

# Project Halogen: Air Quality Assessment

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## Glossary

<b>Term</b>	<b>Definition</b>
$\mu\text{g}/\text{m}^3$	micrograms per cubic metre
$\mu\text{m}$	micrometre
$^{\circ}$	degree
$^{\circ}\text{C}$	degrees Celsius
g/s	grams per second
kg/annum	kilograms per year
km	kilometre
m	metre
m/s	metres per second
$\text{m}^2$	square metre
$\text{m}^3$	cubic metre
$\text{m}^3/\text{s}$	cubic metres per second
$\text{Nm}^3/\text{hr}$	normalised cubic metres per hour
<b>Nomenclature</b>	<b>Definition</b>
$\text{Cl}_2$	chlorine gas
$\text{H}_2$	hydrogen
HCl	hydrogen chloride
$\text{PM}_{10}$	particulate matter with a diameter less than 10 micrometres
$\text{PM}_{2.5}$	particulate matter with a diameter less than 2.5 micrometres
<b>Abbreviation</b>	<b>Definition</b>
AHD	Australian Height Datum
Air EPP	Environmental Protection (Air) Policy 2019
Air NEPM	National Environmental Protection (Ambient Air Quality) Measure
AWS	automatic weather station
BoM	Bureau of Meteorology
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
CQG	CQG Consulting (CQ Environmental Pty Ltd)
DA	Development Application
DETSI	Department of Environment, Tourism, Science and Innovation
EHP	Department of Environment and Heritage Protection (Qld)
EMP	Environmental Management Plan
EP Act	<i>Environmental Protection Act 1994</i>
EPA	Environment Protection Authority
ERA	Environmentally Relevant Activity
Gladstone SDA	Gladstone State Development Area
IAQM	Institute of Air Quality Management
IOA	index of agreement
LPG	liquefied petroleum gas
MCU	material change of use
NEPC	National Environment Protection Council
NPI	National Pollutant Inventory database
POEO Act	Protection of the Environment (Operations) Act 1997
POEO Clean Air Reg	Protection of the Environment Operations (Clean Air) Regulation 2010
QLD	Queensland
RMSE	root mean square error
SDA	State Development Area
TAPM	The Air Pollution Model
UTM	Universal Transverse Mercator

## EXECUTIVE SUMMARY

Katestone Environmental Australia Pty Ltd (Katestone) was commissioned by CQG Consulting on behalf of Grenof to complete an air quality assessment of Project Halogen (the Project), a proposed Chlor-Alkali facility located within the Gladstone State Development Area (Gladstone GSDA) across Lot 1 on MPH32292 and Lot 1 on SP200899.

Grenof is seeking to lodge a Development Application (DA) for a material change of use (MCU) for a concurrence environmentally relevant activity (ERA) 7(6d) *Chemical manufacturing: manufacturing in a year, more than 100,000 tonnes of inorganic chemicals* for the proposed Chlor-Alkali facility.

An air quality assessment to support the DA has been prepared in accordance with the Department of Environment, Tourism, Science and Innovation (DETSI) guideline Application requirements for activities with impacts to air (ESR/2015/1840, version 5.0.3, October 2024) and other relevant legislation and regulatory requirements.

The air quality assessment used recognised techniques for dispersion modelling and emission estimation to determine the potential impacts to sensitive receptors and the surrounding environment. The dispersion modelling has assessed the potential impacts to air from the following sources:

- Waste gas dechlorination stack (chlorine (Cl<sub>2</sub>) emissions)
- Hydrogen chloride vent burner stack (Cl<sub>2</sub> and hydrogen chloride (HCl) emissions).

The following additional potential sources were identified as negligible so were not included in the dispersion modelling:

- Hydrogen vent stacks (two stacks)
- Leaks and failures in storage tanks, pipes and fittings, connections and filled bottles
- Potential fugitive (wind-blown) particulate matter emissions from the salt stockpile.

The dispersion modelling has been conducted to predict the maximum ground-level concentrations of Cl<sub>2</sub> and HCl at the location of the nearest sensitive land use, located approximately 3.7 km to the west of the Project, as well as the maximum ground-level concentration anywhere within the model domain. Concentrations at these locations have been assessed against the relevant air quality assessment criteria for Cl<sub>2</sub> and HCl.

The results of the dispersion modelling show that peak concentrations, including those within the Project site boundary, **comply** with the relevant assessment criteria for Cl<sub>2</sub> and HCl. The highest concentration of either pollutant anywhere in the model domain is predicted to be less than 0.3 percent of the relevant air quality assessment criteria.

The risks to air quality during the operation phase of the Project are minimised through the following design aspects:

- Best practice membrane cell electrolytic process used in the production of chlorine.
- Hydrogen and chlorine gas detector sensors are installed in buildings and key locations across the site that are linked to the plant operations to assist in identifying, managing and fixing leaks in a timely manner.
- Closed loop design whereby any potential sources of release will be minimal, easily identified, and immediately and automatically rectified.

- Systematic collection and redirection of waste gas stream to the chlorine absorption unit to reduce chlorine to trace levels ( $< 1 \text{ mg/Nm}^3$ ) prior to release and installation of a scrubber on the HCl synthesis unit to reduce chlorine and hydrogen chloride to low levels ( $\leq 5 \text{ mg/Nm}^3$  and  $\leq 30 \text{ mg/Nm}^3$ , respectively).
- Maintaining a significant buffer zone to sensitive receptor locations.

Risks of dust impacts at sensitive receptor locations during the construction phase of the Project have been identified as negligible; however, under the General Environmental Duty (GED) of the *Environmental Protection Act 1994 (EP Act)*, during both construction and operation of the Project, all reasonably practicable measures should be applied to prevent or minimise any potential environmental harm.

# 1. INTRODUCTION

Katestone Environmental Australia Pty Ltd (Katestone) was commissioned by CQG Consulting (CQG), on behalf of Grenof, to complete an air quality assessment of Project Halogen (the Project), a proposed Chlor-Alkali facility located within the Gladstone State Development Area (SDA).

Grenof is seeking to lodge a Development Application (DA) for a material change of use (MCU) for a concurrence environmentally relevant activity (ERA) 7(6d) *Chemical manufacturing: manufacturing in a year, more than 100,000 tonnes of inorganic chemicals* for the proposed Chlor-Alkali facility. The Project is to be located within the Gladstone SDA across Lot 1 on MPH32292 and Lot 1 on SP200899.

An air quality assessment to support the DA has been prepared in accordance with the Department of Environment, Tourism, Science and Innovation (DETSI) guideline Application requirements for activities with impacts to air (ESR/2015/1840, version 5.0.3, October 2024) and other relevant legislation and regulatory requirements.

The air quality assessment has addressed the following scope of works:

- Section 2 describes the Project
- The legislative framework for air quality is summarised in Section 3
- The air quality assessment methodology is described in Section 4
- The existing environment of the region surrounding the Project including local terrain, land-use and sensitive receptors is described in Section 5
- Section 6 provides estimates of emissions of air pollutants to the atmosphere that are likely to arise as a result of the Project
- Section 7 details the results of the air quality assessment
- Section 8 describes management measures that will be implemented during the construction and operation phases of the Project
- Section 9 provides conclusions of the air quality assessment.

## 2. PROJECT DESCRIPTION

The proposed Chlor-Alkali facility is to be located within the Gladstone SDA across Lot 1 on MPH32292 and Lot 1 on SP200899 (Figure 1). The Project triggers the requirements for a concurrence ERA7(6d) *Chemical manufacturing: manufacturing in a year, more than 100,000 tonnes of inorganic chemicals*.

Key aspects of the Project in relation to air quality are as follows:

- 24 hours per day, 365 days per year operation
- Production capacity of 160,000 tonnes per annum (tpa)
- Product outputs include sodium hydroxide (NaOH) (caustic soda), liquefied chlorine gas (Cl<sub>2</sub>), hydrogen chloride (HCl), and sodium hypochlorite (NaOCl)
- Best practice membrane cell electrolytic process will be used in the production of chlorine
- All process steam generated by boiler burning an LPG and hydrogen mix.

The typical flow diagram of the membrane cell technique is provided in Figure 2. A schematic view of chlorine electrolysis cells is provided in Figure 3. In comparison to the alternative electrolysis techniques (diaphragm cell process and the mercury cell process), the membrane cell process has the following benefits:

- Low total energy consumption
- Low investment and operating costs
- Does not use mercury or asbestos
- High-purity caustic.

The entire facility will have a closed loop design and consequently will not have any fugitive releases. A potential fugitive source based on facilities elsewhere is the electrolyser room. In the case of the Project, the electrolyser room will be designed so that any leaks will be immediately identified by the control system due to the monitoring of pressure on either side of each electrolyser. The control system will have the capability to detect leaks as small as a pinhole.

Monitoring and preventing the potential exposure of onsite personnel to air pollutants is a critical occupational health and safety issue. A key strategy in the prevention of exposure is the use of hydrogen (H<sub>2</sub>) and chlorine (Cl<sub>2</sub>) gas detector sensors installed in buildings and key locations across the site that are linked to the plant operations to assist in identifying, managing and fixing leaks in a timely manner. Any fugitive releases would be detected and result in the immediate and automatic shutdown of that part of the plant and process.

Grenof proposes to use hydrogen gas that is produced in the chlor-alkali process to partially fuel the boiler for steam production. The fuel is anticipated to be an 80:20 LPG to hydrogen mix, on an energy basis. The boiler presents negligible risk to air quality.

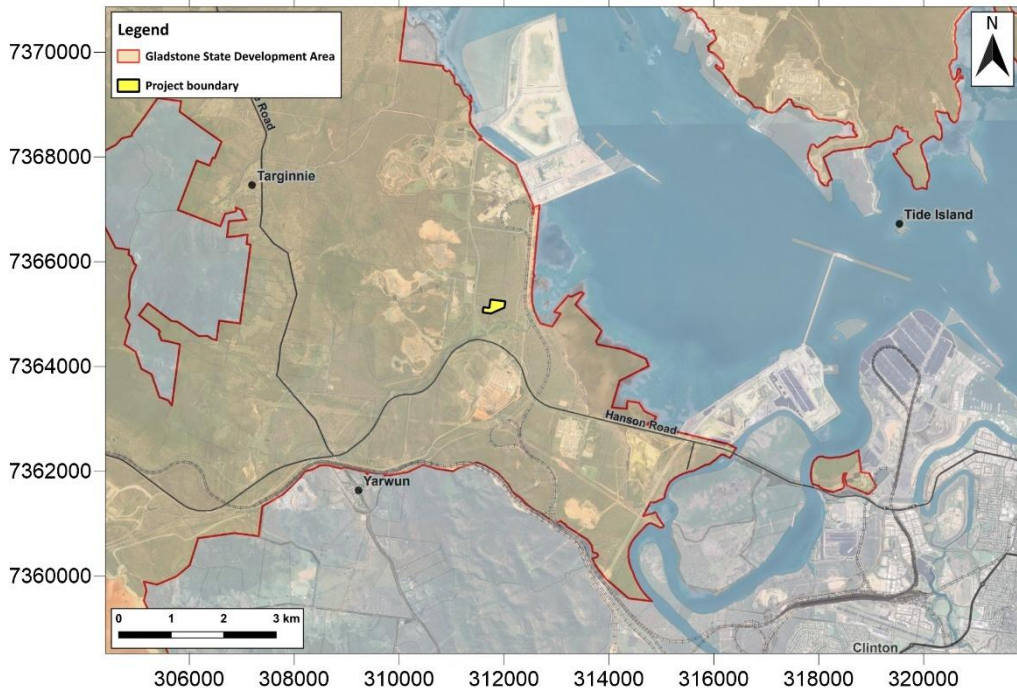


Figure 1 Project location and setting

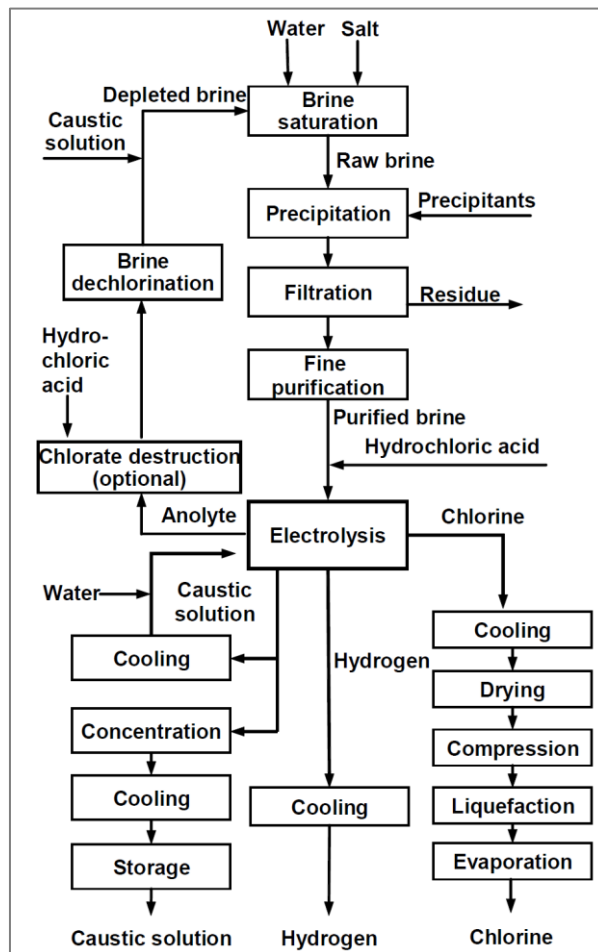


Figure 2 Typical flow diagram of the membrane cell technique (source: European Commission, 2014, Best Available Techniques (BAT) Reference Document for the Production of Chlor-alkali)

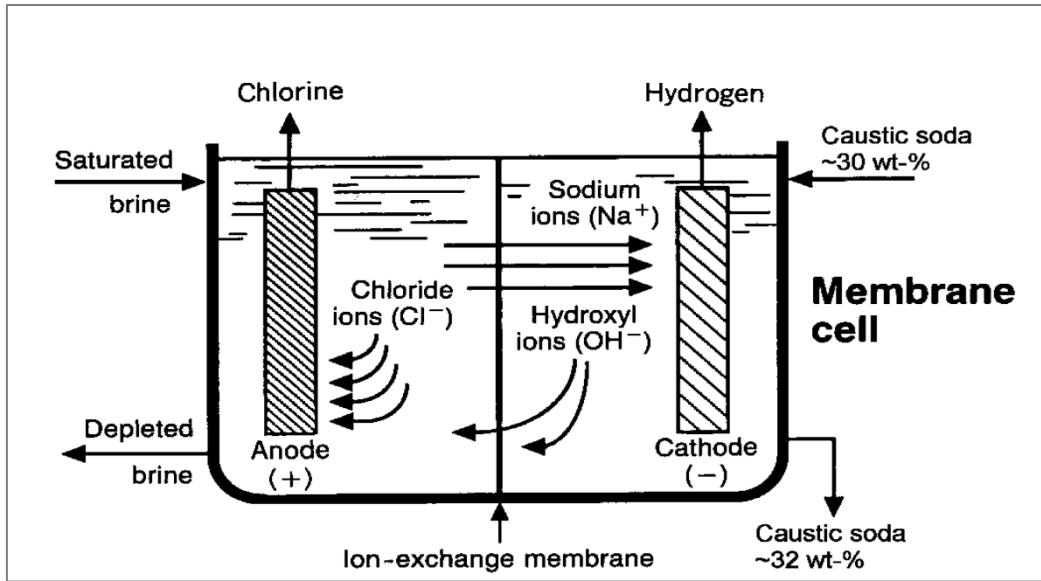


Figure 3 Schematic view of chlorine electrolysis cells for membrane cell technique (source: European Commission, 2014, Best Available Techniques (BAT) Reference Document for the Production of Chlor-alkali)

## 3. LEGISLATIVE FRAMEWORK FOR AIR QUALITY

### 3.1 Relevant State Policy

#### 3.1.1 Overview

The air quality assessment to support the DA has been prepared in accordance with the DETSI guideline *Application requirements for activities with impacts to air* (ESR/2015/1840, version 5.0.3, October 2024) (DETSI Guideline) and all other relevant legislation and regulatory requirements relating to air quality, including:

- *Environmental Protection Act 1994 (EP Act)*
- *Environment Protection Regulation 2019*
- *Environmental Protection (Air) Policy 2019* and the *Environmental Protection (Air) Amendment Policy 2024 (Air EPP)*
- Gladstone Regional Council Planning Scheme
- Gladstone SDA Development Scheme.

