Pinjarra Refinery Efficiency Upgrade – Air Dispersion Modelling

PINJARRA REFINERY EFFICIENCY UPGRADE

- Final
- 3 December 2003

Pinjarra Refinery Efficiency Upgrade – Air Dispersion Modelling

PINJARRA REFINERY EFFICIENCY UPGRADE

- Final
- 3 December 2003

Sinclair Knight Merz
ABN 37 001 024 095
7th Floor, Durack Centre
263 Adelaide Terrace
PO Box H615
Perth WA 6001 Australia

Tel: +61 8 9268 4400
Fax: +61 8 9268 4488
Web: www.skmconsulting.com

Contents

SKM

Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
R01ropxx.doc	16/10/03	Lorie Jones	Owen Pitts	16/10/03	Preliminary Draft for comment
R11ropxx.doc	22/10/03	Lorie Jones	Owen Pitts	22/10/03	Draft
R21ropxx.doc	28/10/03	Lorie Jones	Owen Pitts	28/10/03	Final
R31ropxx.doc	3/12/03	Lorie Jones	Owen Pitts	3/12/03	Final

Distribution of copies

Revision	Copy no	Quantity	Issued to
R01ropxx.doc		e-mail	Environ – Karla Hinkley
R11ropxx.doc		e-mail	Environ – Karla Hinkley
R21ropxx.doc		e-mail	Environ – Karla Hinkley
R21ropxx.doc	1	1	Environ – Karla Hinkley
R21ropxx.doc	2	1	Alcoa – Gordon Baird
R21ropxx.doc	3	1	DoE – Michael Bell
R21ropxx.doc	4	1	DoE – Ray Claudius
R31ropxx.doc		e-mail	Environ – Karla Hinkley

Printed:	3 December 2003
Last saved:	3 December 2003
File name:	I:\WVES\Projects\WV02525\Deliverables\r31ropxx.doc
Author:	Owen Pitts
Project manager:	Owen Pitts
Name of organisation:	Alcoa Australia
Name of project:	Pinjarra Refinery Efficiency Upgrade
Name of document:	Pinjarra Refinery Efficiency Upgrade – Air Dispersion Modelling
Document version:	Final
Project number:	WV02525

1. Introduction

Alcoa of Australia is planning to increase production of their Pinjarra Alumina refinery through an efficiency upgrade (see **Figure 1** for general location of site and nearest residences).

As part of studies to determine the impact of this upgrade, Alcoa commissioned Sinclair Knight Merz to undertake an air quality assessment to:

- Contribute to the design of an ambient air quality monitoring programme which would collect field data appropriate for validation of dispersion models for the Pinjarra Refinery;
- Provide an up to date, validated air quality dispersion model for the Pinjarra Refinery that could be used for the range of air emissions from the refinery; and
- Using this validated model predict the resultant ground level concentrations for a range of air emissions from the existing refinery and proposed expansion.

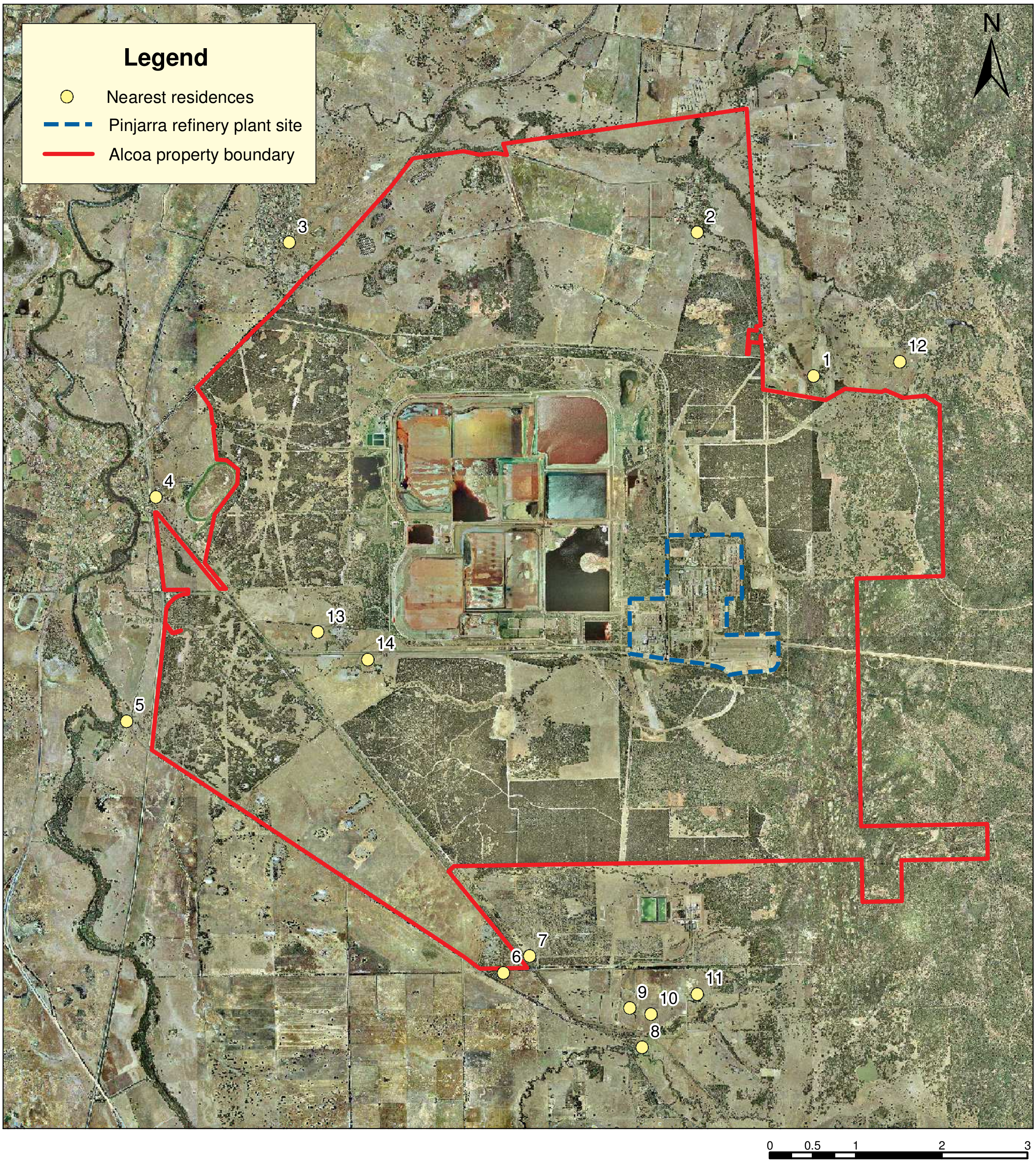
Given the short lead time for the efficiency upgrade, Sinclair Knight Merz in conjunction with Alcoa agreed on a staged assessment to:

1) Conduct an initial assessment and comparison of available dispersion models for the area to determine a representative, but conservative model and meteorological database;
2) Using the chosen model predict concentrations from maximum 1-hour to annual average concentrations for the range of substances specified.
3) At a later date, when the current ambient monitoring programme is finalised, undertake a detailed model comparison to validate the models considered and if necessary refine the model predictions.

The ambient monitoring program commenced in August 2003 and is scheduled to run for 12 months and consists of NO_X and CO monitoring and field surveys. Monitoring for NO_X and CO was selected as they provide tracers or markers of emissions from the taller stacks that can be used to validate dispersion models. The NO_X and CO monitor were installed at three sites that would be representative of maximum concentrations offsite, including areas to the south of the refinery, west of the refinery and on the escarpment. This last monitor location was chosen as previous modelling assessments have indicated that the highest concentrations would occur on the escarpment.

The field surveys were commissioned to provide data for model validation from the short stacks and vents as well as tall stacks and also ground truth the potential impacts from the refinery. The field survey technique has successfully been used in the past at Wagerup and Pinjarra for such purposes.

Other monitoring methods, such as batch sampling with canisters, continuous monitoring instruments such as an OPSIS and field tracer studies as used at the Wagerup refinery were discounted, due to the high costs involved in obtaining a suitable data base.



SKM

Sinclair Knight Merz
263 Adelaide Terrace
PO Box H615
Perth WA 6001
Ph: (08) 9268 4400

PINJARRA REFINERY SITE LOCATION

Figure 1

I:\WVES\Projects\WV02525\Technical\GIS\mapping\workspace\site_loc_map.mxd

2. Meteorology of the Area

2.1 Meteorology of Pinjarra Area

Pinjarra has a typical Mediterranean climate with hot dry summers and cool wet winters. Winds in the region are determined by the:

- Large scale synoptic winds (due to the movement of high and low pressure systems); and
- Local winds (induced by topographical features and by land and sea breezes).

For the Pinjarra site, at the base of the Darling escarpment, topographical features are critically important in modifying the 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.

2.1.1 Development of the Foothill Winds

The most pronounced effect of the Darling Escarpment is the generation of very strong easterly winds. These winds extend from the top of the escarpment to a distance up to 8 km from its face with the winds being up to a factor of two or more, higher than occurs elsewhere on the coastal plain. Ten minute average wind speeds of 15 m/s (30 knots) are commonly recorded in the foothills during the summer months. These very high winds are usually confined to the first few kilometres from the escarpment. However, on occasions they may extend out to 8 km from the face of the escarpment.

Pitts and Lyons (1988 and 1989) found that the development of the very strong easterly winds is linked to the presence of a temperature inversion in the lowest 800 m of the atmosphere and the occurrence of moderate to strong synoptic easterly winds. An area of increased winds in the foothills result from the development of hydraulic jumps or internal standing waves in the airflow. As such, these winds commonly occur in the summer months from early evening to several hours after sunrise.

2.1.2 Development of Rotors

Associated with the “foothill winds” is often the presence of rotors. A rotor is a region of rotating wind, where the wind direction reverses, becoming a westerly in the case of easterly winds. The presence of rotors in the immediate lee of the escarpment under moderate to strong easterly winds

SKM

has been documented by several studies (Dames & Moore, 1977 at Pinjarra and Pitts and Lyons, 1988 at Perth Airport and Pearce) and is also recorded at Wagerup on occasions.

A rotor is characterised (see **Figure 2**) by:

- A region where the wind is in the opposite direction to the general wind flow. For the easterly winds that flow across the escarpment, this typically results in a light to moderate westerly wind at the base of the escarpment.
- A small area where the winds are light but have an appreciable vertical motion. If a pollutant such as dust or smoke is emitted or entrained in this region it will be carried aloft.

As the development of rotors is normally associated with moderate to strong easterly winds, they usually occur during the summer months, from early evening to several hours after sunrise. In the four month study by Dames and Moore (1997) at the Pinjarra Refinery, eleven occurrences of rotors were identified.

