

**PUBLIC SUMMARY REPORT**

**AIR DISPERSION MODELLING  
AND HEALTH RISK ASSESSMENT  
STUDY FOR THE QUEENSLAND  
ALUMINA LTD GLADSTONE  
REFINERY**

**FINAL**

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## **ES1 EXECUTIVE SUMMARY**

### **Introduction**

Queensland Alumina Limited (QAL) commissioned Pacific Air & Environment (PAE) to undertake an air dispersion modelling study of emissions from the QAL Gladstone Refinery, and to assess the potential health risks posed by these emissions on the local community.

PAE conducted the assessment study using a three-step approach:

- reviewing and estimating emissions;
- modelling the dispersion of emissions; and
- assessing health risks based on the results of the modelling study.

The modelling used emissions data from the facility (based on stack monitoring) as well as emission factors from the National Pollutant Inventory. More than 70 pollutants emitted from 12 identified sources were included in the modelling. Meteorological data used in the model came from the two Bureau of Meteorology stations in Gladstone for 2002.

Modelling was performed using an advanced modelling system incorporating the models TAPM, CALMET and CALPUFF, which are all accepted by regulatory authorities in Australia and worldwide.

The modelling results were then provided to an independent specialist firm, Toxikos, who conducted the health risk assessment. The methodology is based on a Hazard Index (HI), which is a sum of Hazard Quotients (HQs) or ratios between the predicted concentration of a pollutant at a receptor and an applicable health-based air quality guideline for that pollutant. Values of HI and HQ below unity indicate the likely absence of health risk.

The health risk assessment was conducted for acute (short-term exposure) and chronic (long-term exposure) health risks, and for sensory irritation using the HI values. Modelling results were also converted into an estimate of lifetime cancer risk using published unit risk factors.

### **Dispersion Modelling Results**

Despite less than favourable dispersion conditions in Gladstone, modelling revealed that emissions of the 70 pollutants are within the acceptable levels based on air quality goals prescribed in regulatory guidelines. Only the maximum 1-hour and 24-hour concentrations of sulfur dioxide were found to exceed their Queensland air quality goals. However, areas affected by the exceedance were confined to the QAL boundaries where there were no residences.

### **Health Risk Assessment**

An inspection of the HQ and HI values at the eight receptors shows that the highest value of the HI for acute exposure is 0.4, indicating the likely absence of health risk. The pollutants that contribute the largest HQ to this index are NO<sub>2</sub> and SO<sub>2</sub>. The highest HI values for chronic exposure and sensory irritation are 0.1 and 0.01

respectively. QAL emissions are therefore unlikely to cause chronic health effects or sensory irritation to Gladstone residents.

The highest calculated cancer risk at the eight discrete receptors representing Gladstone is about  $4 \times 10^{-8}$ . This risk is far below the  $1 \times 10^{-5}$  (1 in 100,000) to  $1 \times 10^{-6}$  (1 in 1,000,000) risk level accepted in most countries, although no guidelines are available in Australia. Among the pollutants modelled, cadmium was found to contribute the highest to the total.

In general, any uncertainties in the emissions estimation, dispersion modelling, exposure estimation and risk assessment have tended towards over-predicting the risk to the population at large. The actual health risk posed by QAL's emissions to Gladstone residents is therefore more likely to be lower than what has been predicted.

An earlier HRA completed in 2003 found that the overall acute hazard index of 0.88 may not provide an adequate margin of safety in all cases. In addition, the predicted total cancer risk although within levels considered acceptable by various national and international bodies (i.e., between 1 in  $10^5$  and 1 in  $10^6$ ) was above the *de minimis* level of 1 in  $10^6$ .

The current report found that it was unlikely that health effects will result from short- or long-term exposures to the QAL refinery air emissions. The new total cancer risk was also calculated to be now less than the *de minimis* risk level of 1 in  $10^6$ . The different conclusion was based on the reduced emissions and predicted ambient concentrations reported in 2008 compared to those in 2003. The biggest reductions were found in criteria pollutants  $\text{NO}_2$  and  $\text{SO}_2$  as well as metals chromium-VI and nickel.