#### 3.1.2 EP Act and Air EPP

The *EP Act* provides for the management of the air environment in Queensland. The *EP Act* gives DETSI the power to create Environmental Protection Policies that identify, and aim to protect, environmental values of the atmosphere that are conducive to the health and well-being of humans and biological integrity. The National Environment Protection Council (NEPC) also defines national ambient air quality standards and goals in consultation with, and with agreement from, all Australian state and territory governments.

The *Environmental Protection (Air) Policy (Air EPP)* was made under the *EP Act* and gazetted in 1997. The Air EPP was revised and reissued in 2019. The *Environmental Protection (Air) Amendment Policy 2024 (EPP Air Amendment 2024)* commenced on 29 August 2024 and made amendments to the *Environmental Protection (Air) Policy 2019 (EPP Air)* to ensure Queensland remains consistent with the NEPC *National Environmental Protection (Ambient Air Quality) Measure (Air NEPM)*. Collectively, the *Environmental Protection (Air) Policy 2019* and the *Environmental Protection (Air) Amendment Policy 2024* are referred to as the Air EPP.

#### 3.1.3 Gladstone Regional Council Planning Scheme

The Gladstone Regional Council Planning Scheme Version 2 commenced in July 2017 and provides a framework for managing development in the Gladstone region that advances the purposes of the *Sustainable Planning Act 2009* (the SP Act). The scheme sets out Gladstone Regional Council's intention for future development in the planning scheme area and is reviewed periodically in accordance with the SP Act to ensure that it responds appropriately to the changes of the community at a local, regional and State level.

The scheme applies to the planning scheme areas of the Gladstone Regional Council and interrelates with the surrounding local government areas. Gladstone Region includes three areas declared by the State Government as SDAs. SDAs, including the Gladstone SDA where the Project is located, are clearly defined areas of land established by the Coordinator-General to promote economic development in Queensland.

### 3.1.4 Gladstone SDA Development Scheme

The Gladstone SDA Development Scheme provides for industrial development of national, State, and regional significance as well as complementary industrial, infrastructure and service uses. Any MCU within the Gladstone SDA requires a development approval.

The vision for the Gladstone SDA is to:

- a) *be Central Queensland's economic powerhouse, with an efficient concentration of large-scale industry of national, State and regional significance that benefit from the SDA's strategic location near the Port of Gladstone and major road and rail networks*
- b) *support development that aligns with the Queensland Government's strategic priorities for the region, particularly related to the hydrogen industry*
- c) *maintain environmental, cultural heritage and community values where possible to support wider ecological processes and provide community benefits.*

The vision is supported by the overall objectives, requiring development in the Gladstone to:

- a) *capitalise on Gladstone SDA's strategic location and support the role and function of the Port of Gladstone*
- b) *identify and implement opportunities for synergies and co-location between other uses, services and infrastructure to minimise waste and inefficiencies*
- c) *use land and infrastructure efficiently and be adequately serviced by infrastructure*
- d) *ensure the integrity and functionality of the Gladstone SDA, including infrastructure corridors and future development opportunities, is maintained and protected from incompatible land uses*
- e) *ensure new lots are appropriately sized to accommodate preferred development*
- f) *be designed, constructed, and operated to a high quality consistent with best practice*
- g) *avoid impacts on environmental, cultural heritage, and community values (including sensitive land uses), or minimise or mitigate impacts where they cannot be avoided and offset any residual impacts*
- h) *not adversely impact on the outstanding universal values of the Great Barrier Reef World Heritage Area*
- i) *manage the risks associated with the projected impacts of climate change and natural hazards to protect people and property*
- j) *manage impacts of air quality on the capacity of the Gladstone airshed.*

The Materials Transportation and Services Corridor Precinct of the Gladstone SDA passes through the Project site. Development in this precinct is required to:

- a) *minimise construction and operation footprints and follow a logical sequence of development to maximise opportunities for future linear infrastructure*
- b) *avoid adverse impacts on existing infrastructure*
- c) *provide and maintain access to the corridor for construction, operation, and maintenance of existing and future linear infrastructure*
- d) *co-exist with other linear infrastructure internal and external to the Gladstone SDA*
- e) *recognises and manages adverse impacts to sensitive land uses adjacent to the Gladstone SDA.*

An MCU within the Materials Transportation and Services Corridor Precinct of the Gladstone SDA is designated as SDA assessable development requiring an SDA application to be made to the Coordinator-General in accordance with Schedule 2 of the Scheme to obtain SDA approval.

### **3.2 Relevant air quality criteria**

Ambient air quality criteria for chlorine and hydrogen chloride are reproduced in Table 1. There are no air quality criteria or stack emission limits for chlorine or hydrogen chloride in Queensland State legislation or national legislation, therefore, in accordance with the DETSI Guideline the following documentation has also been considered:

- NSW *Protection of the Environment Operations (Clean Air) Regulation 2022* (POEO Clean Air Reg)
- New South Wales (NSW) Environment Protection Authority (EPA) publication *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales 2022* (NSW Approved Methods), referred to in the POEO Clean Air Reg
- Texas Commission on Environmental Quality (TCEQ) prescribed standards known as: *Effects Screen Levels (ESL)*
- Victoria Environment Protection Authority (VIC EPA) Publication *1961.2 Guideline for assessing and minimising air pollution in Victoria, 2025* (VIC EPA Air Pollution Guideline)
- WHO Air Quality Guidelines for Europe.

Where relevant, the most stringent air quality criteria have been applied for each pollutant.

**Table 1 Ambient air quality criteria for chlorine and hydrogen chloride**

Air pollutant	Type	Regulatory document	Units	Value	Time period
Chlorine (Cl <sub>2</sub> )	Impact assessment criteria	NSW Approved Methods	µg/m <sup>3</sup>	50	1-hour
	Short-term Effects Screening Level (ESL)	Texas Commission on Environmental Quality	µg/m <sup>3</sup>	43	1-hour
Hydrogen chloride (HCl)	Air pollution assessment criteria (APAC)	VIC EPA Air Pollution Guideline	µg/m <sup>3</sup>	2,100	1-hour
				20	1-year
	Impact assessment criteria	NSW Approved Methods	µg/m <sup>3</sup>	140	1-hour

### 3.3 Emissions limits

The *Protection of the Environment (Operations) Act 1997* (POEO Act) is applied to the regulation of air pollution in New South Wales. The POEO Act is underpinned by a number of regulatory instruments that address air quality including the *Protection of the Environment Operations (Clean Air) Regulation 2010* (Clean Air Regulation) that imposes generic operational requirements for activities and plant. Section 128 of the POEO Act requires each premises to comply with any air emission standards prescribed by applicable regulations; where standards are not prescribed for a particular air impurity, all practical means must be taken to prevent or minimise air pollution. The Clean Air Regulation specifies emission standards that are relevant to Section 128 of the POEO Act.

In the absence of any State-specific emission standards, where relevant, those under the Clean Air Regulation are typically applied to the assessment of development in Queensland. The standards specified by the POEO Clean Air Reg for in-stack concentrations of hydrogen chloride, chlorine and oxides of nitrogen are shown in Table 2.

**Table 2 Air quality emission limits for chlorine and hydrogen chloride**

Pollutant	Activity or plant	Regulatory document	Units	Value
Chlorine (Cl <sub>2</sub> )	General standard of concentration for an activity or plant	POEO Clean Air Reg	mg/m <sup>3</sup>	200
Hydrogen chloride (HCl)	General standard of concentration for an activity or plant, an activity, other than the manufacture of glazed terracotta roofing tiles	POEO Clean Air Reg	mg/m <sup>3</sup>	100
Nitrogen dioxide (NO <sub>2</sub> ) or nitric oxide (NO) or both nitrogen dioxide and nitric oxide, as NO <sub>2</sub> equivalent	A boiler operating on gas	POEO Clean Air Reg	mg/m <sup>3</sup>	350

## 4. AIR QUALITY ASSESSMENT METHODOLOGY

### 4.1 Existing environment

The assessment includes an analysis of the characteristics of the existing environment (Section 5) in the Project area that are important for the dispersion of air pollutants and that may influence the level of air pollutants at sensitive receptors. Characteristics include terrain features, regional land uses, existing sources of emissions, existing ambient pollutant concentrations and the locations of sensitive receptors relative to the sources.

### 4.2 Emissions

#### 4.2.1 Construction risk assessment

Construction phase activities can be broadly described as the erection of structures, installation of plant and minor site clearance, where needed. The primary pollutant emitted to air during the construction phase is likely to be dust (i.e., particulate matter). Minor levels of combustion air pollutants may be associated with vehicle and machinery activity. Emissions to air from these activities are expected to be minimal.

The Institute of Air Quality Management (IAQM) has published a risk assessment methodology titled Guidance on the assessment of dust from demolition and construction (IAQM Methodology) (Stoaling et al, 2024). Whilst the IAQM methodology was drafted with the intention of application in the United Kingdom, it is widely used in Australia to assess construction of industrial infrastructure and is suitable for application to the construction phase of the Project.

Potential dust emissions arising from the construction phase of the Project have been addressed using the IAQM Methodology in Section 6.1.

Recommended measures to minimise impacts to air quality during construction are provided in Section 8.

#### 4.2.2 Operational emissions

Emissions to air due to the operation of the Project are discussed in Section 6.2. The potential impact to air quality from the following sources of air pollutant emissions has been assessed using a dispersion modeling assessment:

- Waste gas dechlorination stack
- Hydrogen chloride vent burner stack.

The following additional potential sources have been considered and identified as a negligible risk to air quality at nearest sensitive receptors:

- Hydrogen vent stacks (two stacks) – only contaminant is hydrogen, therefore no health risk
- Boiler stack – worst case estimate – ground-level concentration of NO<sub>2</sub> is likely to be less than 2% of the objective
- Leaks and failures in storage tanks, pipes and fittings, connections and filled bottles – strictly managed to avoid onsite health and safety issues, consequently, offsite levels will be minimal
- Potential fugitive (wind-blown) particulate matter emissions from the salt stockpile.

### 4.3 Meteorology

A site-specific meteorological data file was generated for the Project by coupling the prognostic model TAPM with the diagnostic meteorological model CALMET. The most recent versions of the TAPM (version 4.0.5) and CALMET (version 6.5.0) models at the time of undertaking the study were utilised.

The coupled TAPM/CALMET modelling system was developed to enable high resolution modelling capabilities for regulatory and environmental assessments. The modelling system incorporates synoptic, mesoscale, and local atmospheric conditions, detailed topographic and land use categorisation schemes to simulate synoptic and regional scale meteorology for input into pollutant dispersion models such as CALPUFF.

Technical details of the TAPM and CALMET model configurations are provided in Appendix A, including a validation of the generated data and a summary of the meteorological data generated for the Project. Local meteorology is of paramount importance for dispersion of air pollutants generated by the Project's activities; key features are wind speed, wind direction, atmospheric stability and boundary layer mixing height. Conditions in the local area, as derived from the meteorological modelling carried out for the assessment, are discussed in detail in Appendix A.

### 4.4 Dispersion modelling

The CALPUFF model (version 7.2.1) was used for dispersion modelling. CALPUFF is an advanced non-steady-state air quality modelling system. Twelve months of modelled meteorological data was used as input for the dispersion model in order to include all weather conditions likely to be experienced in the region during a typical year, as described in Appendix A.

Emission sources were configured in CALPUFF based on the information for each of the following sources:

- Waste gas dechlorination stack (Cl<sub>2</sub> emissions)
- Hydrogen chloride vent burner stack (Cl<sub>2</sub> and HCl emissions).

All other potential Project sources have been discussed and identified as negligible (see Section 6.2). Details of the model configuration are provided in Appendix A.

### 4.5 Cumulative impacts

There is no representative ambient air quality monitoring data for the air pollutants that are associated with the proposed development, namely chlorine and hydrogen chloride. Therefore, the assessment of the potential impact of the Project has been conducted for the Project in isolation.

### 4.6 Limitations and uncertainty

This study relies on the accuracy of a number of data sets that feed into the dispersion model, all of which will have uncertainties associated with them. The input data sets include:

- Meteorological monitoring observations from the Bureau of Meteorology (BoM)
- Emissions data provided by the Project team
- Synoptic and surface information datasets from CSIRO.

It is also important to note that numerical models are based on an approximation of governing equations and will inherently be associated with some degree of uncertainty. The more complex the physical model, the greater the number of physical processes that must be included. There will be physical processes that are not explicitly accounted for in the model and, in general, these approximations tend to lead to an over prediction of air pollutant levels.

In addition to the built-in conservatism described above, Katestone has configured the dispersion model with conservative assumptions and, therefore, the assessment is likely to overpredict potential impacts of the Project.

