AIR QUALITY SUMMARY REPORT
WAGERUP 3 ERMP

for

Alcoa World Alumina Australia

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Air Quality Summary Report
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1. INTRODUCTION

1.1 BACKGROUND

Alcoa World Alumina Australia (Alcoa) proposes to expand its existing Wagerup alumina refinery through completing the construction of a third production unit. Expansion at Wagerup is one of several world-wide options currently being studied by Alcoa to provide additional capacity to meet increased global demand for alumina. The third unit would further improve the environmental efficiency of the Wagerup refinery and provide substantial economic benefits to the region, the State of Western Australia and the Commonwealth of Australia.

The Wagerup Refinery and its associated bauxite residue drying areas (RDAs) are located 120 kilometers south of Perth, two kilometers north of Yarloop and approximately seven kilometers south of Waroona. The refinery is located close to the foot of the Darling Scarp and is separated from the RDAs by the South West Highway and the Perth- Bunbury railway line.

1.2 PURPOSE OF THIS REPORT

This report summarises a comprehensive list of studies undertaken by Alcoa as part of the "Air Quality Impact Assessment" for the Wagerup 3 ERMP to quantify atmospheric emissions from the existing refinery, RDAs and cooling ponds and to assess the potential impacts of the proposed expansion on air emissions. Studies into the potential air quality impacts associated with the Project have been conducted, including the investigation of potential health impacts arising from air emissions from the refinery and RDAs.

A critical component of both the air quality and health impact assessments is the definition of the atmospheric emissions arising from the baseline and expanded refinery scenarios. A summary of the approach, methodology and programmes undertaken to estimate atmospheric emissions from the existing and proposed expansion is included in this document. The programmes include extensive point source, ambient and diffuse monitoring programs to quantify and confirm air emissions with ground truthing undertaken to ensure emissions estimated from various point and diffuse sources represent field observations.

The compounds and emissions determined from this process were input into dispersion models to determine predicted ground level concentrations within the study area. The existing and expanded refinery and RDAs have been modelled using The Air Pollution Model (TAPM) and CALPUFF respectively with the outputs used as input into a Quantitative Health Risk Assessment (QHRA). The QHRA also investigated the potential for short-term exposures and associated health impacts. Air dispersion modelling was undertaken by CSIRO for the refinery using the TAPM model. TAPM was refined to better predict the meteorological conditions experienced at the Wagerup refinery. Modelling of emissions from the RDAs was undertaken by Air Assessments Ltd using CALPUFF. Both model outputs were subsequently integrated into a consolidated data file to produce cumulative emissions of the proposal as required inputs into the QHRA.

The monitoring data and the results of the air quality dispersion modelling provide input into a QHRA. Similar methods as were applied for the QHRA for the Alcoa Pinjarra Refinery Upgrade were adopted in this project and included an assessment of a suite of substances, including particulates, products of combustion, organic compounds (e.g. aldehydes, ketones, aromatics and organosulphides), metals and other compounds (e.g. PAHs, ammonia). This included an assessment of emissions on sensitive receptors based on estimation of typical and worst-case ground-level concentrations, and comparison of these levels against health-based guidelines agreed with relevant regulatory authorities.

The project specific studies undertaken for air quality as part of the ERMP and summarised in this document are:

1. Notes on the Relationship Between Measured Odour Units and Concentration of VOCs, Aldehydes and Ketones of Gases Emitted from Various Units at Wagerup Refinery, Alcoa 2005; (Appendix A)
2. Wagerup Ambient Air Quality Monitoring Programme, Intensive Ambient Air Quality Study, Phase 2, van Emden & Power, 2005; (attached as Appendix B)
3. Alcoa World Alumina, Emissions to Air from Residue Disposal Area, Assessment of Emissions from Diffuse Area Sources, GHD , March 2005; (Attached a Appendix C)
4. Air Dispersion Modelling of Fugitive Emissions Wagerup Refinery, Air Assessments , 2005; (Attached as Appendix D)
5. RDA, Sprinkler Deposition Modelling, 2005; (Attached as Appendix E)
6. Compound Selection Process – Quantitative Health Risk Assessment (QHRA) (ENVIRON 2005): Details the compound selection process undertaken for the QHRA; (Attached as Appendix F)
7. CSIRO, Meteorological and Dispersion Modelling Using TAPM for Wagerup, Phase 1: Meteorology: Details the evaluation of TAPM to predict meteorology matching available field observations at Wagerup; (Attached as Appendix G)
8. CSIRO, Meteorological and Dispersion Modelling Using TAPM for Wagerup, Phase 2: Dispersion; (Attached as Appendix G)
9. CSIRO, Meteorological and Dispersion Modelling Using TAPM for Wagerup, Phase 3A: HRA (Health Risk Assessment) Concentration Modelling- Current Emission Scenario; (Attached as Appendix G)
10. CSIRO. Meteorological and Dispersion Modelling Using TAPM for Wagerup, Phase 3B: HRA (Health Risk Assessment) Concentration Modelling- Expanded Refinery Scenario. (Attached as Appendix G); and

11. Health Risk Assessment of Atmospheric Emissions, expansion of Wagerup refinery to 4.7 Mpta, ENVIRON and Benchmark Toxicological Services, 2005. (Attached as Appendix H)

1.3 SUMMARY OF BASE AND EXPANSION SCENARIOS ASSESSED

Emissions representative of annual average and daily peak mass emissions were considered for the the Base and Expansion scenarios using annual average and peak refinery production rates as an indicator of emission variability.

1.3.1 Base – Current Refinery

Emissions for the baseline emissions scenario have been derived by Alcoa based on various stack emission monitoring programs conducted at the Wagerup refinery, using results obtained between July 2002 and March 2004. Typically peak emissions have been defined using the maximum measured emission concentration over the defined monitoring period, with average emissions defined by calculating the average of all measured emissions concentrations over the defined monitoring period. The subsequent mass emission rates were determined by using flowrates calculated from average and peak refinery alumina production rates.

1.3.2 Expansion - Wagerup Unit 3

Emissions for the expanded refinery emissions scenario have been derived by Alcoa based on a notional design for the expanded refinery, and using conservative estimates of pollution control efficiencies for those sources to be upgraded with new air pollution control equipment as part of the Wagerup refinery expansion. The expansion scenario assumed an average refinery alumina production rate of 12877 tpd and a peak production rate 13699 tpd, which is based on the nominal design production rate and the maximum design production rate for the expansion respectively. This also takes into consideration the expected reduction in emission associated with the installation of various air emission control equipment.

As with the baseline peak production scenario, it should be noted that these assumptions are expected to result in an over-estimation of actual peak emissions, since it is very unlikely that daily peak emissions for all refinery processes and sources would occur at the same time as is implicitly assumed. The additional sources that are to be included in the expansion scenario include calciners, the oxalate kiln, additional boilers or gas turbines. Two options are considered for the expansion proposal, Case 6 is the use of additional gas turbines using a cogeneration facility in the expanded refinery and Case 7 is the use of additional boilers for extra power generation. Refer to Section 3 for further explanation of how Wagerup Unit 3 emission rates were determined.

For both the baseline and expanded refinery emission scenarios, “peak” and “average” emissions have been estimated and applied to the assessment of acute and chronic exposure respectively.

1.4 ERMP COMMITMENTS AND PUBLIC UNDERTAKINGS – AIR QUALITY

Alcoa has given some important public undertakings that set broad-scale air quality objectives for the Wagerup Unit 3 project. The expansion of the refinery will:

1. Cause no increase in odour, dust or noise impacts on residents from mining and refining operations;
2. Cause no increase in short or long-term emission impacts on residents; and
3. Meet world class health risk criteria.

The measurement of air quality parameters as a result of the AQMP will provide much of the information to assess operational performance of the project against these public undertakings.

To achieve the undertakings made for the Unit 3 expansion, Alcoa has developed a decision making framework. The framework is to be used to guide the assessment of compliance with these undertakings. The framework identified that if investigations indicate a likelihood of increased impacts on neighbouring communities from particulates, odour, or short/long-term emission impacts, project modifications will be necessary for the proposal to proceed. In the case of emissions, three general options may be available to offset potential impacts, using the decision making framework:

1. Additional works to reduce emissions;
2. Increased dispersion; or
3. Increased separation between source and receptors.

Emission measurement and air dispersion modelling have been used to assess the potential for air quality impacts from implementation of the proposal, the results of which are detailed in the ERMP. Engineering design and operational changes, coupled with modelling have been used to manage potential increases in emissions and, where appropriate, increased emission dispersion. Furthermore, Alcoa's land management strategy provides an ongoing offer to purchase properties in the immediate vicinity of the refinery (known as Area A) at greater than market value. This offer will remain in place following commissioning of Unit 3, if approved. This combination provides the overall framework to ensure the public undertakings in relation to the expansion can be met.

To assess if Alcoa is meeting its public undertakings, specific objectives have been set for noise, dust, odour and other emissions. The objectives for each of these areas are described by the following:

1.4.1 Odour

Alcoa has given an undertaking that the expansion of the refinery will:

> *Cause no increase in odour, dust or noise impacts on residents from mining and refining operations;*

These undertakings are supported by specific objectives. In respect of odour, Alcoa's specific objective is that the odour impacts predicted for the expansion satisfy the EPA Odour Guidance Statement Number 47 objective 'that for expansion of existing odour sources there would be no deterioration of current amenity values'. Or in other words, that predicted odour concentrations at sensitive land uses will not increase. This will be measured as follows;

1) There will be no increase in 'peak odour impacts', defined as 99.9% 3 minute average odour concentrations at neighbouring residences for refinery peak emissions; and
2) There will be no increase in 'average odour impacts', defined as 99.5% 3 minute average odour concentrations at neighbouring residences for refinery average emissions.

1.4.2 Dust

Alcoa has given an undertaking that predicted ground-level dust concentrations, from refinery operations, meet the National Environmental Protection Measure (NEPM) 24-hour PM_{10} goal of 50 $\mu g/m^3$ and the Kwinana EPP Area B limit for TSP of 260 $\mu g/m^3$ at neighborhood residences.

1.4.3 Short-term air emission impacts

The acute hazard indices, based on 1 and 24 hour values as predicted in the health risk assessment will meet world class guidelines (that is remain < 1 at all neighbouring residences following the expansion). Also predicted short-term refinery emission concentrations (3-10 minute peak values) do not increase at neighbouring residences or if any target compound (VOCs and metals) does show an increase it remains at insignificant concentrations. There are generally not health guidelines for these time periods, however an assessment will be made relative to health guidelines that do exist.

1.4.4 Long-term emission impacts & health risk

Both the chronic health index and incremental cancer risk predictions (parts of the Health Risk Assessment) meet world class guidelines:

The air dispersion modelling and Health Risk Assessment undertaken as part of this ERMP have established that the predicted air quality outcomes following commissioning of the Unit 3 Proposal will satisfy each of the measures described above. This AQMP proposes additional investigations and monitoring to verify that the assumptions inherent in the model predictions are correct and that air quality measurement post-commissioning of the proposal confirms the above targets have been met. Through the ERMP, Alcoa has committed to minimising point and diffuse source emissions where practicable.

1.5 LEGISLATIVE REQUIREMENTS – SUMMARY

The Wagerup Alumina Refinery operates under Ministerial Conditions and an operating licence (Environmental Licence) issued by the Department of Environment under the provision of Parts IV and V of the *Environmental Protection Act 1986* (Appendix I).

The Wagerup Refinery environmental operating Licence (No. 6217/8, Expiry 12 August 2005) details specific operational, monitoring and reporting requirements and details management measures for the control of air pollution at the Refinery. The licence also defines emission limits for NOx, CO and Total Suspended Particulates (TSP) for five emission sources under Section 6 of the licence. The emission sources include the RDAs, Calciners 1, 2, 3 and 4 (individual emission sources), the Liquor Burning Facility (LBF), Boilers (average of boilers 1, 2 and 3) and the GT/ Heat Recovery Steam Generator (HRSG) stacks.

Monitoring programs for each of the emissions sources are specified under Section 5 of the Licence detailing the parameters to be measured, the frequency and standard methods for monitoring where they apply. Results of air quality monitoring are required to be submitted to the Department of Environment (DoE) on a six-monthly basis, in addition to a series of exceedance reporting requirements that commence with notification to the DoE within 24hrs of becoming aware of any exceedance. The operating licence is reviewed annually and amendments made to operating conditions as deemed necessary in response to the demonstrated environmental compliance of the operation of the Refinery and changes in National and State air quality standards.

Air quality is also managed in accordance with national ambient air quality standards known as the National Environment Protection Measure for Ambient Air Quality (the 'Air NEPM'). The Air NEPM is administered by the Environment Protection and Heritage Council (EPHC), a statutory body established under the National Environment Protection Act 1994.

The Air NEPM sets national standards for six key air pollutants of which, carbon monoxide, ozone, nitrogen dioxide and particulates (PM_{10}) are monitored and managed at the Wagerup Refinery. Formal compliance reporting under the Air NEPM commenced in 2002 and in WA is undertaken annually on a statewide basis by the Department of Environment.

The recently introduced Draft Air Toxics Measure (NEPM) is primarily concerned with the collection of data on ambient (i.e. outdoor) levels of formaldehyde, toluene, xylene, benzene and polycyclic aromatic hydrocarbons (PAH) at locations where elevated levels are expected to occur and there is a likelihood that significant population exposure could occur. The aim of the Air Toxics Measure is to provide a framework for monitoring, assessing and reporting on ambient levels of five air toxics; benzene, formaldehyde, toluene, xylenes and PAHs, which will assist in the collection of information for the future development of national air quality standards for these pollutants. The NEPM applies to areas where emissions from cumulative sources give rise to elevated levels of air toxics (e.g. hot-spots). Although industrial point sources may contribute to ambient levels in a specific area, this NEPM is not aimed at direct control of industrial emissions.

2. EXISTING AIR QUALITY

2.1 BACKGROUND

Ambient air quality has been monitored and studied extensively at Wagerup Refinery since 1999, with many external reviews and assessments of the considerable body of data assembled since that time undertaken. These were comprehensively referenced and reviewed in the CSIRO Air Quality Review published in May 2004. The historical focus of ambient air quality monitoring at Wagerup prior to that was on particulate emissions from the residue storage areas, where a network of high volume samplers has been maintained since the 1980's. To this core network of high-volume dust samplers there has been added a range of other samplers, monitoring installations and ambient monitoring campaigns over time: -

- PM_{10} high volume samplers and continuous samplers (TEOM's) at two sites;
- Continuous and campaign based NO_x monitors at two permanent sites, and three temporary sites;
- Ozone samplers at two permanent sites for a year;
- Carbon monoxide continuous monitoring at one of the permanent sites;
- Periodic sulphur dioxide, VOC, carbonyl and acid gas samplers at multiple sites;
- A campaign of intensive fine and ultrafine particle monitoring at the Boundary Rd, Yarloop site;
- Tracer gas monitoring campaigns at multiple locations in Yarloop, Hamel and Wagerup;
- Active and passive VOC and carbonyl compound samplers at a range of sites located around the refinery and residue areas;
- Field odour survey campaigns (trained field assessors making personal odour observations using standard methodology) focusing on refinery and RDA odour impacts on four different occasions; and
- A long-path continuous differential optical absorption system (OPSIS) for simultaneous measurement of multiple pollutant gases.

The above ambient monitoring has been carried out by Alcoa, The Department of Environment (DoE), The WA Chemistry Centre (CCWA), Queensland University of Technology (QUT), and a range of independent NATA certified monitoring consultants and laboratories engaged by Alcoa, DoE and other bodies. The Yarloop community has also participated in some of the above monitoring exercises, working co-operatively with DoE, CCWA and Alcoa in the collection and dispatch for analysis of samples.

All results of the above studies have been published in annual and/or campaign reports submitted to the DoE and have been comprehensively summarised in the CSIRO Air Quality Review. The CSIRO review and the most recent DoE annual environmental report summarise ambient air quality data up to the end of 2003. Hence the approach taken here is to present only a very concise summary of those historical data in tabular form, and to present a more complete assessment of the current ambient monitoring results collected from the end of 2003 to the present.

2.2 METEOROLOGY

The Wagerup Refinery is located on the Swan coastal plain 25 km from the Indian Ocean and to the immediate west of the Darling escarpment, approximately 130 km due south of Perth. The climate of the area is Mediterranean with hot dry summers and cool wet winters.

The winds at Wagerup 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 results in more frequent westerly synoptic flows between periods of lighter winds. For the Wagerup refinery, at the base of the Darling escarpment, topographical features are critically important in modifying these larger scale winds. These topographic features tend to:

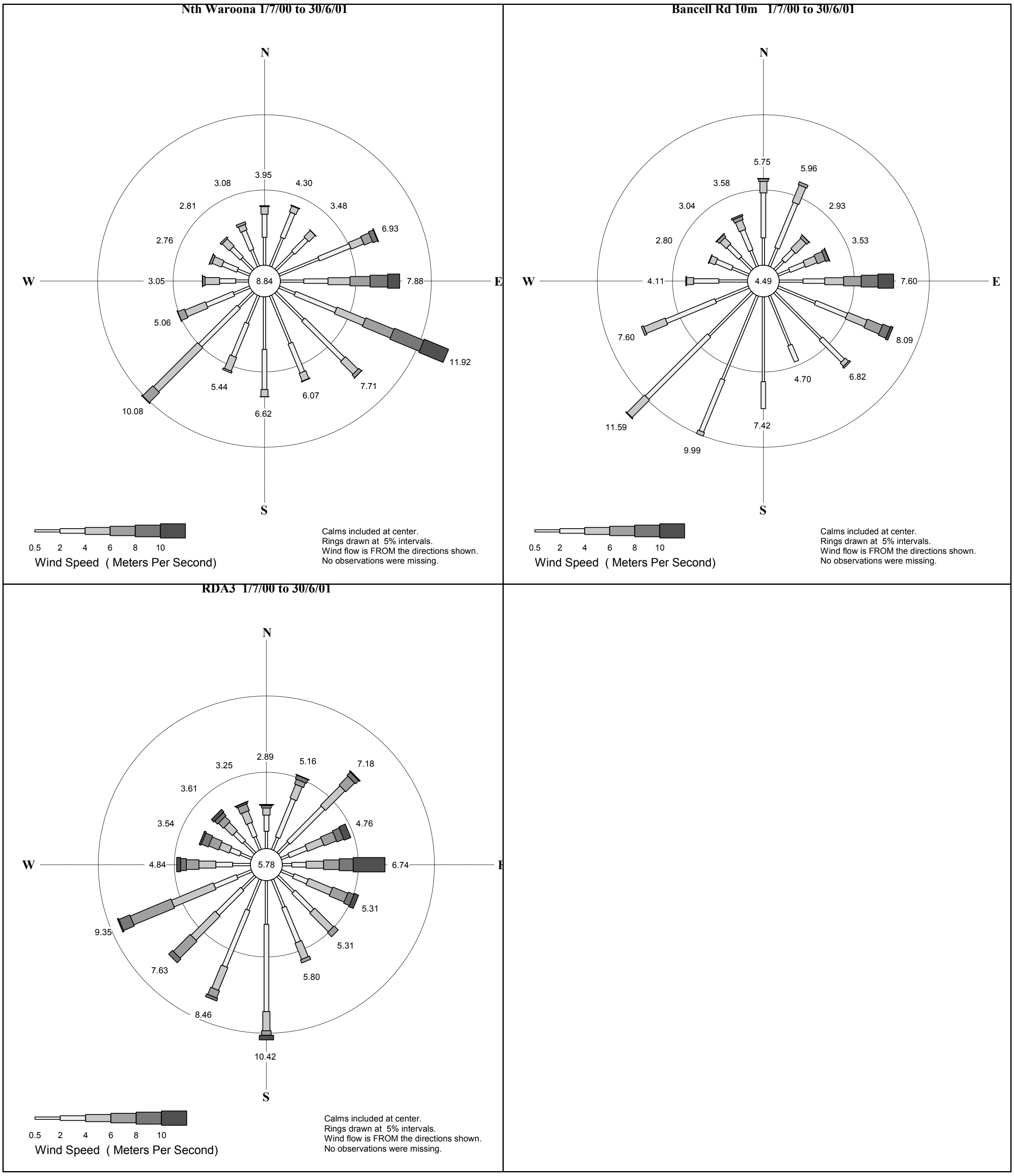
- Generate local very strong winds during summer, principally at night and in the early morning which are known as “gully winds” or “foothill winds”;
- Create rotors or wind reversals near the foothills under easterly winds;
- Channel or deflect westerly winds near the base of the escarpment along the escarpment; and
- Create light drainage (katabatic flows) down the escarpment.

The most pronounced effect of the Darling Escarpment is the generation of very strong easterly winds from early evening to mid/early morning, occurring predominantly in the summer months. These winds extend from the top of the escarpment to the west at distances from several to ten kilometres from its face. Wind speeds in this zone are typically a factor of two or higher than elsewhere on the coastal plain. Hourly averaged wind speeds of 15 m/s (30 knots) are commonly recorded in the foothills during the summer months.

North westerly winds near the scarp can often be more northerly by up to 20 degrees than winds further west, away from the scarp. This is likely due to north/south channelling of the winds by the escarpment. A detailed analysis of winds (and meteorology) in the study area are presented in both the CSIRO and Air Assessment modelling reports.

Wind roses for the three meteorological monitoring sites nearest the Wagerup Refinery are illustrated in Figure 1, with full details given in the report by Assessment by Air Assessments Ltd.

Figure 1 Annual Wind roses for 1/7/00 to 30/6/01 for Nth Waroona, Bancell Rd and RDA3

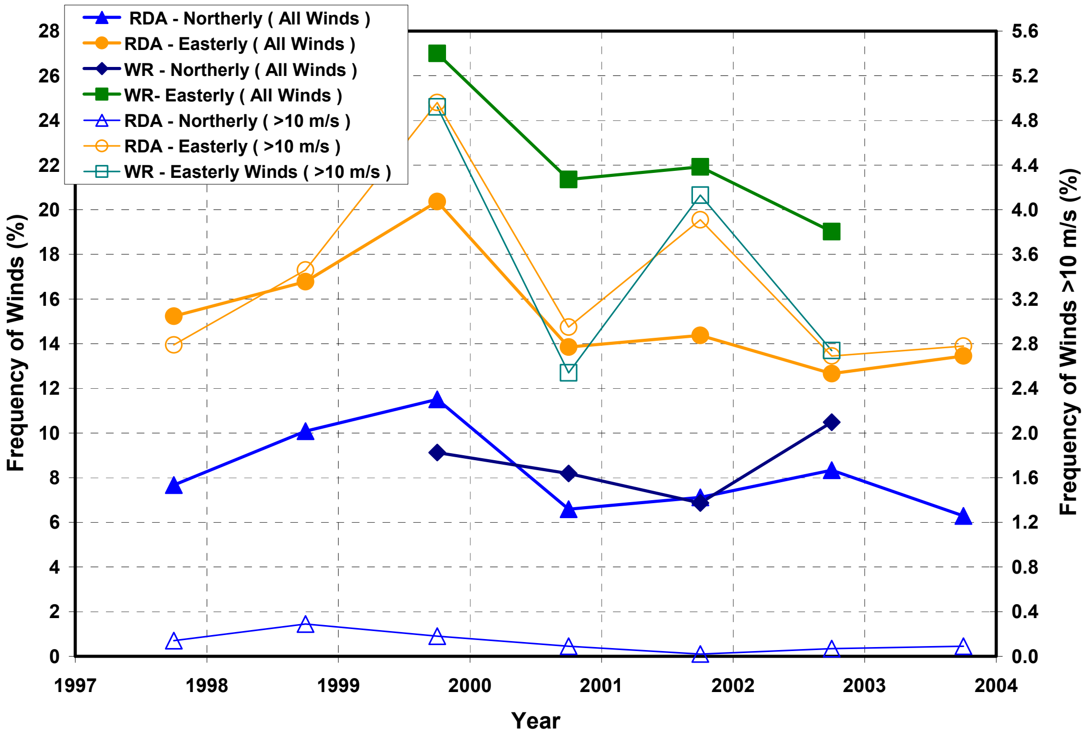


For the odour and dust modelling of refinery emissions, the 12 month period from 1/4/03 to 21/3/04 was selected by CSIRO to predict ground level concentrations. This was selected as it had better meteorological data with the advent of the 30m tower installed in July 2003 at Bancell road. As such, fugitive dust and VOC predictions for RDA emissions are required for the same period to enable the predictions to be combined in order to represent the cumulative emissions of refinery and RDAs.

For fugitive VOC dispersion the conditions that will lead to the highest concentrations off site are light wind stable conditions, whilst for dust it will be the strong wind events that drive the highest impacts. As such, it is the relative frequency of these two classes of wind events that are critical for determining whether the period is representative.

Figure 2 below presents the frequency of all winds from the north and east using both the RDA and Waroona data sets.

Figure 2 Annual Wind frequency for 1/7/00 to 30/6/01 for Nth Waroona and RDA3



A detailed analysis of the meteorological data used in the modelling studies is presented in both the CSIRO and Air Assessment reports.

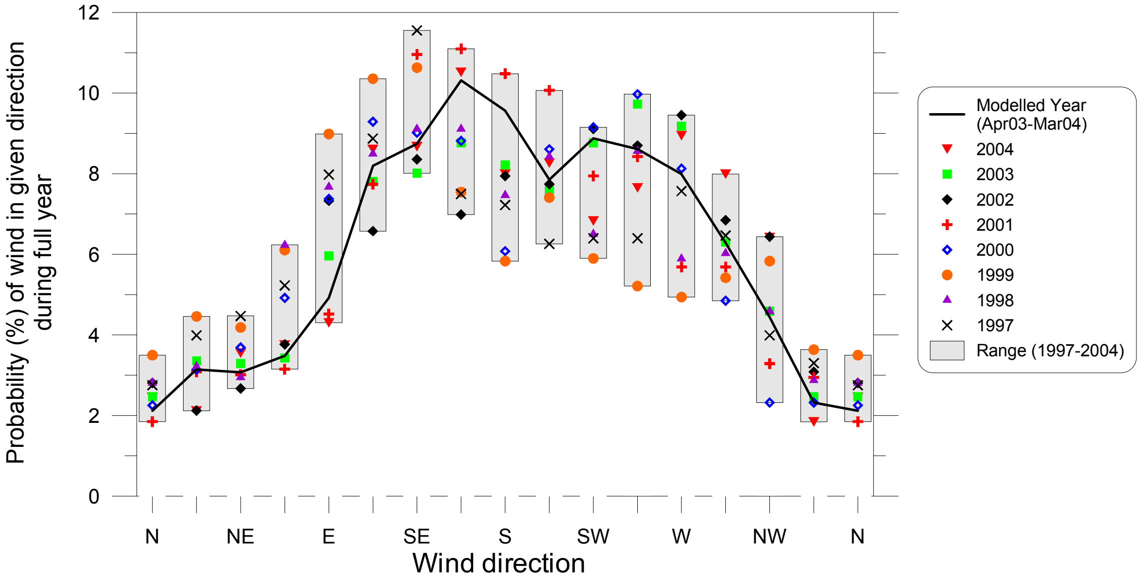
The above figure indicates:

- Good agreement between the trends at the two sites as is expected;
- A higher percentage of easterlies at the North Waroona site, though the frequency of easterly winds greater than 10 m/s is approximately the same. The higher percentage of easterlies at North Waroona is due its close proximity to the scarp;
- 1999/2000 and to a lesser extent 2001/2002 had higher frequencies of strong easterly winds than the other years with 2003/2004 having a lower than average number of strong easterlies. The year 2003/2004 had 7% less easterlies than the average of the 7 years and 17% less easterlies greater than 10 m/s than the average of the past 7 years; and
- 2003/2004 had a lower percentage of strong northerlies.

As such, for strong wind events that may generate dust it is considered that the twelve month period in 2003/2004 would have around 17% lower easterlies and a lower number of northerlies than average

CSIRO (2005b) conducted an analysis of the inter-annual variability of the modelled winds from the Global Analysis and Prediction model (used as input to TAPM) as reproduced in Figure 3.

Figure 3 Probability distribution of 10-m wind directions from the Global analysis and Prediction (GASP) model for the nearest grid point to Wagerup for the years 1997-2004 compared with those from the modelled year (from CSIRO, 2005c)



CSIRO (2005b) found that there was a typical ±30% variation about the mean in the frequency of winds from each wind direction and concluded that the modelled year was “seen to be a fairly average year, just with slightly fewer winds in the NE-N range and more winds in the SSE and SW directions than average”.

It is noted that the data in Figure 3 is from a regional model and reflects primarily the synoptic winds, so may not adequately resolve the finer scale wind fields due to the scarp etc. Nevertheless it is in good agreement with the data, indicating that 1999 was atypical with a much higher frequency of easterlies and lower percentage of westerlies, whilst 2003/2004 selected for the modelling (CSIRO, 2004), had a slightly below average frequency of easterlies and northerly winds.

As such, 2003/2004 should be reasonably typical or slightly conservative for modelling odour and VOC concentrations from low level sources.

2.3 HISTORICAL AMBIENT AIR QUALITY

Table 1 summarises the key ambient monitoring programs conducted between 1999 and 2003 and their results. Full details appear in the listed references and in the CSIRO Air Quality Review.

Table 1 Results of Key Ambient Monitoring Programs 1999- 2003

Program	Year(s)	Parameter(s) Monitored	Averaging Period	Mean (range)	Max	Units	Comments
Alcoa ambient particulate monitoring program	1999 - 2003	TSP	24 hours	24 – 31 (annual)	222	µg/m^3	Typical dust statistics for period at Residue West monitor
	2002 - 2003	PM_{10}	24 hours	7 - 58	58	µg/m^3	Boundary Rd continuous monitor
	2002 - 2003	$PM_{2.5}$	24 hours	1 - 36	36	µg/m^3	Boundary Rd continuous monitor
Alcoa continuous gaseous monitoring program	2002 - 2003	NO_2	1 hour	<1 - 22	22	ppb	Boundary Rd ambient air monitor
	2002 - 2003	O_3	1 hour	<1 -58	58	ppb	Boundary Rd ambient air monitor
	2002 - 2003	CO	8 hours	<0.05 - 0.5	0.5	ppm	Boundary Rd ambient air monitor
Alcoa episodic and campaign monitoring	Winter 2002	VOCs and carbonyls	1 -10 minutes	No carbonyls detected outside refinery, a few VOCs at low levels. Results published in report by Alcoa (Myers, 2004).			
QUT fine particle monitoring program	August 2002	PM_{10} and fine particles	1 minute – 1 week	No association found between fine particle levels and wind direction from the refinery. An association found between alkalinity of particles and refinery wind direction.			
CCWA monitoring programs	2000 – 2003	VOCs TSP respirable dust NO_x & SO_x Carbonyls Mercury vapour	5 minutes – 4 weeks	Summarised in CSIRO review Section 4.1.1 All NO_x, SO_x, VOC and carbonyl levels detected found to be well within applicable WHO or Worksafe Australia exposure standards. Some elevated dust results found using non-standard equipment. No mercury vapour detected.			
DoE monitoring programs	2002 - 2003	VOCs,	3 – 20	Obtained event and background samples - similar levels in each. Unusual level of			

Program	**Year(s)**	**Parameter(s) Monitored**	**Averaging Period**	**Mean (range)**	**Max**	**Units**	**Comments**
		carbonyls	minutes	Methylene chloride in one sample. Full details Section 4.1.2 in CSIRO review.			
Community monitoring (with support of DoE and CCWA)	2002 – 2003	Dust, metals composition, VOCs	3 minutes – 48 hours	Substantial data collected. Anomalous level of Methylene chloride in one sample not accompanied by any other species. Metals levels typical of soil dust. Some elevated dust levels encountered compared to background levels at RDA samplers.			
Field odour surveys (Environmental Alliances Pty Ltd for Alcoa)	2001 – 2003	Odour intensity and concentration	10 minutes	0.6 – 7.0 Yarloop (2001) 0.6 – 5.7 (2003)	11.4 SW Hwy near refinery	Odour units (OU)	Sampling within refinery plumes indicated odour intensities: weak (1) - distinct (3) level. Dominant odour type changed from 2001 to 2003, with overall concentrations lower.

Notes:

1) Chemistry Centre (WA) Report on the Investigation of Health and Irritation Complaints at Wagerup/ Yarloop (1999 testing), May 2000.
2) Chemistry Centre (WA) Final Report: Environmental Monitoring at Wagerup. June- November 2001, February 2002.
3) Chemistry Centre (WA) Wagerup Monitoring Report on Chemistry Centre (WA) Sampling Around Yarloop Townsite July- November 2002, January 2003.
4) Chemistry Centre (WA) and DEP (WA) Report on Environmental Monitoring at Wagerup/ Yarloop July- November 2000. August 2001.
5) Johnson, Sarah 2003 Wagerup Ambient Air Quality Monitoring Report, Alcoa World Alumina, November 2003.
6) Myers, Lance Wagerup Refinery Winter Ambient Sampling Program 2002, Alcoa World Alumina Technology Deliver Group, 2003
7) Morawska L ., Johnson, G, Mejia, J and Ayoko G. Investigations into fine Particle Concentrations in the Vicinity of Alcoa's Wagerup Alumina Refinery.

3. EMISSIONS ESTIMATES

3.1 BACKGROUND

Emissions from the Wagerup Refinery fall into two broad categories, point sources emissions (within the refinery) and diffuse or area source emissions (mainly within the RDAs, although some also present at the refinery).

Wagerup Refinery has been monitoring and reporting emissions to the atmosphere since the mid-1980s. Initially the only substances reported were particulate (dust) emissions from point sources as required under DoE annual environmental performance reporting guidelines. In the early to mid 1990s the advent of voluntary Greenhouse Gas reporting and mandatory National Pollutant Inventory reporting saw substantial effort invested into better monitoring, calculation and estimation for a more complete range of substances.

Wherever possible, use was made of direct monitoring data to provide the most reliable estimation of emissions quantities. In many cases monitoring data were not available for specific substances and thus reliance was placed on other accepted techniques such as mass balances, fuel consumption rates, published emissions factors and engineering calculations. In 1999 Alcoa elected to undertake a comprehensive emissions inventory at Wagerup to enable a more complete range of emissions to be identified and quantified. This was undertaken over the period 2000 to 2001. Also undertaken in 2001 to 2002 were a series of dedicated monitoring programs. Some of this monitoring was required under the DoE licence and some was for performance testing associated with emissions reduction programs and in the development of design criteria. All of these monitoring programs have been described more fully in the CSIRO Air Quality Review (CSIRO, 2004), and were the subject of an independent environmental audit over 2002/03 for the DoE undertaken by Air Water Noise consultants (AWN, 2003).

In the remainder of this section the main aspects and outcomes of these studies on point sources of emissions are presented, however far greater detail is available in the above documents and the actual monitoring reports prepared by Alcoa and independent monitoring consultants.

Diffuse sources had limited monitoring performed up until 2004. However in view of the requirement to include these sources in the HRA for the Wagerup Refinery expansion, as well as in response to recommendations for further monitoring of these areas contained in the CSIRO Review and AWN audit, a comprehensive monitoring program of the diffuse sources has been undertaken over 2004 and continued in 2005. The outcomes of this monitoring program have been used in the diffuse source modelling.

3.2 POINT SOURCES

The point source emissions from Wagerup Refinery fall into two main categories, those associated with non-Bayer process sources, such as the powerhouse boilers and gas turbine/heat recovery steam generator, and the Bayer process sources. Bayer process sources are all those associated with the Bayer process liquor that is used to digest the bauxite for alumina production. These sources generate a variety of substances and emissions that are typical of the alumina refining process, as well as other substances that are more generic in industrial and mineral processing. It is these combined emissions that produce the characteristic odour associated with Bayer process refineries.

The emissions from the non-Bayer sources include products of combustion of natural gas fired boilers and gas turbines, and those related to constituents in the fuels consumed in the refinery. In addition there are fugitive sources of emissions of a generic nature such as dust from unsealed areas of ground and roads, vented emissions from fuel storage tanks, and fugitive emissions from general maintenance and construction activities carried out at the refinery.

3.2.1 Source Selection

The point sources of emissions at Wagerup Refinery are summarised in Table 2 below. Those sources included and not included in refinery emissions modelling for the HRA are shown in the table, along with information on the nature of the process and substances likely to be emitted from it, and comments on the control or removal measures being put in place to manage emissions associated with the expansion from the significant point sources.

