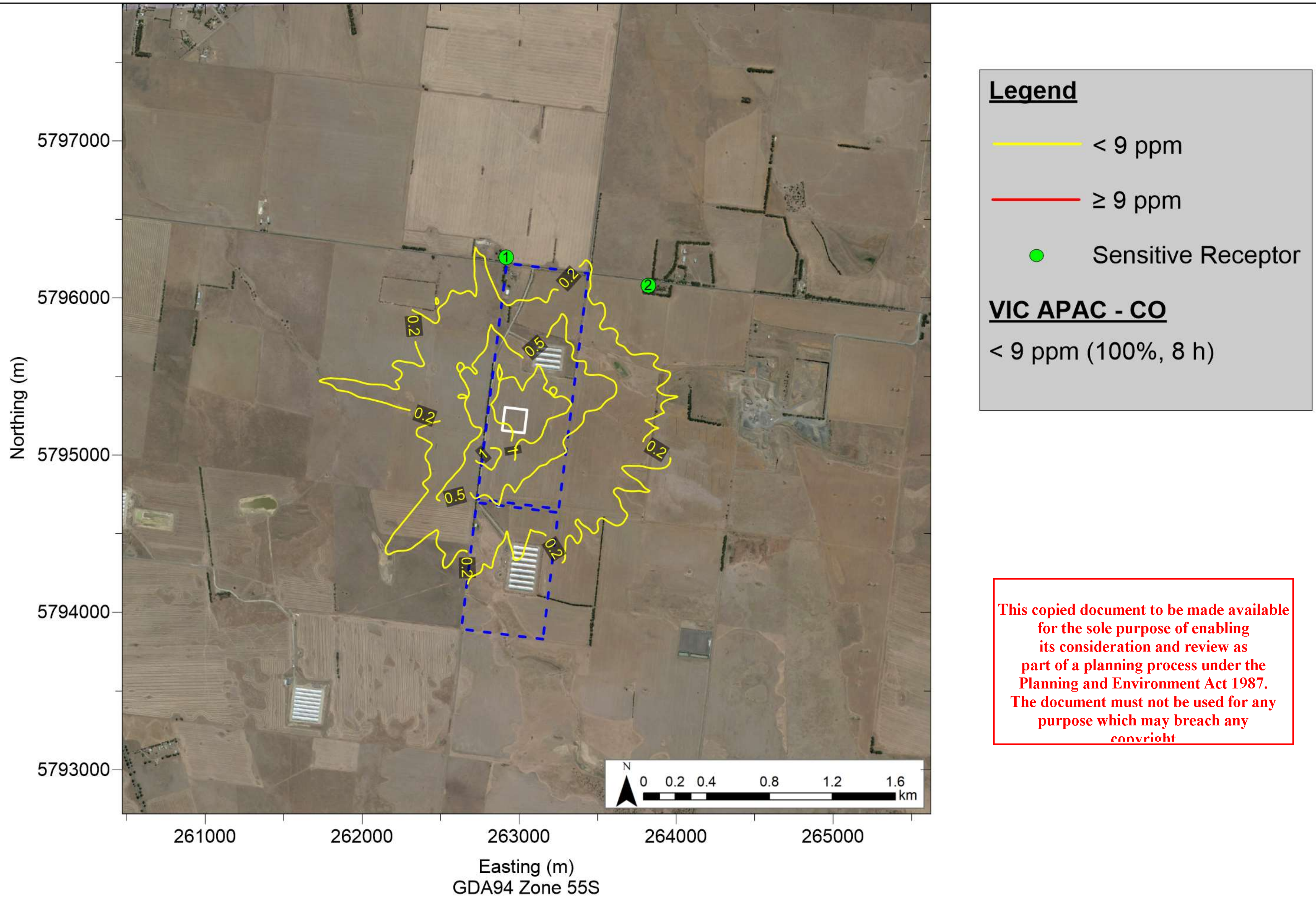
Table 5.14 – Predicted concentrations (ppm) at discrete receptor and at or beyond site boundary locations							
Receptor	**Odour (99.9%. 3 min)**	**CO (100%, 8 h)**	**NO_2 (99.9%, 1 h)**	**NO_2 (100%, 1 y)**	**SO_2 (99.9%, 1 h)**	**SO_2 (100%, 1 d)**	**SO_2 (100%, 1 y)**
1	0.93	0.1125	0.0156	0.0003	2.74E-04	1.15E-04	7.95E-06
2	0.62	0.0935	0.0140	0.0003	2.68E-04	1.26E-04	6.43E-06
Site boundary	54	2.5020	0.2989	n/a	0.0051	n/a	n/a
No. of days exceeded	n/a	0	174	n/a	0	n/a	n/a
APAC (Health)	n/a	< 9.0*	< 0.12*	< 0.03	< 0.20*	< 0.08	< 0.02
APAC (Ter. Veg.)	*n/a*	*n/a*	*n/a*	*< 0.02*	*n/a*	*n/a*	*n/a*
APAC (Ag. Crops)	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*< 0.01*
APAC (Nat. Veg.)	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*< 0.008*

* Maximum limit of days with exceedances = 1 day



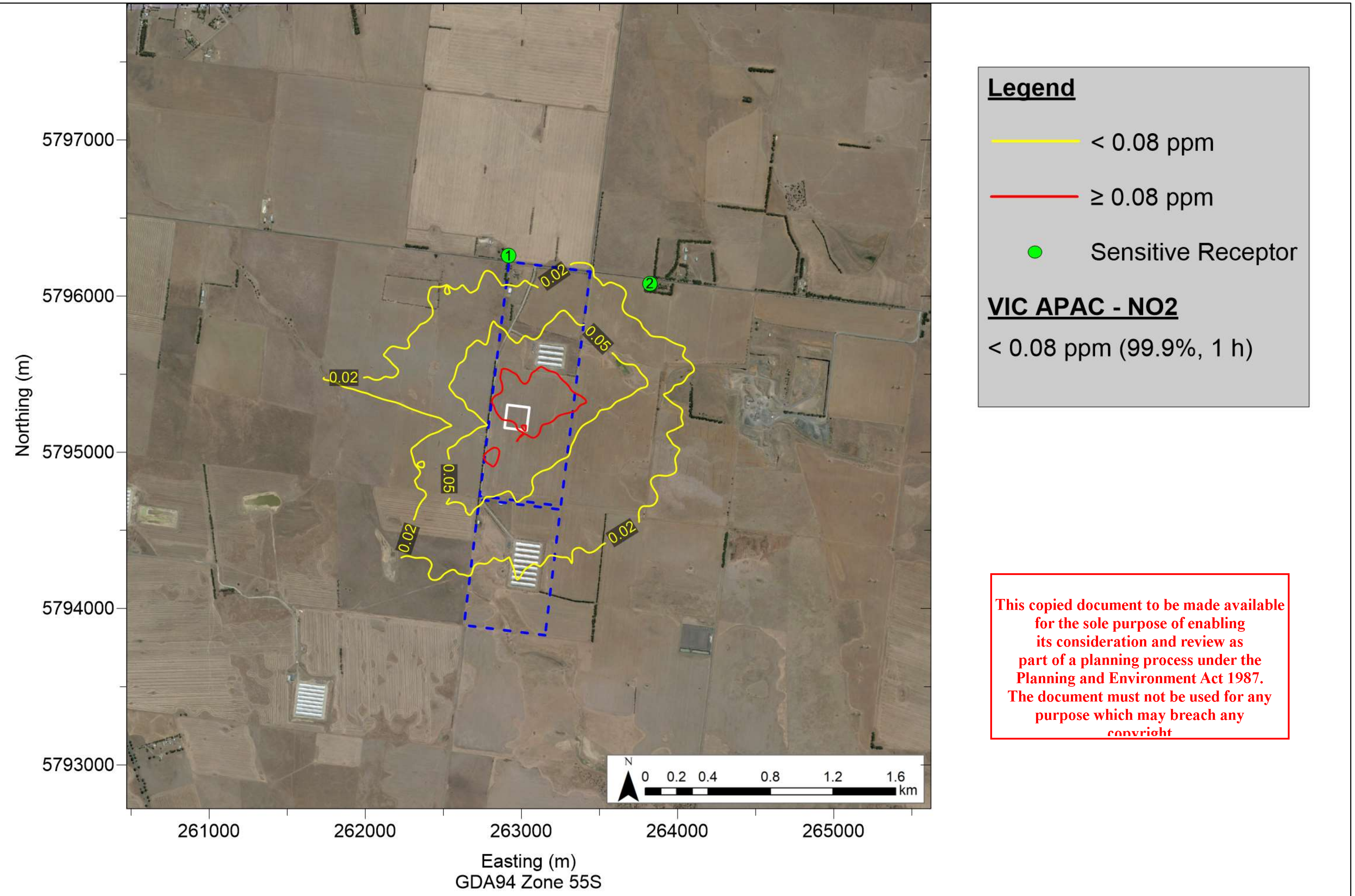
AERMOD Modelling System **Pavilion Biogas Pty Ltd** **Modelled by: AQS 03/08/22** **Checked by: S. Hayes 03/08/22**	**Pavillion Farms** **Proposed Fertiliser Facility** **Predicted Odour Impact**	**Run03 - Baseline as proposed for comparison** **Ground level odour concentrations (ou, 99.9%, 3 min)** **Contour levels as indicated** **2017 - 2021 meteorology**

Figure 5.4 – Predicted Odour Impact (99.9%, 3 min)



AERMOD Modelling System Pavilion Biogas Pty Ltd Modelled by: AQS 03/08/22 Checked by: S. Hayes 03/08/22	**Pavillion Farms Proposed Fertiliser Facility Predicted CO Impact**	**Run03 - Baseline as proposed for comparison Ground level CO concentrations (ppm, 100%, 8 h) Contour levels as indicated 2017 - 2021 meteorology**

Figure 5.5 – Predicted CO Impact (100%, 8 h)



AERMOD Modelling System Pavilion Biogas Pty Ltd Modelled by: AQS 03/08/22 Checked by: S. Hayes 03/08/22	**Pavillion Farms** **Proposed Fertiliser Facility** **Predicted NO_2 Impact**	Run03 - Baseline as proposed for comparison Ground level NO_2 concentrations (ppm, 99.9%, 1 h) Contour levels as indicated 2017 - 2021 meteorology