## 5. EXISTING ENVIRONMENT

### 5.1 Local terrain and land-use

The proposed development is located in Yarwun, approximately 12 km west northwest of Central Gladstone and 2 km inland of the Gladstone Harbour. The coastal region is dominated by littoral zones with mangroves and very large tidal zones.

The proposed development is in a low-lying area (Figure 4), with elevations between 5 m and 20 m Australian Height Datum (AHD). The terrain surrounding the proposed development is also relatively low lying, with elevation increasing at a small hill between the site and Mount Larcom, which reaches just under 250 m AHD. Further to the west, at approximately 6 km from the site, Mount Larcom rises to a peak of about 470 m AHD.

The Project is located within the Gladstone SDA and, consequently, surrounding land use consists predominantly of heavy industrial activity, including alumina refining, concrete production, oil refining, rock and sand quarrying, hydrogen and coal exportation and chemicals manufacturing.

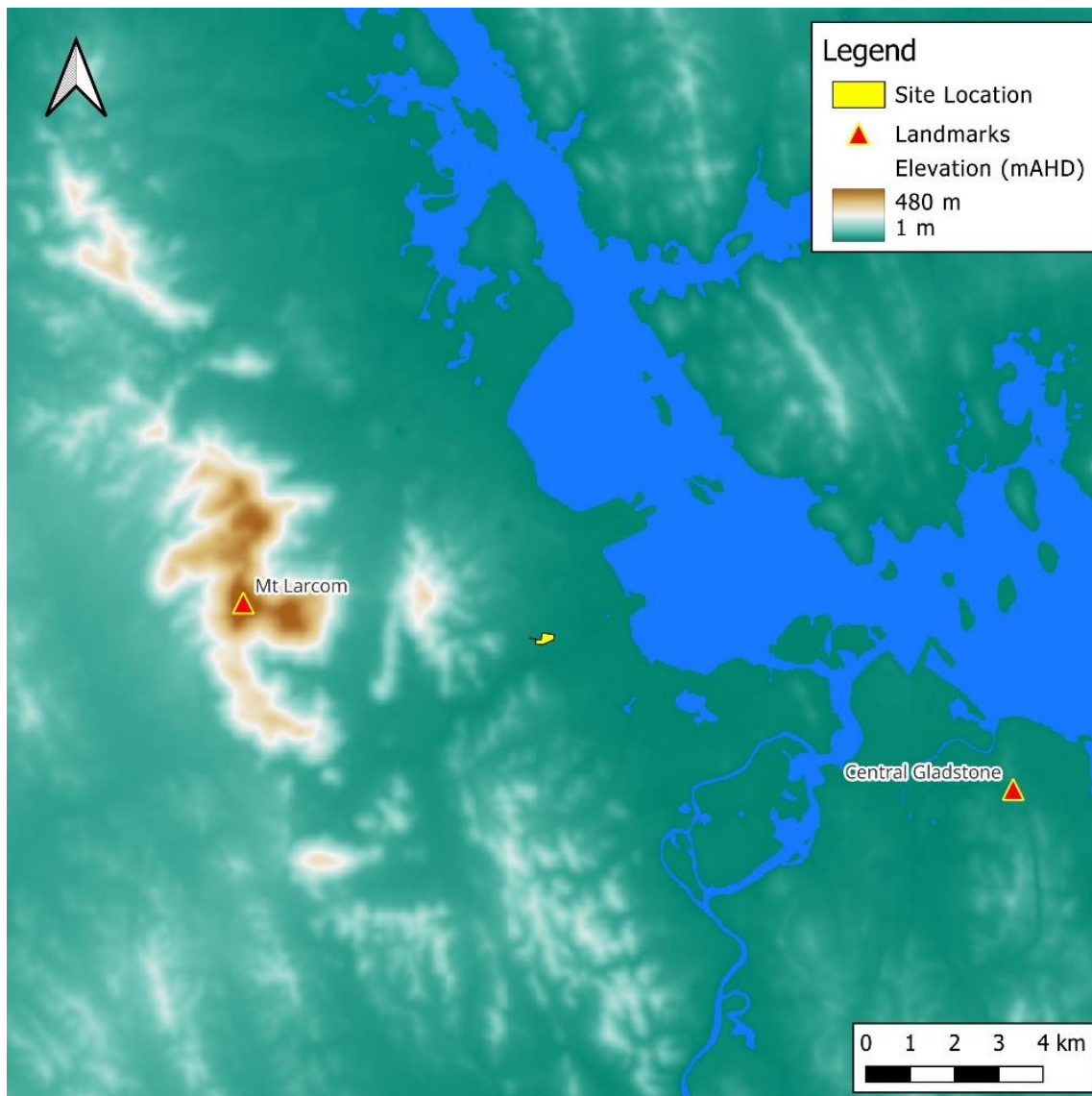


Figure 4 Terrain surrounding the study area

## 5.2 Sensitive receptors

The Project is located within the Gladstone SDA, an area designated and ready to accommodate large-scale industry, including port related industry, high impact industry, and medium industry. The nearest residential receptor is located 3.7 km to the west of the Project, as shown in Figure 5. The nearest township is Yarwun, approximately 4 km southwest of the site boundary.

Maximum ground-level concentrations of key air pollutants have been predicted at the nearest sensitive receptors. Pollutant concentrations have also been predicted at ground level across a Cartesian grid of receptors (250 m resolution) to enable the production of contour plots of concentration across the study area.

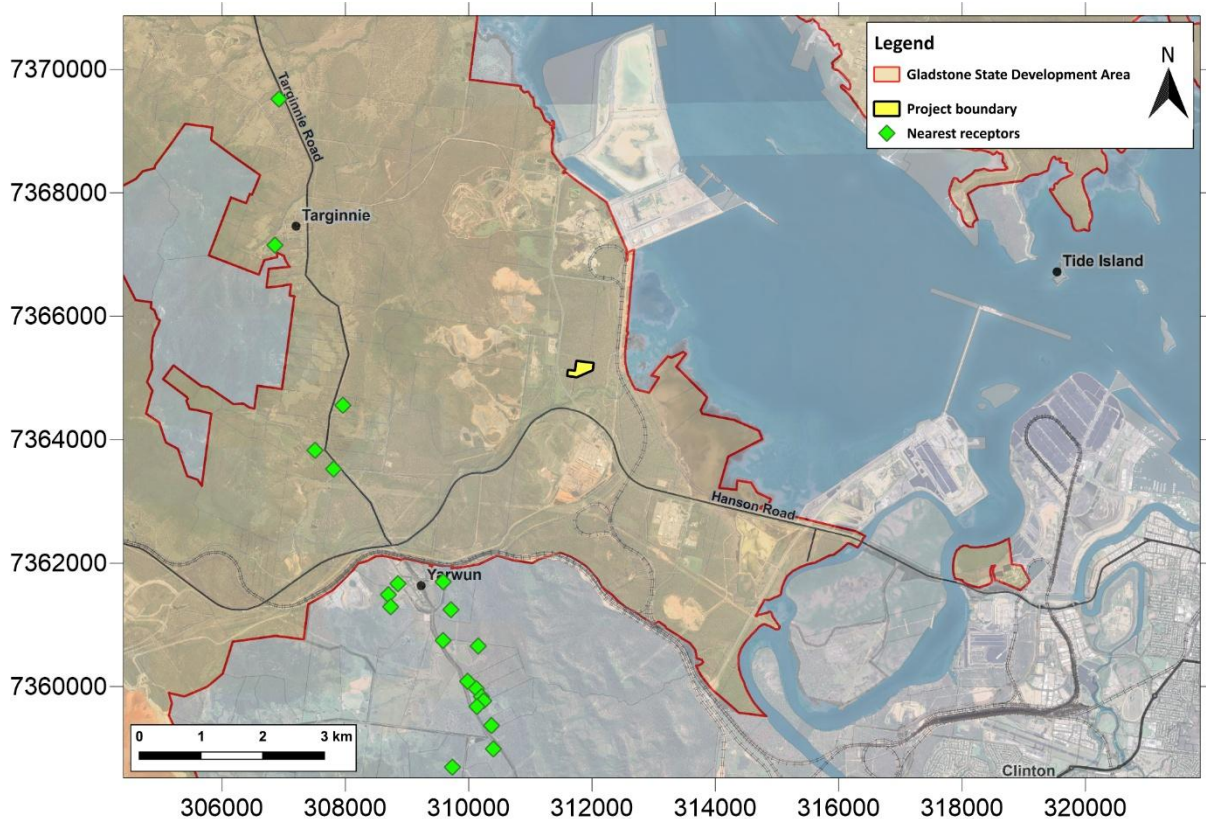


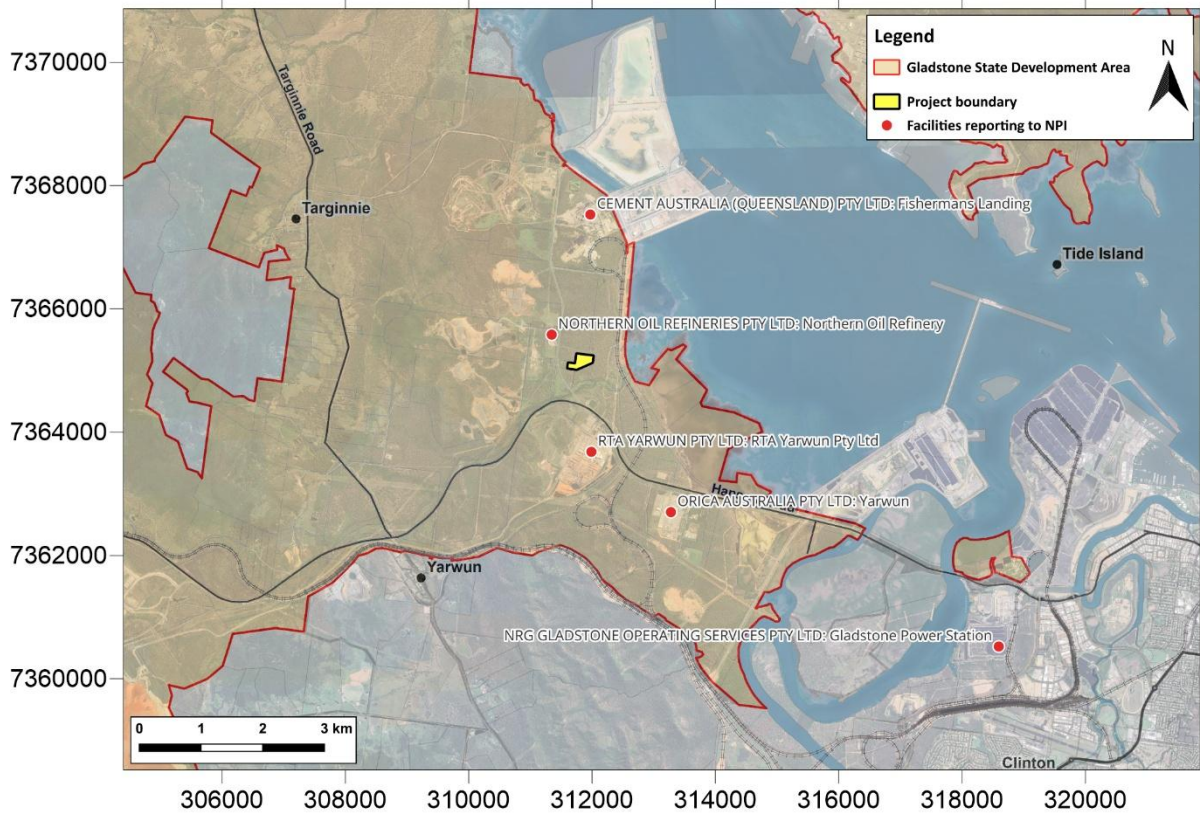
Figure 5 Location of nearest sensitive land uses

## 5.3 Existing air quality

### 5.3.1 Existing sources of emissions

The results of a search of the National Pollutant Inventory (NPI) database for the key air pollutants for the 2023/24 reporting year within the Gladstone area are presented in Figure 6 and in Table 3.

The anticipated annual emissions of Cl<sub>2</sub> and HCl from the Project are approximately 13 kg and 3 kg, respectively (see Section 6.2). The Project contribution of HCl is insignificant compared to the levels of this pollutant emitted by other sources in the Gladstone airshed (Table 3). Project emissions of Cl<sub>2</sub> are of similar magnitude to those emitted by other sources in the Gladstone airshed.



**Figure 6 Gladstone facilities reporting emissions of Cl or HCl to the NPI in the 2023/24 period**

**Table 3 Emissions of Cl and HCl reported to the NPI in the 2023/24 period by Gladstone facilities**

Registered business name	Facility	Main activities	Emissions (kg/year)	
			Chlorine & compounds	Hydrochloric acid
Cement Australia (Queensland) Pty Ltd	Fishermans landing	Cement manufacturing	-	13,600
Northern Oil Refineries Pty Ltd	Northern Oil Refinery	Used oil recycling	-	116
NRG Gladstone Operating Services Pty Ltd	Gladstone Power Station	Electricity generation using coal or coal derived products	4.62	614,000
Orica Australia Pty Ltd	Yarwun	Explosive manufacturing	0.17	0.19
RTA Yarwun Pty Ltd	RTA Yarwun	Alumina refining	-	6,292

### 5.3.2 Existing ambient air quality

DETSI is responsible for undertaking ambient air quality monitoring in Queensland. No DETSI monitoring stations monitor ambient levels of chlorine compounds or hydrogen chloride anywhere in the state.

## 6. EMISSIONS TO THE ATMOSPHERE

### 6.1 Construction dust emissions

Potential dust emissions arising from the construction phase of the Project have been addressed using the IAQM Methodology. This qualitative approach is appropriate due to the temporary nature of the proposed construction activities and well-established mitigation measures that can be applied to minimise potential dust emissions. The magnitude of impacts depends on the mitigation measures adopted. Therefore, the emphasis of the IAQM is primarily on classifying the risk of dust impacts from a site to then identify suitable mitigation measures to reduce those risks.

The IAQM sets out initial screening criteria for determining the need to conduct a construction dust risk assessment, with a risk assessment required where a 'human receptor' is within:

- 250 m of the boundary of the site; or
- 50 m of the route(s) used by construction vehicles on the public highway, up to 250 m from the site entrance(s).

Where the nearest sensitive receptors are located outside the defined distances above, no further assessment is required. Review of the Project boundary and the locations of the nearest sensitive receptors (Section 5.2) against the screening criteria indicates that a detailed risk assessment is not necessary.