2.1.3 Channelling of Winds

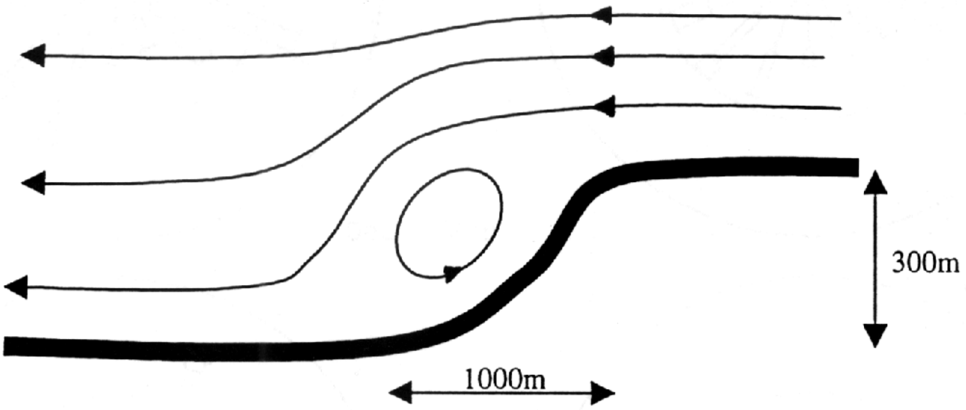
For winds with a westerly component (ie for winds from north westerlies to south westerlies) the Darling Escarpment can channel the airflow into a more northerly or southerly direction. This channelling occurs when the near-ground atmosphere is stable. Such atmospheric conditions typically occur at night.

2.1.4 Katabatic Drainage Winds

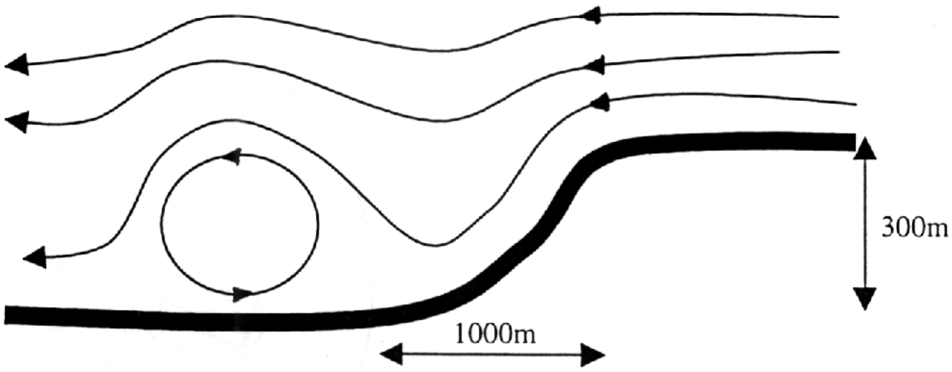
For conditions with lighter winds at night and clear skies, cooling of the air near the ground surface results in the denser, cooler air draining to areas of lower relief. For areas on the coastal plain, the winds will generally drain down the escarpment with greatest flows occurring out of the valleys, such as the Dandalup River. Katabatic drainage flows for the small terrain of the escarpment will result in light winds, and a tendency for night time winds under near calm conditions to turn easterly.

2.2 Seasonal and Daily Variation

Annual wind records from the residue area on a seasonal and hourly basis are presented in **Figure 3** and **Figure 4**. The wind roses indicate a strong seasonal cycle. In summer, the predominant winds are moderate to strong south easterly winds and moderate south westerly winds. The strong south easterlies are the result of the frequent synoptic easterlies at this time of the year and the development of accelerated flows down the escarpment. The south westerly winds are associated with development of the sea breeze. For the winter months, the winds are predominantly north-north easterly to easterly, due to synoptic patterns and katabatic drainage flows.



(a) Rotor formed due to flow separation (note vertical exaggeration)

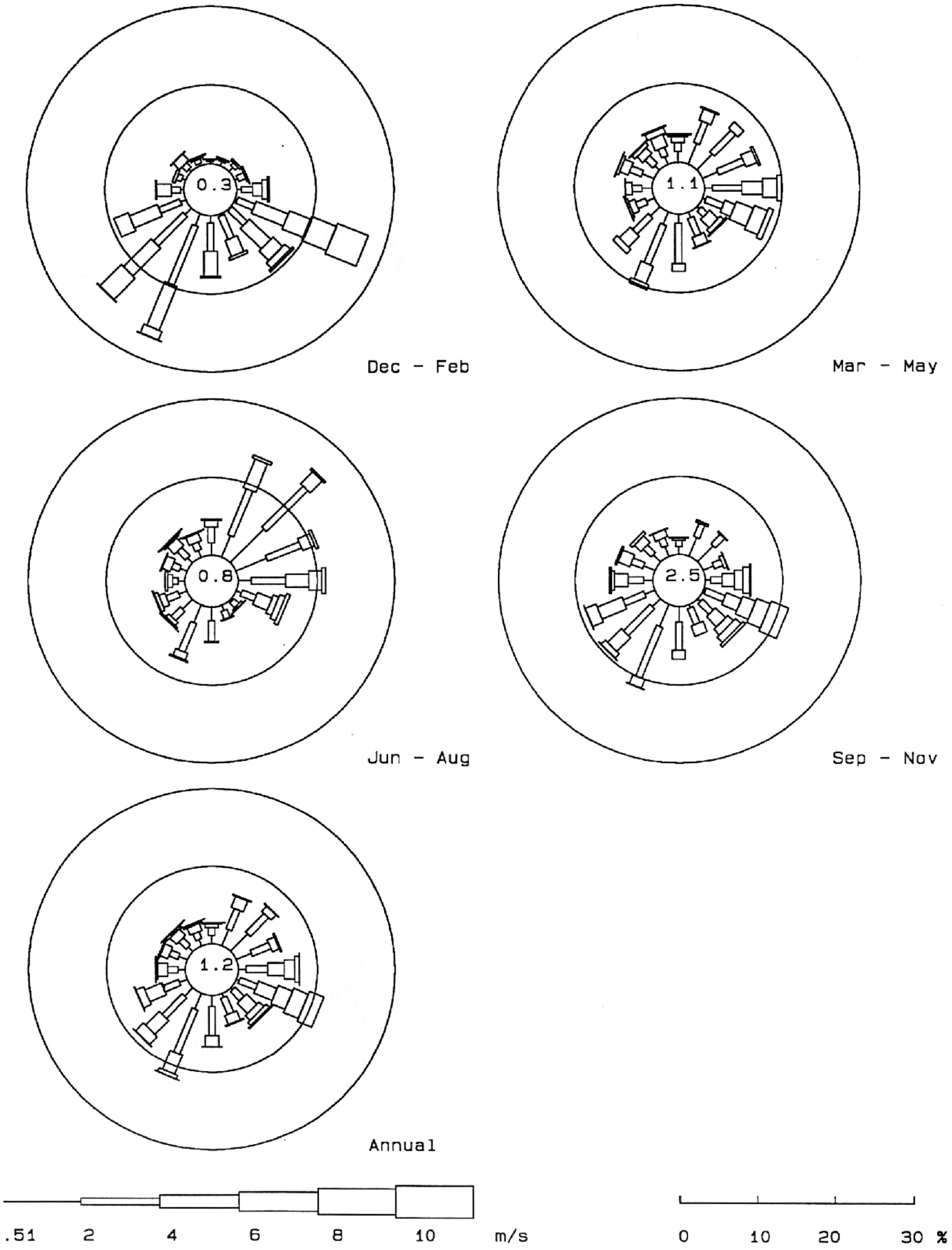


(b) Rotor formed due to development of hydraulic jump or a standing wave (note vertical exaggeration).

Sinclair Knight Merz
263 Adelaide Terrace
PO Box H615
Perth WA 6001
Ph: (08) 9268 4400

Possible processes leading to the development of rotors to the west of the Darling Scarp

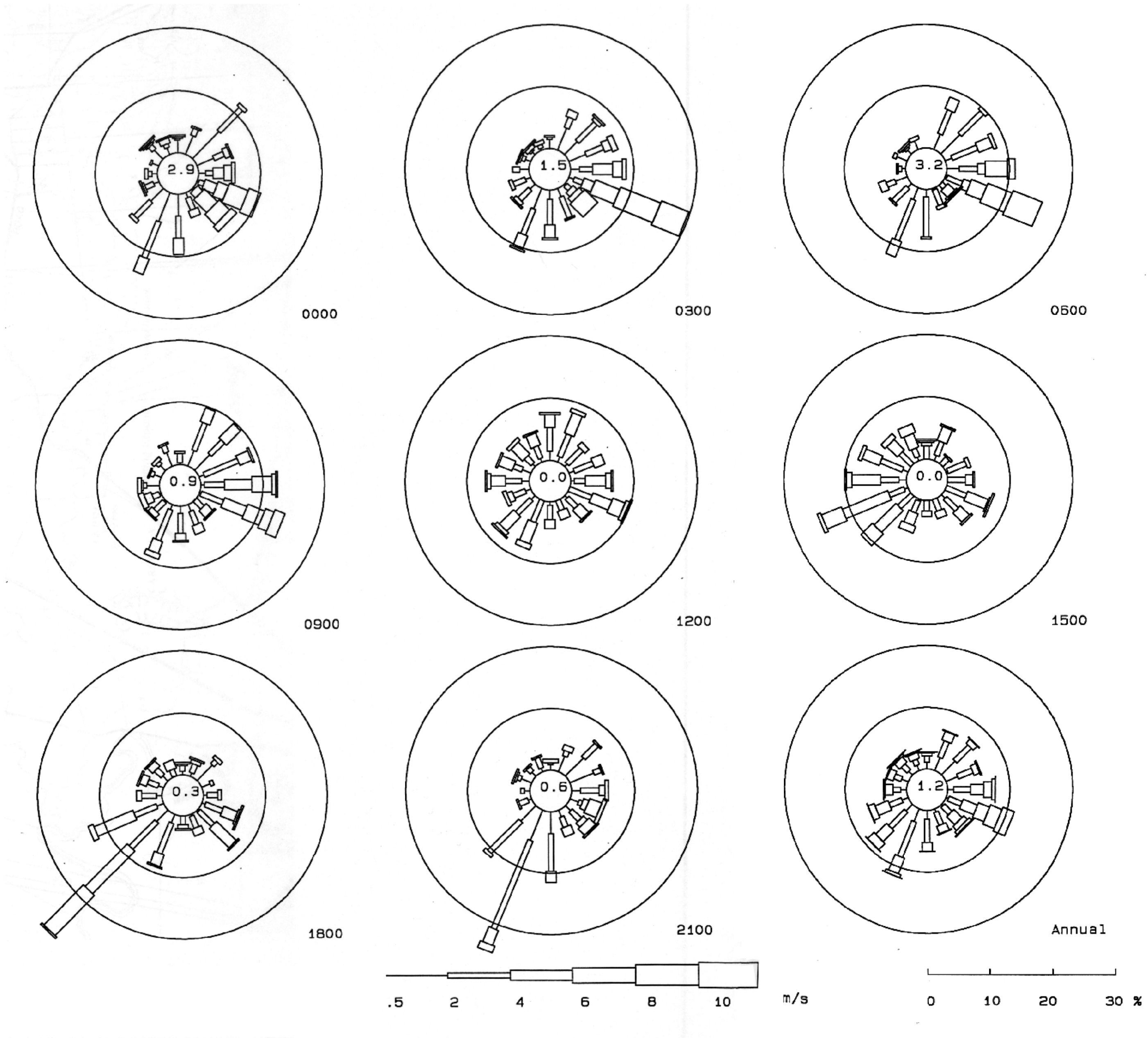
Figure 2



SKM
Sinclair Knight Merz
263 Adelaide Terrace
PO Box H615
Perth WA 6001
Ph: (08) 9268 4400

Seasonal and Annual Wind Roses for the Pinjarra Refinery (Residue Area) for 1986-1987

Figure 3



Sinclair Knight Merz
263 Adelaide Terrace
PO Box H615
Perth WA 6001
Ph: (08) 9268 4400

Annual Hourly Wind Roses for the Pinjarra Refinery (Residue Area) for 1986-1987

Figure 4

I:\WVES\Projects\WV02525\Technical\GIS\mapping\workspace\scan_doc_4.mxd

The hourly variation in winds (**Figure 4)**, indicates that very strong south easterly winds occur most frequently in the period between 0000 and 0900. For the period 1500 to 2100 there is the clear sea breeze signal. Typically, the sea breeze arrives at approximately 1500 as a west-south westerly wind, then turns south-south westerly and weakens by 2100. Easterly winds return around midnight.