The significant point sources included in modelling of refinery emissions account for approximately 96% of the total mass of refinery air emissions. Sources not included in modelling together account for the remaining 4%, with no individual source among these accounting for 1% or more of air emissions. Some of these sources not included in modelling of specific substances for the HRA are included in odour modelling.

Table 2 Details of point sources at Wagerup Refinery

Source Type	Description of source	Sources sampled	Explanation of source selection and other details on emissions
Calciners	Calcination is the processing step of converting hydrated alumina to alumina. This is done by heating hydrate in a fluidised bed furnace at approximately 1000°C to drive off water of crystallisation.	Calciners 1 to 4	All four stacks are individually monitored. Results of monitoring since Q3 2002 used to derive emission rates.
Calciner vacuum pumps	Calciner feed material (alumina trihydrate) is washed on vacuum filters prior to entering the calciners to remove entrained caustic. The vacuum exhaust is collected into one vent for the three filters on Calciners 1-3 while Calciner 4 has its own vent.	Calciner 1-3 vacuum pump	The Calciner 1-3 vac pump vent was sampled as this has the larger combined capacity. Sampling of the larger unit was thought to provide a more accurate estimate of the upper range of emissions from this source type.
Calciner Tank	This source vents the 50B tank, where condensate used for washing hydrate is held prior to passing the hydrate pan filters. The condensate is heated further before being used to wash entrained liquor from the hydrate.	50B tank	There is only one source of this type in the refinery.
Liquor Burner	The Liquor Burner is required to control the build-up of organic compounds in recirculating process liquor. These compounds originate from organic material in bauxite. They inhibit and significantly reduce the extraction of alumina from liquor. The Liquor Burner represents a means of ensuring continued responsible use of the bauxite resource and minimisation of energy wastage and Greenhouse gas emissions. The drying and combustion of organic components in the liquor burner creates a range of organic compounds.	Liquor burner stack	The emissions from this source are currently controlled by cyclones, multiclones, electrostatic precipitator, dehumidifier and a catalytic thermal oxidiser (CTO). A higher efficiency regenerative thermal oxidiser (RTO) will be used to replace the CTO for the expansion.

Source Type	Description of source	Sources sampled	Explanation of source selection and other details on emissions
Cooling Towers	Various parts of the Bayer process require the progressive cooling of hot liquor. Separate (non-contact) cooling water circuits are used to generate cool water. Water that has been used to cool hot liquor is directed to the Cooling Towers where it is cooled again so it can be recycled.	Precipitation (45) Cooling Towers and Calcination (50) Cooling Towers	The precipitation Cooling Tower 2/3 was selected for sampling as it is the largest Cooling Tower on site. Emissions from the other cooling towers calculated based on the data from 2/3.
Powerhouse Boilers	Alcoa refinery powerhouses generate process steam and electricity for the refining process by means of natural gas fired boilers and turbo-alternators.	Boilers 1 – 3 and the GT/HRSG	All boilers and the GT have been sampled in programs from 2002 to the present.
Clarification Tanks – 35A Green Liquor	Green Liquor is held in this tank after it has been filtered to remove all solids remaining after the clarification process and prior to being further cooled before precipitation.	35A (Green Liquor)	There are two Clarified Green Liquor tanks that operate interchangeably. Only one tank is in circuit at any one time. 35A2 is the tank that was in circuit during this monitoring program as well as in the bi-monthly program.
Clarification Tanks – 35J Causticisation	In this processing step, weak caustic liquor is dosed with lime to regenerate caustic soda from sodium carbonate. The process takes place above 100 °C and is accompanied by release of vapour.	35J (causticisation)	There are two Lime Causticisation units at Wagerup, unit 1 containing four tanks in series (35J12, 35J13, 35J14, 35J15) and unit 2 containing two tanks in series (35J24, 35J25). Unit 1 has a larger capacity than unit 2, and although the suite of compounds from each unit is expected to be of a similar nature, sampling of the larger unit was thought to provide a more accurate estimate of the upper range of emissions from this source. On the basis of the bi-monthly monitoring program 35 J15 was chosen as the sample point.
Evaporation vacuum pumps – Bldg 42	A vacuum is maintained in the evaporation flash circuit to minimise energy wastage by removing non-condensable gases from the circuit. The exhaust from the 42B vacuum pumps contains these non-condensable vapours that were previously vented to atmosphere.	42B, B4/C3 U2	There are 4 pump vents operating in parallel. The 42B4/C2/C3 vacuum pumps vent was chosen for sampling as it is the single largest one and is believed to represent the upper end of the range and concentrations of emissions from this source group. Note - this source is now intercepted with all collected exhaust routed to the powerhouse for non-condensable gas destruction.
			Two digestion units operate in parallel. Each unit has one Digestion

Source Type	Description of source	Sources sampled	Explanation of source selection and other details on emissions
Digestion Vacuum Pumps	A vacuum is maintained in the digestion flash circuit to minimise energy wastage by removing non-condensable gases from the circuit. The exhaust from the vacuum pumps contains these non-condensable vapours that were previously vented to atmosphere.	Unit 3	Vacuum Pump stack called 30 vac pump Unit 1 and 30 vac pump Unit 2. U2 is the larger of the two units. The vacuum pump from unit 2 was selected for sampling since this is the larger unit and would provide a more accurate estimate of the upper range of emissions from this source. Note - this source is now intercepted with all collected exhaust routed to the powerhouse for non-condensable gas destruction.
Mills vents	In milling, crushed bauxite from the stockpile is mixed with hot caustic liquor. The process of pre-digestion commences in the mills and is accompanied by release of some vapour via venting through the mills. As the temperatures and residence times are lower and shorter than in subsequent process steps – the amounts of vapour emissions from this source are relatively small.	Mill 3 Vent	There are 3 mills at Wagerup Refinery and Mill 3 Vent was chosen to represent this source group as it is the largest source and is believed to be typical of all other vents. The processes in each mill are essentially identical.
Digestion Stack Blow- off (Digestion Blow-off)	After undergoing digestion, the bauxite slurry and entrained liquor must be flash cooled for subsequent processes in the Bayer circuit. Most of the flash vapour is recovered as an energy source and used for heating. Under the system existing at the time of monitoring, the residual vapour released in the final stages of flashing was collected to a central tank – the digestion containment blow-off tank, prior to venting to atmosphere.	Unit 2	Two digestion units operate in parallel. Each unit has one digestion blow-off containment tank. The capacity of the Unit 2 Blow-off Containment tank is larger and on this basis was considered to be the most representative release point to sample. Note - this source is now intercepted with all collected exhaust routed to the powerhouse for non-condensable gas destruction.

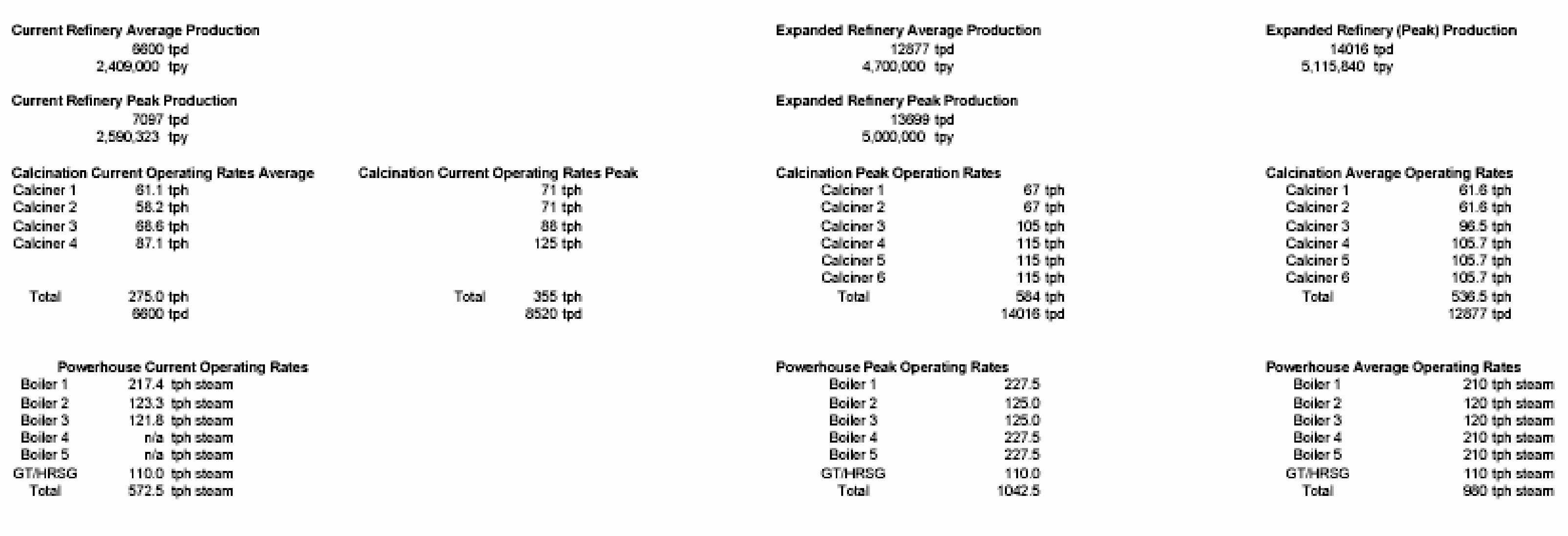
Source Type	Description of source	Sources sampled	Explanation of source selection and other details on emissions
Slurry Storage – 25A Vents	Slurry storage represents the next processing step after milling and receives slurry to remove dissolved silica from the milled ore. It is operates at a lower temperature but has longer residence time than the subsequent digestion process. It utilises excess flash vapour from the digestion process for heating of slurry. As a consequence there is intermittent release of vapour from vents associated with each Slurry Storage Tank.	25A	The Slurry Storage Tanks include four tanks in series. 25A3 is the first tank in the series. Since the 25A3 tank is the hottest and is the only tank that receives digestion vapour directly it was assumed that this tank would be the most significant source of VOC emissions. 25A3 has three tank vent release points that are identical apart from their location. The central vent was chosen and is considered representative of the emissions from this source. ***Note****: As part of the B30 odour destruction project for the expansion the amount of digestion flash/blow-off vapour directed to this source will be greatly reduced, and consequently vapour emissions will reduce to ¼ of the present for a greater number of process units.*
Oxalate Kiln Stack	Sodium oxalate is formed in Bayer liquor from the reaction of organics and caustic soda. In order to minimise adverse process impacts the sodium oxalate is precipitated from the circuit in an oxalate removal unit. A significant amount of sodium oxalate is generated and requires disposal. This has historically been achieved by thermal destruction in an oxalate kiln. The oxalate kiln stack at Pinjarra was included for analysis in the scope of the inventory program.	47 Stack	Data for the estimation of emissions from the design oxalate stack for Wagerup is based on the output from the Pinjarra Refinery oxalate stack, factored for production rate, with an assumed 95% VOC and odour removal efficiency for the designed RTO unit. Operating experience gained by Worsley Alumina with an RTO unit fitted to their liquor burner demonstrates a removal efficiency greater than 99%.
Non-modelled sources			
OBF Filter Vacuum Pump Stack	Oxalate is filtered prior to combustion in the kiln. The vacuum pumps for the filters discharge to air via vacuum pump vents.	47 OBF vent stack	Currently a minor source, not included in the modelling. Will be eliminated in the upgrade by routing to the oxalate kiln RTO.
26 Sand Building Stacks	After separation, sand is washed to maximise recovery of liquor. Vapour can be emitted from vents and the general building		Relatively small source of vapour emissions. Not included in emissions inventory program.

Source Type	Description of source	Sources sampled	Explanation of source selection and other details on emissions
35F & D Vents	Mud thickeners and relay tanks, separation of mud and liquor prior to routing of mud to RDA.		Relatively small source by mass emissions. Will be included in odour modelling, though not in specific substance modelling.
35C Vents	Washers – used to recover the maximum amount of liquor and caustic from mud before thickening		Relatively small source by mass emissions. Will be included in odour modelling, though not in specific substance modelling.

3.2.2 Volumetric Flow Determination

Volumetric flow determination has been based on process variables, confirmed by an independent expert consultant as a robust and acceptable technique for the quantification of stack flow rates for emissions determination (University of Adelaide, 2003). Process flow conditions for the current and expansion cases are summarised in Table 3 below. In the table the production rates of individual process units at current averages, and the assumed expansion average and expansion peak are shown. These production rates have been used to calculate flow rates from the various process units. The summary in Table 3 also provides the change in volume flow rate and concentration that has been used to derive the mass emission rates for the expansion.

Table 3 Wagerup Expansion and Current Refinery Process Flow Assumptions



Current Refinery Average Production
6600 tpd
2,409,000 tpy

Current Refinery Peak Production
7097 tpd
2,590,323 tpy

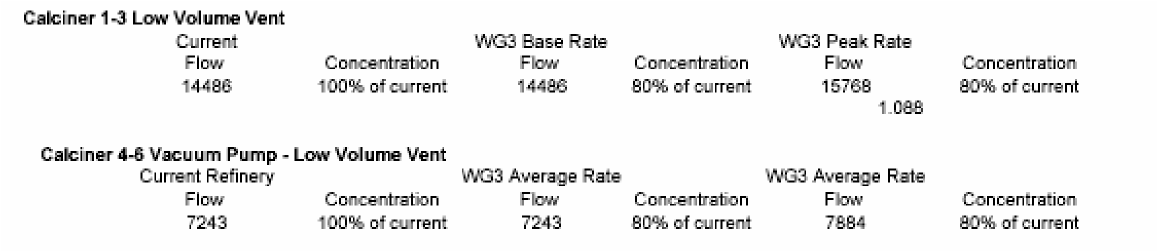
Expanded Refinery Average Production
12877 tpd
4,700,000 tpy

Expanded Refinery Peak Production
13699 tpd
5,000,000 tpy

Expanded Refinery (Peak) Production
14016 tpd
5,115,840 tpy

	Calcination Current Operating Rates Average	**Calcination Current Operating Rates Peak**	**Calcination Peak Operation Rates**	**Calcination Average Operating Rates**
Calciner 1	61.1 tph	71 tph	67 tph	61.6 tph
Calciner 2	58.2 tph	71 tph	67 tph	61.6 tph
Calciner 3	68.6 tph	88 tph	105 tph	96.5 tph
Calciner 4	87.1 tph	125 tph	115 tph	105.7 tph
Calciner 5			115 tph	105.7 tph
Calciner 6			115 tph	105.7 tph
Total	275.0 tph	355 tph	584 tph	536.5 tph
	6600 tpd	8520 tpd	14016 tpd	12877 tpd

	Powerhouse Current Operating Rates	**Powerhouse Peak Operating Rates**	**Powerhouse Average Operating Rates**
Boiler 1	217.4 tph steam	227.5	210 tph steam
Boiler 2	123.3 tph steam	125.0	120 tph steam
Boiler 3	121.8 tph steam	125.0	120 tph steam
Boiler 4	n/a tph steam	227.5	210 tph steam
Boiler 5	n/a tph steam	227.5	210 tph steam
GT/HRSG	110.0 tph steam	110.0	110 tph steam
Total	572.5 tph steam	1042.5	980 tph steam



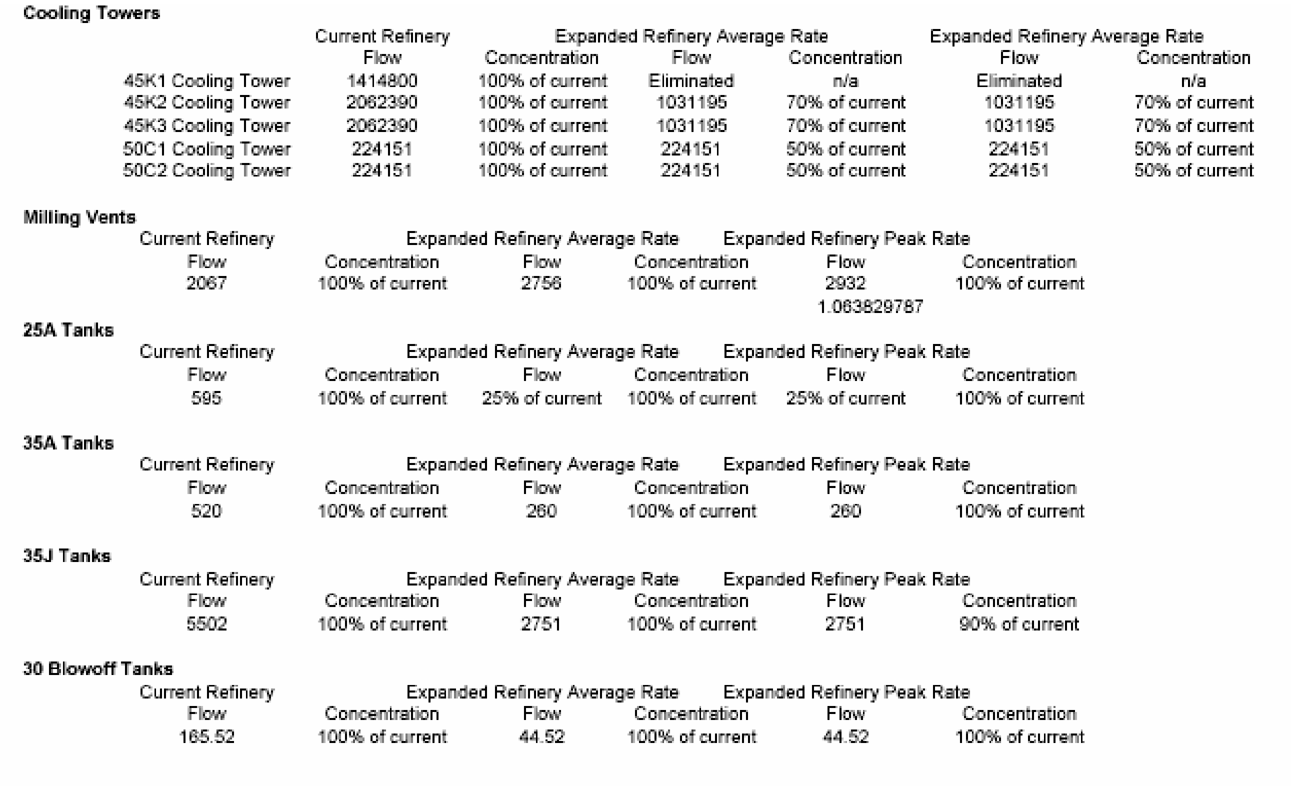
Calciner 1-3 Low Volume Vent

Current Flow	Concentration	WG3 Base Rate Flow	Concentration	WG3 Peak Rate Flow	Concentration
14486	100% of current	14486	80% of current	15768	80% of current
				1.088	

Calciner 4-6 Vacuum Pump - Low Volume Vent

Current Refinery Flow	Concentration	WG3 Average Rate Flow	Concentration	WG3 Average Rate Flow	Concentration
7243	100% of current	7243	80% of current	7884	80% of current

Table 3 (cont) Wagerup Expansion and Current Refinery Process Flow Assumptions



Cooling Towers

	Current Refinery		Expanded Refinery Average Rate		Expanded Refinery Average Rate	
	Flow	Concentration	Flow	Concentration	Flow	Concentration
45K1 Cooling Tower	1414800	100% of current	Eliminated	n/a	Eliminated	n/a
45K2 Cooling Tower	2062390	100% of current	1031195	70% of current	1031195	70% of current
45K3 Cooling Tower	2062390	100% of current	1031195	70% of current	1031195	70% of current
50C1 Cooling Tower	224151	100% of current	224151	50% of current	224151	50% of current
50C2 Cooling Tower	224151	100% of current	224151	50% of current	224151	50% of current

Milling Vents

Current Refinery		Expanded Refinery Average Rate		Expanded Refinery Peak Rate	
Flow	Concentration	Flow	Concentration	Flow	Concentration
2067	100% of current	2756	100% of current	2932	100% of current
				1.063829787	

25A Tanks

Current Refinery		Expanded Refinery Average Rate		Expanded Refinery Peak Rate	
Flow	Concentration	Flow	Concentration	Flow	Concentration
595	100% of current	25% of current	100% of current	25% of current	100% of current

35A Tanks

Current Refinery		Expanded Refinery Average Rate		Expanded Refinery Peak Rate	
Flow	Concentration	Flow	Concentration	Flow	Concentration
520	100% of current	260	100% of current	260	100% of current

35J Tanks

Current Refinery		Expanded Refinery Average Rate		Expanded Refinery Peak Rate	
Flow	Concentration	Flow	Concentration	Flow	Concentration
5502	100% of current	2751	100% of current	2751	90% of current

30 Blowoff Tanks

Current Refinery		Expanded Refinery Average Rate		Expanded Refinery Peak Rate	
Flow	Concentration	Flow	Concentration	Flow	Concentration
165.52	100% of current	44.52	100% of current	44.52	100% of current

3.2.3 Emission Rate Determination

3.2.3.1 Current Scenario

The concentrations of products of combustion and VOCs used to calculate peak emission rates are those derived from monitoring runs conducted between Quarter 3 2002 to Quarter 1 2004. Before that period the refinery was operating in a significantly different condition as the emission reductions programs for NO_x and odour/ VOCs had not yet been undertaken. Peak emission rates have been calculated taking the maximum monitored concentrations, combined with peak flow rates as outlined in table 3, to arrive at mass emission rates.

For metals and metallic compounds, the data in the period 2002 to 2004 is more limited, so data collected in the emissions inventory program is also used in calculating their emission. Where there was a need to improve the input data, for example as indicated in the independent Environmental Audit (AWN 2003), additional monitoring was performed to improve the confidence in the calculated emission rates.

3.2.3.2 Expansion Scenario

Emission reductions (either volumetric flow rates or concentrations, or both) have been factored into the derivation of expansion emission rates for a number of sources in the expanded refinery. The basis for these changes reflects specific design measures and improvements in operational performance that are planned for the refinery expansion. The basis for these design and operational improvements in reducing emissions, or in limiting their increase with the expansion is given below for each source where a reduction or reduced increase in emissions is claimed (Table 4).

Table 4 shows the emission control works included in the Unit Three proposal at this point in the engineering design phase. Design work will continue for several months after release of the ERMP and refinement may result in changes to the emission control measures shown in the ERMP and releated documents (e.g. Table 4). However, where changes eventuate as a result of detailed engineering design, Alcoa will implement modified emission control measures to achieve equivalent emission performance outcomes as part of the Proposal.

The emission rates used in the CSIRO modeling were since updated based on additional information received from Alcoa on the proposed plant design and specifications, changes to the proposed controls and further refinement of calculated emission estimates. The changes to the emission estimates have resulted in additional post processing/scaling of the modelling undertaken by CSIRO, with the new emission rates used to produce concentration contours within the modelled domain and to re-calculate ground level concentrations at nominated receptor locations for use in the QHRA. A copy of the updated emission rates is presented in Appendix J.

Table 4 Operational and Design Improvements to Reduce Emissions

Source	Emission Reduction Mechanisms
Calcination	• Calciners 5 and 6 to be installed with three zone ESP's. Expected dust output will be limited. Existing ESP's are 2 zone - thus peak emissions when rapping will be significantly reduced. Calciner 3 to be improved to Mark VI standard to match emissions levels of Calciner 4 • Peak Wagerup 3 Calcination rate dropped from 14,400 tpd to 14,016 tpd
Powerhouse	• No additional improvements to the Boilers or GT/HRSG are planned over the original scope of work already modelled • New boilers 4 and 5 to have current technology dry low NO_x burners
Calciner 1-3 Low Volume Vent Emissions (Calciner 1-3 vacuum pumps, Dorrco and Filter Scroll Hoods)	
	• It is intended to modify the existing calciners such that the low volume vent emissions from each calciner are directed into the calciner combustion air. VOCs and odour will thus be consumed in the calciner furnace zone
Calciner 4-6 Low Volume Vent Emissions (Calciner 4-6 vacuum pumps, Dorrco and Filter Scroll Hoods)	
	• Calciner 4 to be modified to feed existing stack emissions into calciner • Calciners 5 and 6 to incorporate low volume emissions into combustion air feed system
Cooling Towers	• Operation of Cooling Towers to be modified to achieve a 50% reduction in odorous emissions • This will be achieved by a combination of measures including filtration of cooling water to reduce suspended particulates, reduced water treatment chemical usage and alternative water sources.
Milling Vents	• The installation of additional mill capacity is expected to increase the vapour emission to 133% of the current flow • No technology is currently known that is capable of reducing the concentration of the emission from this source
25A Tanks	• Additional 25A tanks are to be installed with the upgrade • Existing contact heaters to replaced by sealed units. This is expected to reduce vapour flows from this source by 75%. No decrease in the concentration of emissions from the source is expected
Digestion Blow-off containment tank vents	
	• Unit 3 to be construced with a spare flash tank to be used during flash tank outages. • Improved heat recovery through better management of maintenance activities. • Existing vapour emissions of approximately 5tph (2003-4 average) to be reduced to approximately 0.75 tph per unit, improving the collection of

Source	Emission Reduction Mechanisms
	vapour emissions and routing to boilers for thermal destruction • Flowrate expected to decrease from 2.75 m³/h to 0.75 m³/h (or 73% reduction) • Concentration to remain the same as existing
Sand Removal (Building 26) (this source not a significant source, <1% of refinery emissions, and was not modelled)	• No changes planned for existing sand rakes and belt filter • Emissions from proposed new cyclone separation system estimated to be approximately 50% of the current emission levels • Concentration of emissions not expected to change unless a reduction in temperature is achieved
Causticisation (35J)	• 35J causticisation will be either shut down and replaced with high efficiency causticisation units (HEC), or alternative emissions control will be used to reduce emissions.
Clarified Filtrate (35A)	• New filters to be modernised to modern day equivalent. No press air used to dump these filters which should avoid increasing flows from 35A vent • Existing tank vents to be modified to control flow rate from tanks. • Concentration of emissions to remain unchanged from current

3.3 DIFFUSE SOURCES

3.3.1 Source Selection

In the past there has been limited measurement of emissions from diffuse sources at Wagerup Refinery. These sources are made up of the RDAs, the refinery cooling pond, the runoff water storage pond (ROWS pond), runoff collection ponds (ROCP), the lower dam, superthickener and a variety of other associated sub-areas. In the Wagerup emissions inventory final report (Alcoa 2002), two exploratory monitoring runs on the cooling pond and a residue drying area were carried out. No clear conclusions could be drawn from these studies in respect of emission rates due to uncertainties in measurement and the variability of the sources.

The AWN independent audit and the CSIRO Air Quality Review both recommended that Alcoa should address this gap in knowledge of emissions to air from diffuse sources. Alcoa committed to doing this in response to the recommendations, and has been engaged since late 2003 and over 2004 in investigating and developing the means for doing so.

3.3.2 Emission Rate Determination

The RDAs consist of residue in various stages of drying. These sources exhibit relatively low specific emission rates. Nevertheless, they have a large surface area, which increases the significance of their contribution to overall emission rates. The specific emission rates were found to be a function of factors, which vary according to the history, state of dryness, and environment of the residue. These factors are important in determining emission rates, which by analogy with soils are controlled by the following main residue-related factors:

- Air-filled porosity;
- Bulk soil temperature; and
- Surface temperature

The other main determinants of specific emission rates are the concentration and vapour pressure of the contaminants, and the wind speed.

3.3.2.1 Dust

In the development of dust emissions rates for the RDAs, any emission method are indicative due to the complexity of the surfaces. For example, for any area within the RDA the dustiness is extremely dependent on the stage of the drying process, frequency of dozing operations, frequency of sprinkler wetting, equipment failure and accuracy of weather forecasts to enable pre wetting of surfaces and the availability of personnel.

Dust emissions from the RDA area occur due to:

1. Wind erosion under high winds;
2. Normal operations such as dozing of surfaces, light vehicle movement and construction of walls; and
3. Construction of new RDA areas where major earthworks occur.

Of these, wind erosion is considered to be the largest source and hardest to control and has been examined in a number of studies including:

1. Wind tunnel studies using Agwest's large portable wind tunnel to investigate the wind erosion potential of various residue surfaces at the Pinjarra refinery, as reported in Bell (1984) and later by Scott (1994);
2. Dust dispersion modelling by Aust-Environ (1984) for the Kwinana residue area;
3. Dust estimation and modelling of dust levels by Steedman Science & Engineering (1994), followed by the development of a linked water cannon control/dust model by Halpern Glick Maunsell (1996);
4. Dust estimation and modelling for the Pinjarra residue area by SKM (2001), as also reported in Pitts (2000);
5. Evaluation of the wind speed up of the current and future residue area at the Wagerup refinery by SKM(1999); and
6. Recent study by SKM (2004) of dust emissions and the modelling of dust levels for the Kwinana RDA.

To estimate the total particulate emissions from the RDA in the years 2003/2004 (before construction of RDA7), a total erodible area of 168 ha consisting of the dry stacked and sand stockpile areas was used. The dust emissions were then assigned to the various areas within the RDA based on operational knowledge.

1. Approximately 15 % of the estimated dust emissions were from the sand stockpile area;
2. 6 % of the estimated dust emissions were from ROCP1;
3. 10 % of the estimated dust emissions were from RDA2 including the sand areas; and
4. The remainder was assigned to various RDA areas.

To enable a level of consistency in how emissions to the dry stacked areas were apportioned for the base and expansion case, the remaining 69 % were assigned to the various dry stacked RDA areas by the estimated dust control in the area. The level of dust control was determined by a combination of the proportion of water cannons working in the area (percentage lateral failure) and the water cannon control efficiency as detailed in Table 5.

Table 5 Estimated Dust Contribution from the Dry Stacked Areas in the RDA

Source	**Area (ha)**	**Area as percentage of total dry stacked area in 2003 (%)**	**Percentage Lateral Failure (%)**	**Water Cannon Control (%)**	**Overall Dust Control (%)**	**Percentage of 03/04 area not covered (%)**	**Percentage relative to 2003/2004 dry stacked area dust (%)**	**Percentage of total 2003/2004 RDA dust (%)**
2003/2004 Pre RDA7								
RDA1	10.53	6.5	0	61	61	2.55	5.2	3.6
RDA3a	43.87	27.3	21	61	48	14.19	29.1	20.1
RDA3b	21.61	13.4	0	61	61	5.23	10.7	7.4
RDA4	40.7	25.3	27	61	44	14.06	28.8	19.9
RDA5	19.0	11.8	29	61	44	6.66	13.6	9.4
RDA6	25.3	15.7	0	61	61	6.13	12.6	8.7
Total	**161.02**	**100**				**48.82**	**100**	**69.0**
Base Case with RDA7 operational								
RDA1	10.53	6.5	0	61	61	2.55	5.2	3.6
RDA3a	32.74	20.3	14	61	52	9.70	19.9	13.7
RDA3b	32.74	20.3	14	61	52	9.70	19.9	13.7
RDA4	40.7	25.3	27	61	44	14.06	28.8	19.9
RDA5	19.0	11.8	33	61	41	7.00	14.3	9.9
RDA6	25.3	15.7	0	61	61	6.13	12.6	8.7
RDA7	25.5	15.8	0	77	77	3.64	7.5	5.1
Total	**186.52**	**115.8**				**52.79**	**108.1**	**74.6**
Expansion Case								
RDA1	2.9	1.8	3	77	75	0.46	0.9	0.6
RDA2	10.5	6.5	3	77	75	1.65	3.4	2.3
RDA3a	22.7	14.1	3	77	75	3.57	7.3	5.0
RDA3b	22.7	14.1	3	77	75	3.57	7.3	5.0
RDA4	27.1	16.8	3	77	75	4.26	8.7	6.0
RDA5	10.2	6.3	3	77	75	1.60	3.3	2.3
RDA6	16.3	10.1	3	77	75	2.56	5.2	3.6
RDA7	18.4	11.4	3	77	75	2.89	5.9	4.1
RDA8	30.7	19.1	3	77	75	4.83	9.9	6.8
RDA9	36.7	22.8	3	77	75	5.77	11.8	8.2
RDA10	36.3	22.5	3	77	75	5.71	11.7	8.1
RDA11	40.0	24.8	3	77	75	6.29	12.9	8.9
Total	**274.5**	**170.48**				**43.1**	**88.4**	**61.0**

The percentage failure of laterals refers to failures in the pipes along which the water cannon are connected. Water cannon footprints are visible in Figure 4 showing the lines of laterals and some of the missing laterals at the time of the photograph. Here it is assumed that dust control and emissions are directly proportional to the area of sprinkler coverage. It is noted that for an extreme wind event the average area controlled will improve from 61 % to 77% with the new sprinkler arrangement. At lower wind speeds higher coverage occurs, but for the purpose of this exercise a worst case wind event is considered. Emissions from construction activities and wind erosion from exposed areas for the validation year were estimated separately.

Figure 4 Evidence of Water Cannon Footprints on the RDAs

Overall dust control was estimated according to:

Dust control = [water cannon control (%)/100 x (1 - lateral failure (%)/100)] x 100

Percentage of area not covered = area dry stacked in 03/04 (%) - (1 - Dust Control (%)/100)

For this study, wind erosion for the Wagerup RDA was estimated using the relationships derived on a unit area basis for the Kwinana and Pinjarra RDAs, modified by a soil wetness function to account for the effect of rainfall on emissions. These emissions were then input into the dispersion model Calpuff and used to predict the dust concentrations, and then adjusted if needed to provide better agreement with the observations. This approach calibrates the model using the emissions and is required as sites will differ due to differences in work practices and importantly to differences in the anemometer siting.

Dust emissions were estimated for three cases:

1. 1 April 2003 to 31 March 2004, as used for validation/calibration of the dust model. This included the activities associated with the construction of RDA7;
2. A base case, taken as post May 2004, when RDA7 construction had finished and RDA7 was operational; and
3. An expanded case, with 274 ha of dry stacking area available.

For the expanded case dust emissions were estimated based on the following:

1. Existing RDA areas 3, 4, 5 and 6 - The older steel pipes (and poly pies for RDA1) are to be replaced with new poly pipes in a more closely spaced arrangement that will increase water cannon coverage under the extreme wind conditions from 61 % to 77 %.
2. RDA2 - This will be replaced with a new dry stacked area using the new water cannon arrangement;
3. RDA 7 and RDA 8 to RDA 11 - These will have new water cannon arrangement; and
4. Lateral failures - With the new poly pipes it is anticipated that this will be much lower as they do not corrode as do the existing steel pipes when used with caustic water. For the expanded case an overall lateral failure rate of 3% was provided by Alcoa. With over 100 laterals in the RDA in the future, this equates to 3 or more lateral failures at any time.

Based on the above, with the change to the new sprinkler arrangement and corresponding decrease in lateral failures, it is predicted that dust emissions from the dry stacked areas will be 88.4 % of the current dry stacked emissions or 81.8% of the base case. For other sources such as the sand stockpile, no change to the dust emissions has been assumed. The amount of sand pumped to the RDA is forecast to increase significantly from 5,806 tpd to 13,353 tpd, due to shifting the sand/mud split. Though a large increase in sand, the sand stockpile area is not considered to increase as new pumps are being installed that will enable the sand to be pumped directly out to all walls for construction. It is estimated that in future, 97 % of the sand will be able to be directly pumped out compared to only 90% at present. For the ROCP1, no change has been assumed.

Total dust emissions in the expanded case are estimated at 82% of the 2003/2004 case as detailed in Table 6.