Consequently, the risk of dust impacts at sensitive receptor locations during the construction phase of the Project are determined to be negligible. Risks can be minimised further through the application of standard dust management and mitigation measures, which should be applied regardless of risk, in accordance with the general environmental duty (GED) of the *EP Act*. These are discussed in Section 8.

### 6.2 Operation emissions

#### 6.2.1 Overview of chlor-alkali industry emissions

The National Pollutant Inventory (NPI) reports both inputs and pollutant emissions from the chlor-alkali industry as '*relatively small, both in number and volume*'. As per the NPI Emission Estimation Handbook Inorganic Chemicals Manufacturing (version 2.0, February 2004):

*Emissions of gaseous pollutants have decreased in recent years as the industry moves away from the mercury and diaphragm cell processes to the more efficient (in terms of material and energy inputs and emissions) membrane cell process. In addition, improved cell part materials have been developed, such as DSA anodes and Modified Diaphragms, which are more stable and create less undesirable by-products.*

With respect to the membrane cell technology that is proposed for the project, the NPI reports that:

*Chlorine is emitted in relatively small amounts as fugitive emissions from the cells and in the process tail gases. Process tail gases are wet scrubbed with soda ash or caustic soda solutions to remove chlorine. Residual chlorine emissions in tail gases after treatment are negligible. The spent caustic solution is neutralised prior to discharge.*

The spent caustic solution at the proposed facility will not be discharged and will instead be re-used in the production of sodium hypochlorite at the facility.

The following potential sources of air pollutant emissions during operation of the project have been considered:

- Stack and vent sources

- Fugitive sources.

## 6.2.2 Stack and vent sources

The Project will have four stack or vent sources that will emit to air:

- Waste gas dechlorination stack
- Hydrogen chloride vent burner stack
- Hydrogen vent stacks (two stacks).

The hydrogen vent stacks emit only steam and hydrogen at concentrations below its lower explosive limit. Therefore, the hydrogen vent stacks present negligible risk to air quality and have not been considered further.

Regarding the waste dechlorination stack and the hydrogen chloride vent burner stack, relevant details of stack characteristics and emission rates are provided in Table 4. The air pollutants that are emitted from these sources are chlorine gas (Cl<sub>2</sub>) and hydrogen chloride (HCl). These parameters and emission rates have been used in the dispersion modelling assessment of these sources.

As shown in Table 4, the concentrations of hydrogen chloride and chlorine in the emissions from the Project are significantly lower than the emissions standards specified by the POEO Clean Air Regulations (see Table 2), being 30 percent (HCl) and 2.5 percent (Cl<sub>2</sub>) of the standards.

**Table 4 Stack characteristics and emission rates**

Parameter	Unit	Source	
		Waste gas dechlorination stack	Hydrogen Chloride vent burner stack
Stack height	m	20	22
Stack diameter	m	0.2	0.05
Flow rate <sup>a</sup>	Nm <sup>3</sup> /hr	1,400	11.5
Temperature	°C	45	45
Exit velocity	m/s	13.5	1.77
<b>Pollutant concentration and emission rate</b>			
Chlorine (Cl <sub>2</sub> )	mg/Nm <sup>3</sup>	1.0	5.0
	ppm	0.34	1.70
	g/s	0.00039	0.000016
	kg/annum	12.26	0.51
Hydrogen chloride (HCl)	mg/Nm <sup>3</sup>	-	30
	ppm	-	19.8
	g/s	-	0.000096
	kg/annum	-	3.03
Table note: <sup>a</sup> Normalised to 20°C, 101.3 kPa			

### 6.2.3 Fugitive sources

A summary of the fugitive sources during operation of the project, along with an assessment of their risk to air quality, is provided in Table 5. Sources include:

- Leaks and failures in storage tanks, pipes and fittings, connections and filled bottles
- Potential fugitive (wind-blown) particulate matter emissions from the salt stockpile.

As shown in Table 5, the potential impact to air quality from fugitive sources at the project has been identified as minimal. Consequently, these sources have not been included in the dispersion modelling assessment.

**Table 5 Fugitive sources**

Source	Description	Assessment of risk to air quality at sensitive land uses	Summary of risk
Storage tanks	Leaks and overflows of storage tanks (brine, NaOH, HCl, liquefied chlorine gas, LPG, NaCl storage tanks)	<ul style="list-style-type: none"> <li>• Tanks are largely contained in storage sheds/buildings</li> <li>• Leaks and overflows very unlikely to occur</li> <li>• Onsite monitoring of Cl<sub>2</sub> and H<sub>2</sub> will identify elevated ambient concentrations onsite before they result in offsite impacts</li> </ul>	Minimal
Pipes, fittings, connections and filled bottles	Leaks	<ul style="list-style-type: none"> <li>• Cl<sub>2</sub> sniffers will also be installed that will notice any leaks and have the ability to automatically shut-down the facility in the event of a leak</li> <li>• Leaks are an occupational health and safety issue so will be strictly monitored and immediately resolved</li> </ul>	Minimal
Salt stockpile	Potential fugitive (wind-blown) particulate matter emissions from surface of stockpile	<ul style="list-style-type: none"> <li>• Salt is coarse material and the salt stockpile will quickly form a crust, reducing potential for lift-off of material</li> <li>• The stockpile will be covered and enclosed from three sides, minimising exposure to strong wind and capturing any material lift-off</li> </ul>	Minimal

## 7. RESULTS

Results of the dispersion modelling for Cl<sub>2</sub> and HCl are provided in Table 2. Results are provided as:

- Maximum ground-level concentration at the location of the nearest sensitive receptor, located approximately 3.7 km to the west of the Project
- Maximum ground-level concentration anywhere within the model domain.

Contour plots of maximum ground-level concentration across the model domain are also provided for 1-hour Cl<sub>2</sub>, 1-hour HCl, and annual average HCl in Plate 1 to Plate 3, respectively. All results show predicted concentration due to the Project assessed in isolation.

The results of the dispersion modelling show that peak concentrations, including those within the Project site boundary, **comply** with the relevant assessment criteria for Cl<sub>2</sub> and HCl by a significant margin. In particular, the highest concentration of either pollutant anywhere in the model domain is predicted to be less than 0.3 percent of the relevant air quality assessment criteria.

**Table 6 Predicted maximum ground-level concentration of key air pollutants at nearest sensitive receptors**

Location	Pollutant concentration (µg/m <sup>3</sup> )		
	Chlorine (Cl <sub>2</sub> )	Hydrogen chloride (HCl)	
	Maximum 1-hour average	Maximum 1-hour average	Annual average
Nearest sensitive receptor	0.014	0.007	0.00004
Maximum on model domain	0.104	0.033	0.0007
Maximum concentration as percentage of criterion	0.21%	0.02%	0.004%
<b>Criteria</b>	<b>50</b>	<b>140</b>	<b>20</b>

## 8. MANAGEMENT MEASURES

### 8.1 Construction stage

As demonstrated in Section 6.1, risks of dust impacts at sensitive receptor locations during the construction phase of the Project have been identified as negligible. However, under the general environmental duty (GED) of the *EP Act*, during both construction and operation of the Project, all reasonably practicable measures should be applied to prevent or minimise any potential environmental harm. Therefore, it is recommended that the risks of potential offsite dust impacts during the construction phase be further minimised through the inclusion of dust management within the Project's Environmental Management Plan (EMP) and the implementation of standard dust control and mitigation measures such as those in the IAQM Methodology. Key measures include:

- Erect solid screens or barriers around dust activities or the site boundary
- Cover, seed or fence stockpiles and/or exposed surfaces to prevent wind erosion and re-vegetate exposed surfaces as soon as possible
- Seal site haul roads or apply water suppression and minimise vehicle speed on unsurfaced roads
- Use suitable dust suppression techniques (water sprays, local extraction, etc.) during use of cutting, grinding or sawing equipment
- Ensure an adequate water supply on the site for effective dust and particulate matter suppression or mitigation, using non-potable water where possible and appropriate
- Implement a wheel-washing system and ensure vehicles entering and leaving the site are covered.

### 8.2 Operation stage

The risks to air quality during the operation phase of the Project are minimised through the following:

- The facility will use the best practice membrane cell electrolytic process in the production of chlorine, which, compared to alternative electrolysis techniques (diaphragm cell process and the mercury cell process) has no use of mercury or asbestos
- The use of hydrogen and chlorine gas detector sensors installed in buildings and key locations across the site that are linked to the plant operations to assist in identifying, managing and fixing leaks in a timely manner. Any fugitive releases will be detected and result in the immediate and automatic shutdown of that part of the plant and process.
- The entire facility will have a closed loop design and consequently will not have any fugitive releases. The design of the facility is such that any potential sources of release will be minimal, easily identified, and immediately and automatically rectified.
- Systematic collection and redirection of waste gas stream to the chlorine absorption unit to reduce chlorine to trace levels ( $< 1 \text{ mg/Nm}^3$ ) prior to release
- Scrubber on HCl synthesis unit to reduce chlorine and hydrogen chloride to low levels ( $\leq 5 \text{ mg/Nm}^3$  and  $\leq 30 \text{ mg/Nm}^3$ , respectively)
- Maintaining a significant buffer zone to sensitive receptor locations.

## 9. CONCLUSIONS

An air quality assessment has been carried out for Project Halogen, a proposed Chlor-Alkali facility proposed to be located within the Gladstone SDA. The assessment has been prepared in accordance with the DETSI guideline (2024) and all other relevant legislation and regulatory requirements to support a DA for a MCU for a concurrence ERA 7(6d) *Chemical manufacturing: manufacturing in a year, more than 100,000 tonnes of inorganic chemicals* for the proposed Chlor-Alkali facility.

The air quality assessment used recognised techniques for dispersion modelling and emission estimation to determine the potential impacts to sensitive receptors and the surrounding environment. The dispersion modelling has assessed the potential impacts to air from the following sources:

- Waste gas dechlorination stack ( $\text{Cl}_2$  emissions)
- Hydrogen chloride vent burner stack ( $\text{Cl}_2$  and HCl emissions).

The following additional potential sources were identified as negligible so were not included in the dispersion modelling:

- Hydrogen vent stacks (two stacks)
- Leaks and failures in storage tanks, pipes and fittings, connections and filled bottles
- Potential fugitive (wind-blown) particulate matter emissions from the salt stockpile.

The dispersion modelling has been conducted to predict the maximum ground-level concentrations of  $\text{Cl}_2$  and HCl at the location of the nearest sensitive land use located approximately 3.7 km to the west of the Project, as well as the maximum ground-level concentration anywhere within the model domain. Maximum concentrations at these locations have been assessed against the relevant air quality assessment criteria for  $\text{Cl}_2$  and HCl.

The results of the dispersion modelling show that peak concentrations, including those within the Project site boundary, **comply** with the relevant assessment criteria for  $\text{Cl}_2$  and HCl. The highest concentration of either pollutant anywhere in the model domain is predicted to be less than 0.3 percent of the relevant air quality assessment criteria.

The risks to air quality during the operation phase of the Project are minimised through the following design aspects:

- Best practice membrane cell electrolytic process used in the production of chlorine
- Hydrogen and chlorine gas detector sensors are installed in buildings and key locations across the site that are linked to the plant operations to assist in identifying, managing and fixing leaks in a timely manner
- Closed loop design whereby any potential sources of release will be minimal, easily identified, and immediately and automatically rectified.
- Systematic collection and redirection of waste gas stream to the chlorine absorption unit to reduce chlorine to trace levels ( $< 1 \text{ mg/Nm}^3$ ) prior to release and installation of a scrubber on the HCl synthesis unit to reduce chlorine and hydrogen chloride to low levels ( $\leq 5 \text{ mg/Nm}^3$  and  $\leq 30 \text{ mg/Nm}^3$ , respectively)
- Maintaining a significant buffer zone to sensitive receptor locations.

Risks of dust impacts at sensitive receptor locations during the construction phase of the Project have been identified as negligible; however, under the GED of the *EP Act*, during both construction and operation of the Project, all reasonably practicable measures should be applied to prevent or minimise any potential environmental harm.

## 10. REFERENCES

Environmental Protection Authority Victoria (EPA VIC), 2025, Guideline for assessing and minimising air pollution in Victoria, EPA Publication 1961.2

Department of Climate Change, Energy, the Environment and Water (DCCEEW), 2025, National Pollutant Inventory Database, available online: <https://www.npi.gov.au/npidata/action/load/advance-search>

Department of Environment, Tourism, Science and Innovation (DETSI), 2024, Guideline: Application requirements for activities with impacts to air, ESR/2015/1840, version 5.0.3, October 2024