3. Modelling Methodology

3.1 Models Considered

For the sources of atmospheric emissions from the refinery (these range from the 75 m power station stack, to short stacks and vents and vaporous emissions from cooling ponds) the following dispersion processes are considered important;

- Influence of buildings on the plume dispersion;
- Dispersion under light winds, where the plumes may meander;
- Influence of the topography of the area with the darling escarpment to the east of the site;
- Convective dispersion processes; and
- Turbulence and increased plume dispersal due to the development of rotors and hydraulic jumps as described in **Section 2**.

All these processes (except rotors), can be estimated with air dispersion models. The presence of rotors although not modelled are not considered to increase the concentrations offsite, as they are very turbulent and will tend to circulate air in the lowest 100m (where the refinery emissions are released) upwards. At the refinery, if the downdraft area of the rotor is located overhead they may tend to push the plumes released from the taller stacks downward over the refinery. However, as the airflow is very turbulent with the rotors typically lasting or staying in one position for less than 30 minutes, they are not expected to significantly impact ground level concentrations on site.

For this assessment, three models have been considered:

- CALPUFF, the Californian Puff model;
- TAPM, the Air Pollution Model; and
- AUSPLUME, the Victorian regulatory model.

CALPUFF was considered as it can model all the above dispersion processes and, in the recent modelling at the Wagerup refinery, was recommended as the best model for predicting overall concentrations from the range of sources at the refinery. TAPM was considered as it performed credibly at Wagerup, has been upgraded/improved since the Wagerup assessment was undertaken and can model the dispersion processes important here. The only drawback with TAPM is the long run times required which restrict its usage when a large number of model runs are required. AUSPLUME was considered as it is used extensively throughout Australia, although its treatment of terrain and dispersion under light winds is simplistic and may lead to over-prediction of ground level concentrations. AERMOD, another potential model that would have been expected to perform well, was not considered for this study as it does not have regulatory status and is still a beta test version.

3.2 Description of Models

3.2.1 CALPUFF

CALPUFF (v5.711) (the Californian puff model) is a Lagrangian dispersion model that simulates pollutant dispersion as a series of continuous releases of puffs. It is the preferred model of the US EPA for the long-range transport of pollutants. The model differs from traditional Gaussian plume models in that it can model spatially varying wind and turbulence fields that are important in complex terrain, long-range transport and near calm conditions.

3.2.2 TAPM

TAPM (v2.0) is a complex prognostic dispersion model and can predict the meteorology for the region of interest without recourse to observational data, though local observational data can be assimilated within the model. The model has an air pollution module that can predict dispersion of plumes and the photochemistry if required. Depending on the grid configuration, model runs to simulate an entire year may take weeks with the fine resolution grids required for this study. As such, model runs of pollution dispersion over an entire year using TAPM can be prohibitive in terms of cost and time constraints compared with other models.

3.2.3 AUSPLUME

AUSPLUME (v5.4) is the regulatory Gaussian plume dispersion model developed by the Victorian EPA and is widely used within Australia as a tool for assessing the impacts of atmospheric discharges for planning and design purposes. All Australian regulatory authorities including the WA DoE accept the use of AUSPLUME as a suitable tool for such purposes. In Victoria, the use of AUSPLUME is mandated under relevant legislation.

3.3 Model Parameterisation

3.3.1 CALPUFF

For this assessment CALPUFF was configured as follows:

- Dispersion was based on turbulence computed from micrometeorology;
- PDF method for vertical dispersion in the convective boundary layer;
- A 35 by 35 grid with 500m resolution for the meteorology and 500m for pollution predictions (see **Section 3.4.1** for further detail). A finer pollution grid of 250m was trialed but this did not significantly change the concentrations outside Alcoa's property boundary;
- CALPUFF terrain adjustment scheme;
- ISC (Huber-Synder/Schulman Scire) building downwash method; and
- No chemical transformation.

The ISC building downwash scheme was used because a run time error developed in the preferred PRIME downwash scheme. The model developers were contacted but have as yet not responded to the query. Model comparison of AUSPLUME with the PRIME algorithm and the Huber

Snyder/Schulman Scire scheme used within CALPUFF indicated little difference offsite (see **Section 4**).

3.3.2 TAPM

The modelling package TAPM consists of a model and databases of synoptic meteorology, terrain and land use categories for the Australasian region. For this assessment TAPM was configured as follows:

- 35 by 35 by 25 meteorological grid points with nested grids of 30, 10 , 3, 1 km spacing for predicting annual meteorological files (for input into CALPUFF) and with a further 0.5 km grid used when undertaking pollution predictions (August and January only).
- Default model options were used, except with modifications for classification of vegetation in the area;
- Meteorology from the standard LAPS analysis from the Bureau of Meteorology as supplied with TAPM;
- The 9-second terrain data in AGD84 coordinates (approximately 300 m resolution); and
- Meteorological data assimilation using the Pinjarra 10m meteorological station with assimilation over two levels.

3.3.3 AUSPLUME

The AUSPLUME model parameterisation for a typical run is presented in **Appendix A**. Key points in the model set up are:

- A 43 by 39, 300m grid (12.6 by 11.4 km) with discrete receptors at the nearest residences;
- Pasquil Gifford dispersion curves with adjustments for roughness and buoyancy;
- Roughness length of 0.4m to approximate the overall area;
- Terrain effects using the Egan half height method;
- Gradual plume rise (this leads to higher concentrations than the partial plume penetration scheme used with the standard temperature gradient of 0.004K/m); and
- Building downwash using the PRIME algorithm.

3.4 Annual Meteorological File Development

Annual files of the required meteorology were developed for both CALPUFF and AUSPLUME for the period 1 August 2002 through to 31 July 2003. This period corresponded to the period of available data from the new Pinjarra meteorological station with data reliably obtained from mid July 2002 onwards.

SKM

3.4.1 CALPUFF File

Calpuff requires either a three dimensional grid file of winds and temperatures or it can run with a standard ISC3/Ausplume style file. The grid file allows for variations in winds and turbulence properties to be addressed, which is important where there is significant topography or where the surface characteristics change markedly, such as over lakes and land.

For this assessment, the CALMET grid was configured with SW grid cell origin at E 391,150m and N 6,379,110m with 35 by 35 cells of 500m in the east/west north/south direction such that the NE extent of the grid was at E 408,950m and N 6,396,110m. That is, a 17 by 17 km grid. This encompassed Pinjarra to the west and extended 5km east past the scarp, north past North Pinjarra and Fairbridge and south past the residences to the south of the refinery. The combination of grid spacing and domain size was chosen to be fine enough to resolve the terrain, but still encompass sufficient of the scarp such that drainage flows at night could be resolved.

To be consistent with the grid system used by Alcoa the AGD 84 coordinate system was used. Terrain for the model was obtained from TAPM, with the landuse defined from observations as either agricultural or forest land (land use code of 20 and 40 respectively). The roughness lengths associated with these categories are 0.25m and 1.0m respectively. To vary the sensible heat and latent heat flux partitioning with time of the year, the Bowen ratio was varied vary from 3 and 1.5 for agricultural and forest areas in summer to 0.5 for agricultural and forest area in winter (refer to **Table 1**), based on data presented in Ray et al (2003) and that presented in USEPA (1998).

- **Table 1 Bowen ratio used for Agricultural and Forested land as a function of the time of year**

Months	Agricultural	Forested
December to March	3.0	1.5
April	2.2	1.3
May	1.5	1.0
June – August	0.5	0.5
September	1.0	0.8
October	1.5	1.0
November	2.2	1.3

The albedo was set constant at 0.19 for agricultural land and 0.12 for forested land.

3.4.2 Surface Observations Used

Wind observations within the region are available from the Pinjarra meteorological station located south of the refinery in a large open paddock. This site was installed in mid 2002 and comprises wind speed and direction, air temperature, relative humidity, solar radiation and barometric pressure. The wind was measured with a sonic anemometer with wind speed threshold of approximately 0.2 m/s which meets Australian standards for air quality measurement. The wind measurements for the site are presented in **Appendix B** along with those from the 1986/1987 AUSPLUME file developed by Dames & Moore.

Cloud cover for use in estimating the daytime sensible heat flux was obtained from the 3-hourly observations at Perth airport, approximately 75 km to the north. An alternative to using the Bowen ratio method with the estimated Bowen ratios, cloud observations and estimated solar radiation would be to use net radiation measurements directly within CALMET. This was not attempted in this study as there were only a few months data available (from Wagerup). Additionally, this would have required modifications to the CALMET code.

3.4.3 Upper Winds and Temperatures

Upper winds and temperatures for the region are available from:

- Perth airport radiosonde observations; and
- TAPM derived "observations".

The Perth airport observations are undertaken with two wind and temperature soundings per day at 0600 WST in summer (0700 WST in winter) and 1800 WST in summer (1900 WST in winter). Additionally, there are two wind only soundings at 1200 WST in summer (1300WST in winter) and at 0000 WST. The benefits of using the Perth soundings are that actual observations are used. The disadvantages are that the observations are from 75km to the north and that only twice daily profiles are available such that features that are of less than 12 hours duration (an afternoon sea breeze or strong easterlies for part of the night) may not be resolved.

Predicted winds from TAPM will reduce the problems, however they are model predictions and not real observations and may be subject to errors. These errors can be reduced through nudging of the predicted winds with surface observations. TAPM can also provide the local temperature structure. The one draw back with the current TAPM temperature profiles however is that TAPM generally under-predicts the surface inversions and upper inversion because of the resolution of the data (SKM, 2002). A comparison of the differences in the wind fields that can result from the use of TAPM or Perth airport winds is presented in **Appendix C**.