Figure 5.6 – Predicted NO_2 Impact (99.9%, 1 h)

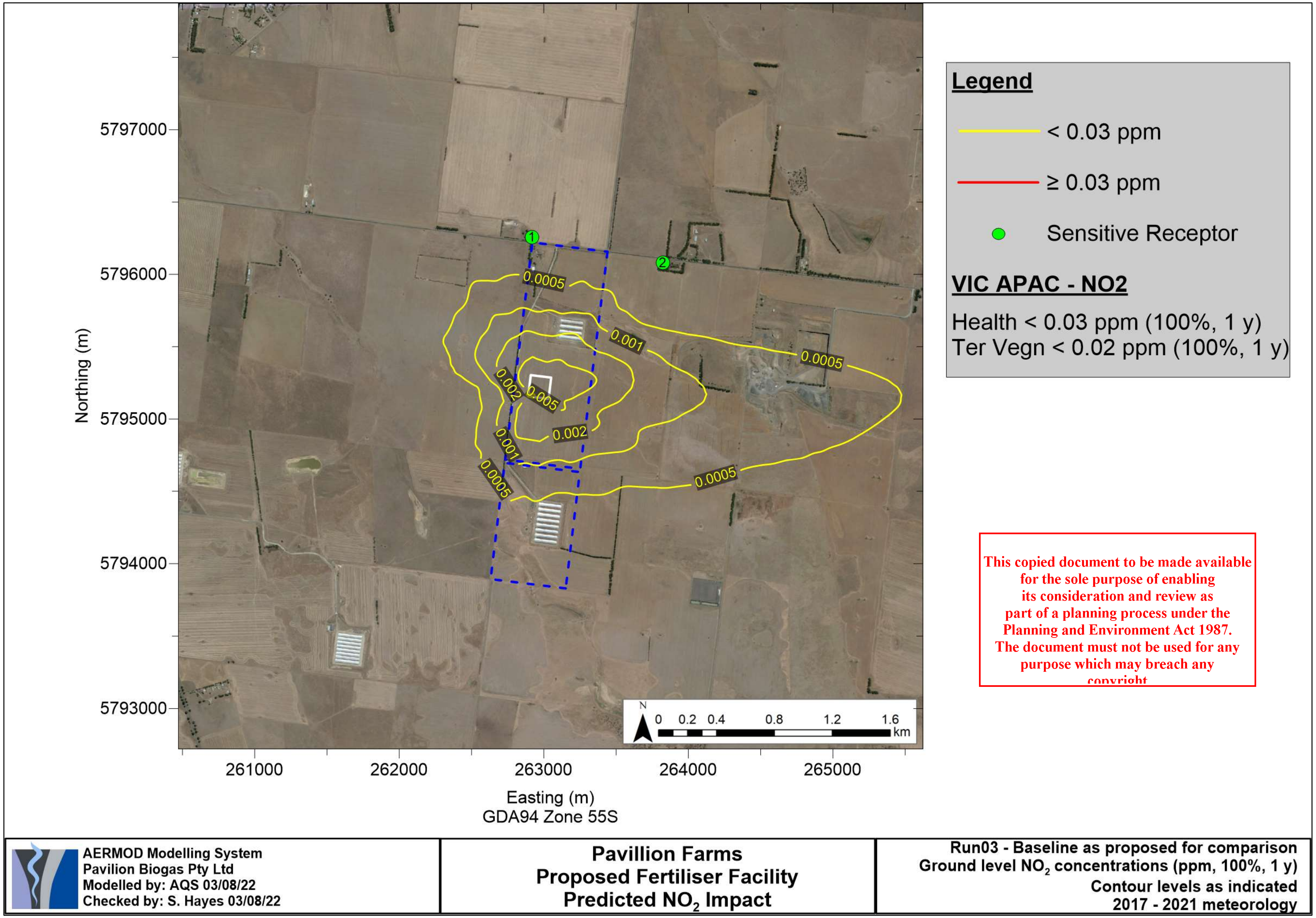
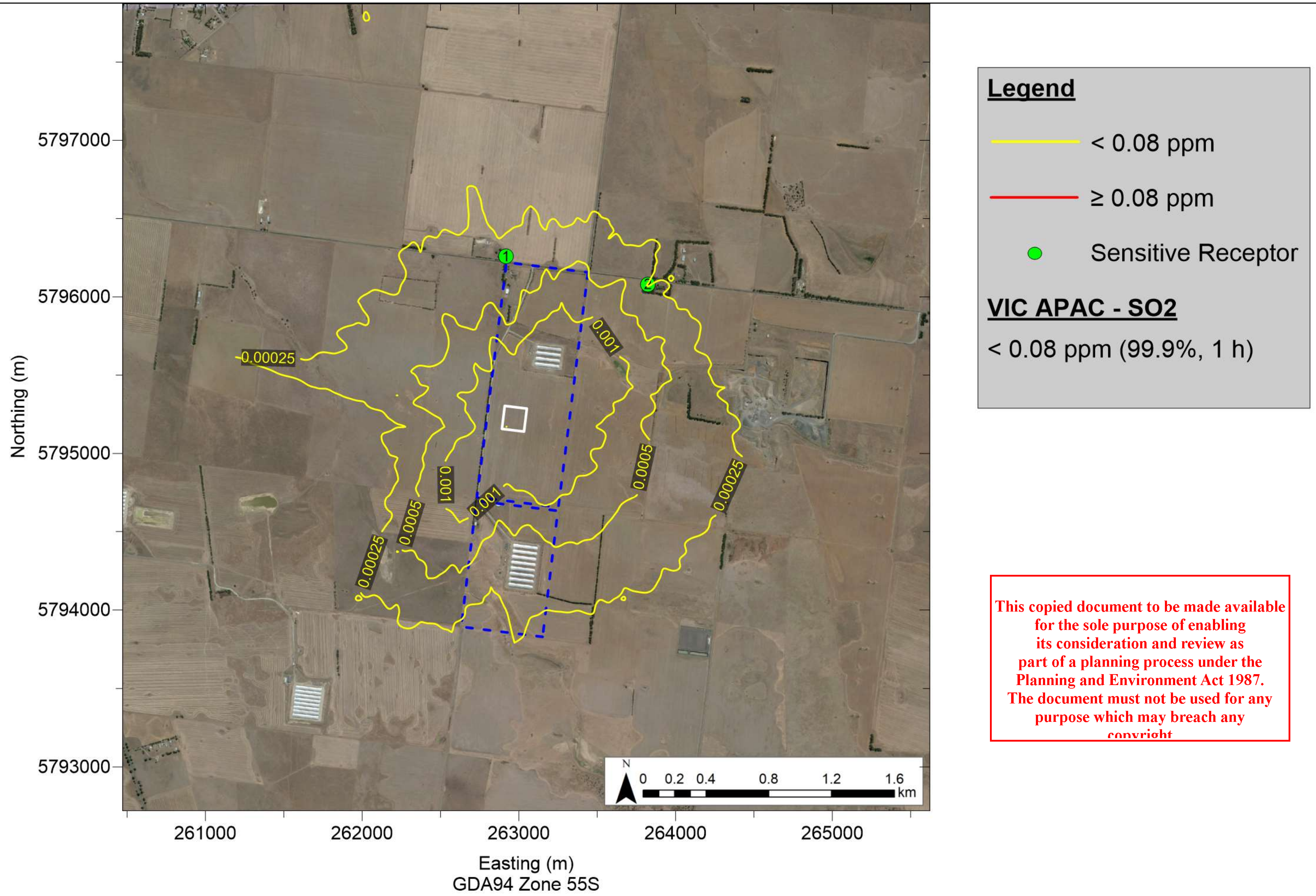
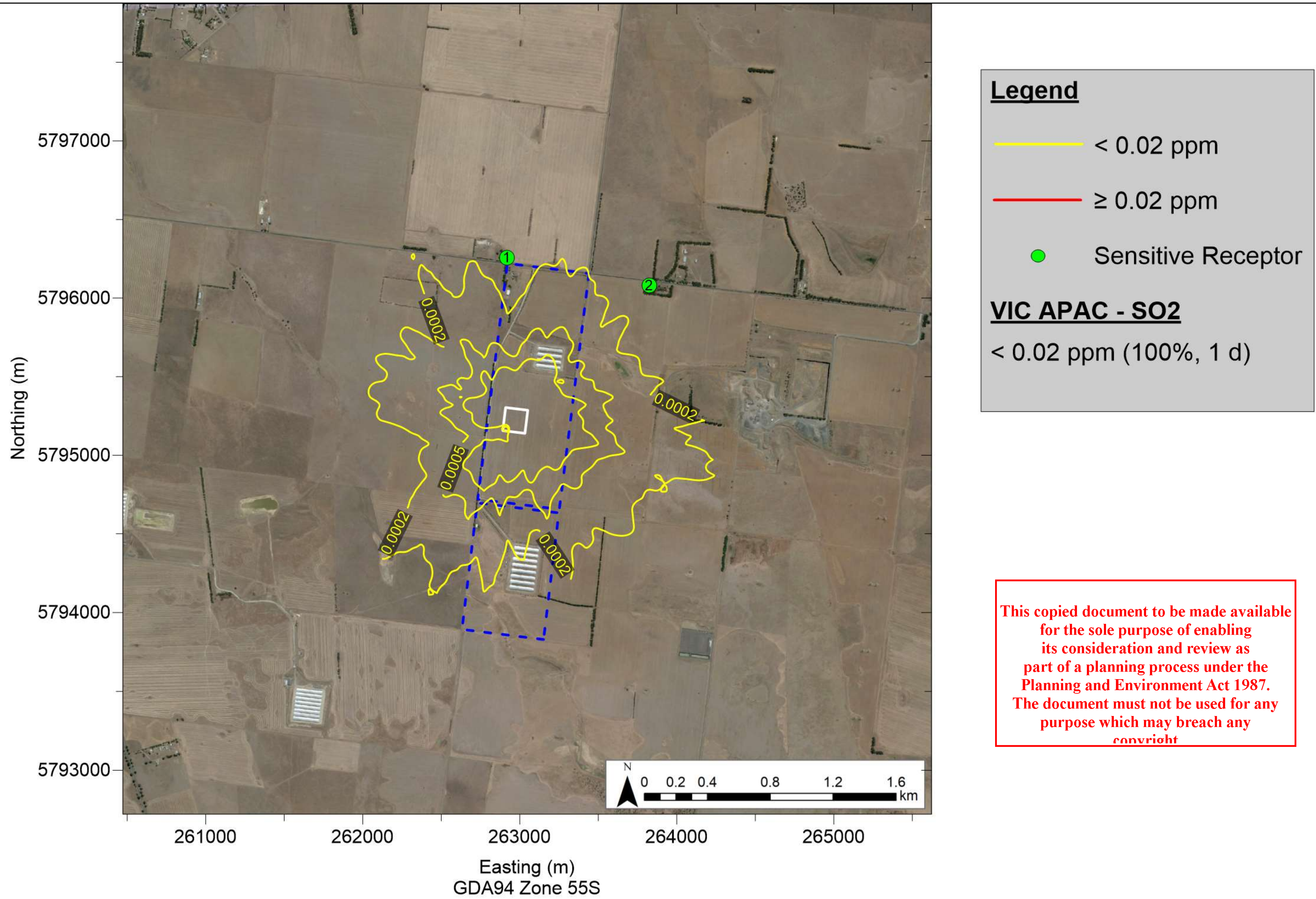