Table 6 Estimated Dust Contribution for the three cases

Source	**Sand Stockpiles**	**ROCP1**	**Sand Areas at RDA2**	**Dry Stacked Areas**	**Overall Dust Emissions as a percentage of 2003/2004**
2003/2004	15	6	10	69	100
Base Case	15	6	10	74.6	104.6
Expanded Case	15	6	0	61	82

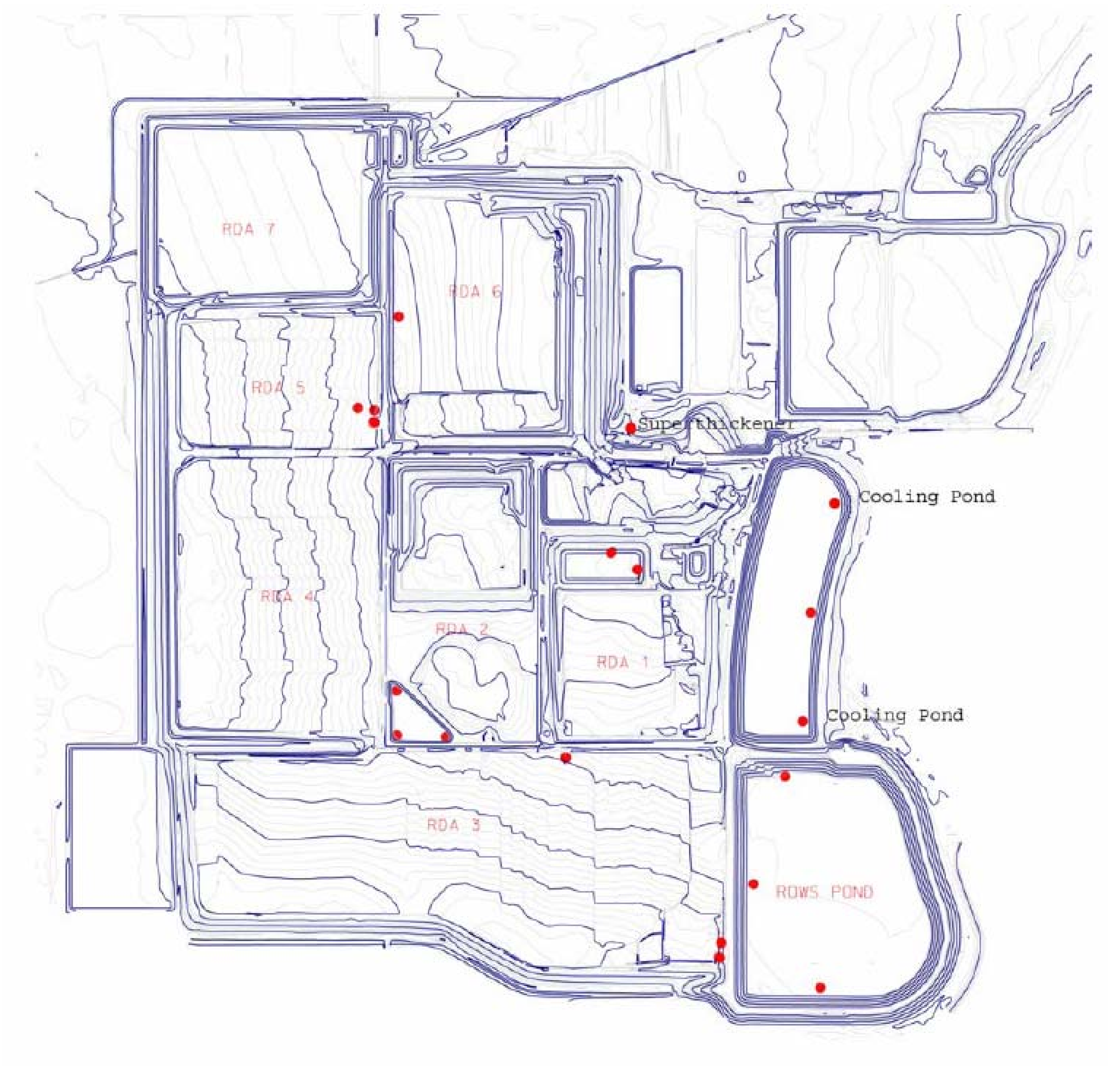
A detailed analysis of the dust emissions, options, controls and estimation techniques can be found in the RDA Air Quality Impact Assessment, Air Assessments [2005].

3.3.2.2 Gaseous Pollutants

A comprehensive monitoring program for diffuse source emission rates of VOCs, carbonyl compounds and odour was undertaken at Wagerup RDAs (Figure 5) over October 2004 to February 2005 by GHD Pty Ltd. Emissions from the diffuse sources have been measured with a US EPA isolation flux chamber by GHD Pty Ltd, following the recommendations of the Wagerup Environmental Audit (AWN 2003) and the Wagerup Air Quality Review (CSIRO 2004 The analysis of the samples collected undertaken for chemical components by Geotech Laboratories and for odour by The Odour Unit, A full description of the measurement program is given in the report on the monitoring program (GHD, 2005).

The emission rates measured in the program were expressed as specific area emission rates in units of mass/area/time, for the chemical substances as micrograms/m^2/minute, and for odour as OU/m^2/minute.

Figure 5 Sampling Locations for Diffuse Emission Sources



In order to apply the measured emission rates from the program to dispersion models aiming to quantify the ground level concentrations of the emitted substances in the surrounding atmospheric environment, a number of assumptions were made and calculations performed. This report details those assumptions and calculations applied to raw emissions data enabling their input as emission rates to dispersion models for the Wagerup Refinery health risk assessment (HRA).

VOCs

The substances specifically included in the HRA of Wagerup Refinery and found in the RDA monitoring campaign were: -

> *Benzene, PAHs (as Benzo(a)pyrene), toluene, and xylenes.*

The emission rates used for modelling these VOC compounds are shown in Table 7. Average emission rates were calculated from the monitoring results for the following sources. Full details of data used to derive these results are presented in the GHD report (GHD, 2005):

> *Superthickener (2 samples), RDA2-1 (liquor surface) (3 samples), Cooling Pond (3 samples, inlet, berm and outlet), dry residue 1 (recently ploughed) and dry residue 2 (aged dry residue), and wet residue.*

The other residue sources/substances have been averaged to derive emission rates, since there was no statistically significant variation in any of the VOC emission rates with temperature. The PAH compounds identified in emissions from two sources, the Cooling Pond and Superthickener, have been expressed here as Benzo(a)pyrene equivalents using weighting factors published by (WHO, 2002). The weighting factors for specific PAH compounds were as follows:

	PAH Potency Factors:	**Relative to Benzo(a)Pyrene**
1.	Naphthalene	0.001
2.	2-Methylnaphthalene	0.001
3.	Phenanthrene	0.001
4.	Acenaphthene	0.001
5.	Fluoranthene	0.01
6.	Chrysene	0.1

Carbonyls

The carbonyl compounds included in the refinery/RDA HRA list of compounds and detected in diffuse source emissions were:

> *Acetone, acetaldehyde, 2-butanone (MEK) and formaldehyde*

The emission rates used for modelling these compounds are also shown in Table 7. Average emission rates were calculated for the following sources. Full details are presented in the GHD report (GHD, 2005):

> *Superthickener (2 samples), RDA2-1 (liquor surface) (3 samples), Cooling Pond (3 samples, inlet, berm and outlet), dry residue 1 (recently ploughed) and dry residue 2 (aged dry residue), and wet residue.*

Only emissions of acetaldehyde from dry residue 1 (recently ploughed) exhibited significant temperature variability, with its emission rate expressed here at 25ºC. The other residue sources/substances have been averaged to derive emission rates. Some outlier values of specific carbonyl compounds have not been included in the calculation of averages.

For a number of low strength/low emission liquor sources, where detailed monitoring was not conducted, the emission rates used in modelling were based on those measured for the Runoff Water Storage (ROWS) pond, on the basis of similarity of liquor strength (expressed as total alkali) as an index of dissolved carbonyls. Use of ROWS pond data is considered to be generally representative for these sources.

Table 7 Diffuse Source Emission Rates for Wagerup Refinery HRA Dispersion Modelling – VOCs and Carbonyls (μg/m^2/min)

Source Type	Comments	BaP Equivalents	Acetone	Acetaldeyhde	Formaldehyde	2-Butanone	Benzene	Toluene	Xylenes
Lower Dam	Use ROWS values - Conservative assumption		0.25	0.07	0.55				
ROCP	use ROWS values - 75% full		0.25	0.07	0.55				
RDA2-1 Liquor Southern			11.60	8.70	0.13	1.47	0.05	0.16	
RDA2-2 Wet Mud	take as wet mud		2.52	0.87	0.44	0.28	0.05	0.03	
Superthickener		1.38E-04	77.35	56.73	0.78	7.63	1.10	4.50	0.71
Cooling Pond		9.00E-06	13.24	9.94	0.08	1.97	0.21	0.30	0.07
Oxalate Pond	use ROWS values		0.25	0.07	0.55				
ROWS			0.25	0.07	0.55				
Dry Mud 1	Run 1 - category 2&3 of residue		0.11	0.42	0.91		0.01	0.01	
Dry Mud 2	Run 2 - category 4 of residue		0.42	0.05	0.08		0.01	0.06	
Wet Mud	Use run 1 + 2 data combined - category 1 of residue		2.52	0.87	0.442	0.28	0.05	0.03	
Composite RDA(winter)	6% wet, 94% dry mud 1, 0% dry res 2		0.55	0.10	0.10	0.02	0.01	0.06	
Wet Sand	use wet mud data		2.52	0.87	0.44	0.28	0.05	0.03	

Notes:

1) Three outlier values >3 μg/m^2/min rejected from average
2) Included values in derivation of average emission rate (set to zero) for Phase 1 & 2 results
3) Dry mud formaldehyde values expressed at ambient temperature 25ºC

In determining the emission rates for the diffuse sources, the operational areas of the RDA surfaces are specified for a current typical residue layout and for the projected residue layout as of 2008 assuming the refinery expansion proceeds. The estimated emission rates developed from the above studies and data analysis for diffuse sources are presented in Table 8.

Implicit in the calculation of emission rates for the expansion are the following changes to the rate of emissions of some diffuse sources: -

- Superthickener will increase by 20% of the equivalent VOC load of the Lower Dam;
- Cooling Pond will increase by 50% of the current VOC load;
- ROWS Pond will increase by 100% of the current VOC load;
- ROCP no change;
- Oxalate Pond no change;
- RDA areas will accept 80% of the load diverted from Lower Dam, distributed across all active surfaces;
- Lower Dam no change;
- Sand Lake - increase wet sand area 50% for expected 3 times increase in sand.

Table 8 presents the annual emissions from the base case along with the emissions from the refinery. These are based on estimating the emissions for each hour based on the wind speed and temperature for that hour. Liquid surfaces, where emissions increase rapidly with wind speed, have a much greater relative contribution at higher wind speeds, and therefore to the annual contribution than indicated in the preceding table. This indicates that for acetaldehyde, 2-butanone and acetone the RDA contributes 79.5%, 47.7% and 36.6% of the annual total emitted from the refinery. For all other substances the emissions are less than a tenth of the refinery emissions.

Table 8 Estimated Annual VOC Emissions for the Base Case

Source	**BaP Equivalents**	**Acetone**	**Acetaldehyde**	**Formaldehyde**	**2-Butanone**	**Benzene**	**Toluene**	**Xylenes**	**Odour**
	(kg/yr)								**(ou/s)**
Dry Stacked Areas	0	3.18E+02	3.92E+02	2.37E+02	1.94E+01	1.26E+01	1.81E+01	0	37,830
Lower Dam	0	1.41E+02	3.96E+01	3.10E+02	0	0	0	0	58,840
ROCP1	0	1.02E+02	2.85E+01	2.24E+02	0	0	0	0	23,880
RDA2 - Wet Residue - North	0	9.74E+01	3.37E+01	1.70E+01	1.08E+01	1.93E+00	1.16E+00	0	10,070
RDA2 - Liquor - South	0	2.96E+03	2.22E+03	3.31E+01	3.75E+02	1.27E+01	4.07E+01	0	298,700
Super Thickener	2.03E-03	1.14E+03	8.33E+02	1.14E+01	1.12E+02	1.61E+01	6.61E+01	1.04E+01	40,400
Cooling Pond	4.45E-03	6.54E+03	4.91E+03	3.96E+01	9.75E+02	1.04E+02	1.48E+02	3.46E+01	666,500
Oxalate Pond	00	1.50E+01	4.20E+00	3.31E+01	0	0	0	0	703
ROWS	0	2.66E+02	7.41E+01	5.83E+02	0	0	0	0	12,100
Sand Cannon	0	4.01E+01	1.39E+01	7.01E+00	4.45E+00	7.97E-01	4.78E-01	0	4,710
Sand Lake	0	1.46E+03	1.08E+03	2.29E+01	1.84E+02	6.92E+00	2.01E+01	0	152,100
Total	6.48E-03	1.31E+04	9.62E+03	1.52E+03	1.68E+03	1.55E+02	2.95E+02	4.50E+01	1,306,000
Refinery Total	3.60E-01	3.56E+04	1.21E+04	1.71E+04	3.52E+03	2.05E+03	3.27E+03	7.15E+02	
Percent of Base Case Refinery	1.8	36.7	79.5	8.9	47.7	7.5	9.0	6.3	

Table 8 presents the percentage contribution from the individual sources of the fugitive emissions to the fugitive emissions total. This indicates that the largest source of the majority of emissions is the cooling pond.

3.3.3 Data Validation/Verification

The diffuse area emission rates are the result of the isolation flux chamber monitoring program described in (GHD, 2005). Monitoring was conducted over the period October 2004 to March 2005. Quality control included duplicate samples; field, laboratory and trip blanks; upwind and downwind samples at the key sources edges; back trajectory modelling using the area source trajectory model Windtrax™ by the Queensland Dept of Primary Industries and Environmental Alliances (DPI, 2005 and Environmental Alliances, 2005) and comprehensive checking of field and laboratory spreadsheets by GHD and Geotech staff.

The initial monitoring runs were conducted under daytime conditions. Additional runs have been conducted late afternoons, evenings and overnight to early mornings, in order to characterise the diurnal variability of emissions with time of day and temperature change. Performance of a stainless steel cover on one flux chamber, otherwise of identical design and operation to another with a Perspex cover, was checked by running parallel samples over periods of 24 hours at 3 locations in both daytimes and at night. Full details of the comparative performance including data validation information are given in (GHD, 2005).

4. AMBIENT MONITORING PROGRAM

4.1 BACKGROUND

Wagerup Refinery has an extensive ambient air monitoring programme in place. This programme has been evolving over several years, in response to concerns and requirements of the community and the environmental regulator. The programme has a number of dimensions, which are managed and developed in a variety of ways to satisfy the various needs and stakeholders. The core of the programme is covered in the requirements of the environmental licence, which specifies targets and limits for key parameters. Additional to that are a range of voluntary and joint projects with DoE, the Chemistry Centre of WA (CCWA), CSIRO and the community. It has often been as a result of such programs that specific requirements for regulation have been defined. The current summary does not attempt to cover in detail all of the various historical and current programs related to ambient monitoring. Rather it is a summary of the current status and future direction. More detailed information on the overall programs is given in the Wagerup Annual Environmental Reports.

4.2 DUST

4.2.1 Site Selection

Ambient dust monitoring at the RDAs was the first ambient monitoring to be incorporated in Wagerup's environmental licence. The 1999 licence specifies a 24 hour average limit of 260ug/m^3 based on continuous monitors located on the RDA boundary. This requirement was upgraded to a limit of 200ug/m^3 and a never to be exceed value of 260ug/m^3 in 2002, when a requirement for chemical analysis of selected samples was also introduced. The locations of the dust monitors are shown in the map below, extracted from the Wagerup Annual Report 2003. The locations have been chosen to provide information for all the main wind directions, and the sites are in conformance with AS 2922-1987. Results of the monitoring are given in the Annual and Triennial Reviews.

Figure 6 RDA Ambient Dust Monitoring Locations

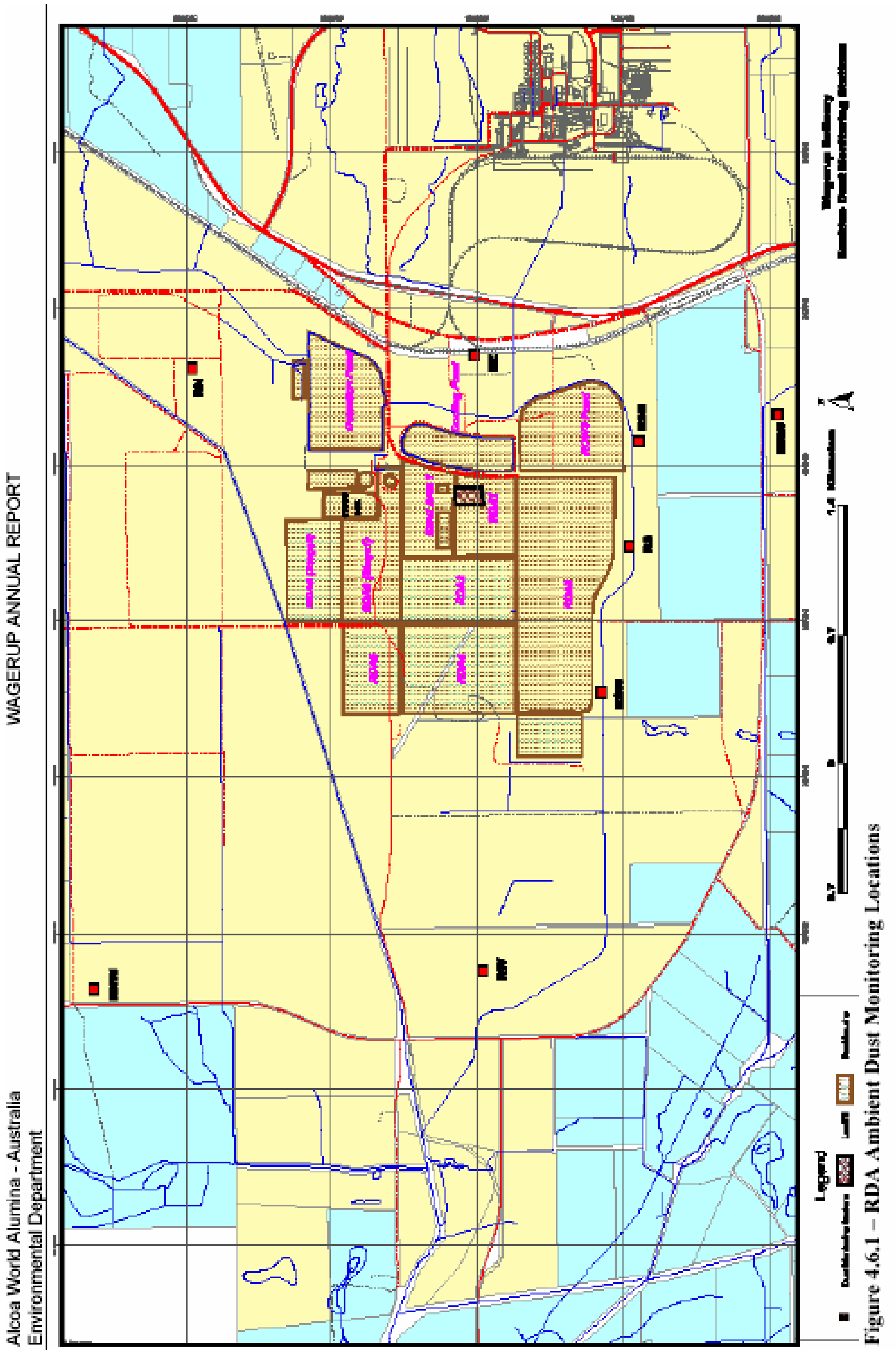


Figure 4.6.1 – RDA Ambient Dust Monitoring Locations

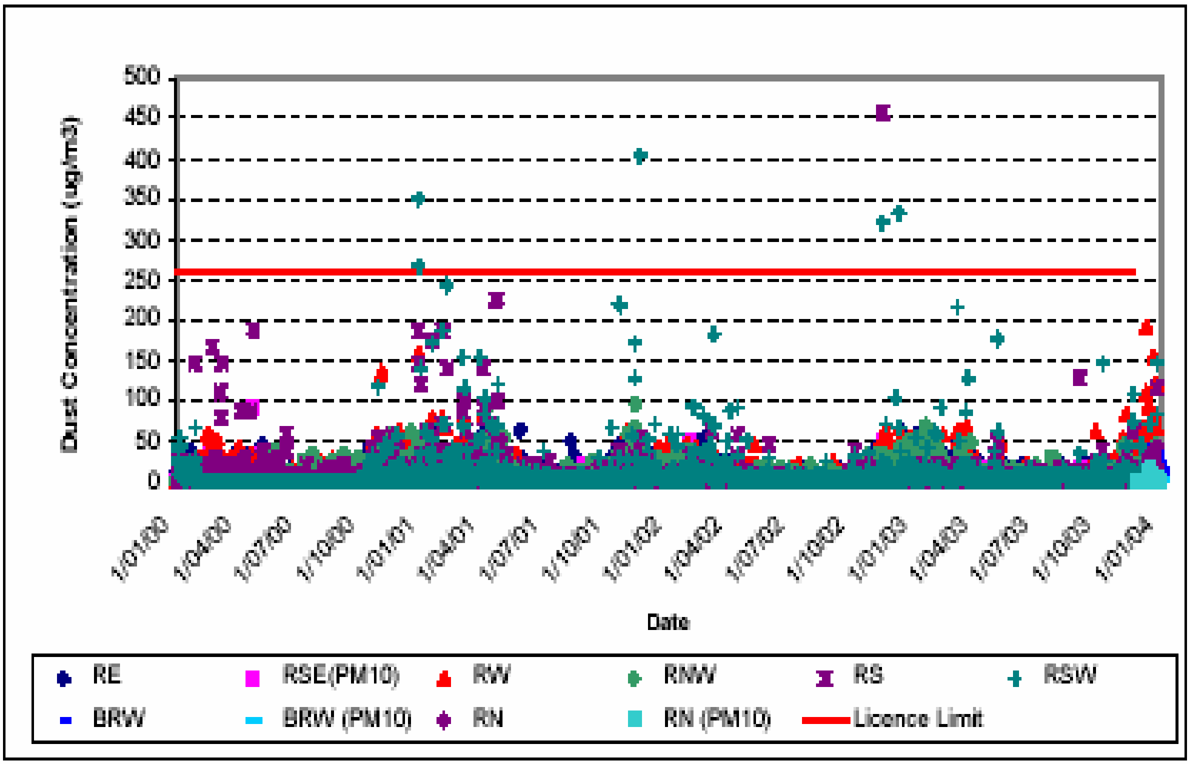
4.2.2 Methodology

From January to October 2003 ambient dust monitoring was conducted at six licensed sites in the vicinity of the RDA boundary known as RE, RS, RSE10, RW, RSW & RNW. Condition A10 (b) of licence 6217/6 required Alcoa to submit a revised dust monitoring program to the DoE for assessment. This program was developed and submitted to the DoE in February 2003. It formed the basis of the revised dust monitoring network specified in conditions A9 (a)(i)-(vi) of licence 6217/7. These conditions required Alcoa to install monitoring equipment at two new sites known as Bancell Road West (BRW) which is situated to the South of the RDA, and Residue North (RN) situated to the North of the RDA. Once independent certification was received confirming that these sites met the requirements of AS 2922-1987 Alcoa was required to commence sampling at BRW and RN and cease sampling at RS and RSW. From 20 December 2003 monitoring has been conducted at RE, RW, RNW, BRW and RN as required by condition A9 (a) (i) to (vi). The location of all current and former monitoring sites is shown in Figure 6.

4.2.3 Ambient Results

Monitoring conducted at the licensed sites during 2003 used high volume samplers that met the requirements of Australian Standard 3580.9.3. Where high volume samplers were used, filter papers were changed daily. The RS and RSW sites used Tapered Element Oscillating Microbalances (TEOM). The TEOM's provide continuous, real time ambient data and allow refinery staff to assess and manage dust emissions as they occur. Monitoring results for the 2000 to 2003 period are shown in Figure 7. These results are 24-hour average dust concentration data that have been background corrected as per the DoE approved background correction procedure. Although the background correction procedure specified the use of the high-volume sampler results only, TEOM data was also used for background correction. The use of TEOM data in the background correction calculation ensures that the lowest of all measured results is used. This results in a higher estimation of dust emissions on those occasions when the TEOMS have the lowest dust concentration. Similarly, data from the RSE monitor which only measured the PM10 size dust fraction rather than total suspended particulate (TSP), has also been used in background correction calculations. Again this will result in a higher estimation of dust from all sources since PM10 results will be lower than a measurement of TSP at the same location.

Figure 7 TEOM's Ambient Monitoring Results 2000-2003



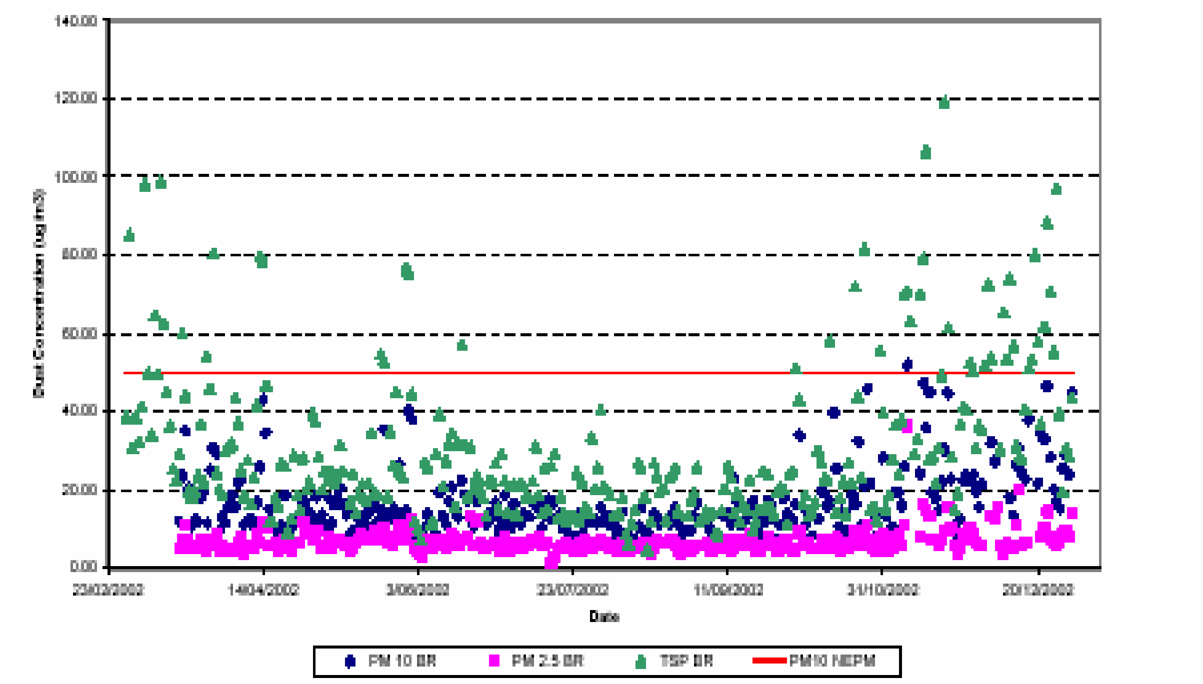
Significant focus has remained on dust management in the residue areas over the past year with short and long term dust management strategies implemented at the residue area. Short-term strategies to prevent dust generation include wetting the RDAs using permanent sprinklers and wetting down roads with water. Long-term strategies include vegetating and tarring open areas and using waste oil on roads as a dust suppressant.

There was no exceedance of the licence limit of 260 µg/m^3 during 2003 and there was only one occasion when dust results were greater than 200 µg/m^3 but less than 260 µg/m^3. Thus dust results for all licenced samplers remained below 200 µg/m^3 for 95% of the time as required.

Sampling and analysis of residue dust filter papers was conducted in 2003 as required by licence. The data presented in the 2003 Annual Report shows that beryllium, cadmium and mercury have not been detected in dust on any of the filter papers analysed. With the exception of aluminium, all compounds that have been detected in RDA dust are present at very low levels (<0.1µg/m^3). Only aluminium is consistently detected at concentrations above 0.1 µg/m^3. The 2003 results were consistent with those obtained in 2002.

In order to better assess the impact of dust and other potential pollutants in the surrounding region, Alcoa implemented an ambient monitoring program at Boundary Road, 3km south of the refinery in 2001. This was initially a voluntary programme, elements of which have since become incorporated into the environmental licence. In relation to dust, the parameters monitored are TSP, PM10 and PM2.5. Results of this monitoring are reported routinely according to licence requirements. Specific influences of the refinery above background have been difficult to discern. Typical results are shown in Figure 8.

Figure 8 Typical results from Ambient Dust Monitoring- Boundary Road



Queensland University of Technology (QUT) performed an intensive monitoring campaign of fine particle levels in Yarloop over a two week period in winter 2002. Fine particles are regarded as those with a mean diameter of 1 micron and less, and are much smaller than the dust levels routinely monitored as total suspended particulate (TSP) and PM10. It was suggested that more work was required to determine whether fine particulates could potentially cause the reported short-term mucous membrane irritations in the local community. The study aimed to determine whether fine particle levels were elevated in Yarloop for winds coming from the direction of Wagerup Alumina refinery; whether the alkalinity of fine particles was higher for wind directions generally from the refinery quadrant; and if there was a correlation between fine particles emanating from the direction of the refinery and air quality complaints. Fine particle data was collected over the two-week period using a scanning mobility particle sizer and an aerodynamic particle sizer. The study concluded that there was no significant elevation of fine particle levels for wind directions emanating from the refinery. It found that the highest fine particle levels seen were associated with wind directions from the south, leading to the conclusion that it is likely that there are other significant sources of fine particles in the region. The alkalinity of particles emanating from the refinery (including the RDAs) direction was found to be elevated in comparison to that from other directions, but at levels very much lower than occupational exposure limits for alkalinity in air. The study also found that there was no significant correlation between fine particle levels emanating from the refinery direction and air quality complaints lodged over the period of the study.

4.2.4 Further Studies and Monitoring

To better understand the composition and variability of dust generated at the RDAs, Alcoa is conducting a WA-wide study of dust characteristics, with the Pinjarra refinery as the main study site. The 15 month study commenced in Q4 2004 and has been scoped in consultation with independent consultants. Details of this program have been provided to the Wagerup Tripartite Group in November 2004. The results of this program will be reviewed as it progresses to determine the need for any further site specific testing at Wagerup. In addition a PM10 monitoring program has been implemented at the Wagerup RDA to collect further information about the PM10 component of Wagerup's residue dust.

A draft program has been developed to collect and characterise dust and rainfall in Yarloop. The program requires further development and should take into account new information recently made available in an independent report of existing data on the quality of rainwater in the Yarloop area and surrounds. The proposal will be presented for review to the Tripartite Group and milestones for its implementation developed.

4.3 GASEOUS POLLUTANTS

4.3.1 Background

There has been concern in the community relating to the possible impacts of refinery emissions on regional air quality since the mid-1990s. At that time there was an increased awareness of the refinery evidenced by a sharp increase in odour complaints, mainly associated with the commissioning of the liquor burner. Pollution control measures retro-fitted to the liquor burner essentially eliminated it as a source of odour emission, however complaints and associated concerns continued. This has led to a wide variety of ambient monitoring studies, by Alcoa, the

DoE and the community. Despite extensive studies and sampling by a wide variety of techniques, the only parameters that have been measured that can be associated with the refinery are odour and NO_x. The odour association is on the basis of complaints data, but also has been confirmed by field odour surveys. Continuous monitoring of NO_x at Boundary Road shows some correlation with the refinery on the basis of wind direction, and so can possibly be used as an indicator of the refinery plume. None of the studies have been able to identify any VOCs that would indicate a refinery influence on the ambient air quality, over and above the existing levels of compounds present from other sources.

4.3.2 2002-2003 Ambient Air Quality Study

The Wagerup Ambient Air Quality Monitoring Report, December 2003 presents the data collected from March 2002 to March 2003 as part of Wagerup's Ambient Air Quality monitoring program. The monitoring for gaseous pollutants was designed to test Dr Barry Carbon's first hypothesis, "That elevated concentrations of ozone could be being produced as a result of reactions of NO_x emitted from the refinery with other species in the atmosphere". It includes assessment of the data against relevant standards and guidelines, and comparisons to ambient data from other locations. As well as the dust parameters discussed above, the program included continuous ambient monitoring of oxides of nitrogen (NO_x) and ozone (O_3) at Boundary Road, Yarloop, as detailed in condition A15 (a) in licence number 6217/6. Although not a licensed monitoring station, the data obtained from the Upper Dam monitoring station for O_3 and NO_x was included to enable examination of the directional influences on air quality as an indicator of refinery influence.

For ozone, the study showed:

- The average level of ozone in the local atmosphere is around 20 ppb, with a one-hour maximum of around 60ppb; all results were well below the 4-hour NEPM value of 80ppb;
- Ozone levels increased with westerly winds, not winds from the direction of the refinery, and increased with wind speed;
- Ozone levels show the expected diurnal variation, i.e. elevated during the day, lower at night; and
- The trends and absolute levels of ozone in the Wagerup region are similar to those recorded at the DoE monitoring stations at South Lake, Quinns Rock and Rockingham.

From these data it is concluded that the local atmospheric ozone concentrations are not measurably influenced by the refinery, and show levels and behaviour typical of the normal atmosphere of the broader region.

For NO_x the study showed:

- The average level of NO_x in the local atmosphere is less than 10ppb, with a one-hour maximum value of around 40ppb; all the results were well below the one hour maximum NEPM value of 120ppb;
- There is a weak correlation between NO_x values and winds from the direction of the refinery, indicative of a detectable refinery influence over the background level of NO_x; however the degree of influence was small and could not be established with the techniques used in this work;
- There appears to have been a detectable reduction the influence of the refinery on NO_x levels following the installation of low-NO_x burners in the refinery powerhouse, although it was not possible to quantify the reduction; and
- The diurnal variation in NO_x concentrations is opposite from ozone, as expected on the basis of the expected reaction between the ozone and NO_x.

From these data it is concluded that the refinery does have a detectable influence on NO_x levels in the local atmosphere. While this influence is too low to quantify accurately by direct ambient monitoring, it could possibly be used to indicate the presence of refinery plume grounding.

CO was also measured in this study, with the following results:

- CO averaged <0.1ppm, with one hour maxima of <1ppm; all values were much lower than the NEPM limit of 9pmm over 8 hours; and
- The observed peaks in CO were highest in south-westerly winds, and do not correlate with winds from the refinery direction.

On the basis of these observations it was concluded that the levels of CO in the local air are very low (close to the limit of detection most of the time) and not detectably influenced by the refinery.

4.3.3 2004 Ambient Air Quality Study

In 2004, Alcoa conducted an extensive programme of ambient air monitoring in the region surrounding the Wagerup refinery. This was in response to a commitment made to the community and regulators to monitor air quality in the region over the winter months. The programme was conducted in two phases. Phase 1 (Wills and Power, in prep) was a preliminary study aimed at establishing overall air quality parameters and providing information on the most applicable techniques for sampling and analysis. Phase 1 commenced in May and ran through until August 2004. Phase 2 was a more intensive study over a six week period from late August to early October. The Phase 2 (Van Emden and Power, 2005) study scope was developed by Alcoa with input from the community, DoE, the CCWA and CSIRO. The independent specialists contracted to perform the sampling and analysis were chosen through a formal, open competitive bidding process managed by Alcoa on behalf of the stakeholders and with direct input from community representatives.

This study provides detailed knowledge of the ambient air quality in the region surrounding the Wagerup alumina refinery, including the townships of Waroona and Yarloop and the associated rural environment.

A variety of recognised sampling and analytical techniques were employed, including USEPA methods for determining VOCs, carbonyls, metals and inorganic compounds. A total of 274 VOCs were analysed. Of these, 35 were detected and quantified, a further 31 were detected at levels too low to quantify, and the remainder were not detected.

The main chemical compounds detected are all known to be present in refinery emissions. The levels found in the ambient environment are generally many times greater than the calculated refinery influence for each compound. There was a lack of any clear spatial distribution that would indicate a refinery influence on the levels of the compounds detected. This is consistent with the proposition that the levels of chemicals in the ambient atmosphere are dominated by human and natural processes other than the refinery operation.

All chemical compounds detected were found to be at levels well below applicable limits set for the protection of human health, and were generally within the ranges expected for rural environments. An exception to the latter is acetaldehyde, which was found at levels more typical of urban environments. This could warrant further investigation to establish the source, but the distribution, levels and relativity to other compounds mean that the refinery is unlikely to be the cause.