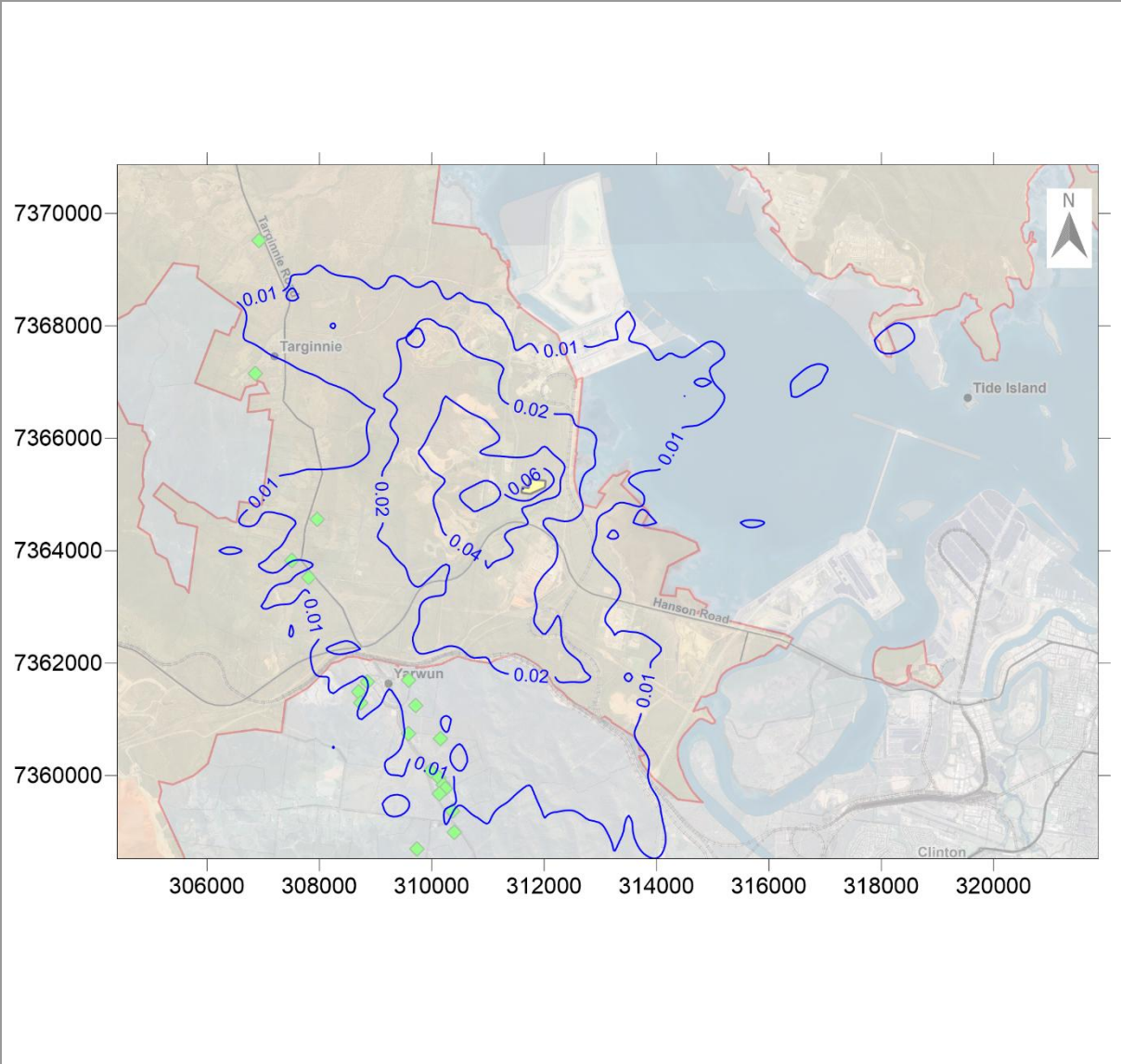
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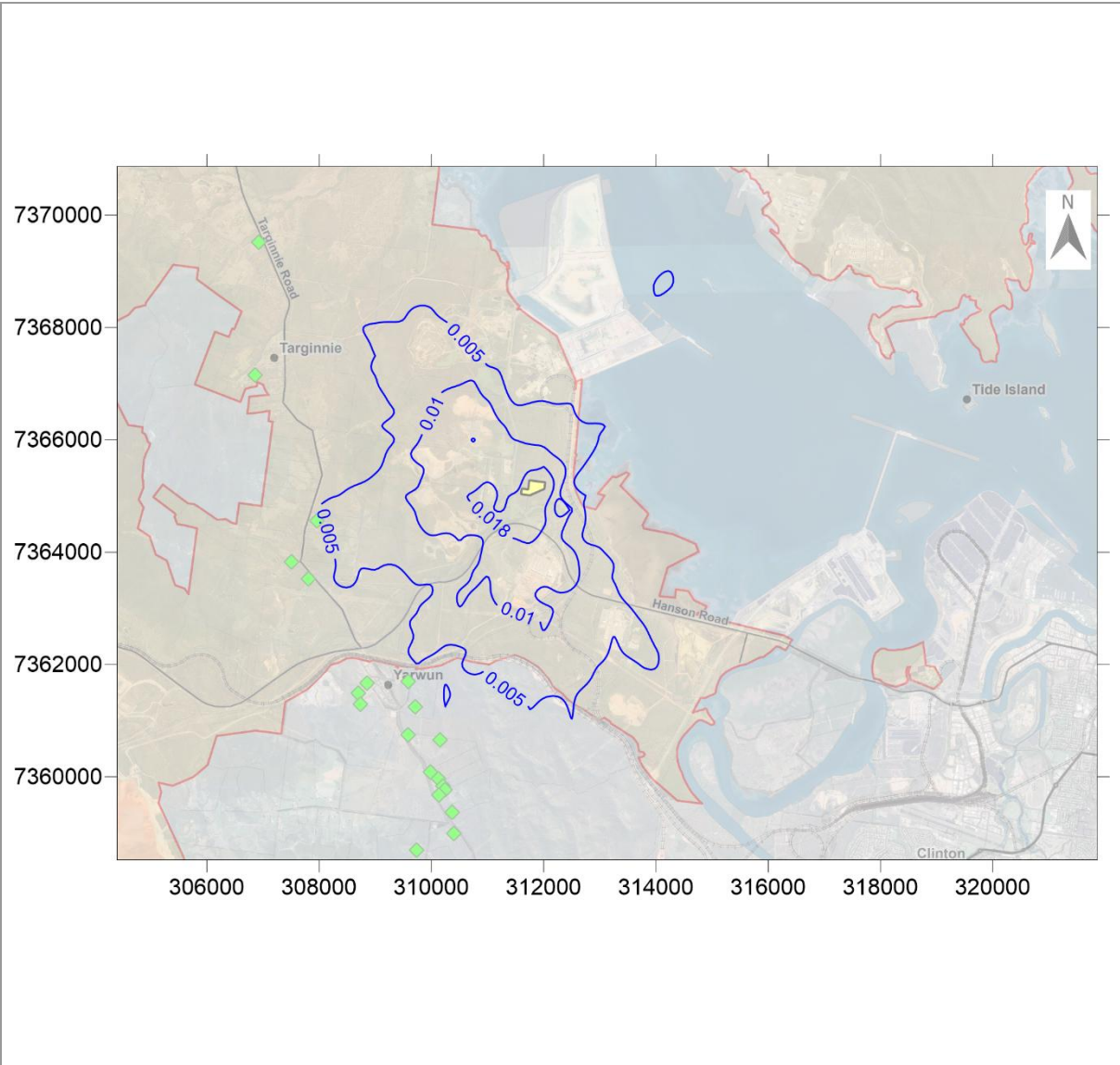
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## 11. CONTOUR PLOTS



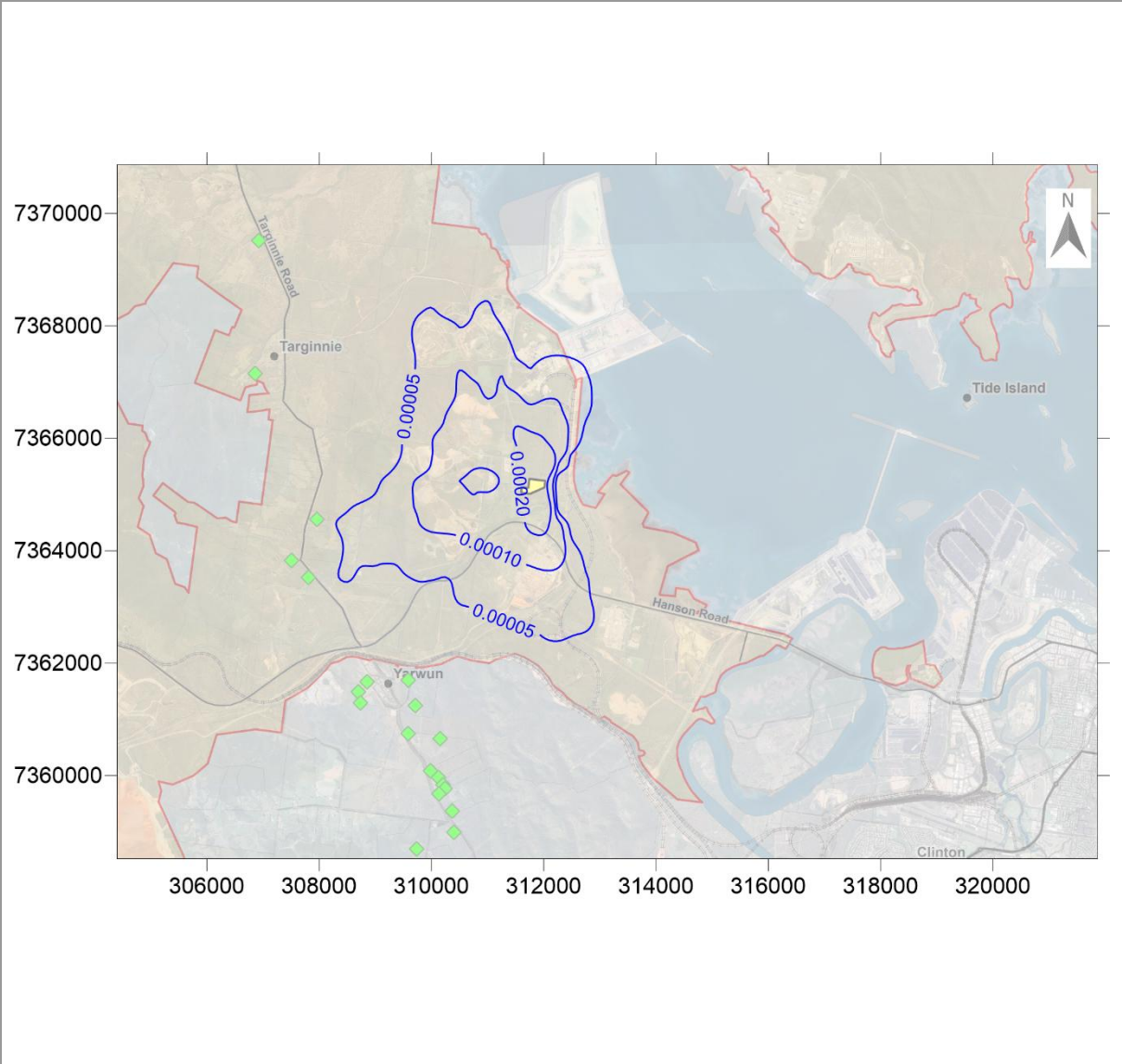
**Plate 1 Chlorine gas (Cl<sub>2</sub>): Predicted maximum 1-hour average ground-level concentrations due to emissions from the Facility in isolation**

<b>Location:</b> Gladstone, Queensland	<b>Averaging period:</b> 1-hour	<b>Data source:</b> CALPUFF	<b>Units:</b> µg/m <sup>3</sup>
<b>Type:</b> Maximum contour plot	<b>Objective:</b> 50 µg/m <sup>3</sup> (NSW Approved Methods)	<b>Prepared by:</b> Sarah Richardson	<b>Date:</b> October 2025



**Plate 2 Hydrogen chloride (HCl): Predicted maximum 1-hour average ground-level concentrations due to emissions from the Facility in isolation**

<b>Location:</b> Gladstone, Queensland	<b>Averaging period:</b> 1-hour	<b>Data source:</b> CALPUFF	<b>Units:</b> $\mu\text{g}/\text{m}^3$
<b>Type:</b> Maximum contour plot	<b>Objective:</b> 140 $\mu\text{g}/\text{m}^3$ (NSW Approved Methods) 2,100 $\mu\text{g}/\text{m}^3$ (VIC EPA APAC)	<b>Prepared by:</b> Sarah Richardson	<b>Date:</b> October 2025



**Plate 3 Hydrogen chloride (HCl): Predicted annual average ground-level concentrations due to emissions from the Facility in isolation**

<b>Location:</b> Gladstone, Queensland	<b>Averaging period:</b> Annual	<b>Data source:</b> CALPUFF	<b>Units:</b> $\mu\text{g}/\text{m}^3$
<b>Type:</b> Maximum contour plot	<b>Objective:</b> $20 \mu\text{g}/\text{m}^3$ (VIC EPA APAC)	<b>Prepared by:</b> Sarah Richardson	<b>Date:</b> October 2025

# APPENDIX A METEOROLOGICAL AND DISPERSION MODELLING METHODOLOGY

## A1 Meteorology

The meteorological modelling methodology for the Project included the following steps:

- Selection of a representative year
- TAPM modelling and validation
- CALMET modelling.

The following sections describe each step of the meteorological modelling conducted for the Project. A summary of the meteorological data generated is provided in Section A1.5.

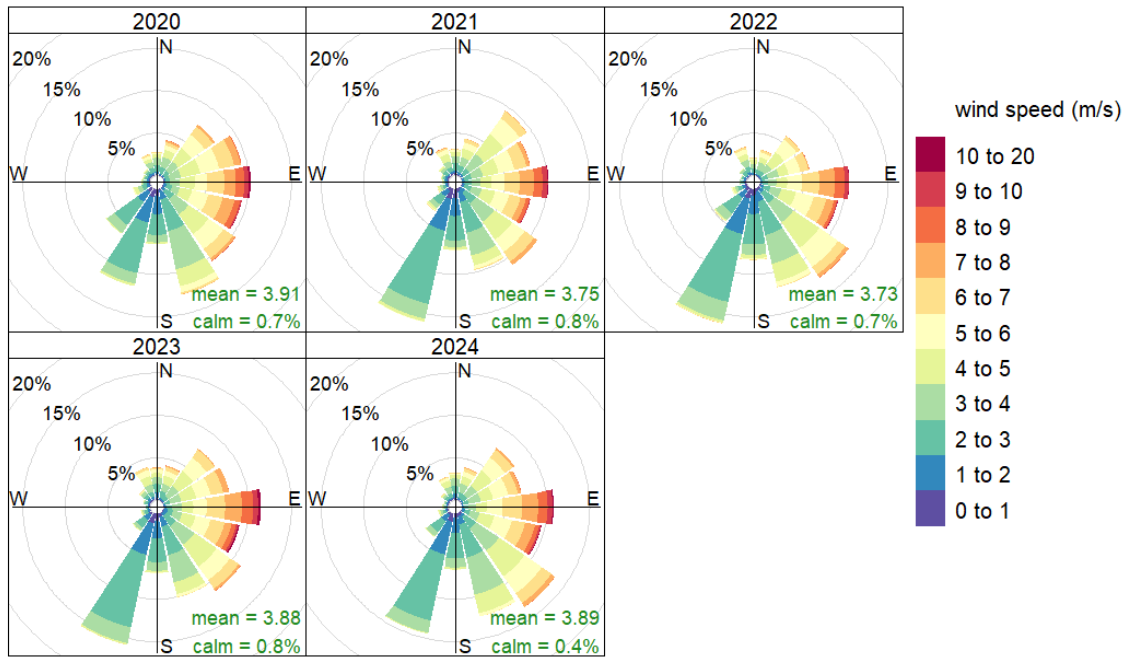
### A1.1 Selection of representative year

A representative year is required to be selected at the beginning of the meteorological modelling process. Using a representative year in the air quality assessment ensures that the typical conditions experienced at the Project site are reflected in the model.

Selection of a representative year has been done through statistical analysis of historical meteorological observations at the Bureau of Meteorology (BoM) automatic weather station (AWS) located at Gladstone Airport. Meteorological observations from the past five years (2020 to 2024) at Gladstone Airport were analysed to assess the inter-annual variability.