Figure 5.7 – Predicted NO_2 Impact (100%, 1 y)



AERMOD Modelling System Pavilion Biogas Pty Ltd Modelled by: AQS 03/08/22 Checked by: S. Hayes 03/08/22	**Pavillion Farms** **Proposed Fertiliser Facility** **Predicted SO_2 Impact**	**Run03 - Baseline as proposed for comparison** **Ground level SO_2 concentrations (ppm, 99.9%, 1 h)** **Contour levels as indicated** **2017 - 2021 meteorology**

Figure 5.8 – Predicted SO_2 Impact (99.9%, 1 h)



AERMOD Modelling System Pavilion Biogas Pty Ltd Modelled by: AQS 03/08/22 Checked by: S. Hayes 03/08/22	Pavillion Farms Proposed Fertiliser Facility Predicted SO_2 Impact	Run03 - Baseline as proposed for comparison Ground level SO_2 concentrations (ppm, 100%, 1 d) Contour levels as indicated 2017 - 2021 meteorology

Figure 5.9 – Predicted SO2 Impact (100%, 1 d)

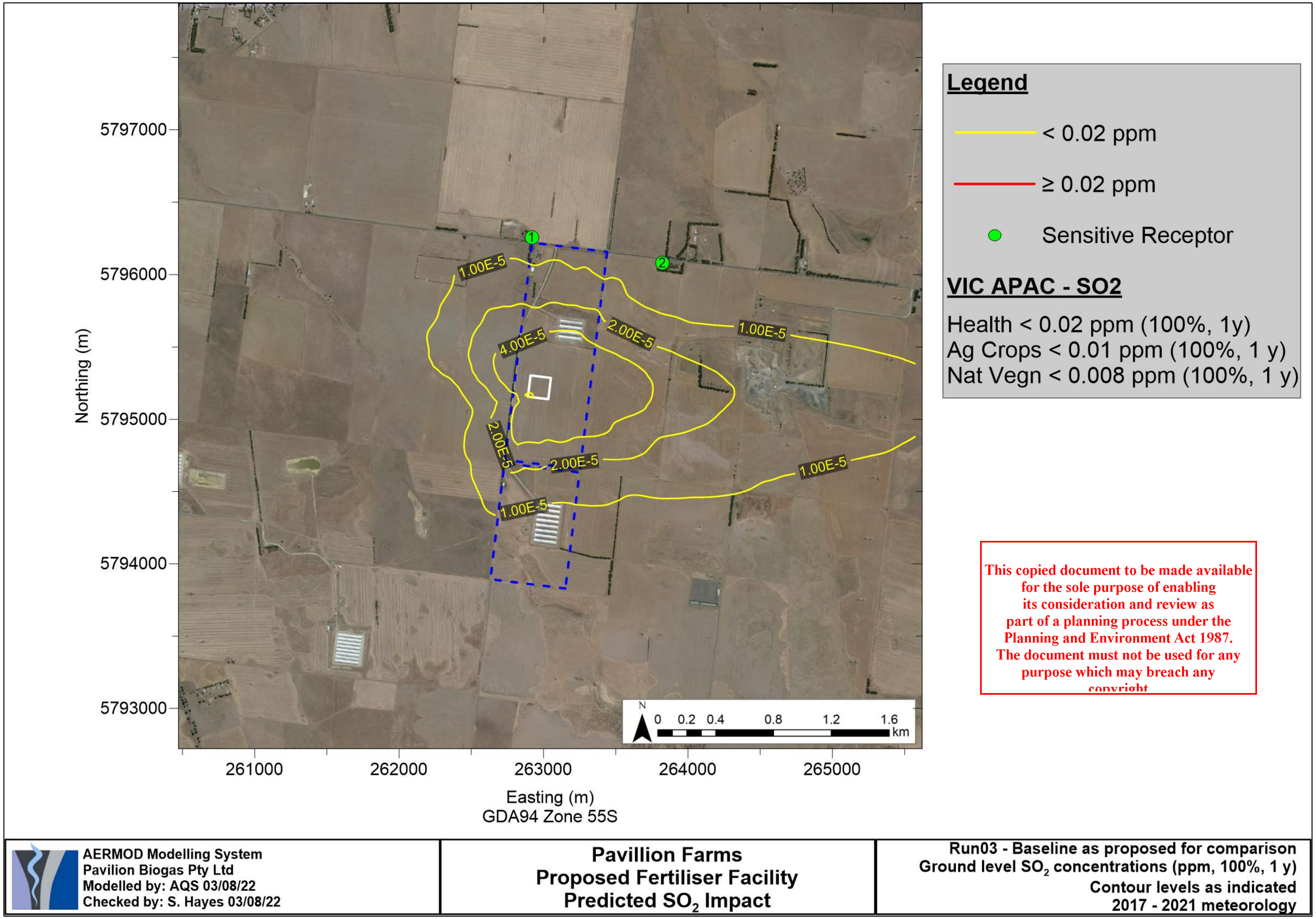


Figure 5.10 – Predicted SO_2 Impact (100%, 1 y)

6 FINDINGS AND RECOMMENDATIONS

The following section provides the key findings and recommendations based on the outcomes documented in **Section 3**, **Section 4** and **Section 5** of the Technical Review and AQOIA.

6.1 TECHNICAL REVIEW AND AQOIA FINDINGS

6.1.1 Locality Analysis

The Proposed Fertiliser Facility is identified to be located at a sufficient distance from nearby sensitive receptors, the closest being approximately 975 m away. This separation distance will be suitable to address atypical/upset scenarios whereby there is an unintended failure of equipment, spillage, uncontrolled or accidental release of emissions or other unforeseen circumstances that may affect the efficacy of the incorporated air quality and odour controls and management practices at the Proposed Fertiliser Facility.

6.1.2 Identified Sources of Air Quality and Odour Emissions

The key sources that are likely to pose an air quality and odour emission risks, collectively or individually, are as follows (categorised as combustion and non-combustion gas emission sources):

- Solid feedstock storage bunkers (non-combustion gases emission source);
- Dried & separated product storage (non-combustion gases emission source);
- Buffer process material storage (non-combustion gases emission source);
- Slurry dryer process (non-combustion gases emission source);
- Particle size reduction process of the input feedstock and digested material(non-combustion gases emission source);
- Drying of digestate and concentrated slurry (non-combustion gases emission source);
- CHPs (continuous combustion gas emission source); and
- The flare and boiler exhaust stacks (transient combustion gas emission sources).

The combustion and non-combustion gas emission sources are discussed in the context of their potential impact and the required level of management to achieve the necessary regulatory air quality objectives set by EPA VIC.

6.1.2.1 Source of Combustion Gas Emission Sources

It is well established that the combustion of renewable fuels (such as biogas from an anaerobic digestion process) in equipment such as CHPs and flare systems result in the release of emissions to air via stack discharge points. The volume and nature of these emissions depend on several factors, including fuel composition and consumption, equipment design and operation, and the existence of any air pollution control devices. For the Proposed Fertiliser Facility, the composition of biogas from the anaerobic digesters includes CH_4, CO_2, H_2S, and balance gases such as N_2 and Ar. In addition, other contaminants may affect the efficiency and effectiveness of the fuel combustion performance and, in turn, the quality of emissions discharged to air from the CHPs, flare, and boiler systems. As such, the performance specifications of the CHPs, flare and boiler systems will need to be validated upon completion of the detailed design process for the Proposed Fertiliser Facility. This can be delivered through a process guarantee or equivalent of future equipment supply by the manufacturer.

Notwithstanding the above, the modelling prediction show that all APAC are satisfied except for short-term NO_2 prediction of 0.3 ppm (99.9%, 1 h), which exceeds the APAC of 0.12 ppm (99.9%, 1 h) at and beyond the boundary of the Proposed Fertiliser Facility. It is noted that the exceedance is largely contained within the property boundary (refer to **Section 6.1.2.1.1**). In the case of odour, the contour presents the baseline predicted ground level concentrations based on the design assumptions and configurations documented in **Section 6.1.2.2**.

6.1.2.1.1 NO_X Emission Findings

The AQOIA notes that the CHPs contribute to over 95% of the Proposed Fertiliser Facility predicted total NOx emissions. Given the performance specification provided by the equipment supplier and emission estimation techniques for determining the combustion conversion to NO_2 and its subsequent predicted exceedance in the AQOIA (refer to **Section 5.7**). If required, this circumstance can be managed in one or more of the following manners, including but not limited to:

- Optimal operation and maintenance of the CHPs and validated performance emissions limits, resulting in a revised conversion performance; and

- If required, additional measures such as a stack extension, pre-conditioning of the biogas fuel, and/or enhanced operating conditions can be adopted to manage NO_2 emission release levels.