The chemical compounds detected and their levels in the atmosphere showed little spatial variation and for the most part appeared to be randomly distributed, limiting the ability to attribute specific sources. Elevated levels of both carbonyls and VOCs were found at the Waroona and Yarloop township sites, consistent with the effects of human activities associated with the use of fossil fuels. Sampling sites closest to the refinery generally showed lower concentrations of the compounds measured, although indications of higher than average levels of carbonyls at the Boundary Rd and to a lesser extent the Hoffman Rd sites could warrant further investigation.

4.3.4 Odour Surveys

Two field surveys of odour have been carried out in the Wagerup region by Environmental Alliances (Sinclair Knight Merz, 2002; Environmental Alliances, 2003). These surveys attempted to capture information from actual refinery plumes as a function of distance from the refinery. The work was therefore carried out in the winter months under morning conditions when the meteorology was conducive to the grounding of the refinery plume. The technique was successful in capturing odour events and tracking the intensity of plumes as at various distances from the refinery.

The data obtained confirmed the existence of the plume grounding phenomenon, and provided semi-quantitative information on the decay of plume odour with distance. The plumes were found to be generally narrow and transient, and the data was gathered as 10 minute average odour concentrations based on 60 observations in each 10 minute period. The odour concentration in plumes was found to decrease sharply with distance, such that the maximum odour concentration fell below the EPA guideline value of 2 Odour Units at a distance of 2,500 metres from the refinery, and was generally undetectable beyond 3,000 metres. These observations were compared with the experience of local residents and complaint patterns, with which they were found to be generally consistent.

4.3.5 Further Studies and Monitoring

The ongoing research programme on Ambient Monitoring is based on the responses to the Recommendations of the Wagerup Air Quality Review, May 2004 (CSIRO, 2004). Table 9 summarises the actions specifically related to ambient monitoring from the Wagerup Air Quality Action Plan, as presented to the Wagerup Tripartite Group on 11 March 2005. This Plan is managed through the Tripartite Group, which sets priorities and monitors progress against the Plan.

Table 9 Wagerup Air Quality Action Plan

	Recommendation	Activity	Outcome	Timeline	Progress
5	**Given the potential for alkaline dust emission from the Refinery, including the RDA, to be transported to the surrounding district, including the Yarloop township, it is recommended that further studies of aerosol including fine particle concentrations, dust deposition and rainfall, and the chemical composition of these components be undertaken, in a more comprehensive fashion. Recognised techniques should be used for collecting dust fall and rainfall.**	Design a program that provides the additional information on dust and rainfall. Review approach at Pinjarra and evaluate applicability at Wagerup	Provide outline of dust and rainfall investigation programme to Working Group and tripartite Group.	Q4 2004 Q1 2005	A draft program has been developed by a consultant to collect and characterise dust and rainfall in Yarloop. The program requires further development and should take into account new information recently made available in an independent report of existing data on the quality of rainwater in the Yarloop area and surrounds. The proposal will be presented for review to the tripartite group and milestones for its implementation discussed. A comprehensive residue dust survey is being performed at Pinjarra. The 15 month study commenced in Q4 2004 and has been scoped in consultation with independent consultants. Details of this program have been provided to the tripartite group in November 2004. It is proposed to review the results of this program as it progresses to determine the need for any further site specific testing at Wagerup. In addition a PM10 monitoring program has been implemented at residue to collect further information about the PM10 component of Wagerup's residue dust.
6	**It would be informative to have RDA filter samples collected and analysed when the background corrected TSP exceeded 100 ug m3.**			Q4 2004	Completed. A systematic process has been established for collecting and analysing dust samples. This requirement has been included in Licence 6217/8 conditions. Analysis requirements and protocols have been finalized and a NATA accredited lab identified. The highest monthly result will be included when 100ug/m3 criterion not reached. Communicated to tripartite group in November 2004. Results from 2004 included in Annual Report.
14	**In future studies the suite of measurements should include respirable aerosol and its composition, those simple organic compounds that are or**	Develop an experimental design to: • Identify key compounds • Suggest suitable analytical methods • Incorporate in future studies	Provide recommendation on research program to deliver the	Oct 2004.	There has been ongoing discussion with the working group, tripartite group and CSIRO on this recommendation. CSIRO have confirmed their intention to purchase a PTRMS and delivery is due in early 2005. Alcoa has indicated a

	Recommendation	Activity	Outcome	Timeline	Progress
	can be emitted by the refinery that have not been measured in previous ambient sampling (including polar compounds) and supporting measurements such as for chemical fingerprints of sources.	Identify and evaluate broad-spectrum analytical techniques, e.g. PTRMS. Expert group (including health expertise) to be convened to develop this, including review of original CSIRO recommendations.	required outcomes. Implement the programme.	Commence Q1 2005.	willingness to support trials of this technology for the purpose indicated in the recommendation. Because of delays in the acquisition of the specialty equipment by CSIRO, the programme has yet to be fully scoped and will not commence in Q1. Discussions will be continued with CSIRO with a view to developing a scope in Q2.
15	**A key issue for Wagerup air quality studies is to measure the key pollutants with a response time of a few minutes to determine what pollutants, at what concentrations are contained in the air associated with short-term high concentration air quality events, and what are the sources of these events and what processes control when they occur in the surrounding district.**	As for 14.			Alcoa has commissioned the CCWA (Chemistry Centre of WA) to conduct a rapid response process to characterise the compounds associated with short-term odour complaints. A Hapsite portable GCMS (Gas Chromatograph Mass Spectrometer) was based in Waroona and available to sample air quality in the surrounding communities for 6 weeks during 2004. The Chemistry Centre completed the report in December 2004 and it is planned for them to present this information to key stakeholders. A long-path Opsis instrument has been installed and commissioned at Boundary road to provide continuous monitoring of ambient formaldehyde levels as an indicator of short-term air quality excursions. The original siting of the instrument proved unsatisfactory, and it was necessary to relocate it to a site north of Boundary Rd. this was completed in February 2005.
18	**Further details concerning the design of future air quality studies at Wagerup are included in the text of the review.**	Utilise Working and Tripartite Groups as a review forum for tracking and contextualising the work programmes.	Monthly updates at regular meetings of the groups.	Monthly.	There is a process of managing and reviewing progress of the work program addressing the above recommendations, with regular stakeholder consultation and review by the Tripartite Group, in particular for any required changes to the program scope, milestones and timeframes.

5. DISPERSION MODELLING STUDIES

5.1 BACKGROUND

This section summarises the air quality dispersion modelling undertaken using TAPM and CALPUFF to assess air quality impacts from the existing refinery and RDAs and to assess the potential impacts of the proposed expansion on air emissions. The approach, methodology, discharge characteristics, model parameterisation, results and model validation studies are summarised in this section. Detailed information on both the TAPM and CALPUFF studies can be found in both the CSIRO and Air Assessment reports.

5.2 TAPM MODELLING

The refinery concentration modelling was carried out using TAPM (The Air Pollution Model) with the configuration determined by the evaluations of meteorology in Phase 1 of the Study and dispersion in Phase 2, which evaluated TAPM for air quality predictions at Wagerup using a database of emissions and observed ambient air concentrations. CSIRO conducted meteorological and dispersion modelling for the refinery using TAPM. The study was segregated into three phases that closely addressed the defined objectives.

(a) Phase 1: Meteorology. Evaluated the capability of CSIRO's The Air Pollution Model (TAPM) to acceptably produce hourly-averaged meteorological predictions matching available field observations in the close proximity of the Wagerup refinery (CSIRO, 2004a).

Specific components of the Phase 1 included:

1. Development of a finer, more accurate land-use database for Wagerup as for use as input in TAPM than the default database;
2. Derivation of the refinery- generated heat flux, its inclusion in TAPM, and evaluation of its effect on meteorological predictions;
3. Analysis of the near-surface meteorological data from the Bancell Road and Residue Disposal Area monitoring sites;
4. Evaluation of TAPM performance against the locally observed meteorology using an internationally accepted set of statistical and graphical methods;
5. Comparison of the model profiles of wind speed, wind direction and temperature with the radiosonde data from the 2003 campaign;
6. Evaluation of the sensitivity of TAPM to surface roughness and deep soil moisture content;

7. An analysis of underlying facts that influence the degree of disagreement in the model vs. observations comparison; and
8. Comparison of the model evaluation results with other studies.

(b) Phase 2: Dispersion. TAPM was evaluated for air quality predictions by modelling hourly-averaged ambient air concentrations of pollutants for defined periods and comparing them with observations; and identified dominant pathways for the transport of the refinery emissions to ground level in the study area (CSIRO, 2005).

The specific components of the Phase 2 objective included:

1. An analysis of the oxides of nitrogen (NOx) data from Alcoa's Upper Dam and Boundary Road monitoring stations measured during a one-year period (1 April 2003–31 March 2004), and an analysis of ANSTO perfluorocarbon tracer data obtained on 13 and 14 August 2002;
2. Running TAPM for NOx and ANSTO tracer data simulations, analysis of the model results, and comparison of the hourly-averaged model results with the data;
3. For some periods, running of TAPM with building effects and local wind data assimilation;
4. Calculation of a standard set of performance statistics for the model runs so that the performance of TAPM in estimating concentrations of air pollutants from given emissions can easily be compared with other models;
5. An analysis of the total suspended particulate (TSP) data measured at the Residue Disposal Area (RDA) obtained for one year, and comparison of the model winds with the observed RDA winds when high TSP concentrations are observed;
6. Identification of dominant meteorological and dispersion mechanisms governing the relative frequency of model events in the Yarloop area; and
7. Information on the Refinery NOx sources and their emission rates (constant with time), and tracer source characteristics was supplied by Alcoa. Alcoa also supplied the observed ambient concentrations of NOx, total suspended particles, and ANSTO tracers.

(c) Phase 3(a) and (b): Concentration Modelling for the Health Risk Assessment (HRA). Concentration modelling was undertaken using TAPM and spilt into two parts; Phase 3A, for the current emission scenarios and Phase 3B, those for an expanded refinery scenario (CSIRO, 2005a/b).

The specific components of Phase 3 (a) and (b) objective included:

1. Run the refined TAPM (as resolved in Phases 1 and 2) for the annual meteorological file (1 April 2003 to 31 March 2004) and agreed sources to produce estimates of the following parameters for 28 pollutants at 15 receptor points:

- Annual average concentration (at average emission rates)
- Maximum 1-hour average concentrations (peak emissions)
- 95th percentile 1-hour average concentrations (peak emissions)
- 95th percentile 24-hour average concentrations (peak emissions)
- Maximum 10-minute average concentrations (peak emissions)
- Maximum 3-minute average concentrations (peak emissions).

2. The 28 pollutants are oxides of nitrogen (NOx), carbon monoxide (CO), sulphur dioxide (SO2), dust, arsenic, selenium, manganese, cadmium, chromium VI, nickel, mercury, ammonia, benzo(a)pyrene equivalents, acetone, acetaldehyde, formaldehyde, 2-butanone, benzene, toluene, xylenes, acrolein, ethylbenzene, methylene chloride, styrene, 1,2,4 trimethylbenzene, 1,3,5 trimethylbenzene, vinyl chloride, and nitrogen dioxide (NO2);

3. Produce contour plots of these six statistics for three example substances (NOx, Formaldehyde and Mercury) to indicate the different concentration distribution patterns for substances predominantly emitted from high and low level sources;

4. Calculate the conversion of NOx to NO_2 using a simple titration algorithmic method;

5. Describe the best practice methods for deriving shorter time period (3 and 10-minute) maximum concentrations from the Wagerup hourly TAPM concentration fields;

6. Investigate the temporal variation of concentration around, and mechanisms causing the modelled 5 highest short-term peak concentrations for NOx and Formaldehyde for three receptors (at sites 1, 3, and 14) for the peak emission scenario;

7. Undertake separate quality assurance runs for selected pollutants to confirm the accuracy of the main modelling technique. Comment on the expected accuracy/level of confidence in model predictions, based on the work performed in Phases 1 and 2;

5.2.1 Methodology

TAPM is a prognostic meteorological and air pollution dispersion model developed by CSIRO Atmospheric Research. The main advantage of the prognostic approach is that rather than requiring local meteorology, the model calculates it. The meteorological component of TAPM predicts the local-scale flow, such as sea breezes and terrain-induced circulations, using the larger-scale synoptic meteorology as boundary conditions. The air pollution component uses the model predicted three dimensional meteorology and turbulence. A detailed description of the model is presented in the CSIRO reports [Appendix G].

5.2.1.1 Phase 1: Meteorology

This phase evaluates the capability of TAPM (version 2.6) with a detailed Wagerup specific land-use specification to acceptably produce hourly-averaged meteorological predictions matching available field observations in the Wagerup region, especially under a range of conditions that include both light and moderate wind speeds.

The period April 2003- March 2004 was selected as the period for model simulation. This period encompasses a complete, continuous winter season and a complete, continuous summer season, with the best meteorological data currently available. No previous continuous seasons were considered because new metrological measurement systems were employed in the year 2003 (e.g. a 30-m tower and radiosonde releases) providing extra meteorological data for a more comprehensive model evaluation.

TAPM was run with four nested grid domains at 20, 7, 2, 0.5 km resolution for meteorology (31 x 31 grid points). The lowest ten of the 25 vertical levels were 10, 25, 50, 100, 150, 200, 250, 300, 400, and 500 m. The default databases of topography monthly sea-surface temperature, soil types, deep soil moisture content and deep soil temperature were used. The results from the innermost model grid domain (with a resolution of 0.5km) were used to compare with the measurements.

An estimation of the Refinery-generated heat flux was made using Alcoa supplied information on heat balance for Wagerup Refinery based on known energy inputs, outputs and losses. The estimated heat flux of 150 W m^{-2} was added to the TAPM surface-energy balance equation.

As part of the Phase 1 work, the default land-use database used as input in TAPM was replaced by a more refined Wagerup specific land-use database at a resolution of 250 m x 250 m using GIS maps and a recent aerial photo covering an area of approximately 25 km x 25 km centered on the Refinery. The Refinery, the RDA and the adjacent cooling lakes were resolved.

5.2.1.2 Phase 2: Dispersion

In order to evaluate TAPM (version 2.6), it was run with four nested grid domains, with the innermost grid resolution of 0.5 km for meteorology and 0.25 km for dispersion. For pollutant dispersion, the innermost domain was about 7 km × 7 km, whereas the outermost domain was about 300 km × 300 km. Model inputs included the Wagerup specific land-use database and a Refinery-generated heat flux of 150 W m-2, both derived as part of the Phase 1 work.

The model evaluation focused on the ability of the model to describe the high concentration occurrences that are observed occasionally during the year and which are of most interest in impact assessments. For air pollution model evaluation, specific statistics are commonly used, including quantile-quantile (q-q) plots, and statistical measures, such as the robust highest concentration (RHC), and these were used in this study. The evaluation procedure involved comparison of modelled and observed concentrations that were unpaired in time and/or space.

5.2.1.3 Phase 3A: HRA Current Emissions

The Phase 3A Concentration Modelling for the Health Risk Assessment (HRA) was undertaken on a current emissions scenario of 6,600 tonnes per day of alumina. The concentration modelling was carried out using TAPM with the configuration determined by the evaluations of meteorology in Phase 1 of the Study and dispersion in Phase 2, which evaluated TAPM for air quality predictions at Wagerup using a database of emissions and observed ambient air concentrations.

5.2.1.4 Phase 3B: Expanded Refinery Emissions

The Phase 3B modelling for the Health Risk Assessment (HRA) was undertaken for the Expanded Refinery (4.7 Mt of alumina per annum). The concentration modelling was carried out using TAPM with the configuration determined by the evaluations of meteorology in Phase 1 of the Study and dispersion in Phase 2, which evaluated TAPM for air quality predictions at Wagerup using a database of emissions and observed ambient air concentrations.

5.2.2 Summary of Model Set-Up

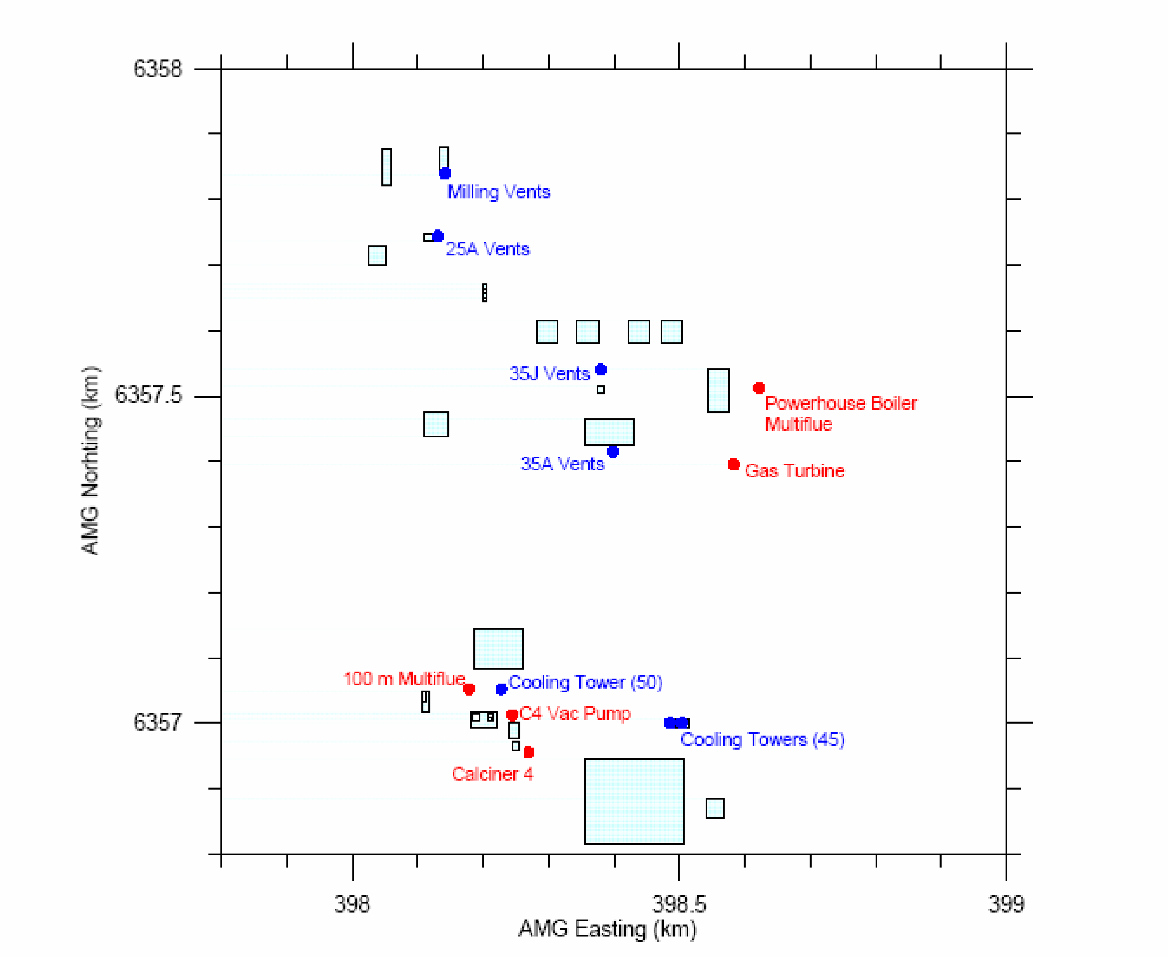
Version 2.6 of TAPM was used for all the simulations presented in the CSIRO reports. This is the same version as used in Phases 1 and 2 (CSIRO, 2004a, 2005) of the present project. The most appropriate settings of TAPM for the Wagerup modelling have been described in Phase 1 (Meteorology) and Phase 2 (Dispersion), the latter of which evaluated TAPM using several different databases of emissions and observed ambient air concentrations at Wagerup.

Four nested domains of 31 × 31 horizontal grid points with resolutions of 20-km, 7-km, 2-km and 0.5-km are used for the meteorological modelling. Similarly four nested domains of 53 × 53 horizontal grid points with resolutions of 10-km, 3.5-km, 1-km and 0.25-km are used for the pollutant dispersion modelling. The pollution grid was selected to include all receptor points with the best possible combination of fine grid resolution and model computing time. The grids are all centered on the location 115°54′ E, 32°54.5′ S, which is equivalent to 397.133 km east and 6358.326 km north in the AMG84 (Australian Map Grid) coordinate system. The centre point is about 1 km north-west of the Refinery and was selected to optimise the locations of the grids with respect to the receptors. This centre point is situated 2 km north-northwest of the centre point used in the Phase 2 modelling and 3.8 km slightly west of north from the centre point used in the Phase 1 modelling. The lowest ten of the 25 vertical levels were 10, 25, 50, 100, 150, 200, 250, 300, 400 and 500 m, with the highest model level at 8000 m. The default databases of soil properties, topography, and the monthly sea-surface temperature and deep soil parameters (with a deep-soil moisture content of 0.15) were used. The Wagerup-specific land-use database and a refinery-generated surface heat flux value of 150 W m-2, both derived as part of the Phase 1 work (CSIRO, 2004a), were used.

The TAPM runs included building wake effects. A total of 29 rectangular buildings were considered, ranging in height between 8 m and 42 m. The locations and horizontal size of these buildings are shown in Figure 9, based on data supplied by Pitts (pers. comm. 20 Aug 2004). The figure also shows the locations of the Wagerup Refinery point sources modelled in this work, as supplied by Coffey (pers. comm. 7 Sep 2004).

The period modelled was one year from 1 April 2003 to 31 March 2004. This is the same as the period used in Phases 1 and 2 and was selected for those phases because it had the best meteorological data available. This period was also used for Phase 3 to maintain consistency. In order to reduce run time for dispersion modelling of the many sources, the meteorological part of the model was only run once with the output stored at hourly intervals (in the TAPM *.m3d files) for use in all further pollution modelling runs.

Figure 9 The locations and horizontal size of the buildings used in the TAPM runs (shown in aqua). The modelled point sources are shown – those in red are the higher stacks (40–100 m), those in blue are shorter than 25 m.



The TAPM runs presented here do not include wind data assimilation. The Phase 2 results on the effect of including data assimilation are mixed with details of the data validation presented in the CSIRO reports. All model runs were carried out on a computer cluster using Intel Pentium IV processors running under the Linux operating system. The TAPM code was compiled using an Intel Fortran compiler version 8.0.

Modelling has been carried out for the Phase 3A Current Emissions Scenario (i.e. an Alumina production rate of 6,600 tonnes per day) and for Phase 3B, the Expanded Refinery Scenario (4.7Mt of alumina per annum).

Two sets of emissions have been considered for Phase 3A including the Average emission rates and the Peak emission rates. For Phase 3B modelling, these two sets of emissions have been considered for two specific scenarios.

- Case 6 with Cogeneration using new Gas Turbines 2 and 3
- Case 7, with New Boilers 4 and 5.

5.2.3 Model Inputs

A summary of the stack discharge characteristics used by CSIRO in the dispersion modelling are presented in Table 10 and Table 11. Some of the stacks (for example, the 100 m Multiflue and the 65 m Boilerhouse stacks) contain several closely-spaced flues which release buoyant plumes, i.e. the exit temperature of the gas emitted from the flue is greater than the temperature of the surrounding air. These stacks have been modeled as a single source with the emission characteristics (stack diameter, exit temperature, exit velocity) of one of the sources and with the emission rates (in g/s) equal to the total from the sources being modeled by the single stack.

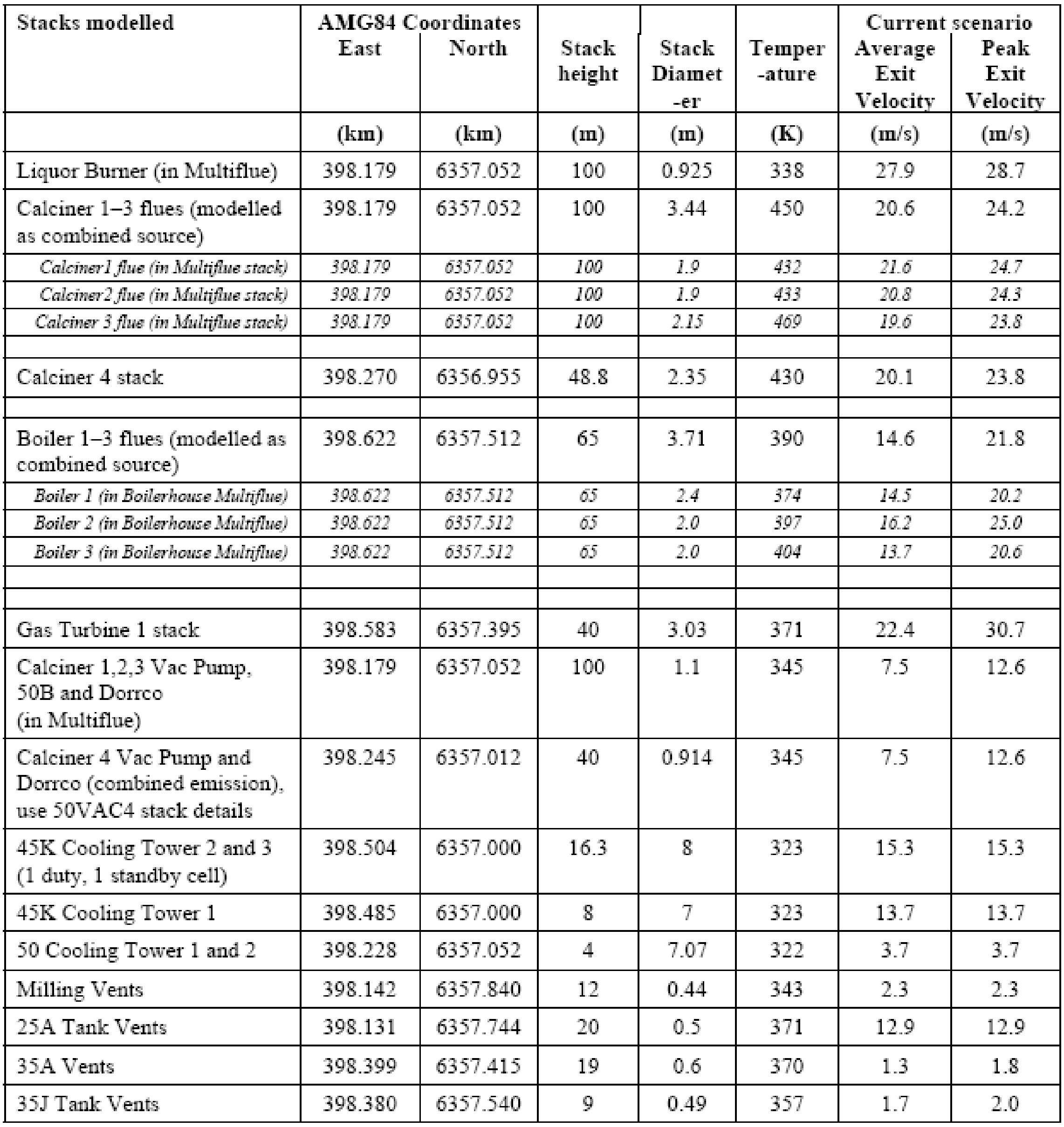
The details of the assumptions made in modelling the other sources are listed below:

- Calciner 4 Vac Pump and Dorrco. There are two separate stacks but the emissions rates supplied by Alcoa are the total for both stacks. Because most of the volume flow (92%) occurs from the 50VAC4 stack and the stack heights are similar (40 m and 37 m), only the 50VAC4 stack was included in the modelling using the exit characteristics of this stack with the total emission rate attributed to this stack;
- Calciners 1-3: The three Calciner stacks in the Multiflue was modeled as a single stack with an effective diameter of 3.44m, exit temperature of 450 K with a nominated average and peak velocity;
- Boilers 1-3 : The three boilers were modeled as a single stack with an effective diameter of 3.71 m, exit temperature of 390K and nominated average and peak velocity;
- Cooling Towers 1 and 2 (50CT). The two cooling towers are treated as one source with the diameter set to give the same effective area as the total of the two separate towers;
- Milling Vents. There are three separate Mill Vents, which are all low enough (12 m) to be affected by building wakes so that they rapidly effectively become volumes sources. As these are close to each other but not so close that they can be considered to produce a single plume, just one of these is modelled with the typical exit characteristics for a single vent. However, the total emission rate of the pollutants released from these vents is considered to all be discharged through the single modelled vent;

- 25A Tank Vents. There are two stacks 25A1 and 25A3. These have been treated in the same way as the Milling Vent stacks with just a single stack included in the modelling at the location of 25A1;
- 35A Vents. There are two separate vent stacks. These have been treated like the Milling Vents with just a single stack included in the modelling; and
- 35J Vents. There are seven separate vent stacks. These have been treated like the Milling Vents with just a single stack included in the modelling.

The discharge characteristics and emission rates for the source modelling undertaken by CSIRO are presented in Appendix G and in detail in the CSIRO reports.

Table 10 Stack Discharge Characteristics modelled in Phase 3A for the Current Emissions Scenario.



Stacks modelled	AMG84 Coordinates East	North	Stack height	Stack Diameter	Temperature	Current scenario Average Exit Velocity	Peak Exit Velocity
	(km)	(km)	(m)	(m)	(K)	(m/s)	(m/s)
Liquor Burner (in Multiflue)	398.179	6357.052	100	0.925	338	27.9	28.7
Calciner 1–3 flues (modelled as combined source)	398.179	6357.052	100	3.44	450	20.6	24.2
Calciner1 flue (in Multiflue stack)	*398.179*	*6357.052*	*100*	*1.9*	*432*	*21.6*	*24.7*
Calciner2 flue (in Multiflue stack)	*398.179*	*6357.052*	*100*	*1.9*	*433*	*20.8*	*24.3*
Calciner 3 flue (in Multiflue stack)	*398.179*	*6357.052*	*100*	*2.15*	*469*	*19.6*	*23.8*
Calciner 4 stack	398.270	6356.955	48.8	2.35	430	20.1	23.8
Boiler 1–3 flues (modelled as combined source)	398.622	6357.512	65	3.71	390	14.6	21.8
Boiler 1 (in Boilerhouse Multiflue)	*398.622*	*6357.512*	*65*	*2.4*	*374*	*14.5*	*20.2*
Boiler 2 (in Boilerhouse Multiflue)	*398.622*	*6357.512*	*65*	*2.0*	*397*	*16.2*	*25.0*
Boiler 3 (in Boilerhouse Multiflue)	*398.622*	*6357.512*	*65*	*2.0*	*404*	*13.7*	*20.6*
Gas Turbine 1 stack	398.583	6357.395	40	3.03	371	22.4	30.7
Calciner 1,2,3 Vac Pump, 50B and Dorrco (in Multiflue)	398.179	6357.052	100	1.1	345	7.5	12.6
Calciner 4 Vac Pump and Dorrco (combined emission), use 50VAC4 stack details	398.245	6357.012	40	0.914	345	7.5	12.6
45K Cooling Tower 2 and 3 (1 duty, 1 standby cell)	398.504	6357.000	16.3	8	323	15.3	15.3
45K Cooling Tower 1	398.485	6357.000	8	7	323	13.7	13.7
50 Cooling Tower 1 and 2	398.228	6357.052	4	7.07	322	3.7	3.7
Milling Vents	398.142	6357.840	12	0.44	343	2.3	2.3
25A Tank Vents	398.131	6357.744	20	0.5	371	12.9	12.9
35A Vents	398.399	6357.415	19	0.6	370	1.3	1.8
35J Tank Vents	398.380	6357.540	9	0.49	357	1.7	2.0

Table 11 Stack Discharge Characteristics modelled in Phase 3B for the Expanded Refinery Emissions Scenario (4.7 Mtpa)

Stacks modelled	**AMG84 Coordinates**					**Expanded scenario**	
	East	**North**	**Stack height**	**Stack Diameter**	**Temperature**	**Average Exit Velocity**	**Peak Exit Velocity**
	(km)	**(km)**	**(m)**	**(m)**	**(K)**	**(m/s)**	**(m/s)**
Oxalate Kiln Stack	398.085	6357.463	50	1.3	363	19.6	19.6
Liquor Burner (in Multiflue)	398.179	6357.052	100	0.925	338	27.9	33.2
Calciner 1–3 flues (modelled as combined source)	398.179	6357.052	100	3.44	450	24.9	27.0
Calciner1 flue (in Multiflue stack)	*398.179*	*6357.052*	*100*	*1.9*	*432*	*23.7*	*25.7*
Calciner2 flue (in Multiflue stack)	*398.179*	*6357.052*	*100*	*1.9*	*433*	*24.0*	*26.1*
Calciner 3 flue (in Multiflue stack)	*398.179*	*6357.052*	*100*	*2.15*	*469*	*26.9*	*29.3*
Calciner 4–6 flues (modelled as combined source)	398.282	6356.933	100	3.44	430	23.8	25.9
Calciner 4 flue (in new Multiflue)	*398.282*	*6356.933*	*100*	*2.35*	*430*	*23.8*	*25.9*
Calciner 5 flue (in new Multiflue)	*398.282*	*6356.933*	*100*	*2.35*	*430*	*23.8*	*25.9*
Calciner 6 flue (in new Multiflue)	*398.282*	*6356.933*	*100*	*2.35*	*430*	*23.8*	*25.9*
Boiler 1–3 flues (modelled as combined source)	398.622	6357.512	65	3.71	390	14.4	15.2
Boiler 1 (in Boilerhouse Multiflue)	*398.622*	*6357.512*	*65*	*2.4*	*374*	*14.1*	*15.2*
Boiler 2 (in Boilerhouse Multiflue)	*398.622*	*6357.512*	*65*	*2.0*	*397*	*15.7*	*16.4*
Boiler 3 (in Boilerhouse Multiflue)	*398.622*	*6357.512*	*65*	*2.0*	*404*	*13.5*	*14.0*
Boiler 4–5 flues (modelled as combined source) **(only included in Case 7)**	398.630	6357.450	75	3.39	374	14.1	15.2
Boiler 4 flue (in new Multiflue)	*398.630*	*6357.450*	*75*	*2.4*	*374*	*14.1*	*15.2*
Boiler 5 flue (in new Multiflue)	*398.630*	*6357.450*	*75*	*2.4*	*374*	*14.1*	*15.2*
Gas Turbine 1 stack	398.583	6357.395	40	3.03	371	22.4	22.4
Gas Turbine 2 stack **(only included in case 6)**	398.663	6357.452	50	6.2	444*	18.0*	18.0*
Gas Turbine 3 stack **(only included in Case 6)**	398.663	6357.371	50	6.2	444*	18.0*	18.0*
Calciner 1,2,3 Vac Pump, 50B and Dorrco (in Multiflue)	398.179	6357.052	100	1.1	345	7.5	8.4
Calciner 4 Vac Pump and Dorrco (combined emission), use 50VAC4 stack details	398.245	6357.012	40	0.914	345	7.5	12.6
45K Cooling Tower 2 and 3 (1 duty, 1 standby cell)	398.504	6357.000	16.3	8	323	15.3	15.3
50 Cooling Tower 1 and 2	398.228	6357.052	4	7.07	322	3.7	3.7
Milling Vents	398.142	6357.840	12	0.44	343	2.3	2.3
25A Tank Vents	398.131	6357.744	20	0.5	371	3.2	3.2
35A Vents	398.399	6357.415	19	0.6	370	1.3	1.3

5.2.4 Model Results

5.2.4.1 Phase 1: Meteorology

The use of the derived Wagerup-specific land use, together with the refinery- generated heat flux, in the model improved the temperature and relative humidity predictions at Bancell Road, but only slightly. A sensitivity test indicated that increasing or decreasing the deep soil moisture content to an acceptable limit in the model does not improve the agreement between the modelled meteorology and the observations. A sensitivity test indicates that increasing the roughness length for the area to an acceptable limit in the model does not improve the agreement between the modelled meteorology and the observations.

Scatter plots, probability density function (or frequency) plots, and model evaluation statistics, such as observed and predicted means and standard deviations, correlation coefficient, root mean square error, systematic root mean square error, unsystematic root mean square error and index of agreement, were used to test TAPM's performance. The model evaluation was done for a whole year, daytime, night time, winter period and summer period and is detailed in the CSIRO phase one report.

The meteorological measurements used in the test of TAPM against observations were; hourly-averaged wind speed, wind direction and temperature (all measured at both 10 m and 30 m AGL), net radiation, and relative humidity observations taken at Alcoa's Bancell Road monitoring site; the hourly averaged wind speed and wind direction observations taken at 8m AGL at the RDA monitoring site; and the radiosonde profiles of wind speed, wind direction, temperature and relative humidity from five monitoring releases conducted over a 3-day period in July 2003.