The preliminary modelling with CALPUFF undertaken for this study used the meteorological file developed from Pinjarra surface winds and Perth airport upper temperatures and winds. A preliminary sensitivity analysis comparing this approach to using a file developed from TAPM derived winds and temperatures indicated relatively small differences in the predicted concentrations.

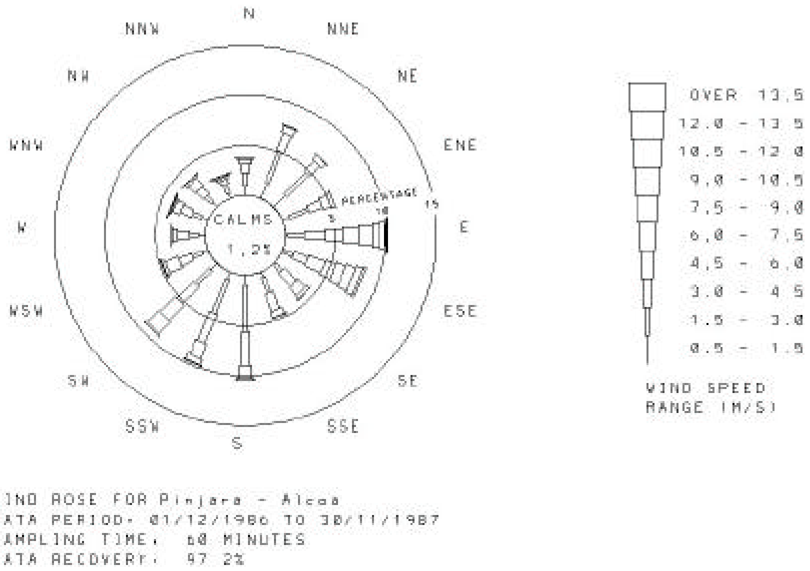
3.4.4 AUSPLUME File

The AUSPLUME file for this assessment was derived from the Pinjarra surface data with mixing heights derived using CALMET when run with Perth Airport temperature soundings. The frequency distribution of stabilities and mixing heights are presented in **Appendix B** along with the frequency from the file derived for 1986/1987. The terrain file required for AUSPLUME was developed from the 9 second DEM file, with terrain heights less than the average refinery elevation (approximately 44m) being set to 44m. This assumption was made to restrict plumes diverging from the ground when using the Egan half height method for easterly winds. Without this restriction, under easterly winds the gradual decrease in terrain would have resulted in the Egan half height method predicting that the plumes would slowly diverge from the ground, which is unrealistic.

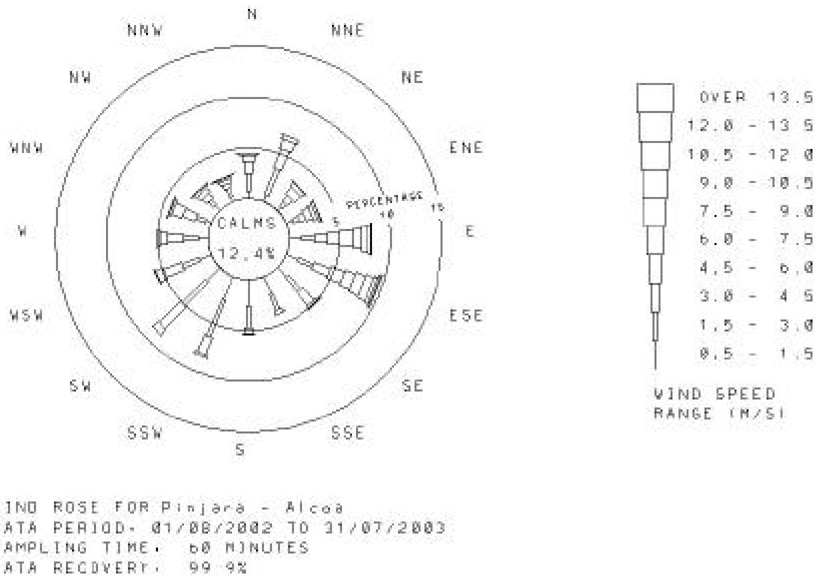
3.5 Representativeness of the Meteorological Data

Annual AUSPLUME files for modelling at Pinjarra are available from those developed for this study in 2002/2003 and from 1986/1987. A comparison of the wind roses and wind distributions are presented in **Figure 5** and **Figure 6** and in **Appendix B.** These indicate similar wind distributions although the 1986/1987 winds were slightly higher with a substantially lower number of calms, where calms are defined as wind speeds below 0.5 m/s.

These differences are considered to be due to the siting of the anemometers. The early meteorological data was developed using data collected from the early eighties until 1996 at the south eastern side of the residue area on one of the internal bunds. The data from the station was of good quality, though this deteriorated in the last few years before it was decommissioned. As this site was on an internal wall and also above the surrounding plain it is expected that the wind speeds will be slightly elevated. In a study for the Wagerup residue area, SKM (2001) using the Wind Atlas and Application Program (WasP) found that the anemometer there on a north south internal bund measured winds around 18% higher than would be measured at 10m over a flat surface, whilst for northerly or southerly winds the wind speed was relatively unaffected. This speed is site specific but does indicate that the increase in the magnitude seen between the two data bases is consistent.



- **Figure 5 Wind Rose from Pinjarra refinery for 1/12/86 to 30/11/87**



- **Figure 6 Wind Rose from Pinjarra refinery from 1/8/02 to 31/07/03**

4. Comparison of Model Performance

4.1 Introduction

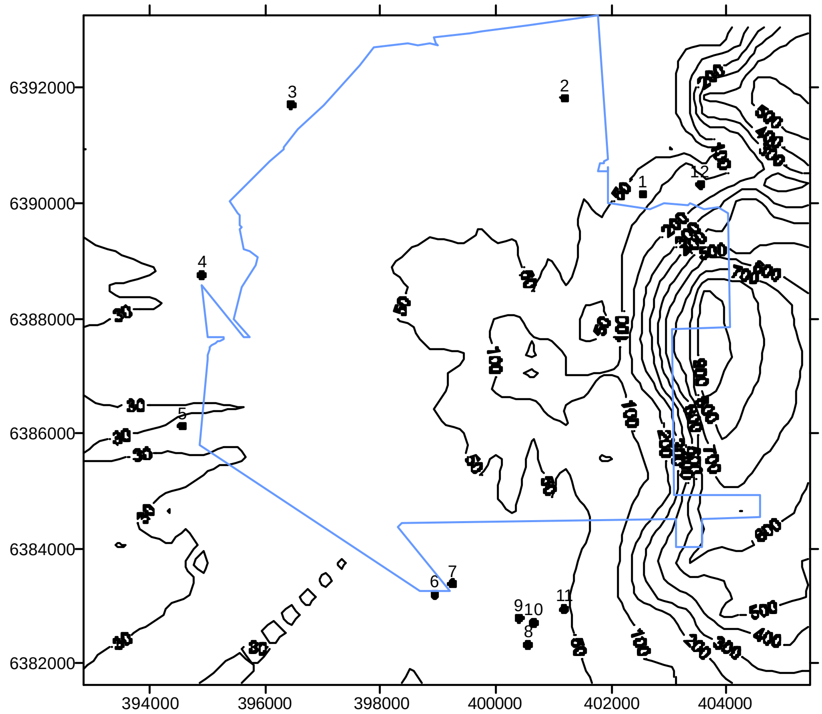
To select an appropriate model for use in this study, a comparison of the predictions from the three models was undertaken as well as an assessment of sensitivity to some of the model parameterisation.

4.2 Sensitivity to Meteorological Data and Building Scheme

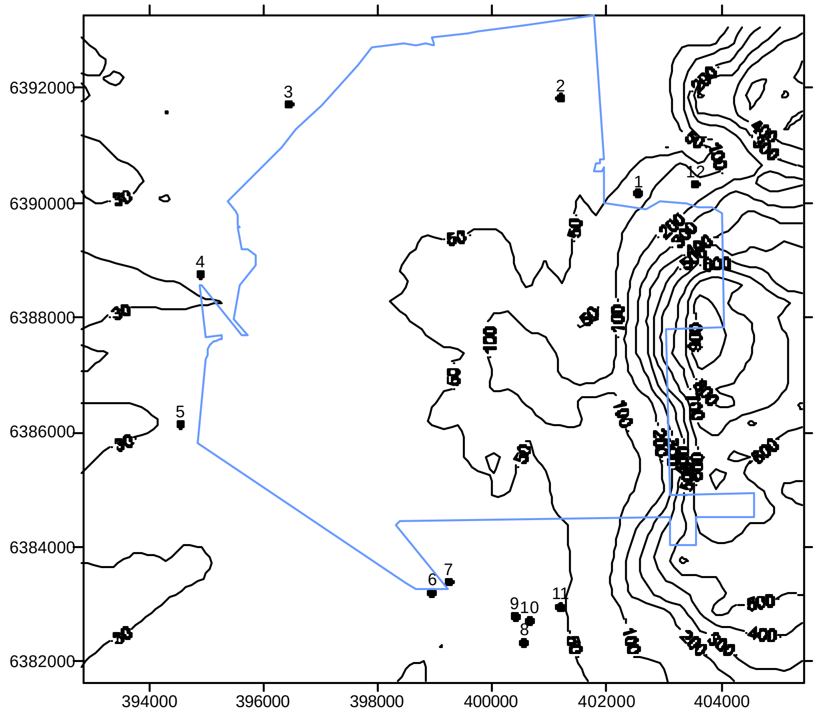
To determine the sensitivity of the model results to the meteorological data (either 1986/1987 or 2002/2003) and to the choice of building downwash schemes (PRIME or Schulman Scire), AUSPLUME was run using:

- Both the 1986/1987 and 2002/2003 data base for:
  - NO_X emissions, which are primarily emitted from the tall stacks; and
  - VOC emissions, which are emitted from a wide range of sources, but with the highest ground level concentrations being primarily the result of the low level stacks/vents.
- Both the PRIME or Schulman Scire building downwash algorithms. This sensitivity study was undertaken to ascertain the importance of the building scheme option as CALPUFF will not run for the sources modelled here with the PRIME algorithm but only with the Schulman Scire algorithm. The developers of CALPUFF were contacted about the run time error, but no reply has been received to date. For comparison of building downwash algorithms, model predictions were conducted using AUSPLUME for the NO_X emissions and also for VOC emissions.

