ENVIRONMENTAL
TECHNOLOGIES &
ANALYTICS

Wagerup Alumina Refinery Residue Storage Area RSA10 North

Air Quality Assessment

Final Report
Version 1.1

Prepared for Alcoa of Australia

February 2024

Project Number: 1364

Wagerup Alumina Refinery Residue Storage Area RSA10 North

Final Report

DOCUMENT CONTROL

Version	Description	Date	Author	Reviewer
0	Draft report – issued for client review	10.11.2023	ETA (KH) EnvAll (DP)	ETA (KH)
1	Final report – issued for client use	20.12.2023	ETA (KH) EnvAll (DP)	Alcoa
1.1	Final report – minor revision	22.02.2024	ETA (KH)	

Approval for Release

Name	Position	File Reference
[redacted]	Director |Principal Air Quality Specialist	1364 Alcoa Wagerup RSA10 North AQA_Ver1.1.docx

Signature
[redacted]

Executive Summary

Alcoa proposes to construct and operate a new Residue Storage Area 10 (RSA10) that will provide approximately 45 Ha of drying area. This is required to maintain the residue storage and drying capacity to meet the requirements of the Refinery. No change to the permitted alumina production rate of the Refinery (2.9 Mtpa) is being sought by Alcoa as part of the RSA10 proposal.

The construction of new RSA on the western side of the current Residue Area footprint forms part of the Alcoa (2020) Long Term Residue Management Strategy. It is necessary to periodically construct new RSAs to replenish the loss in residue storage and drying capacity that occurs over time, as the perimeter embankment walls are lifted to accommodate successive layers of deposited residue and progressively move inwards.

The Wagerup Refinery operation requires approximately 205 Ha of residue drying area to sustain the permitted alumina production rate of 2.9 Mtpa, with the available drying area currently in deficit.

Overview of assessment

An air dispersion modelling study has been undertaken for the proposed addition of RSA10 to inform the assessment of potential air quality impacts of the Wagerup Refinery upon the local communities. The air dispersion modelling study incorporated site-specific meteorological data, emissions information, source characteristics, and the location of model receptors. Potential impact was evaluated through comparison to relevant ambient air quality assessment criteria protective of human health.

The scope of the modelling assessment is summarised below.

Modelled meteorological period	1 June 2021 to 31 May 2022. This is the 12-month period corresponding to the Residue Dust Monitoring and Composition Study (Ecotech, 2022) (ETA, 2023b).
Meteorological data	Three-dimensional prognostic meteorological data developed using the Weather Research and Forecasting (WRF) model.
Model selection	CALMET/CALPUFF model suite, coupled with WRF prognostic meteorological data.
Key pollutants for airborne concentrations	• Particulate Matter (PM) –PM_{10} and $PM_{2.5}$ size fractions • Products of combustion – NO_2 • Inorganic compounds – ammonia (NH_3) • Volatile Organic Compounds (VOCs) – acetaldehyde, acetone and formaldehyde • Trace metals – aluminium (Al), arsenic (As), chromium VI (Cr VI), mercury (Hg), and nickel (Ni).
Key pollutants for dry deposition	• PM – Total Particulate Matter (TSP).

Ambient Air Quality Assessment Criteria	- National Environmental Protection Measure (NEPM) for Ambient Air Quality (as varied 15 April 2021) (NEPC, 2021). - Criteria adopted from the Health Endpoints Review (Katestone, 2023) for the forthcoming Health Risk Assessment of the Wagerup Refinery to be undertaken based on the results in the report. - Air Emissions Guideline (draft for consultation) (DWER, 2019).
Background Air Quality	Consistent with previous modelling studies of the Wagerup Refinery and the Refinery's current licence conditions, background concentrations have not been added to the predicted ground-level concentrations for evaluation against the relevant assessment criteria.
Project Emissions	- Refinery point source (stack and vent) emissions – forecast from the Wagerup 2021 Emission Inventory (Alcoa, 2022), scaled to represent emissions from the Refinery at the operating capacity of 2.9 Mtpa of alumina as permitted under the environmental licence. - Fugitive particulate sources – Residue Area and bauxite stockpile wind erosion and activity related emissions. - Fugitive vapour sources – Residue Area, comprised of RSAs, liquor recovery and cooling water circuit emissions.
Sensitive Receptors	Discrete sensitive receptor locations were nominated in a review by Katestone (2023a), to represent the local communities of Yarloop, Hamel and Waroona and individual residences. These discrete receptors have consequently been updated from the previous modelling assessments for the Wagerup Refinery.
Model Scenarios	The predicted impacts were considered for the Wagerup Refinery only (in isolation), for the following model scenarios: - **Baseline** – the current emissions status of the Wagerup Refinery at the operating capacity of 2.9 Mtpa of alumina as permitted under the environmental licence. - **Proposed** – The current emissions status of the Wagerup Refinery at the operating capacity of 2.9 Mtpa of alumina, with the addition of RSA10 following commissioning.

Key findings

The key findings of the air dispersion modelling assessment conducted for the RSA10 proposal are outlined below.

RSA10 Emission Contribution

It has been assumed that the annual fugitive emissions associated with the addition of RSA10 are a pro-rata area-based addition to the emissions estimated for the current RSAs, of approximately 11.8% from current condition at the time of this study (see Section 5.5.1.3).

Considered on an annual basis (kg/yr), the RSA10 proposal is estimated to result in relatively minor increases in total Wagerup Refinery emissions of particulate matter (as TSP, PM_{10} and $PM_{2.5}$) (8%), VOCs (<1%) and trace metals (<5%), except for chromium VI which has the highest percentage increase (11.6%) with the RSAs the principal emission source.

There is no change in NOx and ammonia emissions associated with the RSA10 proposal, as the existing RSAs, as well as the new RSA10, are not identified as a source of these pollutants.

Evaluation of Model Performance

This study included an evaluation of model performance, with the predicted ground-level concentrations of particulate matter (as TSP and PM_{10}) compared to the continuous ambient monitoring undertaken over the study period. The comparison of the predicted and measured concentrations can be used to assess the bounds of uncertainty in predicted air quality impacts from the RSA10 proposal, for consideration in risk-based decisions regarding potential air quality impacts from the Wagerup Refinery.

The evaluation of model performance for particulate matter shows good correspondence with measured TSP and PM_{10} concentrations across the monitoring network, generally within a factor-of-two (0.5 to 2), the range usually referred to for acceptable model performance. The model's performance at the Residue West (RW) monitoring site which is most representative of potential increased impacts from the addition of RSA10 is most critical for this proposal. At this site, the model shows very good correspondence with the 24-hour average PM_{10} concentration measurements, giving a very good modelled:measured slope (1.07), under-predicting the maximum statistic (0.82) and over-predicting the annual average (1.48).

The overall evaluation of model performance also demonstrates the methodology used for fugitive particulate emissions, most notably for wind erosion from the RSAs, provides credible estimates for use as inputs to the modelling.

Overall Assessment of Potential Impact

Overall, the model results show that emissions of the relevant pollutants of interest from the Wagerup Refinery only (in isolation) for the Proposed model scenario (addition of RSA10), lead to ground-level concentrations that are **below** the assessment criteria, except for the maximum 24-hour PM_{10} concentrations predicted at Receptor 7 (114% of criterion).

Receptor 7 is the maximally impacted discrete sensitive receptor, which is located to the west of the Residue Area, approximately 3 km away, and downwind of the Residue Area under strong easterly winds that are dominant during the summer. The drier summer months causes an increase in the potential for wind-erosion from the surface of the RSAs to generate fugitive dust emissions.

The RSA10 proposal results in an incremental increase (above Baseline) in the maximum predicted 24-hour average ground-level concentrations of PM_{10} (14.8%), $PM_{2.5}$ (14.8%), and the associated trace metals present in residue dust at Receptor 7.

The modelling assessment highlights the potential for elevated ground-level concentrations of PM_{10}, and to a lesser extent $PM_{2.5}$, at Receptor 7, for both the current operations (Baseline model scenario) and with the addition of RSA10 (Proposed model scenario). The predicted impacts occur as a result of fugitive wind-blown dust emissions from the Residue Area under extreme adverse weather conditions. To manage these potential impacts continued emphasis must be placed on ensuring the ongoing effectiveness of Alcoa's dust management strategy.

Table of Contents

Tables

Figures

1 Introduction

1.1 Background

Alcoa of Australia Limited (Alcoa) operate the Wagerup Alumina Refinery (the Wagerup Refinery) located 130 kilometres (km) south of Perth in Western Australia. The Wagerup Refinery is comprised of the alumina refining process (the Refinery) and associated residue storage areas (RSAs) and associated infrastructure (Residue Area). The Refinery has capacity to produce 2.9 million tonnes per annum (Mtpa) of alumina as permitted under the environmental licence (L6217/1983/15).

The Refinery is positioned in the western foothills of the Darling escarpment and is separated from the Residue Area by the South Western Highway and the Perth-Bunbury railway line. The local communities in the proximity of the Wagerup Refinery include Yarloop, Hamel and Waroona. Yarloop is located approximately 3 km south of the Wagerup Refinery, and Hamel and Waroona are located north of the Wagerup Refinery approximately 5 km and 8 km away respectively. The land surrounding the Wagerup Refinery is predominantly operated as a beef farming enterprise by Alcoa's Farmlands operations.

Alcoa proposes to construct and operate a new Residue Storage Area 10 (RSA10) that will provide approximately 45 hectares (ha) of drying area. This is required to maintain the residue storage and drying capacity to meet the requirements of the Refinery.

The construction of new RSAs to the west of the current Residue Area footprint forms part of the Alcoa (2020) Long Term Residue Management Strategy. It is necessary to periodically construct new RSAs to replenish the loss in residue storage and drying capacity that occurs over time, as the perimeter embankment walls are lifted to accommodate successive layers of deposited residue and progressively move inwards.

The Wagerup Refinery operation requires approximately 205 Ha of residue drying area to sustain the permitted alumina production rate of 2.9 Mtpa, with the available drying area currently in deficit.

The Residue Area is a potential source of dust and Volatile Organic Compound (VOC) emissions.

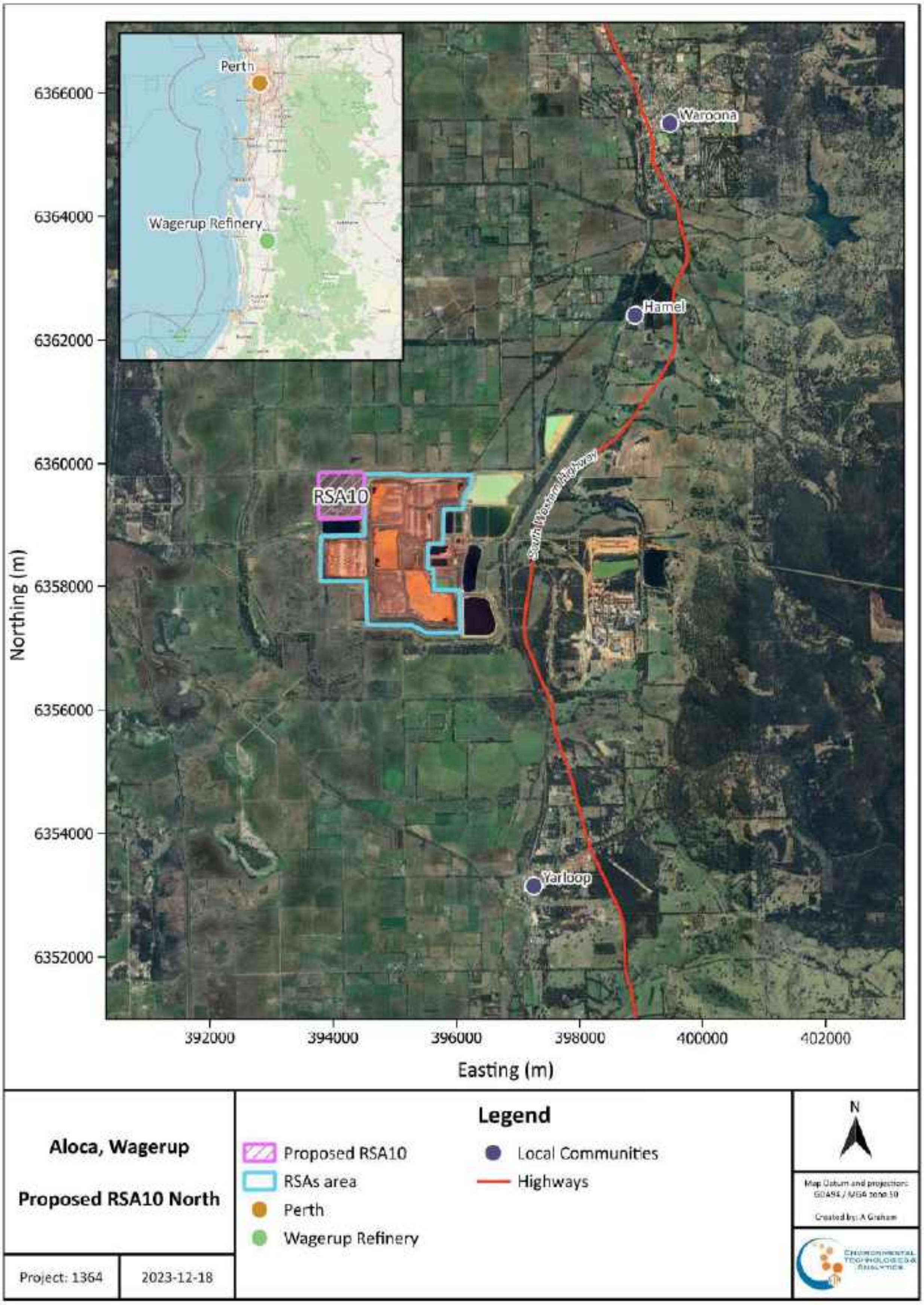


Figure 1-1: Project location and setting

An air dispersion modelling study has been undertaken for the RSA10 proposal to inform the assessment of potential air quality impacts of the Wagerup Refinery upon the local communities.

1.2 Project Description

The Refinery produces alumina using the Bayer process from bauxite mined at the Willowdale mine site. Alumina product is transported by rail from the Refinery to Alcoa's Bunbury shipping terminal and then exported to overseas markets or to Alcoa's aluminium smelter in Victoria. The remaining material (residue) from the alumina refining process is contained in the Residue Area at the site.

Residue generated from the alumina refining process is deposited to the RSAs using the method termed 'dry stacking'. This process involves pre-thickening the residue mud and then depositing it in layers which are dried through solar evaporation. An advantage of dry stacking is that the drying area footprint is significantly reduced from that required for conventional paste type tailings.

As the volume and elevation of dried mud in the RSAs increases over time, the perimeter embankment walls are lifted to accommodate successive layers and progressively move inwards. The total drying area surface consequently reduces by approximately 5 Ha per year.

As storage cells reach their final height, new cells are constructed to maintain the required total drying area. The total drying area tends to dip below the sustainable level prior to the construction of each new cell, then exceed the sustainable level for a period of time immediately after a new cell is commissioned. The cycle of total drying area availability from 1997 to current is shown in Figure 5-4.

The Wagerup Refinery operation requires approximately 205 Ha of residue drying area to sustain the permitted alumina production rate of 2.9 Mtpa. As at May 2022, the drying area is approximately 194.5 Ha - a deficit of 5% from the sustainable level.

To maintain the residue storage and drying capacity to meet the requirements of the Refinery, Alcoa proposes to construct and operate a new RSA (RSA10) that will provide approximately 45 hectares of additional drying area in 2025/26. The layout of the existing Residue Area and the proposed location of RSA10 is shown in Figure 1-2.

The RSAs are a potential source of airborne dust, particularly during the drier months from October to April when the potential for wind erosion under strong and gusty winds is greatest. As well as the residue drying beds themselves, material handling and vehicle traffic on surrounding infrastructure, such as unsealed roads, embankments and drains can also be a source of dust. The dust management systems that are in place consist of a range of both proactive and reactive strategies. The main day to day control mechanism to manage dust emission from the drying beds is the use of the sprinkler system to wet down areas, when alarms are received from the continuous dust monitoring system, and proactively prior to forecasts of adverse weather conditions.

The cooling water circuit is the main source of vapour emissions, containing VOCs. There are currently no management strategies in place to actively manage VOCs reporting to the Residue Area via the cooling circuit. This is because the residue storage areas (RSAs) have a minimal contribution to VOC emissions from the residue area. Therefore, expansion of the drying areas at current Refinery production rates would have a minimal impact on VOC emissions from residue (Alcoa, 2020).

Figure 1-2: Residue Area Layout

1.3 Regulatory Context

The Wagerup Refinery is licenced (Licence Number: L6217/1983/15) under the provisions of Part V of the *Environmental Protection Act 1986* (EP Act) as a Prescribed Premise, Category 46 (bauxite refining). The Refinery currently has capacity to produce 2.9 million tonnes per annum (Mtpa) of alumina as permitted under the environmental licence.

Alcoa is seeking a Works Approval and/or Licence Amendment to construct and operate the proposed new RSA10 at the Wagerup Refinery. No change to the permitted alumina production rate of the Refinery is being sought by Alcoa as part of the RSA10 proposal.

The Wagerup Refinery Phase 2 Study (ETA, 2020a) is a previous air dispersion model validation and comparison study undertaken for the Wagerup Refinery, intended specifically to demonstrate substantial completion of relevant conditions in the Ministerial Statement 1069 (MS:1069)[1]. The modelling approach is broadly consistent with the previous Phase 2 Study, specifically in terms of the dispersion model used, key pollutants and discrete sensitive receptor locations considered in the modelling. Notwithstanding, there are some key changes, most notably:

- Refinery production rate of 2.9 Mtpa compared to 2.85 Mtpa for the Wagerup Refinery Phase 2 Study (ETA, 2020a);
- the modelled meteorological period;
- the use of prognostic meteorology;
- refinement in Residue Area dust emission characteristics; and
- assessment of $PM_{2.5}$ and aluminium, as additional air pollutants of interest.

The justification for changes to these aspects of the modelling study are outlined in Section 1.5.

1.4 Overall Study Program

Several monitoring programs and studies have been undertaken by Alcoa at the Wagerup Refinery to inform the assessment of the potential impact upon air quality associated with emissions from the Residue Area, within the context of the new RSA10 proposal.

A brief overview of the key studies is provided in Table 1-1. The schematic diagram shows how each of the studies interrelate (Figure 1-3). Further detailed information and findings are contained in the supporting technical reports that are referenced.

Table 1-1: Wagerup Refinery Study Program

Study Overview	Category
Residue Dust Monitoring and Composition Study – an intensive 12-month (June 2021 to May 2022) monitoring program of particulate matter of various size fractions (TSP, PM_{10} and $PM_{2.5}$) at a location central to the residue areas (RSA5) and around the periphery, and additional meteorological monitoring (Ecotech, 2022). The monitoring data collected during this study has been supplemented with the data that is routinely collected on an ongoing basis across Alcoa's permanent network of monitors. The measurement data has been reviewed to provide updated baseline information on emission characteristics of residue dust, particle size distribution (PSD) and metal content, from the RSAs (ETA, 2023b). The measurement data has also been used for meteorological and dispersion model validation purposes.	Ambient air quality monitoring
	Source monitoring
	Meteorological monitoring

---

[1] The implementation conditions for the approval of the *Wagerup Alumina Refinery – Production to a Maximum Capacity of 4.7 Mtpa and Associated Bauxite Mining* under Pat IV of the EP Act are set out in MS:1157, published 7 January 2021. Preceding Ministerial Statements relating to this approval include 728, 897 and 1069.

Study Overview	Category
Surface Dust Compositional study of Wagerup Residue – fine residue ('dust') material was collected on 23rd and 24th February 2021 from varying residue surfaces, sand embankments and sand pour operations. The samples were analysed for metal composition in a range of fine particle fractions to determine metal content and partitioning of metals across different particle size fractions (Alcoa, 2022).	Source sampling
Open-Path Fourier-Transform Infrared Spectroscopy (OP-FTIR) Program – a measurement program (September to December 2021) involving the use of Open Path FTIR technology to characterise the emissions of Volatile Organic Compounds (VOCs) and ammonia from the existing Residue Area, targeting significant fugitive sources. The measurement data collected during this program was intended to be used to update the original estimates for VOCs derived using an isolation flux chamber (circa 2004 – 2006). The measurement data has been reviewed but was not fit-for-purpose to derive credible fugitive VOC emissions estimates, except in the case of ammonia emissions from the Superthickener, Cooling Pond and Lower Dam (ETA, 2023c).	Source monitoring
Ambient VOCs Sampling using Method TO-17 – an ambient air monitoring campaign (February to June 2022) for VOCs in accordance with Method TO-17 (USEPA, 1999). This involved limited targeted ambient VOC sampling designed around the daily morning routine High-Volume Air Sampler (HVAS) filter paper replacements (Ecotech, 2022a).	Ambient air quality monitoring
WRF Model Evaluation – A precursor study to evaluate WRF prognostic meteorology against surface and upper air (Perth airport)[2] measurements for the November 2020 to October 2021 period (ETA, 2022).	Meteorological study
WRF-CALMET Model Evaluation – An evaluation of WRF prognostic meteorology incorporated into a CALMET formatted dataset (WRF-CALMET), against surface measurements for the June 2021 to May 2022 (study) period. (ETA, 2023d)	Meteorological study
Residue Area Fugitive Emission Estimates and Model Validations – An evaluation of CALPUFF predictions of fugitive PM using the WRF-CALMET meteorology dataset, against ambient continuous PM measurements for the June 2021 to May 2022 (study) period. A limited assessment of fugitive VOCs emissions was also undertaken (ETA, 2023e).	Model validation study

---

[2] Upper air measurement data is not available for the Wagerup Refinery for the June 2021 to May 2022 (study) period, with the closest sonde measurements taken at the Perth Airport.

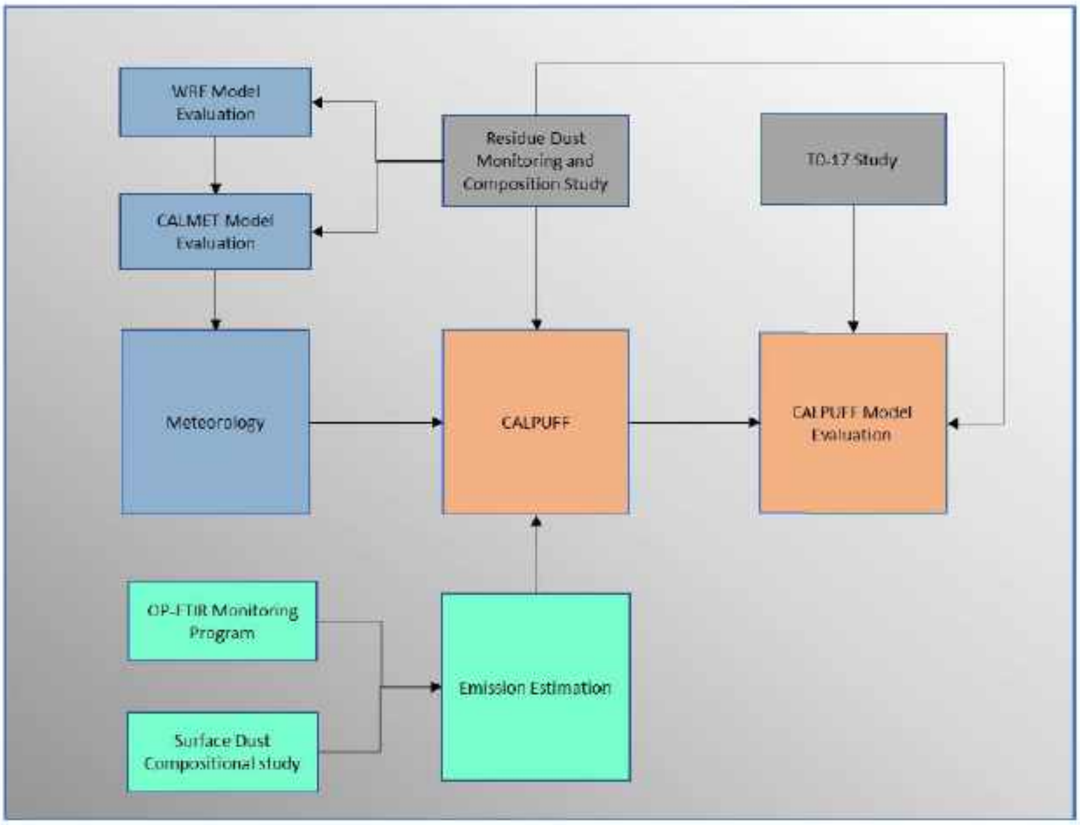


Figure 1-3: Wagerup Refinery Study Program

1.5 Scope of Work

Environmental Technologies & Analytics Pty Ltd (ETA) has been engaged by Alcoa to undertake an air dispersion modelling study for the RSA10 proposal to inform the assessment of potential air quality impacts of the Wagerup Refinery upon the local communities. This report presents the results of the air quality assessment conducted to support the Works Approval and/or Licence application for the RSA10 proposal.

The air dispersion modelling study incorporated site-specific meteorological data, emissions information, source characteristics, and the location of model receptors. Potential impact was evaluated through comparison to relevant ambient air quality assessment criteria.

The emphasis of the emission estimation and modelling is on the potential impact from the operating phase of the RSA10 proposal. Impacts from RSA10 construction[3] activities are excluded from the assessment due to their short-term duration and because the construction methods implemented by Alcoa will incorporate appropriate dust management practices.

---

[3] RSA10 construction refers to the activities that will be initially undertaken to establish the RSA footprint (clearing, earthworks, under-drainage, etc), as opposed to the ongoing embankment construction required to periodically raise the height of the embankment walls (incorporated in the emission estimation and modelling of RSAs).

The scope of the modelling has been developed, taking into account the regulatory context, available meteorological and ambient air quality monitoring data, and the nature of emissions from the Wagerup Refinery.

Reference has been made to the following key regulatory policy and guidance:

- Air Quality Modelling Guidance Notes (DoE, 2006); and
- Guideline - Air Emissions, draft for external consultation (DWER, 2019).

The key aspects and underlying basis of the modelling approach used in this assessment are outlined below.

- *Modelled meteorological period*:

  The modelled meteorological period of this assessment was the 12-month period corresponding to the Residue Dust Monitoring and Composition Study (June 2021 to May 2022).

- *Model selection*:

  The modelling was undertaken using the Weather Research and Forecasting (WRF) model - a mesoscale numerical weather prediction model, coupled with the CALMET/CALPUFF model suite. The WRF model was used to develop a three-dimensional wind field across the model area, which in turn was used as input to CALMET to form the final meteorological dataset used for modelling.

  The meteorology predicted using WRF was evaluated in ETA (2022) and assessed for sensitivity in ETA (2022a). Alcoa has advised that discussions were held with the Department of Water and Environmental Regulation (DWER) to inform this model selection[4].

  The benefits in the use of the WRF prognostic model over the use of surface and/or upper air measurements alone, together with the findings of several precursor studies (refer to Section 4.2.1), has informed the preferred approach to development of the meteorological dataset for use in the air dispersion modelling study of the RSA10 proposal, and the Wagerup Refinery more generally.

  The CALPUFF dispersion model has been used to predict the concentrations across the model domain and at identified sensitive receptor locations. As an advanced non-steady-state meteorological and air quality modelling system, it can be used to simulate near-field impacts in complex flow or dispersion situations, including the influence of terrain which is an important feature of the air pollution meteorology for the Wagerup Refinery site.

---

[4] Meeting held between Alcoa and DWER on 20 September 2022.

- *Key Pollutants:*

  The key pollutants of interest considered in the assessment with respect to potential air quality (health) impacts, are listed below. The basis for selection of key pollutants is detailed in Section 3.1. The existing RSAs, as well as the new RSA10, are not identified as sources of NO_2[5] or ammonia, however these substances have been included for assessment to establish the overall baseline air quality impacts of the Wagerup Refinery.

Particulate matter (PM):	PM_{10} (particulate matter with an aerodynamic diameter of less than 10 microns [µm]), and $PM_{2.5}$ (particulate matter with an aerodynamic diameter of less than 2.5 µm) size fractions.
Products of combustion:	nitrogen dioxide (NO_2)
Inorganic compounds:	ammonia (NH_3)
VOCs:	acetaldehyde, acetone and formaldehyde
Trace metals:	aluminium (Al), arsenic (As), chromium VI (Cr VI), mercury (Hg), and nickel (Ni).

- *Refinery point source emissions:*

  The Alcoa-developed 2021 Wagerup emission inventory has been applied to characterise Refinery point source (stack and vent) emissions. The emission estimates have been scaled by Alcoa to represent emissions from the Refinery at the operating capacity of 2.9 Mtpa of alumina as permitted under the environmental licence.

- *Fugitive source emissions:*

  Fugitive emissions were estimated according to the methods adopted for previous assessments by ETA (2021a) and Air Assessments (2005 and 2015). The meteorological data obtained over the modelled period (June 2021 to May 2022) at the RSA5 meteorological monitoring site was used to estimate hourly varying PM and VOC emissions for sources/substances that have a wind speed dependency. The distribution of PM emissions between the RSAs was modified to improve the prediction of concentrations at monitors north of the Residue Area. The bauxite stockpile PM emissions were slightly increased to account for production increases since the time of the previous estimates and also improve the prediction of concentrations at monitors north of the Residue Area. Operational PM emissions were unchanged from previously. A full description of the estimation methods is described in ETA (2022e).

---

[5] Fuel combustion emissions, comprised of NOx and other combustion by-products, associated with vehicles and other equipment operated at the RSAs, have not been considered in this assessment.

- *Modelling Approach:*

  The CALPUFF model has been used to predict the concentrations of key pollutants at ground-level across the model domain, and at the nominated discrete sensitive receptor locations selected as representative of the local communities. Concentrations predicted for key pollutants were compared with the relevant air quality assessment criteria.

  The predicted impacts were considered for the Wagerup Refinery only (in isolation), taking into account the combined impact of emissions from Refinery point sources (stacks and vents) and fugitive emissions from the Residue Area and bauxite stockpiles. The contribution of background (regional) air quality was not added to the predicted ground-level concentrations for evaluation against the relevant air quality assessment criteria.

  The predicted impacts have been assessed through comparison of the current Wagerup Refinery (Baseline model scenario), with the change associated with RSA10 operations (Proposed model scenario).

1.5.1 Changes to Modelling Approach

The air dispersion modelling approach has retained consistency with the previous Phase 2 air dispersion modelling study undertaken for the Wagerup Refinery (ETA, 2020a), where possible. The key changes to the modelling approach are outlined below:

Modelled meteorological period:	A new meteorological period has been modelled that corresponds to the Residue Dust Monitoring and Composition Study period (June 2021 to May 2022).
Meteorology:	The use of the WRF prognostic model to derive the meteorological data for use in air dispersion modelling, with site measurements used in the evaluation of model performance.
Refinery point source emissions:	The most current Alcoa-developed 2021 Wagerup emission inventory has been applied to characterise Refinery point source (stack and vent) emissions.
Fugitive source emissions:	The estimates of fugitive PM and VOC emissions for sources/substances that have a wind speed dependency have been revised using the meteorological data obtained over the modelled period (June 2021 to May 2022). Modifications to PM emissions from the RSAs and bauxite stockpiles, as noted above. Updates to baseline information on emission characteristics of residue dust, including PSD and metal content, based on results obtained from the Residue Dust and Composition Study (ETA, 2023b). The addition of ammonia as a source of fugitive emissions from the Residue Area from the OP-FTIR study (ETA, 2023c).

Modelled meteorological period:	A new meteorological period has been modelled that corresponds to the Residue Dust Monitoring and Composition Study period (June 2021 to May 2022).
Air pollutants considered:	$PM_{2.5}$ and aluminium have been included as new key pollutants of interest, reflecting the current regulatory context in terms of air quality assessment criteria [6].
Model scenarios:	The model scenarios represent the current emissions status of the Wagerup Refinery at the operating capacity of 2.9 Mtpa of alumina as permitted under the environmental licence.

1.6 Structure of Report

This report describes the methods and findings of an assessment of the potential impacts to the air environment arising from the Project. The assessment includes:

- Project description in Section 1.2
- Characterisation of site meteorology, terrain, and local air quality in Section 2
- Outline of the assessment framework in Section 3
- Model selection and set up in Section 4
- Emissions estimation and operating scenarios considered in Section 5
- Evaluation of model performance in Section 5.5.3
- Predicted concentrations and interpretation of the potential impact of the RSA10 proposal in Section 7
- Conclusions of the assessment are presented in Section 8.

The appendices contain supporting information.

---

[6] At the time of the previous Wagerup air dispersion modelling study (ETA, 2020), the air quality assessment criteria for $PM_{2.5}$ was established under the National Environmental Protection Measure (NEPM) for Ambient Air Quality (NEPC, 2015) as an advisory reporting standard only. Similarly, the DWER (2019) draft Air Emissions Guideline, incorporating an ambient guideline value for alumina (as aluminium in the respirable fraction), had not yet been released for public consultation at the time of the previous study.

2 Site Characteristics

2.1 Meteorology

The winds in the region are controlled by the synoptic weather patterns and local features such as the topography, and sea and land breezes. In the summer, the passage of high-pressure systems to the south generates synoptic easterlies over the region, whilst in the winter months the passage of cold fronts and low-pressure systems result in more frequent westerly synoptic flows, between periods of lighter winds (Air Assessments, 2005).

The Wagerup Refinery is located at the foot of the Darling escarpment, approximately 25 km inland from the coast. The Darling escarpment is a low escarpment running north-south to the east of the Swan Coastal Plain. At the base of the escarpment topographic features are critically important in modifying these larger scale winds. The effect of these topographic features on local winds is described in Air Assessments (2005) to include:

Foothill winds:	local strong winds are generated during summer, particularly over-night and in the early morning;
Rotors:	wind reversals occur near the foothills under moderate to strong easterly winds;
Channelled winds:	north westerly winds are channelled and deflected by the escarpment to northerly winds, particularly at night under stable atmospheric conditions; and
Katabatic drainage:	drainage of denser air down the escarpment due to cooling of the air near the ground surface under light winds and clear skies at night.

The most pronounced effect of the escarpment is the generation of strong easterly 'foothill winds' that occur at night and in the early morning. These winds extend from the top of the escarpment to the west at distances of up to 10 km away, resulting in wind speeds at least twice that elsewhere on the coastal plain.

Alcoa currently has two permanent meteorological monitoring stations near the Wagerup Refinery, and installed an additional meteorological station at RSA5 as part of the Residue Dust Monitoring Study (refer to Section 4.2.2) to inform this study. The RSA5 monitoring site is considered the most representative of winds in the immediate vicinity of the Residue Area for use in this study.

2.1.1 Winds

The annual and seasonal wind roses from measurements obtained at the RSA5 site for the study period is presented in Figure 2-1. Wind roses provide a graphical representation of the frequency distribution of wind speed and direction. Light southerly and strong easterlies dominate the winds. There is a bias towards strong easterlies during summer, north-easterlies during winter and light southerlies during autumn and spring.

The frequency of measured wind speed at the RSA5 site for the study period is presented in Figure 2-2. There is evidence of significantly higher wind speeds across the top of the Residue Area, compared to measurements at the other meteorological monitoring sites located near the Wagerup Refinery, as detailed in ETA (2022 & 2022a).

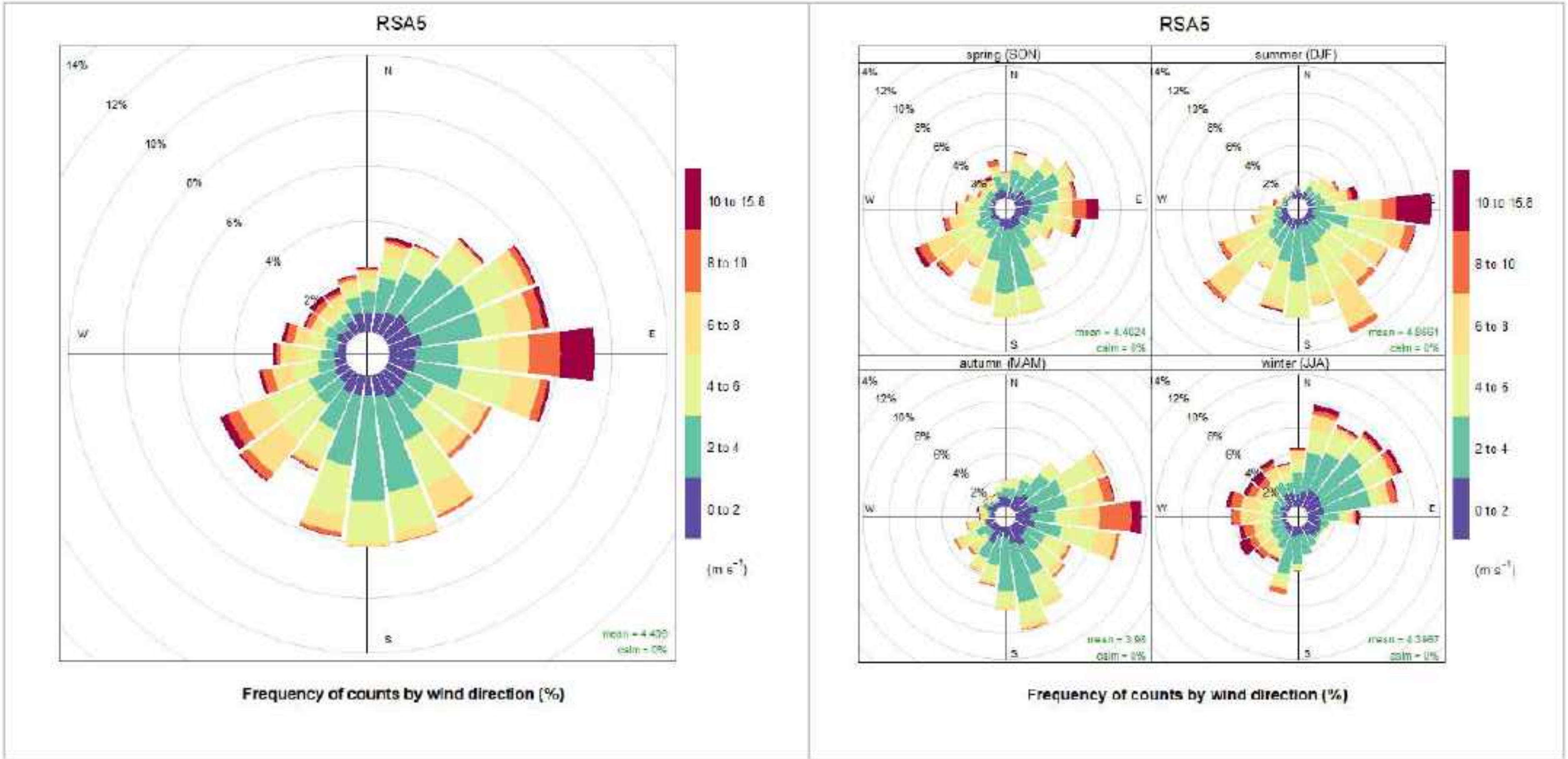


Figure 2-1: Annual (left) and seasonal (right) wind roses for RSA5 site – June 2021 to May 2022

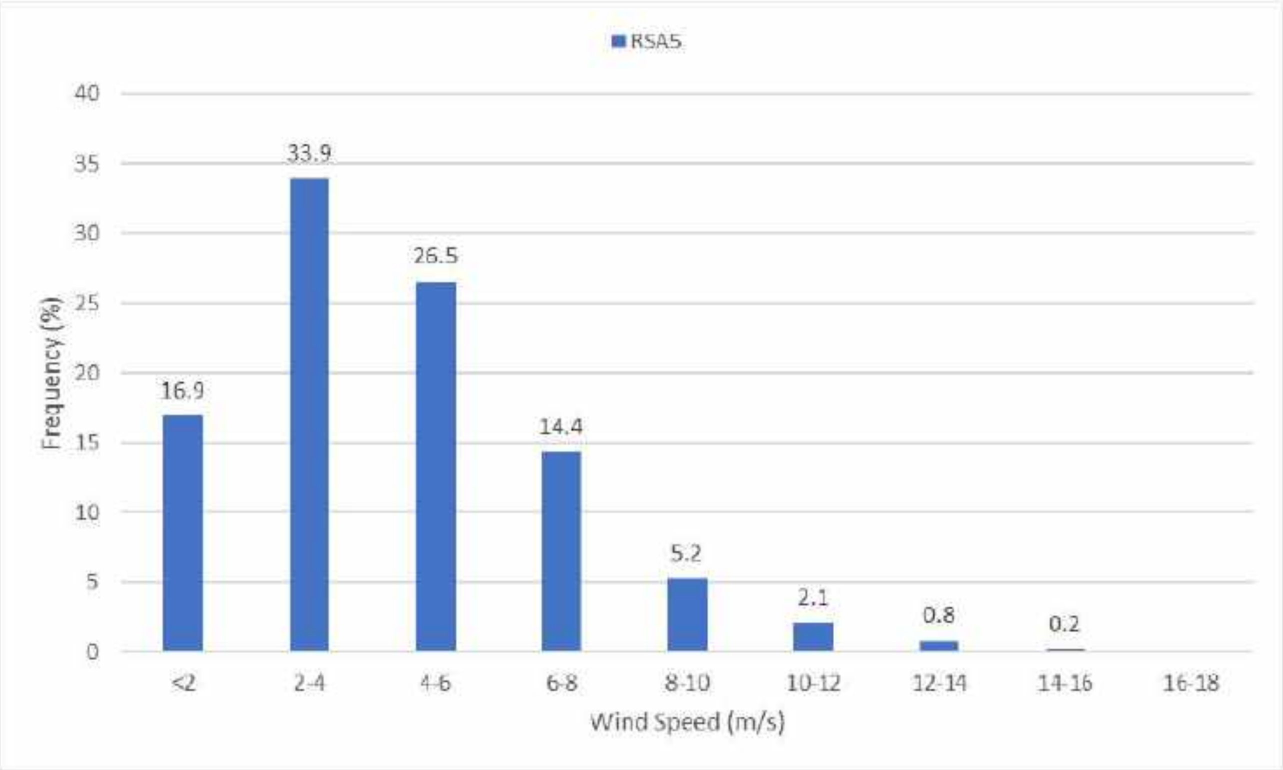


Figure 2-2: Frequency of measured wind speeds at RSA5 site – June 2021 to May 2022

2.1.2 Rainfall

The total monthly rainfall measurements obtained at the Bancell Road site for the study period is presented in Figure 2-3, compared to longer-term rainfall records (1981 to 2022) for the Wagerup Refinery[7]. Rainfall is lowest during the summer months and increases during the winter. During the study period, the monthly rainfall was considerably above the longer-term average in July 2021 (304 mm) and October 2021 (148 mm), compared to longer-term average for July (160 mm) and October (46 mm). However, rainfall from November 2021 to February 2022 was below the longer-term averages for the corresponding calendar months.

Rainfall dampens surface materials, and greatly decreases the potential for fugitive dust emissions to be generated, specifically wind-erosion from the Residue Area and bauxite stockpiles. During the drier summer months, the opposite occurs with low rainfall increasing the potential for fugitive dust emissions.

---

[7] Longer-term rainfall records for Wagerup Refinery obtained from the Bureau of Meteorology (BoM). http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_stn_num=009894

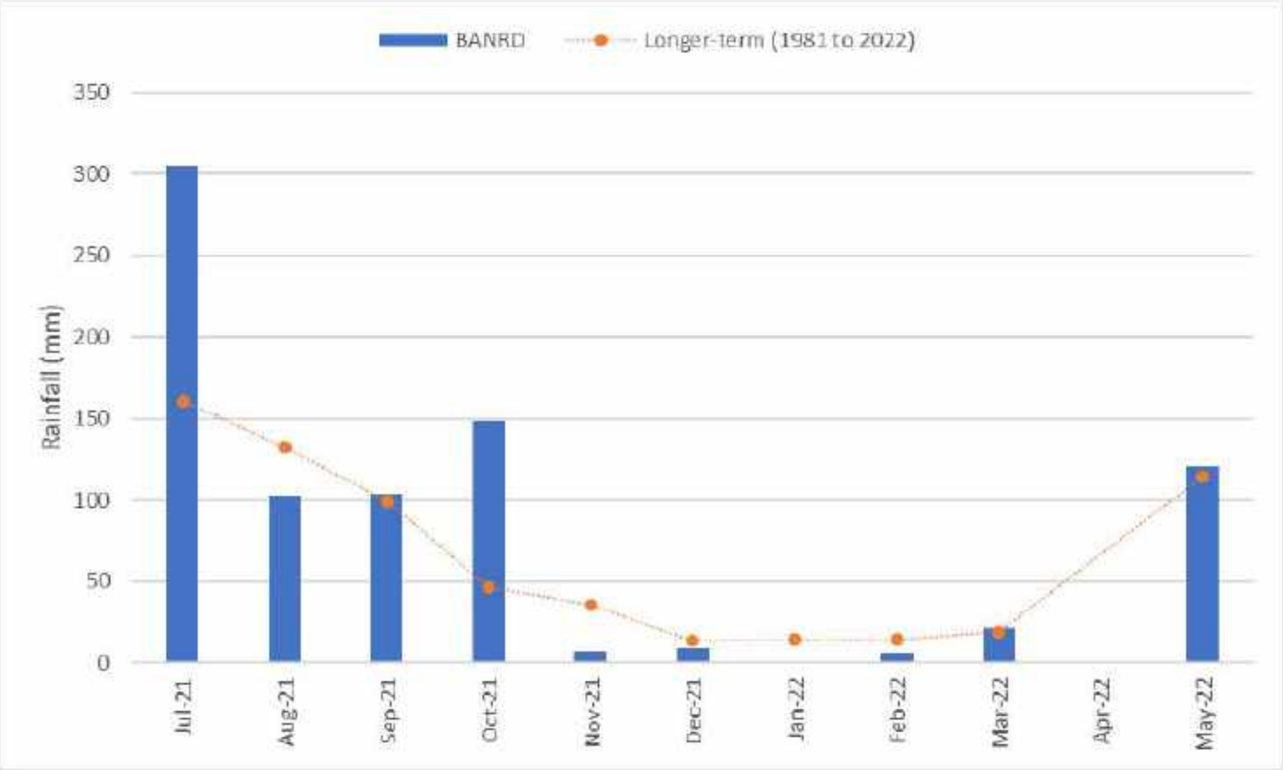


Figure 2-3: Total monthly rainfall measured at Bancell Rd site – Study period (June 2021 to May 2022) and Longer-term mean (1981 to 2022)

2.2 Background Air Quality

The background air quality of the region is influenced by localised anthropogenic sources such as from the Alinta Wagerup Cogeneration Power Plant, motor vehicles, agricultural activities including the Alcoa Farmlands beef farming enterprise, vehicle traffic on unsealed roads and domestic wood heaters. On a more regional scale, airborne particulates associated with smoke from hazard reduction burning and wildfires, pollens and to a lesser extent sea salt, also influence air quality. In some cases, these background sources are substantial contributors to ambient air quality.