Some particular inaccuracies in the wind speed, wind direction and net radiation measurements at Wagerup, already identified, will cause discrepancies between the TAPM outputs and meteorological observations at Wagerup.

The agreement between the TAPM predications and the measurements, as judged by the index of agreement, for Wagerup is the highest for temperature, followed by net radiation, relative humidity, wind direction and wind speed. The model wind predictions are better in the daytime than in the night time, and they are better in winter than in summer. The overall wind-speed comparison at Bancell Road is dominated by the strong night-time easterlies/ south-easterlies. The model performance for wind predictions at RDA is better than that at Bancell Road. The performance of the model is partly dependent on the complexity of the area being studied. The Bancell Road site is only about 1 km west from the western foothills of the north-south Darling escarpment, which rises to about 200 m within a distance of about 1.5 km from the foothills. It is possible that the Bancell road site is sheltered by the escarpment for the easterly/south-easterly winds, and that the model is not able to simulate properly.

The performance of TAPM in predicting the local meteorology at Wagerup is comparable to its performance in predicting the near-surface meteorology elsewhere in the world. TAPM generally predicts stronger wind speeds at Wagerup and its performance for wind speed for Wagerup is not as good as for other locations.

The limitations in TAPM's predications arise from these reasons; approximations to the underlying physics; uncertainties in the input data; problems of matching of the scale of the model to the observations. These are basic limitations that arise from current scientific knowledge and computing power.

5.2.4.2 Phase 2: Dispersion

A summary of the Phase 2 results are outlined below:

- There is evidence that almost all of the Boundary Road NOx data are heavily influenced by unquantified non-Refinery emissions, which are not included in the modelling, whereas the NOx data from Upper Dam are the most extensive data set of measurements available that show a strong Refinery signature. Consequently, the emphasis was placed on the model comparison with the Upper Dam;

- The TAPM modelling performs well at Upper Dam. The model observation comparison agrees to within the uncertainties in the model physics, inputs and concentration data;

- Inclusion of building wake effects in the model does not make a significant difference to the predictions. However, it is physically realistic to include them;

- Slight improvement in the TAPM predictions is achieved with the inclusion of the Refinery-generated heat flux;

- TAPM evaluation using a limited number of data from the ANSTO study indicates that without wind assimilation there is a bias in the model to underpredict the high end concentration levels due to the 100-m Multiflue by a factor of about 2;

- Wind data assimilation has mixed impact on pollution predictions. Meteorological data currently available for wind data assimilation do not cover the whole model year, and at the RDA have quality problems;

- Comparison of evaluation results reported in the present study with other modelling studies suggests that TAPM's overall performance at Wagerup is on par with its performance elsewhere for annual data measured at sparse monitoring networks. At Wagerup, some uncertainty in the model evaluation is generated by possible (unquantified) NOx contributions from sources other than the Refinery; and

- It is estimated that about 77% of the model events at Yarloop due to the Refinery emissions occur for model wind direction between 330°−60° when the Yarloop area is downwind of the Refinery. These events are dominated by morning inversion break-up fumigation, shallow convective mixing, and strong winds and/or cloudy conditions.

5.2.4.3 **Phase 3A (base)**

Average Emissions

The refined TAPM (as resolved in Phases 1 and 2) has been run for the annual meteorological file (1 April 2003 to 31 March 2004) and the agreed sources to produce estimates of the following parameters for 28 pollutants at 15 receptor points for average and peak emission rates:

- Annual average concentration (at average emission rates)
- Maximum 1-hour average concentrations (peak emissions)
- 95th percentile 1-hour average concentrations (peak emissions)
- 95th percentile 24-hour average concentrations (peak emissions)

Contour plots have been produced (of these four statistics) for two example substances (NOx and formaldehyde) to indicate the different concentration distribution patterns for substances predominantly emitted from high and low level sources. A simple titration algorithmic method has been described and used to calculate the conversion of NOx to NO_2 using available data on the diurnal variation in ozone concentrations at Wagerup. The method has been used for deriving shorter time period (3 and 10- minute) maximum concentrations from the Wagerup hourly TAPM concentration fields. A detailed description of this method has been presented.

Figure 10 to Figure 15 show the modelled concentration contour patterns for the six statistics (annual average, 95th percentile 24-hour average, 95th percentile 1-hour average, maximum 1-hour average, maximum 10-minute average, and maximum 3-minute average) for formaldehyde and NOx selected as representative of low-level, medium level and tall-stack releases from the Refinery for investigating the different patterns of ground-level concentrations. For the annual average and 95th percentile 24-hour average, the highest concentrations in the spatial distribution all occur within the Refinery within a few hundred metres of the 100 m Multiflue stack. The same is true for the modelled maximum 1-hour average concentrations for formaldehyde although for formaldehyde there is a lobe with concentrations greater than 2 µg m-3 extending 4 km west-south-west from the Refinery. For NOx, the modelled maximum 1-hour average concentrations show a highest concentration in the spatial distribution of about 180 µg m-3 at a distance of 4 km approximately west-south-west of the 100 m Multiflue stack. Modelled maximum concentrations through Yarloop are lower (from 50 to 100 µg m-3) and less than 50 µg m-3 in Hamel. The NOx results differ from those for formaldehyde because most of the NOx emissions occur from the taller stacks that have significant plume rise because of the high temperature and volume of flow from the Calciner and Boilerhouse stacks. The highest ground-level concentrations from these stacks occur under convective or fumigation conditions. The maximum 10-minute and 3-minute average concentrations show similar patterns but with higher concentrations.

These yearly maximum 1-hour average concentrations represent the most extreme hour in the year with respect to ground-level concentrations. In a different year with different meteorology the location and magnitude of these yearly maximum 1-hour average concentrations could change. This is why the 9th highest concentration (99.9th percentile) or robust highest concentration (RHC) is often chosen as the key statistic to represent the extremes, rather than the modelled or observed maximum.

Figure 10 Annual-average modeled formaldehyde concentrations for current Emissions Scenario (6600tpd)- Average Emissions

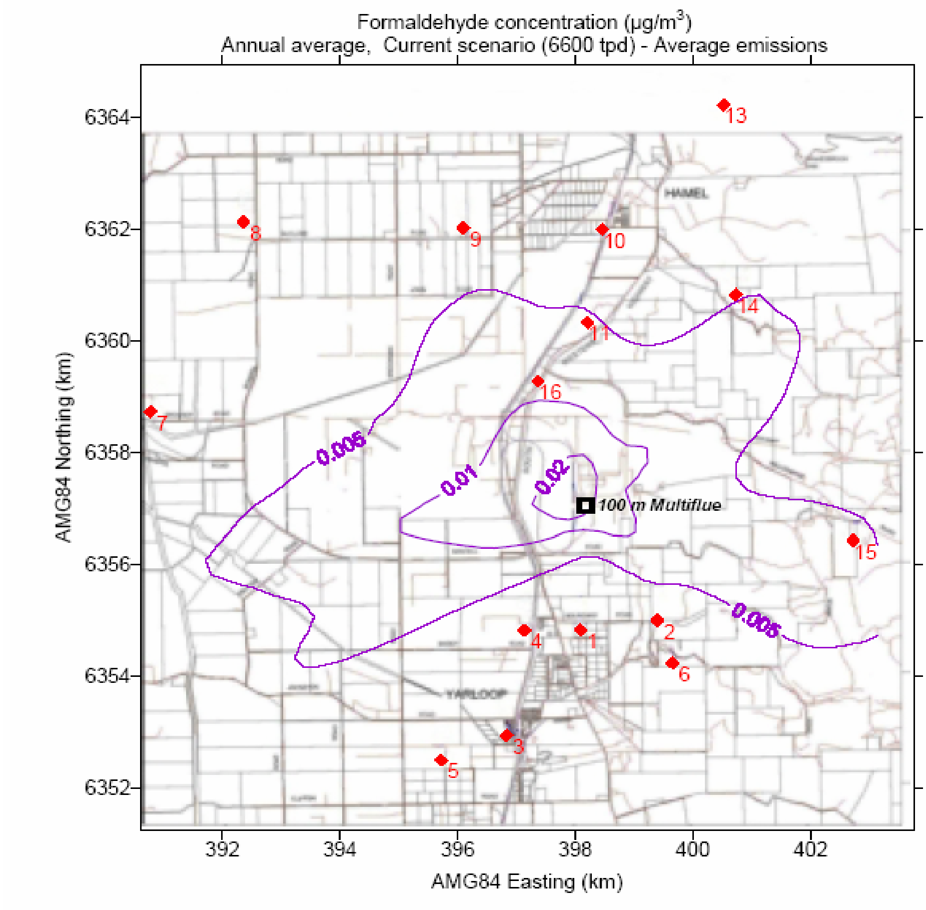


Figure 11 95th percentile 24-hour average modeled formaldehyde concentrations for Current Emissions Scenario (6600 tpd)- Peak Emissions

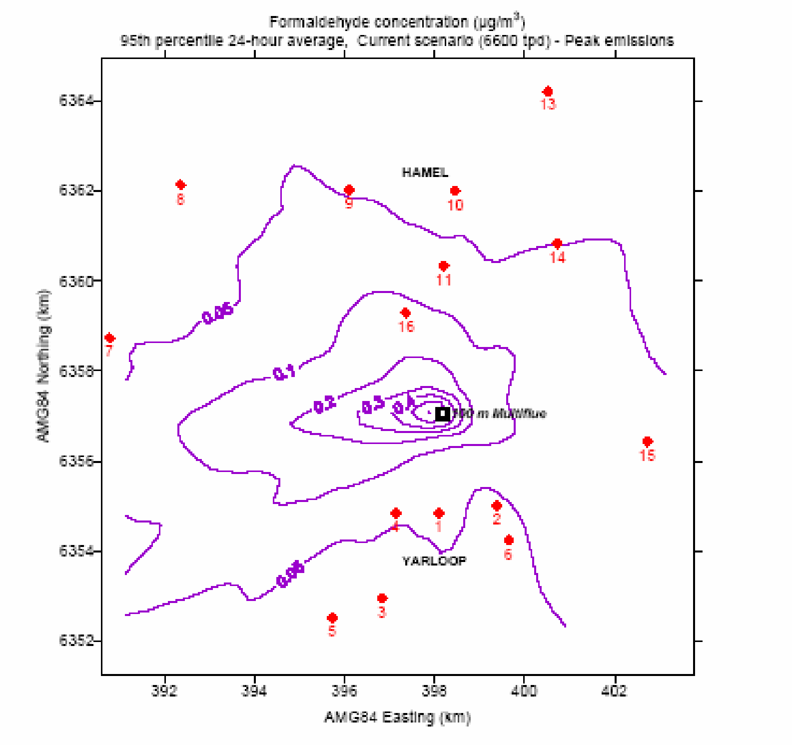


Figure 12 95th percentile 1- hour average modeled formaldehyde concentrations for Current Emissions Scenario (6600 tpd)- Peak Emissions

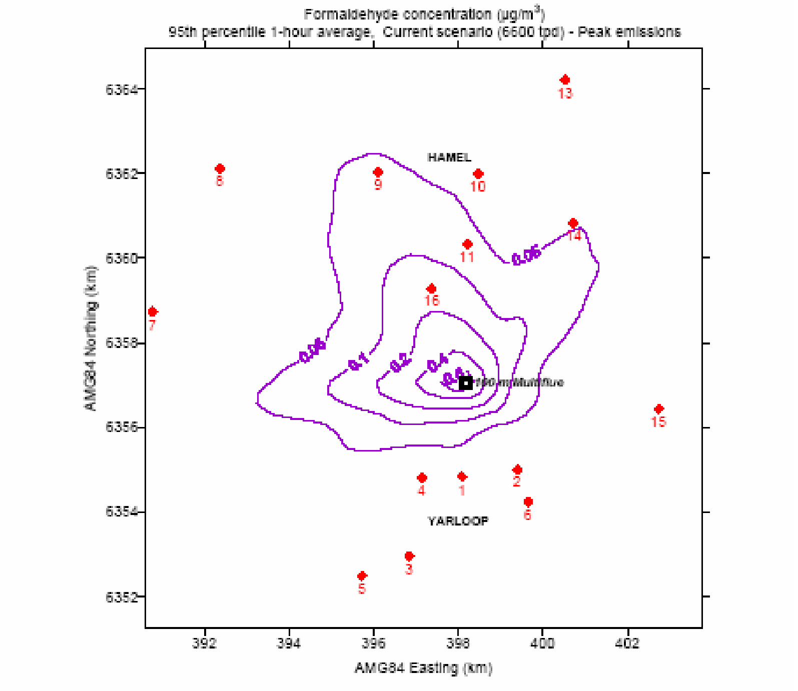


Figure 13 Maximum 1- hour average modeled formaldehyde concentrations for Current Emissions Scenario (6600 tpd)- Peak Emissions

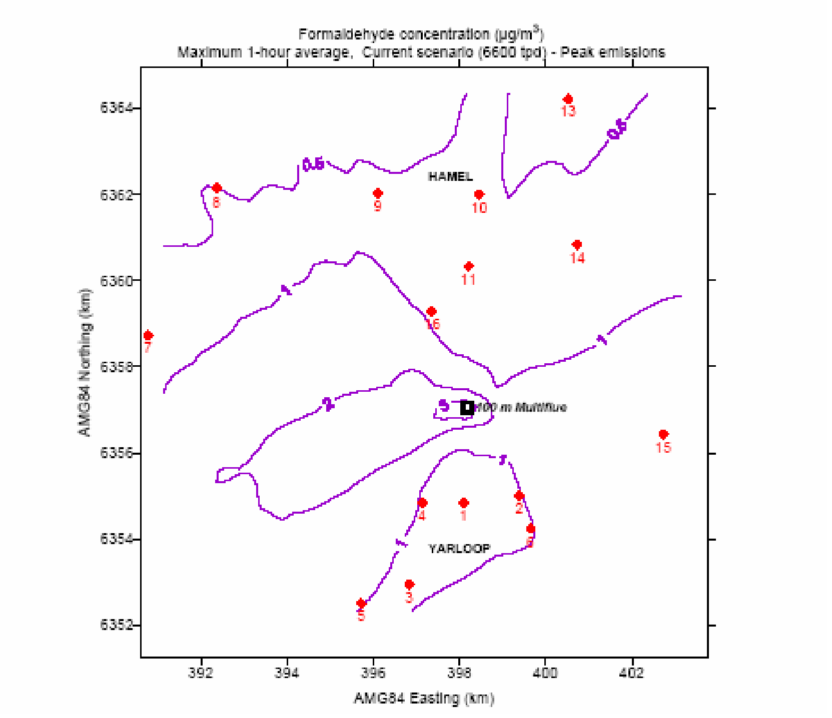


Figure 14 Maximum 10-minute averaged modeled formaldehyde concentrations for Current Emissions Scenario (660 tpd)- Peak Emissions

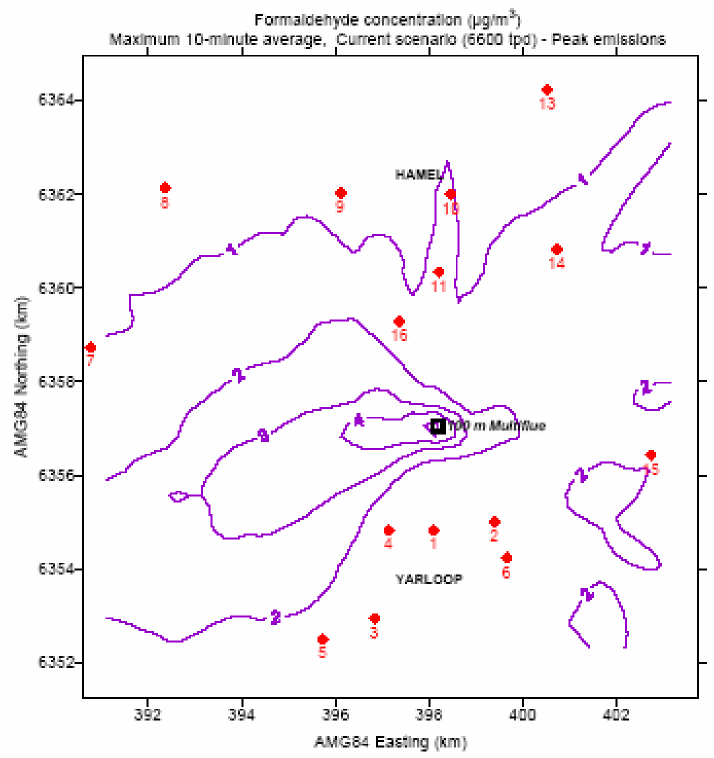
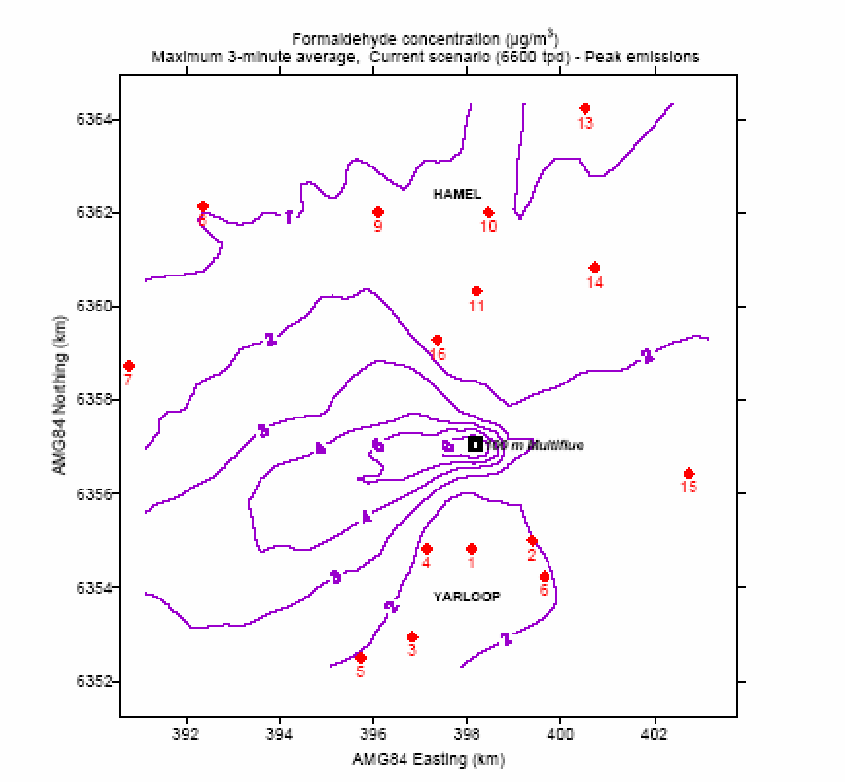


Figure 15 Maximum 3-minute average modeled formaldehyde concentrations for Current Emissions Scenario (6600 tpd)- Peak Emissions



The uncertainty of the model predictions has been determined from consideration of results from a range of TAPM studies and an analysis of the sensitivity of model results to wind data assimilation. CSIRO conclude that the results for the modelled concentrations presented in the report have an uncertainty of a factor of approximately 2 (i.e. the actual values lie in the range of +100% to -50% of the listed concentrations) at the 95% confidence level.

Selected modelled concentration statistics sorted by receptor site for each of the 28 chemical species at each of the 15 receptor sites for the Current Emissions Scenario of 6,600 tonnes per day are presented in Appendix G.

Peak Emission Rates

A summary of peak emission results are outlined below with a detailed assessment presented in the CSIRO reports (Appendix G). For both formaldehyde and NOx the peaks at receptor 14 (Escarpment) all occur between 10:00 to 18:00, whereas at receptors 1 (Boundary Road) and 3 (Yarloop), peaks are observed both at night and during the day. Most of the peaks only last for one hour; the longest is a four-hour formaldehyde peak at site 1 from 19:00 to 23:00.

Wind directions at the times of the peak concentrations correspond closely with the Refinery being directly upwind from the receptor except for one case at receptor 3 for both NOx and formaldehyde. This one case occurred on 9 Aug 2004 at 21:00 with a wind speed of 2 m s-1 and an inversion height of 34 m. It occurs with a more easterly component indicating some turning of the wind and flow from the escarpment towards the receptor. In the other cases, the wind speeds were higher, typically 4 to 8 m s-1. These features are similar to those identified in the Wagerup Air Quality Review (CSIRO, 2004) when examining the peak NOx concentrations observed at Boundary Road and Upper Dam, except that the wind speeds in those cases tended to be lower, generally less than 4m s-1. These features also closely match those identified in Section 6 of the Phase 2 report (CSIRO, 2005), where most model events were identified as occurring with wind speeds from 2 to 6 m s-1 and at lower speeds under easterly flows. Night-time model events occurred with mixing heights less than 300 m, whereas daytime model events occur in strongly convective conditions with mixing heights up to 2000 m.

5.2.4.4 Phase 3B: Expanded Refinery Emissions

Modelling has been carried out for the Expanded Refinery (4.7 Mtpa) Emissions Scenarios. Two scenarios have been considered:

- Case 6, with Cogeneration using new Gas Turbines 2 and 3
- Case 7, with new Boilers 4 and 5.

Two sets of emissions have been considered for each of these scenarios– the Average emission rates and the Peak emission rates. The atmospheric concentrations modelled in this study are the direct consequence of the emissions included in the model. Different emission rates would produce different concentrations.

<u>Case 6, Cogeneration- Average</u>

Contour plots and ground level concentration statistics for Case 6 are presented in the CSIRO report (Phase 3B 2005). For the annual average and 95th percentile 24-hour average, the highest concentrations in the spatial distribution all occur within the Refinery within a few hundred metres of the 100 m Multiflue stack. The same is true for the modelled maximum 1-hour average concentrations for formaldehyde and mercury. Formaldehyde shows a very diffuse pattern with values below 0.5 µg m-3 at all receptors whereas mercury shows small peaks of up to 0.02 µg m-3 about 2 km east of the 100 m Multiflue and one extending about 2 km north of the 100 m Multiflue.

For NOx, the modelled maximum 1-hour average concentrations show a highest concentration in the spatial distribution of about 200 µg m-3 at a distance of 4 km approximately west-south-west of the 100 m Multiflue stack. The NOx results differ from those for formaldehyde because most of the NOx emissions occur from the taller stacks that have significant plume rise because of the high temperature and volume of flow from the Calciner and Boilerhouse stacks. The highest ground-level concentrations from these stacks occur under convective or fumigation conditions. The maximum 10-minute and 3-minute average concentrations show similar patterns but with higher concentrations.

These yearly maximum 1-hour average concentrations represent the most extreme hour in the year with respect to ground-level concentrations. In a different year with different meteorology the location and magnitude of these yearly maximum 1-hour average concentrations could change. This is why the 9th highest concentration (99.9th percentile) or robust highest concentration (RHC) is often chosen as the key statistic to represent the extremes, rather than the modelled or observed maximum.

Case 6, Cogeneration- Peak

Contour plots and ground level concentration statistics for Case 6 peak emissions are presented in the CSIRO report (Phase 3B 2005). One-half of the model events occur at the same time for NOx and formaldehyde, though not always at the same site, with most of these events during the winter months (April to September).

For both formaldehyde and NOx the peaks at receptors 1 (Boundary Road) and 14 (Escarpment) all occur between 10:00 to 18:00, whereas at receptor 3 (Yarloop), peaks are observed both at night and during the day. All the peaks only last for one hour.

The results for NO_2 are similar to those for NOx except for largest peak at receptor 14 (Escarpment) which is capped by the ambient ozone concentration to 53 µg m-3 and lasts for 3 hours on 22 August. Wind directions at the times of the peak concentrations correspond closely with the Refinery being directly upwind from the receptor. Wind directions correspond to the receptor being directly downwind of the Refinery are 0° for receptor 1, 20° for receptor 3, and 215° for receptor 14. The exceptions (when these peaks occurred and the wind direction was not from the Refinery) include two cases at receptor 3 for NOx and formaldehyde which occurred at 2100 and 0400 hours with mixing heights of 34 and 50 m and wind speeds of 2 m s-1 and 3 m s-1). There is also one case at receptor 1 for formaldehyde, which occurred at 1000 hours with a wind speed of 1.6 m s-1 and a mixing height of 480 m. These indicate some turning of the wind, the former with flow from the escarpment towards the receptor, the latter from the north-west back towards the receptor.

In the other cases, the wind speeds were higher, typically 4 to 11 m s-1. These features closely match those identified in Section 6 of the Phase 2 report (CSIRO, 2005), where most model events were identified as occurring with wind speeds from 2 to 6 m s-1 and at lower speeds under easterly flows. Night-time model events occurred with mixing heights less than 300 m, whereas daytime model events occur in strongly convective conditions with mixing heights up to 2000 m.

Case 7, New Boilers- Average

For the annual average and 95th percentile 24-hour average, the highest concentrations in the spatial distribution all occur within the Refinery within a few hundred metres of the 100 m Multiflue stack. The same is true for the modelled maximum 1-hour average concentrations for formaldehyde and mercury. Formaldehyde shows a very diffuse pattern with values below 0.5 μg m^{-3} at all receptors whereas mercury shows small peaks of up to 0.02 μg m^{-3} about 2 km east of the 100 m Multiflue and one extending about 2 km north of the 100 m Multiflue.

For NO_x, the modelled maximum 1-hour average concentrations show a highest concentration in the spatial distribution of about 160 μg m^{-3} at a distance of 4 km approximately west-south-west of the 100 m Multiflue stack. The NO_x results differ from those for formaldehyde because most of the NO_x emissions occur from the taller stacks that have significant plume rise because of the high temperature and volume of flow from the Calciner and Boilerhouse stacks. The highest ground-level concentrations from these stacks occur under convective or fumigation conditions. The maximum 10-minute and 3-minute average concentrations show similar patterns but with higher concentrations.

These differences between the contour patterns for species released at different heights are in agreement with our understanding of the different dispersion processes that are dominant at different heights in the atmosphere.

These yearly maximum 1-hour average concentrations represent the most extreme hour in the year with respect to ground-level concentrations. In a different year with different meteorology the location and magnitude of these yearly maximum 1-hour average concentrations could change. This is why the 9th highest concentration (99.9th percentile) or robust highest concentration (RHC) is often chosen as the key statistic to represent the extremes, rather than the modelled or observed maximum.

Case 7, New Boilers- Peak

For formaldehyde the peaks at receptors 1 (Boundary Road) and 14 (Escarpment) all occur between 10:00 to 18:00, whereas at receptor 3 (Yarloop), peaks are observed both at night and during the day. All except one of the peaks only last for one hour. The exception is on 22 August at 1400 and 1500 hours with a 2-hour peak.

The timing of the NOx peaks are similar to those for formaldehyde NOx but there is one event from 0400 to 0900 hours with elevated NOx concentrations (above 30 µg m-3) at receptor 3 (Yarloop) on 7 August. The NO2 peaks are similar except for one example at each of receptors 3 and 14 of capping due to the ambient ozone concentration to 53 µg m-3 at 1400 hours and 45 µg m-3 at 1800 hours.

Wind directions at the times of the peak concentrations correspond closely with the Refinery being directly upwind from the receptor. Wind directions corresponding to the receptor being directly downwind of the Refinery are 0º for receptor 1, 20º for receptor 3, and 215º for receptor 14. The exceptions (when these peaks occurred and the wind direction was not from the Refinery) include two case at receptor 1 with NOx and formaldehyde, which occurred at 0900 and 1000 hours with mixing heights of 90 m and 480 m and wind speeds of 1.5 m s-1 and 1.6 m s-1. There are also two cases at receptor 3 for formaldehyde, with wind speeds of 3 m s-1 and 2 m s-1 and mixing heights of 50 m and 35 m. These cases all indicate some turning of the wind, three with flow from the escarpment towards the receptor, and one from the north-west back towards the receptor. In the other cases, the wind speeds were higher, typically 4 to 11 m s-1.

These features also closely match those identified in Section 6 of the Phase 2 report, where most model events were identified as occurring with wind speeds from 2 to 6 m s-1 and at lower speeds under easterly flows. Night-time model events occurred with mixing heights less than 300 m, whereas daytime model events occur in strongly convective conditions with mixing heights up to 2000 m.

The refinery expansion modelling undertaken by CSIRO indicate that the cogeneration option produces slightly higher NOx results than the boiler option with the boilers emitting marginally higher VOCs than the cogeneration option. The results of the refinery modelling are combined with the diffuse source modelling and used as inputs into the QHRA.

It must be noted that the emission rates used in the CSIRO modelling were since updated based on additional information received from Alcoa on the proposed plant design and specifications, changes to the proposed controls and further refinement of calculated emission estimates. The changes to the emission estimates have resulted in additional post processing/scaling of the modelling undertaken by CSIRO, with the new emission rates used to produce concentration contours within the modelled domain and to re-calculate ground level concentrations at nominated receptor locations for use in the QHRA. A copy of the updated emission rates is presented in Appendix J.

5.3 CALPUFF MODELLING

Calpuff modelling was used to predict emissions from fugitive (uncontrolled) sources from the residue areas, bauxite stockpile area and lower dam at the Wagerup Refinery operations. Specifically, emissions of dust, metals, odours and VOCs were predicted from these areas for the existing refinery scenario (referred to as the 'base case') and the expanded refinery scenario.

The two major sources of particulates from the RDA areas and from the bauxite stockpile area were estimated and modelled. It is noted that emissions of fugitive dust from vehicles at the refinery itself from the paved roads were not modelled as well as wind erosion at the refinery as they are considered relatively minor, compared to the two larger sources at the RDA and bauxite stockpiles.

Additionally, the modelling only looks at quantifying and modelling Alcoa sources at Wagerup and does not include other sources in the area including the "mothballed" nearby mineral sands mine to the north of the refinery, farming operations which dependent on the time of year can be a significant source, and particulate from burning off and wildfires. These sources are not modelled though they are to some degree taken in to account in determining background dust levels if the source impacts onto all monitors.

Calpuff is considered the best model for modelling dispersion from the fugitive sources as the following issues for dispersion of the pollutants are considered important and can be handled within this modelling system:

1. Releases from large areas from ground or water surfaces. Calpuff is now being used more frequently as it can better predict dispersion under light wind conditions.
2. Model dispersion under light wind conditions where the winds may stagnate and meander. These conditions will be important primarily for modelling VOC emissions from area sources as the offsite concentrations will be highest under light winds.
3. Incorporate variable winds and land uses across the region. Variable land uses will result in different dispersion rates of the plumes as the plumes are blown across them.
4. Incorporate the effects of terrain. This can be important in the turning of the low level winds such as blocking of stable airflow by elevated terrain.

5.3.1 Methodology

5.3.1.1 Development of Meteorological Files

Two meteorological files were developed for modelling. One was based on using the TAPM generated wind fields by CSIRO (2004), to enable generation of wind fields within Calmet which are consistent with TAPM. This is required in that the model predictions from fugitive sources are to be added on an hourly basis with the modelled predictions from the refinery sources predicted using TAPM by CSIRO (2005b) for the Health Risk Assessment (ENVIRON, 2005b). Estimates of the heat fluxes and turbulence fluxes for this file were derived using the Calmet methodologies and therefore these will be not as used within TAPM. As such the winds will be consistent, but there will be some differences in the heat fluxes, mixing depths and therefore turbulence properties of the flow. This meteorological file is used for the concentrations predictions within this report. The second file was based primarily on surface observations and used only the TAPM winds at essentially several hundred metres above the surface. This file was developed as a check on the first file given that there are some concerns to the representativeness of the TAPM winds. A detailed description of the development of the meteorological files are presented in the Air Assessment Report.

5.3.1.2 Calmet Set Up Options

A 28 by 29 grid with SW grid cell centre at 389,883m, 6,351,676m, with 0.5 km interval over the region, with 9 vertical levels. The CALMET grid was selected to match the grid cells used in TAPM by CSIRO (2005b), but extended further to the east than the inner TAPM pollution grid to cover a larger area of the scarp than used in the Calpuff dispersion modelling to resolve any drainage flows. The vertical extent within Calmet was limited to 2250m as the TAPM data supplied by CSIRO as used in TAPM derived meteorological file was limited to 1500m. This limit to the vertical levels results in a less than optimal for modelling tall stacks, but should have no bearing on dispersion from surface releases.

The pre-processor model Calmet (v 5.542) was setup with the following:

- Topographical data in AMG84 coordinates was obtained from 5 m contour interval data supplied by Alcoa (DLI Geo Spatial information reproduced with permission of the Department of Land Information, P339). .
- For the derivation of the meteorological file from the observations, use of the biases presented in the Air Assessment report were used to weight the observational surface and

upper winds. These biases were chosen to rely heavily on the surface observations for the lower atmosphere and minimise the effect of the winds from the profile measurements.

- Bowen ratios for use in predicting sensible heat fluxes that varied by time of the year and land type as presented in the CALPUFF modelling report. In summer a value of 3 and 1.5 was used for agricultural/cleared area and forests respectively with a value of 1.0 used for both in winter. These values were derived to approximately match the heat flux measurements over forest and agricultural land in the south west as reported in Ray et al (2003). Values for the residue area, though barren were chosen to reflect the coverage of wet mud, whilst the refinery was chosen to reflect an industrial area with little vegetation;
- Albedo set to a constant of 0.18 for both surfaces for the year;
- Roughness lengths were determined based on observations of the land uses and the land use roughness categories as presented in Ausplume;
- Use of 0.7 and 1000 for CONSTB and CONSTN respectively, the neutral mechanical and stable mixing height constants and a minimum potential temperature lapse rate in the capping inversion of 0.01 deg K/m;
- Incorporation of surface heat fluxes for the refinery area and the cooling pond. The surface heat flux for the refinery was estimated in CSIRO (2004) as 224 MW. For modelling the sensible heat flux as the area used to represent the cooling, one cell of 500 by 500m (22.5ha) a value of 75 W/m^2 was used such that the overall heat flux was of 18.75MW was comparable to the lake heat flux of 17 MW;
- The maximum radius of influence was specified as small such that the Perth airport winds would have no influence on the derived step 1 winds; and
- For the meteorological file developed from surface observations, a wind barrier was included to limit the influence of the observations on the step one winds on the scarp as specified roughly by the 100 m contour line. This was not required for the file developed from TAPM winds.

The resultant meteorological file from Calmet consisted of 366 days over the period 1/4/2003 to 31/03/2004.

5.3.2 Summary of Model Set-Up

For this study, Calpuff (v5.714) has been used following the set up as follows:

- Concentrations were predicted on a 250m grid, of 53 by 53 grid points (13 by 13km), with the SW corner at 390,633E, 6,351,826m N and NW corner at 403,633mE, 6,364,826m N. This was selected to match the TAPM inner pollution grid used by CSIRO (2005b) for the refinery sources as required for the merging of the TAPM modelling and that conducted here for fugitive sources;
- No chemical transformation of gaseous releases. This has been omitted as they are generally small except for formaldehyde and are not easily modelled within Calpuff. An estimate of the conservatism can be made noting the shortest half life (at 25 degrees C) for each of the VOCs modelled is: 1 to 3 hours for formaldehyde, 6 to 12 hours for acetaldehyde and approximately 17 days for benzene (Chemfate, 1994). For conditions that typically lead to highest concentrations, e.g. low wind speeds at night time the travel time to the nearest receptors will be of the order ½ to 1 hour. In such time formaldehyde may have decayed by up to 50% (assuming a 1 hour travel time and 1 hour half life), but more probably by around 20% (½ hour travel time and 2 hour half life and an exponential decay). For acetaldehyde, the half life is approximately 6 hours in the presence of hydroxyl (OH) radicals which are primarily generated by photochemical reactions in the day time. For the night time, early morning conditions the half life will be lower (up to 12 hours), which at a travel time of 0.5 and 1 hours indicates that concentrations may be reduced by 3 and 6% respectively. Therefore, the predicted concentrations at the locations with highest concentrations may be 30 to 50% overstated for Formaldehyde and 3 to 6% overstated for acetaldehyde;
- Meteorological file using the 3 dimensional wind and turbulence fields generated by Calmet;
- Calm wind speeds defined as less than 0.5 m/s;
- Dispersion estimates using the Pasquill Gifford dispersion curves with roughness length adjustment. This was used as Pasquill Gifford curves are accepted by most regulators for surface dispersion and has more acceptance than the alternative micro-meteorological dispersion algorithms even though they are recommended by Scire (2003) as being theoretically sounder. In an assessment of the dispersion from the refinery stack sources, SKM (2002a) found that the micro-meteorological dispersion provided better estimates of dispersion under stable conditions at night from the near surface release;
- Modelling of fugitive sources using the variable area source within Calmet. This requires coordinates of the vertices of the area, an initial vertical dispersion, source height and allows for plume rise from a source of finite diameter and initial temperature and exit velocity. For these the temperature was set to the ambient temperature, with exit velocity and diameter set

to 0.000001 m/s and 0.000001 m respectively such that the plume rise would be negligible and not influence dispersion;

- Initial vertical standard deviation of the plume from an area source as equal to the dispersion that would occur for the plume travelling half the distance across the area using the Pasquill Gifford dispersion curves and the stability at the time. For area sources from a water bodies the stability class was limited to D class as an approximation. Comparison to CFD modelling results indicates that this will provide a conservative approximation (see Appendix E);
- Initial plume height for the sources were set for the large area source of 1m above the surface, excepting for the elevated source of the super-thickener and from the RDA bauxite stockpiles. For the liquid surfaces this again is conservative as the CDF modelling indicates that the plume rise will be typically 20m from the larger are sources (see Appendix E);
- No adjustment for sampling time was added to convert the plume horizontal plume spread. This in line with the used by the USEPA in models such as ISC3, though in Australia and in general it is accepted that the Pasquill Gifford dispersion curves relate to 3 minute averages. Therefore they are often converted to 1 hour curves by a simple power law with the plume spread for the 1-hour curves increased by a factor of 1.82; and
- Calpuff terrain adjustment scheme. This is considered to be the more theoretical scheme within Calpuff. For surface releases it will have negligible effect on the predicted concentrations.