One or more of the above measures will ensure that human health and the environment are protected both at on-site and off-site locations of the Proposed Fertiliser Facility.

6.1.2.2 Source of Non-Combustion Gas Emission Sources

The findings relating to the source of non-combustion gas emission sources are as follows:

- Open poultry/feedstock receival area (concrete clamps). The poultry litter will be sourced from the existing broiler farms stockpile areas in the vicinity and moved to the Proposed Fertiliser Facility as feedstock for processing. Therefore, it is presumed that the change to the existing local poultry background odour and air quality impact (particulate matter) will be negligible;

- The dryer exhaust air emission will be treated via a biofilter or equivalent odour control system with a treatment airflow capacity of 6,200 m^3/hr. Biofiltration is an established technology and proven air emissions control technology for the treatment of process air emissions in the agricultural and organic resource recovery sector;

- The liquid feedstocks/slurry vessels will be covered and fully enclosed (i.e. closed loop operational circuit). As such, there air quality impacts are anticipated to be negligible emissions;
- The dried and separate storage of product components such as the press filter cake and product from the dryer to be kept under cover in a building. As such, there will be negligible odour and particulate matter emissions on the basis the product is in a dry state and good housekeeping and management practices are followed as part of material transport and handling activities; and
- The input feedstock and digested material particle size reduction process is enclosed (i.e., closed loop operational circuit), with any displaced gas emissions captured and returned to digester.

For the other key pollutants, TOU could not identify any representative sources of background air pollution monitoring data for the region surrounding Anakie. It is assumed that the key pollutants of concern have negligible background levels within a farming land use environment.

6.1.3 Upset Condition and Prudent Planning Practice

As part of best industry practice, the potential upset conditions should be examined, and remedial actions developed as part of a site-specific Air Quality & Odour Management Plan (**AQOMP**) for the Proposed Fertiliser Facility (refer to **Section 6.2**). Notwithstanding this, the locality analysis (agricultural/farming setting) and minimum separation distance from the nearest sensitive receptor (975 m) is considered appropriate to facilitate in the management of accidental release of emissions to air under upset or atypical operating conditions. This separation distance should be preserved for the long-term viability of the operations and as part of prudent practice to avoid any potential future land-use conflict.

6.2 Technical Review Recommendations

Based on the findings documented in the Technical Review and AQOIA, TOU has recommended the following for the Proposed Fertiliser Facility:

1. For the proposed dryer biofilter system, a process monitoring system, consisting of the logging of key operational parameters (airflow, pressure, relative humidity, and temperature);
2. Development of an air quality/odour management plan (**AQOMP**). As a minimum, the details of the AQOMP should include:
    a. Identification and characterisation of the key steps involved in the Proposed Fertiliser Facility activities and the associated air quality/odour emission risks;
    b. A qualitative assessment on the risk rating for each key step;
    c. An identification of the key odour management and monitoring procedures that will be adopted as part of the site activities (including proactive and reactive strategies);

d. The reporting requirements with respect to odour as part of the normal site activities;

e. The training and awareness programs surrounding the activities and its potential odour emissions risk and associated mitigation;

f. An outline of a commitment to operational excellence and continuous improvement in odour management; and

g. A trigger and response action plan to abnormal/atypical events that are beyond the normal operational settings.

7 REFERENCES

- Asimakis, M., 2018. Anakie Broiler Farm Odour Monitoring - Summary of Odour Monitoring, Melbourne VIC: GHD
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Pavilion Farms Fertiliser Facility – Technical Review and Air Quality & Odour Impact Assessment

Anakie, VIC

Appendix

Version 3.0

August 2022

THE ODOUR UNIT

PAVILION BIOGAS PTY LTD

Appendix A:
AQS memorandum Meteorological Dataset – Carrs Rd Anakie VIC

Kyle Gilchrist
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Air Quality Support
kyle@airqualitysupport.com.au

20 May 2022

Steve Hayes
Senior Atmospheric Scientist & Consultant
The Odour Unit (Qld) Pty Ltd

By email: shayes@odourunit.com.au

D21E-1: Meteorological Dataset – Carrs Rd Anakie VIC

Dear Steve

Air Quality Support (AQS) was commissioned by The Odour Unit Pty Ltd (The Odour Unit) to generate a meteorological dataset for Carrs Road, Anakie, VIC.

Analysis of the data available from the two closest Bureau of Meteorology (BoM) automated weather stations (AWS), Avalon Airport and Sheoaks, revealed systematic issues with the wind speed data rendering the data unsuitable for dispersion modelling.

The next closest BoM station was Breakwater (Geelong Racecourse). The quality data from this station was deemed acceptable for modelling purposes. However, the distance from the site (24 km) and its position on a peninsula rendered it unsuitable to represent local meteorological conditions at the Carrs Road Site. Therefore, the TAPM model was used to generate site-specific meteorological data at the site. Model prediction at the Breakwater AWS were compared with observations to evaluate model performance and provide justification in the use of the TAPM model to generate meteorological information to be used as input into the AERMET meteorological pre-process, to produce a dataset suitable to use as input to the AERMOD dispersion model. The results are detailed in Section 3.

The meteorological dataset was generated using data generated by TAPM, with only cloud cover data observed at the Avalon AWS used. It was then processed using the AERMET meteorological processor. The meteorological dataset is suitable to use as direct input to the AERMOD dispersion model.

The configuration of the TAPM model and AERMET meteorological processors were conducted in accordance with guidelines published in the following documents:

- Hurley, P. 2005, The Air Pollution Model (TAPM) Version 3: User Manual, CSIRO Atmospheric Research Technical Paper No. 31, CSIRO Division of Atmospheric Research, Melbourne.
- EPA Victoria (2014). Construction of input meteorological data files for EPA Victoria's regulatory air pollution model.
- USEPA (2019). User's Guide for the AERMOD Meteorological Pre-processor (AERMET).

The modelling period consisting of the last five full years, which was the period from 1 January 2017 to 31 December 2021.

This memorandum summarises the methodology, assumptions. This memo accompanies the AERMET input files, and the SFC and PFL output files.

If you have any questions or comments, please feel free to contact the undersigned.

Kind regards,

Kyle Gilchrist

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Air Quality Support
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1 Meteorological modelling

The prognostic model TAPM (developed by CSIRO, version 4.0.5) and the diagnostic meteorological model AERMET (version 21112) were used to generate the meteorological dataset for the region.

The outputs of TAPM and observational data were combined as an input to AERMET which then created a meteorological file suitable for use with the AERMOD dispersion model.

1.1 TAPM

TAPM (Hurley, 2005) is a prognostic meteorological model widely used in Australia to predict 3D meteorological conditions at varying scales. TAPM solves the fundamental fluid dynamics equations to predict meteorology at a mesoscale (20 km to 200 km) to a local scale (resolution of hundreds of meters). TAPM includes parameterisations for cloud/rain micro-physical processes, urban/vegetation canopy and soil, and radiative fluxes.

TAPM uses synoptic meteorological information for the region, generated by a global using observations from multiple weather stations gridded to an approximate resolution of 75 km. This synoptic information is used in conjunction with surrounding terrain, land-use, soil moisture content and soil type to simulate the meteorology of a region as well as at a specific location.

Landcover data for TAPM are sourced from the US Geological Survey, Earth Resources Observation Systems (EROS) Data Center Distributed Active Archive Center (EDC DAAC) at 30-second (approximately 1 km) grid spacing.

TAPM was configured in accordance with guidelines detailed in the Guidelines for Input Meteorological Data for AERMOD (Vic EPA, 2014)

TAPM (version 4.0.5) was configured as follows:

- Modelling period for five years from 1 January 2017 to 31 December 2021;
- 41 x 41 grid points with an outer grid of 30 km and nesting grids of 10 km, 3 km, and 1 km;
- 30 vertical levels;
- Grid centred near Project site (latitude –37° 57' 30", longitude 144° 18' 30");
- Elevation sourced from default TAPM database, using 9-second (approximately 0.3 km) data from Geoscience Australia;
- Land cover data based on default TAPM databased, using global land cover characterisation data on a longitude/latitude grid at 30-second grid spacing (approximately 1 km) based on public domain data available from the US Geological Survey Earth Resources Observation Systems (EROS) Data Center Distributed Active Archive Center (EDC DAAC);
- Default options selected for advanced meteorological inputs.

1.2 AERMET

AERMOD requires meteorological variables that are both measured and derived from measurements. These require a reassurance of reliable and complete datasets that included measurements of all mandatory variables. When these are not available, some variables are typically sourced from a prognostic model such as TAPM.

Prognostic models, such as the meteorological component of the TAPM model (Hurley, 2005) are capable of producing datasets that can be used directly with the AERMOD model. However, it is generally recommended to process raw model output using the AERMET meteorological pre-processor component of the AERMOD dispersion model, to achieve compliance of the USEPA-sanctioned procedures for modelling (rather than research) processes.

AERMET screens the data, which includes the removal of extremely low wind speeds and adjustment of derived parameters such as friction velocity. If left unadjusted, these can produce extreme modelling results and unusual artefacts in predicted ground level pollutant concentration isopleths.

Surface data from the AWS (wind speed and direction, temperature, relative humidity, station pressure) were supplemented by the TAPM-generated data (solar radiation, mixing height).

Observations and model-generated data were processed as a three-stage process using the most recent version (v21112) of AERMET.

- Stage 1 – extraction or retrieval of data and the assessment of the quality of data
- Stage 2 – combination of data processed during Stage 1, including setting missing value indicators
- Stage 3 – creation of model input files, including computation of boundary layer scaling parameters (surface friction velocity, mixing height, and Monin-Obukhov length)

The following meteorological parameters were used as input to Stage 1 of AERMET:

- Extracted from TAPM:
  - wind speed (m/s)
  - wind direction (°)
  - temperature at 2-m (°C)
  - relative humidity (%)
  - station pressure (mB)
  - net solar radiation (W/m²)
  - mixing height (m)
- Extracted from observations at the Avalon Airport AWS:
  - cloud cover (10ths)

The threshold for calm winds was set at 0.5 m/s. Surface friction velocity (u* or ustar) was configured to run with the ADJ_U* option.