The annual average regional background particulate concentrations have been estimated using measurements obtained during the Residue Dust Monitoring and Composition Study, according to the methods described in ETA (2022e). The annual average background particulate levels estimated for the study period (June 2021 to May 2022) is summarised in Table 2-1.

Table 2-1: Summary of estimated background air quality particulate levels – June 2021 to May 2022

PM Size Fraction	Averaging Period	Statistic	Background Concentration ($\mu g/m^3$)	% of Criteria [1]
TSP	Annual	Average	15	-
PM_{10}			8.5	37 %
$PM_{2.5}$			2.7	39 % [45% from 2025] [2]

Notes:

1. Compared to ambient air quality assessment criteria adopted for the study, shown in Table 3-2.
2. Under the Ambient Air Quality NEPM (NEPC, 2021), increasingly more stringent standards for $PM_{2.5}$ apply from 2025 (see Table 3-2).

A widespread smoke haze event occurred during the study period, with significant impacts evident, particularly evident in PM measurements recorded across Alcoa monitoring network from around 6 to 10 May 2022 (ETA, 2023b). In deriving the annual average background particulate levels shown in Table 2-1, the concentrations measured during the smoke haze event were removed from the dataset.

It is noted that the estimated background PM concentrations are significant compared to the corresponding assessment criteria, equivalent to nearly 40% of the annual PM_{10} and $PM_{2.5}$ criteria.

A (limited) VOC sampling program using the TO-17 method showed that hourly concentrations of Acetone, Methyl Ethyl Ketone (MEK) (also called 2-Butanone), Benzene, Toluene, Ethylbenzene, Styrene, Xylenes, 1,3,5-Trimethylbenzene and 1,2,4-Trimethylbenzene from other industrial, domestic, biological, combustion and transport and atmospheric production sources, are likely to be comparable or higher than contributions from the Residue Area (ETA, 2023e).

Due to the numerous uncertainties regarding how background levels should be interpreted for impact assessments, background concentrations have not been added to the predicted ground-level concentrations for evaluation against the relevant assessment criteria. This is also consistent with previous modelling studies of the Wagerup Refinery and the Refinery's current licence conditions.

3 Assessment Framework

3.1 Air Pollutants Considered

Emissions from the Wagerup Refinery are comprised of a complex mixture of substances, including products of combustion, particulates, volatile and semi-volatile organic compounds, trace metals and inorganic compounds. This assessment has considered the emissions of selected indicator compounds, chosen based on the potential of emissions from the Wagerup Refinery to impact upon air quality and health (ETA, 2022f), or for consistency with the previous air dispersion modelling study of the Wagerup Refinery (ETA, 2020a)[8].

The existing RSAs, as well as the new RSA10, are not identified as sources of NO_2 or ammonia. Notwithstanding, these pollutants have been included for assessment to establish the overall baseline air quality impact of the Wagerup Refinery.

The selected pollutants of interest to be assessed are summarised in Table 3-1.

Table 3-1: Air pollutants considered

Pollutant		Description and potential adverse effects at high concentrations
Particulate Matter (PM)	Airborne particles are a broad class of diverse substances that may be solid or liquid (liquid particles are often called aerosols) and are produced by a wide range of natural and human activities. Airborne particles are commonly classified by their size as total suspended particles (TSP), visibility reducing particles (PM_2), and inhalable particles (coarse fraction PM_{10} and fine fraction $PM_{2.5}$).	
	TSP	Airborne particles which are usually filtered by the nose and throat and hence do not enter the lungs.
	PM_{10}	Inhalable particles are grouped into two size categories: those with a diameter of up to 10 µm (PM_{10}) and those with a diameter of up to 2.5 µm ($PM_{2.5}$). Inhalable particles are associated with increases in respiratory illnesses such as asthma, bronchitis and emphysema, with an increase in risk related to their size, chemical composition and concentration. Particles in the PM_{10} size fraction have been strongly associated with increases in the daily prevalence of respiratory symptoms, hospital admissions and mortality.
	$PM_{2.5}$	Particles in the $PM_{2.5}$ size fraction can be inhaled more deeply into the lungs than PM_{10}, and have been associated with health effects similar to those of PM_{10}. There is some evidence to suggest that $PM_{2.5}$ might be more deleterious to health than other size fractions. No lower limit for the onset of adverse health effects has yet been observed.

---

[8] The indicator compounds considered in the Wagerup Refinery Phase 2 Study (ETA, 2020a) included NO_2, PM_{10}, ammonia, acetaldehyde and acetone.

Pollutant		Description and potential adverse effects at high concentrations
Products of combustion	NO_2	Nitrogen dioxide (NO_2) is a brownish gas with a pungent odour. It exists in the atmosphere in equilibrium with nitric oxide. The mixture of these two gases is commonly referred to as nitrogen oxides (NOx). Nitrogen oxides are a product of combustion processes, and can arise when flame staging is non-ideal and nitrogen present in air is oxidised. Nitrogen dioxide can cause damage to the human respiratory tract, increasing a person's susceptibility to respiratory infections and asthma. Sensitive populations, such as the elderly, children, and people with existing health conditions are most susceptible to the adverse effects of nitrogen dioxide exposure. Nitrogen dioxide can also cause damage to plants, especially in the presence of other pollutants such as ozone and sulphur dioxide. Nitrogen oxides are also present in the reactions that lead to photochemical smog formation.
Inorganic compounds	ammonia	Ammonia is a colourless gas with a very distinct odour. No health effects have been found in humans exposed to typical environmental concentrations of ammonia. Exposure to high levels of ammonia in air may be irritating to skin, eyes, throat, and lungs and cause coughing and burns. Lung damage and death may occur after exposure to very high concentrations of ammonia. Some people with asthma may be more sensitive to breathing ammonia than others (ATSDR, 2004).
VOCs	acetaldehyde	Acetaldehyde has a pungent suffocating odour, but at dilute concentrations it has a fruity and pleasant odour. It has a general narcotic action, causing drowsiness, slow mental response and other severe symptoms (NPI, 2022). Acute (short-term) exposure to acetaldehyde results in effects including irritation of eyes, skin and respiratory tract (USEPA, 2000).
	acetone	Acetone has a distinct odour. When inhaled, acetone enters the bloodstream which carries it to all organs in the body. At low levels of exposure, the liver breaks down acetone into harmless chemicals. Exposure to moderate levels can cause nose, throat, lung, and eye irritation. Exposure to high levels over a short period of time can cause headaches, confusion, nausea, chronic respiratory disease and other severe symptoms (ATSDR, 2022).
	formaldehyde	Formaldehyde has a pungent, distinct odour. It is quickly broken down in air, within hours. When inhaled, formaldehyde is quickly broken down in the cells lining the respiratory tract and exhaled. Only at high levels does formaldehyde enter the bloodstream. Formaldehyde is a highly reactive such that it can be directly irritating to tissues with which it comes into contact – upper respiratory tract and eyes with inhalation exposure. The International Agency for Research on Cancer (IARC) have classified formaldehyde as a human carcinogen (Group 1[9]) based on studies of inhalation exposure studies (ATSDR, 2008).

---

[9] Group 1: "Carcinogenic to humans". There is enough evidence to conclude that it can cause cancer in humans.

Pollutant		Description and potential adverse effects at high concentrations
Trace metals	aluminium	Aluminium is the most abundant metal in the earth's crust. Aluminium is a very reactive element and occurs naturally combined with other elements, in particulate form. Most aluminium-containing compounds do not dissolve to a large extent in water unless the water is acidic or very alkaline (ATSDR, 2008). The Toxikos (2010) review of toxicology of Aluminium (and compounds) indicate evidence of pulmonary effects at high airborne concentrations and suggestive evidence of subtle neurological deficits at lower concentrations. Aluminium bioavailability is generally low at around 2%.
	arsenic	Arsenic is a naturally occurring element widely distributed in the earth's crust, usually present in the environment combined with other elements such as oxygen, chlorine and sulphur (i.e. inorganic arsenic[10]). It is classified chemically as a metalloid, having both properties of a metal and a nonmetal; however it is frequently referred to as a metal. Many common arsenic compounds can dissolve in water. Although based on limited information, studies show that most simple organic arsenic compounds (such as methyl and dimethyl compounds) are less toxic than inorganic forms. Inhalation of inorganic arsenic can cause sore throat and lung irritation. Longer exposure at lower concentrations can lead to skin effects, and also to circulatory and peripheral nervous disorders (ATDSR, 2007). The International Agency for Research on Cancer (IARC) have classified arsenic and inorganic arsenic compounds as a human carcinogen (Group 1[11]).
	chromium VI	Chromium is a naturally occurring element found in rocks and soil, where it exists in combination with other elements to form various compounds. However, chromium VI compounds are not found in nature (NPI, 2022). Most chromium VI compounds are soluble in water. The most common health effects of inhalation of chromium involves respiratory tract irritation and breathing problems. The concentrations of chromium in air that can cause these effects may be different for different types of chromium compounds, with effects occurring at much lower concentrations for chromium VI compared to chromium III (ATDSR, 2012). The International Agency for Research on Cancer (IARC) have classified chromium VI compounds as a human carcinogen (Group 1[6]).
	mercury	Mercury is a naturally occurring element. The form of mercury can be classified into three general categories: elemental mercury, inorganic mercury compounds (e.g. mercuric chloride), and organic mercury compounds (e.g. methyl mercury). Elemental mercury is a silver liquid at room temperature that can also evaporate into the air as a vapour or become a solid at very low temperatures. It can combine with other substances to form inorganic mercury salts and organic mercury compounds. Each form of mercury has distinct chemical properties that contribute to different toxicological effects. All forms of mercury can affect the nervous system and kidneys.

---

[10] Arsenic combined with carbon and hydrogen is referred to as organic arsenic.

[11] Group 1: "Carcinogenic to humans". There is enough evidence to conclude that it can cause cancer in humans.

Pollutant		Description and potential adverse effects at high concentrations
		Atmospheric mercury in the form of gaseous elemental mercury, is subject to long-range transport. When deposited into water bodies, mercury can be methylated by anaerobic bacteria producing a highly bio-accumulative form of organic mercury (methylmercury). (ATSDR, 2022).
	nickel	Nickel is a very abundant natural element. Nickel can combine with other elements such as chlorine, sulfur, and oxygen to form nickel compounds. Many nickel compounds dissolve fairly easily in water. The most common harmful health effect of nickel in humans is an allergic reaction. Approximately 10-20% of the population is sensitive to nickel. The most serious harmful health effects from exposure to nickel, such as chronic bronchitis, reduced lung function, and cancer of the lung and nasal sinus, have occurred in people who have breathed dust containing certain nickel compounds while working in nickel refineries or nickel-processing plants - specifically nickel compounds that were hard to dissolve (such as nickel subsulphide) (ATSDR, 2005). The International Agency for Research on Cancer (IARC) have classified nickel compounds as a human carcinogen (Group 1[6]).

3.2 Air Quality Assessment Criteria

3.2.1 Overview

The air quality criteria that have been applied in this assessment reference:

- National Environmental Protection Measure (NEPM) for Ambient Air Quality (as varied 15 April 2021) (NEPC, 2021),
- Criteria adopted from the Health Endpoints Review (Katestone, 2023) for the forthcoming Health Risk Assessment of the Wagerup Refinery, to be undertaken based on the results in this report, and
- Air Emissions Guideline (draft for consultation) (DWER, 2019).

These air quality criteria are intended to be health protective in respect to acute and chronic non-carcinogenic health effects and carcinogenic risk, having been sourced from various reputable health authorities. Generally, the methods used to derive ambient air quality criteria are inherently conservative, making them highly protective of human health.

The air quality criteria adopted from Katestone (2023) for health risk assessment purposes are not necessarily consistent with the Air Emissions Guideline (draft for external consultation) published by the Department of Water and Environment Regulation (DWER) for Western Australia (DWER, 2019).[12]

---

[12] Apparent inconsistency in air quality criteria is evident for ammonia (1-hour to 24-hour), acetaldehyde (1-hour to 24-hour), acetone (1-hour to 24-hour) and formaldehyde (1-hour to 24-hour), in that it is anomalous for the 1-hour average criterion to be less than the 24-hour criterion (i.e. much more stringent), or vice versa for the 24-hour criterion to be higher than the 1-hour criterion (i.e. much less stringent).

Given the draft status of the Air Emissions Guideline (DWER, 2019), the ambient air quality guideline values contained within are subject to change based on the outcomes of public consultation. Nevertheless, this set of ambient air quality guidelines has also been referenced to inform the assessment regarding prospective regulatory requirements (refer to Section 3.2.3).

The more stringent standards for NO_2 specified in the National Environmental Protection Measure (NEPM) for Ambient Air Quality (as varied 15 April 2021) (NEPC, 2021) have been adopted. To inform the assessment regarding anticipated future regulatory requirements, reference is also made to the increasingly more stringent standards for $PM_{2.5}$ that apply from 2025 (refer to Section 3.2.2).

The ambient air quality guideline for alumina (Al_2O_3) has been adopted from DWER (2019), applied "as Aluminium" present in residue and bauxite dust emissions (refer to Section 3.2.4).

A summary of the adopted air quality assessment criteria is presented in Table 3-2.

Table 3-2: Summary of Air Quality Assessment Criteria

Pollutant	Air quality assessment criteria				
	ppm	$\mu g/m^3$ [1]	Averaging Period	Reference	
				Primary	Secondary
PM_{10}	-	46	24-hour	DWER (2019)	NEPC (2021)
		23	Annual		
$PM_{2.5}$	-	23	24-hour	DWER (2019)	NEPC (2021)
		18 [from 2025[2]]			
		7	Annual		
		6 [from 2025[2]]			
NO_2	0.08	151	1-hour	DWER (2019)	NEPC (2021)
	0.015	28	Annual		
Ammonia	-	330	1-hour	DWER (2019)	EPA NSW (2017)
	1.7	1,290	24-hour	Katestone (2023)	ATSDR (2004)
	0.1	76	Annual		ATSDR (2004)
Acetaldehyde	-	470	1-hour	Katestone (2023)	OEHHA (2020)
	-	1,830	24-hour	DWER (2019)	Toxikos (2010)
	-	9	Annual	Katestone (2023)	IRIS (1991)
	-	46		DWER (2019)	Toxikos (2010)
Acetone	-	22,000	1-hour	DWER (2019)	EPA NSW (2017)
	8	20,740	24-hour	Katestone (2023)	ATSDR (2022)
Formaldehyde	0.018	20	1-hour	DWER (2019)	EPA NSW (2017)
	0.04	53.6	24-hour	Katestone (2023)	NEPC (2004)
	-	9	annual	Katestone (2023)	OEHHA (2020)
Aluminium [3]	-	9.2	24-hour	DWER (2019)	Toxikos (2010)

Pollutant	Air quality assessment criteria				
	ppm	µg/m³ [1]	Averaging Period	Reference	
				Primary	Secondary
Arsenic	-	0.09	1-hour	DWER (2019)	EPA NSW (2017)
	-	0.2		Katestone (2023)	OEHHA (2020)
	-	0.027	24-hour	DWER (2019)	Toxikos (2010)
	-	0.0027	Annual	DWER (2019)	Toxikos (2010)
	-	0.015		Katestone (2023)	OEHHA (2020)
Chromium VI [4]	-	0.09	1-hour	DWER (2019)	EPA NSW (2017)
	-	0.00018	Annual		Toxikos (2010)
	-	0.005		Katestone (2023)	ATSDR (2012)
Mercury (inorganic)[5]	-	0.6	1-hour	Katestone (2023)	OEHHA (2020)
	-	0.55		DWER (2019)	Toxikos (2011)
	-	0.18	Annual		
	-	0.03		Katestone (2023)	OEHHA (2020)
Mercury (organic)	-	0.18	1-hour	DWER (2019)	EPA NSW (2017)
Nickel	-	0.18	1-hour	DWER (2019)	EPA NSW (2017)
	-	0.2		Katestone (2023)	OEHHA (2020)
	-	0.14	24-hour	DWER (2019)	DoH/Duffus J (2009)
	-	0.003	Annual		
	-	0.014		Katestone (2023)	OEHHA (2020)

Notes:

1. DWER (2019) concentrations referenced to 25 ºC and Katestone (2023) concentrations referenced to 0ºC for consistency with the primary reference.
2. See NEPC (2021). Increasingly more stringent $PM_{2.5}$ standards apply from 2025 - 7 µg/m³ (annual average) and 20 µg/m³ (24-hour), referenced at 0°C. These correspond to 6 µg/m³ (annual average) and 18 µg/m³ (24-hour average) referenced at 25°C, which is the criteria reference temperature used for air quality assessments in DWER (2019).
3. The DWER (2019) value for alumina (Al_2O_3) has been adopted, applied "as Aluminium" present in residue and bauxite dust emissions.
4. The ATSDR Minimal Risk Level (MRL) adopted in Katestone (2023) for Chromium IV relates to aerosol mists. There is an alternative (less stringent) MRL for Chromium VI as particulates (0.3 µg/m³) for an Intermediate (15 to 364 days) exposure duration. The Katestone (2023) value has been adopted for this study, as the form of Chromium VI emitted from the Refinery point sources is not known.
5. The OEHHA (2019) and Toxikos (2011) values for mercury (inorganic) are assumed to encompass both the elemental form and inorganic mercury compounds.

3.2.2 National Environment Protection (Ambient Air Quality) Measure

The National Environment Protection Measure (NEPM) for Ambient Air Quality (NEPC, 2021) specifies standards that have been derived for the adequate protection of human health and well-being. They cover a range of common air pollutants including (but not limited to) NO_2, and particulates (as PM_{10} and $PM_{2.5}$).

The Ambient Air Quality NEPM has recently been updated to reflect the latest scientific understanding and to allow for an adequate level of health protection, with more stringent standards adopted for NO_2, amongst other pollutants. As part of a framework for continuous improvement, increasingly more stringent standards for $PM_{2.5}$ apply from 2025.

The Ambient Air Quality NEPM provides a framework for a nationally consistent approach to monitoring and reporting of ambient air quality in Australia, supporting the formulation of air quality management policies. Whilst the Ambient Air Quality NEPM does not directly regulate the activities of individuals or businesses (NEPC, 2021a), the standards have been widely referenced by State and Territory jurisdictions as regulatory instruments.

The more stringent Ambient Air Quality NEPM standards (as varied 15 April 2021) are not reflected in the Air Emissions Guideline (draft for external consultation) (DWER, 2019) for Western Australia, but nevertheless have been referenced in this assessment to align with the most current Ambient Air Quality NEPM standards and to inform the assessment in regard to regulatory requirements.

3.2.3 State Air Emissions Guideline

The Air Emissions Guideline (draft for consultation) was published by the DWER in 2019 (DWER, 2019). The ambient air quality guideline values contained in this guideline are intended to apply to all applications for a Works Approval or Licence under Part V of the EP Act, in Western Australia. Acknowledging their draft status, the ambient air quality guideline values contained in this guideline are subject to change based on the outcomes of public consultation. Nevertheless, this set of ambient air quality guidelines has also been referred to, to inform the assessment in regard to potential future regulatory requirements.

The ambient air quality guideline values are based on the approved health guidelines of Western Australia's Department of Health (DoH), which in turn are based on criteria published by various reputable health authorities, and the New South Wales Environmental Protection Authority publication (EPA NSW, 2017). The set of ambient air quality guideline values are intended 'as a tool to assess the level of risk associated with a proposed emission'. The guideline indicates that the DWER may, in some circumstances, use alternative ambient air quality guideline values to those published. The locations at which the ambient air quality guideline values are intended to be applied (beyond the premises boundary) is described in the guideline, although exceptions may be made on a case-by-case basis (e.g. premises in remote or industrial areas) to allow an alternative approach.

In their current form, the draft Air Emissions Guideline would require the assessment criteria for NO_2 and PM_{10}/$PM_{2.5}$ (defined as *criteria pollutants* under the guideline) to generally be 'met at all existing and future offsite sensitive receptors in the modelling domain'. This has been interpreted to include the identified discrete sensitive receptors (refer to Section 3.4).

3.2.4 Criterion for Aluminium

A literature search was conducted by Toxikos (2010) for existing ambient air quality guidelines/standards applicable for the protection of human health for several substances, including alumina. The reviews on the toxicology of Aluminium and Aluminium compounds consulted in the Toxikos (2010) study indicate evidence of pulmonary effects at high airborne concentrations and suggestive evidence of subtle neurological deficits at lower concentrations.

Air guidelines from competent authorities were not identified for alumina in the Toxikos (2010) review. The ambient guideline value of 10 µg/m³ recommended in Toxikos (2010) was therefore derived *de novo* for a 24-hour averaging time as Aluminium in the respirable fraction, which is recommended to be taken as PM_{10} for monitoring convenience. The pivotal study references relate to occupational exposure to aluminium-containing welding fumes (Buchta et al, 2003) and aluminium potroom workers (Sim et al, 1997). Toxikos (2010) consider the guideline value to be of medium reliability, and more likely to over protect against the health effects of airborne aluminium then under protect.

This recommended ambient guideline value has been adopted in DWER (2019) as 9.2 µg/m³ (referenced to 25°C).

3.3 Dust Deposition Assessment Criteria

The dust deposition criteria adopted to assess the potential amenity (dust nuisance) impacts are based on the criteria adopted in the draft Dust Emissions Guideline (DWER, 2021), as presented in Table 3-3.

Table 3-3: Summary of Dust Deposition Assessment Criteria

Pollutant	Type	Criteria	Averaging Period	Units	Reference
Deposited Dust	Amenity	2 [Maximum Increase] [1]	annual	g/m²/month	DWER (2021) [3]
		4 [Maximum Total] [2]			

Notes:

1. Maximum increase in deposited dust (above background level).
2. Maximum total deposited dust (when background level is unknown).
3. DWER (2021) references NSW EPA (2016) as one of the original sources of these criteria, which has been referred to for this table. NSW EPA (2016) is superseded by NSW EPA (2022), however there has been no change to the deposited dust criteria. DWER (2019) does not reference the annual averaging period specified in NSW EPA (2016 & 2022).

3.4 Sensitive Receptors

The local communities in the proximity of the Refinery include Yarloop, Hamel and Waroona (refer to Figure 3-1). Yarloop is located approximately 3 km south of the Refinery, and Hamel and Waroona are located north of the Refinery approximately 5 km and 8 km away respectively.

The discrete sensitive receptor locations used in the assessment are listed in Table 3-4, and are shown in Figure 3-1. These discrete receptors are consistent with those identified in a recent review commissioned by Alcoa of sensitive receptors located around the Wagerup Refinery (Katestone, 2023a). It is noted that receptor 2 is no longer included as there is no longer a residential dwelling at this site (Katestone, 2023a), and receptor 12 is not included as it ceased being a residence in the mid-2000s (Air Assessments, 2015). The new discrete sensitive receptor locations that have been added are:

- Receptor 17 - introduced due to the common prevailing winds potentially affecting areas to the west of the Wagerup Refinery

- Receptors 18, 19 and 20 – introduced to ensure the region southwest of the Wagerup Refinery is captured.

Table 3-4 Discrete sensitive receptor locations

ID [1]	Descriptor	Type | Current Status [2]	Easting (m) [3]	Northing (m) [3]
R1	Boundary Rd	Individual residence | Alcoa owned	398,231	6,354,984
R3	Yarloop	Individual residence | Area B	396,970	6,353,099
R4		Individual residence | Alcoa owned	397,278	6,354,977
R5		Individual residence | Alcoa owned	395,861	6,352,653
R6 [4]		Individual residence | Alcoa owned	400,247	6,354,650
R7	Bremner Rd	Individual residence | Alcoa owned	390,915	6,358,883
R8	Somers/McClure Rds	Individual residence | Alcoa owned	392,500	6,362,281
R9		Individual residence | Area B	396,239	6,362,174
R10	Hamel	Individual residence | Area B	398,600	6,362,150
R11 [5]		Individual residence | Area A	398,656	6,360,782
R13	Waroona	Residential population	400,660	6,364,365
R14	Escarpment	Individual residence | Area A	400,867	6,360,980
R15 [6]		Individual residence | Alcoa owned	402,871	6,356,592
R16		Individual residence | Area A	397,505	6,359,434.9
R17	Monaco Rd	Individual residence | Alcoa owned	389,386	6,358,097
R18	South of Residue Area	Individual residence | Alcoa owned	392,680	6,354,988
R19		Individual residence | Alcoa owned	393,864	6,354,206
R20		Individual residence | Alcoa owned	395,091	6,353,536

Notes:

1. Receptor 2 and receptor 12 are not included as they are no longer residential dwellings.
2. Area A (immediately surrounding the Refinery). Area B (residential townships of Hamel and Yarloop).
3. Location coordinates given in GDA94 / MGA Zone 50, rounded to the nearest metre.
4. Receptor 6 has been relocated 526 m to sit on the residential dwelling.
5. Receptor 11 has been relocated 432 m to sit on the residential dwelling.
6. Receptor 15 has been relocated 2005 m east to a location with a residential dwelling.

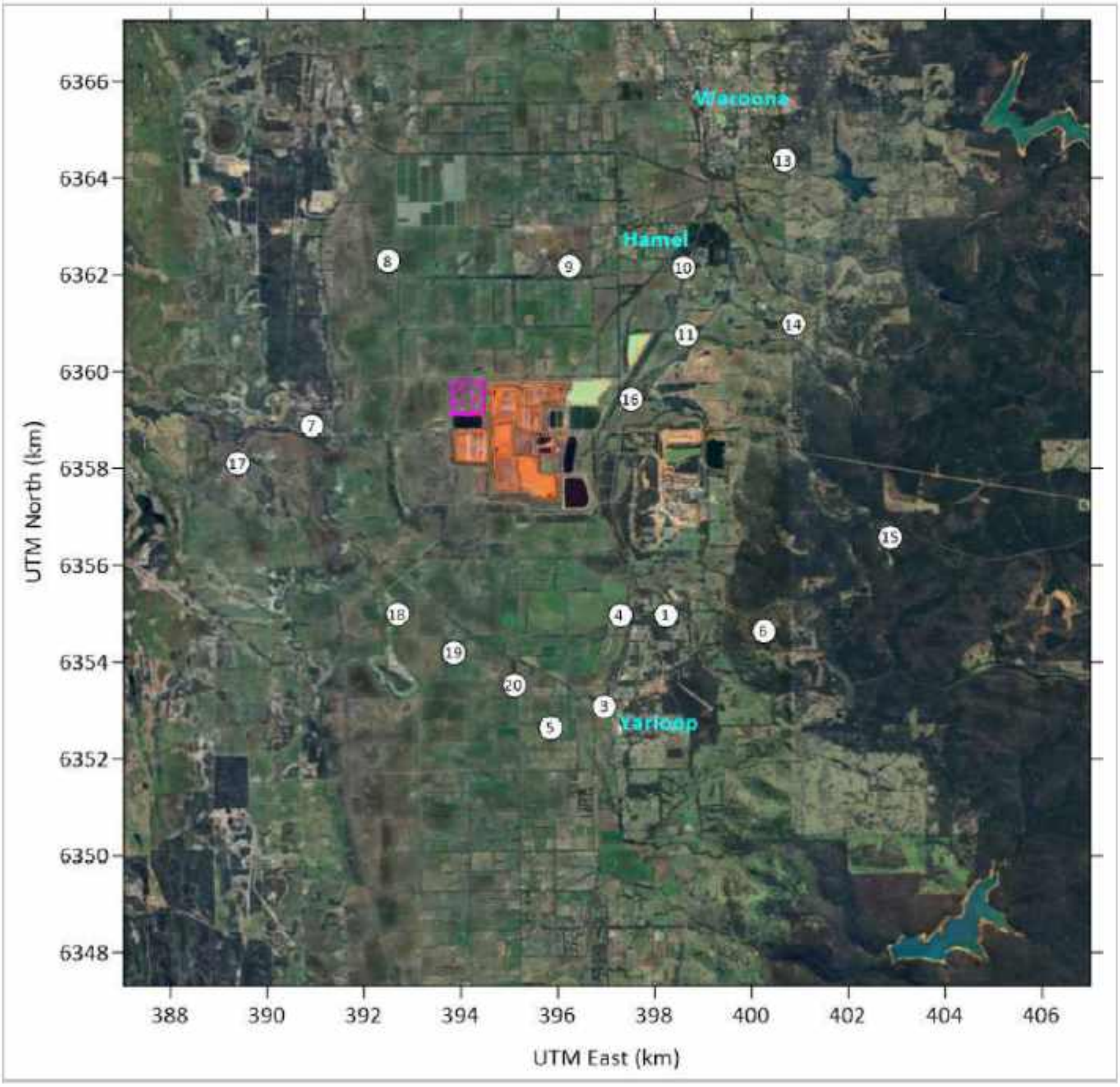


Figure 3-1 Discrete sensitive receptor locations

4 Modelling Methodology

4.1 Overview

For this assessment, air dispersion modelling has been conducted using the CALMET/CALPUFF suite of models with meteorological data produced from the WRF prognostic model. The CALMET meteorological model has been used to develop the required meteorological inputs, and the CALPUFF model has been used to predict the concentrations at ground-level across the model domain and at nominated discrete sensitive receptor locations. Meteorological measurements representative of the site are used to verify the meteorological inputs for the modelling. Site measurements of Residue Area fugitive emissions are used to refine emission estimates and verify ground-level concentrations predicted by the CALPUFF model.

An overview of the air quality modelling approach is shown in Figure 4-1.

Further details of model settings and input parameters are provided in the subsections following.

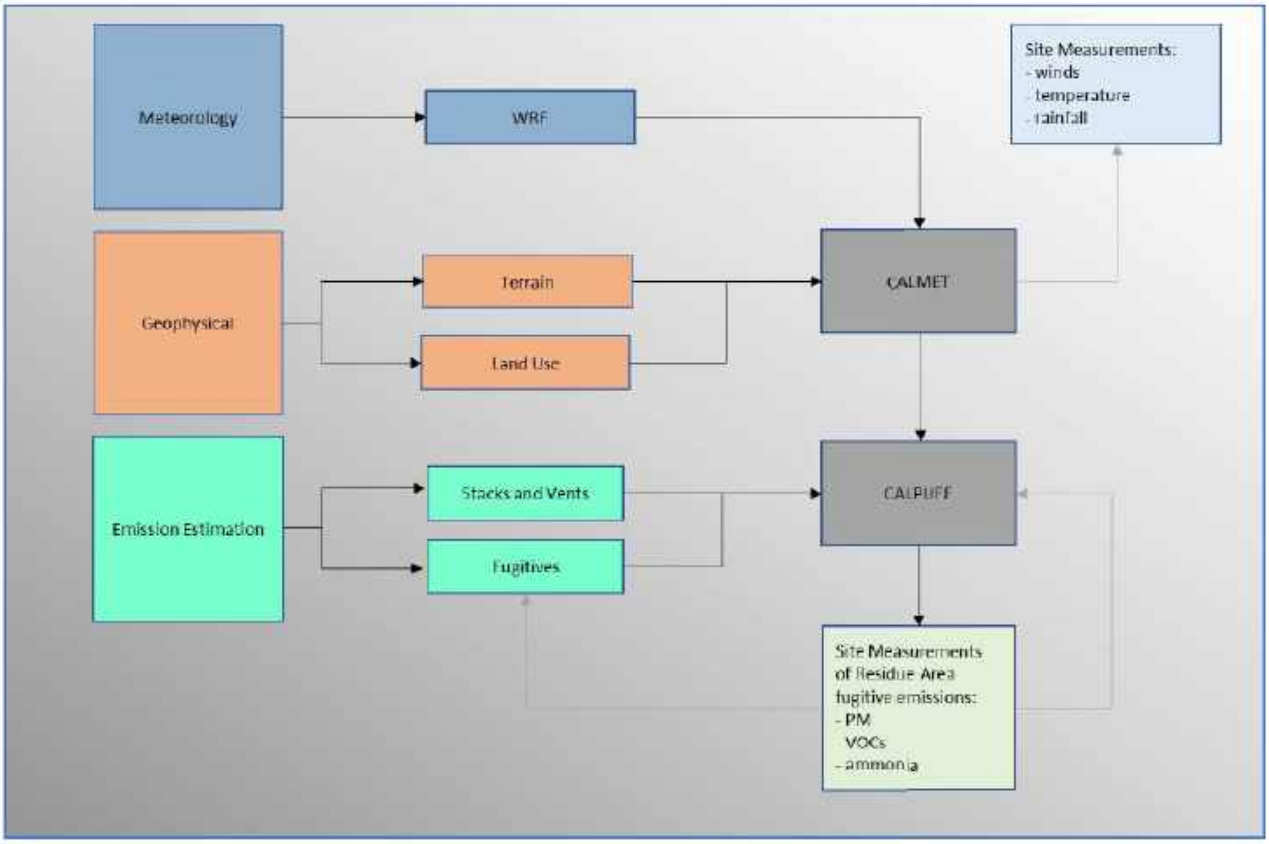


Figure 4-1: Air quality assessment – study approach

4.2 Meteorology

4.2.1 Background

The air dispersion modelling study has been based on a meteorological period that corresponds to the Residue Dust Monitoring Study period (June 2021 to May 2022), as the measurements collected are used to develop credible dust emission estimates for the Residue Area over this period, and to then validate the predictions of downwind concentrations of PM in ambient air against measurements.

The existing network of meteorological monitoring locations at the Wagerup Refinery can be used to characterise conditions at the surface (up to 30 m above ground level). Upper air measurement data, however, is not available for the Wagerup Refinery, with the closest sonde measurements taken at the Perth Airport. The use of a prognostic model in lieu of site measurements is often used to derive the upper air meteorology for air dispersion modelling purposes. There are other benefits to the use of prognostic meteorology over the use of surface and/or upper air measurements alone, such as improvement in:

- spatial resolution of the wind field across the model domain
- temporal resolution between radiosonde measurement times (daily).

As the dust emissions from the Residue Area are of a low-level non-buoyant type, the influence of the upper air conditions upon plume dispersion is not expected to be overly significant. Plume dispersion of elevated point sources (tall stacks), notably the Calciners and Powerhouse stacks, will be influenced to a much greater extent by the upper air conditions.

Several precursor studies have been undertaken to inform the preferred approach to develop the meteorological dataset for use in the air dispersion modelling study of the RSA10 proposal, and the Wagerup Refinery more generally. The first of these was a study to evaluate the performance of the WRF model, an advanced prognostic meteorological model, for predicting surface and upper air meteorology at the Wagerup Refinery (ETA, 2022). The second was a model sensitivity study comparing the use of meteorology from WRF to that derived from surface observations (ETA, 2022a).

The findings of these studies support the use of the WRF prognostic model to derive the meteorological data for use in air dispersion modelling at the Wagerup Refinery. Alcoa has advised that this approach was presented to, and supported by DWER, at a meeting held on 20 September 2022.

4.2.2 Meteorological monitoring network

Alcoa has an established network of meteorological monitoring stations located near the Wagerup Refinery and installed an additional meteorological station at RSA5 as part of the Residue Dust Monitoring Study (Figure 4-2). The meteorological parameters measured is summarised in Table 4-1.

The RSA5 meteorological monitoring site established as part of the Residue Dust Monitoring Study is considered the most representative of winds in the immediate vicinity of the Residue Area for use in this study. The other sites are Bancell Rd West and the Bancell Rd meteorological monitoring site.

Table 4-1: Summary of meteorological monitoring sites

Site name	Location Coordinates (GDA94)		Height (m agl)	Parameters
	mE	mN		
RSA5	395,054	6,358,991	10 m	Wind speed Wind direction
Bancell Road West	395,341	6,355,902	10 m	Wind speed Wind direction Temperature
Bancell Road	397,768	6,356,272	Surface	Temperature (2m) Relative Humidity (2m) Barometric Pressure (2m) Solar/Net radiation (1m) Rainfall (0.3m)
			10 m	Wind speed Wind direction Wind gust Sigma theta Temperature
			30 m	Wind speed Wind direction Wind gust Sigma theta Temperature

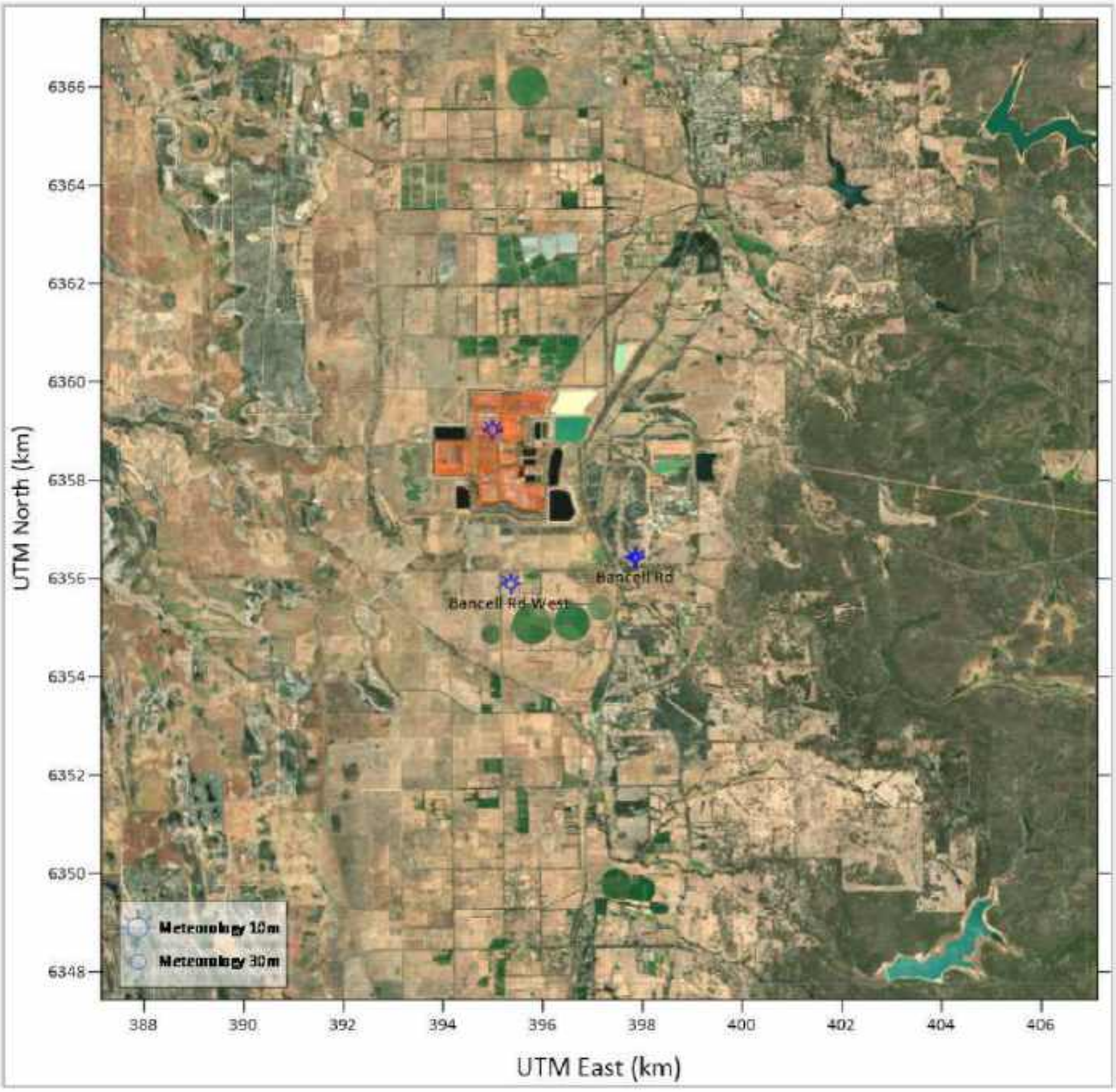


Figure 4-2: Locations of meteorological monitoring sites

4.2.3 Meteorological models

4.2.3.1 WRF

The Weather Research and Forecast (WRF V4.1) model (http://wrf-model.org/index.php) was used to generate hourly 3-dimensional meteorological data for the Wagerup region. WRF is the next-generation mesoscale numerical weather prediction system. The model was primarily designed to serve both operational forecasting and atmospheric research.

WRF was run with a three-nest structure (24 km, 6 km and 1.5 km horizontal grid space resolution) centred on 32.91213°S and 115.901453°E. This is shown in Figure 4-3. The model vertical resolution consists of 50 eta levels[13]. Further detail of the WRF model parameterisation is presented in ETA (2022).

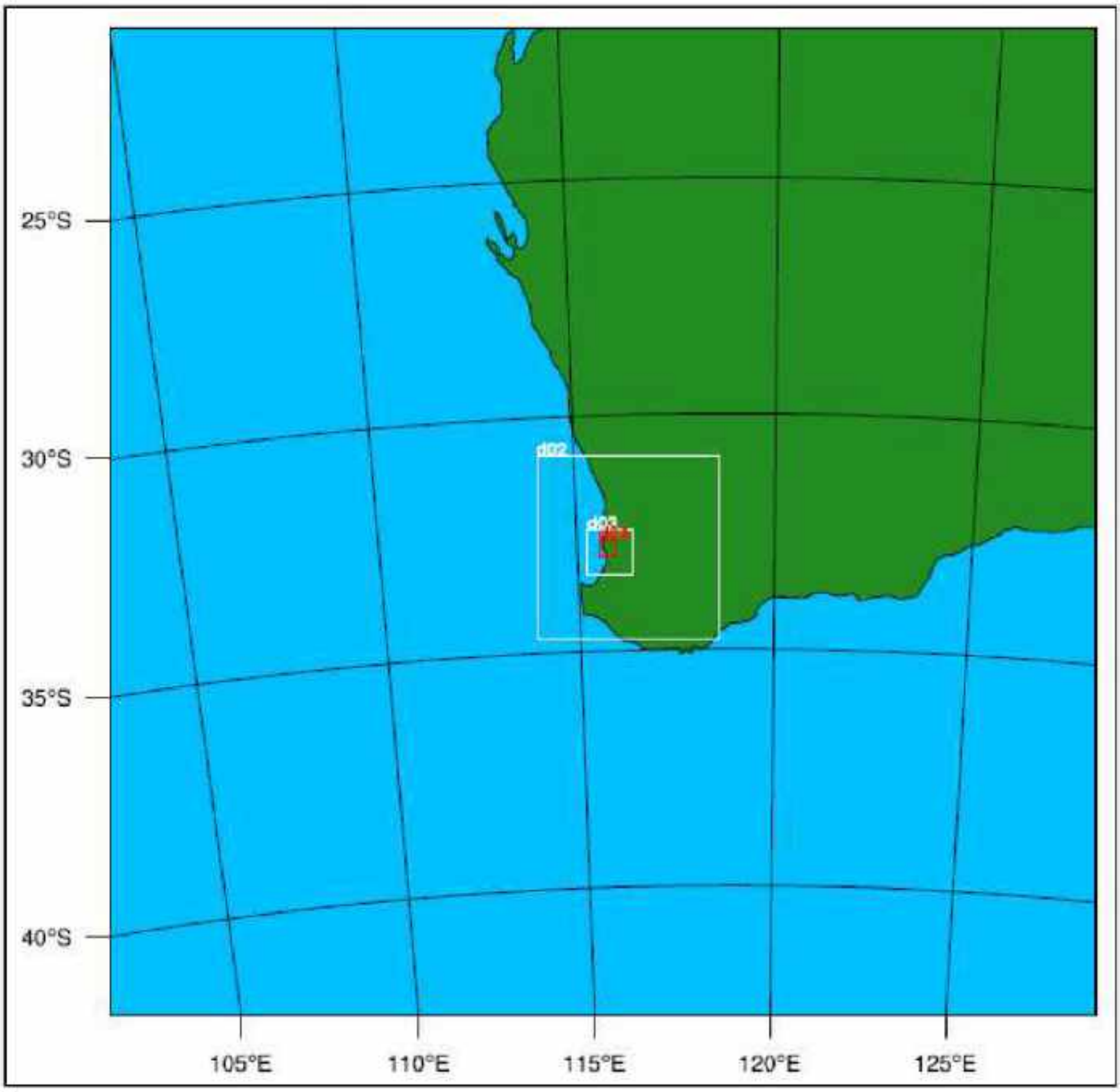


Figure 4-3: WRF model domains

---

[13] Eta levels are terrain-following vertical coordinates in the lower atmosphere, and pressure following coordinates in the upper atmosphere.