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## 1 INTRODUCTION

Queensland Alumina Limited (QAL) commissioned Pacific Air & Environment (PAE) to undertake an air dispersion modelling study of emissions from the QAL Gladstone Refinery, and to assess the potential health risks posed by these emissions on the local community.

A detailed report was prepared by PAE and submitted to QAL on 12 December 2008. This Public Summary report is an abridged version of the detailed report.

## 2 ABOUT THE SITE

QAL operates the Gladstone Alumina Refinery, which is among the largest of its kind in the world, with a maximum annual rated capacity of 3.8 million tonnes. The refinery covers an area of 80 hectares on a 400-hectare site on the south-east outskirts of Gladstone and east of the Gladstone urban district.

QAL produces alumina, a white powder that is used to make aluminium metal. Alumina is also used as an abrasive powder (e.g. in toothpaste). Alumina is found inside bauxite, an ore mined in Weipa, Queensland.

### 2.1 Production process

Alumina at the refinery is produced using the Bayer Process which involves the following key steps:

- **Digestion** – the raw material (bauxite) is finely ground and reacted with a hot caustic solution and the alumina is dissolved from the bauxite. The solution is then cooled in a series of flash tanks.
- **Clarification** – Impurities are allowed to settle as a fine mud in thickening tanks and, after several washing stages to recover caustic soda, the residue is pumped to storage dams. The remaining solution of alumina in caustic soda is further clarified by filtration.
- **Precipitation** – The solution is agitated and turned into solid alumina.
- **Calcination** – The precipitated alumina is dried under high temperature to produce the dry white anhydrous aluminium oxide powder or alumina from which aluminium is made.
- The alumina is then cooled and conveyed to storage.

This production process involves the use of boilers, calciners and a thermal oxidiser. See Section 3 below for details.

### 2.2 Material Usage and Storage

The materials used and stored at the site include:

- Bauxite;
- Coal, which is burnt to create steam used throughout the plant;
- Caustic solution, which is needed to dissolve the alumina inside the bauxite;
- Alumina powder, which is produced and stockpiled on site.

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### 3 EMISSIONS RELEASED FROM THE SITE

As with any other industrial process, the manufacturing of aluminium as described above does result in by-products and waste products that are released into the environment. These emissions and the sources from which they are emitted are described in this section. Also described in this section are the various technologies employed at the site to control the emissions.

#### 3.1 Sources of Air Pollution

Each of the processes as described above release emissions. The main sources of emissions come from:

- Boilers - used to generate steam for use throughout the site. One of the products of coal burning is ash and unburnt coal (particulates). Particulate emissions also contain some of the metals that are naturally present in coal ash, for example nickel, cobalt, cadmium and manganese. As well as particulates, there are emissions of gases typical of combustion processes, such as sulphur dioxide, nitrogen oxides, carbon dioxide, carbon monoxide, hydrogen fluoride (HF), volatile organic compounds and polycyclic aromatic hydrocarbons (PAH). These are the same types of emissions that come from any combustion source, for example, motor vehicles, wood fires, natural gas heaters and coal fired power stations.
- Calcination stacks - during calcination, the wet alumina powder is dried by heating at high temperature (to 1000°C) and the emissions from the calciners are vented through chimney stacks. Emission controls trap most of the particulate matter before release into the atmosphere, but some particulate matter is released. As well as particulates, there are emissions of gases typical of combustion processes, similar to the gases released from the boilers.
- Stockpiles - materials are stored and handled on the site and during these operations particulates can also be released.

#### 3.2 Emission Controls at the Site

QAL use baghouses to reduce the amount of particulate matter released from process sources. These controls trap most of the particulate matter, but some emissions are released to the atmosphere.

## 4 HOW WAS THE STUDY CONDUCTED?

The approach for the study consisted of the following steps:

- Reviewing the source monitoring data from QAL.
- Identifying the pollutants of concern and quantifying their emissions.
- Performing dispersion modelling to calculate short-term peak and long-term average ground-level concentrations of the identified pollutants.
- Determining the health risks associated with these pollutant concentrations.

The methodologies used for the modelling component and health risk assessment are discussed in the following sections.