Figure A1 presents annual wind roses for the five years and shows that annual conditions are typically very similar. Figure A2 presents frequency distribution plots for humidity, wind direction, wind speed and temperature, and demonstrates that there is relatively little variation in the distribution of these variables' year-on-year. Figure A3 presents Z-Scores for each variable for each year, these being a measure of the variation of values in each individual year against the mean of values across all years.

The calendar year 2023 has been used for the modelling as it is judged to be the year with the least variation from the mean when averaged across all of the parameters considered.



Frequency of counts by wind direction (%)

Figure A1 Annual wind roses for Gladstone Airport between 2020 and 2024

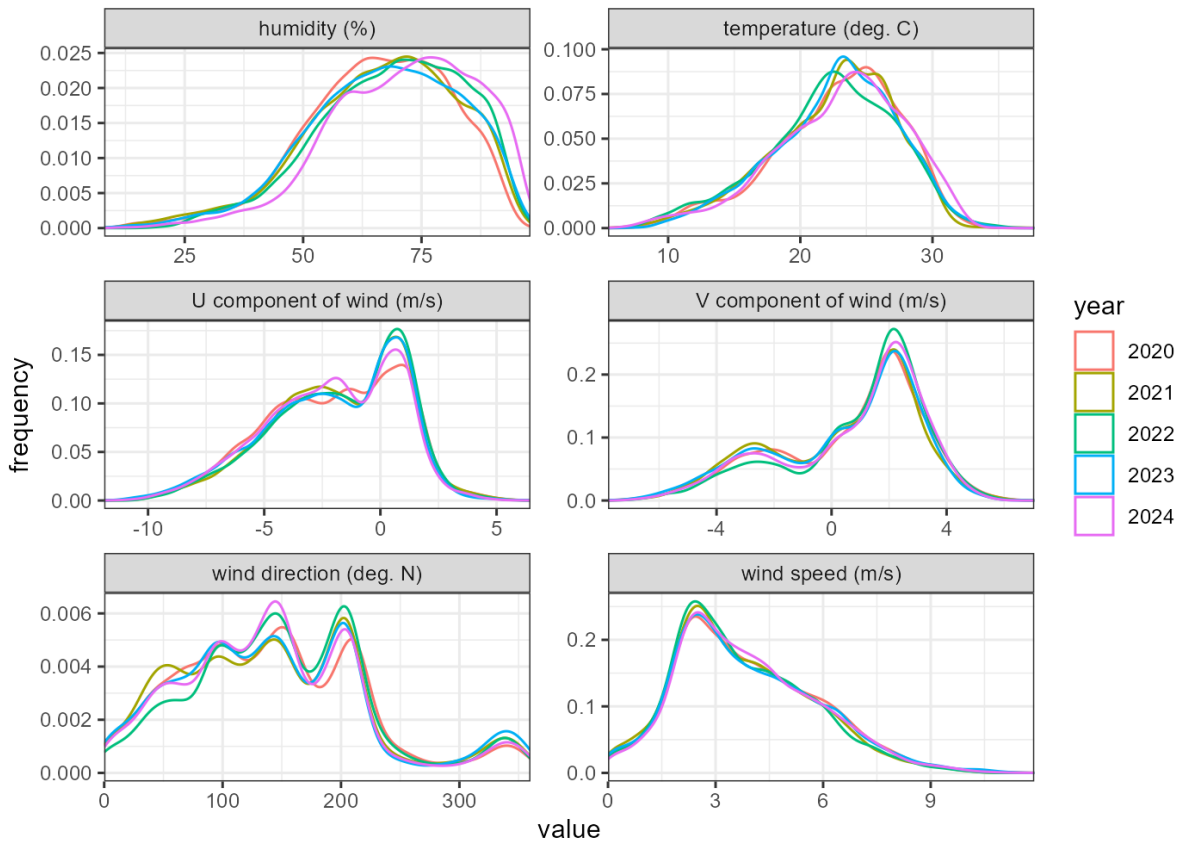
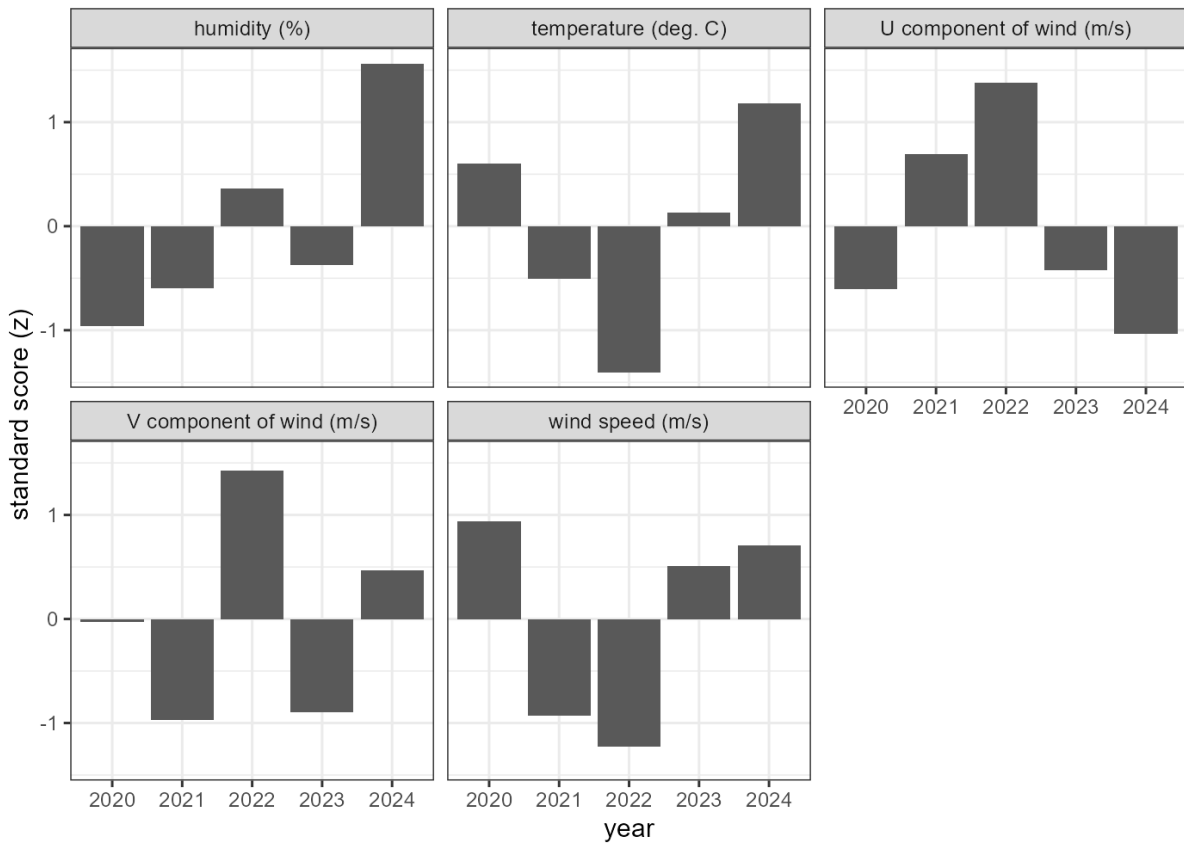


Figure A2 Annual frequency distributions plots for Gladstone Airport between 2020 and 2024



**Figure A3 Z-Scores for Gladstone Airport between 2020 and 2024**

## A1.2 TAPM meteorological modelling configuration

TAPM (The Air Pollution Model) was developed by the CSIRO and has been validated by the CSIRO, Katestone and others for many locations in Australia, in south-east Asia and in North America (CSIRO, 2008). Katestone has extensive experience with TAPM for sites throughout Australia and in parts of America, Bangladesh, New Caledonia and Vietnam. The model performs well in simulating regional wind patterns and has proven to be a useful tool for simulating meteorology in locations where monitoring data providing the vertical distribution of meteorological parameters are unavailable.

TAPM is a prognostic meteorological model which predicts the flows important to regional and local scale meteorology, such as sea breezes and terrain-induced flows from the larger-scale meteorology provided by the synoptic analyses. TAPM solves the fundamental fluid dynamics equations to predict meteorology at a mesoscale (20 km to 200 km) and at a local scale (down to a few hundred metres). TAPM includes parameterisations for cloud/rain micro-physical processes, urban/vegetation canopy, soil type and radiative fluxes.

TAPM requires synoptic meteorological information for the region. This information is generated by a global model similar to the large-scale models used to forecast the weather. The data were supplied on a grid resolution of approximately 75 km, and at elevations of 100 m to 5 km above the ground. TAPM uses this synoptic information, along with specific details of the location such as surrounding terrain, land-use, soil moisture content and soil type to simulate the meteorology of a region as well as at a specific location.

TAPM version 4.0.5 was configured with the following parameters:

- Modelling period from 1 January 2023 to 31 December 2023
- 65 x 65 grid point domain with nesting resolutions of 20 km, 10 km, 3 km, and 1 km

- 30 vertical levels
- Grid centred on latitude -23° 43.5', longitude 151° 11.0'
- Geoscience Australia 9 second DEM terrain data
- TAPM default land cover data edited to be consistent with aerial imagery
- Default options selected for advanced meteorological inputs
- No data assimilation.

## A1.3 Comparison of TAPM output with observational data

### A1.3.1 Overview

Validation of the TAPM predicted meteorological data was carried out by comparing observational data with data derived from running TAPM. The TAPM predicted meteorological data was compared to BoM observational data at the Gladstone Airport, Gladstone Radar and Rundle Island monitoring station sites.

Comparison of the observational data with the model predictions at these three sites showed that the model generally performed well at simulating the meteorology across the region. While TAPM slightly under-predicted the frequency of strong winds across the three sites, the statistical analysis, wind roses and probability density functions illustrate good agreement between predicted and observed meteorological data at all three locations. The dataset was determined to be appropriate for use in the assessment.

The results of the validation of the TAPM run at the location of the Gladstone Airport site are presented in the following section.

### A1.3.2 Validation of TAPM modelling

Figure A4 shows probability density functions that graphically compare statistical distributions of meteorological parameters between the TAPM output and the BoM AWS Gladstone Airport observational data. Figure A5 shows annual wind roses of TAPM output and the BoM AWS Gladstone Airport observational data. Table A1 presents statistical comparisons of TAPM output (wind speed and temperature) to meteorological data recorded at the BoM AWS Gladstone Airport site. The TAPM output was extracted from the closest inner grid point to the location of the weather station.

The following statistical measures of model accuracy are presented in the tables:

- The mean bias, which is the mean model prediction minus the mean observed value. Values of the mean bias close to zero show good prediction accuracy.
- The root mean square error (RMSE), which is the standard deviation of the differences between predicted values and observed values. The RMSE is non-negative and values of the RMSE close to zero show good prediction accuracy. The RMSE is given by

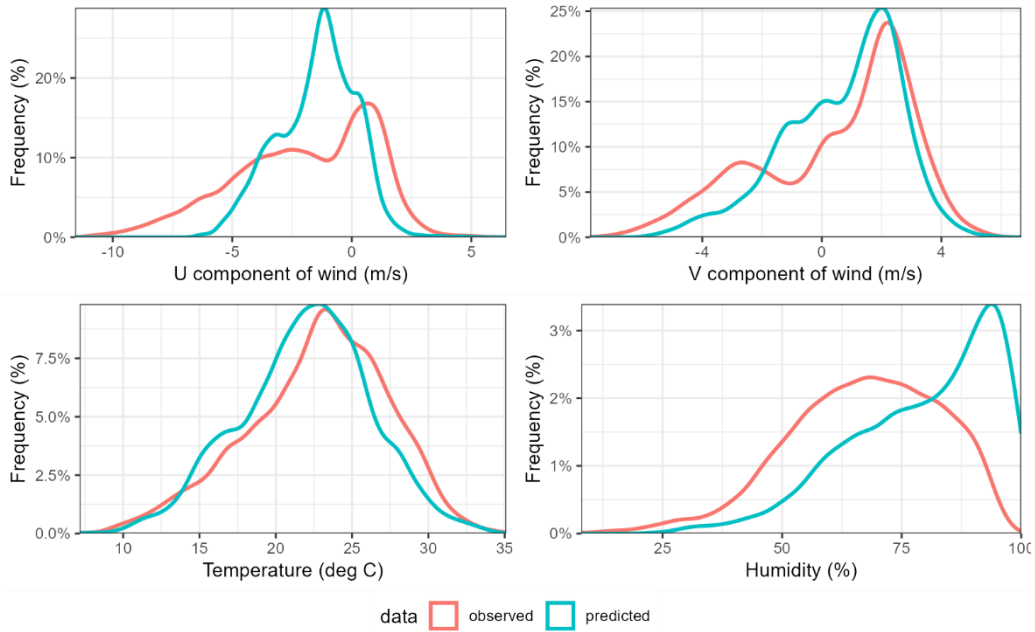
$$\text{RMSE} = \sqrt{\frac{1}{N} \sum_{i=1}^N (P_i - O_i)^2}$$

where  $N$  is the number of observations,  $P_i$  are the hourly model predictions and  $O_i$  are the hourly observations

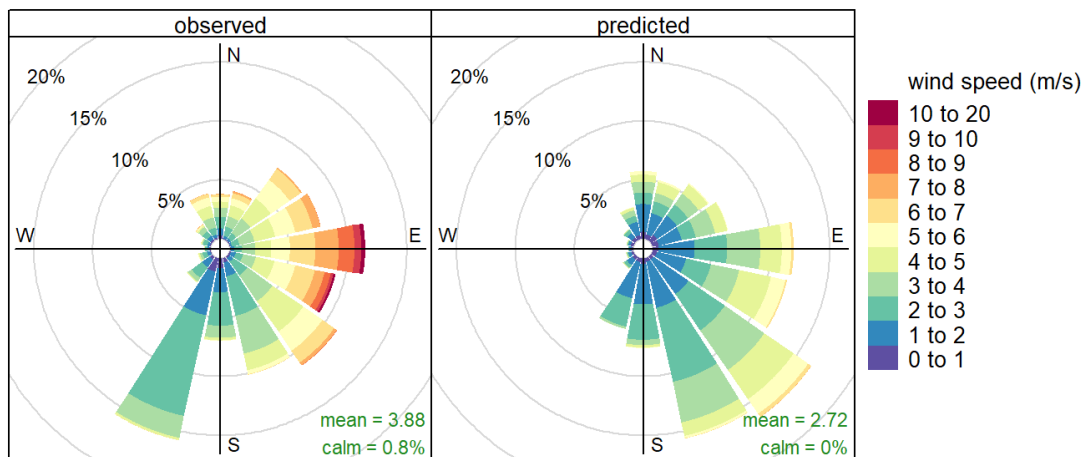
- The index of agreement (IOA), which takes a value between 0 and 1, with 1 indicating perfect agreement between predictions and observations. The IOA is calculated following a method described in Willmott (1982), using the equation

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

where  $N$  is the number of observations,  $P_i$  are the hourly model predictions,  $O_i$  are the hourly observations and  $O_{mean}$  is the observed observation mean.