4.2.3.2 CALMET

CALMET is a three-dimensional meteorological pre-processor that includes a wind field generator containing objective analysis and parameterised treatments of slope flows, terrain effects and terrain blocking effects. The pre-processor produces fields of wind components, air temperature, relative humidity, mixing height and other micro-meteorological variables to produce the three-dimensional, spatially and temporal-varying meteorological fields that are utilised in the CALPUFF dispersion model.

CALMET requires several datasets to resolve the surface and upper air meteorology occurring for each hour of the year:

- surface observations and upper air observations or gridded prognostic meteorological model data
- land use and topographical data.

CALMET was run using the same configuration as produced in ETA (2020a), with a 77 x 77 grid domain at a spatial resolution of 250 m. Vertically, the model consisted of 9 levels extending to 2,040 m. The southwest corner coordinates of the domain were 387.519 km Easting and 6347.790 km Northing (GDA94, Zone 50). Seasonal geophysical (geo.dat) files were also used to reflect the seasonality of rainfall and associated parameters such as roughness length, albedo, and Bowen ratios.

The 3-Dimensional meteorological data generated by WRF was input to CALMET (Version 6.33 Level: 110324) for further processing to the finer resolution used in the dispersion modelling. The output from the CALMET meteorological model is then used to drive the pollution dispersion in the CALPUFF model. The key variable extraction for the CALMET options used is shown in Appendix B.

4.2.4 WRF-CALMET Model Evaluation

The performance of the WRF-CALMET meteorological dataset in predicting surface meteorology at the Wagerup Refinery for air dispersion modelling purposes has been validated against corresponding hourly average measurements at Bancell Rd, Bancell Rd West and Residue RSA5 weather stations for the period June 2021 to May 2022. Objective statistical benchmark tests and visual aids presenting wind roses, time series plots and scatterplots were applied to evaluate model performance.

Overall, WRF-CALMET has simulated the meteorology over Wagerup with an acceptable degree of accuracy given that most of the benchmarks are either met, or just outside the criteria. The results of the benchmark tests are summarised in Table 4-2.

Wind Speed:	Overall, the model performs relatively well for wind speed at RSA5. Model performance is less accurate at Bancell Rd and Bancell Rd West due to data completeness, quality, and potential siting issues affecting 10 m measurements at those locations.
Wind Direction:	Modelled wind direction for the year is just outside both benchmark criteria at Bancell Rd, and within one and just outside the other benchmark criterion at RSA5 and Bancell Rd West. This indicates better model performance at RSA5 and Bancell Rd West.

Table 4-2: The results of the statistical benchmark tests

Variable	Performance Criteria	Benchmark Range	Bancell Rd	Bancell Rd West	RSA5
			Score	Score	Score
Wind Speed	RMSE	<±2 m/s	1.9	1.9	2.3
	BIAS	<± 0.5 m/s	-1.0	-1.0	0.2
	IOA	>0.6	0.79	0.78	0.76
Wind Direction	Gross error	<30 °	39.1	34.7	34.5
	BIAS	<10 °	14.5	0.72	5.5
Temp	Gross error	<±2 K	2.0	2.0	-
	BIAS	<± 0.5 K	0.4	0.5	-
	IOA	>0.8	0.96	0.96	-

Notes:

Cells shaded green are within criterion. Cells shaded orange are outside of criterion.

Further detail of the WRF-CALMET model evaluation study is presented in ETA (2022d).

4.3 CALPUFF

4.3.1 Model selection

The air dispersion modelling has been conducted using the CALPUFF dispersion model (v7.3.2).

CALPUFF is an advanced non-steady-state puff model that is designed for cases involving a high degree of spatial variability of the flow within the boundary layer. As a non-steady-state puff dispersion model, the model can be used to simulate complex meteorological flows influenced by local terrain features, where steady-state straight-line plume transport assumptions are inappropriate. The model incorporates the PRIME (Plume Rise Model Enhancements) building downwash algorithms, important for simulating dispersion of low-level emission sources at the Refinery. The model can also be used to account for pollutant deposition at the surface. For particles, the size, shape and density are taken into account to determine the rate of gravitational settling. The scavenging effects during periods of rainfall can optionally also be considered, and is referred to as "wet deposition". Deposition in the absence of rainfall effects is referred to as "dry deposition".

The CALPUFF model was originally used for the Environmental Review and Management Program (ERMP) modelling of fugitive sources, and was adopted in previous Phase 2 study of the Wagerup Refinery (ETA, 2020a) for modelling Refinery point source emissions also. It is listed by the USEPA as an alternative regulatory dispersion model for assessing certain near-field applications involving complex meteorological conditions (US Federal Register, 2017), and is used extensively throughout Australia for regulatory assessments of industrial facilities.

4.3.2 Model setup

Key CALPUFF model set ups were as follows:

- Dispersion coefficients from micrometeorological variables;
- Minimum over land sigma–v[14] set to 0.4 m/s to make it more consistent with the 0.2 m/s to 0.5 m/s currently being considered for AERMOD (0.2 m/s was the original AERMOD default) (USEPA, 2017). (The CALPUFF default over land sigma v is 0.5 m/s.). This makes plumes narrower during low wind conditions and slightly increases maximum predicted concentrations;
- Partial plume path adjustment for terrain as recommended (Barclay and Scire, 2011);
- PRIME downwash, including the simplified version of the multi-flue plume rise algorithm recommended by Air Assessments (2017); and
- For the dispersion of particles, dry deposition.

The full variables set for the CALPUFF options used is shown in Appendix B.

4.4 Building Wake Effects

The modelling undertaken for this assessment used the PRIME (Plume Rise Model Enhancements) algorithms incorporated in CALPUFF to simulate building wake effects upon plume dispersion. The PRIME algorithm is widely adopted for regulatory assessments.

The information to define the location and dimensions of buildings used as input to the model were sourced from Air Assessments (2017), which in turn was derived from the ENVIRON (2010) modelling, incorporating modifications to a number of the taller structures within the Calcining and Building 46 areas. The placement of the buildings was subsequently refined in the Phase 2 study according to the site aerial. The location of buildings used as input to the model are shown in Figure 4-4.

---

[14] Minimum sigma–v represents the lateral turbulence intensity under low wind conditions.

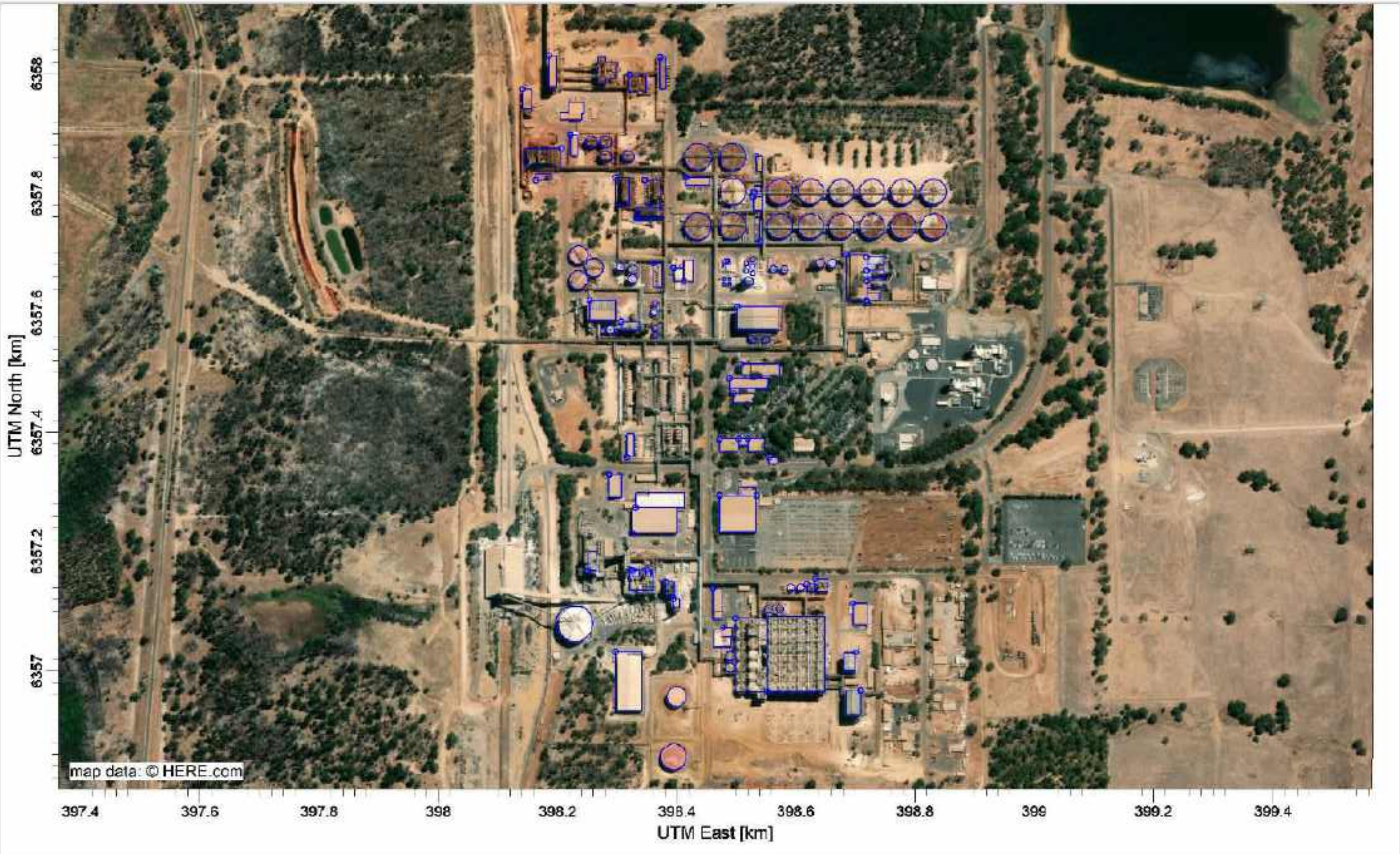


Figure 4-4: Building locations

4.5 Conversion of NOx to NO_2

The assessment was limited to the modelling of NOx (did not simulate conversion of NOx to NO_2), and hence conservative assumptions have been used to account for conversion of NOx to NO_2. For predicted 1-hour averages, 30 % conversion of NOx to NO_2 has been assumed (Katestone, 2007) and has been shown to be consistent with peak NO_2 measurement data collected at the Boundary Road monitoring site for the Refinery wind direction bearing (ETA, 2020a). Total conversion of NOx to NO_2 has been assumed for annual averages.

4.6 Particle Sizing | Gravitational Settling

4.6.1 Point sources

The particle size distribution (PSD) for PM emitted from the Refinery point sources used for determining deposition, is shown in Table 4-3.

Table 4-3: Particle size distribution assumed for all Refinery sources with Total PM (TPM) emissions

Project Sample Details		Date Collected	TPM (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	$PM_{2.5}$:TPM	PM_{10}:TPM
Calciner 1	Run 1	18/01/2023	65	8.1	30	0.12	0.46
Calciner 1	Run 2	18/01/2023	59	11	31	0.19	0.53
Calciner 2	Run 1	18/01/2023	55	17	36	0.31	0.65
Calciner 2	Run 2	18/01/2023	47	12	32	0.26	0.68
Calciner 3	Run 1	25/01/2023	25	3.2	13	0.13	0.52
Calciner 3	Run 2	25/01/2023	28	3.5	15	0.13	0.54
Calciner 4	Run 1	25/01/2023	9.2	0.73	3.4	0.08	0.37
Calciner 4	Run 2	25/01/2023	6.5	<0.58	2.2	-	0.34
Average						0.173	0.511

Notes:

Data sourced from Emission Assessments (2023).

- 1 June 2021 to 31 May 20221 June 2021 to 31 May 2022Table 5-1

The PM_{10} and $PM_{2.5}$ from Refinery point sources was conservatively modelled for airborne concentrations as passively dispersing (i.e. assumes no deposition).

The $PM_{2.5}$ emissions was scaled from the PM_{10} emissions for each source in the inventory using the PSD data ratios ($PM_{2.5}$:PM_{10} ratio of 0.173/0.511=0.338).

These assumptions will potentially overstate the predicted PM_{10} and $PM_{2.5}$ concentrations to the extent that deposition of the PM_{10}/$PM_{2.5}$ is not taken into account, however from tall stacks, this is unlikely to be significant.

The PSD was, however, incorporated for the modelling of TSP and metals dry deposition (gravitational settling of particles), as described in Table 5-1

4.6.2 Fugitive sources

The TSP and PM_{10} airborne concentrations from fugitive sources were modelled with dry deposition. The $PM_{2.5}$ fraction was modelled as passively dispersing.

The particle size fractions of PM from fugitive sources were based on the average TSP, PM_{10} and $PM_{2.5}$ concentration measurements from the RSA5 High Volume Air Samplers (HVASs), as shown in Table 4-4. The sub-fractions within, used to simulate dry deposition, were partitioned according to the original fractions adopted in Air Assessments (2015) as shown in Table 4-5.

Table 4-4: Particle size fractions from concentration measurements

Species	Average concentration from RDA5 HVASs (µg/m^3)	Cumulative fraction of TSP
$PM_{2.5}$	15.15	0.21
PM_{10}	29.77	0.41
TSP	73.13	1.0

Table 4-5: Particle size distribution used for modelling PM from fugitive sources

Species			Modelled species	Original Air Assessments (2015) fractions	Final revised fractions based on RSA5 HVAS sampling	Relative fraction of TSP
TSP	PM_{10}	$PM_{2.5}$	'PM1'	0.15	0.21	0.21
			'PM4'	0.09	0.09	0.20
			'PM8'	0.12	0.11	
			'PM13'	0.11	0.10	0.59
			'PM22'	0.24	0.22	
			'PM40'	0.14	0.13	
			'PM75'	0.15	0.14	

4.7 Model Uncertainty

Atmospheric dispersion models represent a simplification of the many complex processes involved in approximating ground-level concentrations of substances. The model uncertainty is therefore composed of uncertainties associated with model chemistry and physics, data, and stochastic uncertainties. There are also inherent uncertainties in the behaviour of the random turbulence of the atmosphere.

As with any modelling assessment of this nature, there are areas of uncertainty in this air quality assessment. To ensure that potential air quality impacts are not underestimated, conservative assumptions have been applied as appropriate, to provide over-predictions rather than under-predictions of ground-level concentrations.

Factors contributing to the general uncertainty in model results include:

- the turbulent (random) nature of dispersion in the turbulent atmosphere
- inaccuracies in the mathematical description of the physical and chemical processes that occur in the atmosphere (i.e. uncertainties in the numerical solutions)
- stochastic uncertainties, as models predict 'ensemble mean' concentrations (i.e. they predict the mean concentrations that would result from a large set of observations under the specific conditions being modelled)

- data uncertainty or variability, particularly in emission information and meteorological data inputs.

The uncertainty in modelling of extreme events, such as the maximum 1-hour ground-level concentration, is greater than the uncertainty in predicting concentrations averaged over a longer time period. Similarly, uncertainty in modelling the maximum predicted ground-level concentration at a discrete location is greater than the uncertainty in the maximum concentration predicted across the entire modelled domain. This is because the modelled concentration at a particular location is very sensitive to small changes in wind direction.

4.8 Reporting Precision

Most air quality criteria as originally derived from health studies, are only precise to two significant figures (for example, occupational health criteria). When they are converted to different units, additional digits are often included which, unfortunately, can facilitate a misleading interpretation of their actual precision.

Commensurately, emissions from stack sampling are also reported to two significant figures (for example, refer to Emission Assessments (2023)). This implies an uncertainty due to measurement precision alone of 0.50% to 5.0%, depending on the proximity of the true value to a multiple of 10. Scientific reporting convention is that derived values are reported to a precision such that the last digit of a reported value is the only estimated digit. Therefore, derived values from stack sampling measurements (i.e. reported to two significant figures) should be reported to three significant figures. This applies to predicted concentrations in the tables in Sections 7 and 8.

For consistency of presentation, all predicted concentrations have been presented with units of µg/m³.

For this report, the results from the CALPUFF model, which are typically exported with five significant figures (depending on the format statement in the coding) have been imported into Excel spreadsheets to derive tables and figures for this report.

Excel offers numerous options for presenting a numeric value however, as described above, the technically correct approach is to present modelled concentrations with three significant figures, which has been done throughout this report.

The Excel macro function used to format a result to a specified number of significant figures however, has a slight flaw in that trailing zeros are omitted in the presented value. The reader is made aware however, that, as examples, a concentration reported to three significant figures, presented as:

- 3 µg/m³ should be presented as 3.00 µg/m³ where the true concentration lies between 2.95 and 3.05 µg/m³ – a precision uncertainty of ±1.7% due to the underlying value having two significant figures;
- 1.1 µg/m³ should be presented as 1.10 µg/m³ where the true concentration lies between 1.05 and 1.15 µg/m³ – a precision uncertainty of ±4.8% due to the underlying value having two significant figures; and
- 0.009 µg/m³ should be presented as 0.00900 µg/m³ where the true concentration lies between 0.00900 and 0.00905 µg/m³ – a precision uncertainty of ±0.66% due to the underlying value having two significant figures.

Other reporting conventions followed in this report include:

- Where any of the concentrations in a Table column is in millionths of a µg/m³, scientific notation has been used as otherwise there would be five leading zeros to the first significant figure which becomes hard to visually differentiate.
- The format of presentation of values in the same column has been kept consistent to facilitate comparison of values through the column.

- Concentrations as percentage of criteria have been reported to two significant figures where the value is up to 99%, and three significant figures where the value is above 99%. The issues above similarly. For example:
    - 2% should be presented as 2.0%
    - 0.03% should be presented as 0.030%.

Finally, the Excel function used to format a result to a specified number of significant figures also always rounds upwards. Therefore, for example, a calculated concentration of 0.55555 µg/m³ (from CALPUFF) will be presented with three significant figures as 0.556 µg/m³. A calculated concentration of 0.0000055555 µg/m³ will be presented in scientific notation with three significant figures as 5.56E-06 µg/m³. Similarly, using the convention described above:

- a concentration as percentage of the criterion of 98.5% will be presented with two significant figures as 99%; and
- a concentration as percentage of the criterion of 100.5% will be presented with three significant figures as 101%.

5 Emissions Information

5.1 Overview

Emission sources from the Wagerup Refinery are categorised as follows:

- Refinery point sources – emissions released from stacks and vents at the Refinery;
- Fugitive particulate sources – wind-blown particulate emissions, from the RSAs primarily and the bauxite stockpile; and
- Fugitive vapour sources – gaseous emissions from exposed liquid surfaces, primarily VOCs from the Superthickener and Cooling Pond located at the Residue Area.

The general location of the Refinery process area (stacks and vents), RSAs and the cooling pond is shown in Figure 1-1. Refer also to Figure 5-1 (Refinery point sources) and Figure 5-3 (fugitive sources) for details of individual source locations.

The emission inventory that has been applied in the assessment has been forecast from the Wagerup 2021 Emission Inventory (Alcoa, 2022), scaled to represent emissions from the Refinery at the operating capacity of 2.9 Mtpa of alumina as permitted under the environmental licence.

Refinery point source emissions information were provided by Alcoa (refer to Section 5.4), and fugitive particulate and vapour source emissions were estimated according to the methods described in Section 5.5 and Section 5.5.2, respectively.

This section provides details of the emissions information used as input to the model to characterise the various Wagerup Refinery emission sources.

5.2 Emission Sources

The selected pollutants considered in this assessment represent the different categories of sources (Table 5-1).

Table 5-1: Emission Sources of Selected Pollutants

Grouping	Pollutant	Source category		
		Refinery Point	Fugitive Dust	Fugitive Vapour
Particulate Matter	PM_{10}, $PM_{2.5}$	✓	✓	
Product of combustion	NOx	✓		
Inorganic compound	Ammonia	✓		✓
VOCs	acetaldehyde, acetone, formaldehyde	✓		✓
Trace metals	Arsenic, Chromium VI, and Nickel	✓ [2]	✓	
	Aluminium [1]		✓	
	Mercury (particulate) [3]		✓	✓
	Mercury (vapour) [3]	✓		✓

Notes:

1. The Wagerup 2021 emission inventory does not provide emission estimates for aluminium from Refinery point sources, noting it is not a reportable substance under the National Pollutant Inventory (NPI) program.
2. The Wagerup 2021 emission inventory does not specify the form of arsenic, chromium VI, and nickel (particulate and/or vapour) estimated from Refinery point sources.
3. Refinery point source emission estimates for mercury, as contained in the Wagerup 2021 emission inventory, are assumed to be present in vapour phase (Emission Assessments, 2020 & 2022) (Email Vanessa Allan, Environmental Scientist Wagerup Refinery, 16.10.2023).

5.3 Model Scenarios

The model scenarios that have been included for this air quality assessment are listed below.

Baseline model scenario:	the current emissions status of the Wagerup Refinery at the operating capacity of 2.9 Mtpa of alumina as permitted under the environmental licence.
Proposed model scenario:	to support an application for a Works Approval and/or Licence Amendment to construct and operate the proposed new RSA10. The current emissions status of the Wagerup Refinery at the operating capacity of 2.9 Mtpa of alumina, with the addition of RSA10 following commissioning. Construction impacts for RSA10 are not considered (refer to Section 1.5).

5.4 Refinery Point Sources

Refinery point source emissions information were provided by Alcoa, derived from the ongoing emissions monitoring and verification program implemented at the Refinery over many years of operation. The approach used to define the model inputs for Refinery point sources is consistent with previous assessments, including adopted improvements and recommendations, as follows:

- To account for the highly variable nature of Refinery processes, point source emissions are provided for an 'Average' case used to model a longer-term (annual) averaging period, and a 'Peak' case used to model short-term (1-hour and 24-hour) averaging periods. The assumption of Peak emissions as being constant throughout the year is inherently conservative because there is little actual likelihood a fluctuating emission will actually be at the "Peak" in the same period (1-hour or 24-hours) that the maximum concentration at a receptor is predicted – which is then compared to air quality criteria.
- Sources were modelled as either:
    - Individual stacks (Single) – sufficiently separate from other stacks to be treated independently;
    - Combined stacks (Combined) – group of stacks located nearby with the same (or very similar) release characteristics were modelled as if one stack; and
    - Multi-flue stacks (Multi-flue) – plumes from different flues in the stack combine once emitted to atmosphere, including the 100 m tall multi-flue and the Boiler multi-flue, using the approximation to the variable plume merging scheme, as recommended by Air Assessments (2017). Refer to Appendix A.
    - Cluster of stacks (Combined) – the 45 Precipitation Tanks, comprised of 48 individual open top tanks placed into six rows, were modelled as six discrete point source emissions centres across the tank area.

Refinery point source emissions are defined in terms of physical characteristics (stack location, height and stack-tip diameter), exhaust characteristics (exit velocity and temperature), and pollutant emission rates. For the Refinery point sources considered in the modelling, the stack physical and exhaust characteristics used as input to the modelling are presented in Table 5-2.

The location of the Refinery point sources is shown in Figure 5-1

No change to the permitted alumina production rate of the Refinery is being sought by Alcoa as part of the RSA10 proposal. Therefore, the Refinery point source emission characteristics remain the same for the Baseline and Proposed model scenarios.

Figure 5-1: Location of Refinery point sources

Table 5-2: Characteristics of Refinery Stacks and Vents

Source Name	ID	Grouping	Easting MGA94 (m)	Northing MGA94 (m)	Baseline | 2021 Scaled to 2.9 Mtpa					
					Diam. (m)	Hgt. (m)	Vel. (m/s)		Temp. (K)	
							Ave	Peak	Ave	Peak
Liquor Burning [1]	LB	100m Multi-flue	398,317.94	6,357,200.42	1.81 Ave 1.76 Peak	100	19.7	24.8	399	426
Calciners 1-3 [1]	C13	100m Multi-flue	398,317.94	6,357,200.42	1.91 Ave 1.84 Peak	100	21.5	27.8	447	465
Calciner 4	C4	Single	398,396.03	6,357,099.74	2.35	49	24.1	32.8	422	442
Boilers 1-3 [1]	B13	Boiler Multi-flue	398,760.94	6,357,660.42	2.15 Ave 2.15 Peak	65	18.9	22.7	392	407
Gas Turbine 1	GT1	Single	398,721.94	6,357,543.42	3.05	40	21.2	22.7	415	428
Oxalate Kiln	OX	Single	398,224.93	6,357,607.97	1.00	37	16.8	26.6	375	388
Calciner 1-3 Low Volume Vent [1]	C13VP	100m Multi-flue	398,317.94	6,357,200.42	1.48 Ave 1.544 Peak	100	20.7	26.5	451	469
45K Cooling Towers 2-3	45KT23	Combined	398,642.94	6,357,148.42	7.32	18	13.6	13.6	322	337
45K Cooling Tower 1	45KT1	Single	398,621.79	6,357,145.38	7.25	9	9.4	9.4	333	342
50 Cooling Towers 1-2	50T12	Combined	398,365.00	6,357,195.00	3.00	5	0.4	8.6	324	334
44-1 Main Stack	44_1M	Single	398,701.80	6,357,026.20	1.08	35	3.0	3.6	320	330
44-1 LVV1	44_1L1	Single	398,700.40	6,357,022.40	0.60	28	9.2	11.1	325	329
44-1 LVV2	44_1L2	Single	398,700.50	6,357,021.50	0.60	28	Not modelled [2]			
44-2 Main Stack	44_2M	Single	398,692.60	6,356,961.60	1.10	35	3.9	4.5	331	334
44-2 LVV	44_2L	Single	398,714.80	6,356,959.70	1.08	35	5.3	5.9	304	308
Calciner 4 LVV	C4LVV	Single	398,384.00	6,357,161.30	0.89	42	5.7	5.7	341	341
Calciner 4 Extraction Hoods	C4H	Single	398,388.60	6,357,145.30	0.88	38	2.0	2.0	297	297
48A Tank Exhaust	48A	Single	398,276.50	6,357,160.20	0.30	9	2.0	2.0	348	348
47K1 oxalate filter press building stack	47K1	Single	398,248.76	6,357,605.82	0.84	35	3.4	13.1	325	325
Milling Vent Mill 3	MV3	Single	398,344.05	6,357,977.60	0.45	13	9.0	17.2	341	341
Milling Vents 4-5	MV45	Combined	398,288.00	6,357,995.00	0.45	13	9.0	17.2	341	341
25A-1 Tank Vents (Vents 1-2)	25A-1	Combined	398,280.00	6,357,887.00	0.75	25	0.9	1.0	368	367
25A-2 Tank Vent	25A-2	Single	398,280.13	6,357,863.14	0.50	25	3.9	4.7	363	363
25A-3 Tank Vents (Vents 1-2)	25A-3	Combined	398,256.13	6,357,887.14	0.75	25	6.8	10.8	371	369
25A-4 Tank Vent	25A-4	Single	398,317.13	6,357,863.14	0.55	25	3.3	3.9	365	365
Blow-off (stack 1)	BO1	Single	398,358.00	6,357,829.00	0.73	24	0.7	6.0	374	374
Blow-off (stack 2)	BO2	Single	398,311.00	6,357,833.00	0.73	24	3.0	21.3	374	374
35J-11 Tank Vents (Non cons)	35J_11	Single	398,528.23	6,357,667.92	0.24	10	10.7	18.4	327	333
35J-12 Tank Vents (Non cons)	35J_12	Single	398,518.22	6,357,672.92	0.49	10	2.3	4.0	327	333
35J-13 Tank Vents (Non cons)	35J_13	Single	398,528.23	6,357,677.92	0.42	10	2.6	2.7	365	348
35J-14 Tank Vents (Non cons)	35J_14	Single	398,518.24	6,357,682.93	0.49	10	2.4	2.5	365	348
35J-15 Tank Vents (Non cons)	35J_15	Single	398,528.17	6,357,688.03	0.49	10	Not modelled [2]			
35J-24 Tank Vents (Non cons)	35J_24	Single	398,562.68	6,357,679.44	0.49	10	2.4	2.6	365	348
35J-25 Tank Vents (Non cons)	35J_25	Single	398,578.50	6,357,679.48	0.49	10	Not modelled [2]			
B26 Stacks	B26	Single	398,182.68	6,357,857.69	1.13	27	14.5	31.3	355	355
35A-1 Tank Vent (Non cons)	35A-1	Single	398,549.55	6,357,559.27	0.60	16	1.3	6.6	353	367
35A-1 overflow pipe (during filter press dumps)	35A-11	Single	398,549.55	6,357,559.27	0.40	0.1	0.4	12.3	353	367
Building 45 - 1 precip tanks	45P_1	Combined	398,577	6,357,060	37	28	0.016	0.016	297	297
Building 45 - 2 precip tanks	45P_2	Combined	398,625	6,357,060	39	28	0.016	0.016	303	303
Building 45 - 3 precip tanks	45P_3	Combined	398,625	6,356,995	39	28	0.016	0.016	303	303
Building 45 - 4 precip tanks	45P_4	Combined	398,577	6,356,995	37	28	0.016	0.016	297	297
50 Pan Filter Exhaust Vents	C13EV	Single	398,316.05	6,357,142.25	0.31	20	6.2	6.2	344	344

Notes:

1. Multi-flued sources modelled as effective (not physical) release characteristics, indicated as shaded cells. Appendix A describes the basis for the multi-flue stack parameters.
2. Not modelled, as not typically a source of emissions.

5.4.1 Emission Summary

A summary of the Refinery point source emission rates for the selected pollutants, as derived by Alcoa from the ongoing emissions monitoring and verification program, is presented in Table 5-3 and Table 5-4. A summary of the total Average and Peak case emissions for the selected pollutants is presented in Figure 5-2.

From the emissions information presented in Figure 5-2 it is evident that the Peak emissions are typically at least two to three times higher compared to the Average emissions. In the case of acetone, the Peak emissions are even higher, equivalent to seven times the Average emission, indicative of the higher variability seen in VOC emissions generally.

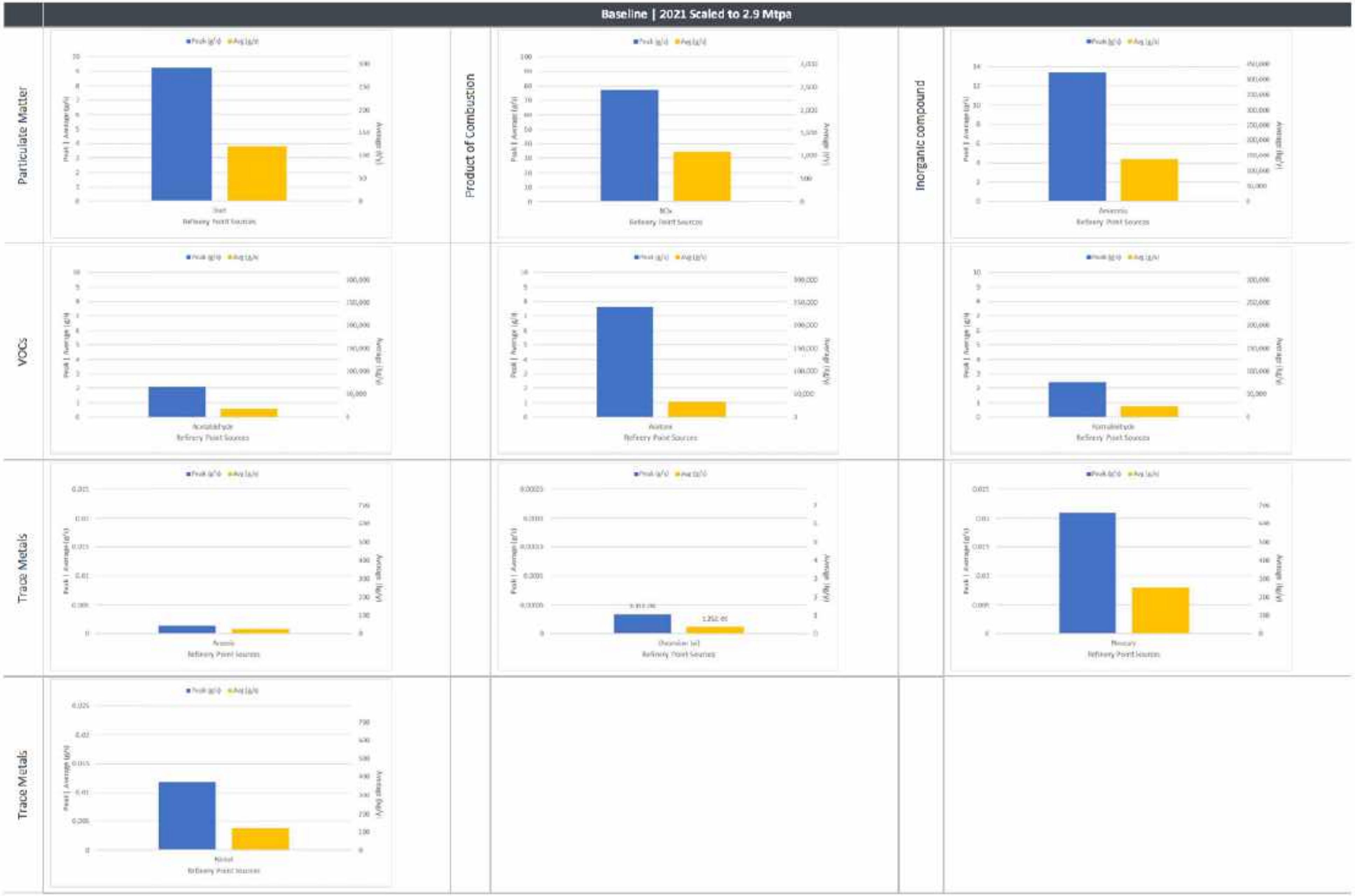


Figure 5-2: Refinery point sources emission estimates

Table 5-3: Refinery stacks and vent emission estimates (g/s) – Particulates, NOx, ammonia and VOCs

Source Name	ID	Baseline | 2021 Scaled to 2.9 Mtpa											
		Particulates		NOx		Ammonia		Acetaldehyde		Acetone		Formaldehyde	
		Ave	Peak	Ave	Peak	Ave	Peak	Ave	Peak	Ave	Peak	Ave	Peak
Liquor Burning	LB	2.77E-02	1.18E-01	2.01	5.17	7.51E-03	2.12E-02	2.15E-03	3.79E-02	1.06E-02	4.19E-01	2.30E-03	2.40E-02
Calciners 1-3	C13	2.32E+00	5.02E+00	6.80	20.39	1.76E-01	3.81E-01	2.08E-01	8.55E-01	1.07E-01	7.48E-01	2.39E-01	1.16E+00
Calciner 4	C4	1.24E+00	3.12E+00	4.70	10.68	9.92E-02	2.10E-01	1.10E-01	2.65E-01	6.98E-02	4.35E-01	1.67E-01	5.54E-01
Boilers 1-3	B13	-	-	18.21	29.93	2.38E-01	3.05E-01	1.45E-02	2.57E-02	6.52E-02	1.37E-01	1.45E-02	2.62E-02
Gas Turbine 1	GT1	-	-	2.88	10.41	1.66E-03	2.93E-03	5.39E-03	7.10E-03	3.98E-02	1.42E-01	2.48E-02	8.71E-02
Oxalate Kiln	OX	1.64E-02	2.53E-01	0.33	0.77	2.22E-03	4.79E-03	-	-	2.46E-03	2.13E-02	3.68E-04	7.99E-04
Calciner 1-3 Low Volume Vent	C13VP	-	-	4.79E-04	1.63E-03	-	-	2.14E-03	9.76E-03	1.91E-02	3.02E-01	-	-
45K Cooling Towers 2-3	45KT23	-	-	-	-	3.37E-01	3.31E-01	-	-	2.70E-02	2.49E+00	2.15E-01	4.13E-01
45K Cooling Tower 1	45KT1	-	-	-	-	1.10E-01	1.11E-01	-	-	8.03E-03	7.68E-01	6.39E-02	1.27E-01
50 Cooling Towers 1-2	50T12	-	-	-	-	1.72E-03	3.53E-02	-	-	1.36E-04	2.76E-01	1.08E-03	4.57E-02
44-1 Main Stack	44_1M	3.97E-02	5.46E-02	-	-	4.69E-02	5.24E-02	1.55E-03	3.28E-03	1.44E-02	3.28E-02	1.20E-04	1.53E-04
44-1 LVV1	44_1L1	1.60E-02	2.06E-02	-	-	3.10E-02	3.57E-02	4.20E-04	8.40E-04	2.87E-03	4.83E-03	1.00E-04	1.37E-04
44-1 LVV2	44_1L2	-	-	-	-	-	-	-	-	-	-	-	-
44-2 Main Stack	44_2M	1.41E-01	1.60E-01	-	-	1.05E-01	1.27E-01	2.25E-03	5.23E-03	3.37E-02	7.15E-02	1.34E-04	1.65E-04
44-2 LVV	44_2L	7.24E-04	8.23E-04	-	-	1.65E-02	1.82E-02	3.18E-04	7.57E-04	2.13E-03	3.56E-03	1.95E-04	2.23E-04
Calciner 4 LVV	C4LVV	-	-	-	-	-	-	7.04E-03	7.37E-03	5.42E-02	5.85E-02	1.08E-04	1.08E-04
Calciner 4 Extraction Hoods	C4H	-	-	-	-	-	-	5.83E-05	5.83E-05	2.39E-03	2.57E-03	5.83E-05	5.83E-05
48A Tank Exhaust	48A	-	-	-	-	-	-	9.33E-05	9.33E-05	1.00E-03	1.07E-03	3.33E-06	3.33E-06
47K1 oxalate filter press building stack	47K1	-	-	-	-	5.26E-02	2.06E-01	7.57E-05	3.06E-04	3.93E-04	1.58E-03	7.57E-05	3.06E-04
Milling Vent Mill 3	MV3	7.67E-03	1.72E-01	-	-	5.98E-02	1.43E-01	1.02E-02	3.09E-02	2.59E-02	9.66E-02	-	-
Milling Vents 4-5	MV45	1.53E-02	3.44E-01	-	-	1.20E-01	2.86E-01	2.05E-02	6.18E-02	5.19E-02	1.93E-01	-	-
25A-1 Tank Vents (Vents 1-2)	25A-1	-	-	-	-	4.59E-01	1.13E+00	1.07E-02	1.89E-02	9.01E-02	1.33E-01	-	-
25A-2 Tank Vent	25A-2	-	-	-	-	4.59E-01	1.13E+00	1.07E-02	1.89E-02	9.01E-02	1.33E-01	-	-
25A-3 Tank Vents (Vents 1-2)	25A-3	-	-	-	-	1.03E+00	5.43E+00	1.04E-01	5.43E-01	1.47E-01	5.93E-01	-	-
25A-4 Tank Vent	25A-4	-	-	-	-	4.59E-01	1.13E+00	1.07E-02	1.89E-02	9.01E-02	1.33E-01	-	-
Blow-off (stack 1)	BO1	-	-	-	-	1.35E-02	1.08E-01	2.31E-05	2.98E-04	1.79E-04	1.49E-03	3.61E-05	2.98E-04
Blow-off (stack 2)	BO2	-	-	-	-	1.35E-02	1.08E-01	2.31E-05	2.98E-04	1.79E-04	1.49E-03	3.61E-05	2.98E-04
35J-11 Tank Vents (Non cons)	35J_11	5.98E-05	1.66E-03	-	-	1.23E-02	3.27E-02	3.33E-03	8.87E-03	1.24E-02	5.45E-02	9.36E-05	4.99E-04
35J-12 Tank Vents (Non cons)	35J_12	5.41E-05	1.51E-03	-	-	1.11E-02	2.96E-02	3.01E-03	8.03E-03	1.13E-02	4.93E-02	8.47E-05	4.52E-04
35J-13 Tank Vents (Non cons)	35J_13	1.55E-05	4.99E-04	-	-	1.22E-02	2.33E-02	1.68E-03	6.79E-03	3.69E-03	1.41E-02	2.87E-05	1.11E-04
35J-14 Tank Vents (Non cons)	35J_14	1.99E-05	6.41E-04	-	-	1.57E-02	2.99E-02	2.16E-03	8.71E-03	4.73E-03	1.80E-02	3.68E-05	1.43E-04
35J-15 Tank Vents (Non cons)	35J_15	-	-	-	-	-	-	-	-	-	-	-	-
35J-24 Tank Vents (Non cons)	35J_24	2.01E-05	6.48E-04	-	-	1.59E-02	3.03E-02	2.18E-03	8.82E-03	4.79E-03	1.83E-02	3.73E-05	1.45E-04

Source Name	ID	Baseline | 2021 Scaled to 2.9 Mtpa											
		Particulates		**NOx**		**Ammonia**		**Acetaldehyde**		**Acetone**		**Formaldehyde**	
		Ave	**Peak**	**Ave**	**Peak**	**Ave**	**Peak**	**Ave**	**Peak**	**Ave**	**Peak**	**Ave**	**Peak**
35J-25 Tank Vents (Non cons)	35J_25	-	-	-	-	-	-	-	-	-	-	-	-
B26 Stacks	B26	-	-	-	-	4.13E-01	1.44E+00	1.15E-02	4.34E-02	2.13E-02	8.51E-02	5.19E-04	3.36E-03
35A-1 Tank Vent (Non cons)	35A-1	-	-	-	-	4.24E-02	2.48E-01	3.41E-03	1.75E-02	1.63E-02	6.00E-02	-	-
35A-1 overflow pipe (during filter press dumps)	35A-11	-	-	-	-	6.44E-03	2.06E-01	5.17E-04	1.45E-02	2.47E-03	4.99E-02	-	-
Building 45 - 1 precip tanks	45P_1	-	-	-	-	-	-	-	-	9.77E-04	1.31E-03	-	-
Building 45 - 2 precip tanks	45P_2	-	-	-	-	-	-	-	-	9.77E-04	1.31E-03	-	-
Building 45 - 3 precip tanks	45P_3	-	-	-	-	-	-	-	-	9.77E-04	1.31E-03	-	-
Building 45 - 4 precip tanks	45P_4	-	-	-	-	-	-	-	-	9.77E-04	1.31E-03	-	-
50 Pan Filter Exhaust Vents	C13EV	-	-	-	-	-	-	9.98E-03	1.74E-02	3.71E-02	6.65E-02	-	-
Total (g/s)		**3.82**	**9.27**	**34.93**	**77.35**	**4.37**	**13.35**	**0.558**	**2.05**	**1.07**	**7.62**	**0.729**	**2.44**

Table 5-4: Refinery stacks and vent emission estimates (g/s) – Trace metals

Source Name	ID	Baseline | 2021 Scaled to 2.9 Mtpa [1]							
		Arsenic		Chromium VI		Mercury		Nickel	
		Ave	Peak	Ave	Peak	Ave	Peak	Ave	Peak
Liquor Burning	LB	3.34E-04	5.99E-04	2.43E-07	4.94E-07	4.76E-04	4.76E-04	4.38E-05	7.98E-05
Calciners 1-3	C13	8.46E-05	1.41E-04	1.82E-06	4.31E-06	3.06E-03	1.13E-02	1.78E-03	4.76E-03
Calciner 4	C4	2.44E-05	2.08E-05	4.97E-07	4.17E-07	1.73E-03	6.23E-03	2.48E-04	2.08E-04
Boilers 1-3	B13	8.53E-05	1.61E-04	4.32E-06	1.27E-05	1.32E-03	1.27E-03	4.33E-04	1.35E-03
Gas Turbine 1	GT1	5.30E-05	1.37E-04	4.17E-06	1.42E-05	-	-	1.05E-03	4.95E-03
Oxalate Kiln	OX	1.03E-04	3.61E-04	3.42E-08	6.67E-08	3.17E-04	3.17E-04	1.08E-05	1.26E-05
Calciner 1-3 Low Volume Vent	C13VP	-	-	-	-	-	-	-	-
45K Cooling Towers 2-3	45KT23	2.81E-07	4.14E-07	-	-	-	-	1.74E-09	3.89E-09
45K Cooling Tower 1	45KT1	8.37E-08	1.28E-07	-	-	-	-	5.19E-10	1.20E-09
50 Cooling Towers 1-2	50T12	1.42E-09	4.58E-08	-	-	-	-	8.79E-12	4.31E-10
44-1 Main Stack	44_1M	2.75E-06	2.78E-06	1.13E-08	1.14E-08	-	-	1.25E-05	1.39E-05
44-1 LVV1	44_1L1	8.47E-07	1.17E-06	1.15E-08	1.19E-08	-	-	5.28E-06	5.56E-06
44-1 LVV2	44_1L2	-	-	-	-	-	-	-	-
44-2 Main Stack	44_2M	9.72E-06	1.08E-05	1.47E-08	1.61E-08	-	-	6.81E-06	7.50E-06
44-2 LVV	44_2L	1.94E-05	2.00E-05	1.88E-08	1.89E-08	-	-	8.54E-06	8.61E-06
Calciner 4 LVV	C4LVV	-	-	-	-	3.98E-08	3.98E-08	-	-
Calciner 4 Extraction Hoods	C4H	-	-	-	-	-	-	-	-
48A Tank Exhaust	48A	-	-	-	-	-	-	-	-
47K1 oxalate filter press building stack	47K1	-	-	-	-	-	-	-	-
Milling Vent Mill 3	MV3	4.10E-06	7.23E-06	-	-	1.06E-04	1.83E-04	7.63E-06	1.78E-05
Milling Vents 4-5	MV45	8.20E-06	1.45E-05	-	-	2.11E-04	2.54E-04	1.53E-05	3.55E-05
25A-1 Tank Vents (Vents 1-2)	25A-1	2.63E-06	1.33E-06	-	-	3.02E-05	3.02E-05	1.46E-05	9.33E-06
25A-2 Tank Vent	25A-2	2.63E-06	1.33E-06	-	-	3.02E-05	3.02E-05	1.46E-05	9.33E-06
25A-3 Tank Vents (Vents 1-2)	25A-3	5.93E-06	6.41E-06	-	-	6.80E-05	6.80E-05	3.29E-05	4.48E-05
25A-4 Tank Vent	25A-4	2.63E-06	1.33E-06	-	-	3.02E-05	3.02E-05	1.46E-05	9.33E-06
Blow-off (stack 1)	BO1	2.85E-06	2.92E-06	6.36E-07	8.33E-07	-	-	1.38E-05	2.92E-05
Blow-off (stack 2)	BO2	2.85E-06	2.92E-06	6.36E-07	8.33E-07	-	-	1.38E-05	2.92E-05
35J-11 Tank Vents (Non cons)	35J_11	2.23E-06	2.48E-06	-	-	2.24E-04	2.24E-04	2.43E-05	4.67E-05
35J-12 Tank Vents (Non cons)	35J_12	2.02E-06	2.24E-06	-	-	2.03E-04	2.03E-04	2.20E-05	4.23E-05
35J-13 Tank Vents (Non cons)	35J_13	5.78E-07	7.43E-07	-	-	5.80E-05	5.80E-05	6.29E-06	1.40E-05
35J-14 Tank Vents (Non cons)	35J_14	5.78E-07	7.43E-07	-	-	7.44E-05	7.44E-05	6.29E-06	1.40E-05
35J-15 Tank Vents (Non cons)	35J_15	-	-	-	-	-	-	-	-
35J-24 Tank Vents (Non cons)	35J_24	7.52E-07	9.65E-07	-	-	7.53E-05	7.53E-05	8.17E-06	1.82E-05
35J-25 Tank Vents (Non cons)	35J_25	-	-	-	-	-	-	-	-
B26 Stacks	B26	1.37E-06	1.39E-06	4.86E-08	6.67E-08	-	-	2.85E-05	1.39E-05
35A-1 Tank Vent (Non cons)	35A-1	-	-	-	-	-	-	-	-
35A-1 overflow pipe (during filter press dumps)	35A-11	-	-	-	-	-	-	-	-
Building 45 - 1 precip tanks	45P_0 to 45P_5	-	-	-	-	-	-	-	-
Building 45 - 2 precip tanks	45P_0 to 45P_5	-	-	-	-	-	-	-	-
Building 45 - 3 precip tanks	45P_0 to 45P_5	-	-	-	-	-	-	-	-
Building 45 - 4 precip tanks	45P_0 to 45P_5	-	-	-	-	-	-	-	-
50 Pan Filter Exhaust Vents	C13EV	-	-	-	-	-	-	-	-
Total (g/s)		**7.56E-04**	**1.50E-03**	**1.25E-05**	**3.41E-05**	**8.01E-03**	**2.09E-02**	**3.83E-03**	**1.17E-02**

Notes:

1. Since the metals emissions in the Refinery inventory were not differentiated between gaseous and particulate form, for conservativism of concentration predictions, the metal emissions were modelled as gases passively dispersing.