### 4.1 Emissions Data

Emissions from the facility were provided by QAL based on results of stack monitoring conducted by a specialist company, AirLabs, on May to July 2007. Emissions of pollutants not included in the stack monitoring were estimated based using the relevant National Pollutant Inventory (NPI)<sup>a</sup> emission factors.

A summary of the emission rates arising from the stack monitoring for more than 70 pollutants is found in Section 4 of the Main Report.

### 4.2 Pollutants of Concern

PAE modelled over 70 pollutants emitted from 12 sources. Not all of these pollutants are expected to have significant concentrations in Gladstone, but all of them were modelled and submitted for inclusion to the health risk assessment.

### 4.3 Dispersion Modelling

To evaluate the potential impact of emissions on the environment and surrounding community, PAE performed modelling used an advanced modelling system incorporating the CALMET/CALPUFF model with the TAPM model (Figure 4.1) - the same as that used in the previous odour modelling study conducted for QAL. This modelling system was pioneered by PAE in 1999 and now represents the current best practice for assessing the dispersion of air pollutants and is widely accepted by regulatory authorities worldwide.

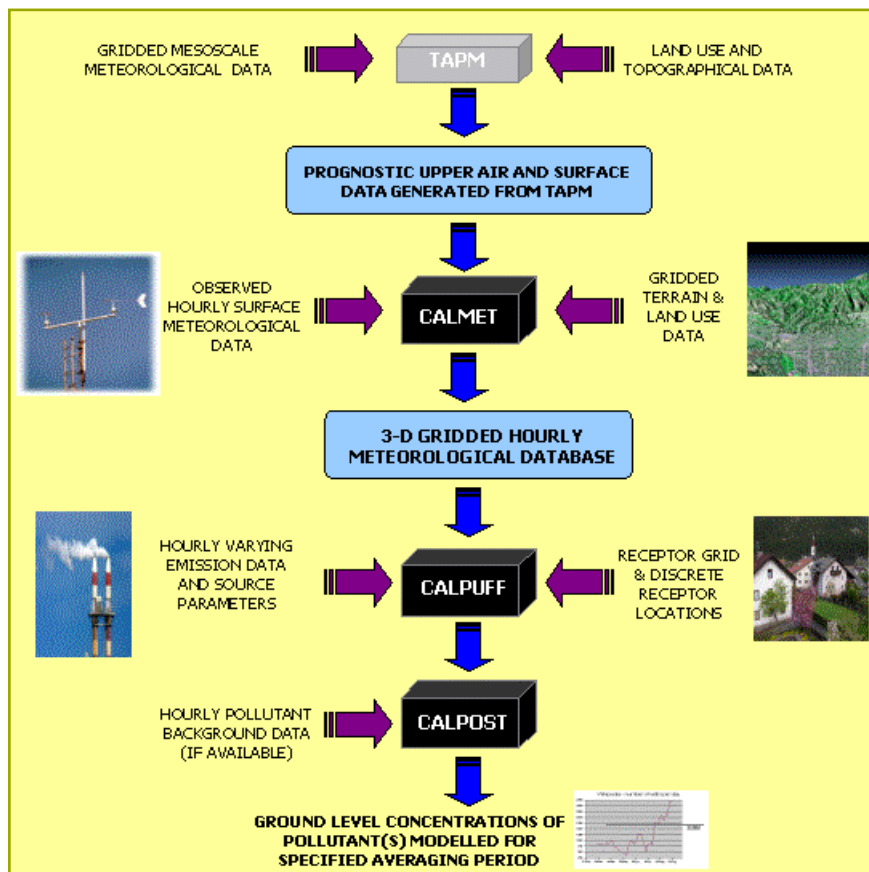
Dispersion models use mathematical equations to simulate the physical and chemical processes that affect air pollutants as they disperse and react in the air, and for them to work most effectively, they need good quality input data on meteorology (e.g. wind speed, wind direction, temperature and turbulence properties), emissions parameters (source locations, physical characteristics and emission rates), topography (terrain and land use) and building parameters (location and shape of buildings).

The modelling system works as follows:

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<sup>a</sup> The NPI is a public database, operated by the Federal Government, covering emissions from industrial facilities, and is used to help industry manage and report on their emissions to the environment.