5.3.3 Model Results

Predicted concentrations for the base case of particulate and metals indicate that the highest concentrations are to the west of the RDA and bauxite areas, due to strong easterly winds that develop during the summer months. For the VOC emissions the predicted concentrations are more circular and are due to the frequency of lighter winds.

Estimates of the emissions for the expansion case were derived based on engineering advice from Alcoa and included, locations of new RDAs and changes in the drying areas, changes to the bauxite stockpile area, increase in tonnages, improvement in dust control with new water cannon layout to be installed on all new and old RDAs and the expected changes in the VOC content and flows of the various liquid streams. The expansion therefore was estimated to decrease fugitive PM10 emissions by 7% at the RDA, increase by 57% the emissions at the stockpile area with an overall increase of 9%. Metals are estimated to increase by between 1 to 13%. Emissions of VOCs for the upgrade may increase between 4% for acetaldehyde to 55% for formaldehyde with odours estimated to increase by 11%. Summarised below predicted ground level concentrations and concentration contours for dust emissions and VOCs with more detailed results presented in the Air Assessment Report.

5.3.3.1 Dust Emissions

Table 12 presents a summary of the estimated emissions from the RDA, bauxite stockpiles and construction activities for the 12 month modelling period 1 April 2003 to 31 March 2004.

Table 12 Estimated PM_{10} Emissions from Wagerup Fugitive sources for 2003/2004

Source	**Units**	**Normal Operations**					**RDA Construction**		
		Stockpile Wind	**Stockpile Activity**	**RDA Wind**	**RDA Activity**	**Total**	**Wind**	**Construct. Activity**	**Total**
Maximum	g/s	159	8.2	469	6.0	637	154	26	180
99 Percentile	g/s	55.9	5.5	177	6.0	240	40.5	26	44.2
95 Percentile	g/s	10.6	3.4	44.5	6.0	60.8	7.2	26	26
90 Percentile	g/s	1.7	2.5	15.2	6.0	22.6	1.5	10.4	18.2
Average	g/s	2.2	1.3	8.4	1.9	13.8	1.5	2.3	3.8
Minimum	g/s	0.0	0.4	0.0	0.54	0.9	0.0	0.0	0.9
Annual	tpa	70	40.3	266	60	436.3	48.5	72.8	121.3

Note: As derived using the TAPM meteorological file and related emission estimates.

The table indicates that maximum emissions are predicted from the wind erosion sources. On an annual basis, wind erosion is still the largest source though with an increased contribution from sources such as vehicle and ore movement, which are generally continuous for the year. It also indicates for the 12 month period that although the RDA 7 construction only occurred for around 3 ½ months of the 12 month period it was responsible for a substantial contribution of 121.3 tpa (22%) to the annual emissions of 557 tpa.

Table 13 presents the predicted emissions using the TAPM meteorological file and the meteorological file from the observations for the base case and the expanded case. Also presented are the Alcoa NPI 2003/2004 emissions.

Table 13 PM_{10} and metal estimates within the PM_{10} from various Sources

Source	**RDA (tpa)**	**Bauxite Stockpiles (tpa)**	**Total (tpa)**	**Mn (kg)**	**Cd (kg)**	**Se (kg)**	**As (kg)**	**Ni (kg)**	**Hg (kg)**
TAPM Winds									
Base Case	343	110	453	96.6	0.014	1.36	18.9	2.27	0.025
Expanded Case	319	173	492	100.9	0.015	1.48	19.1	2.46	0.028
Ratio Expanded/Base	0.93	1.57	1.09	1.04	1.09	1.09	1.01	1.09	1.13
Observed Winds									
Base Case	302	63	366	79.9	0.011	1.10	15.9	1.83	0.020
Expanded Case	287	102	389	82.3	0.012	1.17	16.0	1.94	0.021
Ratio Expanded/Base	0.95	1.61	1.06	1.03	1.06	1.06	1.01	1.06	1.10
Alcoa 03/04 NPI	261	11	272	111.0	0.018	3	24.3	2.7	0.008

The above table indicates:

- A small increase in the emissions of PM10 and most metals for the future case;
- Slightly lower emissions were predicted for the observed winds compared to the TAPM winds; and
- Good agreement between the emissions estimated here and those reported in the NPI, though they were obtained by independent methods. Of the metals, the major differences are that this study's mercury estimates are around 3 times higher and selenium are 2 to 3 times lower than the NPI estimates. These differences will be due to differences in the metal speciations used and how they are applied to the dust. In this study one speciation only was used for RDA dust and one for the bauxite dust.

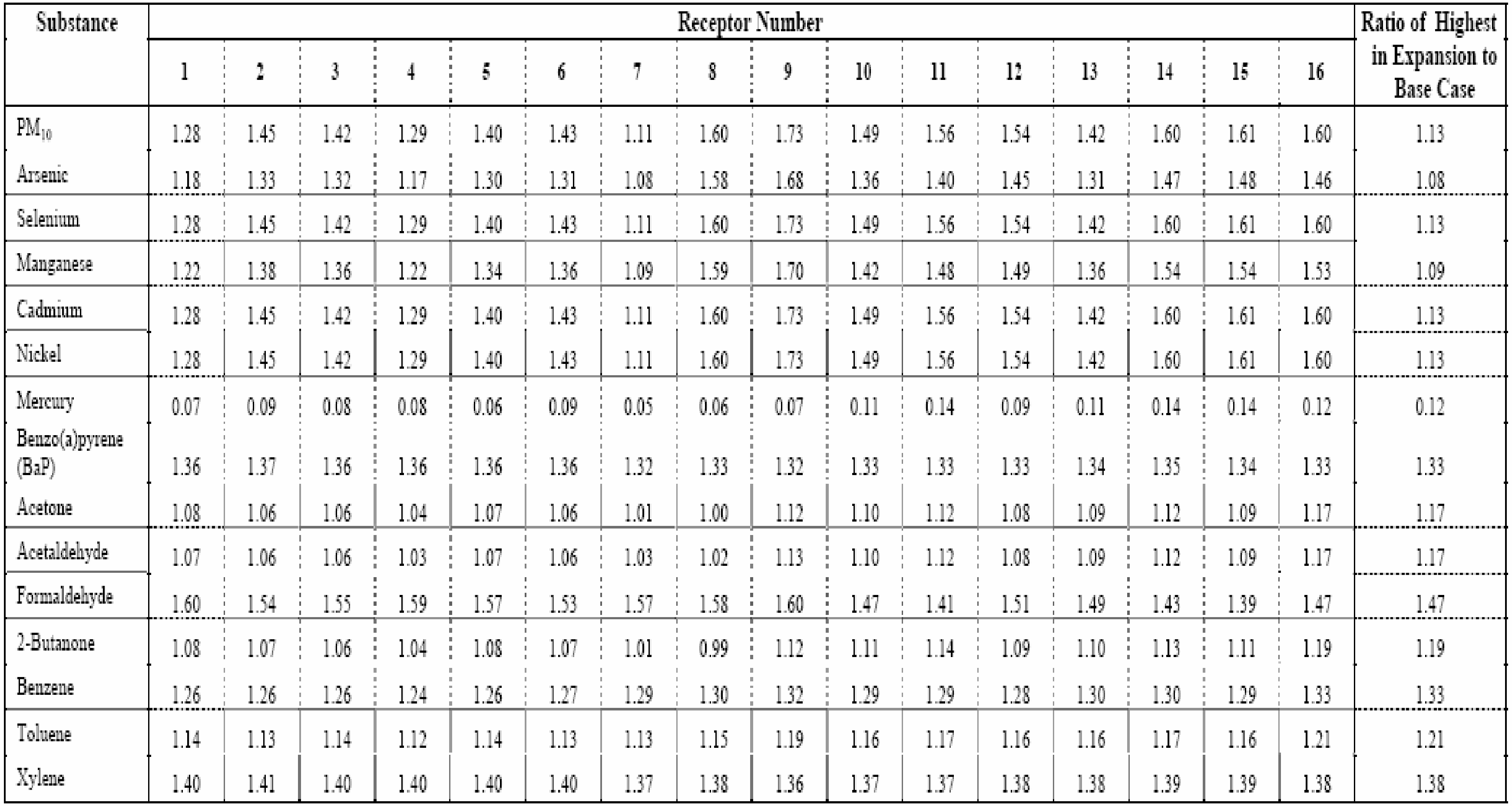
5.3.3.2 VOC Emissions

VOC predictions are considered to have greater uncertainty than dust emissions, but are expected to be conservative. This is because the modelling does not account for plume rise from the heated water surfaces where most of the emissions originate (the cooling pond, RDA2 surface and sand lake). Recent CFD modelling and site observations have shown that appreciable plume rise can occur during night time light wind conditions. This leads to much lower offsite concentrations than otherwise would occur. The uncertainties in the VOCs arise in relating flux hood measurements, which are in a controlled environment to emissions which are a function of conditions such as wind speed and temperature.

Analysis of the conditions that lead to the highest VOC concentrations due to residue area source emissions indicate that these generally occur for wind speeds from 1 to 4 m/s and stable to neutral stabilities. These are higher wind speeds than would occur for a surface release with a constant emission rate, where very low wind speed, class F conditions typically lead to highest concentrations offsite as they result in the lowest amount of dilution and dispersion of the plumes. For emissions which are wind speed dependent, the increase in emissions with wind speed partially counteracts the increase in dilution and dispersion. That the lower incidence of stable class F conditions in the TAPM derived winds compared to the observed winds is not the reason for the lack of higher concentrations from these conditions can be seen in the good comparison with the model predictions using the observed wind data.

Concentration isopleths for the compounds modeled including ground level concentrations at nominated residential receptors are detailed in the Air Assessment Report. A summary of the relative change in ground level concentrations from the base to expansion scenario is presented in Table 14.

Table 14 Relative Changes in Concentrations from Base to Expansion Scenario



Substance	Receptor Number																Ratio of Highest in Expansion to Base Case
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
PM_{10}	1.28	1.45	1.42	1.29	1.40	1.43	1.11	1.60	1.73	1.49	1.56	1.54	1.42	1.60	1.61	1.60	1.13
Arsenic	1.18	1.33	1.32	1.17	1.30	1.31	1.08	1.58	1.68	1.36	1.40	1.45	1.31	1.47	1.48	1.46	1.08
Selenium	1.28	1.45	1.42	1.29	1.40	1.43	1.11	1.60	1.73	1.49	1.56	1.54	1.42	1.60	1.61	1.60	1.13
Manganese	1.22	1.38	1.36	1.22	1.34	1.36	1.09	1.59	1.70	1.42	1.48	1.49	1.36	1.54	1.54	1.53	1.09
Cadmium	1.28	1.45	1.42	1.29	1.40	1.43	1.11	1.60	1.73	1.49	1.56	1.54	1.42	1.60	1.61	1.60	1.13
Nickel	1.28	1.45	1.42	1.29	1.40	1.43	1.11	1.60	1.73	1.49	1.56	1.54	1.42	1.60	1.61	1.60	1.13
Mercury	0.07	0.09	0.08	0.08	0.06	0.09	0.05	0.06	0.07	0.11	0.14	0.09	0.11	0.14	0.14	0.12	0.12
Benzo(a)pyrene (BaP)	1.36	1.37	1.36	1.36	1.36	1.36	1.32	1.33	1.32	1.33	1.33	1.33	1.34	1.35	1.34	1.33	1.33
Acetone	1.08	1.06	1.06	1.04	1.07	1.06	1.01	1.00	1.12	1.10	1.12	1.08	1.09	1.12	1.09	1.17	1.17
Acetaldehyde	1.07	1.06	1.06	1.03	1.07	1.06	1.03	1.02	1.13	1.10	1.12	1.08	1.09	1.12	1.09	1.17	1.17
Formaldehyde	1.60	1.54	1.55	1.59	1.57	1.53	1.57	1.58	1.60	1.47	1.41	1.51	1.49	1.43	1.39	1.47	1.47
2-Butanone	1.08	1.07	1.06	1.04	1.08	1.07	1.01	0.99	1.12	1.11	1.14	1.09	1.10	1.13	1.11	1.19	1.19
Benzene	1.26	1.26	1.26	1.24	1.26	1.27	1.29	1.30	1.32	1.29	1.29	1.28	1.30	1.30	1.29	1.33	1.33
Toluene	1.14	1.13	1.14	1.12	1.14	1.13	1.13	1.15	1.19	1.16	1.17	1.16	1.16	1.17	1.16	1.21	1.21
Xylene	1.40	1.41	1.40	1.40	1.40	1.40	1.37	1.38	1.36	1.37	1.37	1.38	1.38	1.39	1.39	1.38	1.38

In summary, the predicted ground level concentration results of the base and expansion scenarios indicate that emissions for the expanded scenario will:

1. At the receptor with the highest 1 hour (99.9 percentile) and 24-hour (99.5 percentile) PM10 and metal concentrations (receptor 7) concentrations will decrease. This is due to the predicted better control of dust at residue area with this being the largest source of dust at this monitor. At other locations with lower concentrations, the concentrations is predicted to increase, particularly for those closer to the bauxite stockpiles with the concentrations predicted to increase by between 1.6 to 1.8 times at receptor 16. This increase at receptor 16 is due to the predicted increase in dust emissions from the bauxite stockpiles. This predicted increase however, is considered to be overstated due to conservative assumptions used. This primarily being that a new emergency stockpile and associated new area will result in an increase of 33 % (Table 5.4) from wind erosion. This is thought to be overstated as the emergency stockpile should form a crust and be less erodible than the active stockpiles;
2. Annual average metal concentrations are predicted to increase by between 8 and 13% at receptor 7 (the receptor in the base case with highest concentrations), with an increase of between 46 to 60% for receptor 16 (which now becomes the receptor for highest concentrations of 3 of the 5 modelled metals);
3. Mercury concentrations are predicted to substantially decrease with concentrations 4 to 20% of the existing concentrations; and
4. VOC concentrations are predicted to generally increase with a few exceptions for one or two receptors. In general the concentrations are predicted to increase between 11% for acetone and acetaldehyde to 57% for formaldehyde; and
5. The above comparison it is noted is only for the fugitive are source emissions and should be placed in the context that they may only be a small fraction of the total concentrations from the refinery and/or a small percentage of any health based criteria.

A large number of model validation studies have been undertaken by Air Assessments for Dust, VOC and odour emissions and are detailed in the Air Assessment Report (Appendix D).

5.4 SUMMARY OF CUMULATIVE EMISSIONS

A summary of the predicted cumulative ground level concentrations at two nominated receptors, Hamel Town and Yarloop for both the base and expansion scenarios and their comparison against nominated ambient guidelines are presented in Table 15 to Table 17. The results indicate that the maximum predicted ground level concentrations at these two residential receptor locations are below nominated guideline values for both the base and expansion scenarios. Concentration isopleths for a select number of compounds are presented in Figure 16 to Figure 20.

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Table 15 Maximum Predicted Ground Level Concentrations – Hamel Town (Receptor 10)

Pollutant	Averaging Period	Maximum Predicted Concentration (µg/m^3)			Ambient Guideline (µg/m^3)
		Base case	Expansion (cogen)	Expansion (boilers)	
Nitrogen dioxide	1-hour	35	29	30	246
	Annual	0.24	0.33	0.27	62
Carbon monoxide	8-hour	16	20	20	11,250
Sulphur dioxide	1-hour	4.1	4.2	4.8	571
	24-hour	1.1	1.2	1.3	228
	annual	0.02	0.03	0.03	57
Particulates (as PM_{10})	24-hour	5.3	5.8	5.8	50
Benzene	annual	0.0010	0.0009	0.0010	60
Formaldehyde	24-hour	0.119	0.072	0.072	11
Toluene	24-hour	0.062	0.011	0.011	411
Xylenes	24-hour	0.011	0.002	0.002	946

Table 16 Maximum Predicted Ground Level Concentrations – Yarloop (Receptor 4)

Pollutant	Averaging Period	Maximum Predicted Concentration (µg/m^3)			Ambient Guideline (µg/m^3)
		Base case	Expansion (cogen)	Expansion (boilers)	
Nitrogen dioxide	1-hour	42	40	44	246
	Annual	0.25	0.28	0.26	62
Carbon monoxide	8-hour	15	20	20	11,250
Sulphur dioxide	1-hour	6.3	6.5	7.7	571
	24-hour	1.1	1.3	1.4	228
	annual	0.02	0.03	0.03	57
Particulates (as PM_{10})	24-hour	4.4	4.3	4.3	50
Benzene	annual	0.0009	0.0010	0.0011	60
Formaldehyde	24-hour	0.114	0.065	0.065	11
Toluene	24-hour	0.105	0.011	0.011	411
Xylenes	24-hour	0.014	0.001	0.001	946

Table 17 Maximum Concentrations within the Modelled Domain

Pollutant	Averaging Period	Maximum Predicted Concentration (µg/m^3)		Upgrade - Case 6 (Cogeneration)	
		Base case	Expansion (cogen)	Receptor Exhibiting Highest Predicted Impacts	Percentage of Guideline (%)
Nitrogen dioxide	1-hour	51	52	34	21.2%
	Annual	0.57	0.63	34	1.0%
Carbon monoxide	8-hour	31	39	16	0.3%
Sulphur dioxide	1-hour	11.2	14.1	34	2.5%
	24-hour	2.1	2.7	16	1.2%
	annual	0.04	0.07	16,34	0.1%
Particulates (as PM_{10})	24-hour	35.0	32.7	22	65.4%
Benzene	annual	0.0029	0.0034	16	0.01%
Formaldehyde	24-hour	0.476	0.144	25	1.3%
Toluene	24-hour	0.311	0.040	34	0.01%
Xylenes	24-hour	0.051	0.006	25	0.001%

Figure 16 TSP, Peak (99.5) 24-Hour Average Maximum Concentration for Base and Expansion Scenario

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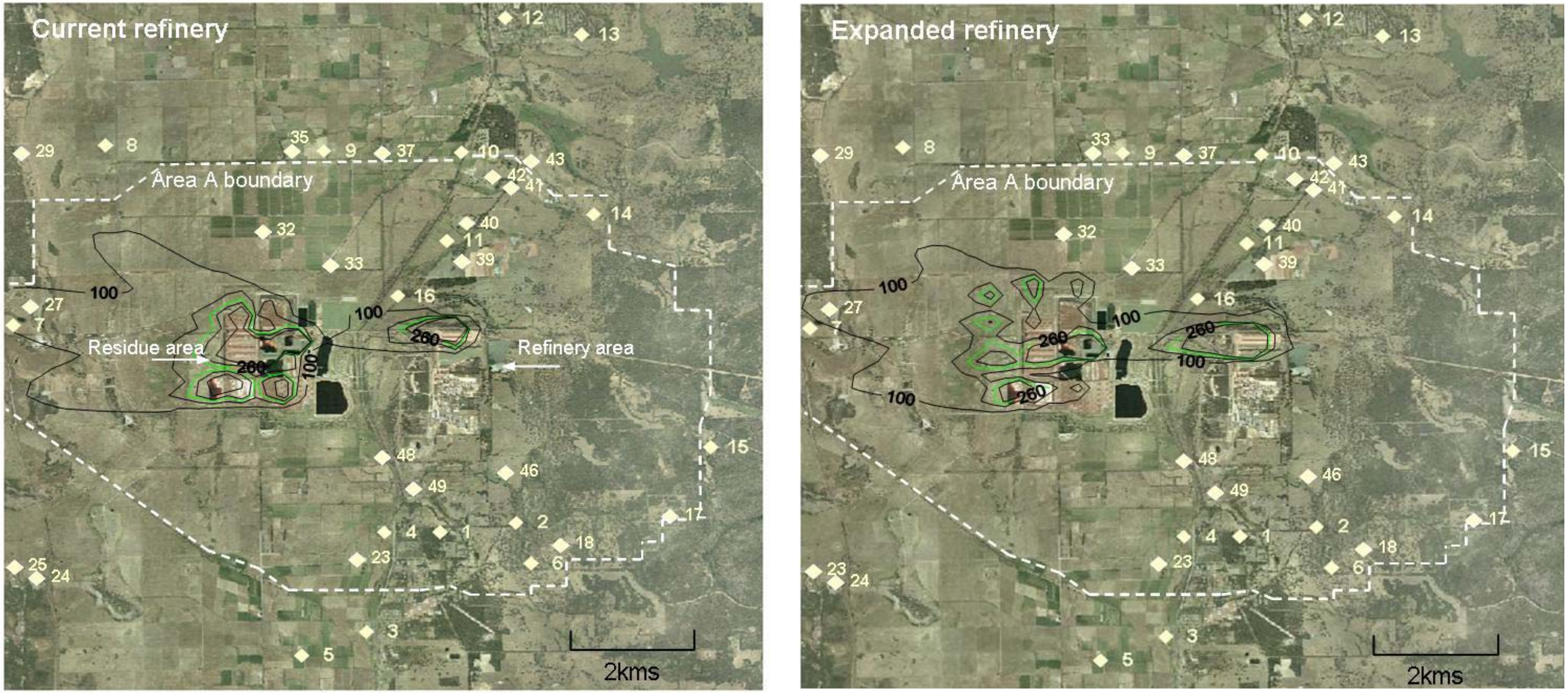
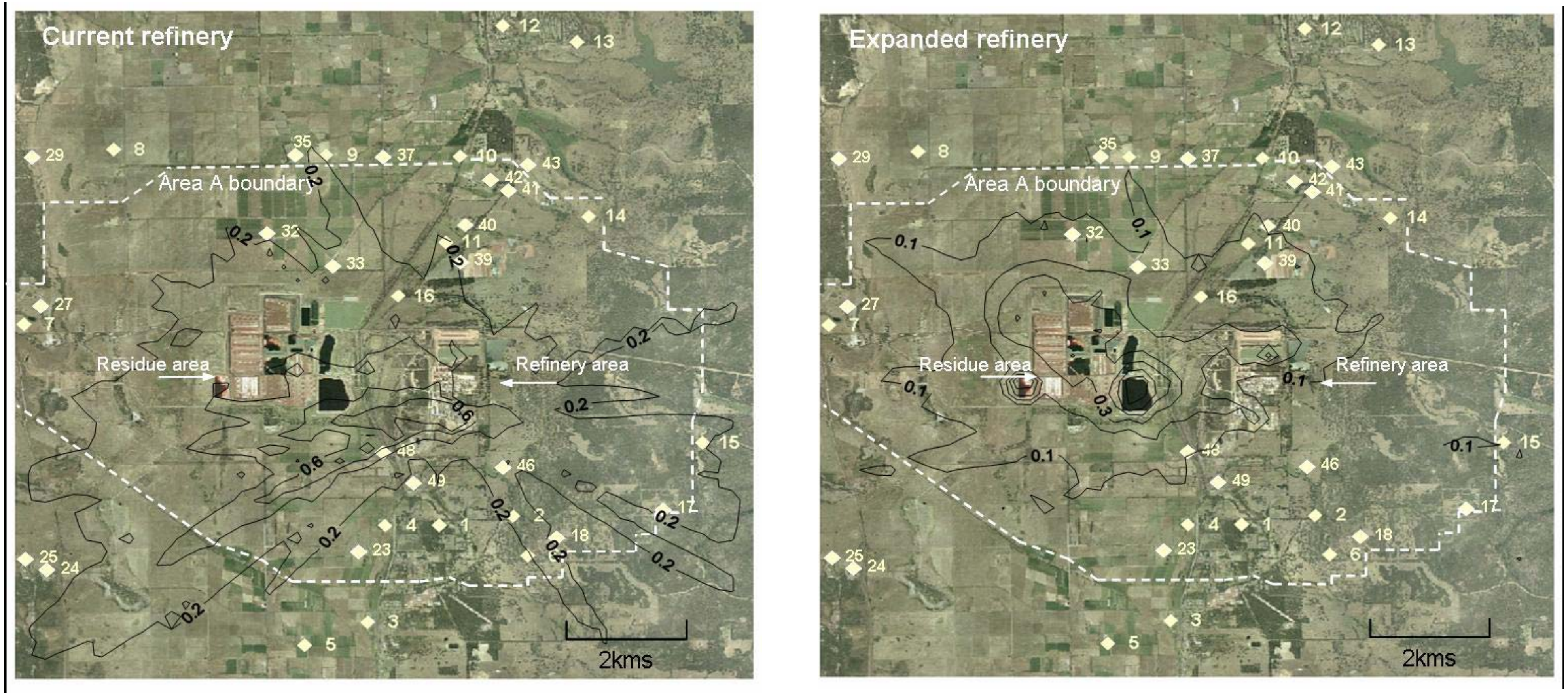


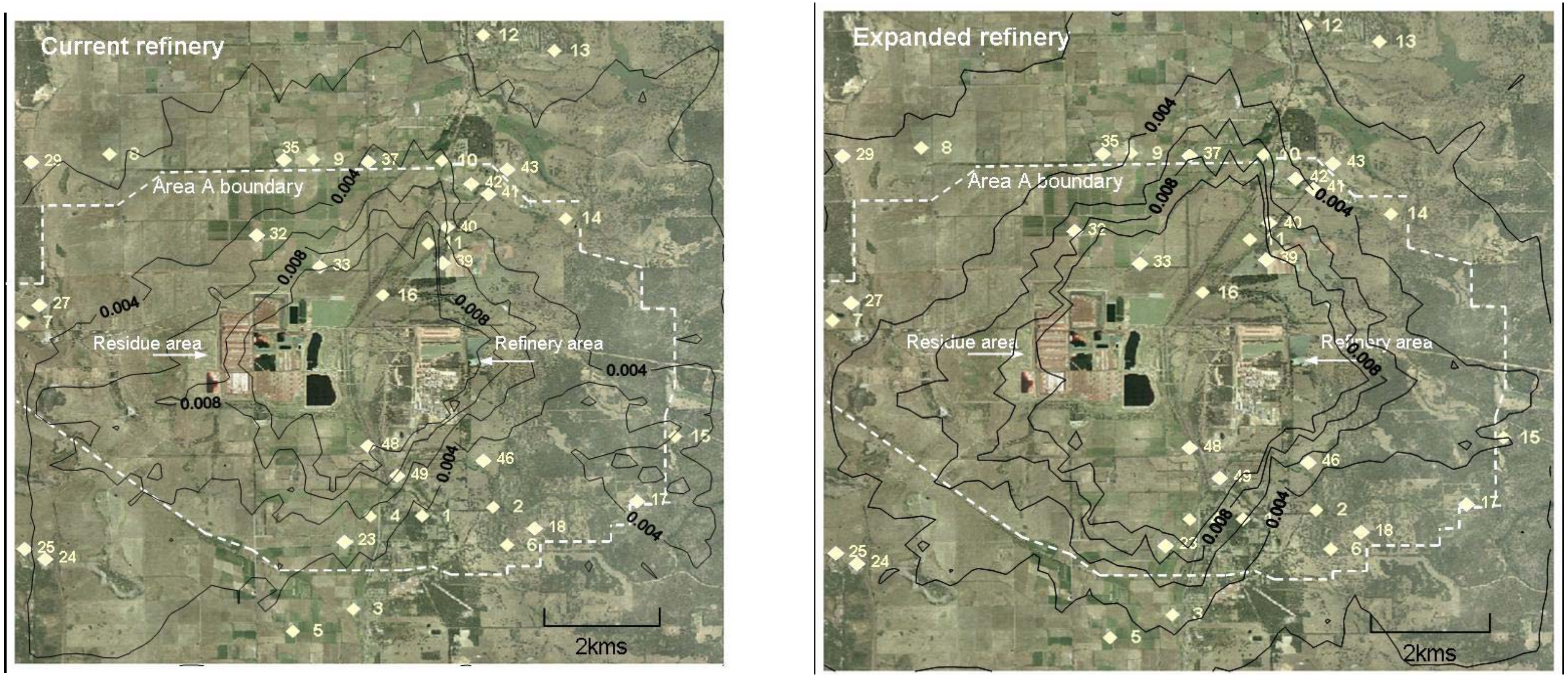
Kwinana EPP Area B limit for TSP is 260 µg/m^3 (Green line)

Figure 17 Formaldehyde, Peak (99.5) 24-Hour Average Maximum Concentration for Base and Expansion Scenario



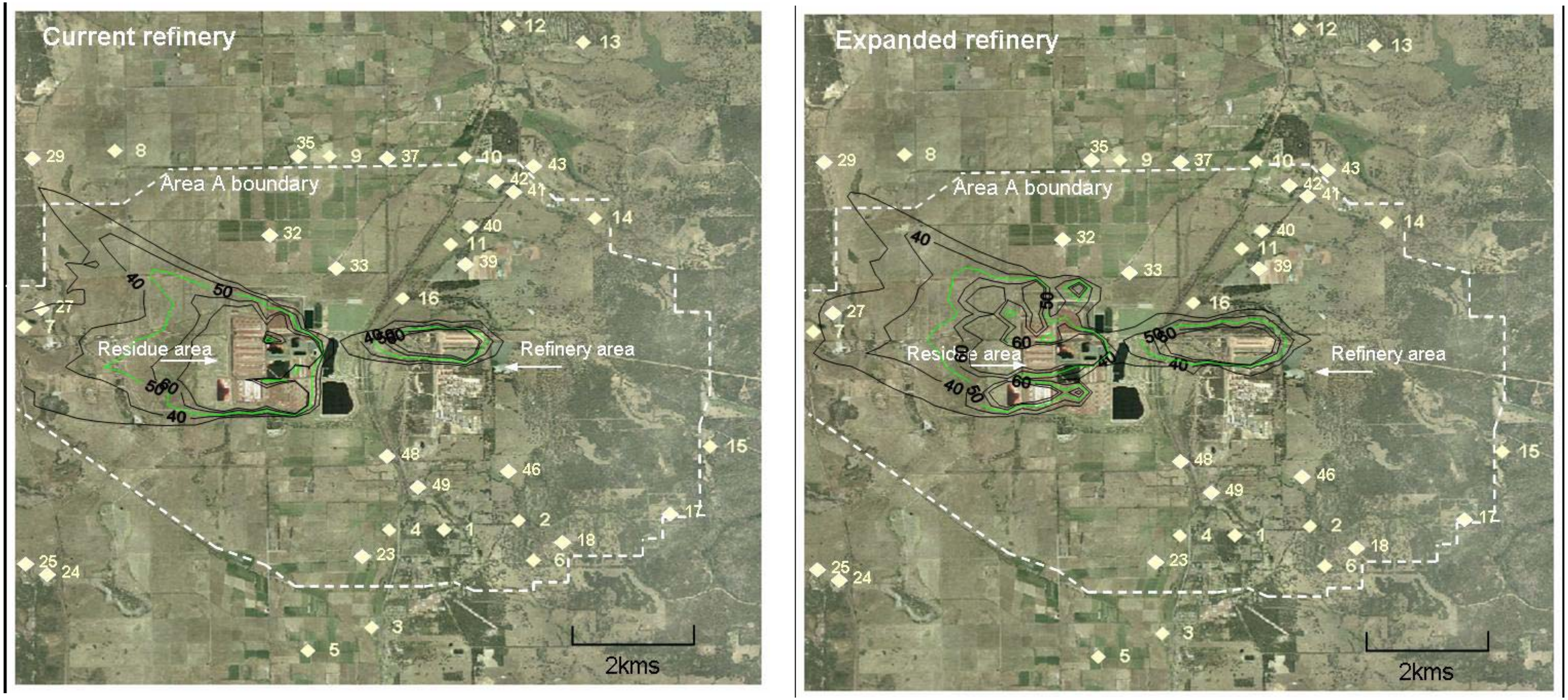
Environmental Protection Measure (NEPM) 24-hour guideline for formaldehyde is 54 µg/m^3

Figure 18 Mercury, Peak (99.5) 1-Hour Average Maximum Concentration for Base and Expansion Scenario



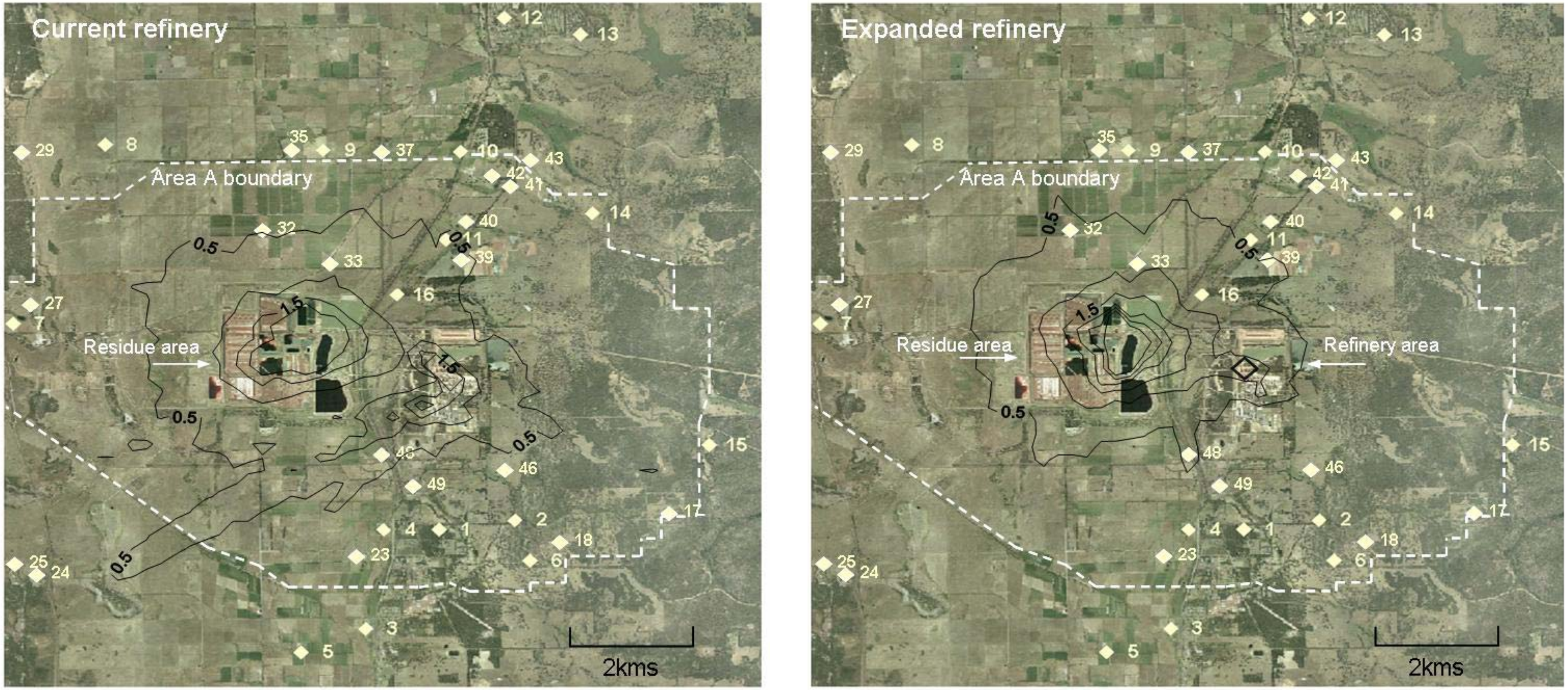
OEHHA 1-hour guideline for mercury is 1.8 µg/m^3

Figure 19 PM$_{10}$, Peak (99.5) 24-Hour Average Maximum Concentration for Base and Expansion Scenario



Environmental Protection Measure (NEPM) 24-hour PM10 standard is 50 µg/m3 (Green line)

Figure 20 Acetaldehyde, Peak (99.5) 24-Hour Average Maximum Concentration for Base and Expansion Scenario



WHO 24-hour for acetaldehyde is 2000 µg/m³

The results of the concentration isopleths presented in Figure 16 to Figure 20 indicate that,

1. The TSP maximum 24-hour concentration isopleths are below the Kwinana EPP guideline value of 260 µg/m^3 at all receptor locations for both the base and expanded refinery scenario, with predicted concentrations at this limit (as indicated by the green line) within the facility boundary;

2. The peak 24-hour formaldehyde concentration isopleths for both the base and expanded refinery scenario are well below (1.3% of the NEPM) the NEPM guideline value of 54 µg/m^3 at all receptor locations with the maximum concentration in the modelled domain of 0.47 µg/m^3 (base) and 0.114 µg/m^3 (expansion) respectively. The results also indicate a decrease in the formaldehyde concentration as a result of the proposed expansion.