5.5 Fugitive Sources

The location of the Refinery fugitive sources is shown in Figure 5-3.

Figure 5-3: Locations of current fugitive sources

Notes:

Fugitive PM emissions, including the collection of RSAs and the Bauxite Stockpiles, shown in blue, and bounded by a blue line.

Fugitive VOCs sources shown in green.

5.5.1 Fugitive Particulate Sources

This section is a summary of a more detailed description provided in ETA (2022e).

5.5.1.1 Estimation method

There are four general classifications of emissions depending on the source and PM emission mechanism, as shown in Table 5-5

Table 5-5: Mechanisms underlying PM emission rates from fugitive sources areas

Source	"Wind erosion" sources	"Activity" sources Dust emissions from entrainment from open transfers or ejection of materials, into the air
Residue Area	RSA cells ("dry" areas), unstable surfaces	Dry sand handling, materials handling for RSA cell embankment construction, other earthworks, wheel-generated
Bauxite stockpile	stockpiles, unstable surfaces	bulk bauxite handling, wheel-generated

For wind erosion sources, varying 1-hour PM emissions rates were estimated using empirical equations based on wind speed (10m height) as measured at the RSA5 anemometer, and soil wetness estimated from accumulated rainfall and evaporation. The empirical equation was validated using the continuous ambient PM monitoring data.

For activity sources, varying 1-hour PM emissions rates were estimated using NPI-based factors, differentiating between day-time operations, and night-time operations when activity and hence emissions are much lower.

5.5.1.2 Trace metal content

The metal composition of fugitive dust emissions from the Residue Area was determined from the analysis of HVAS samples collected at the RSA5 monitoring site for the PM_{10} size fraction. The HVAS was operated to continuously sample over consecutive six-day periods[15], over the duration of the 12-month monitoring program. The PM_{10} samples were collected on Polyvinyl Chloride (PVC) filter media. Further details of the sampling and analysis program is available in the Ecotech (2022) report. Further details of the examination of the metal composition analysis data for fugitive dust from the Residue Area is available in the ETA (2022b) report.

The average metal content present in the PM_{10} fraction of Residue Area dust was derived from all results above the Practical Quantitation Limit (PQL) and used as the basis for characterising exposure concentrations of trace metals present in residue dust. The metal content of dust from the bauxite stockpiles was sourced from previously available data, as referenced in Alcoa (2020a) and Air Assessments (2008) (for Aluminium).

The metal content of fugitive PM emissions from the Residue Area and bauxite stockpiles adopted for use in this study are presented in Table 5-6.

---

[15] The HVAS were initially operated to continuously sample over consecutive seven-day periods, however this was reduced to six days to overcome issues with the filters clogging due to higher-than-expected dust loading.

Table 5-6: Adopted metal content of fugitive PM emissions

Metal Species	Residue Area [1]	Bauxite stockpile [2]
	mg/kg	
Aluminium	32,349	205,556 [3]
Arsenic	22	1
Chromium (VI)	17.3	-
Mercury	3.5	0.09
Nickel	22	2.4

Notes:

1. Sourced from ETA (2022b).
2. Referenced in Alcoa (2020a), except as noted for Aluminium.
3. Referenced in Air Assessments (2008).

5.5.1.3 Emission estimation for RSA10 proposal

For modelling, it has been assumed that the annual fugitive emissions associated with the addition of the RSA10 cell are simply the addition of RSA10 to the current/baseline RSA cells. Since PM emissions are based on area, with the current area of PM emissions in the Residue Area being 413 ha (see blue outline of the area considered as "RSAs" in Figure 5-3), and the area of the proposed RSA10 being 48.6 ha, the PM emissions from the expanded Residue Area are increased by 48.6/413 = 11.8%.

The factors that affect fugitive emissions over the short-to-long term are extremely complex. The underlying rationale for dealing with the importance attached to the various issues of complexity, is described here.

Emissions changes arising from the addition of RSA10 can be loosely considered as "short term" – that is, changes over successive hours or days, or, "long-term" - that is, changes over years or more.

The focus on emissions estimation effort generally, has tended towards the short-term impacts, because the relative variability over successive short-term periods is much higher than the relative variability over successive long-term periods.

The variability over successive short-term periods can easily be an order of magnitude – for example, the PM emission during a rainfall period with light winds can be virtually zero, with no possibility at all that air quality criteria could be exceeded. The PM emission for a dry period with strong winds can be high enough to potentially cause an exceedance of (short-term) air quality criteria. The level of potential emissions variability is increased further still, if control systems (such as sprinklers) need to be relied upon to mitigate even higher emissions in extreme circumstances - infrequent as they are.

Emissions variability over successive long-term periods are, however - all other things being equal, much more stable, due to the "law of large numbers" – that is, the average of successive variable short-term events tends towards a constant value as the number of events considered increases. An annual average emission can be considered to be the average of 8760 successive hours of emissions.

An issue that may affect the long-term fugitive emissions averages from the Residue Area is that the total area available for residue drying changes, as illustrated in Figure 5-4 below.

If areas previously used for drying are fully stabilised for emissions purposes, it is arguable (other things being equal) that the emission of substances arising from this component of the operations (e.g. PM from wind erosion) would vary cyclically in the same relative terms. This would imply a variability around the long-term average emission of up to 28% higher to 17% lower.

As described above, for modelling, it has been assumed that the emissions associated with the addition of the RSA10 cell are simply a 11.8% addition to current/baseline emissions elsewhere within the Residue Area (assumed to correspond to the optimal drying area).

All other things being equal, this will over-state "the average of the long-term average" impacts. This prediction is not, however, the objective of the modelling.

The DWER's Air Quality Modelling Guidance Notes (2006) make it clear that, if a proposal has the potential for an emission magnitude over the time of any air quality criterion, then that emission magnitude has to be considered against the relevant criterion.

The time periods in Figure 5-4 where drying areas are above the average can last more than a year, which is the longest air quality criteria averaging time. For environmental impact assessment purposes, it is necessary to predict the highest potential impacts over any single year of the proposal's life-time. This is different to predicting the average impact over the proposal's lifetime.

This is similar to the logic used for the refinery point source emission impacts for which a maximum short-term emission is used for assessment against short-term air quality criteria.

The difference between the 2021 baseline year and the maximum shown in Figure 5-3 is 27% – 2% = 25%. Therefore the 11.8% assumption inherent in the modelling is less than the potential highest emission year as indicated by the historical record.

It should also be noted that the simplified modelling assumption that the emissions associated with the addition of the RSA10 cell are an addition to current/baseline emissions elsewhere within the Residue Area, incorporates numerous other uncertainties – for example, that the increase in emissions from within the RSA10 cell from vehicle and materials movements is linear (despite, for example, longer distances from water stand-points), and spatially and temporally uniform throughout the life-time of the cell (despite changes in PM emissions that would arise through the construction cycle of the embankment cell wall).

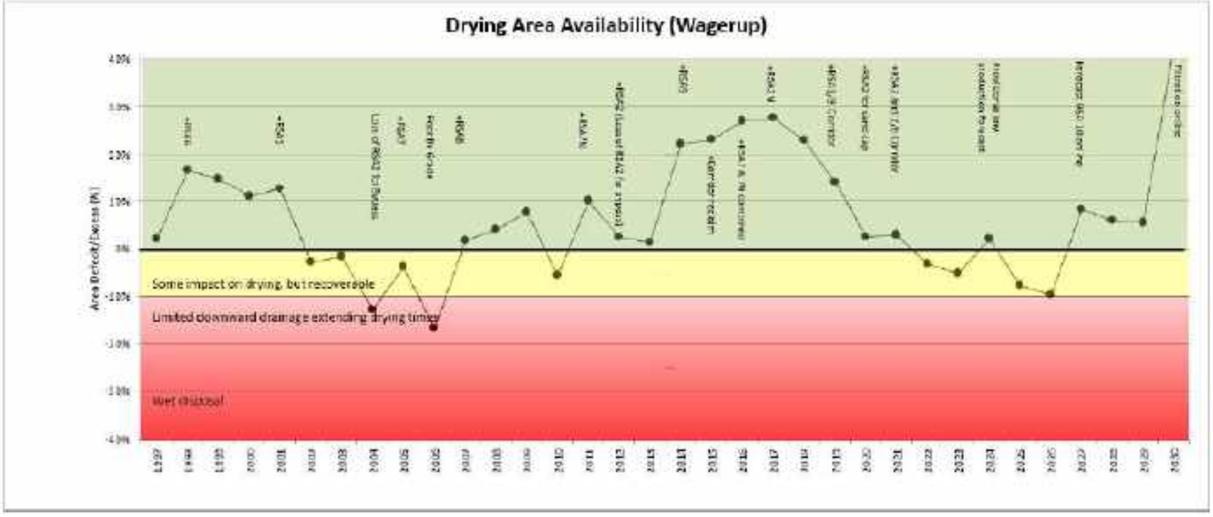


Figure 5-4: Wagerup residue drying area history[16]

5.5.1.4 Emission Summary

A summary of the fugitive particulate emission rates, inclusive of the Residue Area and bauxite stockpiles, for particulates (TSP, PM_{10} and $PM_{2.5}$) and trace metals (PM_{10} fraction) derived for the Baseline model scenario, and for RSA10 (incremental increase) are presented in Figure 5-5.

From the emissions information presented in Figure 5-5, it is evident that RSA10 is estimated to increase particulate and trace metal emissions by approximately 10%. The notable exception is aluminium, with only a 4% increase in fugitive emissions estimated with the addition of RSA10, due to the relatively lower aluminium content of residue dust (32,350 mg/kg) compared to bauxite stockpiles (205,556 mg/kg) (refer to Section 5.5.1.2).

Compared on an annual basis, particulate emissions from fugitive sources, inclusive of the Residue Area and bauxite stockpiles, are noticeably higher than estimated for Refinery point source emissions (Average case) (refer to Section 5.4.1) taking into account the available information regarding particle sizing (refer to Section 4.6). Regarding trace metal emissions, for some metal species the Refinery point source emissions (Average case) are estimated to be higher (As, Ni and Hg), whilst for other metal species the fugitive source emissions are estimated to be higher (Cr VI). It is noted that aluminium is not included in the Wagerup 2021 emission inventory for Refinery point source emissions, therefore it is not possible to undertake such comparison for this metal species.

---

[16] Source: Email Joel Batten, Senior Environmental Scientist, 12.12.2023. Analysis of the data presented in Figure **5-4** is based on estimates only of Area Deficit/Excess (%) shown.

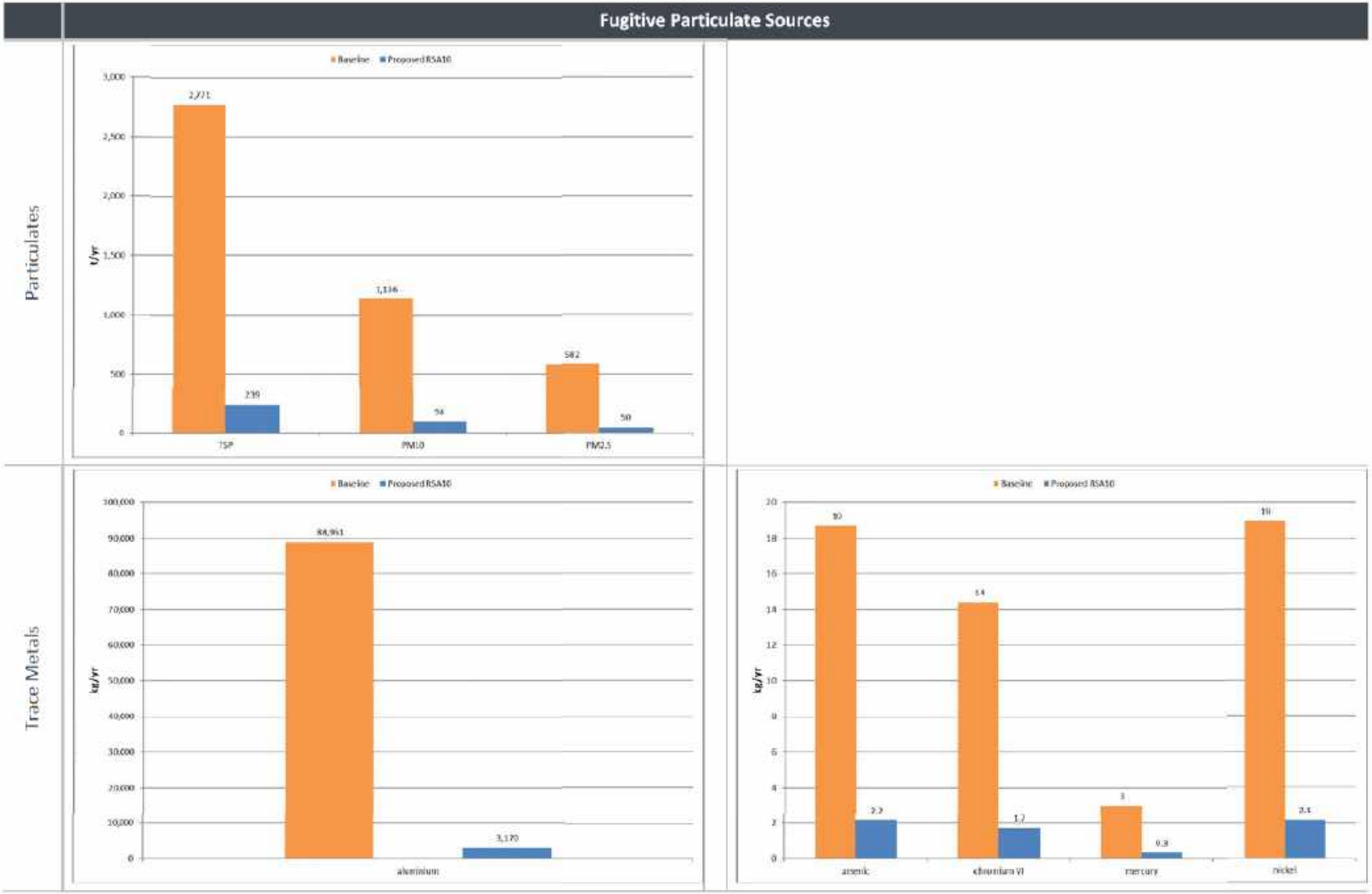


Figure 5-5: Fugitive dust sources emission estimates

5.5.2 Fugitive Vapour Sources

This section is a summary of a more detailed description provided in ETA (2022e).

The location of the fugitive vapour sources is shown in Figure 5-3.

5.5.2.1 Estimation method

Fugitive VOCs emissions have been estimated generally according to the previous methods described in Air Assessments (2015), with the addition of ammonia derived from the OP-FTIR monitoring program (ETA, 2023c).

A summary of the Residue Area sources and VOC species for which emissions were considered is shown in Table 5-7.

Table 5-7: Summary of Residue Area sources and VOC species considered for air quality assessment

Source / VOC species		Acetone	Acetaldehyde	Formaldehyde
Lower Dam (Ldam)		✓	✓	
Runoff Catchment Ponds Liquor (ROCP)		✓	✓	✓
RSA2 (South) for Liquor (rda2s)		✓	✓	✓
RSA2 (North) for Wet Residue (rda2n)		✓	✓	✓
Super Thickener (SupT)		✓	✓	✓
Cooling Pond (CooP)		✓	✓	✓
Oxalate Ponds (OxP)		✓	✓	✓
ROWS Ponds (Rows)		✓	✓	✓
Wet Residue Sand (Wsand)		✓	✓	✓
Residue Storage Areas (RSAs)	Wet residue - up to several days after pouring	✓	✓	✓
	Dry residue 1 - for the period following this	✓	✓	✓
	Dry residue 2 - towards the end of the drying cycle	✓	✓	✓

Notes:

Benzo-a-Pyrene (BaP), 2-Butanone[17], benzene, toluene and xylenes were also modelled but not considered for the RSA10 air quality assessment.

Emissions from the RSAs were also modified according to season, because the relative fraction of each RSA in the "wet", "partially dry" and "dry" states, is affected by the amount of rainfall and drying conditions.

---

[17] 2-Butanone is also known as Methyl Ethyl Ketone (MEK).

Emissions from the open liquid surface sources (i.e. all fugitive sources other than the RSAs) were considered to have a wind speed dependency (because the transfer rate of a dissolved gas in a liquid depends on the gas partial pressure in the immediately overlying air), hence the 1-hourly emission rates derived from isolation flux hood sampling, were increased in proportion to the prevailing wind speed.

5.5.2.2 Emission Summary

A summary of the fugitive vapour emission rates for the selected pollutants derived for the Baseline model scenario, and for RSA10 (incremental increase) is presented in Figure 5-6.

From the emissions information presented in Figure 5-6 it is evident that RSA10 is estimated to increase emissions of VOCs by no more than 5%, and to increase mercury (vapour) emissions by 11%. The difference is because VOCs are emitted from sources other than RSAs (e.g. Superthickener, Cooling Pond) therefore the proportional increase with the addition of RSA10 is less, while mercury (vapour) is (assumed to be) emitted only from RSAs therefore its emission will increase as a proportion of the spatial extent of RSAs. RSA10 is not expected to contribute to ammonia emissions from the Residue Area, as the existing RSAs have not been identified as an ammonia emission source (refer to ETA 2022c).

Compared on an annual basis, the emissions of acetaldehyde, acetone and formaldehyde from Refinery point source emissions (Average case) (refer to Section 5.4.1) are noticeably higher than estimated for the Residue Area fugitive sources (Figure 5-6). Conversely, ammonia emissions are estimated to be higher from the Residue Area fugitive sources than from Refinery point source emissions (Average case).

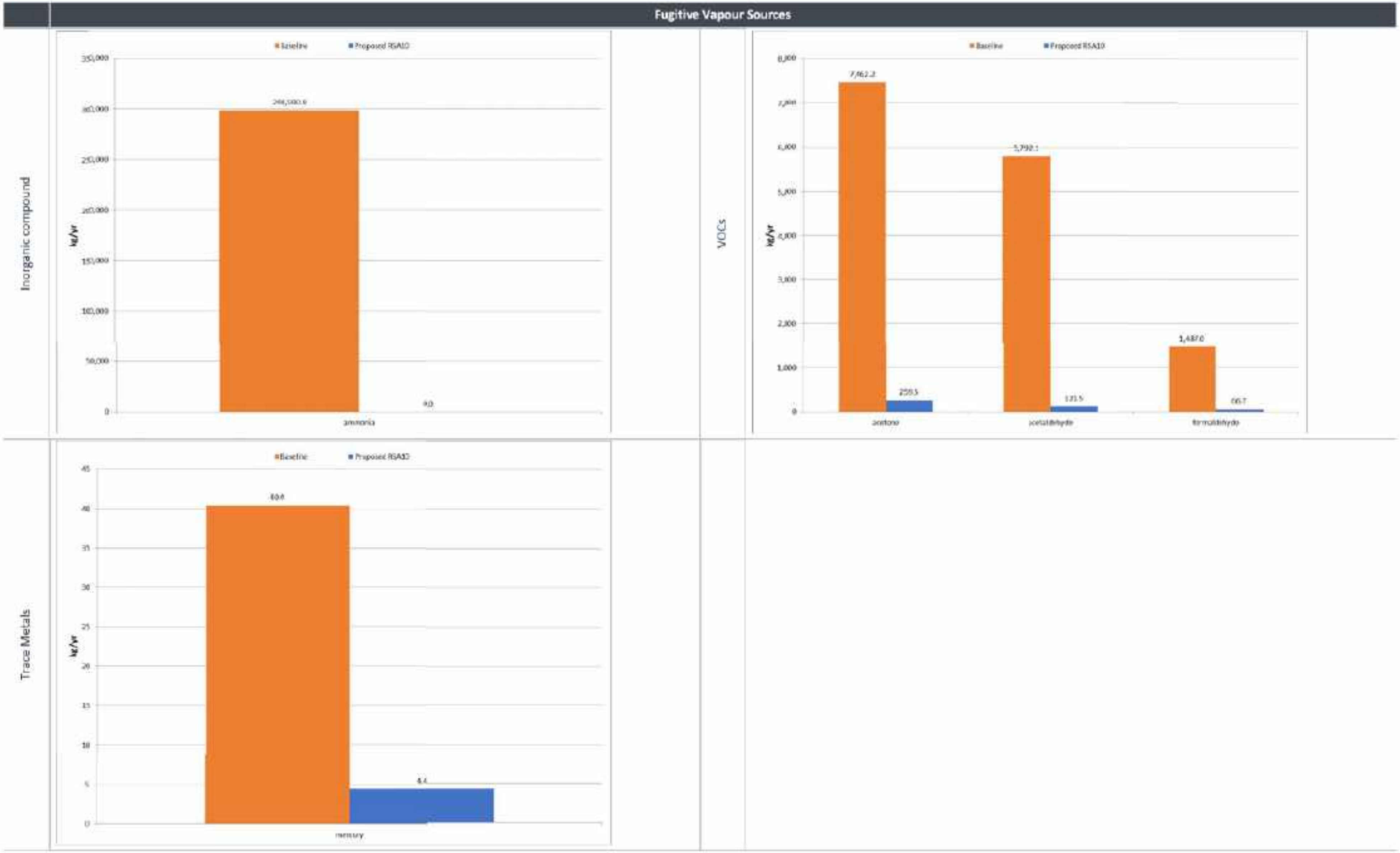


Figure 5-6: Fugitive vapour sources emission estimates

5.5.3 RSA10 Emission Contribution

Considered on an annual basis (kg/y), the RSA10 proposal is estimated to result in relatively minor increases in total Wagerup Refinery emissions of particulate matter (as TSP, PM_{10} and $PM_{2.5}$), VOCs and trace metals, as presented in Table 5-8. There is no change in NOx and ammonia emissions, as the existing RSAs, as well as the new RSA10, are not identified as a source of these pollutants. Chromium VI emissions exhibit the highest percentage increase (11.6%), with the RSAs the principal emission source.

Table 5-8: Summary of Annual Emission Estimates – Baseline and Proposed Model Scenarios

Pollutant	Baseline (kg/y)			Proposed (kg/y)[2]		Increase (%)
	Refinery Point Sources[1]	Fugitive Sources	Total	RSA10	Total	
TSP	120,511[3]	2,770,762	2,891,273	239,013	3,130,286	8.3
PM_{10}	120,511[3]	1,136,012	1,256,524	97,995	1,354,519	7.8
$PM_{2.5}$	40,733[3]	581,860	622,593	50,193	672,785	8.1
NOx	1,101,468	-	1,101,468	-	1,101,468	-
Ammonia	137,848	298,591	436,439	-	436,439	-
Acetaldehyde	17,590	5,792	23,382	121	23,504	0.5
Acetone	33,848	7,462	41,311	260	41,570	0.6
Formaldehyde	22,987	1,487	24,475	67	24,541	0.3
Aluminium	-	88,951	88,951	3,213	92,164	3.6
Arsenic	24	19	43	2.2	45	5.1
Chromium VI	0.4	14	15	1.7	17	11.6
Mercury	252	43	296	4.8	301	1.6
Nickel	121	19	140	2.2	142	1.6

Notes:

1. Calculated assuming continuous emissions according to Average Case estimates. No change from Baseline to Proposed model scenarios.
2. Baseline with the addition of RSA10 emissions.
3. The total particulate emissions from all Refinery point sources were assumed to be PM_{10}, with 0.338 of this being $PM_{2.5}$ (refer to Section 4.6).
4. Emissions from stack sampling are reported to two significant figures. Scientific reporting convention is that derived values are reported to a precision such that the last digit of a reported value is the only estimated digit. Therefore, derived values from stack sampling measurements should only be reported to three significant figures. The actual precision in the emission estimates in the above table should not be inferred by the reported significant figures, but rather is provided for traceability of model inputs.
5. Values in table may not add exactly due to rounding in the table from the original spreadsheet.

6 Model Performance Evaluation

The estimated Residue Area emissions for PM, ammonia and a suite of VOCs were modelled for the study period using the WRF-CALMET meteorological dataset (refer to Section 4.2), and the predicted ground-level concentrations compared to the continuous ambient PM monitoring undertaken over the study period, and some limited ambient ammonia and VOCs measurements collected during the OP-FTIR and Method TO-17 monitoring programs, respectively (refer to Section 1.4). The comparison of the predicted and measured concentrations can be used to assess the bounds of uncertainty in predicted air quality impacts from the RSA10 proposal.

This section provides a summary of the more detailed descriptions of model performance evaluation provided for PM and VOCs (ETA, 2023e), and for ammonia (ETA, 2023c).

6.1 Particulate Matter

The evaluation showed the aggregate predictions of TSP and PM_{10} across all monitoring sites were within the "factor-of-two" (0.5 to 2) predicted:measured ratio (i.e. guideline for accepted model performance), with the key average statistics being:

- for TSP across six sites, 0.93 for annual average concentration predictions and 0.59 for maximum 24-hour average predictions; and
- for PM_{10} across two sites, 1.29 for annual average concentration predictions and 0.70 for maximum 24-hour average predictions.

Notwithstanding, the modelling showed under-predicted concentrations to the south of the Residue Area. This appears to be due to small differences in the northerly wind characteristics in the WRF-CALMET dataset compared to observed winds. This issue will not have a material effect on the outcomes of the RSA10 assessment however, as the nearest sensitive receptor to the south of the Residue Area (approximately 2.5 kms away), is much less affected by Residue Area emissions than the nearest residence to the west (Receptor 7, approximately 3 km away).

At the monitoring site most representative of potential increased impacts from the addition of RSA10 emissions (RW), the annual average ratio for predicted:measured PM_{10} concentrations is 1.48 and the maximum 24-hour average ratio is 0.82 (i.e. within the performance guidelines).

The modelling evaluation is inherently conservative because it is not possible to totally eliminate background contributions to the measured PM used for the comparison to model predictions.

6.2 VOCs and Ammonia

In order to provide ambient VOC data for modelling validation, a limited sampling campaign of VOCs was undertaken in accordance with Method TO-17 for the determination of Toxic Organic Compounds in ambient air (USEPA, 1999). The "TO-17" program involved opportunistic "spot" sample collection to coincide with sample collection during the daily morning HVAS filter paper replacements.. The monitoring contractor was requested to take a TO-17 sample at the HVAS site that appeared to be most down-wind of the Residue Area and Refinery at the time of attendance. The methodology and full results of the TO-17 monitoring program are detailed in the study report (Ecotech, 2022a).

When the TO-17 VOCs sample results were paired with commensurate wind direction measurements, it was found that background air concentrations were higher, or at least similar, to those measured within the plume from the Wagerup Refinery sources. This outcome mirrored the conclusion also reached from the CSIRO PTRMS VOCs monitoring program conducted over 2006-07 (CSIRO, 2008 p7). The possible other sources of these VOCs include industrial, domestic, biological, combustion and transport processes and production in the atmosphere from other organic compounds. This meant that modelling predictions of VOCs concentrations arising from the Residue Area emissions could not be meaningfully compared against commensurate sampling results.

It was, however, confirmed, that the modelled/predicted concentrations from the Wagerup Refinery sources at the locations and times of sampling, were lower than the TO-17 Practical Quantitation Limits (PQLs), and much lower than often measured in "background" air at the sampled locations.

A more useful outcome was achieved for ammonia emissions from key Residue Area sources using the sampling data collected during the OP-FTIR program. While not strictly the objective of the OP-FTIR program, the data enabled wind-dependent ammonia emission rate functions to be developed for the Superthickener, Cooling Pond and Lower Dam. The dispersion of these emissions was validated by comparing modelled concentrations against other OP-FTIR measurements further away from these sources (refer to ETA, 2023c).

7 Predicted air quality impact

7.1 Overview

Predicted ground-level concentrations are compared to the adopted ambient air quality assessment criteria, intended to provide an objective evaluation of the potential air quality impact of the Wagerup Refinery upon the local communities. The adopted ambient air quality assessment criteria are presented in Section 3.2.

Modelling results are inherently uncertain, as discussed in Section 4.7, with assumptions generally intended to be biased towards conservativism i.e. over-prediction, rather than under-prediction. The interpretation of modelling results needs to be considered in this context with modelling often described as a one of a number of "tools" used, in the first instance, to assist the management of impacts so that adverse outcomes do not actually occur in practice, and otherwise, to inform the decision-making process.

In the remainder of this Section, the model results are presented for the selected pollutants of interest for the Wagerup Refinery only (in isolation), for the Baseline and Proposed model scenarios. These model scenarios are defined in Section 5.3.

The incremental increase (above Baseline) in the air quality impact of the RSA10 proposal can be determined from the difference in the Baseline and Proposed ground-level concentration predictions.

The maximum predicted 1-hour and 24-hour average ground-level concentrations are compared to the acute (short-term) assessment criteria, and the annual average ground-level concentrations are compared to the chronic (long-term) assessment criteria that have been adopted for the assessment.

For each pollutant, the predicted concentrations are presented:

- As bar charts at the discrete receptors for the Baseline and Proposed model scenarios for each criterion averaging time;
- The results as above, in tabular form, including the predicted concentrations as a percentage of the relevant criterion; and
- As contours of the modelled maximum ground-level concentrations predicted across the model domain, overlain on an aerial of the Wagerup Refinery and surrounds.[18] Contours shown in red represent the adopted assessment criteria.

Information on background air quality in the Wagerup region is presented in Section 2.2, for context only.

---

[18] Contour plots are presented for the averaging periods that correspond to the relevant ambient air quality assessment criteria. Note that for some pollutants the contour plots are presented for selected averaging periods only, to represent the predicted ground-level concentrations that most closely approach the relevant ambient air quality assessment criteria.

7.2 Particulates

7.2.1 PM_{10}

Since RSA10 is in a new location – effectively expanding the Residue Area, the spatial distribution of the overall Residue Area emissions changes. The resulting change in ground-level concentrations across the modelling domain will vary considerably, with, for example, receptors close to the western perimeter of RSA10 having very large increases whilst receptors to the east on the other side of the Residue Area, only having very small increases.

The model results for PM_{10} are displayed in Figure 7-1. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-1, and contours are presented in Section 7.2.3.

To assess the potential air quality impact, modelled PM_{10} concentrations are compared to the following criteria, referenced to the Ambient Air Quality NEPM (NEPC, 2021):

- 24-hour average of 46 µg/m³ DWER (2019)
- annual average of 23 µg/m³ DWER (2019).

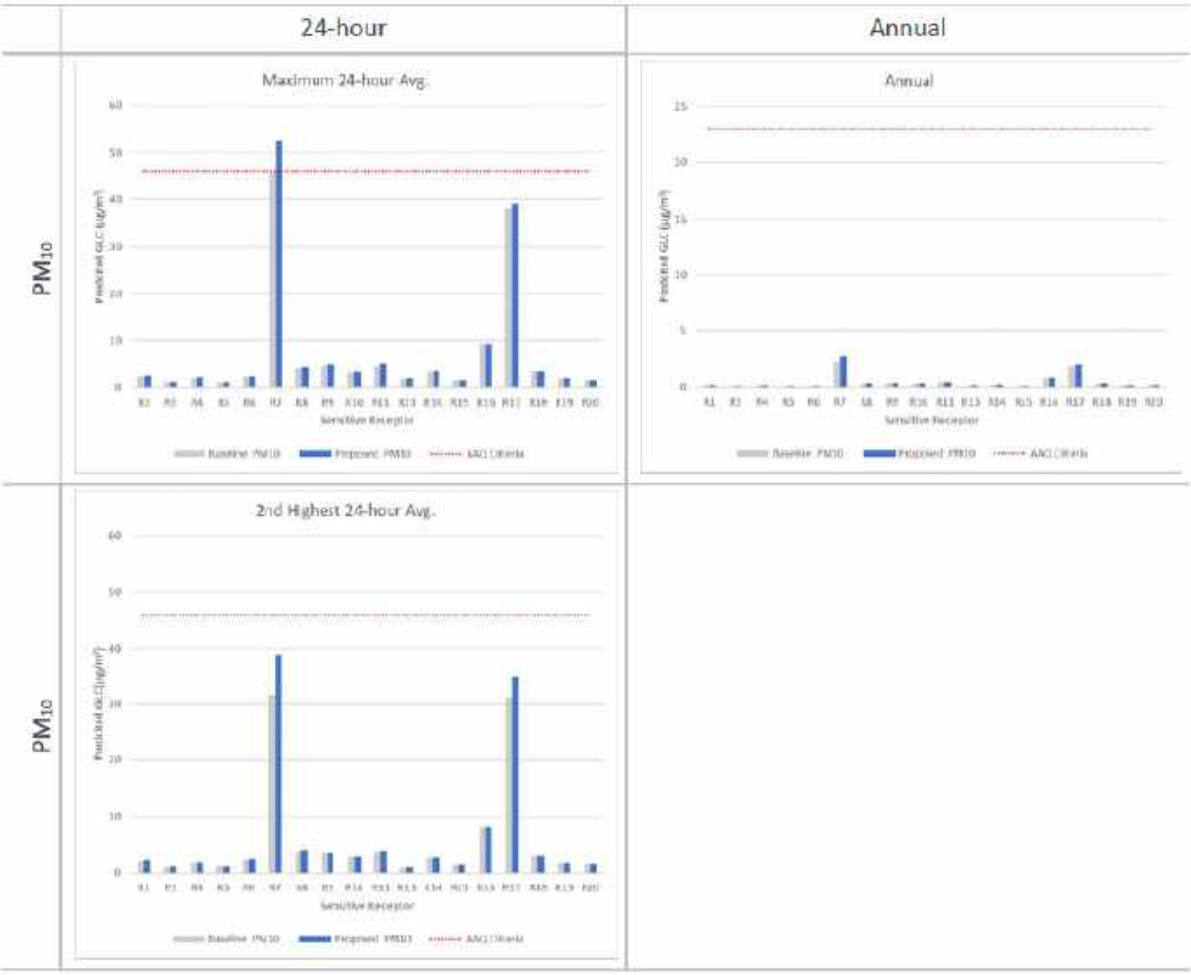


Figure 7-1: Summary of predicted PM_{10} concentrations (µg/m³) – Baseline and Proposed model scenarios

The modelling results for PM_{10} show:

- the maximum 24-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (85% or less), except at Receptor 7.
- the highest impacts are predicted at Receptor 7, which is located to the west of the Residue Area, approximately 3 km away, with:
    - the maximum 24-hour average ground-level concentration **above** the assessment criterion for the Proposed model scenario (114% of criterion);
    - the 2nd highest 24-hour average ground-level concentration **below** the assessment criterion for the Proposed model scenario (85% of criterion); and
    - the maximum and 2nd highest 24-hour average ground-level concentrations **below** the assessment criterion for the Baseline model scenario (99.6% and 68% of criterion, respectively).
- the annual average ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (11% or less).
- the RSA10 proposal results in an incremental increase in the predicted ground-level concentrations at the sensitive receptors, most evident at Receptor 7 and Receptor 17, located to the west of the Residue Area. Otherwise, at the remaining sensitive receptors, the incremental increase is not predicted to be significant considered in the context of the assessment criteria.

The maximum 24-hour concentration at Receptor 7 was predicted to occur on 7.12.2021. A time-series plot of the winds (from WRF-CALMET at RSA5 location) and estimated PM_{10} emissions rates for the day and the time period either side, is shown in Figure 7-2. The wind speeds over 7.12.2021 and 8.12.2021 were exceptionally high, often at around 12 m/s, with the wind direction being also persistent at between approximately 50 and 100° (SE to E). The wind direction on 7.12.2021 was a little more aligned along the bearing from the Residue Area to Receptor 7, giving rise to the highest concentrations being on this day, however PM_{10} concentrations on 8.12.2021 west of the Residue Area would be generally similar. It is worth noting that this single event that occurred within the study period, has ultimately driven the air quality assessment outcomes for the RSA10 proposal.

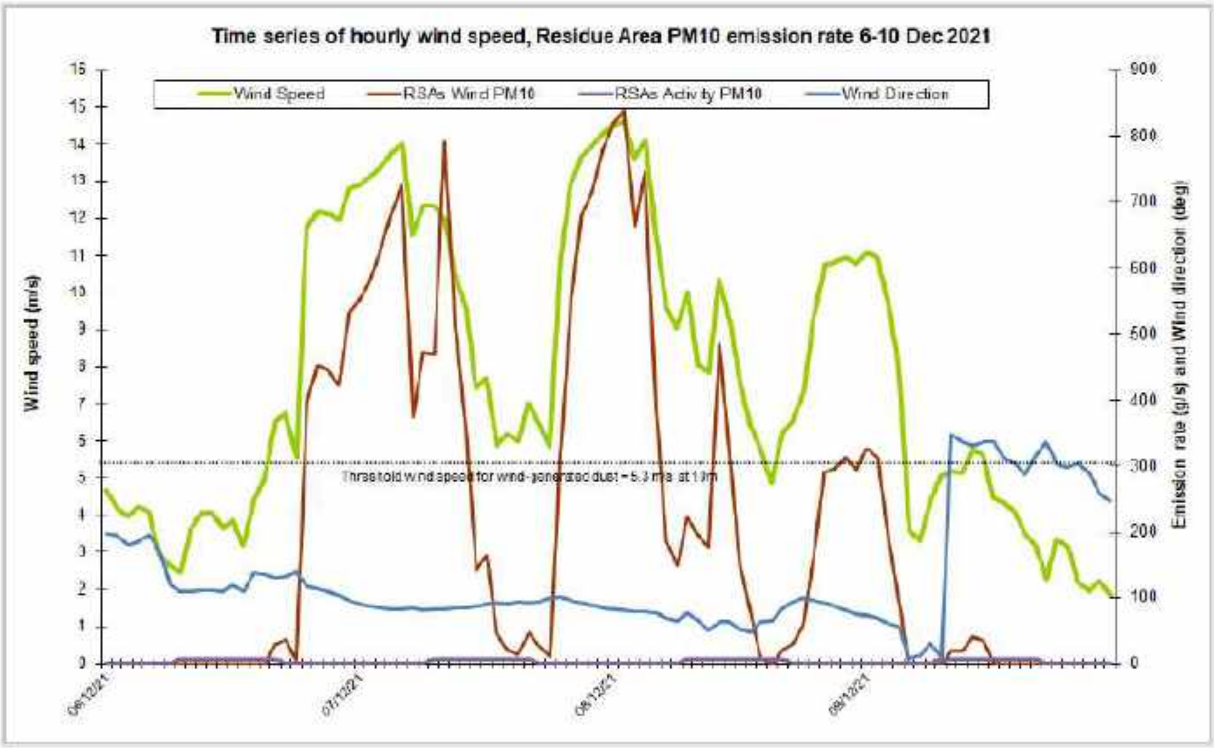


Figure 7-2: Time series of hourly wind speed, Residue Area PM₁₀ emission rate 6-10 Dec 2021

Table 7-1: Summary of Model Results at Discrete Receptors – PM_{10}

Statistic		24-hour Average [1]								Annual Average [2]			
		Maximum				2nd Highest							
Model scenario		Baseline		Proposed		Baseline		Proposed		Baseline		Proposed	
Receptor ID	Model Receptor	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria
R1	1	2.26	4.9	2.63	5.7	2.05	4.5	2.26	4.9	0.157	0.68	0.161	0.7
R3	3	1.15	2.5	1.23	2.7	1.07	2.3	1.13	2.5	0.082	0.36	0.085	0.37
R4	4	1.93	4.2	2.2	4.8	1.75	3.8	1.78	3.9	0.151	0.66	0.156	0.68
R5	5	1.18	2.6	1.23	2.7	1.14	2.5	1.18	2.6	0.0889	0.39	0.0918	0.4
R6	6	2.34	5.1	2.43	5.3	2.23	4.8	2.31	5	0.103	0.45	0.105	0.46
R7	8	45.8	99.6	52.6	114	31.4	68	39	85	2.24	9.7	2.63	11
R8	9	4.02	8.7	4.3	9.3	3.87	8.4	4.2	9.1	0.241	1	0.269	1.2
R9	10	4.61	10	4.94	11	3.47	7.5	3.5	7.6	0.333	1.4	0.351	1.5
R10	11	3.18	6.9	3.29	7.2	2.92	6.3	2.92	6.3	0.279	1.2	0.288	1.3
R11	12	4.36	9.5	5.04	11	3.85	8.4	3.99	8.7	0.462	2	0.471	2
R13	14	1.77	3.8	1.88	4.1	0.958	2.1	1.02	2.2	0.104	0.45	0.108	0.47
R14	15	3.29	7.2	3.59	7.8	2.7	5.9	2.7	5.9	0.182	0.79	0.187	0.81
R15	16	1.58	3.4	1.59	3.5	1.41	3.1	1.42	3.1	0.078	0.34	0.0791	0.34
R16	18	9.23	20	9.23	20	8.06	18	8.06	18	0.797	3.5	0.807	3.5
R17	19	38	83	39	85	31.1	68	35.2	77	1.83	8	2.03	8.8
R18	20	3.43	7.5	3.47	7.5	2.93	6.4	2.95	6.4	0.283	1.2	0.291	1.3
R19	21	1.78	3.9	1.96	4.3	1.65	3.6	1.66	3.6	0.149	0.65	0.156	0.68
R20	22	1.52	3.3	1.55	3.4	1.44	3.1	1.49	3.2	0.117	0.51	0.121	0.53

Notes:

1. 24-hour averages based on Refinery point source Peak emissions.
2. Annual averages based on Refinery point source Average emissions.

7.2.2 $PM_{2.5}$

The model results for $PM_{2.5}$ are displayed in Figure 7-3. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-2 and contours are presented in Section 7.2.3.

To assess the potential air quality impact, modelled $PM_{2.5}$ concentrations are compared to the following criteria, referenced to the Ambient Air Quality NEPM (NEPC, 2021):

- 24-hour average of 23 µg/m³ DWER (2019) and 18 µg/m³ from 2025 NEPC (2021)
- annual average of 7 µg/m³ DWER (2019) and 6 µg/m³ from 2025 NEPC (2021).