Surface characteristics for the land use classification of the area surrounding the location of the site at Carrs Road, Anakie, shown in Figure 1-1. These are based on the array of seasonal surface roughness, albedo, and Bowen ratio compiled by EPA Victoria (EPAV, 2014) for Australian geography, detailed in Table 1-1 and Table 1-2. These are combined in a manner consistent with the guidelines for AERMET (USEPA, 2019).

Albedo is based on a simple unweighted arithmetic mean, and the Bowen ratio is based on the unweighted geomean, of the combined land use classification of the sectors for the area covering a 10-km area centred at the site. Surface roughness was based on the sectors for the area covering a 1-km radius centered on Carrs Road, Anakie.

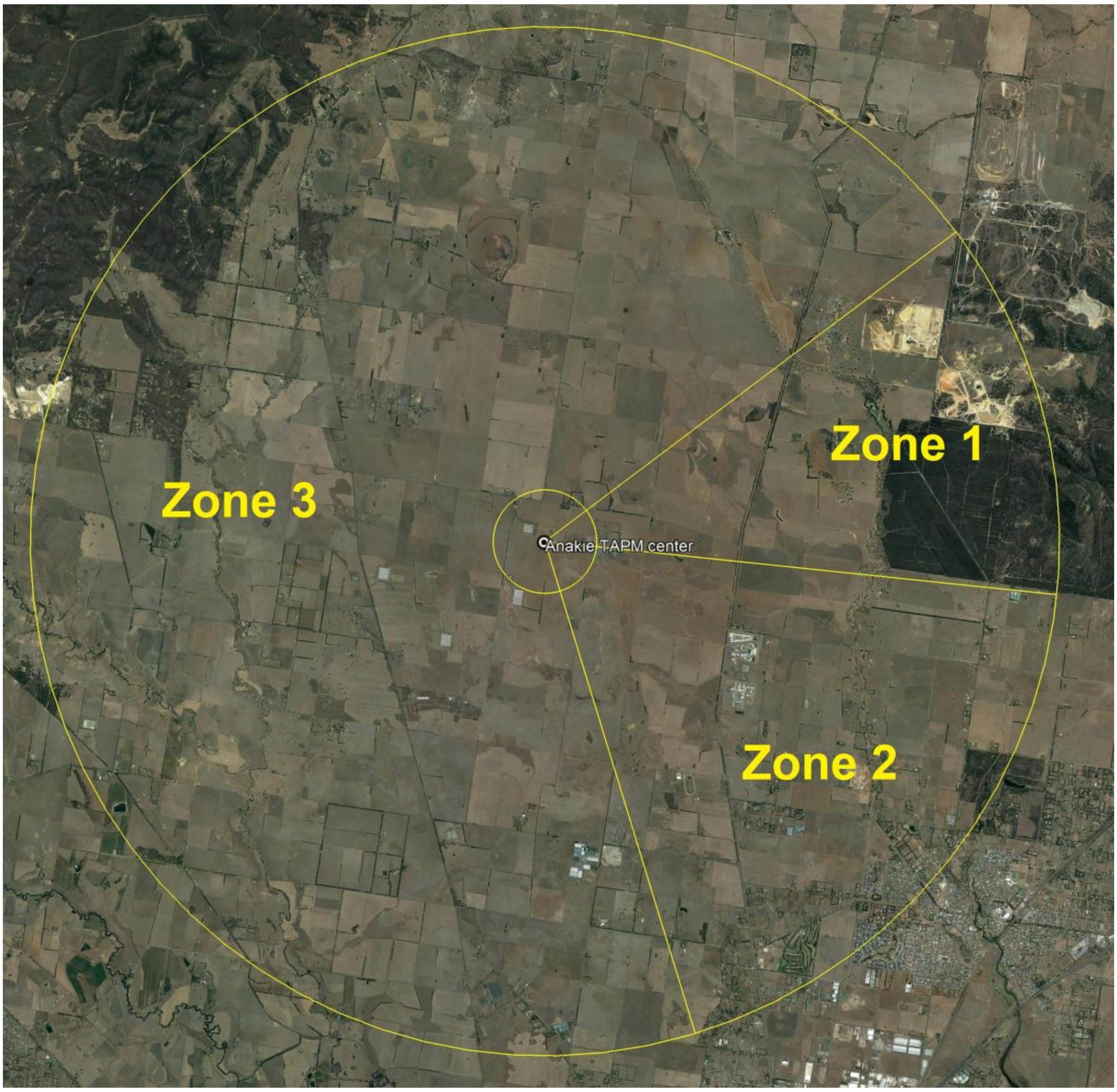

Figure 1-1 Zone segments used in AERMET modelling

Table 1-1: Surface characteristics used in the AERMET model

Zone	Land use	Albedo				Bowen Ratio			
		Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
Zone 1 (53°- 96°)	**Sector**	**0.173**	**0.173**	**0.180**	**0.173**	**0.711**	**1.105**	**1.105**	**0.749**
	Grassland	0.180	0.180	0.200	0.180	0.80	1.00	1.00	0.40
	Mixed Forest	0.140	0.140	0.140	0.140	0.30	0.90	0.90	0.70
	Quarries/Strip Mines/Gravel	0.200	0.200	0.200	0.200	1.50	1.50	1.50	1.50
Zone 2 (96°- 163°)	**Sector**	**0.170**	**0.170**	**0.190**	**0.170**	**0.800**	**1.000**	**1.000**	**0.566**
	Grassland	0.180	0.180	0.200	0.180	0.80	1.00	1.00	0.40
	Low intensity Residential	0.160	0.160	0.180	0.160	0.80	1.00	1.00	0.80
Zone 3 (163°- 53°)	**Sector**	**0.180**	**0.180**	**0.200**	**0.180**	**0.80**	**1.00**	**1.00**	**0.40**
	Grassland	0.180	0.180	0.200	0.180	0.80	1.00	1.00	0.40

Table 1-2: Surface characteristics used in the AERMET model

Zone	Land use	Surface Roughness			
		Summer	Autumn	Winter	Spring
Zone 1	Grassland	0.100	0.010	0.001	0.050
Zone 2	Grassland	0.100	0.010	0.001	0.050
Zone 3	Grassland	0.100	0.010	0.001	0.050

2 Dispersion Meteorology

This section presents an analysis of the site-specific meteorological data generated by the AERMET meteorological modelling pre-processor. Analysis of meteorological parameters critical to the dispersion of pollutants at the locations of the proposed facilities are presented in the following sections.

2.1 Wind speed and direction

Wind speed and wind direction are important meteorological parameters that drive the dispersion of air pollutants. Distributions of winds predicted at the site location is presented in Figure 2-1.

Figure 2-1 shows that predominant winds originating from the west south-west to north-west sectors (WSW to NW) sectors, occurring approximately 43% of the time. Winds from the northern sectors are also common, occurring approximately 12% of the time. 60% of winds are in the range of 2 – 6 m/s, while calm winds occur approximately 1% of the time. Strong wind speeds (> 8 m/s) are infrequent, occurring around 3% of the time.

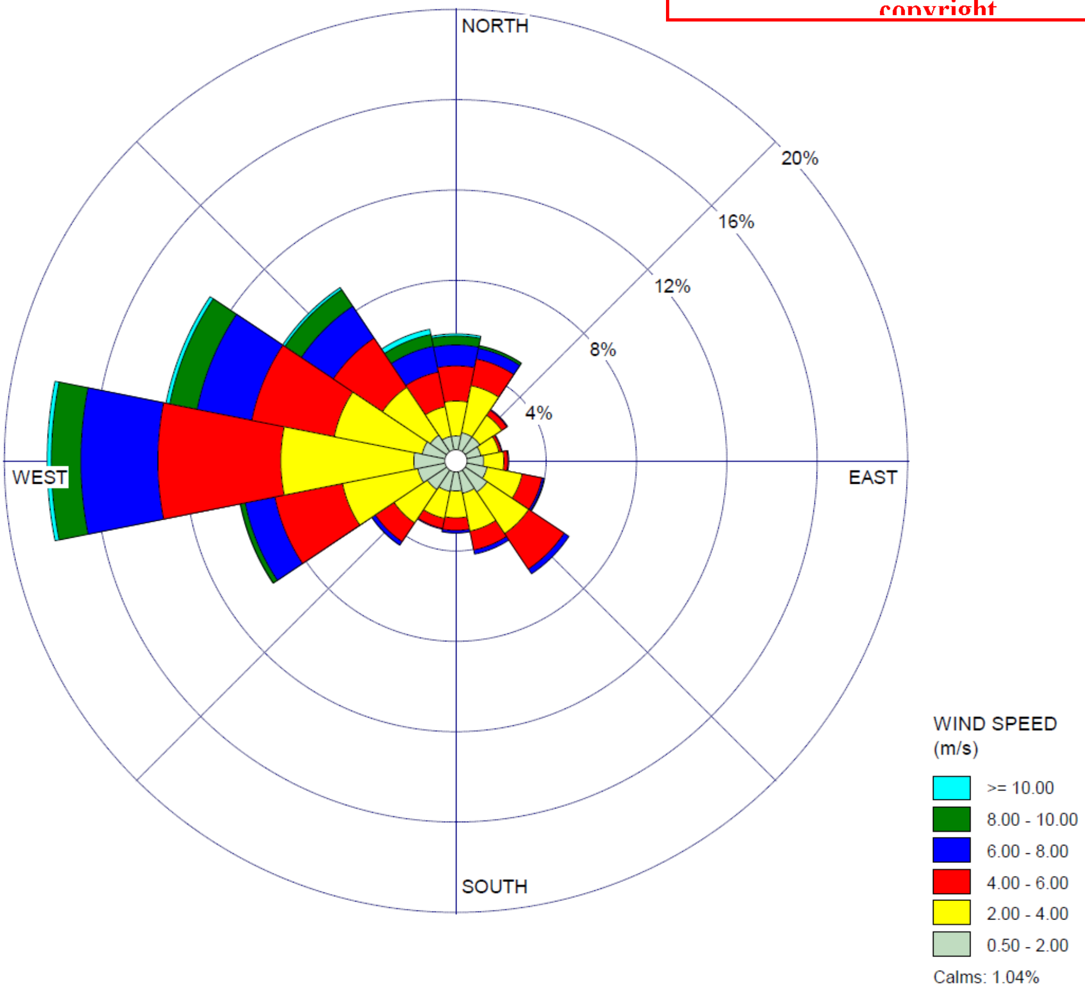

Figure 2-1 Summary of wind distribution at site location

2.2 Atmospheric stability

The flow of air in the planetary boundary layer (lowest one kilometre of the atmosphere) is an important factor in the dispersion of air pollutants. This flow is affected by turbulence, which describes the vertical and horizontal motion of air and how a plume may be spread out and diffused. The rate of plume diffusion is proportional to turbulence. Lower diffusion rates resulting from low turbulence results in higher concentrations in the plume.