3. The 1-hour mercury concentration isopleths for the base and expanded refinery scenarios are well below the OEHHA mercury guideline value of 1.8 µg/m^3 with a reduction in overall mercury concentrations within the modelled domain predicted to occur as part of the Wagerup 3 project.

4. The PM$_{10}$ concentration isopleths for the base and expanded refinery are below the NEPM guideline value of 50 µg/m^3 with a marginal difference between the base and expanded refinery scenario. The maximum predicted concentration in the modelled domain is predicted to be 65.7% (Case-6) of the NEPM guideline.

5. The acetaldehyde concentration isopleths for the base and expanded refinery are well below the WHO guideline value of 2000 µg/m^3, with the results well below the guideline value in the modelled domain.

The implications of the predicted cumulative ground level concentration of the expanded refinery are assessed in detail in the QHRA(ENVIRON 2005) a summary of which is presented in Section 6.0.

6. HEALTH RISK ASSESSMENT

6.1 BACKGROUND

A Health Risk Assessment (HRA) of the atmospheric emissions from Alcoa's Wagerup refinery has been undertaken to investigate the potential health risks arising from the emissions. The HRA considered the potential health risks associated with a baseline and an expanded refinery emissions scenario, defined as follows:

1. Baseline emissions scenario representative of emissions from the existing Wagerup refinery operating at an alumina production rate of 2.41 Mtpa; and
2. Expanded emissions scenario representative of emissions from an expanded Wagerup refinery operating at an alumina production rate of 4.7 Mtpa.

6.2 METHODOLOGY

6.2.1 Compound selection & Screening Process

The pollutants considered in the Quantitative Health Risk Assessment (QHRA) represent Alcoa's current best available knowledge of the nature of emissions released to air from the refinery. This knowledge has been gathered primarily from source emissions monitoring campaigns conducted at the refinery, supported by the findings of the comprehensive emissions monitoring program conducted for the *Wagerup Refinery Air Emissions Inventory* (Alcoa, 2002) program, and the air emission estimates reported to the NPI for the refinery.

The refinery emissions inventory program was a comprehensive program specifically designed to screen a wide range of compound classes to allow a broad understanding of the emissions composition. The findings from the study have therefore been used as the primary reference source to identify the classes of compounds expected to be present in emissions from the refinery. The subsequent emissions monitoring program conducted for the refinery was designed to target the key classes of compounds likely to be present in gaseous emissions.

The culmination of the findings from these studies, and the inclusion of the pollutants covered in the Ambient Air NEPM (NEPC, 1998) and the draft Ambient Air Toxics NEPM (NEPC, 2004) resulted in the development of the list of compounds considered in the QHRA.

A two step screening method was used to identify those compounds most likely to contribute to potential health risk, and therefore included in the suite of compounds to undergo air dispersion modelling.

The first stage of the compound screening identified the compounds that are estimated to be emitted in the largest quantities on an annual mass emission basis from the refinery. The second stage of the compound screening method used an approach endorsed by the USEPA, which involved using the ratio of the NPI emission estimate reported divided by the relevant acute (i.e. short-term) and chronic (i.e. long-term) health-based ambient air quality guidelines as an indicator of the relative significance of each of the pollutants. The ambient air quality guidelines used in the screening approach were the World Health Organisation (WHO), USEPA Integrated Risk Information System (IRIS), and the Californian Office of Environmental Health Hazard Assessment (OEHHA) /Air Resources Board (ARB) guidelines, and the pollutants considered were all those reported to the NPI for the refinery. A detailed description of the screening methodology is presented in Appendix H.

Based on the comprehensive list of methods detailed above, a concise list of compounds was determined based on their contribution to the total refinery emissions and their potential to contribute to health risk. A list of compounds initially considered for the screening method with those compounds chosen based on their contribution to potential health risk and to overall emissions are presented in the compound selection report and the QHRA report [ENVIRON 2005].

6.2.2 HRA

The HRA has been confined to the inhalation pathway as this is expected to represent the most significant exposure route to the Wagerup refinery's emissions. It did not take into account alternative exposure pathways (e.g. ingestion, dermal absorption), nor other sources of atmospheric emissions of these compounds. Of the pollutants considered in this HRA, only cadmium (chronic non-carcinogenic HI) and arsenic (incremental carcinogenic risk) were assessed as requiring further assessment based on the results of the HARP developed by Californian environmental agencies. This subsequent assessment indicated that non inhalation exposure pathways for these substances did not result in any unacceptable impacts.

The following quantitative health risk indicators were calculated across the model domain and for key receptors located in the vicinity of the Wagerup refinery:

- acute HI;
- chronic HI; and

- ICR.

ENVIRON was provided with ground level concentrations predicted from air dispersion modelling for a number of compounds present in the atmospheric emissions from the Wagerup refinery for both the baseline and expanded emissions scenarios. The air dispersion modelling included both the refinery and RDA emissions and was completed by the CSIRO (Refinery) and Air Assessments (RDA) with the modelling results integrated by ENVIRON.

The potential health effects arising from the predicted short-term (acute; 1-hour and 24-hour averages) and long-term (chronic; annual averaged) exposure to non-carcinogenic compounds, and potential carcinogenic risks were considered in the HRA assessment by comparing the exposure concentrations predicted buy the modelling with health protective guidelines for ambient air developed by reputable authorities such as the National Environment Protection Council (NEPC), World Health Organisation (WHO) and the U.S Environmental Protection Agency (USEPA).

The acute and chronic Hazard Indices (HI) were calculated to evaluate the potential for non-carcinogenic adverse health effects from simultaneous exposure to multiple compounds by summing the ratio of the predicted concentration in air to the health protective guidelines for individual compounds. A HI of less than one is generally considered to represent no cause for concern with respect to adverse health effects.

To assess the potential health effects associated with exposure to carcinogens, the incremental carcinogenic risk (ICR) was calculated to provide an indication of the incremental probability that an individual will develop cancer over a lifetime as a direct result of exposure to potential carcinogens. The incremental carcinogenic risk that is considered acceptable varies amongst jurisdictions, typically ranging from one in a million ($1x10^{-6}$) to one in ten thousand ($1x10^{-4}$). The most stringent criterion of one in a million represents the USEPA's *de minimis*, or essentially negligible incremental risk level, and has therefore been adopted for this screening assessment as a conservative (i.e. health protective) indicator of acceptable carcinogenic risk.

The acute and chronic HIs and the ICRs were calculated for each model grid point and these data were contoured to provide the calculated health risks across the entire model domain. The HIs and ICRs at 16 discrete receptor locations were then calculated from the contours. The discrete receptor locations were identified by Alcoa to represent populations or individual residences that could be potentially exposed. The HI and ICR contours can be used to estimate the potential health risks at other locations if required.

6.3 QHRA RESULTS SUMMARY

6.3.1 Acute Non-Carcinogenic Effects

Acute HIs have been calculated for the baseline and expanded Wagerup refinery emission scenarios and are presented as Figures 2a, 2b and 2c in Appendix H, for the base case and the two expansion scenarios calculated using the predicted 99.9th percentile 1-hour and 99.5th percentile 24-hour ground level concentrations. Figures 3a, 3b and 3c (Appendix H) present the Acute HIs for the base case and the two expansion scenarios calculated using the predicted 99.5th percentile 1-hour and 95th percentile 24-hour ground level concentrations. Figures 4a and 4b (Appendix H) present the percentage contribution that the predicted PM_{10} concentrations make to the overall acute HIs for the existing and expanded refinery emission scenarios (note that Expansion Case 6 and Case 7 have essentially the same predicted impacts arising from the PM_{10} emissions). These figures show the significance of the particulate emissions from the RDA and bauxite stockpile areas on the overall acute HIs, particularly in close proximity to these sources. The Acute HIs calculated for each of the receptor locations are presented in Table 18 along with the relative change associated with the Wagerup refinery expansion scenarios compared to the baseline. Receptors 7 and 16 are predicted to have the highest acute HI with receptors 12 and 13 predicted to have the lowest.

Table 18 Summary of Acute Hazard Indices

Acute HI					
		Expansion Case 6		Expansion Case 7	
Receptor No	Base Case HI	HI	Change from Base Case (%)	HI	Change from Base Case (%)
Based on the 99.9th Percentile 1-Hour and 99.5th Percentile 24-hr Predicted Ground Level Concentrations					
1	0.3248	0.2917	-10.2%	0.3059	-5.8%
2	0.3861	0.3314	-14.2%	0.3433	-11.1%
3	0.3155	0.3167	0.4%	0.3326	5.4%
4	0.4028	0.3974	-1.3%	0.4131	2.6%
5	0.3001	0.2948	-1.8%	0.3133	4.4%
6	0.3375	0.3118	-7.6%	0.3240	-4.0%
7	0.8997	0.8128	-9.7%	0.8049	-10.5%
8	0.2759	0.3121	13.1%	0.3141	13.9%
9	0.3045	0.3038	-0.3%	0.3137	3.0%
10	0.3582	0.3709	3.5%	0.3749	4.6%
11	0.4385	0.4902	11.8%	0.4928	12.4%
12	0.1757	0.2004	14.0%	0.2038	16.0%
13	0.1793	0.2077	15.8%	0.2044	14.0%
14	0.3648	0.4188	14.8%	0.4287	17.5%
15	0.4703	0.4439	-5.6%	0.4653	-1.1%
16	0.5060	0.5959	17.8%	0.6139	21.3%
Based on the 99.5th Percentile 1-Hour and 95th Percentile 24-hr Predicted Ground Level Concentrations					
1	0.1894	0.1938	2.3%	0.1980	4.5%
2	0.2112	0.1938	-8.3%	0.2020	-4.4%
3	0.1615	0.1583	-2.0%	0.1628	0.8%
4	0.2103	0.2122	0.9%	0.2140	1.7%
5	0.1568	0.1527	-2.7%	0.1571	0.2%
6	0.1869	0.1808	-3.3%	0.1901	1.7%
7	0.3264	0.3422	4.8%	0.3413	4.6%
8	0.1413	0.1532	8.4%	0.1523	7.7%
9	0.1831	0.2092	14.2%	0.2082	13.7%
10	0.1806	0.2186	21.1%	0.2146	18.9%
11	0.2675	0.3246	21.3%	0.3235	20.9%
12	0.0831	0.1019	22.6%	0.0998	20.1%
13	0.1050	0.1205	14.8%	0.1206	14.9%
14	0.2264	0.2470	9.1%	0.2517	11.2%
15	0.2789	0.2780	-0.3%	0.2867	2.8%

16	0.3252	0.3981	22.4%	0.4009	23.3%

Note:

1. The 99.9th percentile 1-hour average concentration is derived from the 9th highest 1-hour average predicted ground level concentration. The 99.5th percentile 24-hour average concentration is derived from the 2nd highest 24-hour average predicted ground level concentration.
2. The 99.5th percentile 1-hour average concentration is derived from the 44th highest 1-hour average predicted ground level concentration. The 95th percentile 24-hour average concentration is derived from the 18th highest 24-hour average predicted ground level concentration.
3. The Expansion Case 6 emission scenario includes cogeneration units while the Expansion Case 7 emission scenario includes additional boilers.

The maximum acute HIs for the baseline and the two expansion emission scenarios presented in Table 18 are less than one, indicating no cause for concern based on the predicted ground level concentrations, the health protective guidelines used and the compounds considered. The maximum acute HI for either of the expanded Wagerup refinery emission scenarios is predicted to occur at Receptor 7 and is approximately 80% of the acceptable threshold of one. The acute HI at Receptor 7 is strongly influenced by the particulate emissions from the RDA and proposed improvements to the dust management measures employed at the RDA are predicted to result in a decrease in the acute HI calculated at this receptor based on the 99.9th percentile 1-hour average concentration and the 99.5th percentile 24-hour average ground level concentrations predicted by the modelling.

Table 18 shows that the expansion scenarios are predicted to result in both decreases and some increases in the acute HI's depending upon their location. Receptors to the southwest of the refinery are predicted to experience a decrease in the acute HIs, primarily due to the proposed development of the RDA from the northeast of the existing facility. The expansion of the RDA is also predicted to contribute to the predicted increase in the acute HI at receptor 8, although the maximum acute HI presented in Table 7 for this location is less than one third of the acceptable threshold of one.

The data presented in Table 18 also indicates that Expansion Case 6 scenario is generally expected to result in the prediction of lower HIs than the Expansion Case 7 scenario as a result of the enhanced dispersion of the emissions from the cogeneration units (Expansion Case 6) compared to the boilers (Expansion Case 7) although neither scenario results in acute HIs above the acceptable threshold of one.

6.3.2 Chronic Non-Carcinogenic Effects

Chronic HIs have been calculated for the baseline and expanded Wagerup refinery emission scenarios and are presented in Table 8. The maximum chronic HI is predicted to occur at Receptor 16 and that this (maximum of 0.047 for the Expansion Case 6 scenario) is well below the acceptable threshold of one, indicating no cause for concern.

Table 19 also indicates that the expansion of the Wagerup refinery is generally predicted to result in increases in the chronic HI's and although the percentage increases are relatively large (up to 38.7%) the absolute magnitude of these changes is low being less than 0.01, or one hundredth of the acceptable threshold of one.

Table 19 Summary of Chronic Hazard Indices

	Chronic HI				
		Expansion Case 6		Expansion Case 7	
Receptor No	Base Case HI	HI	Change from Base Case (%)	HI	Change from Base Case (%)
1	0.01394	0.01422	2.1%	0.01495	7.3%
2	0.01442	0.01366	-5.3%	0.01369	-5.1%
3	0.00986	0.01050	6.4%	0.01050	6.4%
4	0.01408	0.01599	13.6%	0.01599	13.5%
5	0.00902	0.00969	7.4%	0.00969	7.4%
6	0.01268	0.01172	-7.6%	0.01212	-4.4%
7	0.01169	0.01215	3.9%	0.01136	-2.8%
8	0.00876	0.01005	14.7%	0.00996	13.7%
9	0.01513	0.01723	13.9%	0.01703	12.6%
10	0.01300	0.01802	38.7%	0.01702	31.0%
11	0.02315	0.03135	35.4%	0.03034	31.1%
12	0.00611	0.00811	32.8%	0.00797	30.5%
13	0.00699	0.00900	28.7%	0.00846	21.0%
14	0.01735	0.01995	15.0%	0.01946	12.2%
15	0.01879	0.01704	-9.3%	0.01767	-5.9%
16	0.03751	0.04729	26.1%	0.04717	25.7%

6.3.3 Carcinogenic Effects

The incremental carcinogenic risk (ICR) has been calculated for the baseline and expanded Wagerup refinery emission scenarios and the results are presented in Table 20. The highest incremental carcinogenic risks are predicted to occur in the immediate vicinity of the refinery and the RDA. Receptor 16, located near the refinery and the RDA, is predicted to experience the highest ICR with the maximum of 0.632 x 10^{-6} predicted for the Expansion Case 7 scenario which is below the USEPA's *de minimis* threshold of one in a million (i.e. 1 x 10^{-6}). Arsenic emissions from the refinery are predicted to be one of the major contributors to the calculated ICR and the increase in the ICRs predicted for the expansion scenarios.

Table 20 Summary of Incremental Carcinogenic Risk

	Incremental Carcinogenic Risk (ICR)				
		Expansion Case 6		Expansion Case 7	
Receptor No	**Base Case ICR**	**ICR**	**Change from Base Case (%)**	**ICR**	**Change from Base Case (%)**
1	9.16E-08	1.28E-07	40.2%	1.79E-07	95.9%
2	7.41E-08	9.85E-08	32.9%	1.58E-07	113.2%
3	6.37E-08	8.76E-08	37.5%	1.26E-07	98.2%
4	1.04E-07	1.43E-07	38.1%	1.92E-07	84.7%
5	5.27E-08	7.85E-08	49.0%	1.16E-07	120.2%
6	6.05E-08	8.51E-08	40.6%	1.48E-07	144.3%
7	1.21E-07	1.63E-07	34.4%	1.97E-07	62.7%
8	6.22E-08	9.43E-08	51.5%	1.26E-07	102.0%
9	1.11E-07	1.63E-07	46.8%	2.16E-07	94.8%
10	1.05E-07	1.51E-07	43.8%	2.05E-07	94.5%
11	2.06E-07	3E-07	45.4%	3.81E-07	84.9%
12	4.67E-08	6.74E-08	44.1%	9.15E-08	95.8%
13	4.44E-08	6.27E-08	41.1%	9.33E-08	110.2%
14	9.26E-08	1.38E-07	48.6%	2.21E-07	139.2%
15	7.66E-08	1.08E-07	41.6%	1.99E-07	160.1%
16	3.68E-07	5.29E-07	43.5%	6.32E-07	71.8%

The expression of the incremental carcinogenic risk values presented in Table 20 are best explained by way of example, with the incremental carcinogenic risk calculated for Receptor 16 for the baseline emissions scenario of 3.68x10^{-7} (0.000000368) which can also be interpreted as a risk of 1 in 2,717,391.

An increase in the incremental carcinogenic risk compared to the baseline incremental carcinogenic risk is predicted to result form the Wagerup refinery expansion at all receptor locations, with an increase in the incremental carcinogenic risk ranging from approximately 33% (Receptor 2, Expansion Case 6) to 160% (Receptor 15, Expansion Case 7). However, while the predicted percentage increases in the ICRs is significant, the absolute maximum increase at any of the receptors is 0.26 x 10^{-6} at Receptor 16, the closest receptor to the refinery and the RDA.

The data presented in Table 20 also indicates that the increases in the predicted ICR for the Expansion Case 6 scenario are considerably less than those predicted for the Expansion Case 7 scenario. This is primarily due to the increase in the arsenic emissions estimated to occur from the new boilers (boilers 4 & 5) whereas the proposed cogeneration units are not predicted to have any arsenic emissions.

For this HRA, uniformly conservative assumptions have been used to ensure that potential exposures and associated health risks are over- rather than under-estimated. As a result of the compounding of conservatism, the quantitative risk indicators are considered to be upper-bound estimates, with the actual risk likely to be lower.

6.4 HRA RESULTS SUMMARY AND CONCLUSION

ENVIRON has conducted a HRA of the potential health risks arising from atmospheric emissions emitted from the Wagerup refinery, considering the potential risks associated with a baseline (i.e. representative of emissions from the existing refinery operating at an alumina production rate of 2.41 Mtpa) and expanded (i.e. representative of emissions from an expanded refinery operating at an alumina production rate of 4.7 Mtpa) emissions scenarios.

Quantitative health risk indicators were calculated for exposure via the inhalation pathway to atmospheric emissions from the Wagerup refinery in isolation, and therefore did not take into account the alternative exposure pathways (e.g. ingestion, dermal absorption), nor other sources of atmospheric emissions of these compounds. Of the pollutants considered in this HRA, only cadmium (chronic non-carcinogenic HI) and arsenic (incremental carcinogenic risk) were assessed as requiring further assessment based on the results of the HARP developed by Californian environmental agencies. This subsequent assessment indicated that non inhalation exposure pathways for these substances did not result in any unacceptable impacts.

Based upon the results of the health screening assessment it can be concluded that:

- the potential for emissions from the existing or expanded Wagerup refinery to cause acute health effects is low and is primarily driven by the particulate emissions from the RDA and oxides of nitrogen emissions from the refinery;

- the potential for emissions from the existing or expanded Wagerup refinery to cause chronic non-carcinogenic health effects is very low; and

- the potential for emissions from the existing or expanded Wagerup refinery to contribute to the incidence of cancer based on inhalation exposure is below USEPA *de minimis* threshold of one in a million (i.e. 1×10^{-6}) at all of the residential receptors considered;

As with any risk evaluation, there are areas of uncertainty in this assessment. To ensure that potential risks are not underestimated, uniformly conservative assumptions have been used to characterize exposure and toxicity. Due to the resultant compounding of conservatism, the quantitative risk indicators should be considered as over-estimates of potential health risks associated with emissions from the Wagerup refinery.

7. SHORT TERM IMPACTS – A SUMMARY

Ground level concentrations (GLC) for 27 individual compounds or groups of compounds were estimated using air dispersion modelling based on known or estimated emissions for alumina refinery for current operation and the proposed expansion at Wagerup . The compounds modelled were selected on the basis of their hazardous characteristics and the estimated quantities in the emissions. GLC concentrations were modelled for different averaging times of 1-h, 24-h and 12 months (annual). In addition, shorter averaging times were calculated for 3-min and 10-min averages (CSIRO, 2005)1.

Broadly speaking, chemicals can have two types of effects, acute or chronic. Acute effects generally occur within a short time of coming in contact with relatively high levels of a substance. They can range from simple, mild irritation of mucous membranes, eyes or skin to serious organ damage and death at sufficiently high concentrations. At elevated concentrations that might be found in ambient air, chemicals are likely to have only minor acute effects. With spillage accidents or occupational exposure in the unregulated workplace, acute effects can be more serious. The time of the effect will depend on the chemical properties as well as the dose, but can range from immediately coming in contact with the chemical, for irritants for example, to a several hours of contact with the chemical for a systemic poison. For example, it takes about 6-8 h for the concentration of carboxyhaemoglobin in the blood to reach a steady state on exposure to CO (Section 1.2.1).

Chronic effects tend to occur after continued exposure for some time and at lower doses or concentrations than acute effects.

To address these types of effects reference criteria are expressed in term of averaging periods: ≤ 24-h averaging periods for acute effects; > 24-h averaging period (usually annual averages) for chronic effects. Generally, the lowest averaging time used for reference values is 1 h. For some substances, such as strong irritants, duration of exposure is not the critical determinant for the effect to occur if the substance is present at concentrations above the threshold for the effect. Thus the effect may occur in the first few seconds or minutes of exposure and shorter averaging times such as 3 min averages and 10 min averages would be more appropriate to assess their potential risk.

Unfortunately guidelines or standards for short term averaging periods in this range are rarely established – a 10-min average concentration for sulfur dioxide is one of the few exceptions (see

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[1] CSIRO (2005). Meteorological and Dispersion Modelling Using TAPM for Wagerup Phase 3B: HRA (Health Risk Assessment) Concentration Modelling – Expanded Refinery Scenario *Prepared for* Alcoa World Alumina Australia *By* CSIRO Atmospheric Research Private Aspendale, Vic. Report C/0986 11 February 2005.

Section 1.2.4) – mainly because it may not be possible to measure substances over such short periods using current analytical techniques. Similarly, air dispersion models may not be able to estimate short term GLC for periods < 1 h.

The toxicological or epidemiological data may not be available for setting short-term reference values. Studies on irritants with human subjects in environmental chambers may be useful in extrapolating to short term averages, since concentrations can be controlled and maintained constant and the time the effects first occur can be noted by the subject or the experimenter.

In the absence of reference values for short-term averaging times, it is still possible to assess potential impacts over the shorter averaging periods, albeit in a limited way, by comparing with the reference values for 1-h or longer averaging period. If the estimated 3-min or 10-min average concentration are less that the reference value for the longer averaging time, then the substance is unlikely to pose a health risk. If on the other hand the short term average concentration exceeds the longer averaging period reference value, then the likelihood of adverse effects needs to be examined on a case by case basis.

A comparison of modelled maximum 3-min and 10-min GLC reported in table 9 by CSIRO (2005)2 with the reference values used in this risk assessment (Section 1.1.3) indicates that the short term averaging GLC are lower than the reference values for 1-h averages or annual averages (where no 1-h average was available). In most cases, the short term estimated GLC were lower that the reference values for annual averages.

These observations indicates that short peaks in the concentration of irritant substances in air are unlikely to be sufficiently high to cause adverse health effects at any of the sixteen receptor locations examined.

Further details on the short term health impacts are detailed in ENVIRON & Benchmark Toxicology Services (BTS) QHRA report (Appendix H).

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[2] CSIRO (2005). Meteorological and Dispersion Modelling Using TAPM for Wagerup Phase 3B: HRA (Health Risk Assessment) Concentration Modelling – Expanded Refinery Scenario *Prepared for* Alcoa World Alumina Australia *By* CSIRO Atmospheric Research Private Aspendale, Vic. Report C/0986 11 February 2005. pp

8. ODOUR EMISSION STUDY

8.1 BACKGROUND

Odour emissions from the refinery and diffuse sources such as the RDAs, Cooling Ponds, Super thickeners and ROWS have been assessed for both the base and proposed expanded refinery scenarios. Odour emission rates for the refinery was developed based on comprehensive emission monitoring program with subsequent development of an odour/VOC relationship, whereas odours from diffuse sources were developed based on intensive fuxhood sampling programmes with the emission rates validated with ambient and back trajectory modelling . The emissions are modeled using TAPM (refinery) and CALPUFF (diffuse sources) with the results combined to produce concentration isopleths within the modeled domain. The predicted ground level concentrations are subsequently assessed against nominated legislative criteria and ERMP commitments.

8.2 ASSESSMENT CRITERIA

In 2002, the Western Australia DoE released a guidance document on the assessment of odour impacts from new proposals. . This Guidance Statement provides criteria which will assist the EPA to determine whether odour impacts from, or on, a new proposal, are likely to be acceptable in terms of their impact on amenity for sensitive land uses. The guidance statement specifies odour criteria that should be met for a new proposal and this is detailed further in the DoE document, Assessment of Environmental Factors Western Australia (in accordance with the Environmental Protection Act 1986) No. 47 March 2002 Assessment of Odour Impacts from New Proposals. However for those facilities that are proposing to expand its existing premises such as detailed in this study, the DoE has alternative requirements as specified in the extract from the DoE guidance document:

"If an existing facility wishes to expand but does not itself comply with the odour criteria for new sources then the EPA would expect, as a minimum requirement, that predicted odour concentrations at sensitive land uses would not increase (i.e. there would be no deterioration of current amenity values). Alternatively if the odour emissions from the existing facility do comply with the odour criteria for new sources, the expansion should be carried out such that compliance with the criteria is maintained. As with new facilities, best practice emission control would be expected for the expansion program."

8.3 ODOUR EMISSION ESTIMATES

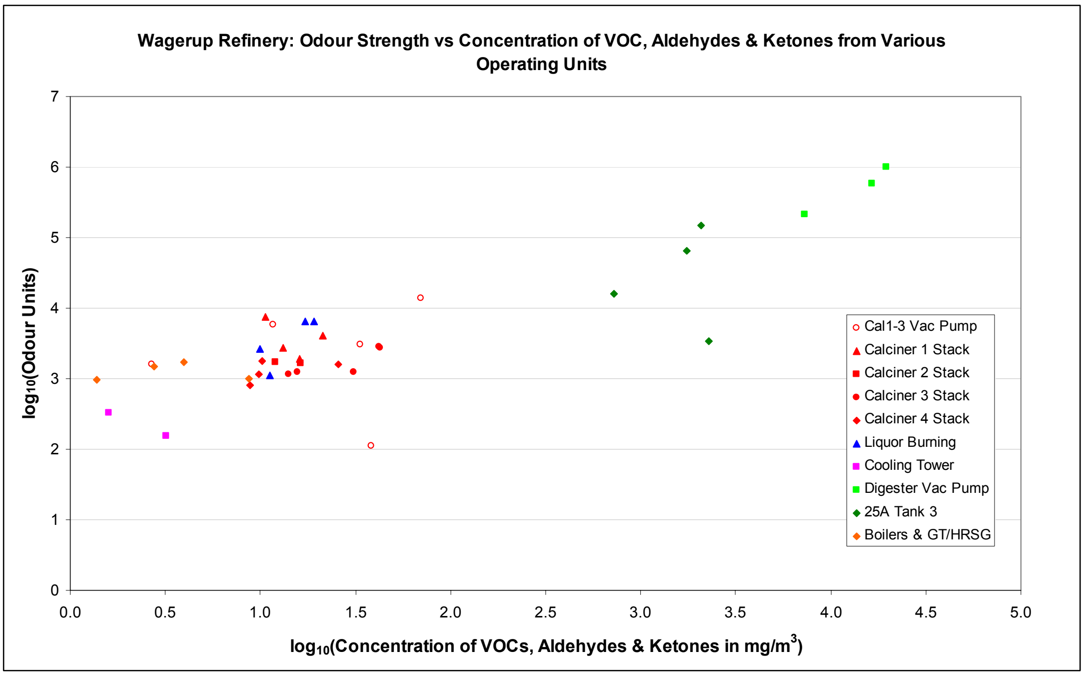
The determination of odour emission rates for point and diffuse sources are similar to that outlined in Section 3, with the exception that further validation and ground truthing was undertaken due to the inherent complexity of measuring and estimating odour emission rates. The point source odour emission rates were based on a odour /VOC regression relationship developed by Alcoa with diffuse source odour emission rates based on a comprehensive diffuse source odour monitoring program using fluxhoods.

8.3.1 Point Sources

Odour emission rates used in dispersion modelling of the baseline and expanded Wagerup Refinery were based on the development of an odour/VOC regression relationship. The development process undertaken during 2001, 2002, 2003 and 2004, sampled emitted gases from operating units at the Wagerup Refinery. Samples were analysed for Volatile Organic Compounds (VOCs), aldehydes and ketones and others were measured by olfactometry to produce Odour Unit (OU) measurements.

The measurements of OU were then plotted against concentrations of gases taken on the same day. The OU measurements ranged from 110 to 984,000 while total VOC, aldehyde and ketone concentration ranged from 1.38 to 19652 mg/m^3. The fact that both variables ranged over several orders of magnitude led to plotting of $\log_{10}$ values rather than raw data values as presented in Figure 21.

Figure 21 Odour strength vs Concentration of VOC Aldehydes and Ketones from Various Operation



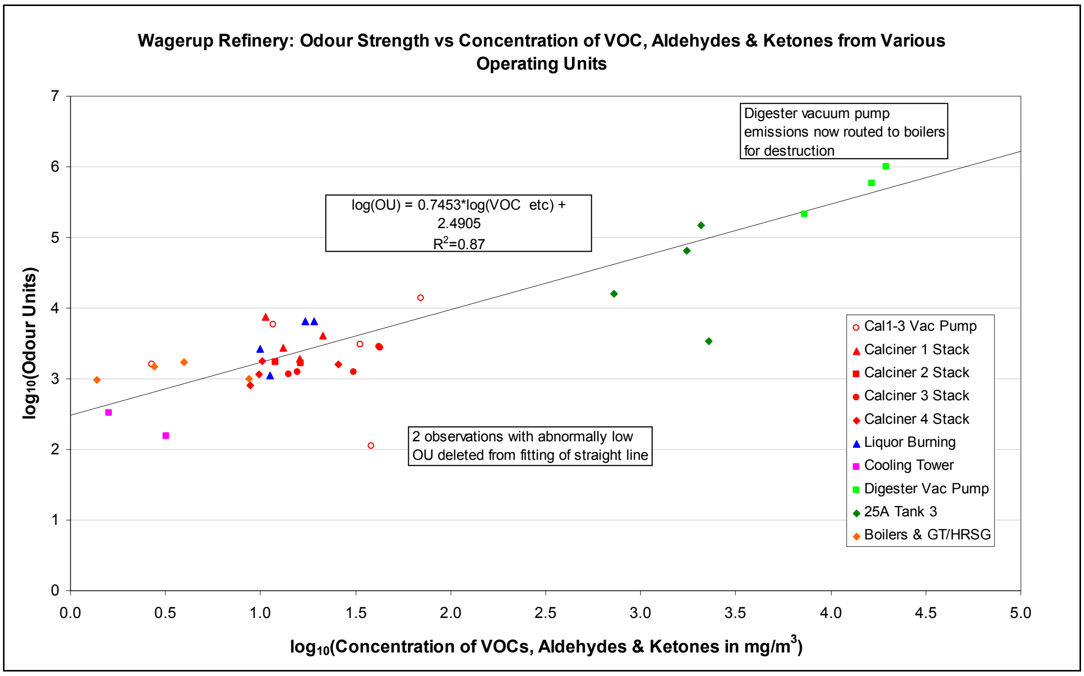
A line of best fit (excluding the one anomalous observation for each of the Calciner Vacuum Stack and 25A-3 tank) was produced by linear regression with the equation presented below.:

$$\log10(OU) = 0.7453 \times \log10(\text{Total VOC etc}) + 2.4905$$

with R2 = 0.87 and standard deviation of the residual equal to 0.32.

The subsequent fitted line is shown in Figure 22.

Figure 22 Odour strength vs Concentration of VOC Aldehydes and Ketones from Various Operation – Line of Best Fit



This equation is equivalent to:

$$OU = 309.4 \times (\text{Total VOC etc})^{0.7453}$$

and an error term that is multiplicative to Total VOC as a concentration.

The above equation indicates that given a nominated concentration of a gas, predictions, (subject to some uncertainty, as is inherent in any measurement of OU) of odour unit of the gas will be as measured by olfactometry.

This developed relationship was subsequently used for estimating the odour emission rates for the refinery from measured VOC data. This is described more fully in an Alcoa report by (Peterson, 2004, a copy of which is presented in Appendix A).

The use of a regression relationship improves the statistical validity of odour emission rates derived from VOC emission rates for the following reasons: -

1. Uncertainty for individual and collective odour concentration measurements is higher than that for individual and total VOC and carbonyl species measurements;
2. This is so because the accuracy and precision of chemical species measurement is greater than that for dynamic olfactometry;
3. In addition there have generally been many more VOC and carbonyl monitoring runs performed compared to odour monitoring, especially since late 2002 onwards;
4. This also increases the statistical significance and reduces the uncertainty of VOC and carbonyl monitoring results; and
5. By extension (through the regression relationship) use of a greater number of VOC monitoring results improves certainty and statistical significance of estimated odour emission rates.

Use of a regression relationship also enables prediction of odour concentrations for future emissions knowing what actions and reductions will be achieved in VOC emission rates.

For a number of sources the odour emission rates used in modelling the expanded refinery are significantly changed to those previously published and used in past odour modelling. These changes are both positive (reductions) and negative (increases). The overall effect of the changes is an increase in the total refinery odour emission rate estimated for the base case of April 2003 – March 2004, a period when the refinery was operating at a design rate of 2.41 Mtpa.