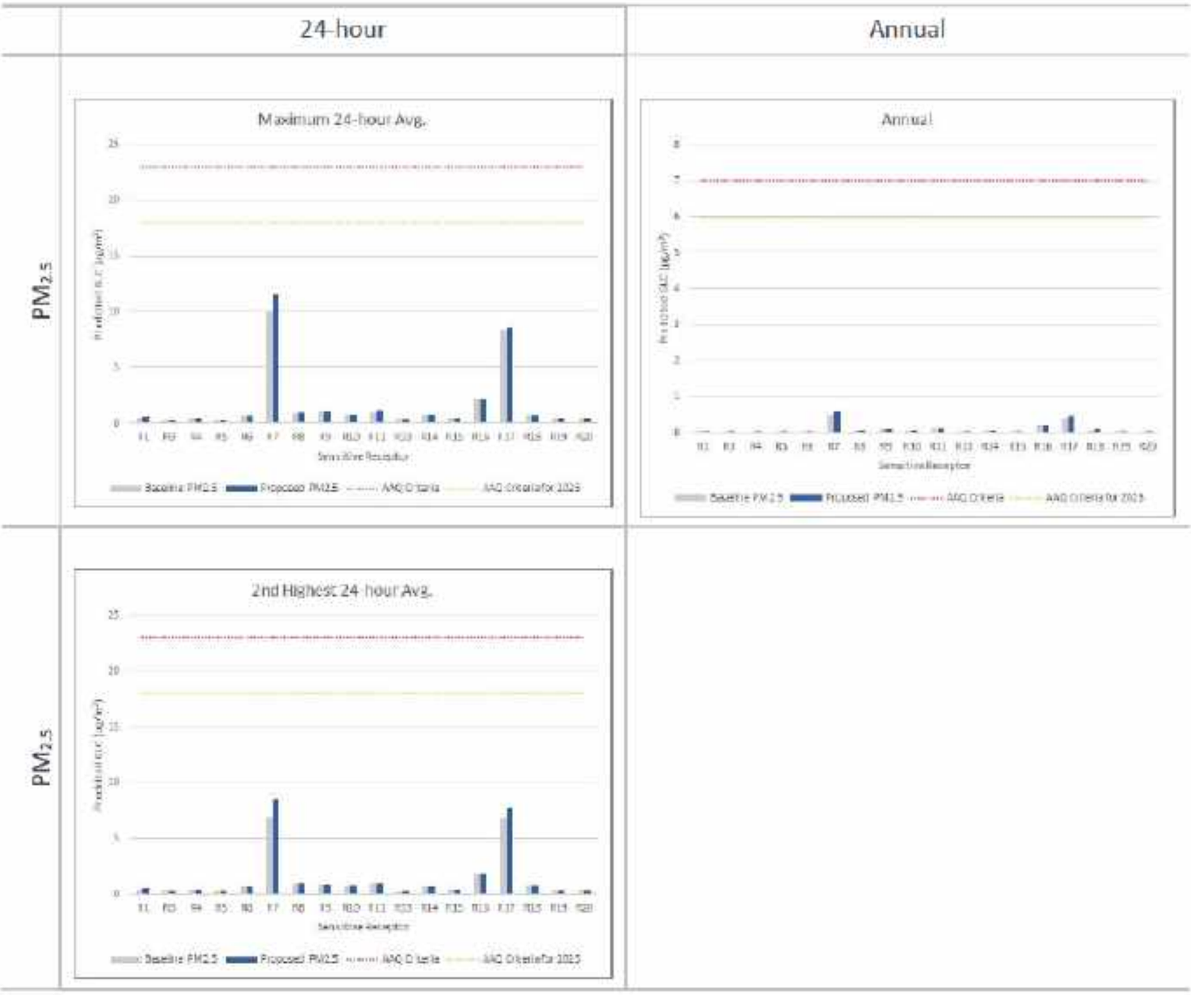


Figure 7-3: Summary of predicted $PM_{2.5}$ concentrations (µg/m³) – Baseline and Proposed model scenarios

The modelling results for $PM_{2.5}$ show:

- the maximum 24-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (44% and 50% or less, respectively).
- the highest impacts are predicted at Receptor 7, which is located immediately to the west of the Residue Area, approximately 3 km away, with:
    - the maximum and 2nd highest 24-hour average ground-level concentrations **below** the assessment criterion for the Proposed model scenario (50% and 37% of criterion, respectively)

  - the maximum and 2nd highest 24-hour average ground-level concentrations **below** the assessment criterion for the Baseline model scenario (44% and 30% of criterion, respectively).
- the annual average ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (8.3% or less).
- the RSA10 proposal results in a small incremental increase in the predicted ground-level concentrations at the sensitive receptors, most evident at Receptor 7 and Receptor 17, located to the west of the Residue Area. Otherwise, at the remaining sensitive receptors, the incremental increase is not predicted to be significant considered in the context of the assessment criteria.

To inform the assessment regarding anticipated future regulatory requirements, reference is also made to the increasingly more stringent standards for $PM_{2.5}$ that apply from 2025 under the Ambient Air Quality NEPM (NEPC, 2021) in Table 9-1 (refer to Section 9.1).

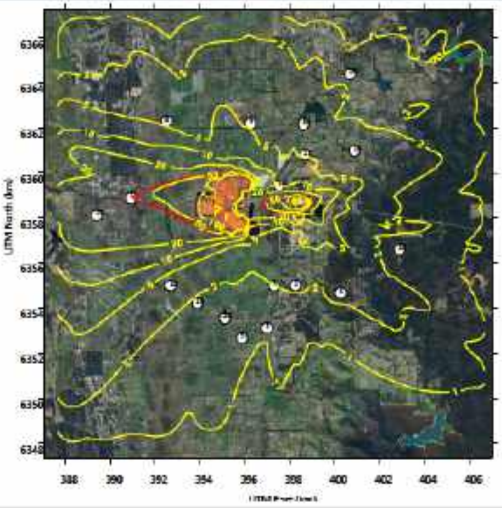
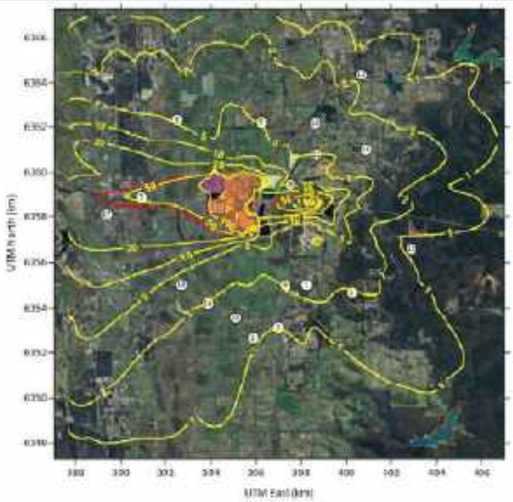
Table 7-2: Summary of Model Results at Discrete Receptors – $PM_{2.5}$

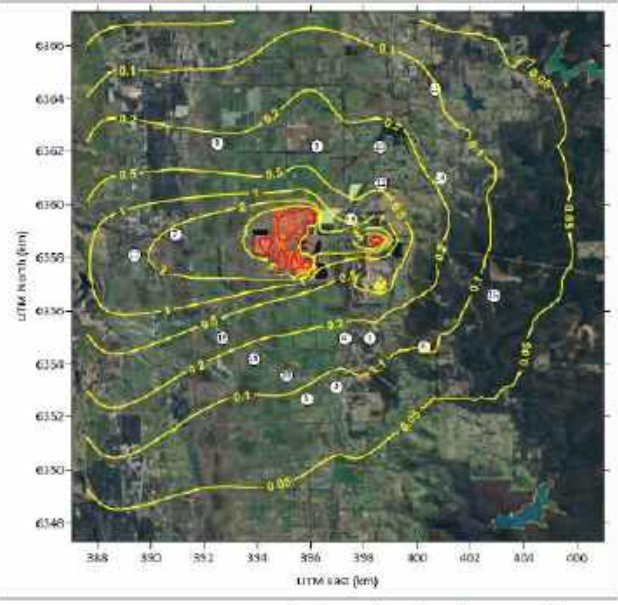
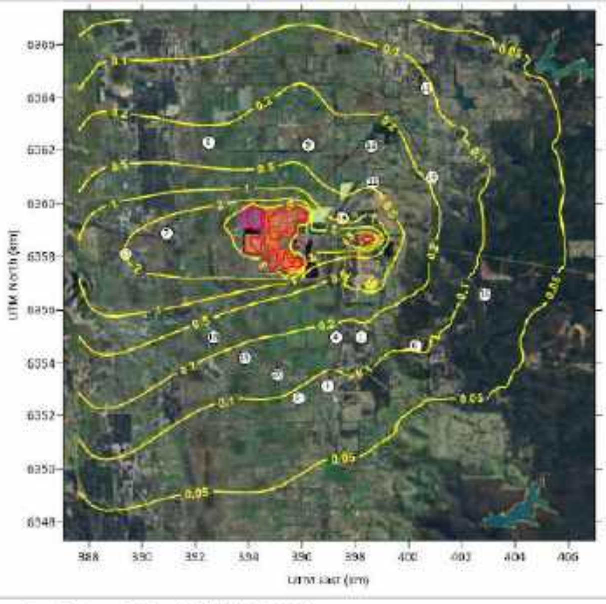
Statistic		24-hour Average [1]								Annual Average [2]			
		Maximum				2nd Highest							
Model scenario		Baseline		Proposed		Baseline		Proposed		Baseline		Proposed	
Receptor ID	Model Receptor	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria
R1	1	0.502	2.2	0.579	2.5	0.497	2.2	0.549	2.4	0.0429	0.61	0.0438	0.63
R3	3	0.293	1.3	0.312	1.4	0.285	1.2	0.299	1.3	0.0214	0.31	0.0221	0.32
R4	4	0.44	1.9	0.483	2.1	0.428	1.9	0.447	1.9	0.0401	0.57	0.0411	0.59
R5	5	0.313	1.4	0.313	1.4	0.306	1.3	0.307	1.3	0.0229	0.33	0.0236	0.34
R6	6	0.619	2.7	0.638	2.8	0.619	2.7	0.637	2.8	0.0288	0.41	0.0293	0.42
R7	8	10.1	44	11.6	50	6.92	30	8.59	37	0.497	7.1	0.583	8.3
R8	9	0.892	3.9	0.954	4.1	0.879	3.8	0.952	4.1	0.0559	0.8	0.0621	0.89
R9	10	1.02	4.4	1.09	4.7	0.813	3.5	0.82	3.6	0.077	1.1	0.0809	1.2
R10	11	0.769	3.3	0.769	3.3	0.73	3.2	0.73	3.2	0.0664	0.95	0.0684	0.98
R11	12	0.979	4.3	1.11	4.8	0.972	4.2	0.979	4.3	0.109	1.6	0.111	1.6
R13	14	0.394	1.7	0.418	1.8	0.266	1.2	0.269	1.2	0.0258	0.37	0.0266	0.38
R14	15	0.723	3.1	0.79	3.4	0.65	2.8	0.65	2.8	0.046	0.66	0.0469	0.67
R15	16	0.507	2.2	0.509	2.2	0.457	2	0.458	2	0.0222	0.32	0.0224	0.32
R16	18	2.12	9.2	2.12	9.2	1.8	7.8	1.8	7.8	0.185	2.6	0.187	2.7
R17	19	8.4	37	8.62	37	6.85	30	7.75	34	0.406	5.8	0.45	6.4
R18	20	0.757	3.3	0.767	3.3	0.742	3.2	0.745	3.2	0.0697	1	0.0716	1
R19	21	0.437	1.9	0.438	1.9	0.391	1.7	0.432	1.9	0.0378	0.54	0.0394	0.56
R20	22	0.436	1.9	0.436	1.9	0.379	1.6	0.38	1.7	0.0299	0.43	0.0308	0.44

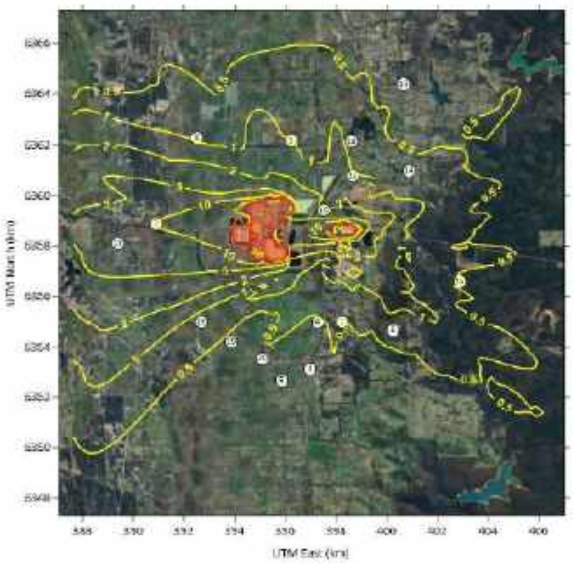
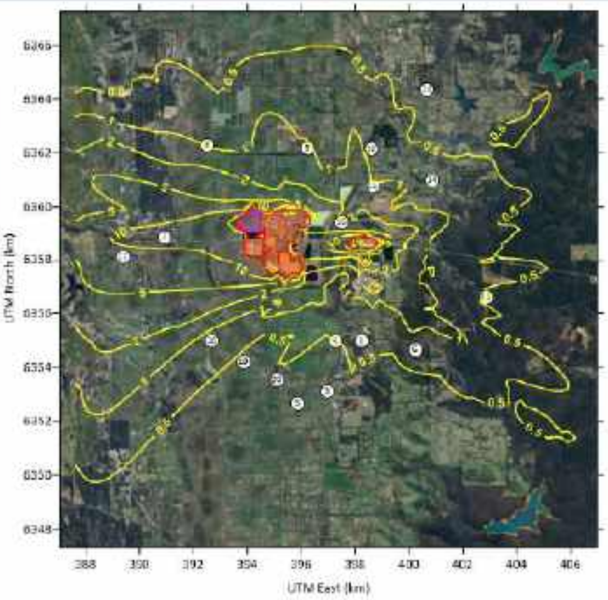
Notes:

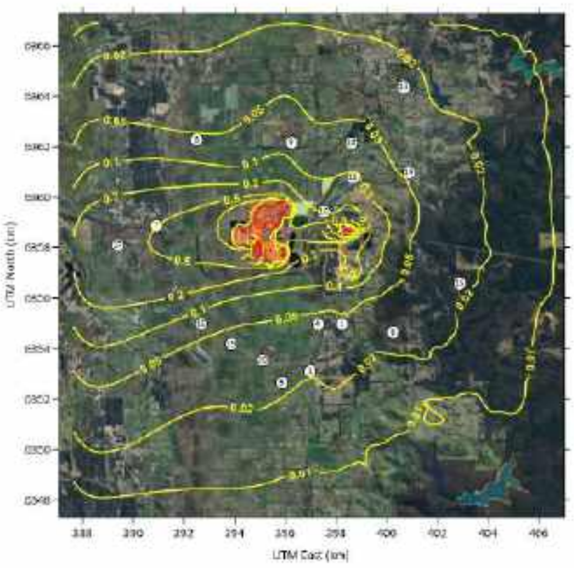
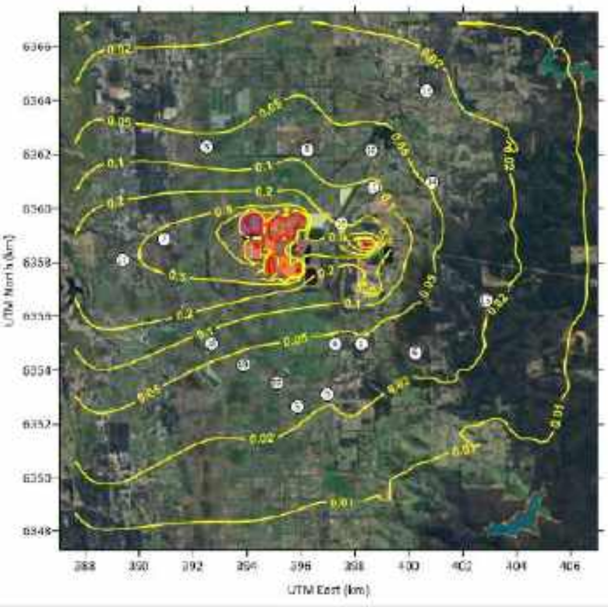
1. 24-hour averages based on Refinery point source Peak emissions.
2. Annual averages based on Refinery point source Average emissions.

7.2.3 Concentration Contours for Particulates

	BASELINE	PROPOSED
Predicted GLC (µg/m³)		
	Contours shown in red represent the assessment criterion of 46 µg/m³ (DWER, 2019).	
	Figure 7-4: Maximum 24-hr Avg GLC contours of PM$_{10}$ – Baseline	Figure 7-5: Maximum 24-hr Avg GLC contours of PM$_{10}$ – Proposed
Pollutant	PM$_{10}$	PM$_{10}$
Statistic	24-hour Average – Maximum	24-hour Average – Maximum

Predicted GLC (µg/m³)		
	Contours shown in red represent the assessment criterion of 23 µg/m³ (DWER, 2019).	
	Figure 7-6: Annual Avg GLC contours of PM$_{10}$ – Baseline	Figure 7-7: Annual Avg GLC contours of PM$_{10}$ – Proposed
Pollutant	PM$_{10}$	PM$_{10}$
Statistic	Annual average	Annual average

	BASELINE	PROPOSED
Predicted GLC (µg/m³)		
	Contours shown in red represent the assessment criterion of 23 µg/m³ (DWER, 2019).	
	Figure 7-8: Maximum 24-hr Avg GLC contours of $PM_{2.5}$ – Baseline	Figure 7-9: Maximum 24-hr Avg GLC contours of $PM_{2.5}$ – Proposed
Pollutant	$PM_{2.5}$	$PM_{2.5}$
Statistic	24-hour Average – Maximum	24-hour Average – Maximum

Predicted GLC (µg/m³)		
	Contours shown in red represent the assessment criterion of 7 µg/m³ (DWER, 2019).	
	Figure 7-10: Annual Avg GLC contours of $PM_{2.5}$ – Baseline	Figure 7-11: Annual Avg GLC contours of $PM_{2.5}$ – Proposed
Pollutant	$PM_{2.5}$	$PM_{2.5}$
Statistic	Annual average	Annual average

7.3 Nitrogen Dioxide

The model results for NO_2 are displayed in Figure 7-12. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-3, and contours are presented in Section 7.3.1. The existing RSAs, as well as the new RSA10, are not identified as sources of NO_2, such that the model results for the Baseline and Proposed model scenarios are the same.

To assess the potential air quality impact, modelled NO_2 concentrations are compared to the following criteria, referenced to the Ambient Air Quality NEPM (NEPC, 2021):

- 1-hour average of 151 µg/m³ DWER (2019)
- annual average of 28 µg/m³ DWER (2019).

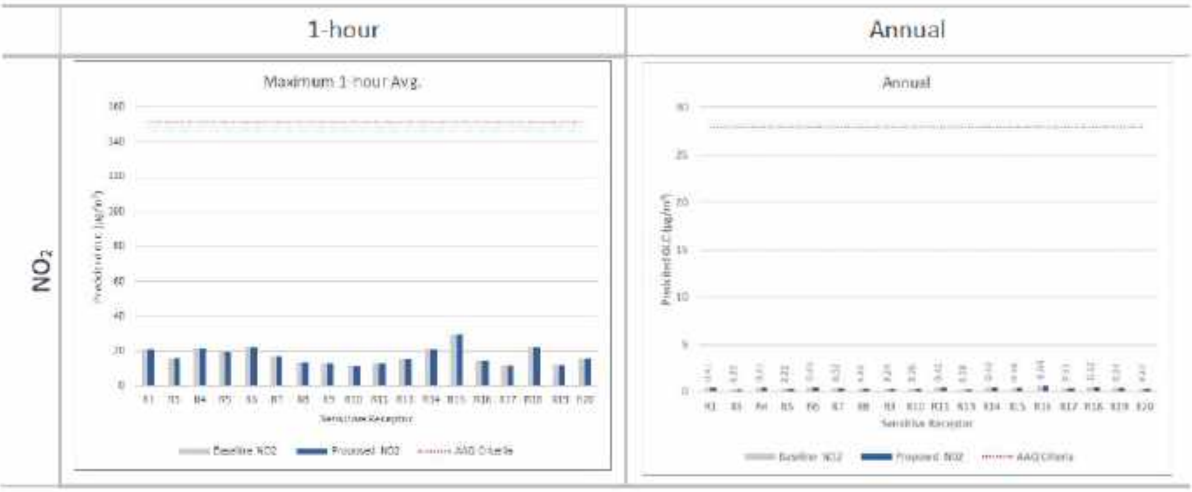


Figure 7-12: Summary of predicted NO_2 concentrations (µg/m³) – Baseline and Proposed model scenarios

Table 7-3: Summary of Model Results at Discrete Receptors – NO_2

Statistic		1-hour Average [1]		Annual Average [2]	
		Maximum			
Model scenario		Baseline and Proposed		Baseline and Proposed	
Receptor ID	Model Receptor	µg/m³	% of Criteria	µg/m³	% of Criteria
R1	1	20.8	14	0.414	1.5
R3	3	15.6	10	0.21	0.75
R4	4	21.4	14	0.406	1.5
R5	5	19.5	13	0.216	0.77
R6	6	22.2	15	0.45	1.6
R7	8	16.7	11	0.315	1.1
R8	9	13.6	9	0.222	0.79
R9	10	13.4	8.9	0.24	0.86
R10	11	10.9	7.2	0.264	0.94
R11	12	13	8.6	0.419	1.5
R13	14	15	9.9	0.183	0.65
R14	15	20.5	14	0.448	1.6
R15	16	29.7	20	0.394	1.4
R16	18	14.4	9.5	0.639	2.3
R17	19	11.6	7.7	0.315	1.1
R18	20	22.3	15	0.515	1.8
R19	21	11.9	7.9	0.339	1.2
R20	22	15.3	10	0.268	0.96

Notes:

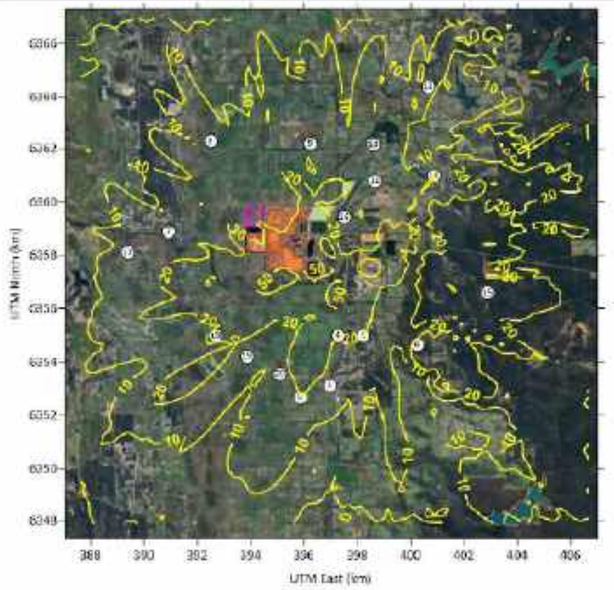
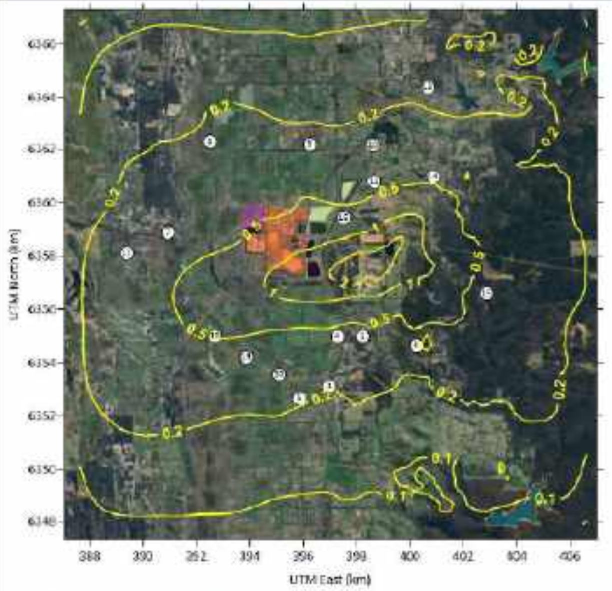
1. 1-hour averages based on Peak Refinery point source emissions.
2. Annual averages based on Average Refinery point source average emissions.

The modelling results for NO_2 show:

- the maximum 1-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (20% or less).
    - the highest impacts are predicted at Receptor 15, which is located to the southeast of the Refinery, approximately 2 km away.
- the annual average ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (2.3% or less).
- the RSA10 proposal does not result in any change to the predicted ground-level concentrations at the sensitive receptors, as the RSAs are not identified as a source of NO_2.

Although the predicted ground-level concentrations of NO_2 (20% or less) are relatively high when compared to ambient air quality assessment criteria, they are not considered to be of significance within the context of this assessment as RSA10 is not identified as a source of this pollutant.

7.3.1 Concentration Contours for NO_2

	BASELINE | PROPOSED	BASELINE | PROPOSED
Predicted GLC (µg/m³)		
	Figure 7-13: Maximum 1-hr Avg GLC contours of NO_2 – Baseline and Proposed	Figure 7-14: Annual Avg GLC contours of NO_2 – Baseline and Proposed
Pollutant	NO_2	NO_2
Statistic	1-hour Average – Maximum	Annual average

7.4 Ammonia

The model results for ammonia are displayed in Figure 7-12. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-3, and contours are presented in Section 7.3.1. The existing RSAs, as well as the new RSA10, are not identified as sources of ammonia, such that the model results for the Baseline and Proposed model scenarios are the same.

To assess the potential air quality impact, modelled ammonia concentrations are compared to the following criteria:

- 1-hour average of 330 µg/m³ (DWER, 2019)
- 24-hour average of 1,290 µg/m³ Katestone (2023)[19]
- annual average of 76 µg/m³ Katestone (2023).

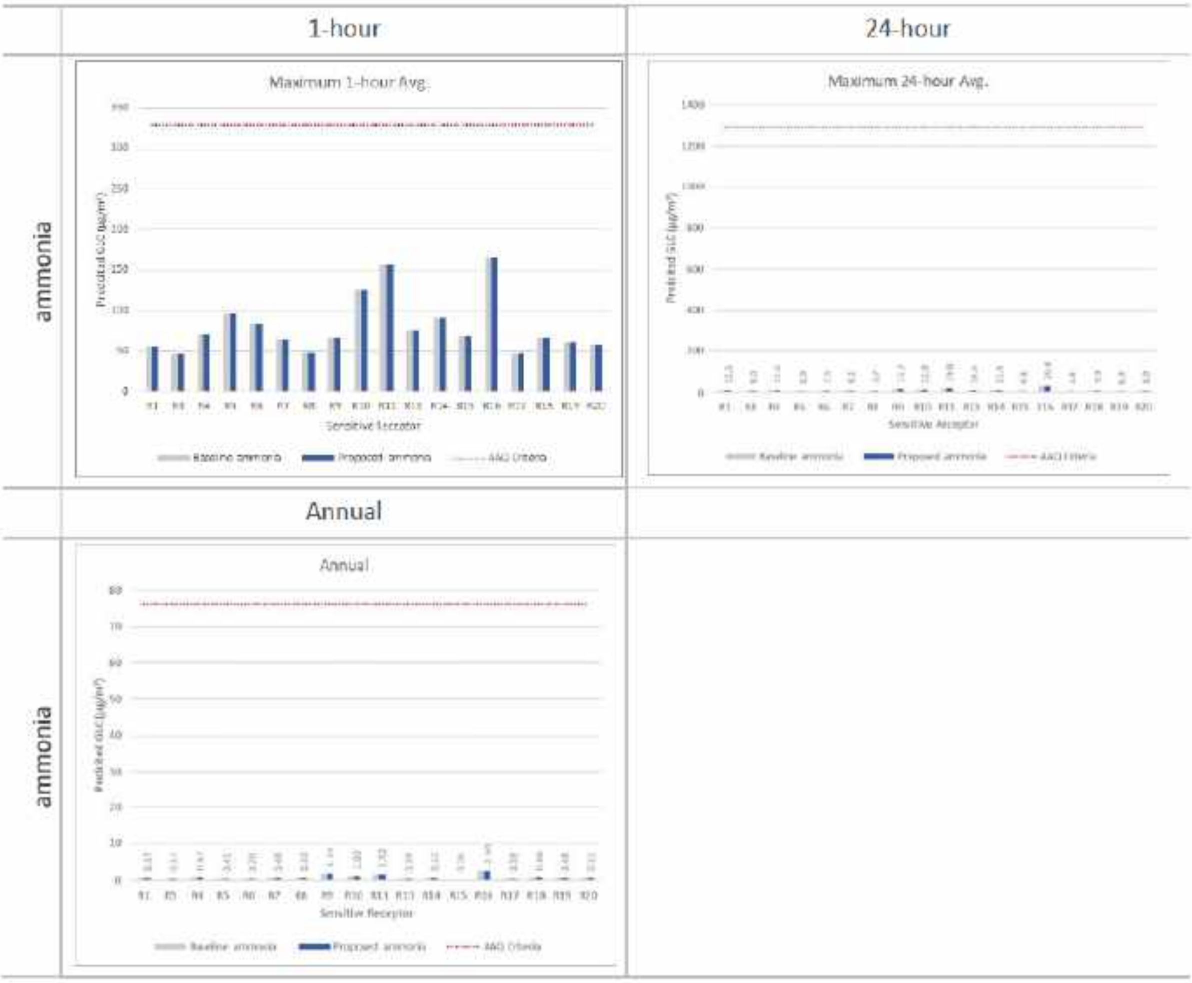


Figure 7-15: Summary of predicted ammonia concentrations (µg/m³) – Baseline and Proposed model scenarios

---

[19] Note that the 1-hour and 24-hour average criteria for ammonia, from DWER (2019) and Katestone (2023) respectively, are inconsistent (see Section 3.2.1).

Table 7-4: Summary of Model Results at Discrete Receptors – Ammonia

Statistic		1-hour [1]		24-hour [1]		Annual Average [2]	
		Maximum		Maximum			
Model scenario		Baseline | Proposed		Baseline | Proposed		Baseline | Proposed	
Receptor ID	Model Receptor	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria
R1	1	56.5	17	12.5	0.97	0.572	0.75
R3	3	46.4	14	8.01	0.62	0.373	0.49
R4	4	70.5	21	12.6	0.98	0.674	0.89
R5	5	95.3	29	6.89	0.53	0.414	0.54
R6	6	85	26	7.49	0.58	0.293	0.39
R7	8	64.9	20	8.21	0.64	0.476	0.63
R8	9	48.4	15	9.68	0.75	0.529	0.7
R9	10	65.8	20	15.7	1.2	1.74	2.3
R10	11	126	38	12.9	1	1.02	1.3
R11	12	156	47	19.8	1.5	1.52	2
R13	14	75.6	23	10.6	0.82	0.385	0.51
R14	15	91	28	11.4	0.88	0.514	0.68
R15	16	68.8	21	4.75	0.37	0.159	0.21
R16	18	164	50	29.8	2.3	2.5	3.3
R17	19	48.1	15	5.77	0.45	0.385	0.51
R18	20	66.4	20	9.92	0.77	0.662	0.87
R19	21	60.4	18	6.02	0.47	0.479	0.63
R20	22	58.5	18	8.86	0.69	0.508	0.67

Notes:

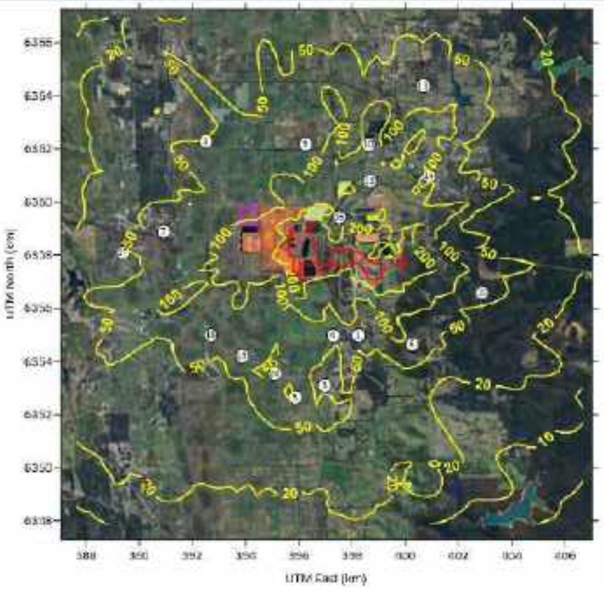
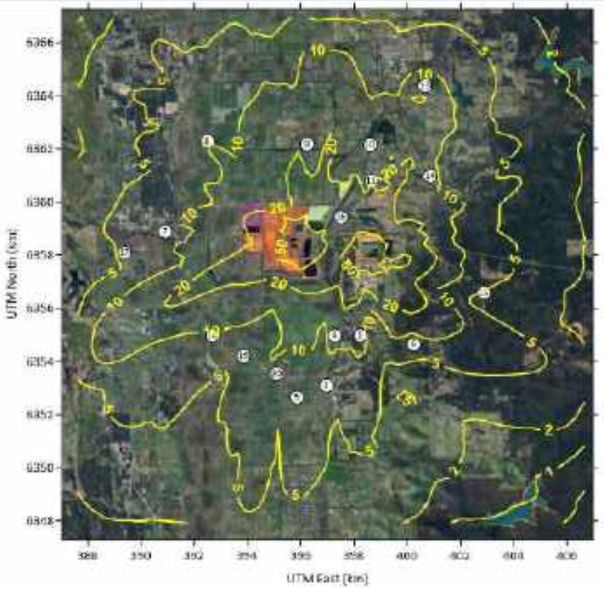
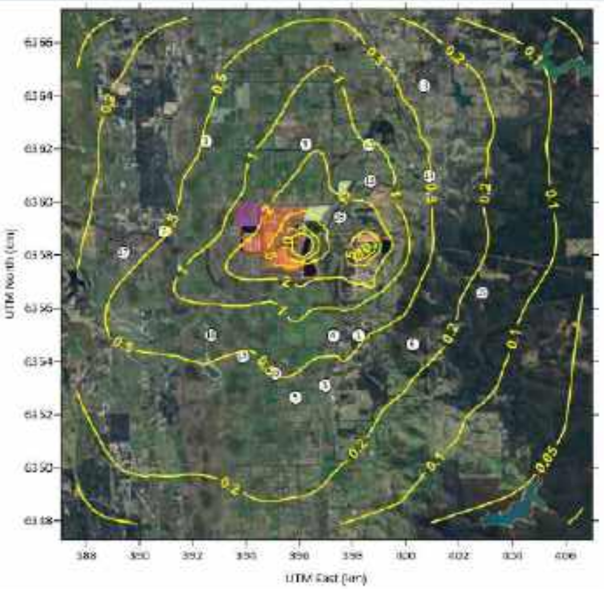
1. 1-hour and 24-hour averages based on Peak Refinery point source emissions.
2. Annual averages based on Average Refinery point source average emissions.

The modelling results for ammonia show:

- the maximum 1-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (50% or less).
    - the highest impacts are predicted at Receptor 11 located to the north of the Refinery approximately 2 km away, and Receptor 16 located closest to the Residue Area.
- the maximum 24-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (2.3% or less).
- the annual average ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (3.3% or less).
- the RSA10 proposal does not result in any change to the predicted ground-level concentrations at the sensitive receptors, as the RSAs are not identified as a source of ammonia.

Although the predicted ground-level concentrations of ammonia (50% or less) are relatively high when compared to ambient air quality assessment criteria, they are not considered to be of significance within the context of this assessment as RSA10 is not identified as a source of this pollutant.

7.4.1 Concentration Contours for ammonia

	BASELINE | PROPOSED	BASELINE | PROPOSED	BASELINE | PROPOSED
Predicted GLC (µg/m³)			
	Contours shown in **red** represent the assessment criterion of 330 µg/m³ (DWER, 2019).		
	Figure 7-16: Maximum 1-hr Avg GLC contours of ammonia – Baseline and Proposed	Figure 7-17: Maximum 24-hr Avg GLC contours of ammonia – Baseline and Proposed	Figure 7-18: Annual Avg GLC contours of ammonia– Baseline and Proposed
Pollutant	ammonia	ammonia	ammonia
Statistic	1-hour Average – Maximum	24-hour Average – Maximum	Annual average

7.5 Volatile Organic Compounds

7.5.1 Acetaldehyde

The model results for acetaldehyde are displayed in Figure 7-19. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-5, and contours are presented in Section 7.5.4. The existing RSAs, as well as the new RSA10, are not identified as a significant source of acetaldehyde, such that the model results for the Baseline and Proposed model scenarios are very similar.

To assess the potential air quality impact, modelled acetaldehyde concentrations are compared to the following criteria:

- 1-hour average of 470 μg/m^3 Katestone (2023)
- 24-hour average of 1,830 μg/m^3 DWER (2019)[20]
- annual average of 9 μg/m^3 Katestone (2023) and 46 μg/m^3 DWER (2019).

---

[20] Note that the 1-hour and 24-hour average criteria for acetaldehyde, from Katestone (2023) and DWER (2019) respectively, are inconsistent (see Section 3.2.1).

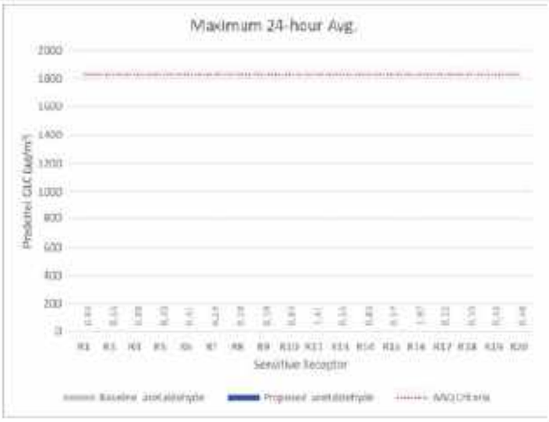
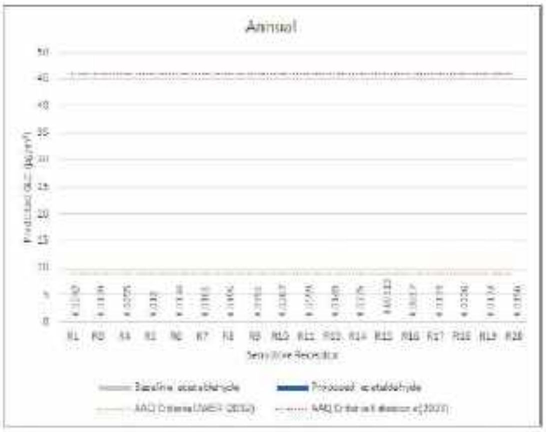
	1-hour	24-hour
acetaldehydye		
	Annual	
acetaldehyde		

Figure 7-19: Summary of predicted acetaldehyde concentrations (µg/m³) – Baseline and Proposed model scenarios

The modelling results for acetaldehyde show:

- the maximum 1-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (2.1% or less).
- the maximum 24-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (0.11% or less).
- the annual average ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (0.91% or less of the more stringent Katestone (2023) criterion).
- the RSA10 proposal does not result in any perceptible change to the predicted ground-level concentrations at the sensitive receptors, as the RSAs are not identified as a significant source of acetaldehyde.

Table 7-5: Summary of Model Results at Discrete Receptors – Acetaldehyde

Statistic		1-hour [1]				24-hour [1]				Annual Average [2]			
		Maximum				Maximum							
Model scenario		Baseline		Proposed		Baseline		Proposed		Baseline		Proposed	
Receptor ID	Model Receptor	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria [3]	µg/m³	% of Criteria [3]
R1	1	4.1	0.87	4.1	0.87	0.839	0.046	0.839	0.046	0.024	0.27	0.0242	0.27
R3	3	2.36	0.5	2.36	0.5	0.552	0.03	0.552	0.03	0.0138	0.15	0.0139	0.15
R4	4	3.49	0.74	3.49	0.74	0.883	0.048	0.884	0.048	0.0253	0.28	0.0255	0.28
R5	5	6.14	1.3	6.14	1.3	0.427	0.023	0.428	0.023	0.0128	0.14	0.013	0.14
R6	6	3.88	0.83	3.88	0.83	0.414	0.023	0.414	0.023	0.0137	0.15	0.0138	0.15
R7	8	1.81	0.39	1.81	0.39	0.286	0.016	0.288	0.016	0.0152	0.17	0.0161	0.18
R8	9	2.94	0.63	2.94	0.63	0.281	0.015	0.282	0.015	0.0143	0.16	0.0155	0.17
R9	10	4.52	0.96	4.52	0.96	0.586	0.032	0.586	0.032	0.0345	0.38	0.0351	0.39
R10	11	7.47	1.6	7.47	1.6	0.844	0.046	0.844	0.046	0.0365	0.41	0.0367	0.41
R11	12	8.21	1.7	8.21	1.7	1.41	0.077	1.41	0.077	0.0557	0.62	0.0559	0.62
R13	14	5.42	1.2	5.42	1.2	0.553	0.03	0.553	0.03	0.0149	0.17	0.0149	0.17
R14	15	5.76	1.2	5.76	1.2	0.825	0.045	0.826	0.045	0.0224	0.25	0.0225	0.25
R15	16	4.23	0.9	4.23	0.9	0.365	0.02	0.366	0.02	0.00909	0.1	0.00913	0.1
R16	18	9.81	2.1	9.81	2.1	1.97	0.11	1.97	0.11	0.0812	0.9	0.0817	0.91
R17	19	1.76	0.37	1.76	0.37	0.316	0.017	0.317	0.017	0.0128	0.14	0.0133	0.15
R18	20	3.31	0.7	3.31	0.7	0.523	0.029	0.525	0.029	0.0221	0.25	0.0226	0.25
R19	21	2.67	0.57	2.69	0.57	0.427	0.023	0.428	0.023	0.0169	0.19	0.0173	0.19
R20	22	3.13	0.67	3.13	0.67	0.476	0.026	0.476	0.026	0.0154	0.17	0.0156	0.17

Notes:

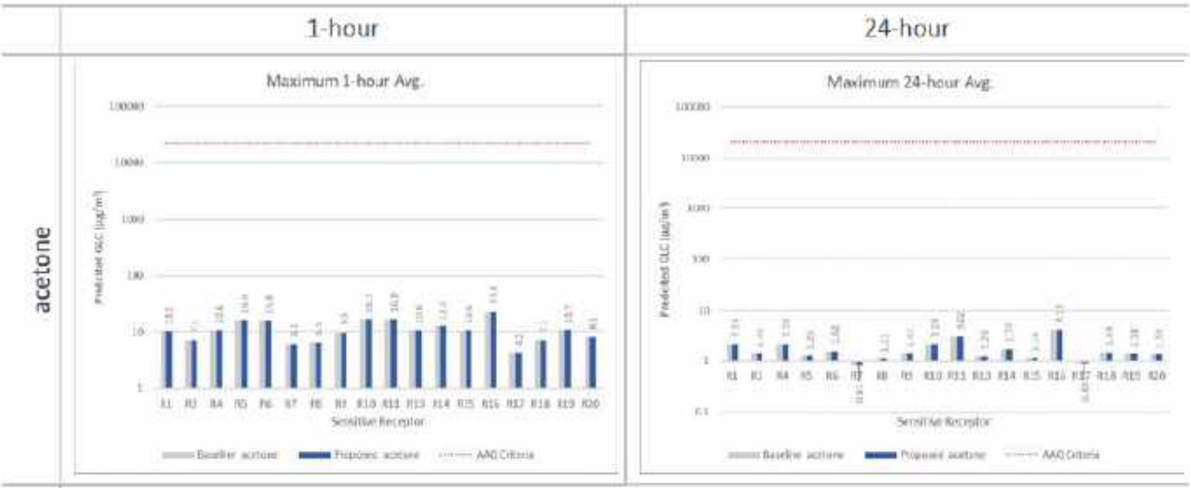
1. 1-hour and 24-hour averages based on Peak Refinery point source emissions.
2. Annual averages based on Average Refinery point source average emissions.
3. Compared to more stringent of the alternative annual criteria for acetaldehyde (annual average of 9 µg/m³ Katestone (2023)).

7.5.2 Acetone

The model results for acetone are displayed in Figure 7-20. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-6, and contours are presented in Section 7.5.4. The existing RSAs, as well as the new RSA10, are not identified as a significant source of acetone, such that the model results for the Baseline and Proposed model scenarios are very similar.

To assess the potential air quality impact, modelled acetone concentrations are compared to the following criteria:

- 1-hour average of 22,000 µg/m³ DWER (2019)
- 24-hour average of 20,740 µg/m³ [21] Katestone (2023).



Note vertical scale is logarithmic.

Figure 7-20: Summary of predicted acetone concentrations (µg/m³) – Baseline and Proposed model scenarios

The modelling results for acetone show:

- the maximum 1-hour and 24-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (0.11% or less).
- the RSA10 proposal does not result in any perceptible change to the predicted ground-level concentrations at the sensitive receptors, as the RSAs are not identified as a significant source of acetone.

---

[21] Note that the 1-hour and 24-hour average criteria for acetone, from DWER (2019) and Katestone (2023) respectively, are inconsistent (see Section 3.2.1).

Table 7-6: Summary of Model Results at Discrete Receptors – Acetone

Statistic		1-hour [1]				24-hour [1]			
		Maximum				Maximum			
Model scenario		Baseline		Proposed		Baseline		Proposed	
Receptor ID	Model Receptor	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria
R1	1	10.1	0.046	10.1	0.046	2.15	0.01	2.15	0.01
R3	3	7.06	0.032	7.07	0.032	1.41	0.0068	1.41	0.0068
R4	4	10.6	0.048	10.6	0.048	2.16	0.01	2.16	0.01
R5	5	16.4	0.075	16.4	0.075	1.25	0.006	1.25	0.006
R6	6	15.8	0.072	15.8	0.072	1.62	0.0078	1.62	0.0078
R7	8	6.07	0.028	6.07	0.028	0.804	0.0039	0.806	0.0039
R8	9	6.47	0.029	6.49	0.03	1.11	0.0054	1.11	0.0054
R9	10	9.46	0.043	9.46	0.043	1.41	0.0068	1.41	0.0068
R10	11	16.7	0.076	16.7	0.076	2.19	0.011	2.19	0.011
R11	12	16.9	0.077	16.9	0.077	3.02	0.015	3.02	0.015
R13	14	10.6	0.048	10.6	0.048	1.24	0.006	1.24	0.006
R14	15	12.4	0.056	12.4	0.056	1.74	0.0084	1.74	0.0084
R15	16	10.6	0.048	10.6	0.048	1.14	0.0055	1.14	0.0055
R16	18	23.3	0.11	23.3	0.11	4.13	0.02	4.13	0.02
R17	19	4.13	0.019	4.15	0.019	0.885	0.0043	0.886	0.0043
R18	20	7.12	0.032	7.12	0.032	1.48	0.0071	1.49	0.0072
R19	21	10.7	0.049	10.7	0.049	1.38	0.0067	1.38	0.0067
R20	22	8	0.036	8.1	0.037	1.33	0.0064	1.33	0.0064

Notes:

1. 1-hour and 24-hour averages based on Peak Refinery point source emissions.