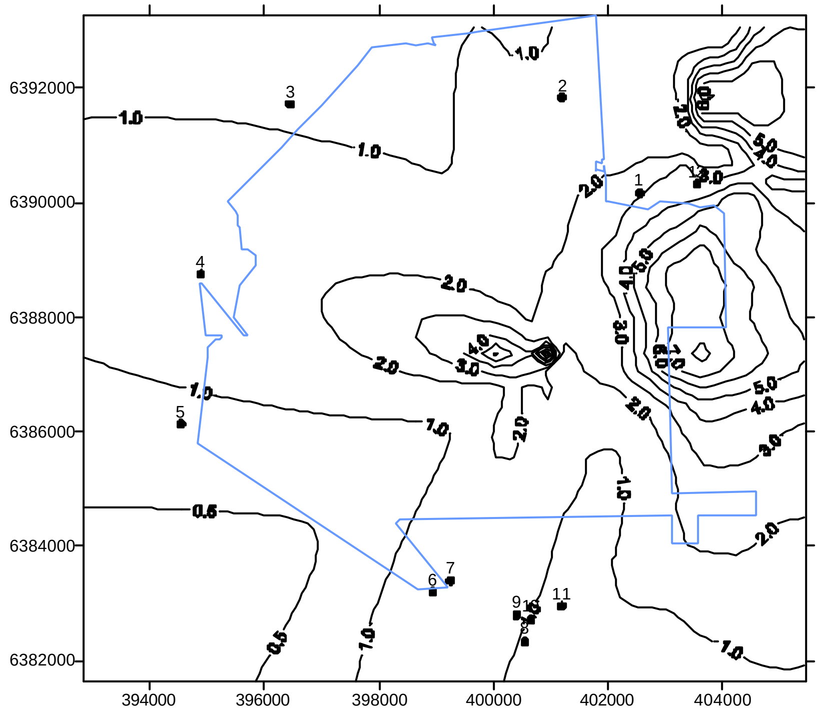
The results from the comparison of the meteorological data and building schemes are presented in **Figure 7** to **Figure 15**.



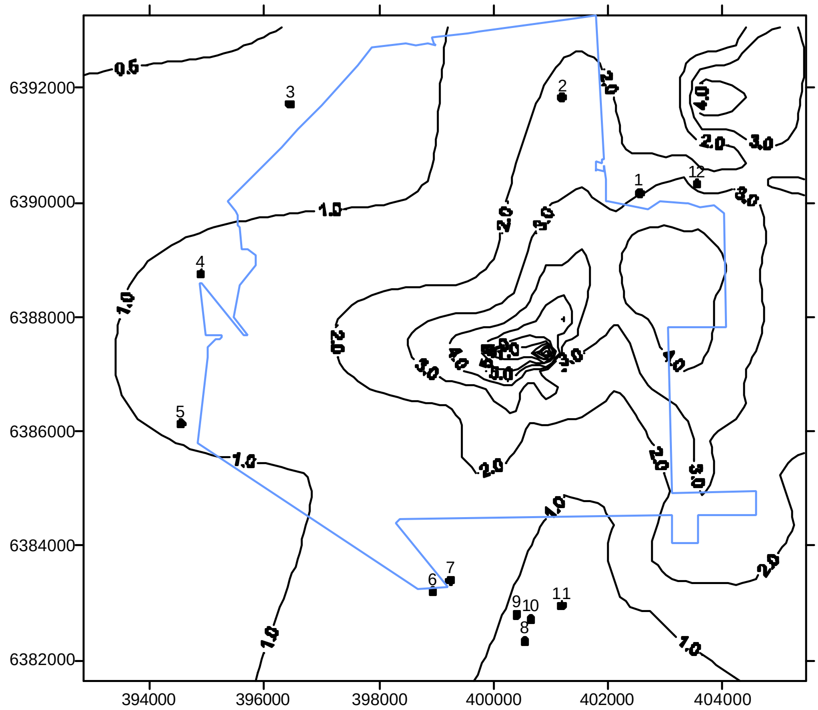
- **Figure 7 Predicted maximum 1-hour concentration (μg/m³) of NO_X from AUSPLUME using the 2002/2003 data and PRIME downwash scheme**



- **Figure 8 Predicted maximum 1-hour concentration (μg/m³) of NO_X from AUSPLUME using the 1986/1987 data and PRIME downwash scheme**

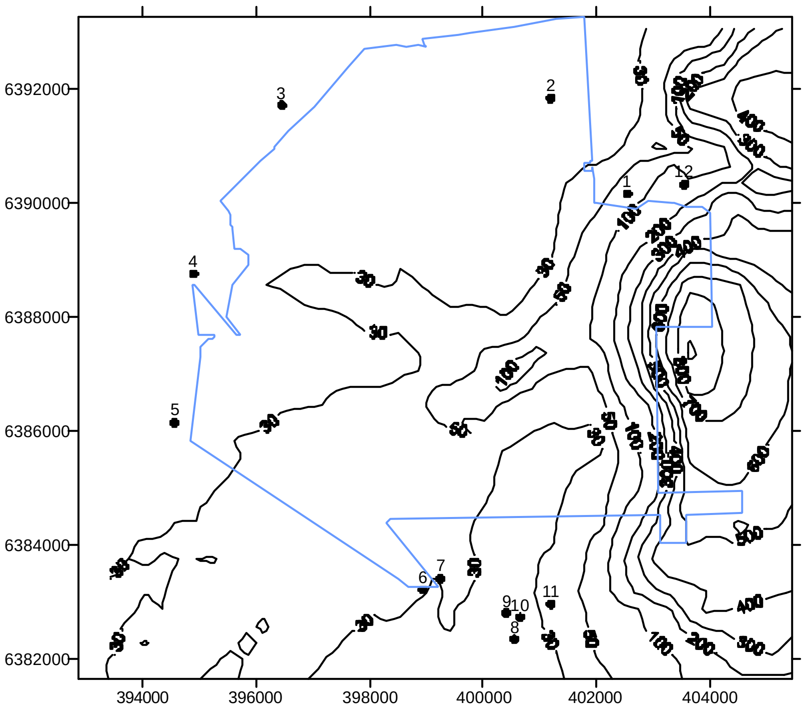


- **Figure 9 Predicted annual concentration (μg/m³) of NO_X from AUSPLUME using the 2002/2003 data and PRIME downwash scheme**

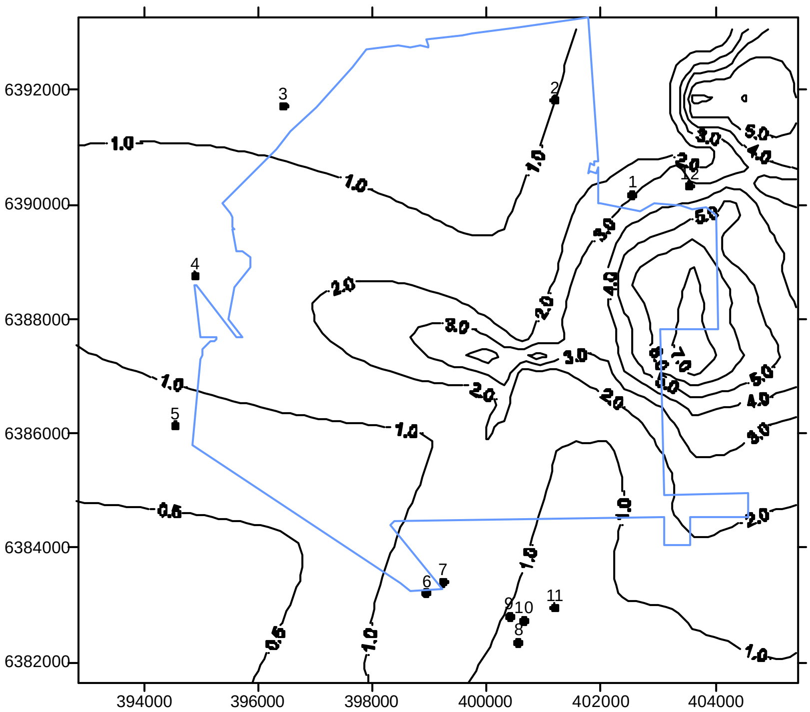


- **Figure 10 Predicted annual concentration (μg/m³) of NO_X from AUSPLUME using the 1986/1987 data and PRIME downwash scheme**

SKM

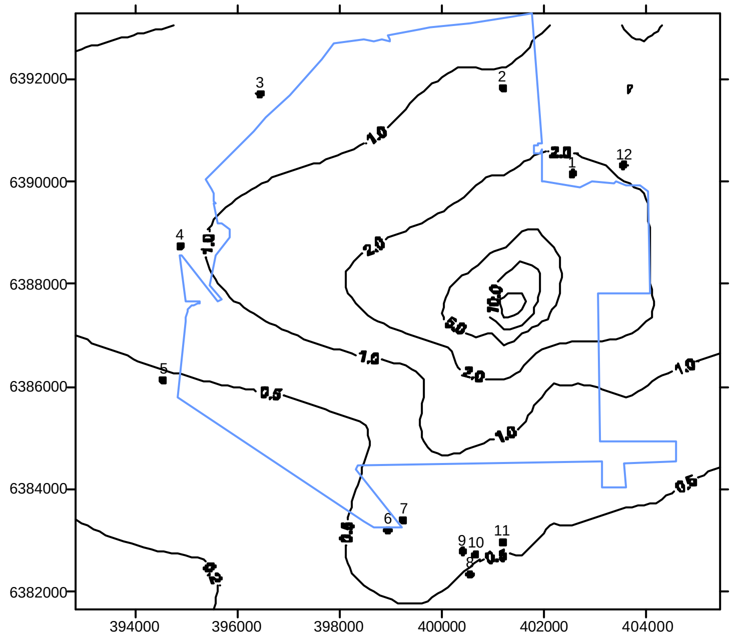


- **Figure 11 Predicted maximum 1-hour concentration ($\mu g/m^3$) of NO_X from AUSPLUME using the 2002/2003 data and the Schulman Scire downwash scheme**

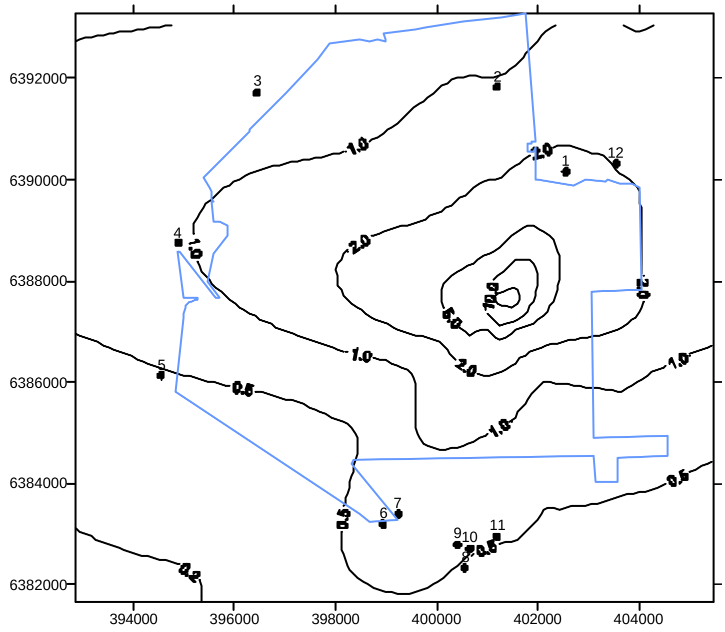


- **Figure 12 Predicted annual average concentration ($\mu g/m^3$) of NO_X from AUSPLUME using the 2002/2003 data using the Schulman Scire downwash scheme**