The key sources with differing odour emission rates are captured in Table 21 below. Shown in the table are odour emission rates for these sources as previously published by Alcoa (or others) for the periods: -

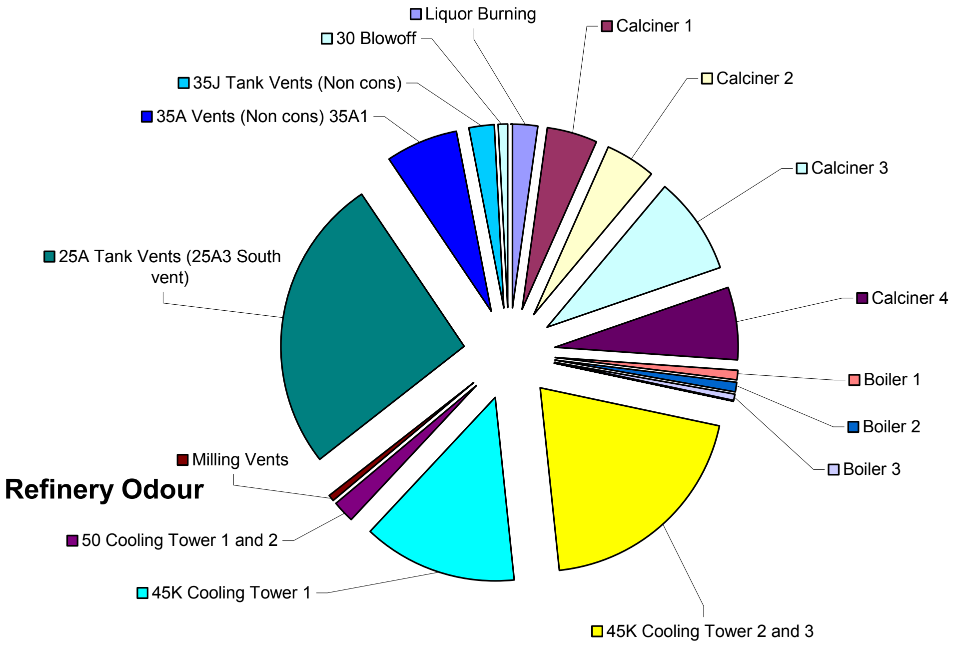
- Jan – Sep 2000 – the 'odour baseline' for licensing purposes;
- Oct 2001 to Feb 2002 – the odour reductions Alcoa claimed for 2000/01 odour reduction initiatives;
- Oct 2001 to Feb 2002 – the odour reductions substantiated by AWN Consultants (the independent auditor, Frank Fleer);
- Post July 2002 – the odour reductions Alcoa claimed for the 2002 odour reduction program;
- Apr 2003 – Mar 2004 – the current refinery baseline; and
- Post Wagerup III refinery expansion with planned odour reduction projects.

Table 21 Major Changes of Odour Emission Rates 2000- 2004 Including Expansion

Source Group	**Jan - Sep 2000 Baseline**	**Oct 01 - Feb 02**	**Oct 01 - Feb 02 Audited**	**Odour Projects Implemented Post July 02**	**2003/04 Base WG III Modelling**	**2003/04 WG III Expansion Modelling**
Reference	Alcoa	Alcoa	Fleer	Alcoa	Alcoa	Alcoa
25A Tank Vents	286425	202296	206500	66907	328704	82204
35A Vents	240870	230547		0	81250	6568
35J Vents	6135	12888		4155	28267	0
Calciners	829540	752059	722231	337109	302532	555315
Cooling Towers	200112	229313		229313	448052	190000
Refinery Total	2026060	1693629		872342	1356314	965748

The most notable differences in current odour emission rates to those previously published are for the 25A slurry tank vents, the 35A and 35J tank vents and the 45K2/3 and 45K1 cooling towers. The major sources of odour at Wagerup Refinery currently are the calcination stacks, 25A slurry vents, and the precipitation building (45) cooling towers. Liquor burning, digestion (30) and evaporation buildings have been significant sources in the past, but with emission reductions performed over 2000 – 2002 have now been almost eliminated, or reduced to very minor contributors. Less prominent though still significant sources of odour are the green liquor tank (35A) vents and causticisation building (35J) vents. A pie chart showing the breakup of odour contributions for the above sources is given in Figure 23 below:

Figure 23 Wagerup Refinery Odour Source Contributions



Further details on the specific sources are summarised below.

25A Slurry Tank Vents

The current refinery estimated odour emission rates for the 25A slurry tank vents represent an increase of 62% above the 2002 emission rate as substantiated by the independent auditor, and 390% above the rate Alcoa estimated it would achieve in the 2002 odour reduction projects. The increase is almost completely due to increased vapour emissions from tank vents, with a small component due to increased odour concentrations from the source.

At the time of the implementation of the 2002 odour reduction program, it was anticipated by Alcoa that a 60% reduction in vapour emissions would occur for the 25A process. This was to be achieved by improved temperate control in the 25A tanks. In fact the vapour reductions have not been achieved in practice, with the vapour discharge flow rates now at over 13400 m^3/hour compared to an anticipated 3600 m^3/hour.

35A and 35J Tank Vent Emissions

The 35A and 35J tank vents were included in the non-condensable gas destruction system implemented in 2002. The previous vents were closed off and a vacuum system installed to collect these sources for destruction in the powerhouse.

In practice the emissions from these sources have been observed to only be partially intercepted by the vacuum collection system, with a portion of the former emissions now being emitted at various other exit points in those buildings. For 35A the system is estimated to be approximately 65% effective; less than this for the 35J emissions. Two of the seven 35J vent emissions were not included in the original design.

As the observations and experience of refinery staff and employees has confirmed that the redirection of these sources was not completely successful, they have been conservatively re-included in the base case for the expansion. Design of the expansion will address the 35J emissions by replacing with a high efficiency causticisation process, and improvements will be made to further reduce the proportion of 35A emissions not captured.

Calciners

Calciners have undergone further improvements aimed at obtaining odour emissions reductions. These modifications include further improvements in hydrate washing and dewatering, and changes to additives. The effect of the improvements is seen in a further reduction of odour emission rates from that anticipated with the 2002 odour reduction program. With the Wagerup III expansion there will be two new calciners, so the overall odour emission rate for calcination will increase in the expanded refinery.

Cooling Towers

The cooling towers are relatively low odour concentration sources, but with very high flow rates. The accuracy of odour measurements for such sources is typically low in comparison to sources with more significant odour concentrations, or lower flow rates. As a consequence odour monitoring data for the cooling towers is uncertain and extends over a large range. We have therefore used the more reliable and more available VOC and carbonyl data with the odour/VOC regression relationship to predict the odour concentration for cooling towers in the current and expanded refinery cases. This has resulted in an increase (approx. 95%) in the odour emission rates estimated for the current refinery baseline.

Planned actions for the cooling towers in the expansion will lead to reduced flow rates and more than a 50% reduction in VOC & odour emissions from this source.

As with the dispersion modelling undertaken by CSIRO for the other compounds, the odour emission rates supplied to CSIRO during the post-processing[3] altered based on further monitoring and refinement of the odour VOC relationship. Therefore for the combined odour impacts, ENVIRON post-processed the TAPM produced concentration fields for a nominal pollutant using the current odour emission rates supplied by Alcoa. A summary of the emission rates used to calculate predicted ground level concentrations are detailed in Appendix J.

8.3.2 Diffuse Sources

Estimation of emissions from diffuse sources was based on flux hood measurements undertaken by GHD[2005], with the method chosen based on the sensitivity of the method. The odour levels were then validated by back calculations to verify the emissions from the diffuse sources. Flux chamber results as presented in the GHD report are summarised in Table 22 below.

Table 22 Flux Chamber Results

Source	**Odour** (ou/m^2/min)
Lower Dam	3.29
ROCP	1.85
RDA2-1 Liquor Southern	37.0
RDA2-2 Wet Mud - North	16.78
Super Thickener	86.8
Cooling Pond	42.6
Oxalate Pond	0.37
ROWS	0.36
Dry Mud 1	0.60
Dry Mud 2	1.46
Wet Mud	16.78
Composite RDA(winter)	**2.38**
Wet Sand	16.78

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[3] Due to the complexity and large computing times, the emission rates in TAPM was assumed to be 1 g/s of a notional pollutant. The TAPM runs then produced concentration fields for a nominal pollutant for each stack. The results of the runs were then combined and scaled according to the actual emission rates for each pollutant for each stack. CSIRO Phase 3A & 3B , 2005

For the majority of the sources the emissions in Table 22 have been given at a constant rate with no dependence on temperature or time of day or time of year. Exceptions to this are the following areas and substances based on the flux chamber data (GHD, 2005) as a function of air temperature. Further details of odour emission rates for dry mud, wed mud and wet mud as a function of temperature are detailed in the Air Assessment report.

8.3.3 Estimated Emissions on an hourly basis

Estimated emissions from fugitive sources were derived from the emission measurements presented by GHD and summarised as follows:

1. Odour (and VOC) emissions from the "dry" stacked areas (wet mud, dry mud 1 and dry mud2) were independent of the wind speed. This was assumed as it is considered that the emissions will be controlled by diffusion through the soil (Eklund, 1992);
2. Emissions from wet areas increased with the wind speed raised to the power of 0.5, as given by Jiang and Kaye (1996) in equation 6.1.
3. No temperature or solar radiation dependency apart from that specified for the mud drying areas.

The resultant emissions for the base case and expansion scenario are presented in Table 23. These have been estimated at conditions of 25 degrees Celsius, winter and a wind speed of 0.5 m/s and F class stability. Emissions from the lake surface are proportional to the wind speed raised to the power of 0.5. For the expansion scenario the emissions are based on the following changes as supplied by Alcoa (pers comms P. Coffey 2005) with:

1. Super thickener will increase by 20% of the equivalent VOC load of the Lower Dam;
2. Cooling Pond will increase by 50% of the current VOC load;
3. ROWS Pond will increase by 100% of the current VOC load;
4. RDA areas will accept 80% of the load diverted from Lower Dam, distributed across all active surfaces;
5. Sand Lake. An increase wet sand area 50% for expected 3 times increase in sand;
6. RDA2 will be converted to dry stacking;
7. Addition of RDAs 8, 9 , 10 and 11;and
8. Oxalate ponds. An additional 1 ha pond in the SE corner of RDA 1 will be constructed.

Table 23 Estimated Odour Emissions for the Base and Expansion Scenarios

Source	Diffuse Source Area (Base)	Base Odour Emission Rate (ou/s)	Diffuse Source Area (Expansion)	Expansion – Odour Emission Rate (ou/s)
Dry Stacked Areas	186.52	74,000	275	117,000
Lower Dam	17.7	9,710	17.7	9,710
ROCP1	8.217	2,530	8.217	2,530
ROCP2	4.58	1,410	4.58	1,410
RDA2-1 Liquor Southern	8.0	49,300	NA	NA
RDA2-2 Wet Mud - North	7.36	20,600	NA	NA
Super Thickener	0.461	6,670	0.461	8,610
Cooling Pond	15.52	11,000	15.52	165,000
Oxalate Pond	1.888	116	2.888	178
ROWS	33.28	200	33.28	3990
Sand Cannon	0.5	1,400	0.5	1,400
Sand Lake	4.34	25,100	4.59	25,800
Total		**303,000**		**336,000 (111% increase in Emissions)**

Notes:

1) Emissions are presented uncorrected from the flux chamber, at 25 degrees Celsius in winter for a wind speed of 0.5 m/s and F class conditions.
2) Emissions are presented uncorrected from the flux chamber, at 25 degrees Celsius in winter for a wind speed of 0.5 m/s and F class conditions

To verify the representativeness of the emission fluxes from the flux chamber, a series of down wind concentration samples and the back calculation of the emission fluxes were undertaken using different sampling techniques. The sampling was undertaken using a portable gas chromatograph and mass spectrometer (GC-MS), pump and tube method based on the USEPA TO-11A method and field odour surveys to determine odour concentrations by use of the odour intensity relationship. The results of the comparison are presented in detail in the Air Assessment report. The back calculations were all performed using the model Windtrax either by Geordie Galvin of the Queensland DPI or David Pitt of Environmental Alliances.

8.4 MODEL RESULTS

Predicted odour ground level concentration results for both the refinery and diffuse sources were produced by ENVIRON (post processing based on CSIRO dispersion modelling) and Air Assessments (CALPUFF modelling) respectively, with the data combined by ENVIRON to predict cumulative impacts from the refinery and diffuse sources for both the base and expansion scenario. The dispersion modelling was undertaken using a meteorological file that was derived using winds predicted by TAPM as use in the refinery modelling by CSIRO. This was selected as the concentration data from the TAPM refinery emissions are added to the CALPUFF predictions on an hourly basis and consistent wind fields between the two models are required. The modelling results were combined for each hour and each grid location within the modeled domain to produce a cumulative ASCII file of concentration fields for both the refinery and diffuse sources. The 3-minute average data for point sources has been calculated using the power law and a p of 0.18 . Difference in multiplier 1-hr to 3-min range from 1.433 for a p of 0.12 to 2.05 for a p of 0.24. The mean p of 0.18 gives a multiplier of 1.715. The mean as the higher ratios are likely to occur closer to the source and would not be representative of residential exposure.

For diffuse sources, the maximum 3 minute concentrations were estimated from the 1-hour concentrations using a simple power law formula as commonly used in odour assessments of:

C1 = C2 (Tave1/Tave2) pa Equation 8-1

Where Tave1 and Tave2 are the averaging times for 1 and 2 C1 and C2 are the concentrations for averaging times 1 and 2; and pa is an exponent

For the exponents a value of 0.1 for the stable conditions and 0.15 for the neutral and unstable conditions was used based on that recommended by Katestone Scientific (1998) for area sources and utilised within the NSW guidelines (NSW EPA, 2004). This results in a multiplier of 1.35 and 1.57 for converting from the 1-hour concentrations to 3minute concentrations. The diffuse odour results detailed in the Air Assessment report indicate that the highest predicted odour concentrations extend in the east west direction with relatively lower concentrations in the north and south direction. The lower concentrations in the north south direction are due to the effect of plume rise over the cooling pond when the wind is along the near north south axis of the cooling pond. For winds across the cooling pond there is minimal plume lift off and therefore higher concentrations.

Cumulative 99.5 and 99.9 percentile 3-minute odour concentration isopleths for the base and expanded refinery scenarios are presented in Figure 24 to Figure 27 below.

Figure 24 Average (99.5th percentile) 3-minute odour concentrations for the base case

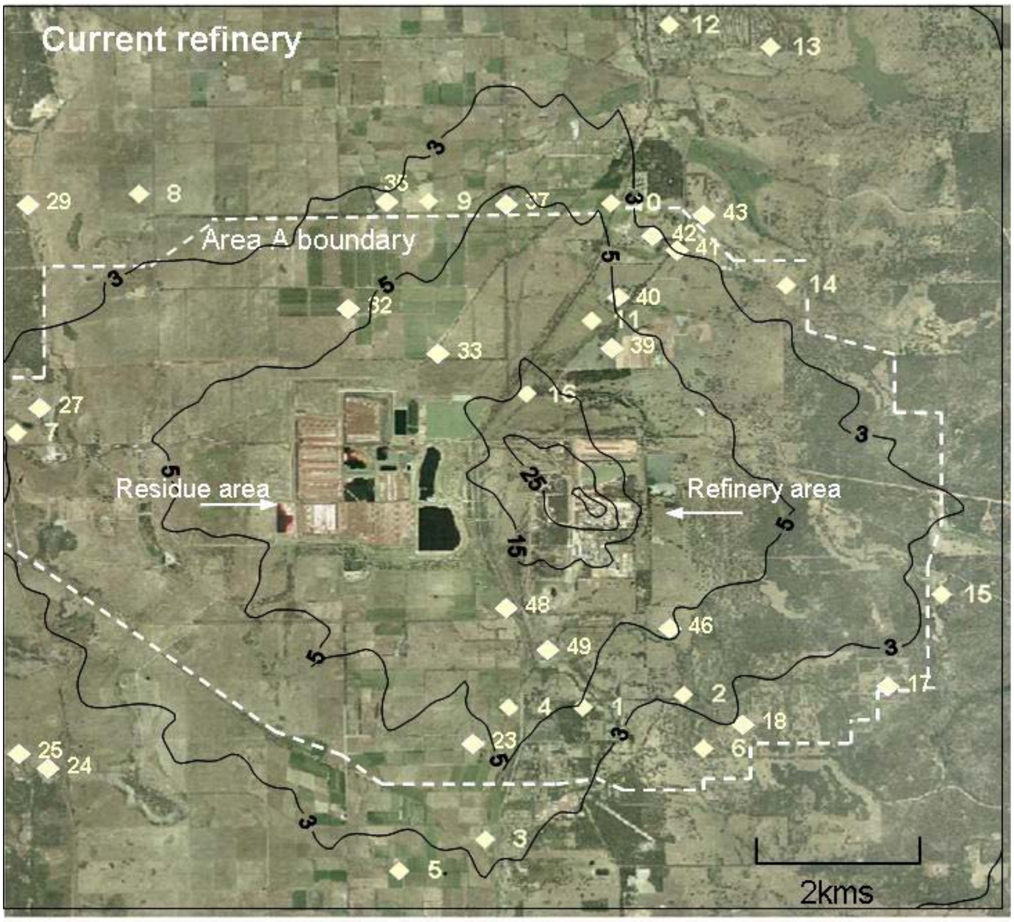


Figure 25 Average (99.5th percentile) 3-minute odour concentrations for the expanded case

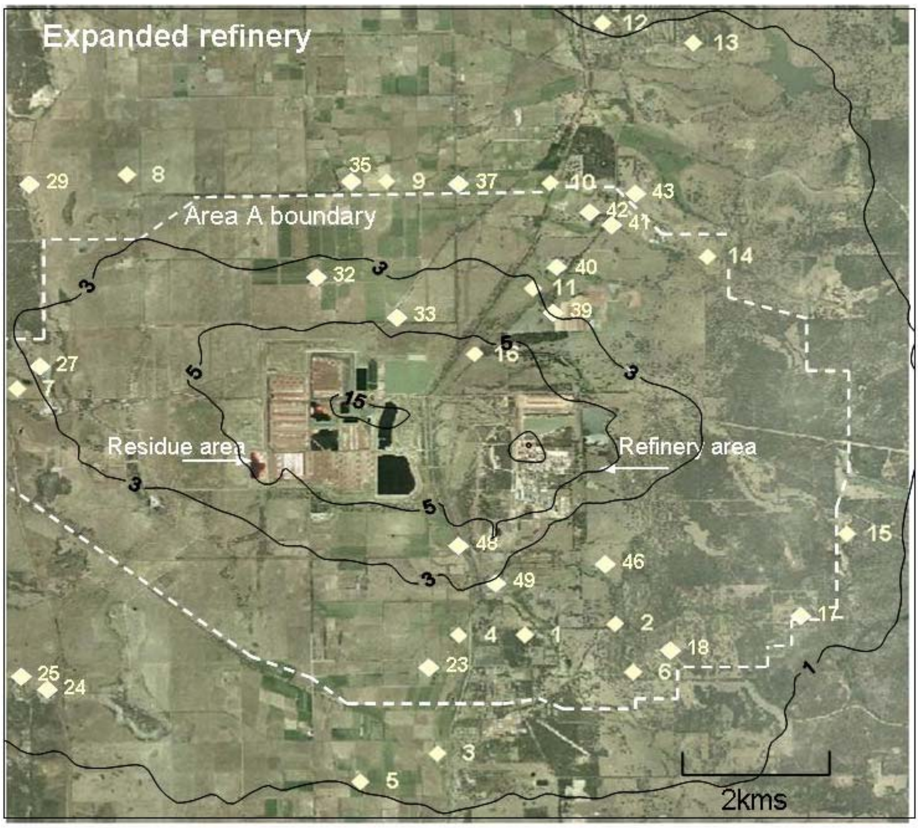


Figure 26 Peak (99.9th percentile) 3-minute odour concentrations for the base case

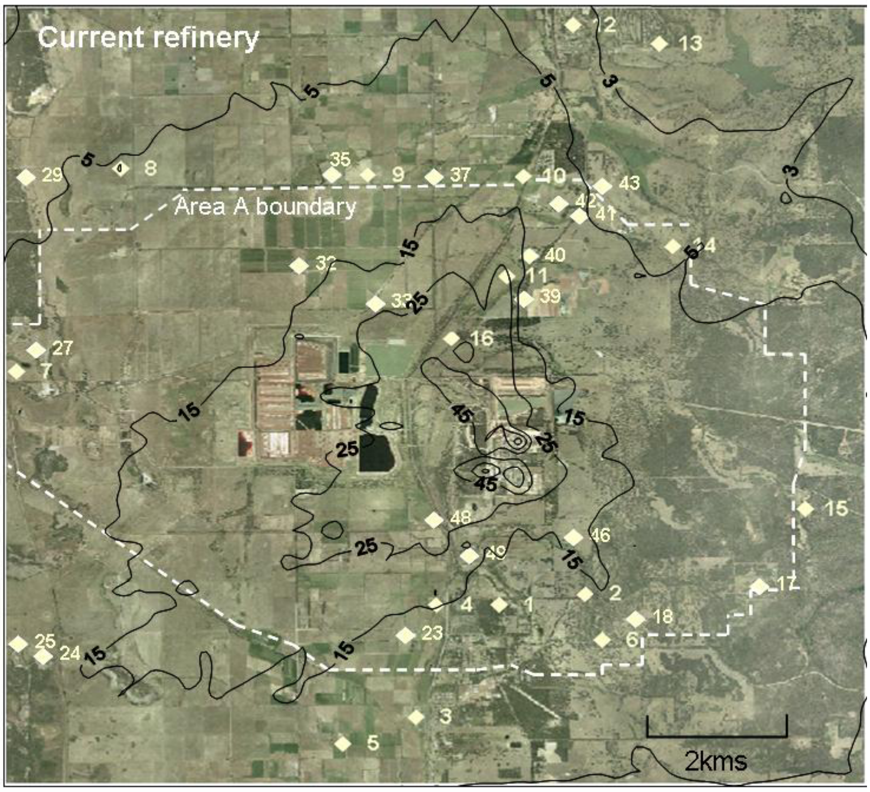
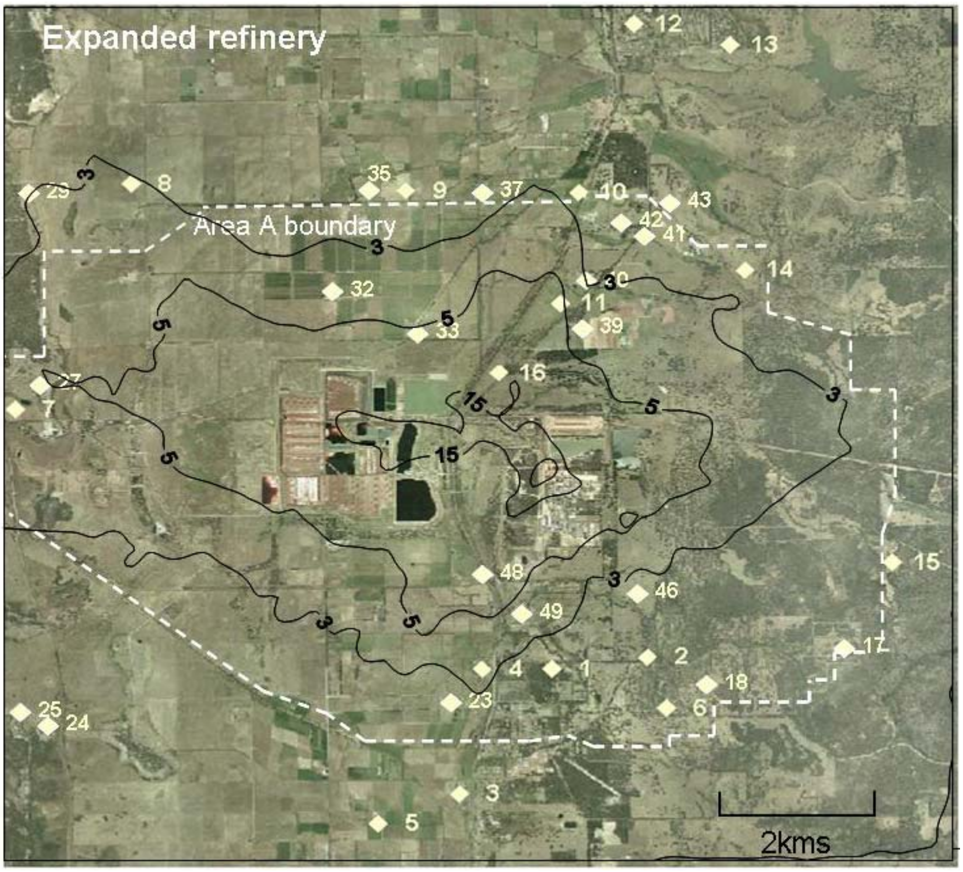


Figure 27 Peak (99.9th percentile) 3-minute odour concentrations for the expanded case



The above figures show that the highest predicted odour concentrations extend in the east west direction with relatively lower concentrations in the north and south direction. The lower concentrations in the north south direction are due to the effect of plume rise over the diffuse sources and reflect the influences such as the dominant wind directions from which stable light winds contribute to the skewing of the odour contours. The review of odour contours for the RDAs and the refinery indicate that for both the base and expanded scenarios, refinery odour emissions are the major contributor to cumulative odours.

In a comparison of model performance against measured odour concentrations indertaken in 2001, Sinclair Knight Mertz found TAPM may over-predict ground level concentrations from low height refinery emission sources, which are important contributors to modelled ground level concentrations of odour. This could mean the predicted odour concentrations may be higher than would actually occur and the reduction between the current and expanded cases may be slightly smaller than shown.

The odour contours therefore reflects the contribution of major refinery odour sources such as calcination stacks, 25A slurry vents, precipitation building (45) and cooling towers. The low volume sources such as the 25A tank vents impact at receptors closer to the refinery whereas the high level sources impact further a field.

The cumulative odour 3 minute (99.5 and 99.9) concentration isopleths indicate that there is a significant decrease in the predicted odour concentrations for the expansion scenario for both the 99.5 and 99.9th percentile ground level odour concentrations based on a number of management and engineering controls proposed for the Wagerup 3 proposal.

The reduction in ground level odour concentrations is due to various emission control works associated with the Proposal, such as:

- A Regenerative Thermal Oxidiser (RTO) on the liquor burner;
- An RTO on oxalate process emissions;
- Restricting flow in calciners 1 and 2;
- An upgrade of calciner 3 performance;
- Low NO_x burners in new boilers;
- Redirection of calciner low volume vent emissions for destruction;
- Reduction in cooling tower voc emissions;
- Reduced emissions from causticisation;
- Sealing of some additional tank vents;
- Green liquor filter upgrades; and
- Upgraded sprinkler system for the RDA

These predicted reductions in the odour ground level concentrations will be assessed during the operation of the expanded refinery through further ground truthing, ambient monitoring, odour surveys, confirmatory dispersion modelling and odour complaint monitoring.

9. CONCLUSIONS

This report presents a comprehensive summary of the numerous studies undertaken by Alcoa as part of the "Air Quality Assessment" for the Wagerup ERMP to quantify atmospheric emissions from the existing refinery, RDAs and cooling ponds and to assess the potential impacts of the proposed expansion on air emissions.

The definition of atmospheric emission arising from the base and expanded refinery scenarios was based on an intensive and comprehensive program by Alcoa and included extensive point source, ambient and diffuse source monitoring programs to confirm air emission data.

The point sources that are covered in this study include major sources such as calciners, boilers, gas turbines, liquor burner, the proposed oxalate kiln, milling and tank vents with the predominant emission from these sources being VOCs, odour, NOx and particulate matter. Fugitive sources that are covered in this study include particulate matter emitted from the residue area and bauxite stockpile area and VOC emissions from the residue area and the lower dam. Minor sources such as vehicular generated dust and vehicular generated dust and wind erosion at the refinery have been omitted as they are quite minor compared to these sources.

The compounds and emissions determined from this process were input into dispersion models to determine predicted ground level concentrations within the study area. The existing and expanded refinery and RDAs have been modelled using The Air Pollution Model (TAPM) and CALPUFF respectively with the outputs combined by ENVIRON for use in the QHRA. The meteorological file used for both models was derived using winds predicted by TAPM as used in the refinery modelling by CSIRO. This was selected as the predictions from the TAPM refinery emissions modelling are to be added with CALPUFF predictions on an hourly basis and consistent wind fields between the two models are required to enable this.

The predicted cumulative modelling results indicate a marked reduction in ground level concentrations at residential receptors as a result of the proposed expansion based on implementation of the proposed management and engineering controls. In addition, comparison of the maximum base and expanded predicted ground level concentrations against nominated ambient guideline values indicate that these predict concentrations are well below these guidelines.

The result of the dispersion modelling was used as inputs to a QHRA undertaken by ENVIRON (2005). The HRA considered the potential health risks associated with the baseline and expanded refinery emission scenarios. Based on the results of the QHRA it can be concluded that:

1. the potential for emissions from the existing or expanded Wagerup refinery to cause acute health effects is low and is primarily driven by the particulate emissions from the RDA and oxides of nitrogen emissions from the refinery;
2. the potential for emissions from the existing or expanded Wagerup refinery to cause chronic non-carcinogenic health effects is very low; and
3. the potential for emissions from the existing or expanded Wagerup refinery to contribute to the incidence of cancer based on inhalation exposure is below USEPA de minimis threshold of one in a million (i.e. 1 x 10-6) at all of the residential receptors considered;

As with any risk evaluation, there are areas of uncertainty in this assessment. To ensure that potential risks are not underestimated, uniformly conservative assumptions have been used to characterize exposure and toxicity. Due to the resultant compounding of conservatism, the quantitative risk indicators should be considered as over-estimates of potential health risks associated with emissions from the Wagerup refinery.

9.1 SHORT TERM IMPACTS

Acute effects generally occur within a short time of coming in contact with relatively high level of a substance whereas chronic effects tend to occur after a continuous exposure for some time and at lower doses or concentrations than acute effects. To address these types of effects reference criteria are expressed in terms of averaging periods, ≤ 24-h averaging periods for acute effects; > 24-h averaging period (usually annual averages) for chronic effects. However guidelines or standards for short term averaging periods in this range are rarely established and in the absence of short term reference values, potential impacts over the shorter averaging periods are assessed by comparing with the reference values for 1-hour or longer.

BTS compared the short term modelling results (3-min and 10-min) undertaken by CSIRO with the reference values used in the HRA risk assessment. The results of the comparison indicate that the short term averaging GLC is lower than the reference values for 1-hr overages or annual averages (where no 1-hour was available). These observations indicate that short term peaks in concentrations of irritant substances in the air are unlikely to be sufficiently high to cause adverse health effects at any of the nominated receptors.

9.2 ODOUR

The odour emission rates for point sources was based on a odour/VOC regression relationship with the diffuse source odour emission rates estimated based on comprehensive diffuse source monitoring with the results validated against field surveys, ambient data and back trajectory modelling. The results of the predicted 3-min 99.5 average and 3-min 99.9 peak odour concentration isopleths for the base and expanded refinery scenarios indicate a marked reduction in concentrations for the expanded refinery scenario. It is therefore considered that the Proposal satisfies the EPA's guidance statement requiring no deterioration of amenity values.

In this regard, the Proposal also satisfies Alcoa's undertaking that there be no increase in odour impacts on residents associated with the expansion.

9.3 DUST

The predicted ground level concentrations for both TSP and PM_{10} at residential receptors are well below the nominated Kwinana EPP (TSP) and NEPM (PM_{10})guideline values at all residential receptors. Comparison of the proposed expanded refinery scenario with the current refinery scenario indicates a reduction in both the TSP and PM_{10} emissions, albeit small. This satisfies Alcoa's undertakings that predicted ground level concentrations for the expanded refinery meet the above nominated guidelines at neighborhood residences.

10. REFERENCES

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11. GLOSSARY

Alcoa	Alcoa World Alumina Australia
Ausplume	The Victorian EPA regulatory dispersion model
CALM	Conservation and Land Management
Calmet	The meteorological pre processor to the dispersion model Calpuff
Calpuff	The Californian puff model. A US regulatory dispersion model for the prediction of long range transport and the dispersion in complex terrain
CSIRO	Commonwealth Industrial Research Organisation
DMA	Decision making authority
DoE	Department of Environment (Western Australia)
DoH	Department of Health (Western Australia)
DoIR	Department of Industry and Resources
DoPI	Department of Planning and Infrastructure
EMS	Environmental management system
EPA	Environmental Protection Authority (Western Australia)
Lapse Rate	The temperature change with height. A temperature decrease of 1 deg C per 100m increase in height has a lapse rate of 0.01 deg C/m
MDL	Method detection limit. The lower detection limit of the measurements technique
MW	Mega watts
NEPC	National Environmental Protection Council
NEPM	National Environmental Protection Measure
Odour Unit	The number of dilutions required for a sample of air to be diluted until it can only be detected by 50% of odour panellists. A sample with 10 ou would need to be diluted ten times to be dilute enough such that half the panellists could not detect it
PCE	Pollution Control Equipment
PM10	Particulate matter below 10 µm
RA Residue Surface	Area approximately 2 km to the west of the refinery used for the drying and storage of bauxite residue from the refining process
RDA	Residue drying Areas
RDA Residue Drying Area	Area within the residue area used for the drying and storage of residue fines. Presently there are 7 RDAs.
RHC	RHC Robust Highest Concentration. A robust measure of the peak concentration. It is used as the actual maximum concentration can often contain unrepresentative or untypical values whereas the RHC provides a more "robust" value of the maximum. It is defined as: RHC = C(R) + (Cm - C(R))ln(3R-1)/2)

ROWS	Run Off Water Storage
SRG	Stakeholder Reference Group
STINK	A Gaussian plume model used for the back calculation of odours by the Queensland Department of Primary Industry
TAPM	The Air Pollution Model. A meteorological and dispersion model developed by the CSIRO Division of Atmospheric Research. This model can be run without local wind observations, instead predicting the local winds and dispersion by solving the relevant equations
TSP	Total suspended particulate. Nominally particulate matter below 50 µm
VOC	Volatile organic compounds
Wagerup3	Wagerup3 refers to the expansion to 4.7 Mpta
WAsP	The Wind Atlas and siting Program used to predict wind speed changes over terrain and used extensively in the wind turbine industry
Windtrax	A model used to model dispersion from area sources that can be used to back calculate the emission flux rate from areas using a down wind concentration measurement
A$	Australian dollars
dB	decibels
dB (A)	decibels (A-weighted)
oC	degrees Celsius
ha	hectares
km	kilometres
kL	kilolitres
mm	millimetres
m	metres (length)
m2	square metres (area)
m3	cubic metres (volume)
m/s	metres per second
MJ	mega joules
MW	mega watts
ML	megalitres
ML/yr	megalitres per year
MLpa	megalitres per annum
Mt	megatonnes
Mtpa	megatonnes per annum
ppm	parts per million
ppb	parts per billion
□g	micrograms (one-millionth of a gram)
□g/m3	micrograms per cubic metre
t	tonnes
tph	tonnes per hour
tpa	tonnes per annum

w/w	weight for weight
%	percent
% w/w	percent by weight

APPENDIX A

Alcoa 2005, Notes on the Odour /VOC relationship

(refer to CD with Technical Appendices)

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APPENDIX B

Wagerup Ambient Air Quality Monitoring Programme, Intensive Ambient Air Quality Study (Phase 2), Van Emden and Powers, 2005

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APPENDIX C

Emissions to Air from Residue Disposal Areas, Assessment of Emissions from Diffuse Area Sources, GHD 2005

(refer to CD with Technical Appendices)

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APPENDIX D

Air Dispersion Modelling of Fugitive Emissions from Wagerup Refinery, Air Assessments 2005

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APPENDIX E

RDA, Sprinkler Deposition Modelling , ENVIRON 2005

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APPENDIX F

Compound Selection Process, QHRA , ENVIRON 2005

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APPENDIX G

CSIRO Dispersion Modelling Studies

1. *Phase 1: Meteorology, Meteorological and Dispersion Modelling Using TAPM for Wagerup*
2. *Phase 2: Dispersion, Meteorology, Meteorological and Dispersion Modelling Using TAPM for Wagerup*
3. *Phase 3A & 3B: HRA Concentration Modelling – Current and Expanded Emission Scenario*

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APPENDIX H

Quantitative Health Risk Assessment, ENVIRON and Benchmark toxicological Services 2005

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APPENDIX I

Alcoa Wagerup Alumina Refinery Environmental License

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APPENDIX J

Emission Estimates (Base and Expanded Refinery)

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