7.5.3 Formaldehyde

The model results for formaldehyde are displayed in Figure 7-19. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-5, and contours are presented in Section 7.5.4. The existing RSAs, as well as the new RSA10, are not identified as a significant source of formaldehyde, such that the model results for the Baseline and Proposed model scenarios are very similar.

To assess the potential air quality impact, modelled formaldehyde concentrations are compared to the following criteria:

- 1-hour average of 20 $\mu g/m^3$ (DWER, 2019)
- 24-hour average of 53.6 $\mu g/m^3$[22] (Katestone, 2023)

---

[22] Note that the 1-hour and 24-hour average criteria for formaldehyde, from DWER (2019) and Katestone (2023) respectively, are inconsistent (see Section 3.2.1).

- annual average of 9 µg/m³ Katestone (2023).

Figure 7-21: Summary of predicted formaldehyde concentrations (µg/m³) – Baseline and Proposed model scenarios

The modelling results for formaldehyde show:

- the maximum 1-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (16% or less).
  - the highest impacts are predicted at Receptor 18, which is located to the southwest of the Residue Area, approximately 3.5 km away.
- the maximum 24-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (0.80% or less).
- the annual average ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (0.21% or less).
- the RSA10 proposal does not result in any perceptible change to the predicted ground-level concentrations at the sensitive receptors, as the RSAs are not identified as a significant source of formaldehyde.

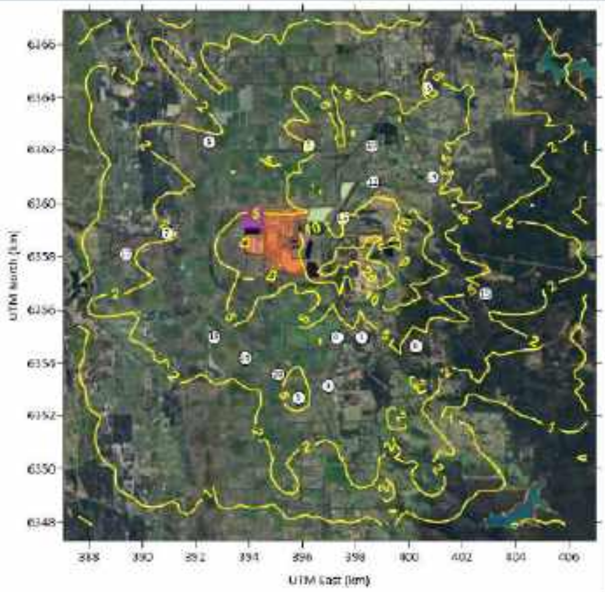
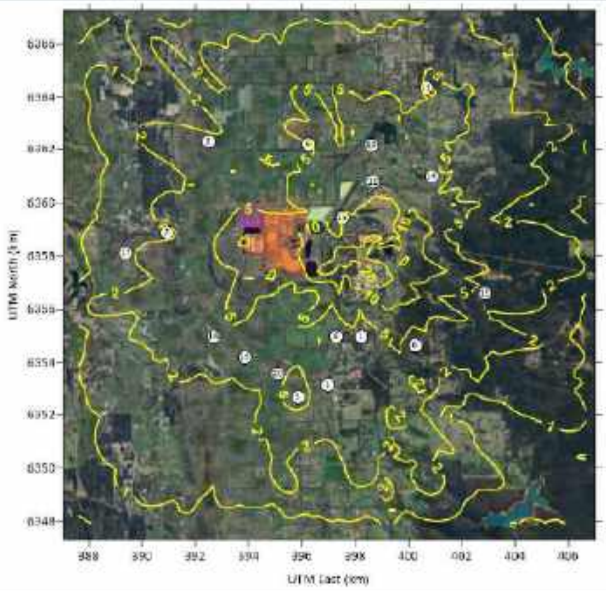
Table 7-7: Summary of Model Results at Discrete Receptors – Formaldehyde

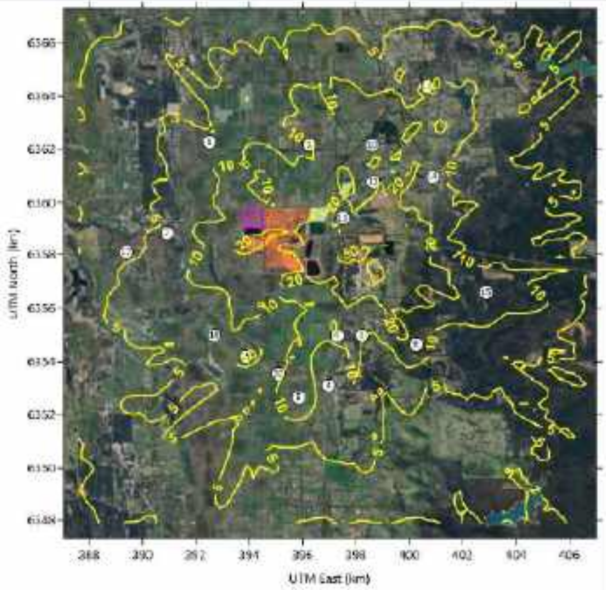
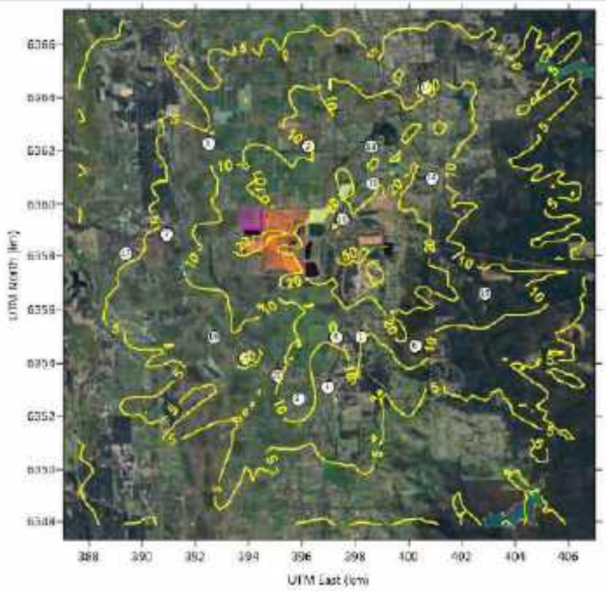
Statistic		1-hour [1]				24-hour [1]				Annual Average [2]			
		Maximum				Maximum							
Model scenario		Baseline		Proposed		Baseline		Proposed		Baseline		Proposed	
Receptor ID	Model Receptor	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria
R1	1	2.91	15	2.91	15	0.374	0.7	0.374	0.7	0.012	0.13	0.0121	0.13
R3	3	1.52	7.6	1.53	7.7	0.198	0.37	0.198	0.37	0.0062	0.069	0.00625	0.069
R4	4	1.57	7.9	1.57	7.9	0.388	0.72	0.388	0.72	0.0131	0.15	0.0131	0.15
R5	5	1.92	9.6	1.92	9.6	0.231	0.43	0.231	0.43	0.00716	0.08	0.00721	0.08
R6	6	2.07	10	2.07	10	0.396	0.74	0.396	0.74	0.0109	0.12	0.011	0.12
R7	8	1.81	9.1	1.81	9.1	0.25	0.47	0.25	0.47	0.00828	0.092	0.00864	0.096
R8	9	1.51	7.6	1.51	7.6	0.183	0.34	0.183	0.34	0.00686	0.076	0.00726	0.081
R9	10	1.02	5.1	1.02	5.1	0.162	0.3	0.162	0.3	0.0103	0.11	0.0105	0.12
R10	11	1.19	6	1.19	6	0.159	0.3	0.159	0.3	0.00745	0.083	0.00753	0.084
R11	12	1.18	5.9	1.18	5.9	0.21	0.39	0.21	0.39	0.0108	0.12	0.0109	0.12
R13	14	1.08	5.4	1.08	5.4	0.131	0.24	0.131	0.24	0.00429	0.048	0.00432	0.048
R14	15	1.58	7.9	1.58	7.9	0.217	0.4	0.217	0.4	0.00878	0.098	0.00881	0.098
R15	16	2.77	14	2.77	14	0.339	0.63	0.339	0.63	0.00819	0.091	0.0082	0.091
R16	18	1.73	8.7	1.73	8.7	0.275	0.51	0.275	0.51	0.0184	0.2	0.0186	0.21
R17	19	1.28	6.4	1.28	6.4	0.275	0.51	0.275	0.51	0.0072	0.08	0.0074	0.082
R18	20	3.14	16	3.14	16	0.429	0.8	0.43	0.8	0.0146	0.16	0.0147	0.16
R19	21	1.3	6.5	1.3	6.5	0.245	0.46	0.245	0.46	0.0111	0.12	0.0112	0.12
R20	22	1.61	8.1	1.61	8.1	0.279	0.52	0.279	0.52	0.0093	0.1	0.00937	0.1

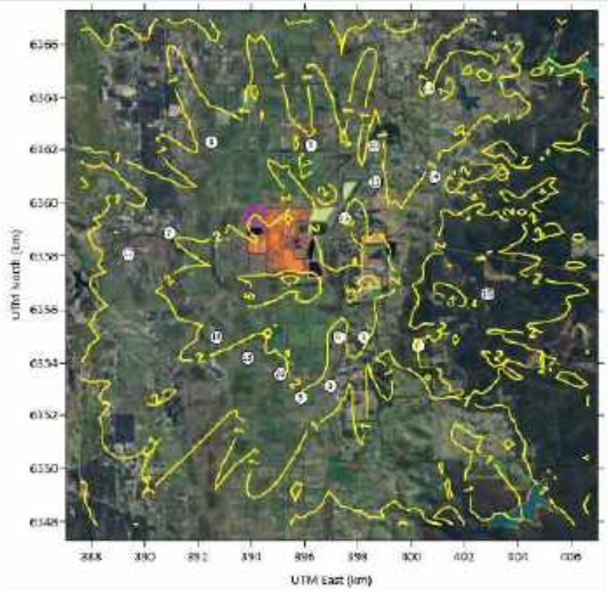
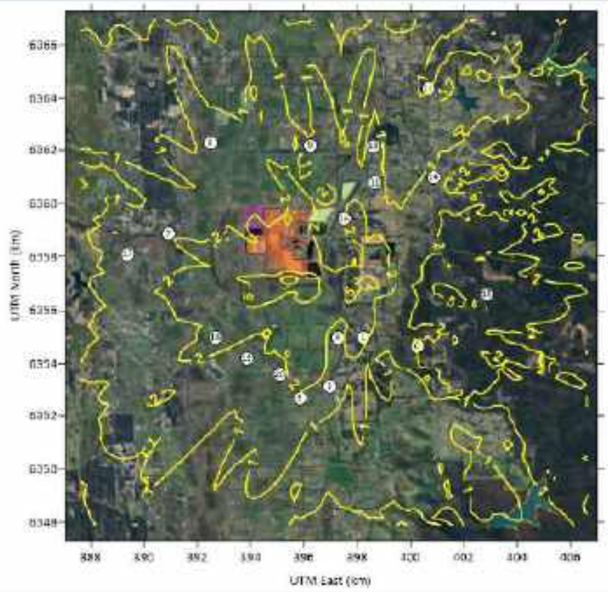
Notes:

1. 1-hour and 24-hour averages based on Peak Refinery point source emissions.
2. Annual averages based on Average Refinery point source average emissions.

7.5.4 Concentration Contours for VOCs

	BASELINE	PROPOSED
Predicted GLC (µg/m³)		
	Figure 7-22: Maximum 1-hr Avg GLC contours of acetaldehyde – Baseline	Figure 7-23: Maximum 1-hr Avg GLC contours of acetaldehyde – Proposed
Pollutant	acetaldehyde	acetaldehyde
Statistic	1-hour Average – Maximum	1-hour Average – Maximum

	BASELINE	PROPOSED
Predicted GLC (µg/m³)		
	Figure 7-24: Maximum 1-hr Avg GLC contours of acetone – Baseline	Figure 7-25: Maximum 1-hr Avg GLC contours of acetone – Proposed
Pollutant	acetone	acetone
Statistic	1-hour Average – Maximum	1-hour Average – Maximum

	BASELINE	PROPOSED
Predicted GLC (µg/m³)		
	Figure 7-26: **Maximum 1-hr Avg GLC contours of formaldehyde – Baseline**	Figure 7-27: **Maximum 1-hr Avg GLC contours of formaldehyde – Proposed**
Pollutant	formaldehyde	formaldehyde
Statistic	1-hour Average – Maximum	1-hour Average – Maximum

7.6 Trace Metals

7.6.1 Aluminium

The model results for aluminium are displayed in Figure 7-28. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-8, and contours are presented in Section 7.6.6. The existing RSAs, as well as the new RSA10, are a contributing source of aluminium contained in residue dust.

To assess the potential air quality impact, modelled aluminium concentrations are compared to the following criteria:

- 24-hour average of 9.2 µg/m³ DWER (2019).

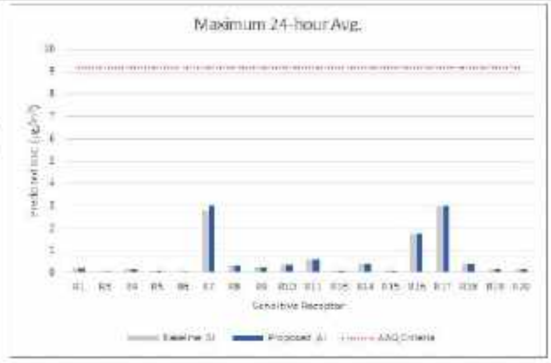
	24-hour	
aluminiumyeye		

Figure 7-28: **Summary of predicted aluminium concentrations (µg/m³) – Baseline and Proposed model scenarios**

The modelling results for aluminium show:

- the maximum 24-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (33% or less).
  - the highest impacts are predicted at Receptor 7, which is located to the west of the Residue Area, approximately 3 km away.
- the RSA10 proposal results in a very small incremental increase in the predicted ground-level concentrations at the sensitive receptors, that is not significant considered in the context of the assessment criteria.

Table 7-8: Summary of Model Results at Discrete Receptors – Aluminium

Statistic		24-hour			
		Maximum			
Model scenario		Baseline		Proposed	
Receptor ID	Model Receptor	µg/m³	% of Criteria	µg/m³	% of Criteria
R1	1	0.197	2.1	0.197	2.1
R3	3	0.0878	0.95	0.088	0.96
R4	4	0.152	1.7	0.152	1.7
R5	5	0.106	1.2	0.106	1.2
R6	6	0.0841	0.91	0.0843	0.92
R7	8	2.8	30	3.02	33
R8	9	0.322	3.5	0.331	3.6
R9	10	0.237	2.6	0.237	2.6
R10	11	0.368	4	0.368	4
R11	12	0.598	6.5	0.598	6.5
R13	14	0.115	1.3	0.116	1.3
R14	15	0.418	4.5	0.418	4.5
R15	16	0.112	1.2	0.112	1.2
R16	18	1.75	19	1.75	19
R17	19	2.95	32	2.99	33
R18	20	0.412	4.5	0.413	4.5
R19	21	0.171	1.9	0.171	1.9
R20	22	0.159	1.7	0.159	1.7

Notes:

1. 1-hour and 24-hour averages based on Peak Refinery point source emissions.
2. Annual averages based on Average Refinery point source average emissions.

7.6.2 Arsenic

The model results for arsenic are displayed in Figure 7-29. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-9, and contours are presented in Section 7.6.6. The existing RSAs, as well as the new RSA10, are a contributing source of arsenic contained in residue dust.

To assess the potential air quality impact, modelled arsenic concentrations are compared to the following criteria:

- 1-hour average of 0.09 µg/m³ (DWER, 2019) and 0.2 µg/m³ Katestone (2023)
- 24-hour average of 0.027 µg/m³ (DWER, 2019)
- annual average of 0.0027 µg/m³ (DWER, 2019) and 0.015 µg/m³ Katestone (2023).

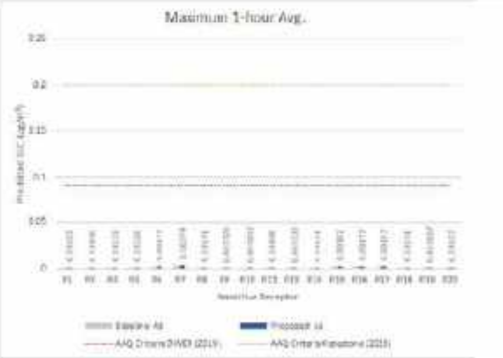
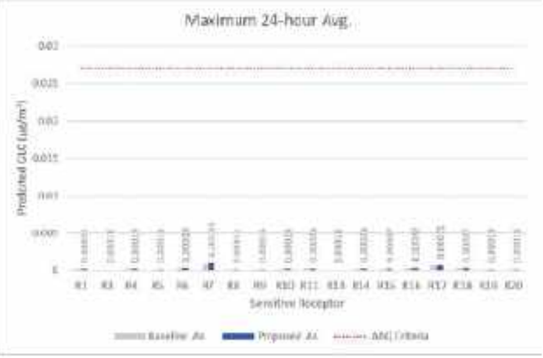
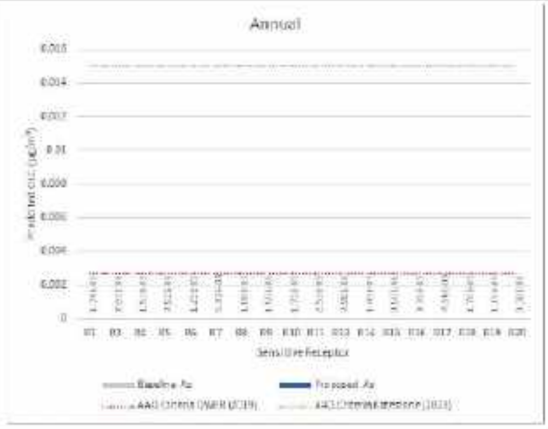
	1-hour	24-hour
arsenic		
	Annual	
arsenic		

Figure 7-29: Summary of predicted arsenic concentrations (µg/m³) – Baseline and Proposed model scenarios

The modelling results for arsenic show:

- the maximum 1-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (4.2% or less of the more stringent DWER (2019) criterion).
- the maximum 24-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (3.8% or less).
- the annual average ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (1.9% or less of the more stringent DWER (2019) criterion).
- the RSA10 proposal results in a very small incremental increase in the predicted ground-level concentrations at the sensitive receptors, that is not significant considered in the context of the assessment criteria.

Table 7-9: Summary of Model Results at Discrete Receptors – Arsenic

Statistic		1-hour[1]				24-hour[1]				Annual Average[2]			
		Maximum				Maximum							
Model scenario		Baseline		Proposed		Baseline		Proposed		Baseline		Proposed	
Receptor ID	Model Receptor	µg/m³	% of Criteria[3]	µg/m³	% of Criteria[3]	µg/m³	% of Criteria	µg/m³	% of Criteria	µg/m³	% of Criteria[4]	µg/m³	% of Criteria[4]
R1	1	0.00103	1.1	0.00103	1.1	0.000215	0.8	0.000215	0.8	1.73E-05	0.12	1.74E-05	0.12
R3	3	0.00096	1.1	0.00096	1.1	0.000101	0.37	0.000101	0.37	7.86E-06	0.052	7.93E-06	0.053
R4	4	0.00133	1.5	0.00133	1.5	0.000193	0.71	0.000193	0.71	1.50E-05	0.1	1.51E-05	0.1
R5	5	0.00126	1.4	0.00126	1.4	0.000159	0.59	0.000159	0.59	7.44E-06	0.05	7.51E-06	0.05
R6	6	0.00177	2	0.00177	2	0.000293	1.1	0.000293	1.1	1.24E-05	0.083	1.25E-05	0.083
R7	8	0.00343	3.8	0.00374	4.2	0.000877	3.2	0.00103	3.8	5.06E-05	0.34	5.92E-05	0.39
R8	9	0.00123	1.4	0.00141	1.6	0.000139	0.51	0.000139	0.51	1.02E-05	0.068	1.08E-05	0.072
R9	10	0.000926	1	0.000926	1	0.000163	0.6	0.000164	0.61	1.55E-05	0.1	1.59E-05	0.1
R10	11	0.000857	0.95	0.000857	0.95	0.000201	0.74	0.000201	0.74	1.69E-05	0.11	1.71E-05	0.11
R11	12	0.00098	1.1	0.00098	1.1	0.00026	0.96	0.00026	0.96	2.51E-05	0.17	2.53E-05	0.17
R13	14	0.000933	1	0.000933	1	0.000103	0.38	0.000103	0.38	7.90E-06	0.053	7.98E-06	0.053
R14	15	0.00131	1.5	0.00131	1.5	0.000257	0.95	0.000257	0.95	1.48E-05	0.099	1.49E-05	0.099
R15	16	0.00182	2	0.00182	2	0.000266	0.99	0.000266	0.99	9.48E-06	0.063	9.50E-06	0.063
R16	18	0.00177	2	0.00177	2	0.000323	1.2	0.000323	1.2	3.36E-05	0.22	3.39E-05	0.23
R17	19	0.00188	2.1	0.00197	2.2	0.000674	2.5	0.00071	2.6	4.11E-05	0.27	4.56E-05	0.30
R18	20	0.00141	1.6	0.00141	1.6	0.000272	1	0.000272	1	1.68E-05	0.11	1.70E-05	0.11
R19	21	0.000827	0.92	0.000827	0.92	0.000179	0.66	0.000179	0.66	1.14E-05	0.076	1.15E-05	0.077
R20	22	0.00107	1.2	0.00107	1.2	0.000162	0.6	0.000162	0.6	9.29E-06	0.062	9.38E-06	0.063

Notes:

1. 1-hour and 24-hour averages based on Peak Refinery point source emissions.
2. Annual averages based on Average Refinery point source average emissions.
3. Compared to more stringent of the alternative 1-hour criteria for arsenic (1-hour average of 0.09 µg/m³).
4. Compared to more stringent of the alternative annual criteria for arsenic (annual average of 0.0027 µg/m³).

7.6.3 Chromium VI

The model results for chromium VI are displayed in Figure 7-30. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-10, and contours are presented in Section 7.6.6. The existing RSAs, as well as the new RSA10, are a contributing source of chromium VI contained in residue dust.

To assess the potential air quality impact, modelled chromium VI concentrations are compared to the following criteria:

- 1-hour average of 0.09 µg/m³ DWER (2019)
- Annual average of 0.00018 µg/m³ DWER (2019) and 0.005 µg/m³ Katestone (2023).

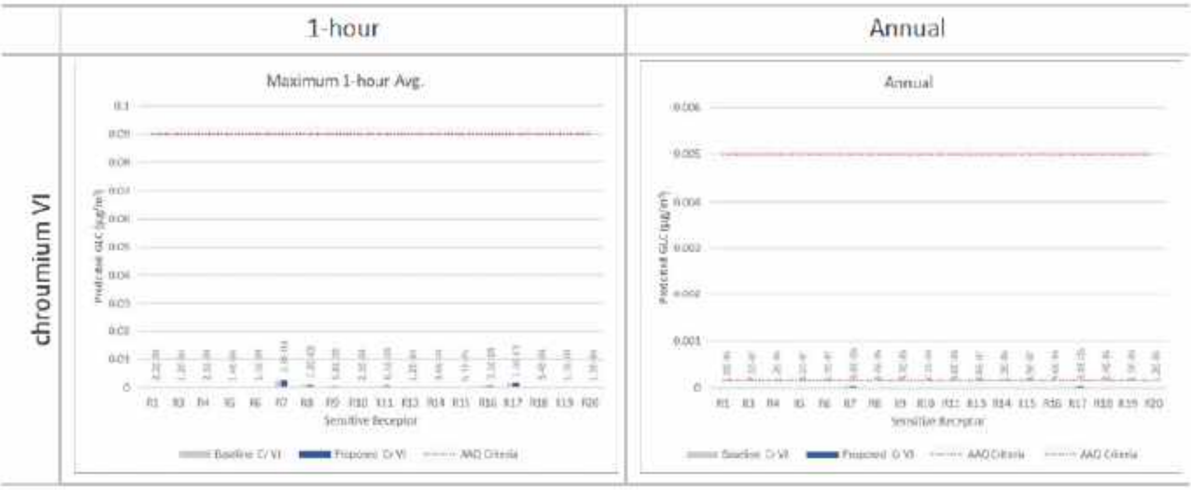


Figure 7-30: Summary of predicted chromium VI concentrations (µg/m³) – Baseline and Proposed model scenarios

The modelling results for chromium VI show:

- the maximum 1-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (3.3% or less).
- the annual average ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (22% or less of the more stringent DWER (2019) criterion).
    - the highest impacts are predicted at Receptor 7, which is located to the west of the Residue Area, approximately 3 km away.
- the RSA10 proposal results in a very small incremental increase in the predicted ground-level concentrations at the sensitive receptors, that is not significant considered in the context of the assessment criteria.

Table 7-10: Summary of Model Results at Discrete Receptors – Chromium VI

Statistic		1-hour [1] Maximum				Annual Average [2]			
Model scenario		Baseline		Proposed		Baseline		Proposed	
Receptor ID	Model Receptor	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria [3]	$\mu g/m^3$	% of Criteria [3]
R1	1	0.000188	0.21	0.00022	0.24	9.55E-07	0.53	1.03E-06	0.57
R3	3	0.000099	0.11	0.000116	0.13	6.57E-07	0.37	7.08E-07	0.39
R4	4	0.000211	0.23	0.000248	0.28	1.15E-06	0.64	1.23E-06	0.68
R5	5	0.000125	0.14	0.000137	0.15	7.61E-07	0.42	8.12E-07	0.45
R6	6	0.000141	0.16	0.000154	0.17	6.28E-07	0.35	6.68E-07	0.37
R7	8	0.00268	3	0.00293	3.3	3.32E-05	18	3.99E-05	22
R8	9	0.00087	0.97	0.00102	1.1	2.95E-06	1.6	3.44E-06	1.9
R9	10	0.000504	0.56	0.000504	0.56	4.38E-06	2.4	4.69E-06	2.6
R10	11	0.000244	0.27	0.00025	0.28	1.99E-06	1.1	2.14E-06	1.2
R11	12	0.000595	0.66	0.000651	0.72	2.80E-06	1.6	2.95E-06	1.6
R13	14	0.000114	0.13	0.000118	0.13	7.98E-07	0.44	8.61E-07	0.48
R14	15	0.000283	0.31	0.000297	0.33	1.18E-06	0.66	1.25E-06	0.69
R15	16	0.0000612	0.068	6.14E-05	0.068	3.70E-07	0.21	3.89E-07	0.22
R16	18	0.000691	0.77	0.000753	0.84	4.42E-06	2.5	4.60E-06	2.6
R17	19	0.00147	1.6	0.00154	1.7	2.62E-05	15	2.97E-05	17
R18	20	0.000338	0.38	0.000343	0.38	2.27E-06	1.3	2.42E-06	1.3
R19	21	0.000172	0.19	0.000172	0.19	1.33E-06	0.74	1.45E-06	0.81
R20	22	0.000129	0.14	0.000134	0.15	1.08E-06	0.6	1.15E-06	0.64

Notes:

1. 1-hour averages based on Peak Refinery point source emissions.
2. Annual averages based on Average Refinery point source average emissions.
3. Compared to more stringent of the alternative annual criteria for chromium VI (annual average of 0.00018 $\mu g/m^3$).

7.6.4 Mercury

The model results for mercury are displayed in Figure 7-29. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-9, and contours are presented in Section 7.6.6. The existing RSAs, as well as the new RSA10, are a contributing source of mercury, contained in residue dust (as mercury particulate) and identified as a source of mercury vapour.

To assess the potential air quality impact, modelled mercury concentrations (as sum of particulate and vapour forms) are compared to the following criteria:

- 1-hour average of 0.6 $\mu g/m^3$ Katestone (2023) and 0.55 $\mu g/m^3$ (DWER, 2019) for mercury (inorganic), or 0.18 $\mu g/m^3$ Katestone (2023) for mercury (organic)
- annual average of 0.18 $\mu g/m^3$ (DWER, 2019) and 0.03 $\mu g/m^3$ Katestone (2023).

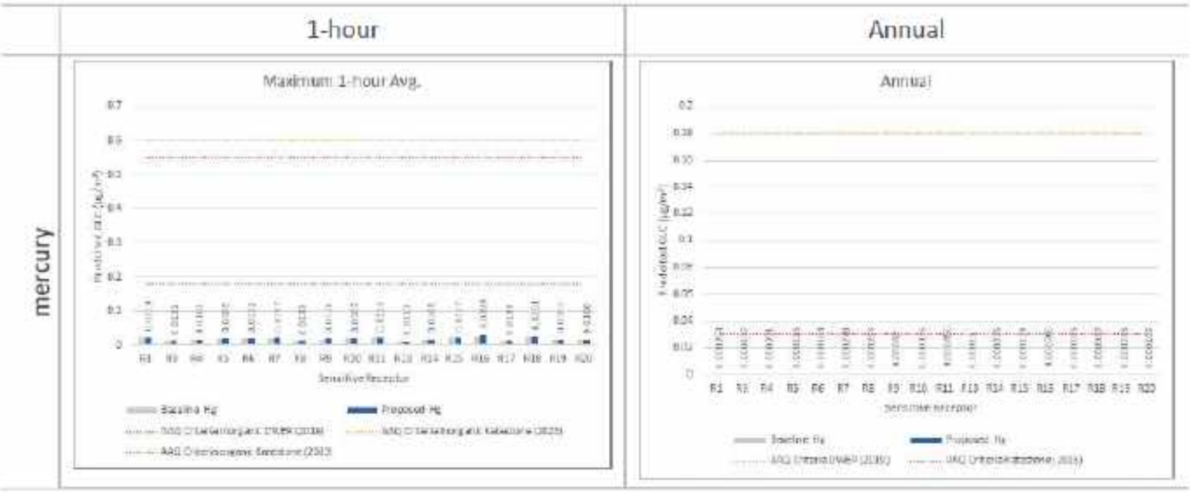


Figure 7-31: Summary of predicted mercury concentrations (µg/m³) – Baseline and Proposed model scenarios

The modelling results for mercury show:

- the maximum 1-hour ground-level concentrations predicted at the sensitive receptors are:
  - **below** the mercury (inorganic) assessment criteria for the Baseline and Proposed model scenarios (5.2% or less of the more stringent DWER (2019) criterion).
  - **below** the mercury (organic) assessment criteria for the Baseline and Proposed model scenarios (16% or less).
- the annual average ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (2.4% or less of the more stringent Katestone (2023) criterion).
- the RSA10 proposal results in a very small incremental increase in the predicted ground-level concentrations at the sensitive receptors, that is not significant considered in the context of the assessment criteria.

Table 7-11: Summary of Model Results at Discrete Receptors – Mercury

Statistic		1-hour [1]						Annual Average [2]			
		Maximum									
Model scenario		Baseline			Proposed			Baseline		Proposed	
Receptor ID	Model Receptor	µg/m^3	% of Criteria [3] mercury (inorganic)	% of Criteria mercury (organic)	µg/m^3	% of Criteria [3] mercury (inorganic)	% of Criteria mercury (organic)	µg/m^3	% of Criteria [4]	µg/m^3	% of Criteria [4]
R1	1	0.0219	4	12	0.0219	4	12	0.000254	0.85	0.000259	0.86
R3	3	0.013	2.4	7.2	0.0131	2.4	7.3	0.000153	0.51	0.000157	0.52
R4	4	0.016	2.9	8.9	0.0161	2.9	8.9	0.000285	0.95	0.000291	0.97
R5	5	0.0185	3.4	10	0.0185	3.4	10	0.00015	0.50	0.000156	0.52
R6	6	0.0171	3.1	9.5	0.0171	3.1	9.5	0.000162	0.54	0.000164	0.55
R7	8	0.0188	3.4	10	0.0197	3.6	11	0.000214	0.71	0.000248	0.83
R8	9	0.0133	2.4	7.4	0.0133	2.4	7.4	0.000225	0.75	0.000265	0.88
R9	10	0.0159	2.9	8.8	0.0176	3.2	9.8	0.000401	1.3	0.00042	1.4
R10	11	0.0183	3.3	10	0.0187	3.4	10	0.000308	1	0.000315	1.1
R11	12	0.0214	3.9	12	0.0214	3.9	12	0.000449	1.5	0.000456	1.5
R13	14	0.0111	2	6.2	0.0111	2	6.2	0.000127	0.42	0.00013	0.43
R14	15	0.0165	3	9.2	0.0165	3	9.2	0.000212	0.71	0.000215	0.72
R15	16	0.0217	3.9	12	0.0217	3.9	12	0.000114	0.38	0.000115	0.38
R16	18	0.027	4.9	15	0.0284	5.2	16	0.000688	2.3	0.000705	2.4
R17	19	0.0119	2.2	6.6	0.0133	2.4	7.4	0.000165	0.55	0.000185	0.62
R18	20	0.0261	4.7	15	0.0261	4.7	15	0.0003	1	0.000317	1.1
R19	21	0.0164	3	9.1	0.0167	3	9.3	0.000234	0.78	0.000245	0.82
R20	22	0.0159	2.9	8.8	0.016	2.9	8.9	0.000188	0.63	0.000195	0.65

Notes:

1. 1-hour and 24-hour averages based on Peak Refinery point source emissions.
2. Annual averages based on Average Refinery point source average emissions.
3. Compared to more stringent of the alternative 1-hour criteria for mercury (inorganic) (1-hour average of 0.55 µg/m^3).
4. Compared to more stringent of the alternative annual criteria for mercury (annual average of 0.03 µg/m^3).

7.6.5 Nickel

The model results for nickel are displayed in Figure 7-32. Tabulated results of predicted ground-level concentrations at discrete sensitive receptors are summarised in Table 7-12, and contours are presented in Section 7.6.6. The existing RSAs, as well as the new RSA10, are a contributing source of nickel, contained in residue dust.

To assess the potential air quality impact, modelled nickel concentrations are compared to the following criteria:

- 1-hour average of 0.18 μg/m³ (DWER, 2019) and 0.2 μg/m³ Katestone (2023)
- 24-hour average of 0.14 μg/m³ (DWER, 2019)
- annual average of 0.003 μg/m³ (DWER, 2019) and 0.014 μg/m³ Katestone (2023).

Figure 7-32: Summary of predicted nickel concentrations (μg/m³) – Baseline and Proposed model scenarios

The modelling results for nickel show:

- the maximum 1-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (8.6% or less of the more stringent DWER (2019) criterion).

  - the highest impacts are predicted at Receptor 15, which is located to the east of the Refinery, approximately 2 km away.
- the maximum 24-hour ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (1.3% or less).
- the annual average ground-level concentrations predicted at the sensitive receptors are **below** the assessment criteria for the Baseline and Proposed model scenarios (3.7% or less of the more stringent DWER (2019) criterion).
- the RSA10 proposal results in a very small incremental increase in the predicted ground-level concentrations at the sensitive receptors, that is not significant considered in the context of the assessment criteria.

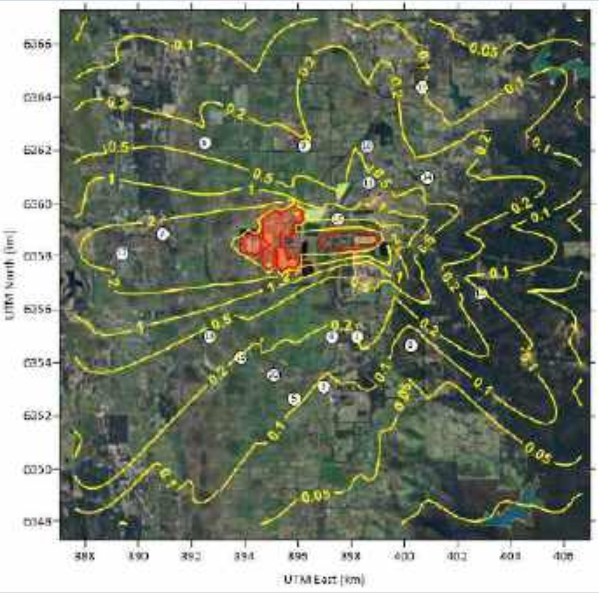
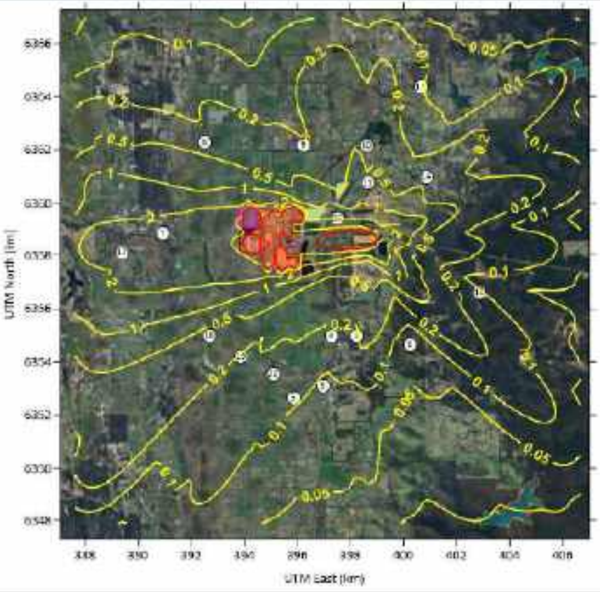
Table 7-12: Summary of Model Results at Discrete Receptors – Nickel

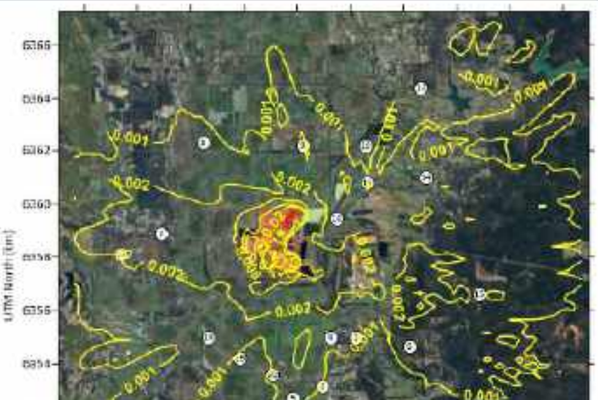
Statistic		1-hour[1]				24-hour[1]				Annual Average[2]			
		Maximum				Maximum							
Model scenario		Baseline		Proposed		Baseline		Proposed		Baseline		Proposed	
Receptor ID	Model Receptor	$\mu g/m^3$	% of Criteria[3]	$\mu g/m^3$	% of Criteria[3]	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria	$\mu g/m^3$	% of Criteria[4]	$\mu g/m^3$	% of Criteria[4]
R1	1	0.00806	4.5	0.00807	4.5	0.00142	1	0.00142	1	0.0000599	2	0.0000600	2
R3	3	0.00721	4	0.00721	4	0.00101	0.72	0.00101	0.72	0.0000303	1	0.0000304	1
R4	4	0.00784	4.4	0.00784	4.4	0.00172	1.2	0.00172	1.2	0.0000580	1.9	0.0000581	1.9
R5	5	0.0112	6.2	0.0112	6.2	0.00113	0.81	0.00113	0.81	0.0000294	0.98	0.0000295	0.98
R6	6	0.0119	6.6	0.0119	6.6	0.00164	1.2	0.00164	1.2	0.0000497	1.7	0.0000498	1.7
R7	8	0.00847	4.7	0.00847	4.7	0.00122	0.87	0.00123	0.88	0.0000785	2.6	0.0000871	2.9
R8	9	0.00696	3.9	0.00696	3.9	0.00105	0.75	0.00105	0.75	0.0000307	1	0.0000314	1
R9	10	0.00524	2.9	0.00524	2.9	0.000757	0.54	0.000757	0.54	0.0000431	1.4	0.0000435	1.5
R10	11	0.00578	3.2	0.00578	3.2	0.000944	0.67	0.000944	0.67	0.0000548	1.8	0.0000550	1.8
R11	12	0.00649	3.6	0.00649	3.6	0.00119	0.85	0.00119	0.85	0.0000846	2.8	0.0000848	2.8
R13	14	0.0064	3.6	0.0064	3.6	0.000789	0.56	0.000789	0.56	0.0000287	0.96	0.0000288	0.96
R14	15	0.0094	5.2	0.0094	5.2	0.00122	0.87	0.00122	0.87	0.0000588	2	0.0000589	2
R15	16	0.0154	8.6	0.0154	8.6	0.00181	1.3	0.00181	1.3	0.0000417	1.4	0.0000417	1.4
R16	18	0.0062	3.4	0.0062	3.4	0.00169	1.2	0.00169	1.2	0.0001100	3.7	0.0001110	3.7
R17	19	0.00596	3.3	0.00596	3.3	0.00141	1	0.00141	1	0.0000680	2.3	0.0000725	2.4
R18	20	0.0117	6.5	0.0117	6.5	0.00173	1.2	0.00173	1.2	0.0000629	2.1	0.0000631	2.1
R19	21	0.00596	3.3	0.00596	3.3	0.000931	0.67	0.000931	0.67	0.0000426	1.4	0.0000427	1.4
R20	22	0.0078	4.3	0.0078	4.3	0.00114	0.81	0.00114	0.81	0.0000344	1.1	0.0000345	1.2

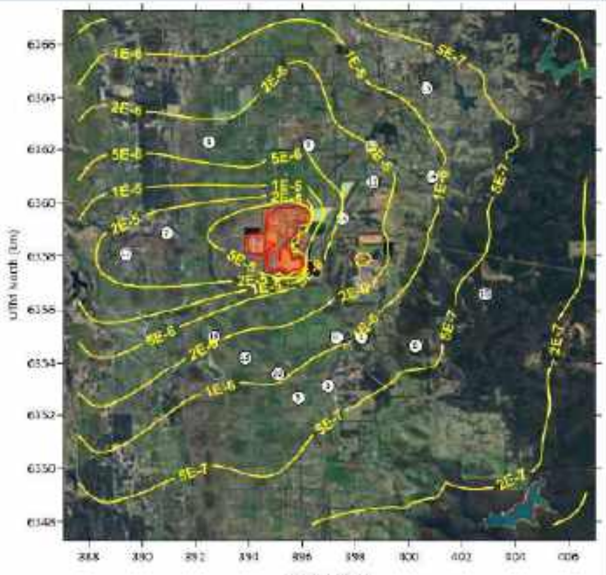
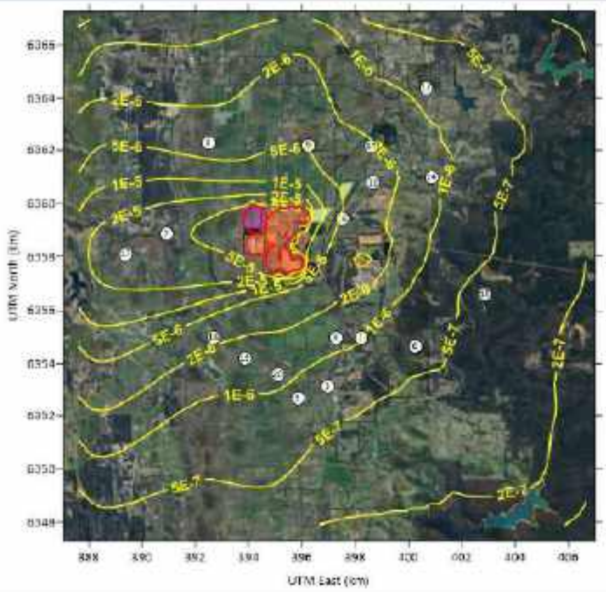
Notes:

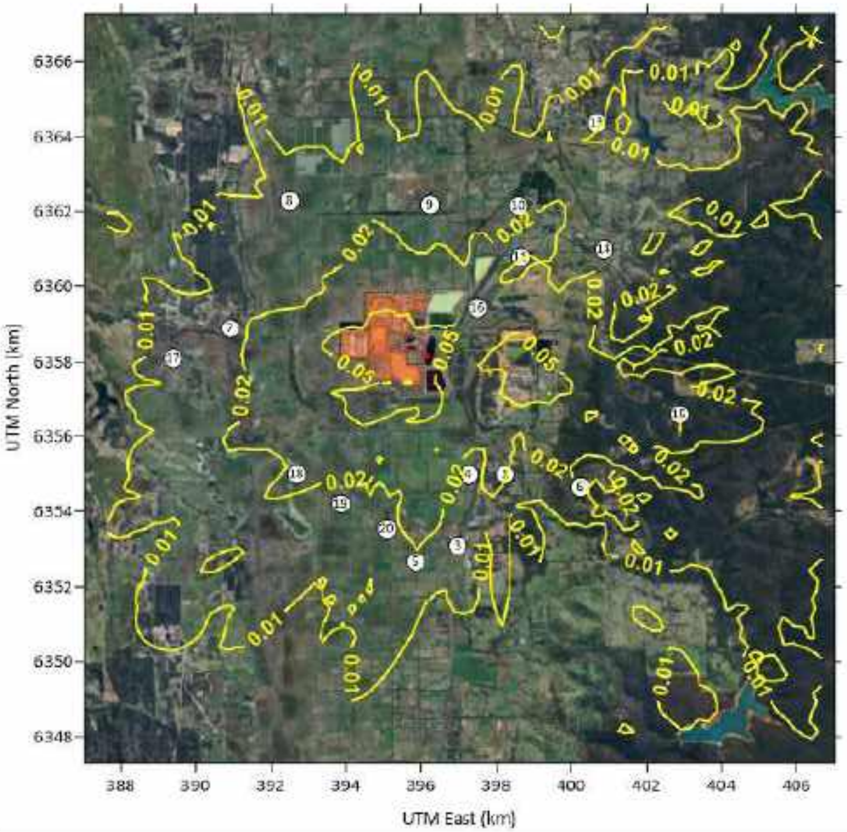
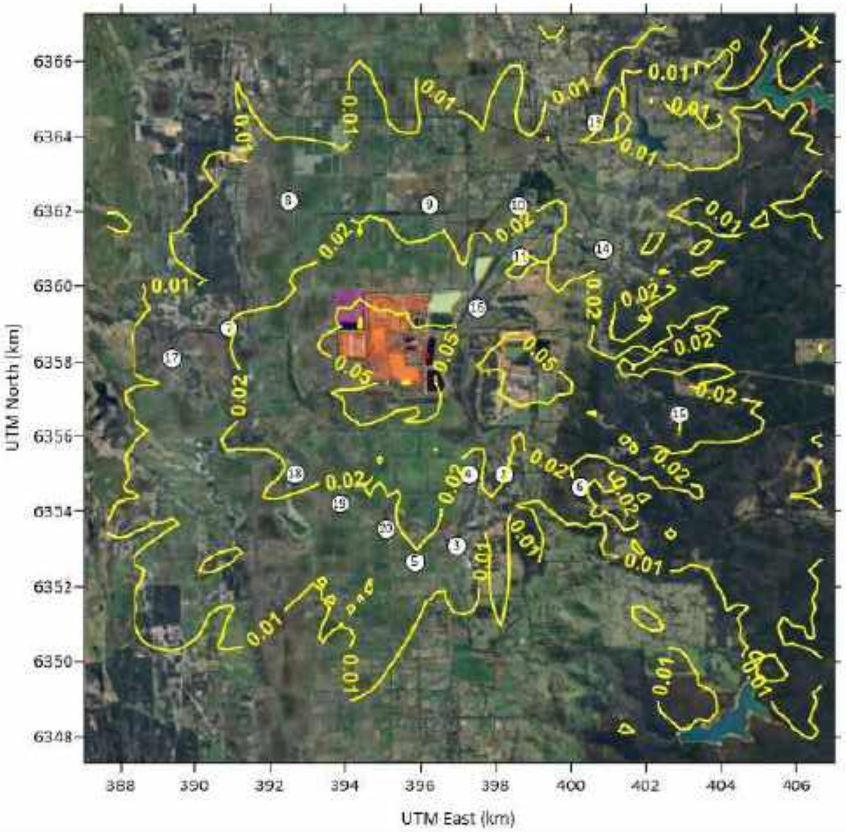
1. 1-hour and 24-hour averages based on Peak Refinery point source emissions.
2. Annual averages based on Average Refinery point source average emissions.
3. Compared to more stringent of the alternative 1-hour criteria for nickel (1-hour average of 0.18 $\mu g/m^3$).
4. Compared to more stringent of the alternative annual criteria for nickel (annual average of 0.003 $\mu g/m^3$).