**Figure A4** Probability density functions comparing 2023 observational data (blue) with TAPM data (red) at the location of the BoM AWS Gladstone Airport site



**Frequency of counts by wind direction (%)**

**Figure A5** Annual wind rose of 2023 observational data (left) and TAPM data (right) at the location of the BoM AWS Gladstone Airport site

**Table A1 Comparison of the observed meteorological data with the TAPM output for 2023 at the location of the BoM AWS Gladstone Airport site**

Statistic	“Good” value	Wind speed			Temperature		
		Benchmark	Observational data	TAPM	Benchmark	Observational data	TAPM
Mean	-	-	3.9	2.7	-	22.7	21.9
SD	-	-	2.0	1.3	-	4.6	4.3
Min	-	-	0.0	0.0	-	7.2	7.2
Max	-	-	11.6	7.9	-	35.1	34.4
Bias	0	< ± 0.5 m/s	-1.16		< ± 0.5°C	-0.78	
RMSE	Close to 0	< 2 m/s	1.77		-	1.88	
IoA	Close to 1	> 0.6	0.74		≥ 0.8	0.95	

## A1.4 CALMET meteorological modelling configuration

CALMET is an advanced non-steady-state diagnostic 3D meteorological model with micro-meteorological modules for overwater and overland boundary layers. The model is the meteorological pre-processor for the CALPUFF modelling system. CALMET is capable of reading hourly meteorological data as data assimilation from multiple sites within the modelling domain; it can also be initialised with the gridded three-dimensional prognostic output from other meteorological models such as TAPM. This can improve dispersion model output, particularly over complex terrain as the near surface meteorological conditions are calculated for each grid point.

CALMET version 6.5.0 was used to simulate meteorological conditions in the region. The CALMET simulation was initialised with the gridded TAPM 3D wind field data from the 1 km grid. CALMET treats the prognostic model output as the initial guess field for the CALMET diagnostic model wind fields. The initial guess field is then adjusted for the kinematic effects of terrain, slope flows, blocking effects and 3D divergence minimisation.

CALMET was configured using default options and parameters, with the following selections:

- Modelling period from 1 January 2023 to 31 December 2023
- 50 x 50 grid point domain with 500 m resolution, nested within the TAPM inner domain
- 12 vertical levels at heights of 20, 60, 100, 150, 200, 250, 350, 500, 800, 1600, 2600 and 4600 metres
- Prognostic wind fields generated by TAPM input as MM5/3D.DAT at surface and upper air for “initial guess” field (no-observations mode)
- Gridded cloud cover from prognostic relative humidity at all levels
- No extrapolation of surface wind observations to upper layers
- Terrain radius of influence of 1 km.

## A1.5 CALMET meteorological outputs

The following sections provide a description of the CALMET outputs as utilised in the CALPUFF dispersion modelling for the meteorological parameters that are important for the dispersion of air pollutants in the atmosphere, namely wind speed, wind direction, atmospheric stability, mixing layer height, and temperature. These parameters have been extracted from the CALMET dataset at the Project site.

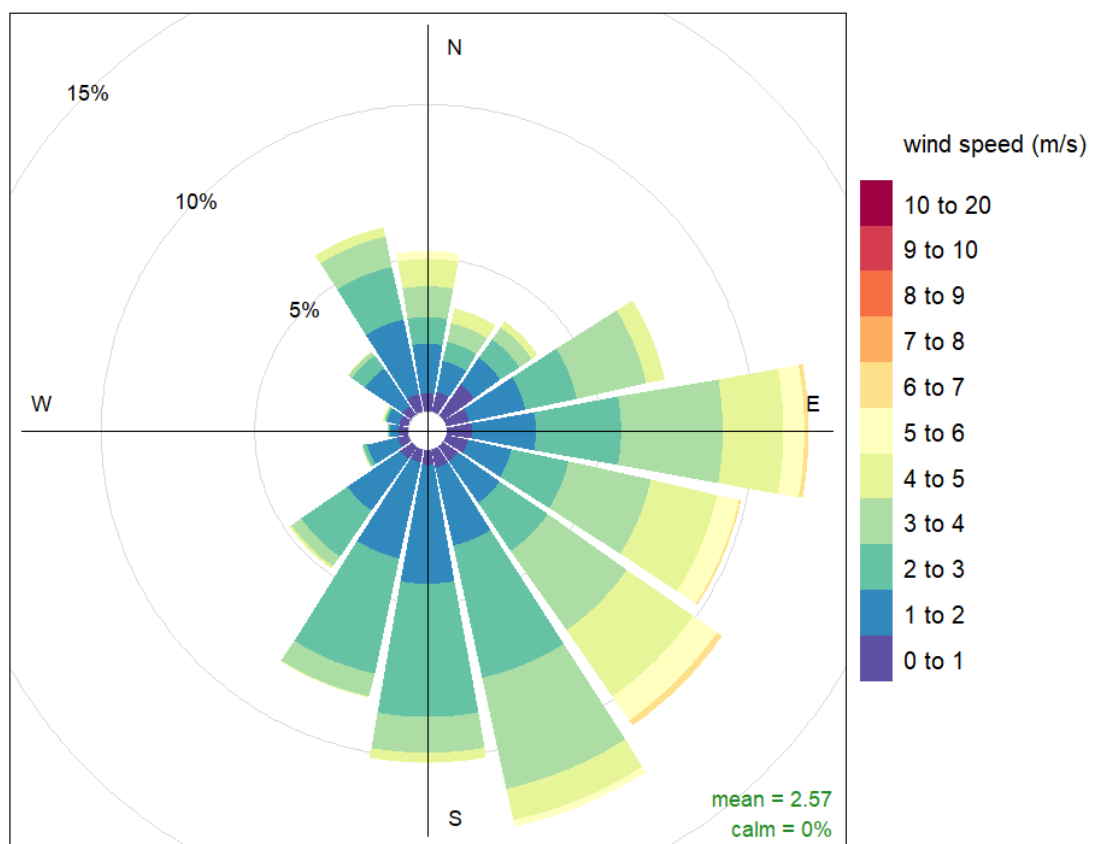
### A1.5.1 Wind speed and wind direction

The annual distribution of winds predicted by CALMET for 2023 is presented in Figure A6. The seasonal and diurnal distributions of winds are presented in Figure A7 and Figure A8.

Winds across the study area are predicted to be predominantly light to moderate (up to around 6 m/s) and from the east-northeast through to south-southwest direction. Winds from the west are least frequent.

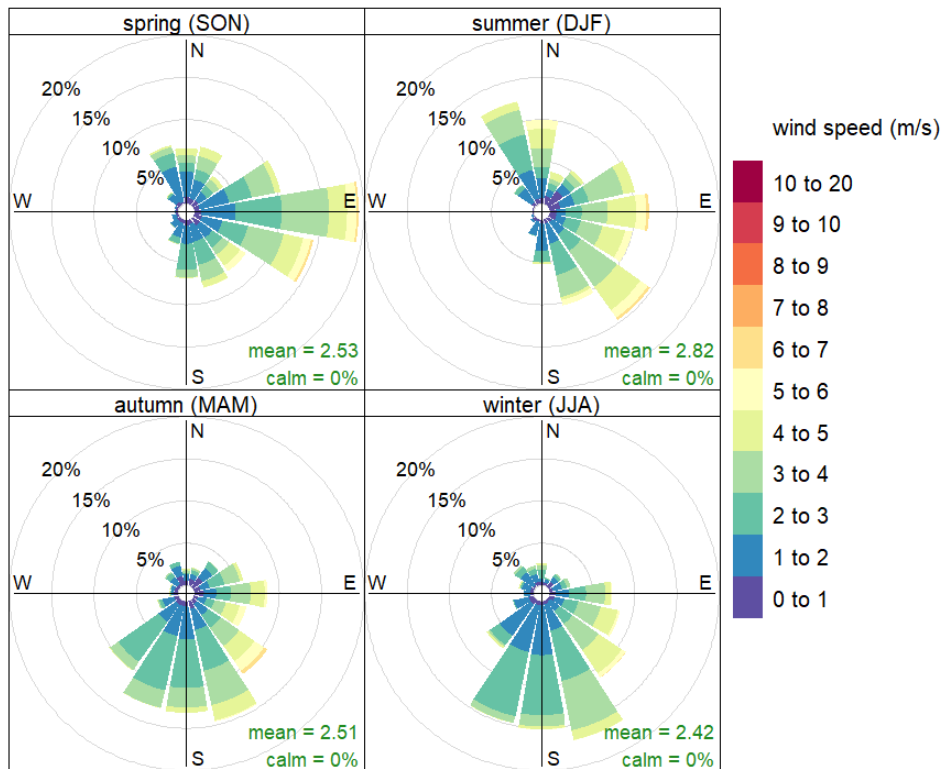
The seasonal breakdown of winds shows that winds at the site are more east to southeasterly during spring and summer, shifting to more southerly during autumn and winter. Spring and summer also experience an increase in winds from the north-northwest to north-northeast.

The diurnal breakdown of winds shows that the strongest winds are predicted during the afternoon (midday to 6pm) when winds are predominantly from the northeast to southeast. The lightest winds are predicted during the night (midnight to 6am) when winds are predominantly from the south-southeast to southwest direction.



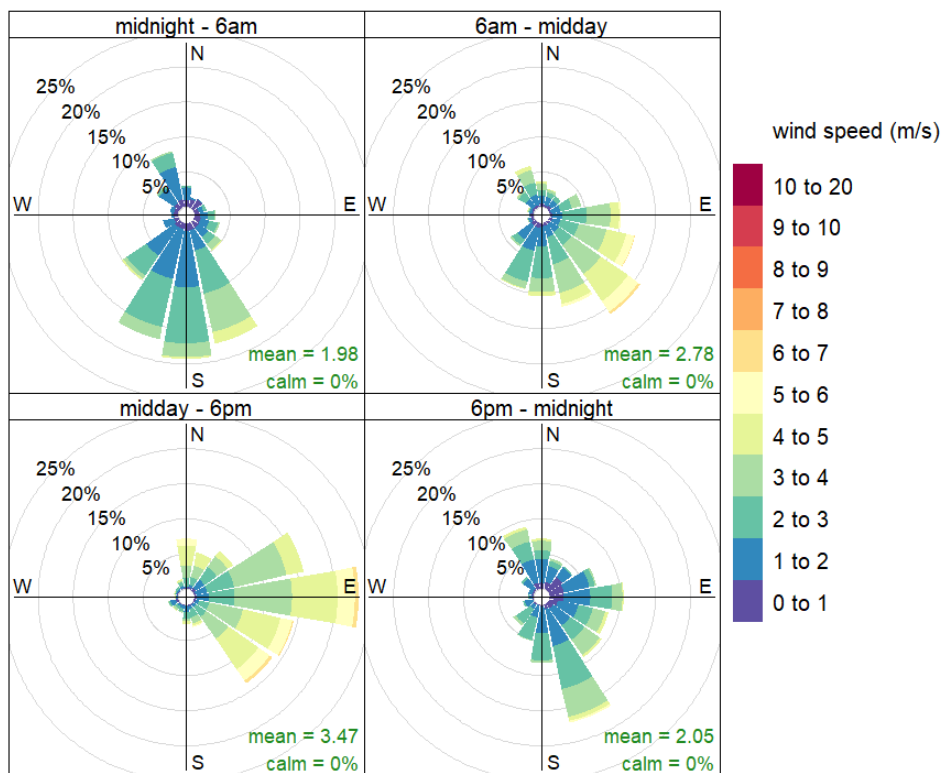
Frequency of counts by wind direction (%)

Figure A6 2023 annual distribution of winds predicted by CALMET



Frequency of counts by wind direction (%)

Figure A7 2023 seasonal distribution of winds predicted by CALMET



Frequency of counts by wind direction (%)

Figure A8 2023 diurnal distribution of winds predicted by CALMET

### A1.5.2 Atmospheric stability

Stability classification is a measure of the stability of the atmosphere and can be determined from wind measurements and other atmospheric observations. The stability classes range from A Class, which represents very unstable atmospheric conditions that may typically occur on a sunny day, to F Class, which represents very stable atmospheric conditions that typically occur during light wind conditions at night. Unstable conditions (Classes A to C) are characterised by strong solar heating of the ground that induces turbulent mixing in the atmosphere close to the ground. This turbulent mixing is the main driver of dispersion during unstable conditions. Dispersion processes for Class D conditions are dominated by mechanical turbulence generated as the wind passes over irregularities in the local surface. During the night, the atmospheric conditions are generally stable (often Classes E and F).

Figure A9 shows the distribution of stability classes extracted from the CALMET dataset, where Class A represents the most unstable conditions and Class F represents the most stable. Neutral (D class) conditions are present throughout the day, comprising 43% of total time. Stable (E class) and very stable (F class) conditions are the next most frequent, comprising 37% of total time, and only occur between 5 pm and 7 am.