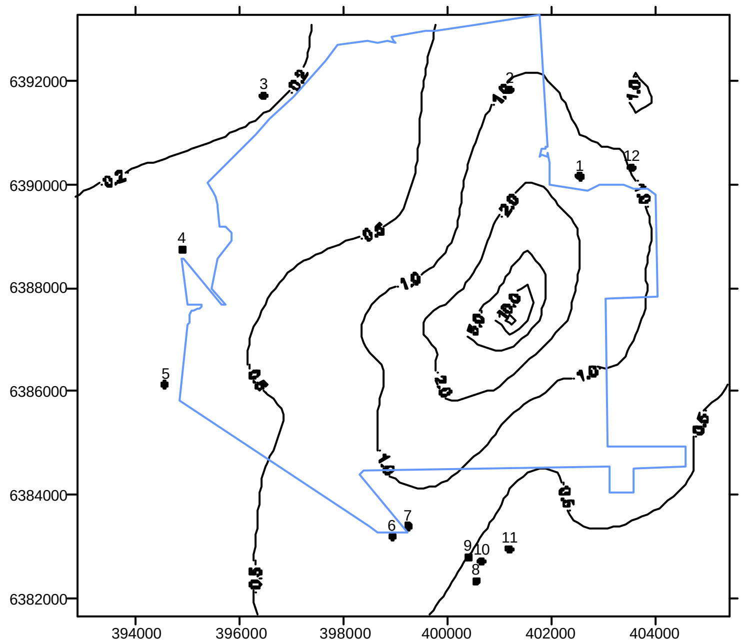
SKM



- **Figure 13 Predicted annual average concentration ($\mu g/m^3$) of VOC from AUSPLUME for 2002/2003 and the PRIME downwash scheme**



- **Figure 14 Predicted annual average concentration ($\mu g/m^3$) of VOC from AUSPLUME for 2002/2003 using the Schulman Scire downwash scheme**



- **Figure 15 Predicted annual average concentration (mg/m^3) of VOC from AUSPLUME for 1986/1987 and the PRIME downwash scheme.**

The results from the NO_X modelling indicates minor differences in the predicted maximum 1-hour concentrations for the different annual data bases (**Figure 7** compared to **Figure 8**), whilst for the predicted annual average concentrations the 2002/2003 file results in higher concentrations on the hills to the west and slight increase in concentrations at Pinjarra (location 4) (**Figure 9** compared to **Figure 10**). These higher annual concentrations are due to the higher frequency of light wind, stable conditions in the 2002/2003 file. Likewise for the predicted annual average VOC concentrations, generally higher concentrations are predicted from the 2002/2003 data (**Figure 13** compared to **Figure 15**). The exception to this is an area to the SSW of the refinery where slightly higher concentrations are predicted from the 1986/1987 data.

The comparison of the results from the different building downwash schemes indicates little difference in the ground level concentrations. This may be in part due to the fact that the majority of the NO_X emissions are from the taller stacks which are not significantly affected by downwash, whilst the VOC concentrations are dependent on the small vents/stacks which have been modelled as volume sources, where again downwash is not explicitly considered.

Therefore, it is concluded that the use of the 2002/2003 meteorological file will result in generally higher concentrations, particularly for the longer averaging periods, with the choice of building wake scheme being not critically important in the modelling.

4.3 Comparison of models

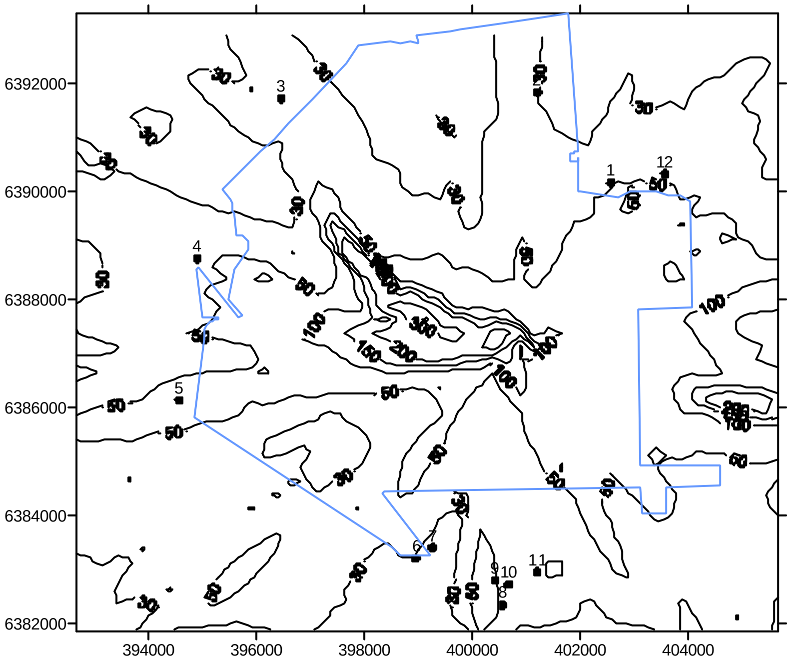
To assess the sensitivity of the predicted results to the choice of model, a comparison was made of the predicted concentrations from the three models (AUSPLUME, CALPUFF and TAPM). This comparison was limited to predictions only, with no attempt made to compare the modelled results to the ambient NO_X and CO monitoring that has commenced at Pinjarra, due to the small amount of data (a few weeks) available at the time this sensitivity study was conducted.

4.3.1 Comparison of Models for NO_X sources

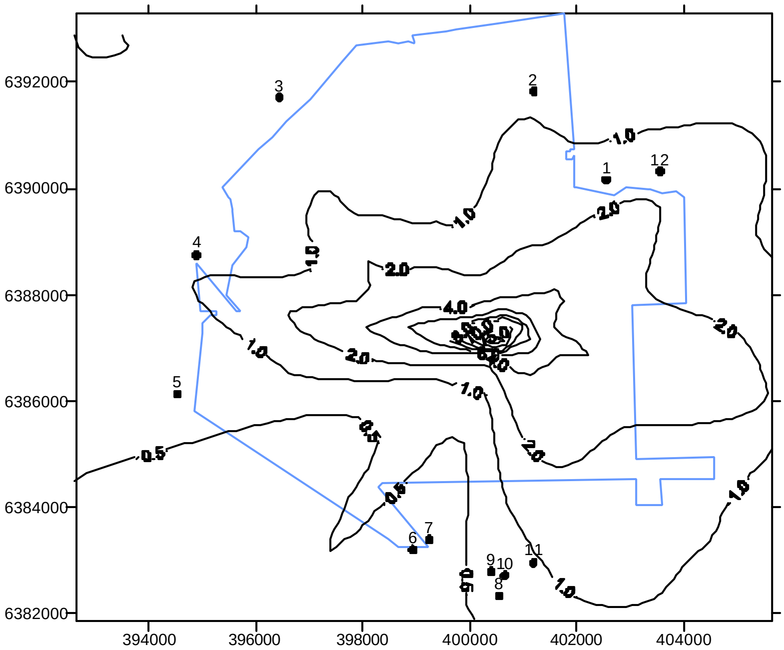
A comparison of the predicted maximum concentrations from the three models was made for two months, August 2002 and January 2003. Only two months were used due to the long run times required for TAPM as configured in this assessment. The month of August 2002 was chosen as this was the first month of the available data from the new Pinjarra meteorological station and is generally representative of the winter months. January 2003 was chosen to be representative of the summer months.

The results are presented for the second highest 1-hour average concentration and for the average concentrations for the two months in **Figure 16** to **Figure 21** and summarised at selected locations in **Table 2.** The second highest 1-hour average concentration was used as this is a more robust measure of the models performance.

SKM

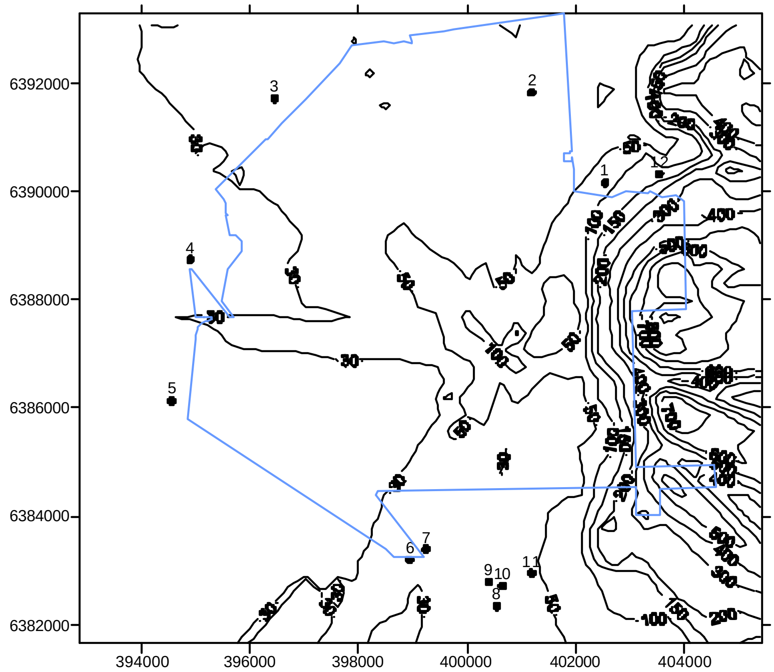


- **Figure 16 Predicted 2nd highest 1-hour average NO_X concentrations ($\mu g/m^3$) for August 2002 and January 2003 from TAPM**

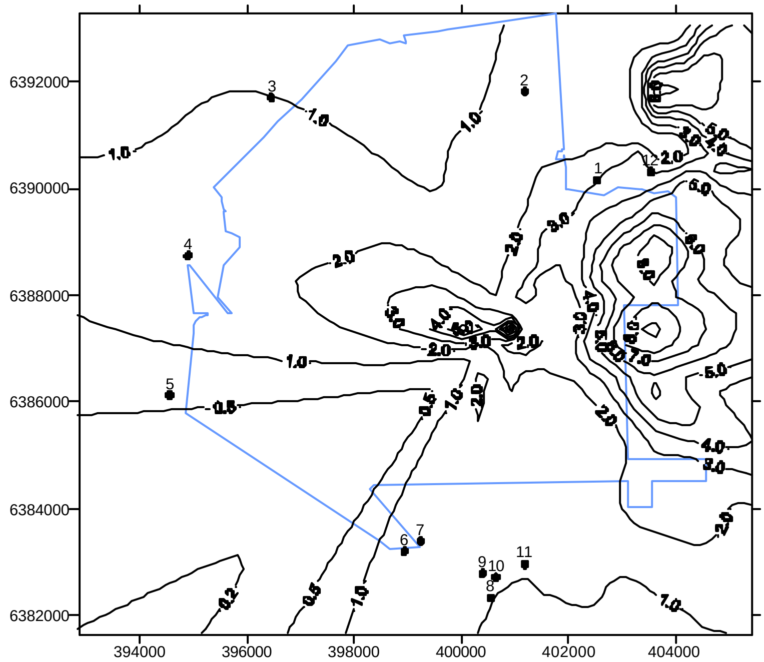


- **Figure 17 Predicted average NO_X concentrations ($\mu g/m^3$) for August 2002 and January 2003 from TAPM**