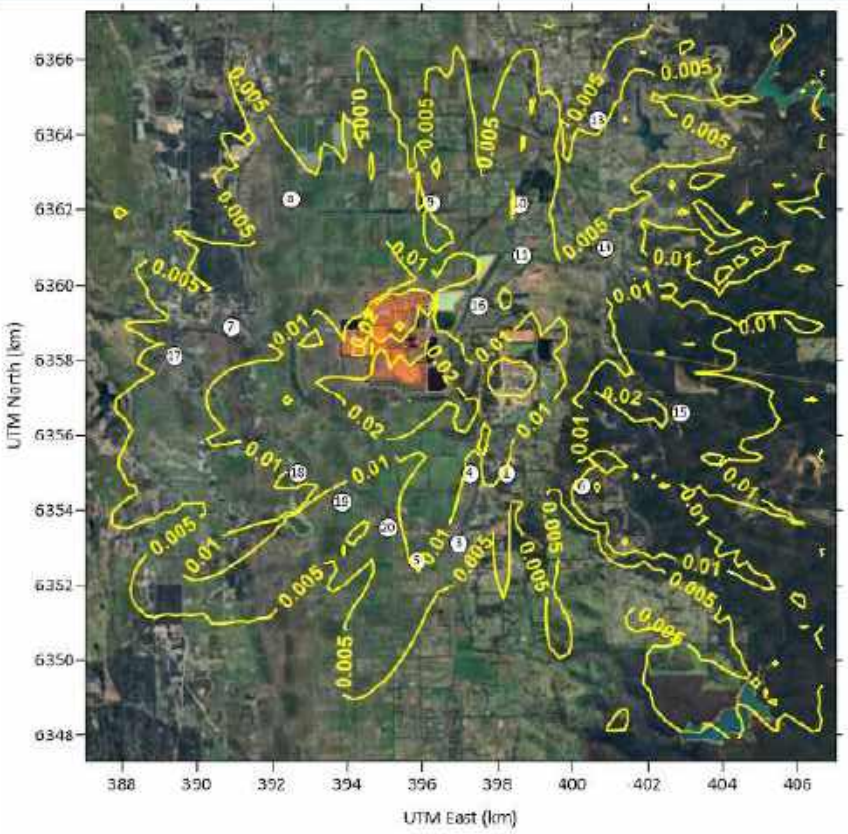
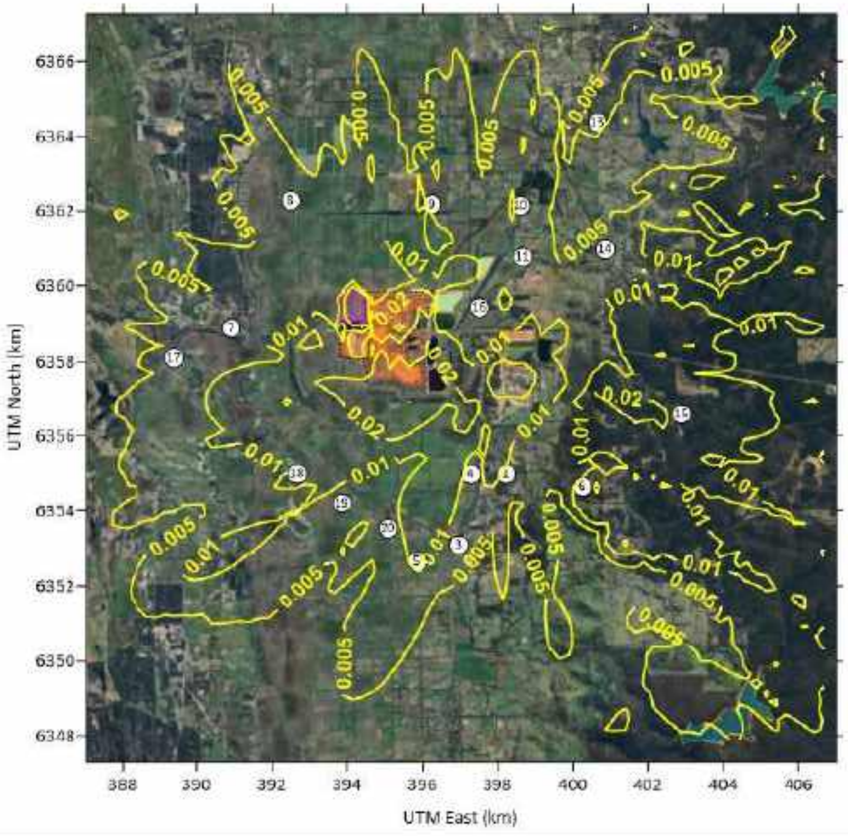
7.6.6 Concentration Contours for Trace Metals

	BASELINE	PROPOSED
Predicted GLC (µg/m³)		
	Contours shown in red represent the assessment criterion of 9.2 µg/m³ (DWER, 2019).	
	Figure 7-33: Maximum 24-hr Avg GLC contours of aluminium – Baseline	**Figure 7-34: Maximum 24-hr Avg GLC contours of aluminium – Proposed**
Pollutant	aluminium	aluminium
Statistic	24-hour Average – Maximum	24-hour Average – Maximum

	BASELINE	PROPOSED
Predicted GLC (µg/m³)		
	Contours shown in red represent the assessment criterion of 0.09 µg/m³ (DWER, 2019).	
	Figure 7-35: Maximum 1-hr Avg GLC contours of arsenic – Baseline	**Figure 7-36: Maximum 1-hr Avg GLC contours arsenic– Proposed**
Pollutant	arsenic	arsenic
Statistic	1-hour Average – Maximum	1-hour Average – Maximum

	BASELINE	PROPOSED
Predicted GLC (µg/m³)		
	Contours shown in red represent the assessment criterion of 0.00018 µg/m³ (DWER, 2019).	
	Figure 7-37: Annual Avg GLC contours of chromium VI – Baseline	Figure 7-38: Annual Avg GLC contours of chromium VI – Proposed
Pollutant	chromium VI	chromium VI
Statistic	Annual Average	Annual Average

	BASELINE	PROPOSED
Predicted GLC (µg/m³)		
	Contours shown in red represent the assessment criterion of 0.18 µg/m³ (Katestone, 2023).	
	Figure 7-39: Maximum 1-hr Avg GLC contours of mercury – Baseline	**Figure 7-40: Maximum 1-hr Avg GLC contours mercury– Proposed**
Pollutant	mercury	mercury
Statistic	1-hour Average – Maximum	1-hour Average – Maximum

	BASELINE	PROPOSED
Predicted GLC (µg/m³)		
	Figure 7-41: Maximum 1-hr Avg GLC contours of nickel – Baseline	**Figure 7-42: Maximum 1-hr Avg GLC contours nickel– Proposed**
Pollutant	nickel	nickel
Statistic	1-hour Average – Maximum	1-hour Average – Maximum

8 Predicted Dry Deposition

8.1 TSP

To assess the potential impact upon amenity (dust nuisance), modelled TSP dry deposition rates are compared to the following criteria, referenced to the draft Dust Emissions Guideline (DWER, 2021[23]):

- 2 g/m^2/month (incremental contribution above background).

The results for TSP dry deposition are presented in units of g/m^2/month[24] for reference to the criterion.

To establish some context, Figure 8-1, shows the difference in the Baseline dry deposition from the fugitive sources only (dash line) and the combined deposition from the fugitive and Refinery point sources (solid line).

---

[23] Original source used NSW EPA (2016).

[24] g/m^2/month is calculated from model output in µg/s per m^2 x (3600 x 24 x 365 s/year)/(12 month/year)/(1000,000 µg/g) = µg/s per m^2 x 2.628.(g/µg)/(s/month)

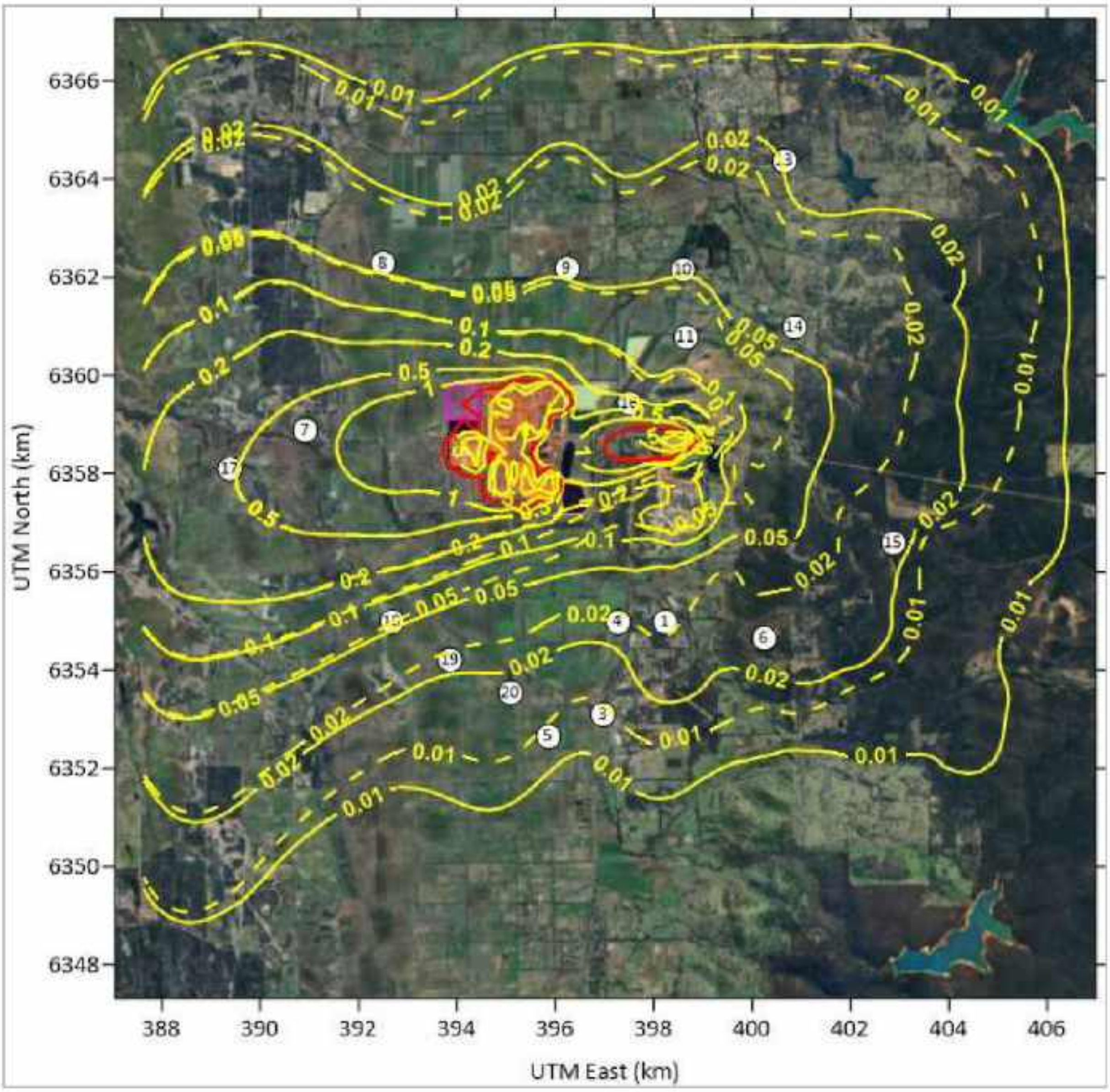


Figure 8-1: Annual average TSP dry deposition for Baseline fugitive sources only (dash line) and fugitive sources plus Refinery point sources (solid line) (g/m²/month)

Red contour shows criterion level of 2g/m²/month incremental contribution.

The contours show more difference eastwards - closer to Refinery point sources, than westwards – where the fugitive sources contributions dominate. Also, the relative magnitude between the fugitive and Refinery point source contributions appears reasonable (i.e. fugitive much larger).

The predicted TSP dry deposition at discrete receptors for the Baseline and Proposed model scenarios are shown in Table 8-1.

The modelling results for TSP dry deposition show:

- the TSP dry deposition rates predicted at the sensitive receptors are below the assessment criterion for the Baseline and Proposed model scenarios (43% or less).

- the highest impacts are predicted at Receptor 7, which is located to the west of the Residue Area, approximately 3 km away.
- the RSA10 proposal results in a small incremental increase in the predicted TSP dry deposition rates at the sensitive receptors, most evident at Receptor 7 and Receptor 17, located to the west of the Residue Area. Otherwise, at the remaining sensitive receptors, the incremental increase is not predicted to be significant considered in the context of the assessment criteria.

Table 8-1: Summary of Model Results at Discrete Receptors – TSP dry deposition

Statistic		Annual			
Model scenario		**Baseline**		**Proposal**	
Receptor ID	**Model Receptor**	**g/m²/month**	**% of Criteria**	**g/m²/month**	**% of Criteria**
R1	1	0.0332	1.7	0.0345	1.7
R3	3	0.0129	0.65	0.0135	0.68
R4	4	0.0253	1.3	0.0263	1.3
R5	5	0.012	0.6	0.0124	0.62
R6	6	0.0287	1.4	0.0295	1.5
R7	8	0.707	35	0.851	43
R8	9	0.0421	2.1	0.0465	2.3
R9	10	0.0453	2.3	0.0501	2.5
R10	11	0.0481	2.4	0.0506	2.5
R11	12	0.0758	3.8	0.0781	3.9
R13	14	0.0197	0.99	0.0208	1
R14	15	0.0445	2.2	0.0456	2.3
R15	16	0.0222	1.1	0.0226	1.1
R16	18	0.257	13	0.259	13
R17	19	0.479	24	0.545	27
R18	20	0.0578	2.9	0.0591	3
R19	21	0.0229	1.1	0.0242	1.2
R20	22	0.0174	0.87	0.0181	0.91

9 Summary

Alcoa proposes to construct and operate a new RSA (RSA10) that will provide approximately 45 Ha of drying area. This is required to maintain the residue storage and drying capacity to meet the requirements of the Refinery. No change to the permitted alumina production rate of the Refinery (2.9 Mtpa) is being sought by Alcoa as part of the RSA10 proposal.

The construction of new RSAs to the west of the current Residue Area footprint forms part of the Alcoa (2020) Long Term Residue Management Strategy. It is necessary to periodically construct new RSAs to replenish the loss in residue storage and drying capacity that occurs over time, as the perimeter embankment walls are lifted to accommodate successive layers of deposited residue and progressively move inwards.

The Wagerup Refinery operation requires approximately 205 Ha of residue drying area to sustain the permitted alumina production rate of 2.9 Mtpa, with the available drying area currently in deficit.

An air dispersion modelling study has been undertaken for the proposed addition of RSA10 to inform the assessment of potential air quality impacts of the Wagerup Refinery upon the local communities. The air dispersion modelling study incorporated site-specific meteorological data, emissions information, source characteristics, and the location of model receptors. Potential impact was evaluated through comparison to relevant ambient air quality assessment criteria protective of human health.

The emphasis of the emission estimation and modelling is on the potential impact from the operating phase of the RSA10 proposal. Impacts from RSA10 construction activities[25] are excluded from the assessment due to their short-term duration and on the basis that the construction methods implemented by Alcoa will incorporate appropriate dust management practices.

The scope of the modelling assessment is summarised below.

Modelled meteorological period	1 June 2021 to 31 May 2022. This is the 12-month period corresponding to the Residue Dust Monitoring and Composition Study (Ecotech, 2022) (ETA, 2023b).
Meteorological data	Three-dimensional prognostic meteorological data developed using the Weather Research and Forecasting (WRF) model.
Model selection	CALMET/CALPUFF model suite, coupled with WRF prognostic meteorological data.

---

[25] RSA10 construction refers to the activities that will be initially undertaken to establish the RSA (clearing, earthworks, under-drainage, etc), as opposed to the ongoing embankment construction required to periodically raise the height of the embankment walls (incorporated in the emission estimation and modelling of RSAs).

Key pollutants for airborne concentrations	• Particulate Matter (PM) –PM_{10} and $PM_{2.5}$ size fractions • Products of combustion – NO_2 • Inorganic compounds – ammonia (NH_3) • Volatile Organic Compounds (VOCs) – acetaldehyde, acetone and formaldehyde • Trace metals – aluminium (Al), arsenic (As), chromium VI (Cr VI), mercury (Hg), and nickel (Ni).
Key pollutants for dry deposition	• PM – Total Particulate Matter (TSP).
Background Air Quality	Consistent with previous modelling studies of the Wagerup Refinery and the Refinery's current licence conditions, background concentrations have not been added to the predicted ground-level concentrations for evaluation against the relevant assessment criteria.
Project Emissions	• Refinery point source (stack and vent) emissions – forecast from the Wagerup 2021 Emission Inventory (Alcoa, 2022), scaled to represent emissions from the Refinery at the operating capacity of 2.9 Mtpa of alumina as permitted under the environmental licence. • Fugitive particulate sources – Residue Area and bauxite stockpile wind erosion and activity related emissions. • Fugitive vapour sources – Residue Area, comprised of RSAs and cooling water circuit emissions.
Sensitive Receptors	Discrete sensitive receptor locations were nominated in a review by Katestone (2023a), to represent the local communities of Yarloop, Hamel and Waroona and individual residences. These discrete receptors have consequently been updated from the previous modelling assessments for the Wagerup Refinery.
Model Scenarios	The predicted impacts were considered for the Wagerup Refinery only (in isolation), for the following model scenarios: • **Baseline** - the current emissions status of the Wagerup Refinery at the operating capacity of 2.9 Mtpa of alumina as permitted under the environmental licence. • **Proposed** - The current emissions status of the Wagerup Refinery at the operating capacity of 2.9 Mtpa of alumina, with the addition of RSA10 following commissioning

9.1 Key Findings

The key findings of the air dispersion modelling assessment conducted for the RSA10 proposal are outlined below.

RSA10 Emission Contribution

Considered on an annual basis (kg/yr), the RSA10 proposal is estimated to result in relatively minor increases in total Wagerup Refinery emissions of particulate matter (as TSP, PM_{10} and $PM_{2.5}$) (8%), VOCs (<1%) and trace metals (<5%, except for chromium VI). Chromium VI emissions exhibit the highest percentage increase (11.6%), with the RSAs the principal emission source.

There is no change in NOx and ammonia emissions associated with the RSA10 proposal, as the existing RSAs, as well as the new RSA10, are not identified as a source of these pollutants.

Evaluation of Model Performance

This study included an evaluation of model performance, with the predicted ground-level concentrations of particulate matter (as TSP and PM_{10}) compared to the continuous ambient monitoring undertaken over the study period. The comparison of the predicted and measured concentrations can be used to assess the bounds of uncertainty in predicted air quality impacts from the RSA10 proposal, for consideration in risk-based decisions regarding potential air quality impacts from the Wagerup Refinery.

The evaluation of model performance for particulate matter shows good correspondence with measured TSP and PM_{10} concentrations across the monitoring network, generally within a factor-of-two (0.5 to 2), the range for accepted model performance. The model's performance at the monitoring site most representative of potential increased impacts from the addition of RSA10 (RW) is most critical for this proposal. At this site, the model shows very good correspondence with the 24-hour average PM_{10} concentration measurements, under-predicting the maximum statistic (0.82) and over-predicting the annual average (1.48).

The overall evaluation of model performance also demonstrates the methodology used for fugitive particulate emissions, most notably for wind erosion from the RSAs, provides credible estimates for use as inputs to the modelling.

Predicted Air Quality Impacts

Predicted ground-level concentrations are compared to the adopted ambient air quality assessment criteria for the Baseline and Proposed model scenarios. This is intended to provide an objective evaluation of the potential air quality impact of the Wagerup Refinery upon the local communities. Table 9-1 presents a summary of the model results compared to the adopted assessment criteria for the maximally impacted sensitive receptor locations.

The potential air quality impacts associated with PM_{10} emissions from the RSA10 proposal are most significant, in that the predicted ground-level concentrations for the Proposed model scenario most closely approach the relevant ambient air quality assessment criteria. Similarly, in the context of the RSA10 proposal, other pollutants of significance also include $PM_{2.5}$, formaldehyde, aluminium and chromium VI.

The modelling results for PM_{10} show:

- the highest impacts are predicted at Receptor 7, which is located to the west of the Residue Area, approximately 3 km away,
- the maximum 24-hour average ground-level concentration predicted at Receptor 7 is **above** the assessment criterion for the Proposed model scenario (114% of criterion), however the 2nd highest 24-hour average ground-level concentration is **below** the assessment criterion (85% of criterion),
- the annual average ground-level concentration predicted at Receptor 7 is **below** the assessment criterion for the Proposed model scenario (11% of criterion).

The modelling results for $PM_{2.5}$ show:

- the highest impacts are predicted at Receptor 7,
- the maximum and 2nd highest 24-hour average ground-level concentrations predicted at Receptor 7 are **below** the assessment criterion for the Proposed model scenario (50% and 37% of criterion, respectively),
- the annual average ground-level concentration predicted at Receptor 7 is **below** the assessment criterion for the Proposed model scenario (8.3% of criterion).

The modelling results for formaldehyde show:

- the highest impacts are predicted at Receptor 18, which is located to the southwest of the Residue Area, approximately 3.5 km away,
- it is only the maximum 1-hour average ground-level concentrations compared to the corresponding criterion (20 µg/m³) that are of significance, noting the impacts are predicted to remain **below** the assessment criterion (16%) for the Baseline and Proposed model scenarios.

The modelling results for aluminium show:

- the highest impacts are predicted at Receptor 7,
- the maximum 24-hour average ground-level concentration predicted at Receptor 7 is **below** the assessment criterion for the Proposed model scenario (32% of criterion).

The modelling results for chromium VI show:

- the highest impacts are predicted at Receptor 7,
- it is only the annual average ground-level concentrations compared to the more stringent corresponding criterion (0.00018 µg/m³) that are of significance, noting the impacts are predicted to remain **below** the assessment criterion (18% and 22%) for the Baseline and Proposed model scenarios, respectively.

At Receptor 7, the maximally impacted sensitive receptor location, the RSA10 proposal results in an incremental increase in the maximum predicted 24-hour average ground-level concentrations of PM_{10} (14.8%), $PM_{2.5}$ (14.8%) aluminium (7.8%), and the annual average ground-level concentrations of chromium VI (20.2%).

Overall Assessment of Potential Impact

Overall, the model results show that emissions of the relevant pollutants of interest from the Wagerup Refinery only (in isolation) for the Proposed model scenario (addition of RSA10), lead to ground-level concentrations that are **below** the assessment criteria, except for the maximum 24-hour PM_{10} concentrations predicted at Receptor 7 (114% of criterion).

Receptor 7 is the maximally impacted discrete sensitive receptor, which is located to the west of the Residue Area, approximately 3 km away, and downwind of the Residue Area under strong easterly winds that are dominant during the summer. With the drier summer months, comes an increase in the potential for wind-erosion from the surface of the RSAs to generate fugitive dust emissions.

The RSA10 proposal results in an incremental increase (above Baseline) in the maximum predicted 24-hour average ground-level concentrations of PM_{10} (14.8%), $PM_{2.5}$ (14.8%), and the associated trace metals present in residue dust, particularly evident at Receptor 7.

The modelling assessment highlights the potential for elevated ground-level concentrations of PM_{10}, and to a lesser extent $PM_{2.5}$, to adversely impact upon Receptor 7, for both the current operations (Baseline model scenario) and with the addition of RSA10 (Proposed model scenario). The predicted impacts occur as a result of fugitive wind-blown dust emissions from the Residue Area under extreme adverse weather conditions. To manage these potential impacts continued emphasis must be placed on ensuring the ongoing effectiveness of Alcoa's dust management strategy.

Table 9-1: Summary of Model Results

Pollutant		Statistic		Maximum Receptor	Predicted GLC (µg/m³)		Criteria (µg/m³)		% of Criteria	
					Baseline	Proposed	DWER (2019) [or NEPC (2021) as noted][1]	Katestone (2023)	Baseline	Proposed
Particulates	PM_{10}	24-h	Max	7	45.8	52.6	46		99.6	114
		24-h	2nd	7	31.4	39.0			68	85
		Annual	Avg	7	2.24	2.63	23		9.7	11
	$PM_{2.5}$	24-h	Max	7	10.1	11.6	23		44 [56]	50 [64]
		24-h	2nd	7	6.92	8.59	[18][1]		30 [38]	37 [48]
		Annual	Avg	7	0.497	0.583	7 [6][1]		7.1 [8.3]	8.3 [9.7]
Combustion Products	NO_2	1-h	Max	15	29.7	29.7	151		20	20
		Annual	Avg	16	0.639	0.639	28		2.3	2.3
Inorganic Compounds	ammonia	1-h	Max	16	164	164	330		50	50
		24-h	Max	16	29.8	29.8		1,290	2.3	2.3
		Annual	Avg	16	2.5	2.5		76	3.3	3.3
VOCs	acetaldehyde	1-h	Max	16	9.81	9.81		470	2.1	2.1
		24-h	Max	16	1.97	1.97	1,830		0.11	0.11
		Annual	Avg	16	0.0812	0.0817		9	0.90	0.91
							46		0.18	0.18
	acetone	1-h	Max	16	23.3	23.3	22,000		0.11	0.11
		24-h	Max	16	4.13	4.13		20,740	0.02	0.02
	formaldehyde	1-h	Max	18	3.14	3.14	20		16.0	16.0
		24-h	Max	18	0.429	0.430		53.6	0.8	0.8
		Annual	Avg	16	0.0184	0.0186		9	0.20	0.21

Pollutant		Statistic		Maximum Receptor	Predicted GLC (µg/m³)		Criteria (µg/m³)		% of Criteria	
					Baseline	Proposed	DWER (2019) [or NEPC (2021) as noted]¹	Katestone (2023)	Baseline	Proposed
Trace Metals	Aluminium	24-h	Max	7	2.8	3.02	9.2		30	33
	Arsenic	1-h	Max	7	0.00343	0.00374		0.2	1.7	1.9
							0.09		3.8	4.2
		24-h	Max	7	0.000877	0.00103	0.027		3.2	3.8
		Annual	Avg	7	5.06E-05	5.92E-05		0.015	0.34	0.39
							0.0027		1.87	2.19
	Chromium VI	1-h	Maximum	7	0.00268	0.00293	0.09		3.0	3.3
		Annual	Average	7	3.32E-05	3.99E-05		0.005	0.66	0.80
							0.00018		18	22
	Mercury	1-h	Maximum	16	0.0270	0.0284		0.6 inorganic	4.5	4.7
							0.55 inorganic		4.9	5.2
								0.18 organic	15	16
		Annual	Average	16	6.9E-04	7.0E-04		0.030	2.3	2.4
							0.18		0.38	0.39
	Nickel	1-h	Maximum	15	0.0154	0.0154		0.2	7.7	7.7
							0.18		8.6	8.6
		24-h	Maximum	15	0.00181	0.00181	0.14		1.3	1.3
		Annual	Average	16	0.0001100	0.0001110		0.014	0.8	0.8
							0.003		3.7	3.7

Notes:

1. To inform the assessment regarding anticipated future regulatory requirements, reference is also made to the increasingly more stringent standards for $PM_{2.5}$ that apply from 2025 under the Ambient Air Quality NEPM (NEPC, 2021).

10 References

Alcoa (2022). Wagerup 2021 Emission Inventory. Alcoa of Australia Ltd, September 2022.

Alcoa (2020). 2017 Wagerup Alumina Refinery Long Term Residue Management Strategy (LTRMS). Alcoa of Australia Ltd, 9 April 2020.

Alcoa (2020a). Briefing Note – Background to the Treatment of Metals and Metallic Compounds in fugitive dust from RSA's, 2018 Wagerup Emissions Inventory and 2020 Health Risk Assessment, Internal Document. Alcoa of Australia Ltd, April 2020.

Air Assessments (2017). Wagerup Alumina Refinery Air Quality Modelling Evaluation of Alternate Prognostic Winds, Final. Air Assessments, October 2017.

Air Assessments (2015). Wagerup Alumina Refinery 2014 Air Quality Modelling. Prepared for Alcoa of Australia Limited, Final. Air Assessments, December 2015.

Air Assessments (2008). Evaluation of Residue Dust Emissions Pinjarra and Kwinana Refineries. Prepared for Alcoa World Alumina, Australia. Air Assessments, May 2008.

Air Assessments (2005). Air Dispersion Modelling of Fugitive Emissions. Wagerup Refinery. Appendix D in Appendix G of ENVIRON (2005). Wagerup Refinery Unit Three Expansion, Environmental Review and Management Program. May 2005.

ATSDR (2022). Acetone - ToxFAQs™. Agency for Toxic Substances and Disease Registry, June 2022.
https://wwwn.cdc.gov/TSP/ToxFAQs/ToxFAQsDetails.aspx?faqid=4&toxid=1

ATSDR (2022). Toxicological Profile for Mercury, Draft for Public Comment. Agency for Toxic Substances and Disease Registry, April 2022.

ATSDR (2012). Public Health Statement Chromium CAS # 7440-47-3. Agency for Toxic Substances and Disease Registry, September 2012.
https://wwwn.cdc.gov/TSP/PHS/PHS.aspx?phsid=60&toxid=17#bookmark05

ATSDR (2008). Public Health Statement Formaldehyde CAS # 50-00-0. Agency for Toxic Substances and Disease Registry, September 2008.
https://wwwn.cdc.gov/TSP/PHS/PHS.aspx?phsid=218&toxid=39

ATSDR (2008). Public Health Statement Aluminum CAS # 7429-90-5. Agency for Toxic Substances and Disease Registry, September 2008.
https://wwwn.cdc.gov/TSP/PHS/PHS.aspx?phsid=1076&toxid=34

ATSDR (2007). Public Health Statement Arsenic CAS # 7440-38-2. Agency for Toxic Substances and Disease Registry, August 2007.
https://wwwn.cdc.gov/TSP/PHS/PHS.aspx?phsid=18&toxid=3

ATSDR (2005). Public Health Statement Nickel CAS # 7440-02-0. Agency for Toxic Substances and Disease Registry, August 2005.
https://wwwn.cdc.gov/TSP/PHS/PHS.aspx?phsid=243&toxid=44

ATSDR (2004). Division of Toxicology ToxFAQs™ Ammonia CAS # 7664-41-7. Agency for Toxic Substances and Disease Registry, September 2004. https://wwwn.cdc.gov/TSP/ToxFAQs/ToxFAQsDetails.aspx?faqid=10&toxid=2

Barclay, J., and Scire, J. (2011). Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the 'Approved Methods for the Modelling and Assessments of Air Pollutants in NSW, Australia', March 2011.

Briggs, G.A. (1975). Chapter 3, Plume Rise Predictions. pp 59-111 in: Lectures on Air Pollution and Environmental Impact Analysis. (Duane A. Haugen, Ed.) Am. Meteororl. Soc. Boston, MA. 296 pp.

CSIRO (2008). A Study of VOCs during Winter 2006 at Wagerup, Western Australia. A report to Alcoa World Alumina Australia. CSIRO, 2 June 2008.

DWER (2021) Guideline: Dust Emissions. Draft for external consultation. Department of Water and Environment Regulation, July 2021.

DWER (2019). Guideline: Air Emissions. Draft for external consultation. Department of Water and Environment Regulation, October 2019.

DoE (2006). Air Quality Modelling Guidance Notes. Department of Environment, Western Australia.

Department of Health (DoH) & Duffus J (2009). Assessment of the potential for health problems associated with the export of sulfidic nickel concentrate through the Port of Esperance, Perth, Western Australia.

Ecotech (2022). Wagerup Dust Study – Wagerup Residue Storage Area 10 (RSA 10). Ecotech Pty Ltd, 23 September 2022.

Ecotech (2022a). Volatile Organic Compounds Sampling Using Method TO-17 Report for Wagerup Refinery. Ecotech Pty Ltd, 5 July 2022.

Emission Assessments (2023). Emission Assessments Pty Ltd. Report Number: 2223-172. Alcoa Australia - Wagerup. 2023 Q1 Total Particulate Matter - Particle Size Distribution. Version Number: 1.0. Final. 20-Jun-23. ATTENTION: Mark Ferron.Emission Assessments (2022). Emission Assessments Pty Ltd. Report Number: 1920-202. Alcoa Australia – Wagerup Refinery Inventory Program Part B & D 2020, 3 October 2022. ATTENTION: Maya Hogarth.

Emission Assessments (2020). Emission Assessments Pty Ltd. Report Number: 1920-202. Alcoa Australia – Wagerup Refinery Inventory Program Part A 2020, 29 May 2020. ATTENTION: Maya Hogarth.ETA (2020a). Wagerup Alumina Refinery Air Quality Modelling, Phase 2 Study, Prepared for Alcoa of Australia. Environmental Technologies & Analytics Pty Ltd, 7 July 2020.

ETA (2020b). Wagerup Alumina Refinery Phase 3 – Fugitive Source VOCs Modelling Technical Memorandum, Prepared for Alcoa of Australia. Environmental Technologies & Analytics Pty Ltd, March 2020.

ETA (2022). Wagerup Alumina Refinery WRF Model Evaluation, Final Report, Prepared for Alcoa of Australia. Environmental Technologies & Analytics Pty Ltd, 9 September 2022.

ETA (2022a). Alcoa Wagerup Support Air Quality Studies: Model Sensitivity Study – Comparison in the use of meteorology from WRF or surface observations, Prepared for Alcoa of Australia. Environmental Technologies & Analytics Pty Ltd, 6 September 2022.

ETA (2022g). Technical Memorandum Alcoa Wagerup Alumina Refinery: Review of Baseline Preliminary Model Results, Prepared for Alcoa of Australia. Environmental Technologies & Analytics Pty Ltd, 12 December 2022 (unpublished).

ETA (2023b). Wagerup Alumina Refinery Residue Storage Area – RSA10 Project: Dust and Composition Study, Prepared for Alcoa of Australia. Environmental Technologies & Analytics Pty Ltd, 14 March 2023.

ETA (2023c). Alcoa Wagerup Residue Area OP-FTIR Fugitive VOC Program: Estimation of Emissions, Prepared for Alcoa of Australia. Environmental Technologies & Analytics Pty Ltd, 13 March 2023.

ETA (2023d). Wagerup Alumina Refinery WRF-CALMET Model Evaluation, Prepared for Alcoa of Australia. Environmental Technologies & Analytics Pty Ltd, 7 February 2023.

ETA (2023e). Wagerup Alumina Refinery Residue Storage Area - RSA10: Residue Area Fugitive Emission Estimates and Model Validation, Prepared for Alcoa of Australia. Environmental Technologies & Analytics Pty Ltd, 14 March 2023.

Prepared for Alcoa of Australia. Environmental Technologies & Analytics Pty Ltd, EPA NSW (2017). Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, Environment Protection Authority, January 2017. Online at: https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/air/approved-methods-for-modelling-and-assessment-of-air-pollutants-in-nsw-160666.pdf?la=en&hash=D4131297808565F94E13B186D8C70E7BD02B4C3D

ENVIRON (2010). Wagerup Air Dispersion Modelling. Report prepared for Alcoa Australia Ltd. ENVIRON, November 2010.

IARC (2022). IARC Monographs on the Identification of Carcinogenic Hazards to Humans, List of Classifications. Online at: https://monographs.iarc.who.int/list-of-classifications

Katestone (2023). Wagerup Alumina Refinery – Health Endpoints Review. Prepared for: Alcoa of Australia Ltd. Katestone Environmental Pty Ltd, 20 December 2023.

Katestone (2023a). Memorandum: Review of Sensitive Receptors (Final). Client name: Alcoa of Australia Ltd. Katestone Environmental Pty Ltd, 16 June 2023.

Katestone (2021). Wagerup Alumina Refinery Expansion – Health Risk Assessment 2020. Prepared for: Alcoa of Australia Ltd. Katestone Environmental Pty Ltd, 25 March 2021.

Katestone (2007). Air Quality Assessment of the proposed Newgen 330 MW Gas-Fired Power Station. ERM Power Ltd. July 2007.

NSW EPA (2022). Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, NSW Environment Protection Authority, August 2022.

NSW EPA (2016). Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, NSW Environment Protection Authority.

NEPC (2021). National Environment Protection (Ambient Air Quality) Measure. Compilation No. 3. Registered 26 May 2021. National Environment Protection Council.

NEPC (2021a). Explanatory Statement for the National Environment Protection (Ambient Air Quality) Measure Variation Instrument 2021. Issued by the National Environment Protection Council, 17 May 2021.

NEPC (2015). Variation to the National Environment Protection (Ambient Air Quality) Measure. National Environment Protection Council.

NEPC (2011). National Environment Protection (Air Toxics) Measure. Compilation prepared 16 September 2011. National Environment Protection Council.

NPI (2022). National Pollutant Inventory (NPI) Fact Sheet: Acetaldehyde. Accessed 21 December 2022: https://www.dcceew.gov.au/environment/protection/npi/substances/fact-sheets/acetaldehyde#tabs-5

NPI (2022). National Pollutant Inventory (NPI) Fact Sheet: Chromium VI. Accessed 21 December 2022: https://www.dcceew.gov.au/environment/protection/npi/substances/fact-sheets/chromium-vi-compounds

Pacific Air & Environment (2007). Wagerup Refinery Unit 3 Expansion- Air Dispersion Model Investigations: Multi-Flue Plume Rise, Draft Report. Pacific Air & Environment (PEA), 24 June 2007.

Scire, J. S., Robe, F. R., Fernau, M. E., Yamartino, R. J., (2000). A User's Guide for the CALPUFF Dispersion Model (Version 5). Earth Tech Inc., Concord, Massachusetts.

Scire, J. S., Robe, F. R., Fernau, M. E., Yamartino, R. J., (2011). CALPUFF Modeling System Version 6 User Instructions. Earth Tech Inc., Concord, Massachusetts

Toxikos (2010). Air guideline values for selected substances, prepared for the Department of Environment and Conservation, Perth, Western Australia.

Toxikos (2011). Air guideline values for selected substances, prepared for the Department of Environment and Conservation, Perth, Western Australia.

USEPA (2000). Hazard Summary for Acetaldehyde. United States Environmental Protection Agency, January 2000.

US Federal Register (2017). Vol. 82, No. 10 / Tuesday, January 17, 2017 / Rules and Regulations.

USEPA (2017). EPA White Papers on Planned Updates to AERMOD Modelling System, 19 September 2017 file:///C:/Users/DP/Desktop/20170919_AERMOD_Development_White_Papers.pdf

USEPA (2016). Guideline on Air Quality Models (Appendix W to 40 CFR Part 51). U United States Environment Protection Agency, December 2016.

USEPA (1999). Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition, Compendium Method TO-17, Determination of Volatile Organic Compounds in Ambient Air Using Active Sampling onto Sorbent Tubes. EPA/625/R-96/010b. United States Environmental Protection Agency, January 1999.

11 Acronyms and Glossary

Acronym	Description
AS	Australian Standard
Al	Aluminium
As	Arsenic
BoM	Bureau of Meteorology
ATSDR	Agency for Toxic Substances and Disease Registry
C	Degrees Celsius (temperature)
Cr VI	Chromium VI
DWER	Department of Water and Environmental Regulation
EE	Emissions estimation
EET	Emissions Estimation Technique
EF	Emission factor
EPA NSW	Environmental Protection Authority New South Wales, Australia
ETA	Environmental Technologies & Analytics Pty Ltd
ERMP	Environmental Review and Management Program
GLC	Ground-level concentration
g/s	grams per second
Hg	mercury
HRA	Health Risk Assessment
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System (United States Environment Protection Agency)
kg/yr	kilograms per year
kPa	kiloPascals
km	kilometre
m	metre
m/s	metres per second
mm	millimetre
Mtpa	Million tonnes per annum
MS	Ministerial Statement
Ni	Nickel
NEPC	National Environment Protection Council
NEPM	National Environmental Protection Measure
NPI	National Pollutant Inventory
NH_3	Ammonia
NOx	Oxides of Nitrogen
NO_2	Nitrogen Dioxide
OEHHA	The Office of Environmental Health Hazard Assessment
PM	Particulate matter, small particles and liquid droplets that can remain suspended in air.
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 10 µm or less.
PM_{10}	Particulate matter with an aerodynamic diameter of 2.5 µm or less.
ppm	Parts per million
ppb	Parts per billion
PTRMS	Proton Transfer Reaction – Mass Spectrometry
RSA	Residue Storage Area. Area within the bauxite residue storage area used for the drying and storage of residue fines. This is synonymous with previous references to "RDA".
ROCP	Runoff Collection Pond
ROWS	Runoff Water Storage
TAPM	The Air Pollution Model
t/y	Tonnes per year
TSP	Total suspended particulates

Acronym	Description
$\mu g/m^3$	micro grams (one millionth of a gram) per cubic metre
USEPA	United States Environment Protection Agency

Acronym	Description
VOC	Volatile organic compounds
WHO	World Health Organisation

12 Appendices

Appendix A– Multi-flue Stack Parameters

A.1: Background

For the ERMP modelling, some of the emissions discharged via multi-flue stacks were assumed to mix and rise as a combined source. In order to satisfy the relevant requirements of MS:728, Alcoa subsequently commissioned Pacific Air & Environment (PAE, 2007) to investigate the validity of this assumption.

It was considered that, due to the influence of wind direction on flue alignments and therefore plume behaviour, and taking into account the boiler plumes, the emissions from these respective sources should be modelled as being from 23 'pseudo-sources' for which a theoretical stack configuration be assigned to each hour, based on the observed wind direction for the hour. The PAE approach was used in the Air Assessments (2017) report, in which 23 different pseudo-sources were modelled to represent the five flues in the 100 m multi-flue stack and three flues in the power station boiler multi-flue stack.

Air Assessments (2017) concluded that this modelling process is complicated, and therefore not only increases the modelling required, but also increases the likelihood of errors when modelling. The report proposed a simpler approach based on just four pseudo-sources with constant emissions. Using NOx as an indicator, the report showed that predicted GLCs were negligibly different to that using the original PAE (2007) findings, with all differences being slightly conservative.

The implication of this is that the wind direction influence on plume behaviours from the respective actual stacks and flues, is much less than that arising from the physical configuration of the multi-flue on the plume rise from the composite flues. In addition, the plume rise from the boilers could potentially be estimated using more conventional buoyancy enhancement approaches. Potential drawbacks from following this approach include that it has not been verified in the refinery context.

An approximation to the variable plume merging scheme (PAE, 2007), as recommended by Air Assessments (2017) has been adopted for this assessment, with some adjustment to the stack release parameters to account for reduced buoyancy flux, described in further detail below.

A.2: Adjustment to multi-flue stack parameters

Adjustment of the source release characteristics adopted for multi-flue stacks as an approximation to the variable plume merging scheme recommended by Air Assessments (2017) were made to account for reduced buoyancy flux.

The changes to the emissions parameters for this study are shown in Appendix Table 1.