- **TAPM** is used to calculate the large-scale three-dimensional movements of weather conditions, such as wind speed and direction. This model contains details about the meteorology, terrain and vegetation for all of Australia. TAPM was designed by the Commonwealth Research and Industrial Research Organisation, CSIRO.
- **CALMET** takes output from TAPM and combines it with local weather observations, and generates a three-dimensional pattern of the weather over a region. For this study, data was obtained from two Bureau of Meteorology weather stations in Gladstone.
- **CALPUFF** uses the three dimensional weather information calculated from the models described above with detailed site information, such as emission data, plant physical properties, and the number and location of nearby buildings, to predict the concentration of any emission from QAL at a number points on the ground in Gladstone.



**Figure 4.1: Modelling Methodology Utilised in this Study**

#### 4.4 Input Parameters

The source parameters required for modelling (e.g. stack locations, release heights, gas exit velocities and temperatures) were taken from the site-wide odour modelling study recently completed by PAE for the QAL Gladstone refinery, which were based on stack monitoring results conducted in 2007 for QAL.

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## **5 METEOROLOGY OF GLADSTONE**

### **5.1 The Influence of Weather**

Weather conditions have a major influence on the dispersion of emissions over an area, which means meteorological data is vital for dispersion modelling. The key factors are wind direction, wind speed and atmospheric turbulence.

Wind direction determines the direction of transport of pollutants; wind speed influences the dilution in the atmosphere and the speed at which the pollutants travel from source to sensitive receptors (e.g. homes), and atmospheric turbulence influences rate at which pollutants disperse from a source.

The modelling of emissions from QAL was based on a previous modelling study conducted by PAE which made use of a three-dimensional meteorological dataset for the Gladstone area for the year 2000. A report outlining the methodology and findings of this study was accepted by the Queensland EPA.

### **5.2 Key Meteorological Factors Influencing Air Pollution in Gladstone**

Gladstone has a subtropical coastal climate, characterised by warm humid summers and mild dry winters.

In summer, Gladstone experiences predominantly onshore flow, with winds from between south-east and north-east. During winter, anticyclones linger over Gladstone, producing clear skies and light winds – conditions which lead to strong surface temperature inversions. These conditions generally bring about poor dispersion and higher pollution concentrations.

Wind direction is mainly from the east, which exposes the city's population to emissions from QAL. However, one factor that helps reduce this exposure is the decrease in easterly winds at night when mixing heights are lowest and the atmosphere is most stable. Further, in the winter months of June and July when dispersion conditions are least favourable, south-westerly winds become most pronounced, causing emissions to be transported offshore and away from the population.

The limited mixing heights and high frequency of stable conditions can also constrain the dispersion of air pollution.