Turbulence is driven by thermal and mechanical influences as the atmosphere interacts with the land surface. Thermally driven turbulence is generated by convection as the sun heats the ground and the air above it is warmed, causing it to rise. Mechanically driven turbulence is generated by frictional effects as wind passes over the surface or by wind shear, produced at the boundary of two coinciding layers of wind or two different air masses.

A key indicator of thermally driven turbulence or convection in the atmosphere is stability, which is measured by the environmental lapse rate or vertical temperature profile of the atmosphere. Stability is a term applied to the properties of the atmosphere that govern the acceleration of the vertical motion of an air parcel. The acceleration is positive in an unstable atmosphere (turbulence increases), zero when the atmosphere is neutral, and negative (deceleration) when the atmosphere is stable (turbulence is suppressed). The vertical temperature gradient in the atmosphere governs whether a parcel of air or plume, released into it will rise, fall, disperse, or remain relatively still. Plume warmer than the surrounding will tend to rise, while a plume cooler than the atmosphere will sink. Wind, or horizontal air movement, affects mechanical turbulence and therefore also affects atmospheric stability. As the wind speed increases, atmospheric stability will tend toward neutral conditions.

Atmospheric stability is commonly defined in terms of six main stability classifications. This is known as the Pasquill-Gifford (PG) stability classification and is widely used to describe the turbulent state of the atmosphere. The stability classes range from A Class, which represents very unstable atmospheric conditions that may typically occur on a sunny day, to F Class stability which represents very stable atmospheric conditions that typically occur during light wind conditions at night.

Unstable conditions (Classes A-C) are characterised by strong solar heating of the ground that induces turbulent mixing in the atmosphere close to the ground, and usually results in material from a plume reaching the ground closer to the source than for neutral or stable conditions. This turbulent mixing is the main driver of dispersion during unstable conditions. Dispersion processes for neutral conditions (Class D) are dominated by mechanical turbulence generated as the wind passes over irregularities in the local surface, such as terrain features and building structures. During the night, the atmospheric conditions are neutral or stable (Class D, E and F). During stable conditions, plumes from fugitive releases will be subject to minimal atmospheric turbulence. A plume released below an inversion layer during stable conditions that has insufficient vertical momentum or thermal buoyancy to penetrate the inversion will be trapped beneath it and result in elevated ground-level concentrations.

Atmospheric stability classes were derived from the meteorological dataset generated by the TAPM/AERMET meteorological modelling system using the Golder (1972) relationship for calculating Pasquill-Gifford stability classes based on surface roughness and Monin-Obukhov length. This method allows for unstable conditions at night and stable conditions during the day, if warranted. The frequency distribution of the PG classes by time of day at the site location during 2017 is presented in Figure 2-2.

Figure 2-2 shows that daytime hours are dominated by A, B and C classes, while D, E and F classes are most common at night.

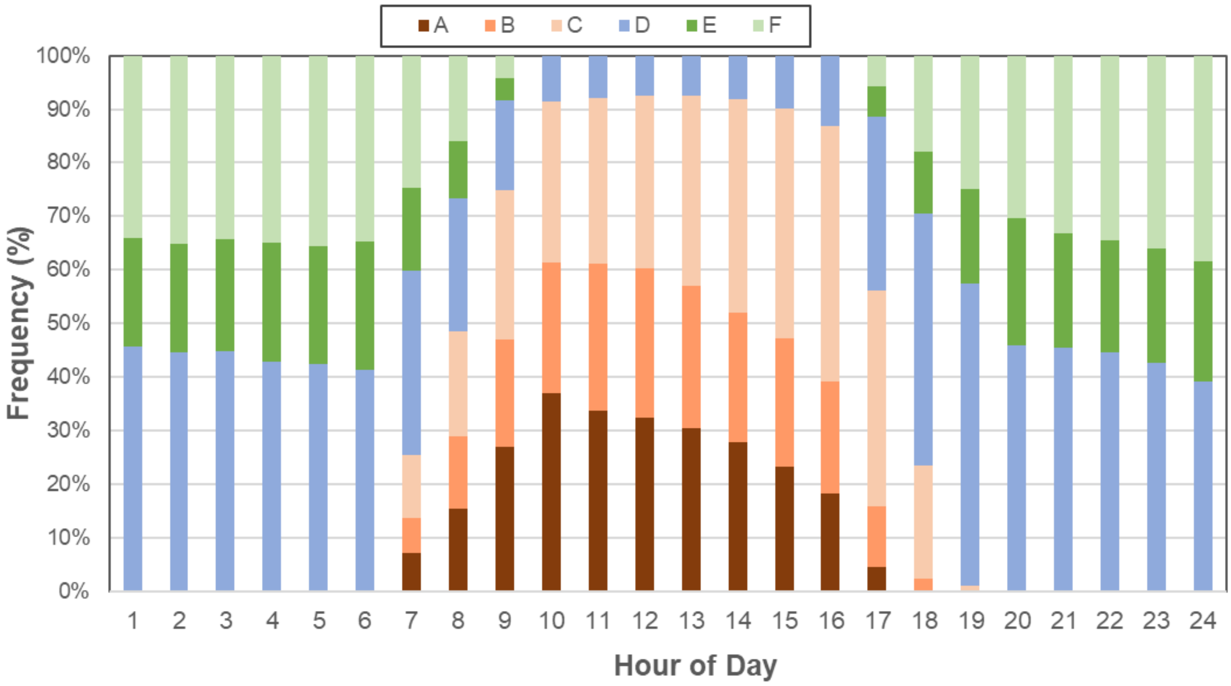

Figure 2-2 Diurnal distribution of atmospheric stability classes (2021)

2.3 Mixing height

The mixing height refers to the height above ground within which pollutants released at or near ground can mix with ambient air. During stable atmospheric conditions at night, the mixing height is often quite low, and pollutant dispersion is limited within this layer. During the day, incoming short-wave solar radiation from the sun heats the ground, which in turn re-radiates long wave radiation back into the atmosphere, heating the air above it. The heating of the air near the ground generates the growth of convection cells causing the air, and hence the mixing height, to rise. The air above the mixing height during the day is generally cooler. The growth of the mixing height is dependent on how well the air can mix with the cooler upper levels of air and therefore depends on turbulence, i.e., meteorological factors such as the intensity of solar radiation and wind speed. During strong wind speed conditions, the air will be well mixed, resulting in a high mixing height.

The hourly profile of the mixing height predicted by the AERMET meteorological pre-processor is shown in Figure 2-3. Figure 2-3 shows that the mixing height starts to develop around 8am, increases to a peak around 2pm before descending rapidly.

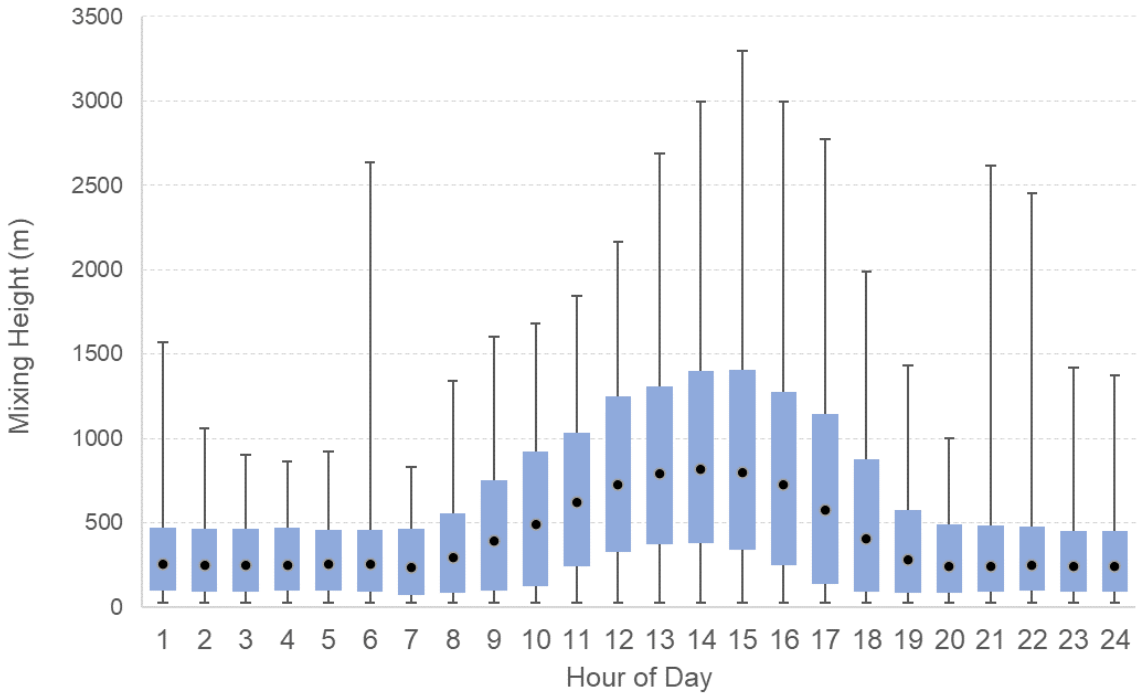

Figure 2-3 Diurnal mixing height profile (2021)

3 Evaluation Of Meteorological Model Performance

3.1 Methodology

Though there are two BoM stations located closer to the site, analysis of the meteorological datasets show values inconsistent with the expected meteorological conditions for the site. To assess model performance, data collected from the BOM Breakwater AWS were compared with predictions by the TAPM model

- The data validation process took into account statistical measures as described in the meteorological monitoring guidance for regulatory modelling applications (USEPA, 2000). Model predictions were validated using the following statistical measures:
  - Root Mean Square Error (RMSE)
  - Systematic Root Mean Square Error (RMSES)
  - Unsystematic Root Mean Square Error (RMSEU)
  - Mean Error (ME)
  - Mean Absolute Error (MAE)
  - Index of Agreement (IOA)
  - Skill E
  - Skill V
  - Skill R

In addition to these measures, basic statistics such as the minimum, mean, maximum, and standard deviation were also derived and compared.