SKM

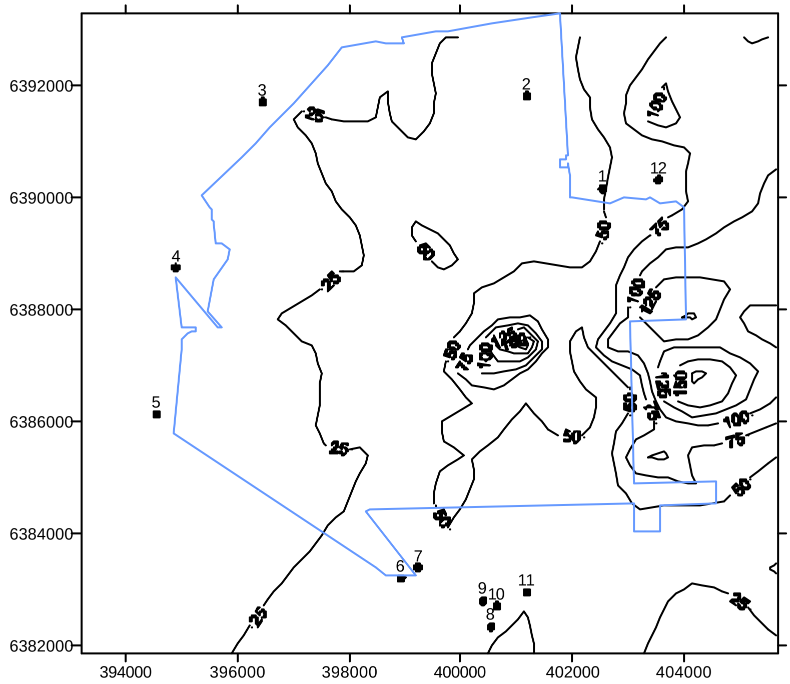


- **Figure 18 Predicted 2nd highest 1-hour average NO_X concentrations (mg/m^3) for August 2002 and January 2003 from AUSPLUME**

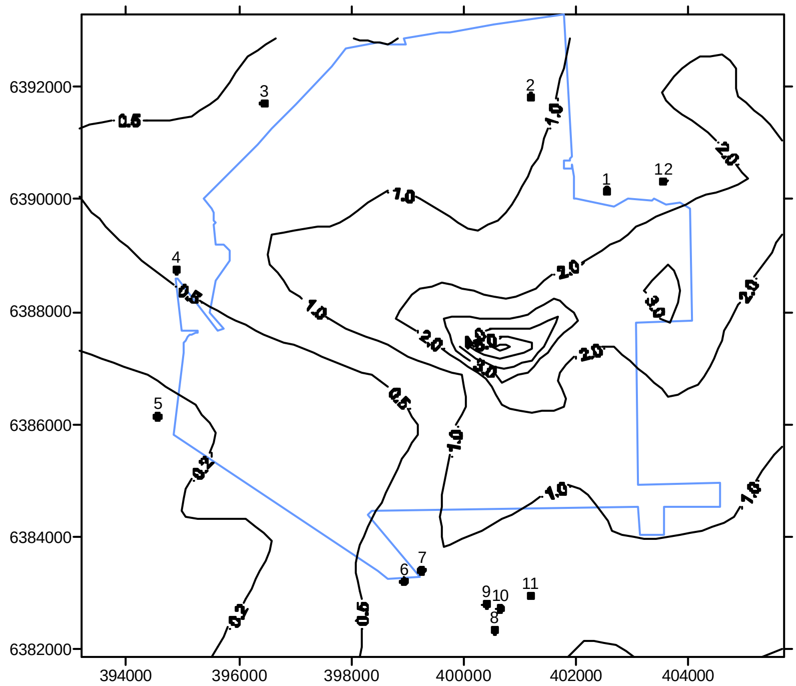


- **Figure 19 Predicted average NO_X concentrations (mg/m^3) for August 2002 and January 2003 from AUSPLUME**

SKM



- **Figure 20 Predicted 2nd highest 1-hour average NO_X concentrations ($\mu g/m^3$) for August 2002 and January 2003 from CALPUFF**



- **Figure 21 Predicted average NO_X concentrations ($\mu g/m^3$) for August 2002 and January 2003 from CALPUFF**

SKM

- **Table 2 Summary of Concentrations (mg/m³) predicted by TAPM, AUSPLUME and CALPUFF**

Concentration	TAPM	AUSPLUME	CALPUFF
2nd highest 1-hour average			
Max modelled Outside lease	240	937	180
Location 1	48	80	49
Location 4	45	25	17
Location 11	45	45	32
Average (August 2002 and January 2003)			
Max modelled Outside Lease	3.3	9.6	3.0
Location 1	1.55	2.95	1.2
Location 4	0.8	1.5	0.55
Location 11	0.95	1.1	0.66

Note: The results are dependent on the model configuration used. Therefore they should not necessarily be used to infer that one model is superior to the other. This requires a full comparison made of all model parameters available.

The results indicate that:

- For the 2nd highest 1-hour average predictions, AUSPLUME predicts significantly higher NO_X concentrations (937 µg/m³) than the other models with the maximum occurring on the hills to the east of the refinery. These high 1-hour average concentrations are predicted to occur under light winds and stable conditions. Maximum concentrations from the other models outside the Alcoa property are also predicted to occur on these hills to the east with a maximum of 240 µg/m³predicted from TAPM and 180 µg/m³ from CALPUFF.
- The 2nd highest 1-hour average concentrations from TAPM anywhere on the grid (**Figure 16**) are predicted to occur to the west of the refinery with these being due to building downwash or plume trapping in the early morning. Relatively high concentrations in this area are also predicted from CALPUFF.
- For the 2-month average concentrations, AUSPLUME again predicts the highest on the hills (9.6 µg/m³), with TAPM and CALPUFF predicting similar maximums (3.3 and 3.0 µg/m³ respectively). Generally the average concentrations from TAPM and CALPUFF are in good agreement, with CALPUFF predicting slightly lower concentrations than TAPM.
- All three models predict a region of relatively high average concentrations within 1-km west of the calciner area. This is considered to be the result of building downwash under easterly winds from stacks in this area (the calciner and ALD stacks).

4.3.2 Comparison of Models – Low level Sources

To determine the dispersion processes for short stacks, CALPUFF and AUSPLUME were run for one month (August 2002) for the low level sources which were modelled as volume sources (see **Appendix A** for a list of the sources).

The results are presented in **Figure 22** to **Figure 25** and show that:

- For the maximum 1-hour average concentrations, AUSPLUME predicts significantly higher concentrations than CALPUFF; and
- For the 1-month average concentrations, CALPUFF predicts higher concentrations on the coastal plain, with AUSPLUME predicting higher concentrations at locations 1 and 12 on the scarp. These higher concentrations on the scarp are due to CALPUFF predicting that the plume under stable light winds will not travel up the scarp but be deflected along it. This is evidenced by the rapid decrease in the average concentration with increasing terrain height. This feature is considered to be more realistic of the dispersion of low level sources under stable night time conditions.

4.4 Basis for Model Selection

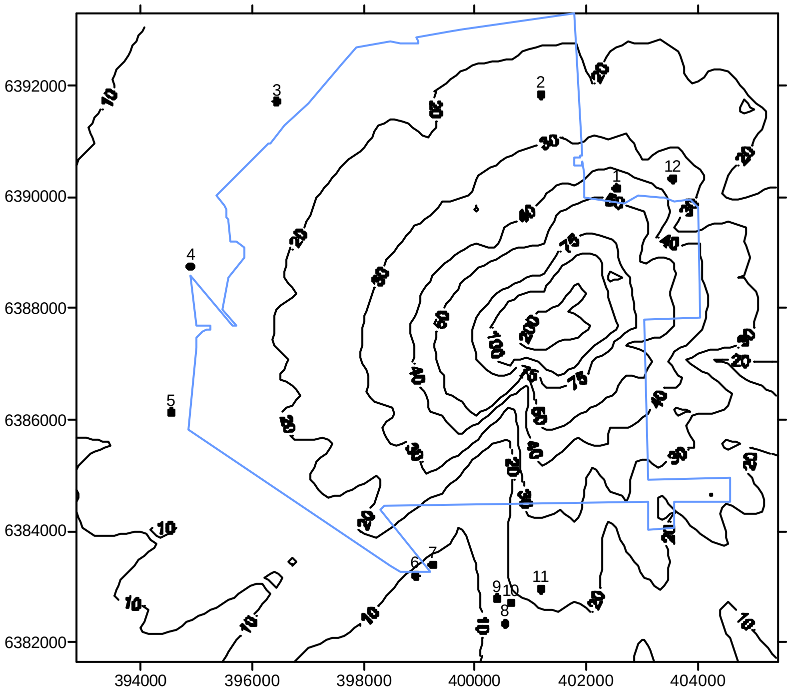
Of the three models considered for the assessment AUSPLUME generally predicts the highest concentrations offsite. This is due to its prediction of dispersion under light winds and stable conditions at night when the plumes are predicted to have greater impact on the hills. Given the simplistic terrain scheme within AUSPLUME, it is considered that the AUSPLUME predicted concentrations on the hills are overly conservative, with the results from TAPM and CALPUFF considered to be more realistic. For locations with lower concentrations such as at Pinjarra, AUSPLUME predicts the highest annual average concentrations offsite, whilst for 1-hour average concentrations it predicts higher concentrations than CALPUFF, but lower concentrations than TAPM.

Therefore on balance, of the two models which can be used for prediction of the large number of model runs required here (AUSPLUME and CALPUFF), AUSPLUME has been selected as it:

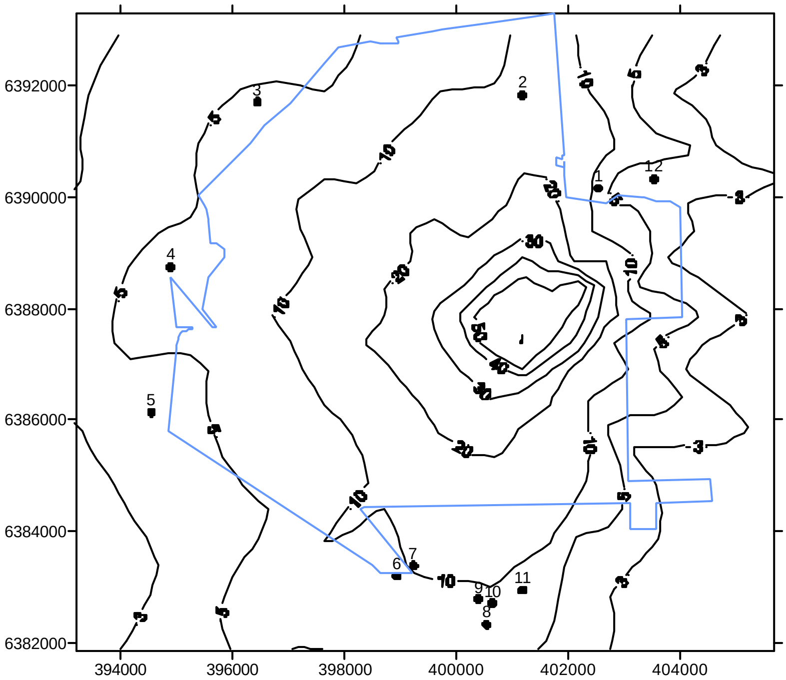
- Generally provides the most conservative concentration predictions of the three models at any of the nearest residences; and
- For the residences which are predicted to have highest concentrations (those to the north east) it provides the most conservative predictions of the three models for all averaging periods.