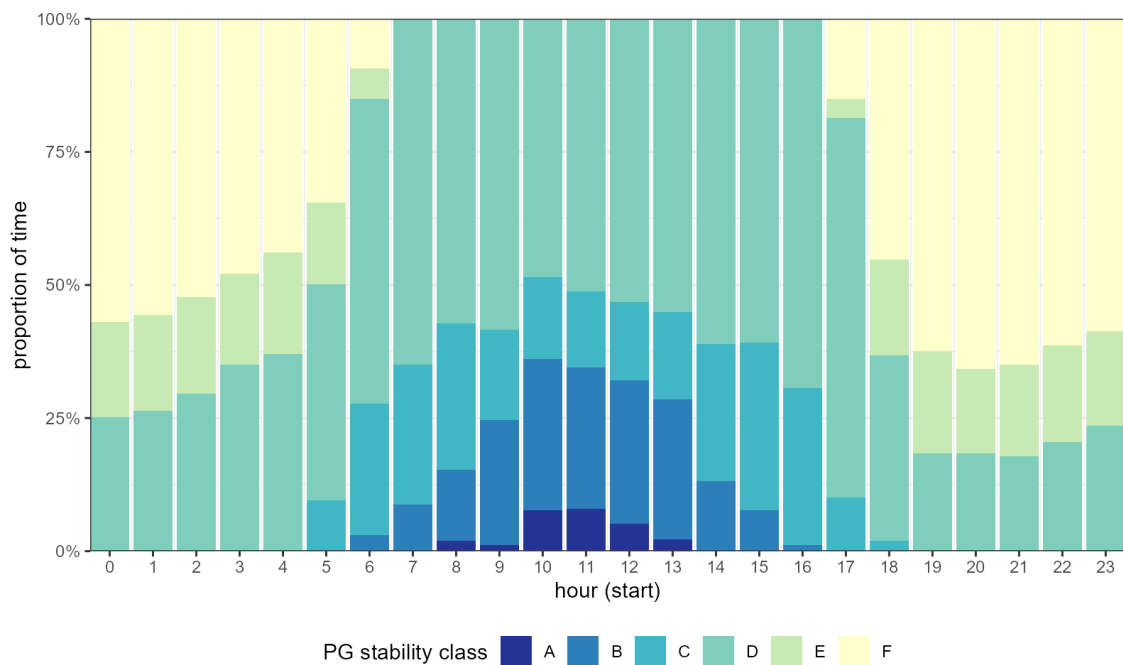
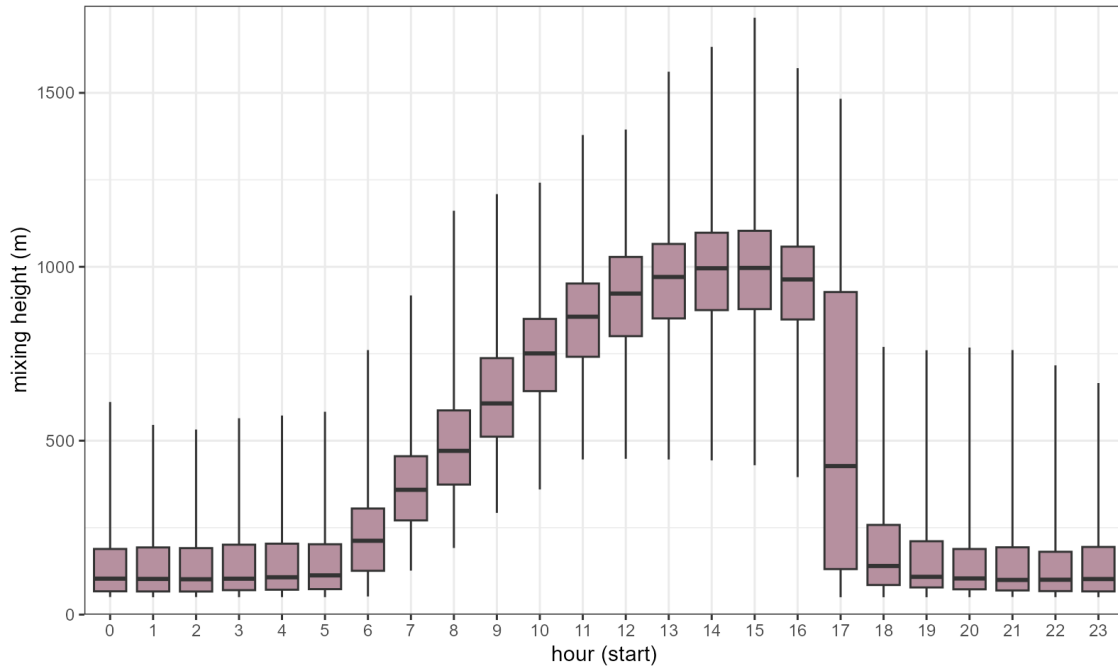


Figure A9 2023 frequency distribution of atmospheric stability conditions predicted by TAPM/CALMET

### A1.5.3 Mixing height

The mixing height defines the height of the mixed atmosphere above the ground (mixed layer), which varies diurnally. Air pollutants released at or near the ground will become dispersed within the mixed layer. During stable atmospheric conditions, the mixing height is often quite low, and dispersion is limited to within this layer. During the day, solar radiation heats the ground and causes the air above it to warm, resulting in convection and an increase to the mixing height. The growth of the mixing height is dependent on how well the warmer air from the ground can mix with the cooler upper-level air and, therefore, depends on meteorological factors such as the intensity of solar radiation and wind speed. Strong winds cause the air to be well mixed, resulting in a high mixing height.

Mixing height information extracted from the CALMET dataset are presented as a diurnal frequency (box and whisker) plot in Figure A10. The plot shows that, on average, the mixing height begins to increase around 6am and peaks around 3- 4pm before descending rapidly into the evening.

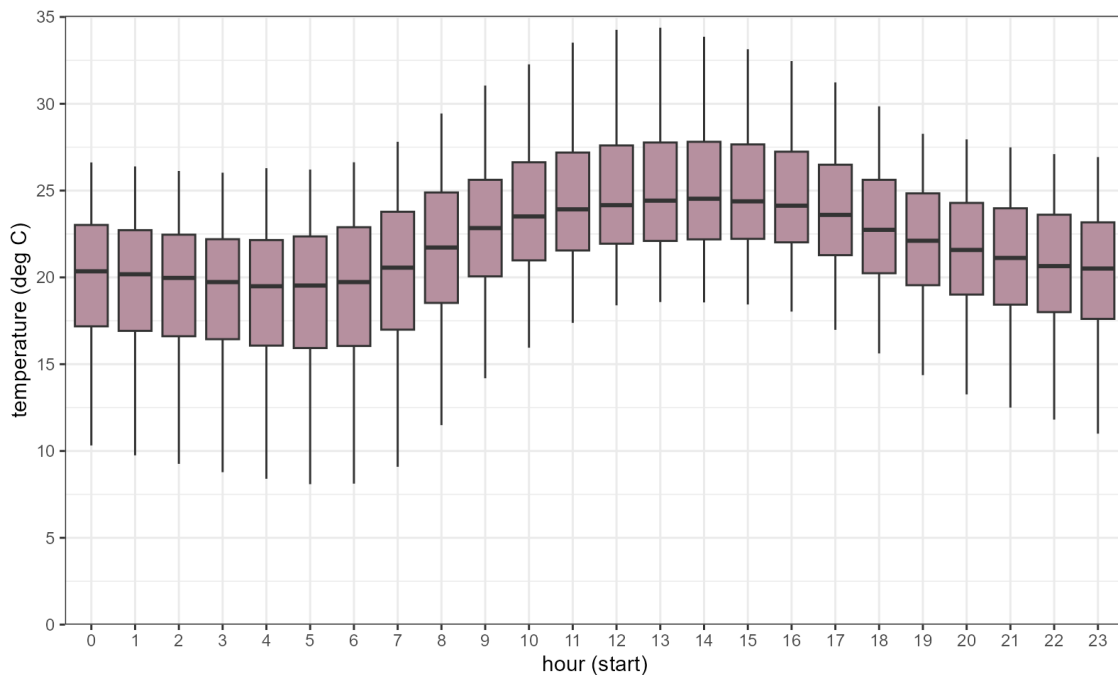


**Figure A10 2023 diurnal profile of mixing height predicted by CALMET**

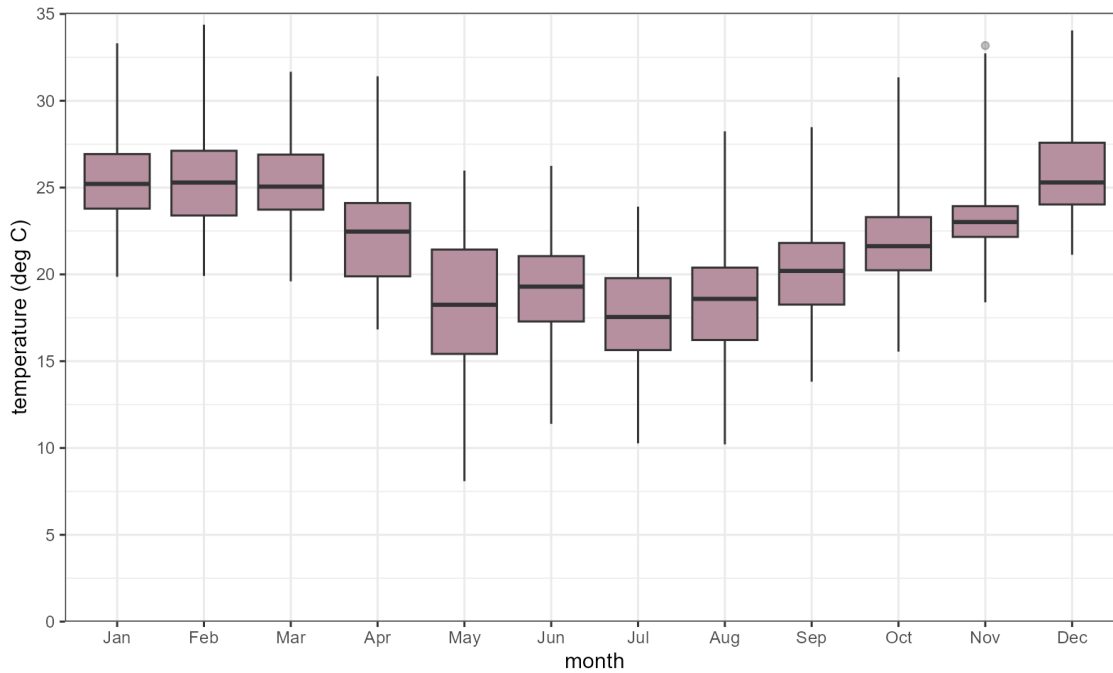
### A1.5.4 Temperature

The hourly distribution of CALMET predicted temperature is provided in Figure A11 and the monthly distribution is provided in Figure A12. Over the twelve-month meteorological simulation, the temperature was predicted to range between 8.1°C and 34.4°C (average of 21.9°C).

During winter the temperature was predicted to range between 10.2°C and 28.2°C (average of 18.4°C). During summer the temperature was predicted to range between 19.9°C and 34.4°C (average of 25.6°C).



**Figure A11 2023 hourly distribution of CALMET predicted temperature**



**Figure A12 2023 monthly distribution of CALMET predicted temperature**

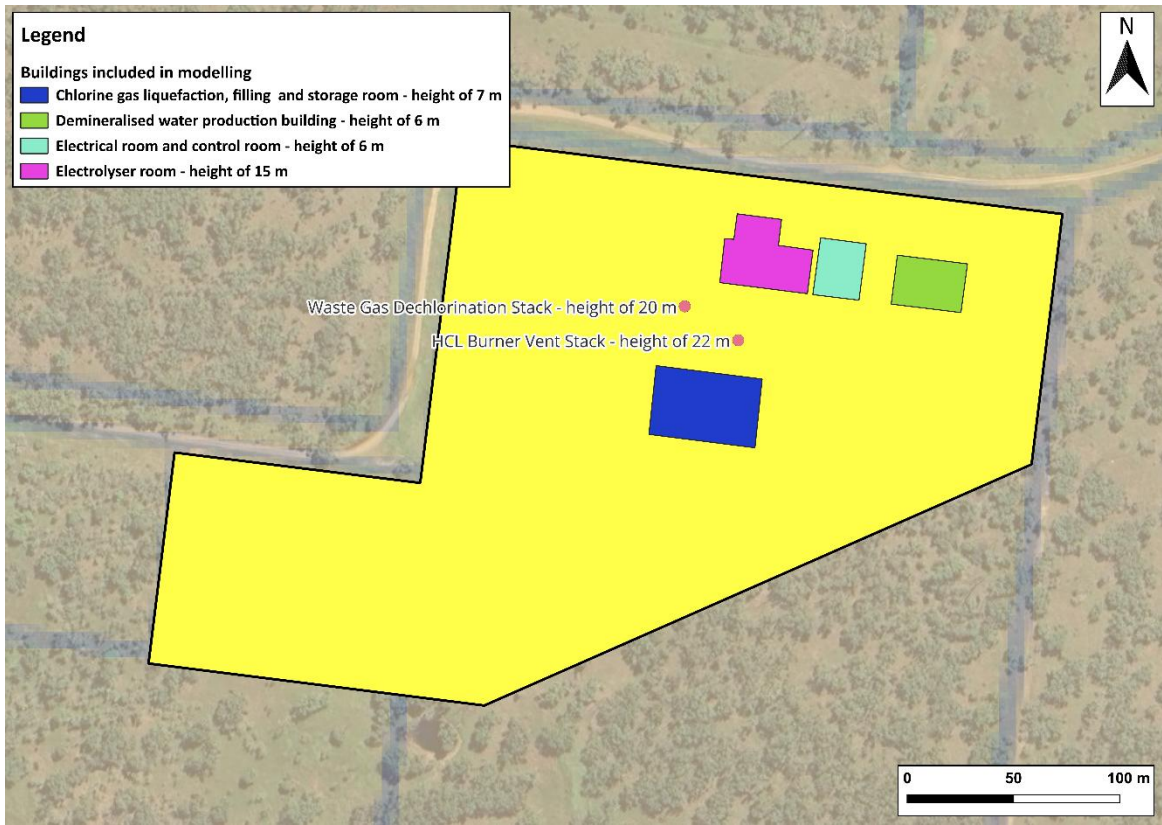
## A2 Dispersion modelling

CALPUFF simulates the dispersion of air pollutants to predict ground-level concentration and deposition rates across a network of receptors spaced at regular intervals, and at identified discrete locations. CALPUFF is a non-steady-state Lagrangian Gaussian puff model containing parameterisations for complex terrain effects, overwater transport, coastal interaction effects, building downwash, wet and dry removal, and simple chemical transformation. CALPUFF employs the 3D meteorological fields generated from the CALMET model by simulating the effects of time and space varying meteorological conditions on pollutant transport, transformation, and removal.

CALPUFF takes into account the geophysical features of the study area that affect dispersion of pollutants and ground-level concentrations of those pollutants in identified regions of interest. CALPUFF contains algorithms that can resolve near-source effects such as building downwash, transitional plume rise, partial plume penetration, sub-grid scale terrain interactions, as well as the long-range effects of removal, transformation, vertical wind shear, overwater transport and coastal interactions. Emission sources can be characterised as arbitrarily varying point, area, volume and lines or any combination of those sources within the modelling domain.

Key features of CALPUFF used to simulate dispersion:

- Domain area of 100 by 100 grids at 0.25 km spacing, nested within the domain defined in CALMET
- 365 days modelled (1 January 2023 to 31 December 2023)
- Gridded 3D hourly-varying meteorological conditions generated by CALMET
- Partial plume path adjustment for terrain modelled
- Dispersion coefficients calculated internally from sigma v and sigma w using micrometeorological variables
- Stack tip downwash, transitional plume rise and PDF used for dispersion under convective conditions
- Building wakes included for onsite structures shown in Figure A13
- All other options set to default.



**Figure A13** Onsite building wake structures included in the assessment