## **6 RESULTS FROM MODELLING**

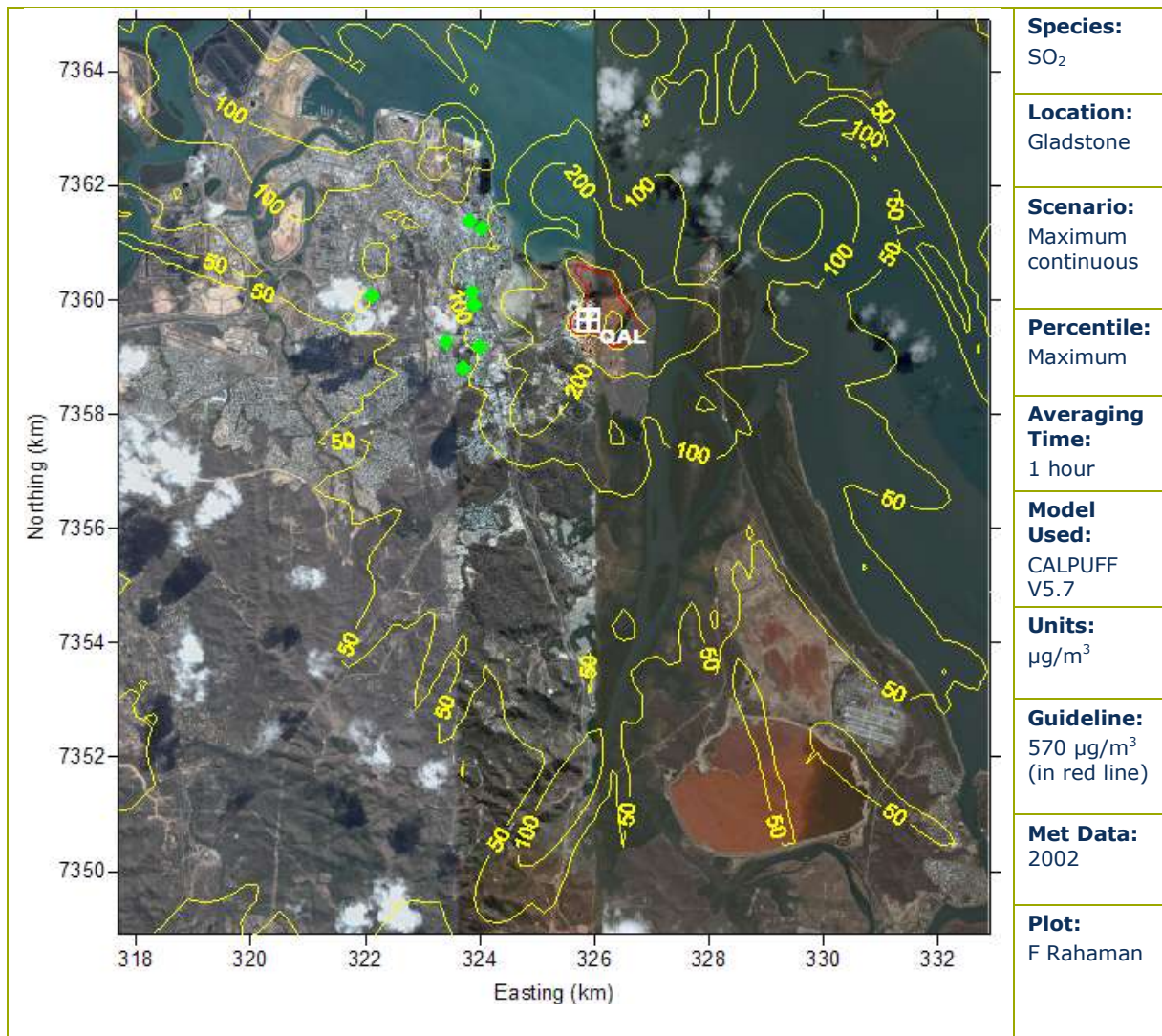
The modelling produced contour maps which indicated whether predicted levels of concentrations are within or exceed guideline levels – see example in Figure 4.1. For each substance contour maps were produced for predicted maximum 1-hour, 24-hour and annual average concentrations.

In the main report, due to the large number of pollutants in the study, only a selected number of pollutants were discussed. These are summarised in the following sections.

### **6.1 Sulfur Dioxide**

Concentrations of sulfur dioxide over the populated areas, particularly at the sensitive receptors, are seen to be within the Queensland EPP goal of 570  $\mu\text{g}/\text{m}^3$ . Over these locations the highest impact is less than half of this value. Exceedances are seen but these are either onsite or north of the facility where land use is industrial. This result, wherein highest concentrations are found at QAL's facility boundaries, is true for all the pollutants.

The dominance of winds from the east is evident from the isopleths of annual concentrations, which tend to be found over land. However, low emission rates keep ambient concentrations within criteria values.



**Figure 6.1: Maximum 1-hour SO<sub>2</sub> Concentrations (µg/m<sup>3</sup>)**

## 6.2 Nitrogen Dioxide

Predicted concentrations of 1-hour NO<sub>2</sub> concentrations fall well within the goal of 320 µg/m<sup>3</sup>.

## 6.3 Particulate Matter

Predicted concentrations of particulates are far below their Qld EPA goals, whether for 24-hour and annual PM<sub>10</sub> or annual TSP.

## 6.4 Carbon Monoxide

Maximum 8-hour running averages of CO do not appear to be of any concern, as predicted concentrations are a small fraction of the guideline value.

## 6.5 Metals

The three heavy metals with the highest emissions are lead, cadmium and manganese. Highest values were all found very close to QAL, and all were within the applicable goals. Even for cadmium, whose ambient goal is more stringent than the other two, peak concentrations were about two orders of magnitude below the allowable limit.