The key parameter affecting plume rise, which is used in most dispersion models, is buoyancy flux, which can be calculated from stack diameter, emission velocity, emissions temperature and ambient temperature, using the Briggs (1975) equation. Any increases to the buoyancy flux will increase plume rise and hence decrease GLCs, while any decreases to the buoyancy flux will decrease plume rise and hence increase GLCs.

The resulting changes in buoyancy fluxes for the actual sources, and the components of the four pseudo sources determined in Air Assessments (2017) report, are shown in Appendix Table 2.

Appendix Table 2 shows that the buoyancy fluxes for the 2.9 Mtpa pseudo-source are all lower than used in Air Assessments (2017), except for:

- "Total of all Calciners" Average; and
- "Total all Boilers" Average

which were very marginally higher.

Appendix Table 1: Characteristics of Refinery multi-flue sources

Source Name	Hgt. (m)	Physical Diam. (m)	As per Air Assessments (2017)				2.9 Mtpa				Change (%)			
			Vel. (m/s)		Temp. (K)		Vel. (m/s)		Temp. (K)		Vel. (m/s)		Temp. (K)	
			Ave	Peak	Ave	Peak	Ave	Peak	Ave	Peak	Ave	Peak	Ave	Peak
Liquor Burning	100	1.10	19.6	28.8	319	340	19.7	27.5	319.1	332.0	0.3	-4.4	0.0	-2.4
Calciner 1	100	1.90	22.4	39.7	445	465	20.4	27.2	445.4	458.7	-8.8	-31.4	0.0	-1.3
Calciner 2	100	1.90	22.0	30.6	451	469	21.0	27.4	448.4	460.5	-4.8	-10.5	-0.6	-1.8
Calciner 3	100	2.15	18.3	26.2	481	499	23.5	30.3	480.5	491.7	28.4	15.9	-0.1	-1.4
Boiler 1	65	2.40	17.0	23.2	388	403	18.4	21.7	392.8	402.8	8.2	-6.3	1.2	-0.2
Boiler 2	65	2.00	17.7	23.1	388	398	20.2	24.8	409.4	415.2	14.7	7.0	5.6	4.3
Boiler 3	65	2.00	16.8	22.3	409	424	14.7	20.1	403.6	420.9	-12.7	-9.7	-1.3	-0.6

Appendix Table 2: Buoyancy fluxes for tall Refinery sources and corresponding pseudo-sources characteristics for Air Assessments (2017) and 2.9 Mtpa

Sources	Emission configuration determined from	Buoyancy Flux (m^4s^{-3}) [1] for Air Assessments (2017) parameters		Buoyancy Flux (m^4s^{-3}) [2] for 2.9 Mtpa parameters		% change	
		Avg emissions	Peak emissions	Avg emissions	Peak emissions	Avg emissions	Peak emissions
Actual sources							
Liquor Burning	-	4.8	11.8	4.8	9.6	-	-
Calciner 1	-	67.8	129.7	61.8	87.0	-	-
Calciner 2	-	68.4	101.7	64.3	88.2	-	-
Calciner 3	-	81.1	122.3	104.1	138.9	-	-
Boiler 1	-	58.9	89.6	66.1	83.6	-	-
Boiler 2	-	42.3	59.9	56.4	71.4	-	-
Boiler 3	-	46.8	67.2	39.5	59.8	-	-
Multi-flue Pseudo-sources [1]							
Liquor burner (LB)	Total Liquor Burner and Calciner 1	72.5	141.5	66.6	96.6	-8.2	-31.7
Vac Pump and Calciner 2 (C13VP)	Calciner 2	68.4	101.7	64.3	88.2	-6.0	-13.3
Calciners 1-3 (C13)	Total all Calciners	72.4	117.9	230.2	314.1	5.9	-11.2
Boilers 1-3 pseudo-source	Total all Boilers	74.0	108.4	162.0	214.9	9.5	-0.8

Notes:

1. Abbreviations in brackets are source IDs in model files. Buoyancy fluxes for pseudo-sources are summed fluxes from composite actual sources.
2. Calculated for ambient temperature of 20°C.

A.3: Multi-flue stack parameters

To account for the reduced buoyancy fluxes for the other pseudo-source characteristics, the Average and Peak stack velocities were reduced to reduce the buoyancies accordingly as shown in Appendix Table 3.

Appendix Table 3: Approximation to variable plume merging scheme

Stack Emissions	Air Assessments (2017)							Baseline | 2021 Scaled to 2.9 Mtpa					
	Flue approximated as	Diameter (m)		Exit Velocity (m/s)		Exit Temperature (K)		Diameter (m)		Exit Velocity (m/s)		Exit Temperature (K)	
		Ave	Peak	Ave	Peak	Ave	Peak	Ave	Peak	Ave	Peak	Ave	Peak
Liquor Burner	Liquor Burner and Calciner 1	1.81	1.76	21.4	36.3	399	426	NC	NC	19.7	24.8	NC	NC
Vac Pump	Vac pump and Calciner 2	1.48	1.544	22.0	30.6	451	469	NC	NC	20.7	26.5	NC	NC
Calciners 1 to 3	Average of 1.5x each Calciner	1.91	1.84	20.3	31.3	447	465	NC	NC	21.5	27.8	NC	NC
Boilers 1 to 3	Average of Inline cases i.e., once boiler plus ½ boiler flue	2.15	2.15	17.3	22.9	392	407	NC	NC	18.9	22.7	NC	NC

Notes:

Shaded cells indicate adjustment made to stack release parameters developed by Air Assessments (2017), to account for reduced buoyancy flux.

'NC' – No change.

Appendix B– Model Configuration

B.1: CALMET Key Variable Extraction

```
File Examined: M:\1330\WRF\CALMET\JUN2021.MET

Titles:
 Produced by CALMET Version: 6.4.0  Level: 121203
 Internal Coordinate Transformations  ---  COORDLIB   Version: 1.10.0  Level: 140313
 CALMET.INP     2.1          Hour Start and End Times with Seconds
 L9094/ETA1073 Alcoa Wagerup
 1/7/2006 to 31/8/2006 using: GEO_Win.geo
 WAG.SUR, up_WAG.dat, w005a_m035018V6.up

Time Period:
 Data BEGIN on 01 Jun 2021 at 00:00:00 (hh:mm:ss)    UTC+0800
 Data   END on 01 Jul 2021 at 00:00:00 (hh:mm:ss)    UTC+0800

Number of model steps =      720

3-D Meteorological Variables:
 Horizontal Wind [U,V]       (m/s)
 Vertical  Wind [W]          (m/s)
 Air Temperature             (K)

2-D Meteorological Variables:
 Pasquill-Gifford Stability Class
 Friction Velocity [U-star]      (m/s)
 Mixing Height [Zi]              (m)
 Monin-Obukhov Length [L]           (m)
 Convective Velocity Scale [W-star] (m/s)
 Precipitation rate              (mm/hr)
 Precipitation code
 Air Density                 (kg/m3)
 Relative Humidity               (%)
 Short-wave Solar Radiation         (W/m2)

Grid Configuration:
 NX Cells     = 77
 NY Cells     = 77
 Cell Size (km)  =  0.250000000
 SW Corner (km)  = 387.519012 6347.79053
 Vertical Layers = 9

  ZFACE (m)    0.  20.  50.  100.  150.  250.  400.  700.  1200.  2040.
  LAYER          1   2   3   4   5   6   7   8   9
  MID-PT (m)      10.  35.  75.  125.  200.  325.  550.  950.  1620.

Coordinate System:
 DATUM Code          = WGS-84
 Map Projection       = UTM
 UTM Zone (1-60)       = 50
 Hemisphere           = S


[<NA> indicates values that are Not Used given options selected]
```

Critical Wind Field Settings

```
  Value Found       Typical Values
TERRAD  0.000001     None   Terrain scale (km) for terrain effects
IEXTRP  1       <NA> 4,-4   Similarity extrap. of wind (-4 ignore upper stn sfc)
ICALM   0       <NA> 0     Do Not extrapolate calm winds
RMAX1   0.000001 <NA> None    MAX radius of influence over land in layer 1 (km)
RMAX2   0.000001 <NA> None    MAX radius of influence over land aloft (km)
RMAX3   0.000001 <NA> None    MAX radius of influence over water (km)
R1      0.000001 <NA>  None    Distance (km) where OBS wt = IGF wt in layer 1
R2      0.000001 <NA>  None    Distance (km) where OBS wt = IGF wt aloft
```

Vertical Variables

```
ZFACE        0.  20.  50.  100.  150.  250.  400.  700. 1200. 2040.
LAYER          1   2   3   4   5   6   7   8   9
MID-PT         10.  35.  75.  125.  200.  325.  550.  950. 1620.
BIAS   <NA>    0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
NSMTH          2   8   8  12  12  12   4   4   0
NINTR2        99  99  99  99  99  99  99  99   0
FEXTRP2 <NA>    0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
```

Typical Values

```
ZFACE        0.  20.  40.  80.  160.  320.  640. 1000. 1500. 2000. 3000.
LAYER          1   2   3   4   5   6   7   8   9  10
BIAS   <NA>    0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
NSMTH          2   4   4   4   4   4   4   4   4   4
NINTR2        99  99  99  99  99  99  99  99  99  99
FEXTRP2 <NA>    0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
```

Data Choices

```
  Value Found       Typical Values
NOOBS   2          0,1,2  0=w/Obs; 1=Partial Obs/No-Obs; 2=No-Obs mode
ICLOUD  4          0,3,4  0=Obs.Clouds; 3,4=Clouds from Prog. RH
ITPROG  2          0,1,2  0=Obs.; 1=Obs.Sfc/Prog.Upr; 2=Prog. temperatures
ITWPROG 0           0,1,2  0=Obs.; 1=Obs.T_Diff/Prog.Lapse; 2=Prog. Overwater T
IRHPROG 1           0,1   0=Obs.; 1=Prog. relative humidity data
IPROG   13         4,14   Use gridded prognostic winds as Initial Guess Field
IGFMET  0           0     Do Not use coarse CALMET as Initial Guess
ISURFT  -1         -1    Surface temperature is 2D interpolated field
IUPT   -1         -1    Lapse rate is 2D interpolated field
IUPWND  -1          -1    Initial guess wind from 3D interpolated field
NSSTA   0        <NA> None    Number of surface met stations
NUSTA   0        <NA> None    Number of upper-air met stations
NOWSTA  0          <NA> None    Number of overwater met stations
NPSTA   0           None    Number of precipitation stations
NM3D    1           None    Number of prognostic data files
NIGF    0          None    Number of CALMET data files for initial guess
```

Method Choices - Winds: Wind Field Modules

```
  Value Found       Typical Values
IWFCOD  0          1     Use Diagnostic Wind Model
IFRADJ  1         1     Compute Froude number adjustment
IKINE   1         0     Do Not compute kinematic effects
IOBR    0         0     Do Not use OBrien adjustment to w-velocities
ISLOPE  1          1     Compute slope flow effects
```

```
ISTEPPGS 3600      3600  Timestep in prognostic data files (s)

 Method Choices - Winds: Spatial Features

  Value Found        Typical Values
NBAR   0        0    Do Not use interpolation barriers (in general)
KBAR   9        NZ   Level to which barriers apply (typically NZ)
LLBREZE F        F   Do Not use lake breeze model (in general)

Method Choices - Mixing Height

  Value Found        Typical Values
IMIXH  1          1,2  M-C or BG Conv. Mixing Ht. for land & water
THRESHL 0.          0.   Buoyancy flux for mixing ht growth (land) (W/m3)
THRESHW 0.05         .05  Buoyancy flux for mixing ht growth (water) (W/m3)
ILUOC3D 16         16,7  Land use category for Ocean in 3D.DAT file
IAVEZI 0          1   Spatial averaging of mixing heights ON
MNMDAV 3            1   Search radius for mixing ht averaging (cells)
HAFANG 30.          30   Half-angle of upwind-looking cone (deg)
ILEVZI 1          1   Layer for wind in upwind averaging
ZIMIN  50.         50.  MIN over-land mixing height (m)
ZIMAX  3000.         3000.  MAX over-land mixing height (m)
ZIMINW  50.         50.  MIN overwater mixing height (m)
ZIMAXW  2000.          3000.  MAX overwater mixing height (m)
DPTMIN  0.005        .001  MIN potential temp lapse rate above lid (K/m)
DZZI   200.        200.  Layer above lid for computing lapse rate (m)

Method Choices - Temperature

  Value Found        Typical Values
IRAD   1          1   1/R type of temperature interpolation
TRADKM  500.    <NA> 500.  Radius of influence for temperature interp. (km)
NUMTS  5      <NA> 5    MAX # stations for temperature interpolation
JWAT1  55         55   Beginning LU for temperature interp over water
JWAT2  55         55   Ending LU for temperature interp over water
IAVET  0          1   Spatial averaging of temperatures ON

Method Choices - Precipitation

  Value Found        Typical Values
NFLAGP 1          2   1/R**2 spatial precipitation interpolation
SIGMAP 100.         100.  Radius of influence for precipitation interp. (km)
CUTP   0.15        .01  MIN precipitation rate cut-off (mm/hr)

Method Choices - Overwater Fluxes

  Value Found        Typical Values
ICOARE 10         10   COARE overwater fluxes without wave adjustment
IWARM  0          0   COARE warm layer SST adjustment Not computed
ICOOL  0          0   COARE cool skin SST adjustment Not computed
DSHELF 0.          0.   Coastal/shallow-water length scale for COARE (km)

Miscellaneous Variables – Default values normally retained

  Value Found        Typical Values
LVARY  F          F   Do Not use varying radius of influence (winds)
RMIN   0.000001 <NA> 0.1   MIN radius of influence for wind interpolation (km)
RMIN2  -1.0   <NA> -1.   Z-Extrapolate at all surface stations (no min)
CRITFN 1.          1.   Critical Froude Number for terrain channeling
TGDEFB -0.0098       -.0098  Default lapse rate below lid over water (K/m)
```

```
TGDEFA  -0.0035     -.0045  Default lapse rate above lid over water (K/m)
ZUPT    200.        200.    Depth for computing domain-scale lapse rate (m)
ZUPWND  1.,1000.    1.,1000.Layer for computing domain-scale wind (m)
IRTYPE  1           1       Computes wind fields AND micromet. variables
LCALGRD T           T       Create ALL fields needed for CALPUFF & CALGRID
DIVLIM  5.0E-06     5.0E-06 MAX acceptable divergence in minimization
NITER   50          50      MAX # iterations in divergence minimization
ALPHA   0.1         0.1     Empirical parameter for kinematic effects
CONSTB  1.          1.41    Neutral, mechanical mixing ht. constant
CONSTE  0.15        0.15    Convective mixing ht. constant
CONSTN  1000.       2400.   Stable mixing ht. constant
CONSTW  0.16        0.16    Overwater mixing ht. constant
FCORIOL 1.0E-04     1.0E-04 Absolute value of Coriolis parameter (1/s)
```

B.2: CALPUFF Set-up

Extraction for LB.INP (Peak)

```
CALPUFF.INP    7.0          Generated by CALPUFF View 9.0.0 - 28/10/2023
PEAK.INP 44 Discrete, B13, C13, C13VP, LB with modified buoyancy
1351/1364 Alcoa Wagerup Refinery- Peak Emissions Case

---------------- Run title (3 lines) ---------------------------------------


          CALPUFF MODEL CONTROL FILE
! PUFLST = LB.LST !
! CONDAT = LB.CON !
! DFDAT = LB.DRY !
! WFDAT = LB.WET !
! LCFILES = F !
! NMETDOM = 1 !
! NMETDAT = 12 !
! NPTDAT = 0 !
! NARDAT = 0 !
! NVOLDAT = 0 !
! NFLDAT = 0 !
! NRDDAT = 0 !
! NLNDAT = 0 !
!END!
! METDAT=..\CALMET\JUN2021.MET    !
! METDAT=..\CALMET\JUL2021.MET    !
! METDAT=..\CALMET\AUG2021.MET    !
! METDAT=..\CALMET\SEP2021.MET    !
! METDAT=..\CALMET\OCT2021.MET    !
! METDAT=..\CALMET\NOV2021.MET    !
! METDAT=..\CALMET\DEC2021.MET    !
! METDAT=..\CALMET\JAN2022.MET    !
! METDAT=..\CALMET\FEB2022.MET    !
! METDAT=..\CALMET\MAR2022.MET    !
! METDAT=..\CALMET\APR2022.MET    !
! METDAT=..\CALMET\MAY2022.MET    !
! METRUN = 0 !
! IBYR = 2021 !
! IBMO = 6 !
! IBDY = 1 !
! IBHR = 0 !
! IBMIN = 0 !
! IBSEC = 0 !
! IEYR = 2022 !
! IEMO = 6 !
! IEDY = 1 !
! IEHR = 0 !
! IEMIN = 0 !
! IESEC = 0 !
! ABTZ = UTC+0800 !
! NSECDT = 3600 !
! NSPEC = 1 !
! NSE = 1 !
! ITEST = 2 !
! MRESTART = 0 !
! NRESPD = 0 !
! METFM = 1 !
! MPRFFM = 1 !
! AVET = 60 !
! PGTIME = 10 !
! IOUTU = 1 !
!END!
! MGAUSS = 1 !
! MCTADJ = 3 !
! MCTSG = 0 !
! MSLUG = 0 !
! MTRANS = 1 !
! MTIP = 1 !
! MRISE = 1 !
! MTIP_FL = 0 !
! MRISE_FL = 2 !
! MBDW = 2 !
! MSHEAR = 0 !
! MSPLIT = 0 !
! MCHEM = 0 !
! MAQCHEM = 0 !
! MLWC = 1 !
! MWET = 0 !
! MDRY = 0 !
! MTILT = 0 !
! MDISP = 2 !
! MTURBVW = 3 !
! MDISP2 = 3 !
! MTAULY = 0 !
! MTAUADV = 0 !
! MCTURB = 1 !
! MROUGH = 0 !
! MPARTL = 1 !
! MPARTLBA = 1 !
! MTINV = 0 !
! MPDF = 1 !
! MSGTIBL = 0 !
! MBCON = 0 !
! MSOURCE = 0 !
! MFOG = 0 !
! MREG = 0 !
!END!
```

```
! CSPEC =     Tracer !
!    Tracer  =      1,         1,       0,          0  !
!END!
! PMAP = UTM !
! FEAST = 0.0 !
! FNORTH = 0.0 !
! IUTMZN = 50 !
! UTMHEM = S !
! RLAT0 = 0.00N !
! RLON0 = 0.00E !
! XLAT1 = 30S !
! XLAT2 = 60S !
! DATUM = WGS-84 !
! NX = 77 !
! NY = 77 !
! NZ = 9 !
! DGRIDKM = 0.25 !
! ZFACE =  0.0, 20.0, 50.0, 100.0, 150.0, 250.0, 400.0,
700.0, 1200.0, 2040.0 !
! XORIGKM = 387.5190 !
! YORIGKM = 6347.7900 !
! IBCOMP = 1 !
! JBCOMP = 1 !
! IECOMP = 77 !
! JECOMP = 77 !
! LSAMP = T !
! IBSAMP = 1 !
! JBSAMP = 1 !
! IESAMP = 77 !
! JESAMP = 77 !
! MESHDN = 1 !
!END!
! ICON = 1 !
! IDRY = 0 !
! IWET = 0 !
! IT2D = 0 !
! IRHO = 0 !
! IVIS = 0 !
! LCOMPRS = T !
! IQAPLOT = 1 !
! IPFTRAK = 0 !
! IMFLX = 0 !
! IMBAL = 0 !
! INRISE = 0 !
! ICPRT = 0 !
! IDPRT = 0 !
! IWPRT = 0 !
! ICFRQ = 6 !
! IDFRQ = 1 !
! IWFRQ = 1 !
! IPRTU = 3 !
! IMESG = 2 !
!    Tracer =   1,      1,      1,      0,      1,      0,
0  !
! LDEBUG = F !
! IPFDEB = 1 !
! NPFDEB = 1 !
! NN1 = 1 !
! NN2 = 10 !
!END!
! NHILL = 0 !
! NCTREC = 0 !
! MHILL = 2 !
! XHILL2M = 1.0 !
! ZHILL2M = 1.0 !
! XCTDMKM = 0.0 !
! YCTDMKM = 0.0 !
! END !
!END!
!END!
! RCUTR = 30 !
! RGR = 10 !
! REACTR = 8 !
! NINT = 9 !
! IVEG = 1 !
!END!
!END!
! MOZ = 1 !
! BCKO3 = 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00,
80.00, 80.00, 80.00, 80.00, 80.00 !
! MNH3 = 0 !
! MAVGNH3 = 1 !
! BCKNH3 = 10.00, 10.00, 10.00, 10.00, 10.00, 10.00,
10.00, 10.00, 10.00, 10.00, 10.00, 10.00 !
! RNITE1 = 0.2 !
! RNITE2 = 2 !
! RNITE3 = 2 !
! MH2O2 = 1 !
! BCKH2O2 = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00,
1.00, 1.00, 1.00, 1.00 !
! RH_ISRP = 50.0 !
! SO4_ISRP = 0.4 !
! BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00,
1.00, 1.00, 1.00, 1.00 !
! OFRAC = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20,
0.20, 0.20, 0.20, 0.15 !
! VCNX = 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00,
50.00, 50.00, 50.00, 50.00, 50.00 !
! NDECAY = 0 !
!END!
! SYTDEP = 550 !
! MHFTSZ = 0 !
! JSUP = 5 !
! CONK1 = 0.01 !
! CONK2 = 0.1 !
```

```
! TBD = 0.5 !
! IURB1 = 10 !
! IURB2 = 19 !
! ILANDUIN = 20 !
! Z0IN = .25 !
! XLAIIN = 3.0 !
! ELEVIN = .0 !
! XLATIN = -999.0 !
! XLONIN = -999.0 !
! ANEMHT = 10.0 !
! ISIGMAV = 1 !
! IMIXCTDM = 0 !
! XMXLEN = 1 !
! XSAMLEN = 1 !
! MXNEW = 99 !
! MXSAM = 99 !
! NCOUNT = 2 !
! SYMIN = 1 !
! SZMIN = 1 !
! SZCAP_M = 5000000 !
! SVMIN = 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.3, 0.3, 0.3, 0.3, 0.3,
0.3 !
! SWMIN = 0.2, 0.12, 0.08, 0.06, 0.03, 0.016, 0.2, 0.12,
0.08, 0.06, 0.03, 0.016 !
! CDIV = 0, 0 !
! NLUTIBL = 4 !
! WSCALM = 0.5 !
! XMAXZI = 3000 !
! XMINZI = 50 !
! TKCAT = 265., 270., 275., 280., 285., 290., 295., 300.,
305., 310., 315. !
! PLX0 = 0.07, 0.07, 0.1, 0.15, 0.35, 0.55 !
! PTG0 = 0.02, 0.035 !
! PPC = 0.5, 0.5, 0.5, 0.5, 0.35, 0.35 !
! SL2PF = 10 !
! FCLIP = 0 !
! NSPLIT = 3 !
! IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
!
! ZISPLIT = 100 !
! ROLDMAX = 0.25 !
! NSPLITH = 5 !
! SYSPLITH = 1 !
! SHSPLITH = 2 !
! CNSPLITH = 1E-007 !
! EPSSLUG = 0.0001 !
! EPSAREA = 1E-006 !
! DSRISE = 1.0 !
! HTMINBC = 500 !
! RSAMPBC = 10 !
! MDEPBC = 1 !
!END!
! NPT1 = 1 !
! IPTU = 1 !
! NSPT1 = 0 !
! NPT2 = 0 !
!END!
! SRCNAM = LB !
! X = 398.318, 6357.200,  100.0, 54.48,    1.76, 24.8,
426.0, 1.0,    1 !
! ZPLTFM =    0.0 !
! FMFAC =    1.0 !
! SRCNAM = LB !
  1 ! HEIGHT =  31.60,  28.00,  29.00,  29.00,  29.00,
22.00,
          22.00,  22.00,  22.00,  22.00,  34.00,  34.00,
          31.60,  34.00,  31.60,  31.60,  31.60,  31.60,
          31.60,  28.00,  10.00,  10.00,  22.00,  10.00,
           0.00,   0.00,   0.00,   0.00,  34.00,  34.00,
          31.60,  34.00,  31.60,  31.60,  31.60,  31.60 !
  1 ! WIDTH  =  33.42,  85.27,  62.13,  61.69,  61.44,
34.21,
          34.52,  33.77,  32.00,  33.77,  33.64,  28.65,
          37.33,  30.22,  33.21,  33.83,  33.42,  32.00,
          33.42,  85.27,  87.32,  85.86,  32.87,  75.24,
           0.00,   0.00,   0.00,   0.00,  33.64,  28.65,
          37.33,  30.22,  33.21,  33.83,  33.42,  32.00 !
  1 ! LENGTH =  16.39,  46.23,  61.30,  61.72,  61.35,
27.26,
          23.16,  18.36,  13.00,  18.36,  59.90,  63.70,
          82.55,  65.45,  25.53,  21.28,  16.39,  12.00,
          16.39,  46.23,  75.24,  81.79,  30.53,  87.32,
           0.00,   0.00,   0.00,   0.00,  59.90,  24.62,
          82.55,  65.45,  25.53,  21.28,  16.39,  12.00 !
  1 ! XBADJ  = -39.74, -60.77, -180.18, -181.82, -177.94,
-75.05,
         -74.93, -72.54, -67.94, -66.83,  37.71,  40.38,
          24.84,  41.98,  30.24,  31.60,  31.99,  30.42,
          23.35,   14.54, -106.45, -109.21,   42.36, -
104.79,
           0.00,   0.00,   0.00,   0.00, -97.61, -104.08,
        -107.39, -107.43,  -55.77,  -52.88,  -48.38,  -
42.42 !
  1 ! YBADJ  = -28.14, -54.98,  18.23,  -7.86, -34.16,
16.50,
           5.58,  -5.50, -16.42, -26.84, -33.08, -20.83,
          -9.17,  10.10,   1.14,   8.44,  15.49,  22.06,
          28.14,  54.98,   3.05,  -8.94, -26.91, -31.77,
           0.00,   0.00,   0.00,   0.00,  33.08,  20.83,
           9.17, -10.10,  -1.14,  -8.44, -15.49, -22.06 !
!END!
! NAR1 = 0 !
! IARU = 1 !
! NSAR1 = 0 !
! NAR2 = 0 !
!END!
```

```
! NLN2 = 0 !
! NLINES = 0 !
! ILNU = 1 !
! NSLN1 = 0 !
! MXNSEG = 7 !
! NLRISE = 6 !
! XL = 2270.0 !
! HBL = 3.0 !
! WBL = 6.0 !
! WML = 3.0 !
! DXL = 0.0 !
! FPRIMEL = 0.2 !
!END!
! NVL1 = 0 !
! IVLU = 1 !
! NSVL1 = 0 !
! NVL2 = 0 !
!END!
! NFL2 = 0 !
!END!
! NRD1 = 0 !
! NRD2 = 0 !
! NSFRDS = 0 !
!END!
! NSFTAB = 0 !
!END!
! NREC = 308 !
! NRGRP = 0 !
!END!
! X = 398.231 , 6354.984 , 43 , 0 !
! X = 398.533 , 6355.156 , 44 , 0 !
! X = 396.970 , 6353.099 , 22 , 0 !
! X = 397.278 , 6354.977 , 30 , 0 !
! X = 395.861 , 6352.653 , 21 , 0 !
! X = 400.247 , 6354.650 , 197 , 0 !
! X = 399.790 , 6354.390 , 142 , 0 !
! X = 390.915 , 6358.883 , 15 , 0 !
! X = 392.500 , 6362.281 , 14 , 0 !
! X = 396.239 , 6362.174 , 24 , 0 !
! X = 398.600 , 6362.150 , 33 , 0 !
! X = 398.657 , 6360.782 , 44 , 0 !
! X = 398.347 , 6360.481 , 34 , 0 !
! X = 400.660 , 6364.365 , 78 , 0 !
! X = 400.867 , 6360.980 , 119 , 0 !
! X = 402.871 , 6356.592 , 268 , 0 !
! X = 400.866 , 6356.585 , 243 , 0 !
! X = 397.505 , 6359.435 , 30 , 0 !
! X = 389.386 , 6358.097 , 14 , 0 !
! X = 392.681 , 6354.988 , 16 , 0 !
! X = 393.864 , 6354.206 , 15 , 0 !
! X = 395.091 , 6353.536 , 17 , 0 !
! X = 397.910 , 6355.111 , 41 , 2 !
! X = 395.408 , 6357.207 , 20 , 2 !
! X = 394.263 , 6357.416 , 16 , 2 !
! X = 392.859 , 6359.860 , 14 , 2 !
! X = 396.731 , 6360.047 , 23 , 2 !
! X = 392.703 , 6358.209 , 14 , 2 !
! X = 396.348 , 6356.061 , 24 , 2 !
! X = 396.626 , 6358.256 , 23 , 2 !
! X = 398.333 , 6361.493 , 33 , 2 !
! X = 392.882 , 6360.855 , 15 , 2 !
! X = 395.053 , 6358.991 , 33 , 2 !
! X = 400.469 , 6364.340 , 69 , 0 !
! X = 400.469 , 6364.440 , 73 , 0 !
! X = 400.469 , 6364.540 , 75 , 0 !
! X = 400.469 , 6364.640 , 75 , 0 !
! X = 400.469 , 6364.740 , 75 , 0 !
! X = 400.469 , 6364.840 , 74 , 0 !
! X = 400.469 , 6364.940 , 74 , 0 !
! X = 400.469 , 6365.040 , 75 , 0 !
! X = 400.469 , 6365.140 , 76 , 0 !
! X = 400.569 , 6364.340 , 72 , 0 !
! X = 400.569 , 6364.440 , 77 , 0 !
! X = 400.569 , 6364.540 , 77 , 0 !
! X = 400.569 , 6364.640 , 79 , 0 !
! X = 400.569 , 6364.740 , 78 , 0 !
! X = 400.569 , 6364.840 , 77 , 0 !
! X = 400.569 , 6364.940 , 77 , 0 !
! X = 400.669 , 6364.340 , 78 , 0 !
! X = 400.669 , 6364.440 , 83 , 0 !
! X = 400.669 , 6364.540 , 88 , 0 !
! X = 400.669 , 6364.640 , 87 , 0 !
! X = 400.669 , 6364.740 , 88 , 0 !
! X = 400.769 , 6364.440 , 89 , 0 !
! X = 400.769 , 6364.540 , 91 , 0 !
! X = 400.769 , 6364.640 , 92 , 0 !
! X = 398.144 , 6365.666 , 27 , 0 !
! X = 398.144 , 6365.916 , 26 , 0 !
! X = 398.394 , 6365.666 , 28 , 0 !
! X = 398.394 , 6365.916 , 27 , 0 !
! X = 398.394 , 6366.166 , 28 , 0 !
! X = 398.644 , 6365.666 , 28 , 0 !
! X = 398.644 , 6365.916 , 29 , 0 !
! X = 398.644 , 6366.166 , 31 , 0 !
! X = 398.894 , 6365.666 , 31 , 0 !
! X = 398.894 , 6365.916 , 31 , 0 !
! X = 398.894 , 6366.166 , 34 , 0 !
! X = 399.144 , 6364.166 , 47 , 0 !
! X = 399.144 , 6364.416 , 48 , 0 !
! X = 399.144 , 6364.666 , 47 , 0 !
! X = 399.144 , 6364.916 , 46 , 0 !
! X = 399.144 , 6365.166 , 43 , 0 !
! X = 399.144 , 6365.416 , 41 , 0 !
! X = 399.144 , 6365.666 , 45 , 0 !
! X = 399.144 , 6365.916 , 46 , 0 !
! X = 399.144 , 6366.166 , 51 , 0 !
```

```
! X = 399.394 , 6364.166 , 43 , 0 !
! X = 399.394 , 6364.416 , 48 , 0 !
! X = 399.394 , 6364.666 , 54 , 0 !
! X = 399.394 , 6364.916 , 55 , 0 !
! X = 399.394 , 6365.166 , 51 , 0 !
! X = 399.394 , 6365.416 , 50 , 0 !
! X = 399.394 , 6365.666 , 52 , 0 !
! X = 399.394 , 6365.916 , 57 , 0 !
! X = 399.394 , 6366.166 , 59 , 0 !
! X = 399.644 , 6364.416 , 50 , 0 !
! X = 399.644 , 6364.666 , 56 , 0 !
! X = 399.644 , 6364.916 , 62 , 0 !
! X = 399.644 , 6365.166 , 56 , 0 !
! X = 399.644 , 6365.416 , 56 , 0 !
! X = 399.644 , 6365.666 , 59 , 0 !
! X = 399.644 , 6365.916 , 62 , 0 !
! X = 399.644 , 6366.166 , 64 , 0 !
! X = 399.894 , 6364.416 , 53 , 0 !
! X = 399.894 , 6364.666 , 57 , 0 !
! X = 399.894 , 6364.916 , 61 , 0 !
! X = 399.894 , 6365.166 , 65 , 0 !
! X = 399.894 , 6365.416 , 66 , 0 !
! X = 399.894 , 6365.666 , 65 , 0 !
! X = 399.894 , 6365.916 , 71 , 0 !
! X = 399.894 , 6366.166 , 71 , 0 !
! X = 400.144 , 6365.666 , 81 , 0 !
! X = 400.144 , 6365.916 , 83 , 0 !
! X = 400.144 , 6366.166 , 80 , 0 !
! X = 400.394 , 6365.666 , 91 , 0 !
! X = 400.394 , 6365.916 , 93 , 0 !
! X = 400.394 , 6366.166 , 89 , 0 !
! X = 398.869 , 6362.240 , 41 , 0 !
! X = 398.869 , 6362.340 , 40 , 0 !
! X = 398.869 , 6362.440 , 41 , 0 !
! X = 398.969 , 6362.240 , 46 , 0 !
! X = 398.969 , 6362.340 , 45 , 0 !
! X = 398.969 , 6362.440 , 45 , 0 !
! X = 398.969 , 6362.540 , 45 , 0 !
! X = 396.894 , 6362.166 , 26 , 0 !
! X = 396.894 , 6362.416 , 26 , 0 !
! X = 396.894 , 6362.666 , 26 , 0 !
! X = 396.894 , 6362.916 , 27 , 0 !
! X = 397.144 , 6362.166 , 27 , 0 !
! X = 397.144 , 6362.416 , 27 , 0 !
! X = 397.144 , 6362.666 , 27 , 0 !
! X = 397.144 , 6362.916 , 28 , 0 !
! X = 397.394 , 6362.166 , 27 , 0 !
! X = 397.394 , 6362.416 , 28 , 0 !
! X = 397.394 , 6362.666 , 28 , 0 !
! X = 397.394 , 6362.916 , 29 , 0 !
! X = 397.644 , 6362.166 , 28 , 0 !
! X = 397.644 , 6362.416 , 29 , 0 !
! X = 397.644 , 6362.666 , 29 , 0 !
! X = 397.644 , 6362.916 , 29 , 0 !
! X = 397.894 , 6362.166 , 29 , 0 !
! X = 397.894 , 6362.416 , 29 , 0 !
! X = 397.894 , 6362.666 , 30 , 0 !
! X = 397.894 , 6362.916 , 30 , 0 !
! X = 398.144 , 6362.166 , 29 , 0 !
! X = 398.144 , 6362.416 , 30 , 0 !
! X = 398.144 , 6362.666 , 30 , 0 !
! X = 398.144 , 6362.916 , 31 , 0 !
! X = 398.394 , 6362.166 , 30 , 0 !
! X = 398.394 , 6362.666 , 31 , 0 !
! X = 398.394 , 6362.916 , 32 , 0 !
! X = 398.644 , 6362.166 , 33 , 0 !
! X = 398.644 , 6362.916 , 33 , 0 !
! X = 398.069 , 6354.740 , 45 , 0 !
! X = 398.169 , 6354.540 , 48 , 0 !
! X = 398.169 , 6354.640 , 47 , 0 !
! X = 398.169 , 6354.740 , 46 , 0 !
! X = 398.169 , 6354.840 , 45 , 0 !
! X = 398.169 , 6354.940 , 43 , 0 !
! X = 398.169 , 6355.040 , 42 , 0 !
! X = 398.269 , 6354.540 , 49 , 0 !
! X = 398.269 , 6354.640 , 48 , 0 !
! X = 398.269 , 6354.740 , 46 , 0 !
! X = 398.269 , 6354.840 , 45 , 0 !
! X = 398.269 , 6354.940 , 43 , 0 !
! X = 398.269 , 6355.040 , 43 , 0 !
! X = 398.369 , 6354.540 , 49 , 0 !
! X = 398.369 , 6354.640 , 48 , 0 !
! X = 398.369 , 6354.740 , 46 , 0 !
! X = 398.369 , 6354.840 , 45 , 0 !
! X = 398.369 , 6354.940 , 43 , 0 !
! X = 398.369 , 6355.040 , 43 , 0 !
! X = 398.469 , 6354.540 , 50 , 0 !
! X = 398.469 , 6354.640 , 49 , 0 !
! X = 398.469 , 6354.740 , 47 , 0 !
! X = 398.469 , 6354.840 , 46 , 0 !
! X = 398.469 , 6354.940 , 44 , 0 !
! X = 398.469 , 6355.040 , 44 , 0 !
! X = 398.569 , 6354.540 , 50 , 0 !
! X = 398.569 , 6354.640 , 49 , 0 !
! X = 398.569 , 6354.740 , 47 , 0 !
! X = 398.569 , 6354.840 , 46 , 0 !
! X = 398.569 , 6354.940 , 45 , 0 !
! X = 398.569 , 6355.040 , 45 , 0 !
! X = 398.669 , 6354.540 , 50 , 0 !
! X = 398.669 , 6354.640 , 49 , 0 !
! X = 398.669 , 6354.740 , 49 , 0 !
! X = 398.669 , 6354.840 , 48 , 0 !
! X = 398.669 , 6354.940 , 47 , 0 !
! X = 398.669 , 6355.040 , 48 , 0 !
! X = 397.269 , 6353.640 , 27 , 0 !
! X = 397.369 , 6353.640 , 30 , 0 !
```

```
! X = 397.369 , 6353.740 , 28 , 0 !
! X = 397.369 , 6353.840 , 27 , 0 !
! X = 397.369 , 6353.940 , 27 , 0 !
! X = 397.369 , 6354.040 , 25 , 0 !
! X = 397.469 , 6353.640 , 36 , 0 !
! X = 397.469 , 6353.740 , 35 , 0 !
! X = 397.469 , 6353.840 , 35 , 0 !
! X = 397.469 , 6353.940 , 33 , 0 !
! X = 397.469 , 6354.040 , 33 , 0 !
! X = 397.469 , 6354.140 , 31 , 0 !
! X = 397.469 , 6354.240 , 31 , 0 !
! X = 397.569 , 6353.640 , 39 , 0 !
! X = 397.569 , 6353.740 , 38 , 0 !
! X = 397.569 , 6353.840 , 38 , 0 !
! X = 397.569 , 6353.940 , 37 , 0 !
! X = 397.569 , 6354.040 , 36 , 0 !
! X = 397.569 , 6354.140 , 36 , 0 !
! X = 397.569 , 6354.240 , 35 , 0 !
! X = 397.569 , 6354.340 , 35 , 0 !
! X = 397.669 , 6353.740 , 44 , 0 !
! X = 397.669 , 6353.840 , 44 , 0 !
! X = 397.669 , 6353.940 , 43 , 0 !
! X = 397.669 , 6354.040 , 43 , 0 !
! X = 397.669 , 6354.140 , 42 , 0 !
! X = 397.669 , 6354.240 , 42 , 0 !
! X = 397.669 , 6354.340 , 43 , 0 !
! X = 397.669 , 6354.440 , 42 , 0 !
! X = 397.769 , 6353.740 , 45 , 0 !
! X = 397.769 , 6353.840 , 45 , 0 !
! X = 397.769 , 6353.940 , 44 , 0 !
! X = 397.769 , 6354.040 , 44 , 0 !
! X = 397.769 , 6354.140 , 44 , 0 !
! X = 397.769 , 6354.240 , 44 , 0 !
! X = 397.769 , 6354.340 , 44 , 0 !
! X = 397.769 , 6354.440 , 43 , 0 !
! X = 397.869 , 6353.740 , 46 , 0 !
! X = 397.869 , 6353.840 , 46 , 0 !
! X = 397.869 , 6353.940 , 46 , 0 !
! X = 397.869 , 6354.040 , 45 , 0 !
! X = 397.869 , 6354.140 , 46 , 0 !
! X = 397.869 , 6354.240 , 45 , 0 !
! X = 397.869 , 6354.340 , 45 , 0 !
! X = 397.869 , 6354.440 , 45 , 0 !
! X = 397.969 , 6353.740 , 49 , 0 !
! X = 397.969 , 6353.840 , 49 , 0 !
! X = 397.969 , 6353.940 , 48 , 0 !
! X = 397.969 , 6354.040 , 49 , 0 !
! X = 397.969 , 6354.140 , 48 , 0 !
! X = 397.969 , 6354.240 , 48 , 0 !
! X = 397.969 , 6354.340 , 48 , 0 !
! X = 397.969 , 6354.440 , 46 , 0 !
! X = 398.069 , 6353.840 , 50 , 0 !
! X = 398.069 , 6353.940 , 50 , 0 !
! X = 398.069 , 6354.040 , 49 , 0 !
! X = 395.869 , 6353.340 , 19 , 0 !
! X = 395.969 , 6353.340 , 19 , 0 !
! X = 396.069 , 6353.340 , 19 , 0 !
! X = 396.169 , 6353.340 , 18 , 0 !
! X = 396.269 , 6353.340 , 18 , 0 !
! X = 396.469 , 6353.240 , 19 , 0 !
! X = 396.569 , 6353.140 , 20 , 0 !
! X = 396.569 , 6353.240 , 19 , 0 !
! X = 396.669 , 6352.940 , 20 , 0 !
! X = 396.669 , 6353.040 , 20 , 0 !
! X = 396.669 , 6353.140 , 20 , 0 !
! X = 396.669 , 6353.240 , 20 , 0 !
! X = 396.769 , 6352.940 , 21 , 0 !
! X = 396.769 , 6353.040 , 21 , 0 !
! X = 396.769 , 6353.140 , 21 , 0 !
! X = 396.769 , 6353.240 , 20 , 0 !
! X = 396.869 , 6352.940 , 21 , 0 !
! X = 396.869 , 6353.040 , 21 , 0 !
! X = 396.869 , 6353.140 , 21 , 0 !
! X = 396.869 , 6353.240 , 20 , 0 !
! X = 396.969 , 6352.940 , 21 , 0 !
! X = 396.969 , 6353.040 , 22 , 0 !
! X = 396.969 , 6353.140 , 21 , 0 !
! X = 396.969 , 6353.240 , 21 , 0 !
! X = 397.069 , 6352.940 , 22 , 0 !
! X = 397.069 , 6353.040 , 22 , 0 !
! X = 397.069 , 6353.140 , 22 , 0 !
! X = 397.069 , 6353.240 , 21 , 0 !
! X = 397.169 , 6352.940 , 24 , 0 !
! X = 397.169 , 6353.040 , 26 , 0 !
! X = 397.169 , 6353.140 , 24 , 0 !
! X = 397.169 , 6353.240 , 25 , 0 !
! X = 397.269 , 6352.940 , 28 , 0 !
! X = 397.269 , 6353.040 , 28 , 0 !
! X = 397.269 , 6353.140 , 28 , 0 !
! X = 397.269 , 6353.240 , 27 , 0 !
! X = 397.269 , 6353.340 , 27 , 0 !
! X = 397.269 , 6353.440 , 27 , 0 !
! X = 397.369 , 6353.140 , 31 , 0 !
! X = 397.369 , 6353.240 , 30 , 0 !
! X = 397.369 , 6353.340 , 30 , 0 !
! X = 397.369 , 6353.440 , 31 , 0 !
! X = 397.469 , 6353.340 , 36 , 0 !
! X = 397.469 , 6353.440 , 36 , 0 !
! X = 397.069 , 6351.840 , 26 , 0 !
! X = 397.069 , 6351.940 , 26 , 0 !
! X = 397.069 , 6352.040 , 25 , 0 !
! X = 397.169 , 6351.840 , 31 , 0 !
! X = 397.169 , 6351.940 , 29 , 0 !
! X = 397.169 , 6352.040 , 31 , 0 !
! X = 397.169 , 6352.140 , 28 , 0 !
! X = 397.169 , 6352.240 , 29 , 0 !
```

```
! X = 397.169 , 6352.340 , 29 , 0 !
! X = 397.269 , 6351.840 , 34 , 0 !
! X = 397.269 , 6351.940 , 34 , 0 !
! X = 397.269 , 6352.040 , 34 , 0 !
! X = 397.269 , 6352.140 , 33 , 0 !
! X = 397.269 , 6352.240 , 32 , 0 !
! X = 397.269 , 6352.340 , 32 , 0 !
! X = 397.369 , 6351.840 , 37 , 0 !
! X = 397.369 , 6351.940 , 39 , 0 !
! X = 397.369 , 6352.040 , 36 , 0 !
! X = 397.369 , 6352.140 , 38 , 0 !
! X = 397.369 , 6352.240 , 35 , 0 !
! X = 397.369 , 6352.340 , 35 , 0 !
! X = 397.369 , 6352.440 , 36 , 0 !
! X = 397.469 , 6351.840 , 44 , 0 !
! X = 397.469 , 6351.940 , 44 , 0 !
! X = 397.469 , 6352.040 , 44 , 0 !
! X = 397.469 , 6352.140 , 43 , 0 !
! X = 397.469 , 6352.240 , 42 , 0 !
```

www.envanalytics.com.au