It should be noted that there are no defined standards for numerical weather model performance. Statistical scores simply provide a means to quantify the magnitude of the difference between predictions and observations. These provide a useful guide to performance benchmarks of what should be expected from a model. These values are guidelines and not absolute determinants of pass or fail.

3.2 Statistics

3.2.1 Root mean square error (RMSE)

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2}$$

Where:

N = number of observed and predicted hours in analysis (i.e. one year)

P = hourly prediction

O = hourly observation

The RSME can be described as the standard deviation of the difference for hourly predicted and observed pairings at a specific point. The RMSE is a quadratic scoring rule, which measures the average magnitude of the error. The difference between predicted and corresponding observed values are each squared and then averaged over the sample. Finally, the square root of the average is taken. Since the errors are squared before they are averaged, the RMSE gives a relatively high weight to large errors. This means the RMSE is most useful when large errors are particularly undesirable. Overall, the RSME is a good overall measure of model performance, but since large errors are weighted heavily (due to squaring), its value can be distorted. RMSE is equal to the unit of the values being analysed i.e., an RMSE of 1.2 for wind speed = 1.2 m/s.

3.2.2 Systematic root mean square error (RMSEs)

$$RMSE_S = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\bar{P} - O_i)^2}$$

Where:

N = number of observed and predicted hours in analysis (i.e. one year)

$\bar{P}$ = mean of predictions

O = hourly observation

The RMSEs is calculated as the square root of the mean square difference of hourly predictions from the regression formula and observation pairings, at a specific point. The regressed predictions are taken from the least squares formula. The RMSEs estimates the model's linear (or systematic) error. The systematic error is a measure of the bias in the model due to user input or model deficiency, i.e., data input errors, assimilation variables, and choice of model options. The RMSEs is a metric for the model's accuracy

3.2.3 Unsystematic root mean square error (RMSEu)

$$RMSE_U = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\bar{P} - P_i)^2}$$

Where:

N = number of observed and predicted hours in analysis (i.e. one year)

$\bar{P}$ = mean of predictions

P = hourly prediction

The RMSEu is calculated as the square root of the mean square difference of hourly predictions from the regression formula and model prediction value pairings, at a specific point. The RMSEu is a measure of how much of the difference between predictions and observations result from random processes or influences outside the legitimate range of the model. This error may require model refinement, such as new algorithms or higher resolution grids, or that the phenomena being simulated cannot be fully resolved by the model. The RMSEu is a metric for the model's precision.

Ultimately, for good model performance, the RMSE should be a low value, with most of the variation explained in the observations. Here, the systematic error RMSEs should approach zero and the unsystematic error, RMSEu, should approach the RMSE since:

$$RMSE^2 = RMSE_S{}^2 + RMSE_U{}^2$$

3.2.4 Mean error and mean absolute error

The Mean Error (ME) is simply the average of the hourly modelled values minus the hourly observed values. It contains both systematic and unsystematic errors and is heavily influence by high and low errors.

The Mean Absolute Error (MAE) measures the average magnitude of the errors in a set of predictions, without considering their direction. It measures accuracy for continuous variables. Expressed in words, the MAE is the average of the absolute values of the differences between predictions and the corresponding observation. The MAE is a linear score, which means that all the individual differences are weighted equally in the average. The MAE and the RMSE can be used together to diagnose the variation in the errors in a set of predictions. The RMSE will always be larger or equal to the MAE; the greater difference between them, the greater the variance in the individual errors in the sample. If the RMSE = MAE, then all the errors are of the same magnitude. Both the MAE and RMSE can range from 0 to ∞. They are negatively-oriented scores, i.e., lower values are better.

3.2.5 Index of agreement

The Index of Agreement (IOA) is defined as:

$$IOA = 1 - \frac{\sum_{i=1}^{N}(P_i - O_i)^2}{\sum_{i=1}^{N}(|P_i - O_{mean}| + |O_i - O_{mean}|)^2}$$

The IOA is calculated using a method described in Willmott (1982). The IOA can take a value between 0 and 1, with 1 indicating perfect agreement. The IOA is the ratio of the total RMSE to the sum of two differences, i.e., the difference between each prediction and the observed mean, and the difference between each observation and observed mean. From another perspective, the IOA is a measure of the match between the departure of each prediction from the observed mean and the departure of each observation from the observed mean. A value of 0.5 is considered acceptable and >0.6 is considered good performance for time and space predictions.

Where:

N = number of observations

P_i = hourly model predictions

O_i = hourly observations

O_{mean} = observation mean

3.2.6 Skill measures

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 (Chang and Hanna, 2004).

The Skill_E (s_e) 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 Skill_E should be less than one, i.e.:

SKILL_E = (RMSE_U/ STDEV OBS) < 1 shows skill

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

SKILL_V = (STDEV_MOD/ STDEV _OBS) close to 1 shows skill

SKILL_R (s_r) takes into account systematic and unsystematic errors in relation to the observed standard deviation. For good model performance, the value for Skill_E should be less than one, i.e.:

SKILL_R = (RMSE/ STDEV _OBS) < 1 shows skill

3.3 Model performance evaluation

The basic statistics for TAPM predictions and meteorological data collected from Breakwater AWS are compared in **Error! Reference source not found.**, showing that the basic statistics for observations and model predictions are within similar ranges.

Correlation statistics for the different meteorological variables are detailed in Table 3-2. When compared with the ideal scores, the TAPM model is shown to have performed well in predicting wind, temperature, and relative humidity.

The probability density function (PDF) of observed and modelled winds, temperature, and relative humidity are presented in Figure 3-1 to Figure 3-5 showing similar profiles in distributions at both locations. There are no significant fluctuations in the distributions, which supports the quantitative results of the model evaluation that the TAPM model performed adequately in predicting the meteorological variables important to atmospheric dispersion.

Wind roses showing the distribution of observed and modelled winds are presented in Figure 3-6**Error! Reference source not found.**.

Table 3-1: Statistics for meteorological observations and TAPM model prediction (2017-21)

Parameter	Units	Source	Average	Standard deviation	Minimum	Maximum
Wind speed	m/s	Obs	3.2	1.7	0.0	9.9
		Model	3.2	1.9	0.0	11.3
U component	m/s	Obs	0.9	2.6	-5.2	9.4
		Model	1.1	2.7	-5.3	10.5
V component	m/s	Obs	-0.1	2.3	-8.8	7.0
		Model	-0.2	2.4	-10.8	7.2
Temperature	°C	Obs	15.1	4.9	4.4	35.8
		Model	14.9	5.5	2.4	36.6
Relative Humidity	%	Obs	72.8	15.7	18.0	100.0
		Model	72.7	17.2	16.7	100.0

Table 3-2: Correlation statistics for TAPM meteorological model performance (2017-21)

Statistic	Ideal score	Wind speed	U component	V component	Temperature	Relative Humidity
Root Mean Square Error	0	0.6	0.6	0.6	0.9	4.4
Systematic Root Mean Square Error	0	1.7	2.7	2.3	4.9	15.7
Unsystematic Root Mean Square Error	0	1.9	2.7	2.4	5.5	17.2
Mean Error	0	0.0	0.2	-0.2	-0.2	-0.1
Mean Absolute Error	0	0.4	0.4	0.4	0.6	3.3
Index of Agreement	1	1.0	1.0	1.0	1.0	1.0
$Skill_e$	< 1	1.1	1.0	1.0	1.1	1.1
$Skill_v$	1	1.1	1.0	1.0	1.1	1.1
$Skill_r$	<1	0.4	0.2	0.3	0.2	0.3