## 6.6 Other Gases

As with the previous results, no compliance issues were predicted for pollutants like formaldehyde, hydrogen sulfide and more than 60 other substances that were part of the assessment.

## 6.7 Summary of Compliance with Air Quality Guidelines

Air quality guidelines and the highest predicted concentrations at different averaging periods for which a Queensland, NSW or NEPM guideline exists are summarised in Table 6.1. As noted earlier, only the guideline value for 1-hour and 24-hour sulfur dioxide concentrations were found to be exceeded, but only within the facility boundaries.

For most pollutants, highest concentrations are far below the standards.

**Table 6.1: Summary of Highest Concentrations and Comparison with Guidelines**

Species	Averaging time	Maximum concentration ( $\mu\text{g}/\text{m}^3$ )	Guideline ( $\mu\text{g}/\text{m}^3$ )	Guideline Reference
Acetaldehyde	1 hour	8.6	42	NSW Impact Assessment Criteria <sup>a</sup>
Acetone	1 hour	3.9	22000	NSW Impact Assessment Criteria <sup>a</sup>
Ammonia	1 hour	4.4	330	NSW Impact Assessment Criteria <sup>b</sup>
Antimony	1 hour	0.002	9	NSW Impact Assessment Criteria <sup>b</sup>
Arsenic	1 hour	0.048	0.09	NSW Impact Assessment Criteria <sup>c</sup>
Benzene	1 hour	0.17	29	NSW Impact Assessment Criteria <sup>c</sup>
Benzo(a)pyrene	1 hour	$4.6 \times 10^{-5}$	0.4	NSW Impact Assessment Criteria <sup>c</sup>
Beryllium	1 hour	$9.29 \times 10^{-5}$	0.004	NSW Impact Assessment Criteria <sup>c</sup>
Cadmium	1 year	$2.8 \times 10^{-4}$	0.02	Queensland EPP
Chlorine	1 hour	1.05	50	NSW Impact Assessment Criteria <sup>b</sup>
Chromium-VI	1 hour	0.01	0.09	NSW Impact Assessment Criteria <sup>c</sup>
CO	1 hour	372.1	30000	NSW Impact Assessment Criteria <sup>c</sup>
	8 hrs	299.0	10000	Queensland EPP
Copper	1 hour	0.004	3.7	NSW Impact Assessment Criteria <sup>b</sup>
CS <sub>2</sub>	24 hours	0.0002	100	Queensland EPP
Ethanol	1 hour	0.009	140	NSW Impact Assessment Criteria <sup>b</sup>
Ethylbenzene	1 hour	0.001	800	NSW Impact Assessment Criteria <sup>b</sup>
Formaldehyde	1 hour	1.2	20	NSW Impact Assessment Criteria <sup>c</sup>
	30 min	1.38	100	Queensland EPP
H <sub>2</sub> S	24 hours	0.003	150	Queensland EPP

Species	Averaging time	Maximum concentration ( $\mu\text{g}/\text{m}^3$ )	Guideline ( $\mu\text{g}/\text{m}^3$ )	Guideline Reference
HCl	1 hour	23.7	140	NSW Impact Assessment Criteria <sup>b</sup>
Lead	24 hours	$2.4 \times 10^{-4}$	1.5 (90 days)	Queensland EPP
	1 year	$3.4 \times 10^{-5}$	0.5	NEPM
Manganese	1 hour	0.014	18	NSW Impact Assessment Criteria <sup>b</sup>
	1 year	$1.8 \times 10^{-4}$	1	Queensland EPP
Mercury	1 hour	0.0286	0.18	NSW Impact Assessment Criteria <sup>b</sup>
Xylenes	1 hour	0.003	190	NSW Impact Assessment Criteria <sup>a</sup>
Nickel	1 hour	0.018	0.18	NSW Impact Assessment Criteria <sup>c</sup>
NO <sub>2</sub>	1 hour	68.6	320	Queensland EPP
PM <sub>10</sub>	24 hours	9.4	150	Queensland EPP
			50	NEPM
	1 year	1.5	50	Queensland EPP
SO <sub>2</sub>	1 hour	1390.6	570	Queensland EPP
	1 year	6.3	60	
SO <sub>3</sub>	1 year	0.095	15	Queensland EPP
Styrene	1 hour	0.002	120	NSW Impact Assessment Criteria <sup>a</sup>
	24 hours	0.0002	800	Queensland EPP
TSP	1 year	1.76	90	Queensland EPP
Zinc	1 hour	0.09	18	NSW Impact Assessment Criteria <sup>b</sup>

<sup>a</sup>NSW Impact Assessment Criteria for Individual Odorous Air Pollutants

<sup>b</sup>NSW Impact Assessment Criteria for Individual Toxic Air Pollutants

<sup>c</sup>NSW Impact Assessment Criteria for Principal Toxic Air Pollutants

## 7 HEALTH RISK ASSESSMENT

### 7.1 Overview of Methodology

The Human Health Risk Assessment (HHRA) component of the project was prepared by a specialist firm, Toxikos Pty Ltd, based on the results of the modelling provided by PAE. It was conducted in accordance with the methods recommended in enHealth (2004)<sup>b</sup> and the US Environmental Protection Agency for the evaluation of toxicological effects from direct exposure to ambient pollutant concentrations.

The assessment was conducted for acute (short-term exposure) and chronic (long-term exposure) health risks and for sensory irritation, which are based on peak concentrations shorter than 1 hour. The impacts on health were characterised by comparing the predicted ground-level concentration with a health-based air guideline established by a competent authority. The ratio of the concentration to the guideline was denoted by a hazard quotient, and the health effects are presented as statistical factors - hazard indices - related to the risk of health effects occurring in a large population.

Most of the common chemicals emitted from industry have such risk indices. Generally, the longer the exposure, or the higher the concentration of the chemical exposed to, the higher the hazard index. The total hazard index is then an indicator of the overall risk of health effects in a large population.

Modelled results were also converted into an estimate of lifetime cancer risk using published unit risk factors. A lifetime cancer risk is the estimated number of additional cancer cases resulting from the increase in pollutant concentrations emitted by a source.

### 7.2 Summary of Results

An inspection of the hazard quotient and hazard index values at the eight receptors showed very low values, indicating the likely absence of health risk. The pollutants that represented the highest hazard quotient are nitrogen dioxide and sulfur dioxide.

The same two gases are also responsible for the highest hazard quotient for chronic exposure and sensory irritation, but the values were very low.

As a result of these findings, Toxikos concludes that QAL emissions are unlikely to cause chronic health effects or sensory irritation to Gladstone residents.

Based on the modelling results, Toxikos also estimates that the highest calculated cancer risk at the eight discrete receptors representing Gladstone is far below the risk level accepted in most countries, although no guidelines are available in Australia. Among the pollutants modelled, cadmium was found to contribute the highest risk value to the total.

The Toxikos report concludes with an assessment of the uncertainties in the estimation of health risk. In general, any uncertainties in the emissions estimation,

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<sup>b</sup> Environmental health risk assessment guidelines for assessing human health risks from environmental hazards

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dispersion modelling, exposure estimation and risk assessment have tended towards over-predicting the risk to the population at large. The actual health risk of QAL's emissions to Gladstone residents is therefore more likely to be lower than what has been predicted.

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## 8 CONCLUSIONS

Using advanced atmospheric dispersion models and best practice modelling methodology, PAE found that predicted concentrations of pollutants emitted from QAL's facility are within acceptable levels as prescribed by the relevant air quality regulations. The maximum 1-hour concentration of sulfur dioxide exceeds its Queensland air quality goal; however, the areas affected by the exceedance were confined to the QAL boundaries, and so did not impact on any residences.

The impact of emissions is relatively low even though prevailing weather conditions in Gladstone are not particularly conducive to dispersing emissions.

The assessment study also found that the acute and chronic health risks and sensory irritation risk arising from the predicted concentrations of pollutants emitted from QAL's facility to be very low risk. In addition, the lifetime cancer risk arising from the same emissions were well below 1 in  $10^6$ . Actual health risks are expected to be lower since any uncertainty in the methodology deliberately tended towards over-predicting this risk.

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