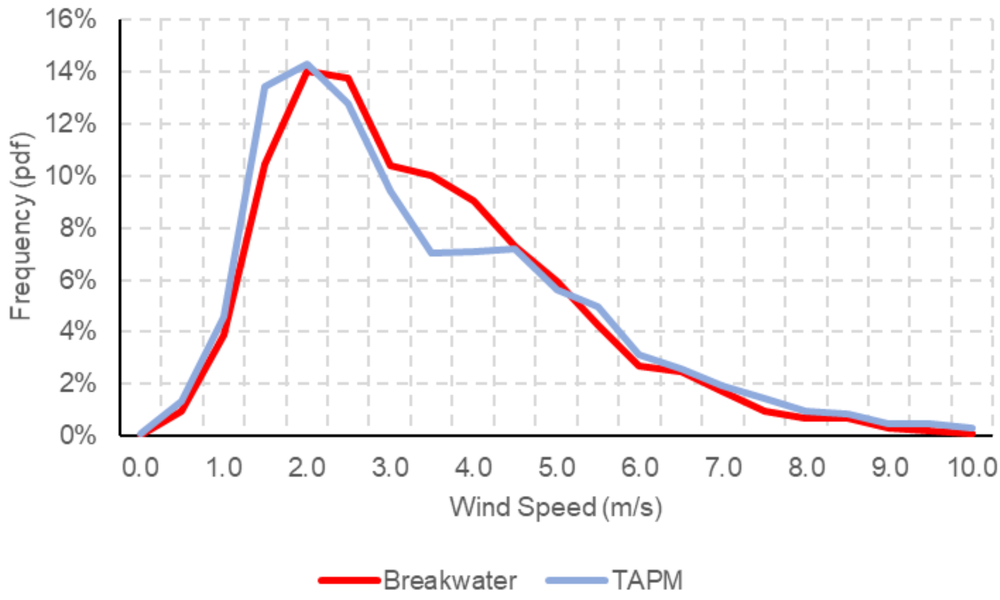

Figure 3-1 Distribution of wind speeds from 2017 to 2021

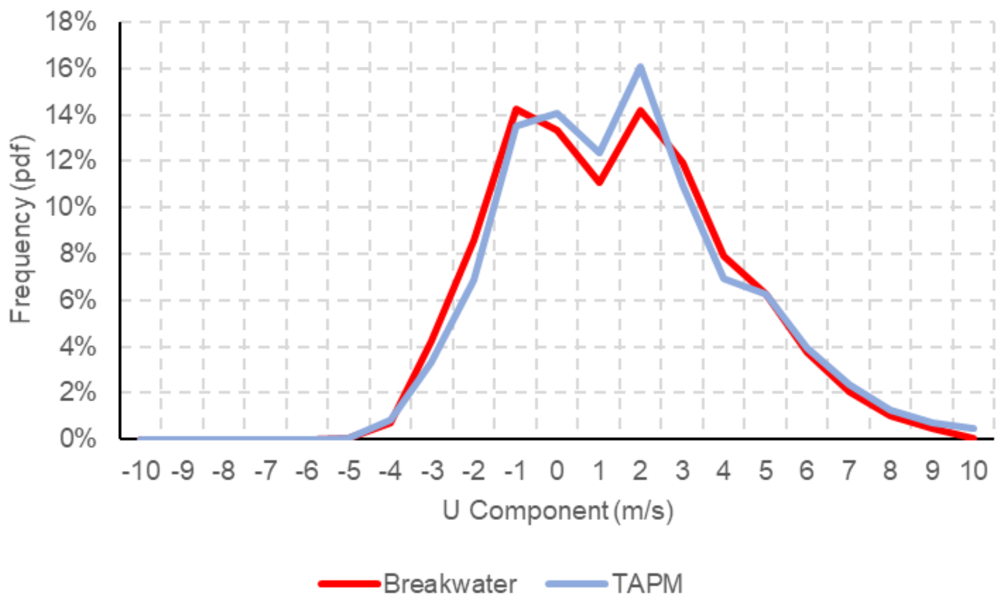

Figure 3-2 Distribution of U-component of wind from 2017 to 2021

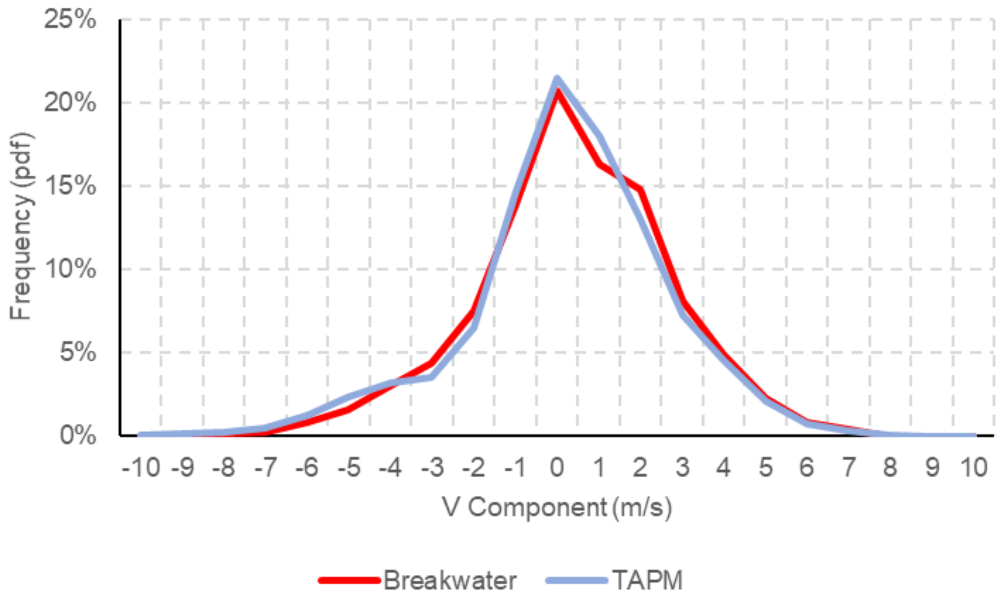

Figure 3-3 Distribution of V-component of wind from 2017 to 2021

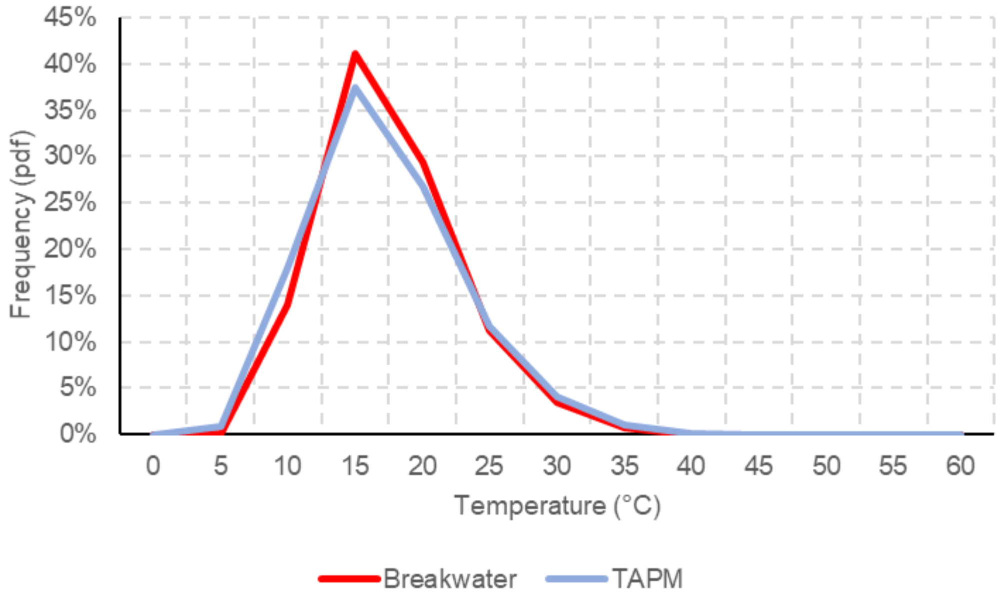

Figure 3-4 Distribution of temperature from 2017 to 2021

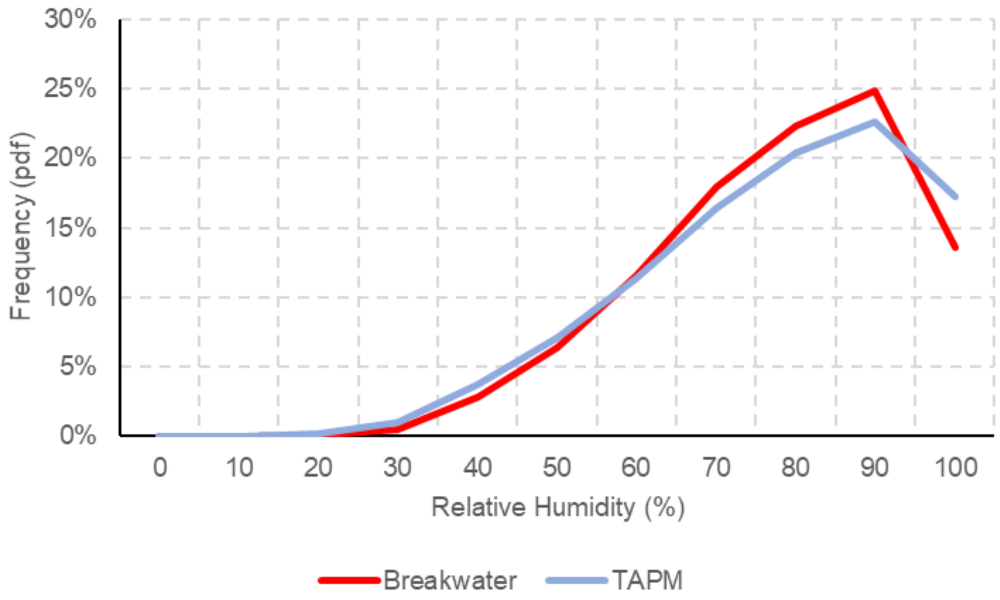

Figure 3-5 Distribution of relative humidity from 2017 to 2021

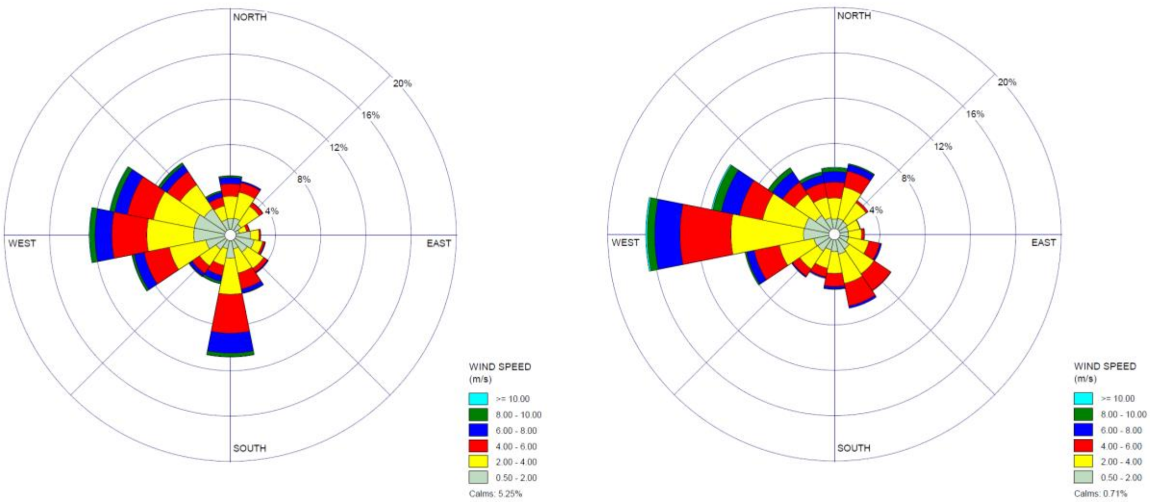

Figure 3-6 Distribution of observed (left) and modelled (right) winds from 2017 to 2021

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