The selection of AUSPLUME will be verified along with the other two models at the completion of ambient monitoring programs. This is scheduled to occur in 2004, at the end of the NO_X, CO and field surveys.

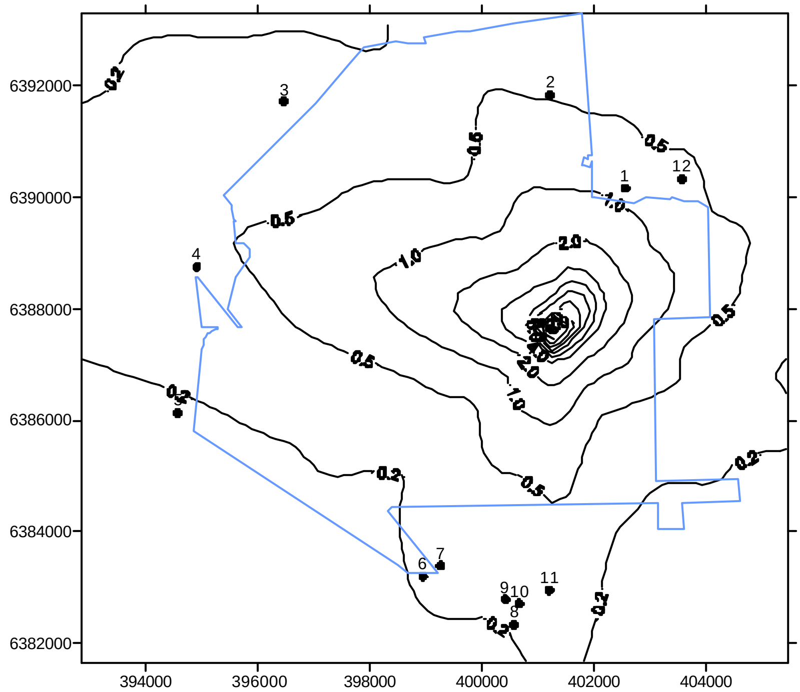
SKM



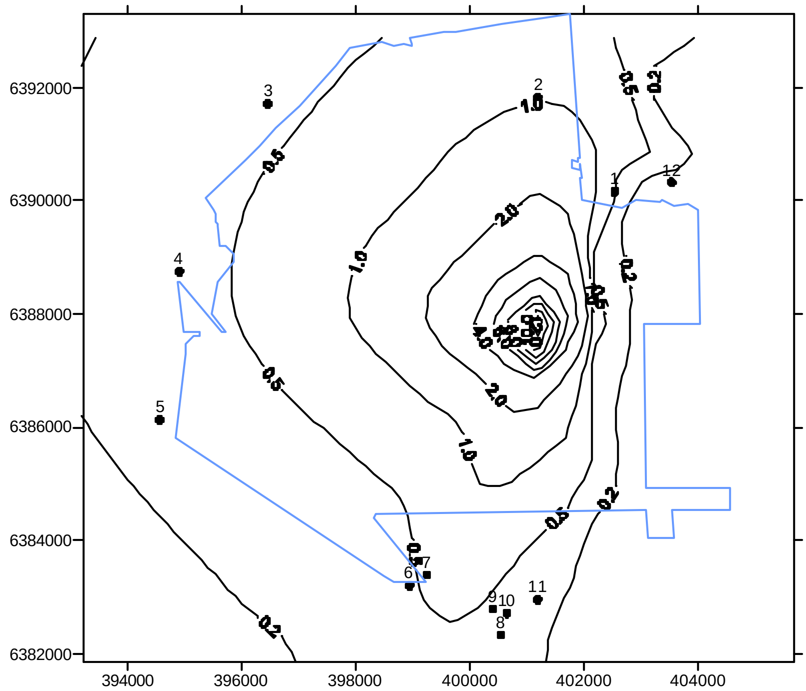
- **Figure 22 Predicted maximum 1-hour average concentrations (mg/m^3) of VOC for August 2002 from AUSPLUME for the "volume" sources**



- **Figure 23 Predicted maximum 1-hour average concentrations (mg/m^3) of VOC for August 2002 from CALPUFF for the "volume" sources**



- **Figure 24 Predicted 1-month average concentrations (mg/m[3]) of VOC for August 2002 from AUSPLUME for the "volume" sources**



- **Figure 25 Predicted 1-month average concentrations (mg/m[3]) of VOC for August 2002 from CALPUFF for the "volume" sources**

5. Emissions

5.1 Refinery Emissions

Emissions from the Pinjarra refinery for the baseline case (existing refinery with addition of the two co-generation plants) and for the upgrade were provided by Alcoa (Cox, 2003a). These have been summarised in **Table 3** to **Table 6** and are for the:

- Baseline case at peak emissions (peak flows and the maximum concentrations measured);
- Baseline case at average emissions (average flow rates and average concentrations);
- Upgrade case at peak emissions (peak flows and the maximum concentrations measured); and
- Upgrade case at average emissions (average flow rates and average concentrations).

In general with the upgrade, the flow rates for the majority of the sources increase. There is also the addition of a new source, the 44 Seed filtration building. For a description of the changes and the rationale for these changes see the Emission report (Alcoa, 2003).

The sources in **Table 3** to **Table 6** include all significant sources of VOCs, the metals of concern and combustion products. It is noted that sources of fugitive dust, such as wind blown dust, are not included in this list (see **Section 5.7** for further details on this).

The sources listed in **Table 3** to **Table 6** are classified as:

- Combustion equipment, for example the power station and calciners;
- Non combustion equipment, such as the vacuum pump stacks; and
- Grouped sources.

Grouped sources are those sources where there are a number of generally low level vents in the same area which have similar exit parameters and similar emissions. Examples of these are the various vents from tanks such as the 25A tanks and the 25C vents, which were grouped together as two single sources. These grouped sources were then modelled either as a:

Representative vent/stack, with the emissions being the sum of the individual emissions, but with exit parameters such as velocity and temperature being representative of one vent. This will provide a conservative estimate of the concentrations as the approximation neglects the separation of the individual stacks such that the horizontal spread is smaller than actually occurs. One example of a grouped source is given in **Figure 26** where the 8 rake/hood vents were modelled as one typical vent.

Table 3 Pinjarra Refinery Air Emissions - Baseline Case at Peak Emissions

	Temp.	Stack Diameter	Velocity	NO_x	CO	SO_2	Dust	VOC	Acetone	Acetaldehyde	Formaldehyde	2-Butanone	Benzene	Toluene	Xylenes	PAHs	Mercury	Arsenic	Selenium	Dioxins & Furans(ITEQ)	Ammonia	Manganese & Compounds	Cadmium & Compounds	Nickel & Compounds
	(°C)	(m)	(m/s)	Emission Rate (g/s)																				
Combustion Equipment Point Sources:																								
Oxalate Kiln Stack	65	1.00	9.1	0.18	2.79	0.146	0.495	4.30E-01	3.12E-01	3.10E-02	1.61E-02	1.19E-01	8.06E-03	8.06E-03	8.48E-04	1.78E-03	1.93E-03	3.78E-03	2.70E-03	2.80E-10			8.48E-05	8.48E-05
Calciner 1	161	1.54	38.8	2.53	4.78	0.629	0.528	1.19E+00	4.92E-01	1.19E-01	3.96E-01	1.23E-02	1.28E-02	3.52E-03	5.72E-04	3.96E-04	1.62E-04							
Calciner 2	162	1.54	37.3	1.73	25.42	1.630	2.407	1.14E+00	4.72E-01	1.14E-01	3.80E-01	1.18E-02	1.22E-02	3.38E-03	5.49E-04	3.80E-04	1.51E-04							
Calciner 1 & 2	**161**	**2.09**	**37.3**	**4.26**	**30.20**	**2.26**	**2.93**	**2.33E+00**	**9.63E-01**	**2.33E-01**	**7.76E-01**	**2.41E-02**	**2.50E-02**	**6.90E-03**	**1.12E-03**	**7.76E-04**	**3.14E-04**							
Calciner 3	157	1.54	38.6	4.35	12.08	1.074	0.972	1.20E+00	4.94E-01	1.19E-01	3.98E-01	1.24E-02	1.28E-02	3.53E-03	5.74E-04	3.98E-04	1.68E-04							
Calciner 4	165	1.83	19.2	2.39	8.23	0.622	0.932	8.41E-01	3.47E-01	8.39E-02	2.80E-01	8.70E-03	9.01E-03	2.49E-03	4.04E-04	2.80E-04	1.65E-04							
Calciner 3 & 4	**160**	**2.09**	**32.6**	**6.74**	**20.31**	**1.70**	**1.90**	**2.04E+00**	**8.41E-01**	**2.03E-01**	**6.77E-01**	**2.11E-02**	**2.18E-02**	**6.02E-03**	**9.78E-04**	**6.77E-04**	**3.33E-04**							
Calciner 5	179	1.83	20.1	3.38	8.48	0.723	1.169	8.55E-01	3.53E-01	8.54E-02	2.84E-01	8.85E-03	9.16E-03	2.53E-03	4.11E-04	2.84E-04	1.64E-04							
Calciner 6	180	1.83	24.1	6.59	8.49	0.918	2.738	1.02E+00	4.22E-01	1.02E-01	3.40E-01	1.06E-02	1.10E-02	3.02E-03	4.91E-04	3.40E-04	1.44E-04							
Calciner 5 & 6	**179**	**2.49**	**22.1**	**9.97**	**16.97**	**1.64**	**3.91**	**1.88E+00**	**7.75E-01**	**1.87E-01**	**6.24E-01**	**1.94E-02**	**2.01E-02**	**5.55E-03**	**9.02E-04**	**6.24E-04**	**3.08E-04**							
ALD	77	1.50	17.2	1.93	0.42	0.332	2.485	7.12E-01	5.23E-01	2.47E-02	8.72E-03	7.26E-03	7.41E-05	2.91E-03										
Boiler 2	120	3.05	8.7	9.99	8.68	2.091		1.93E-01	3.95E-02		2.93E-02	1.79E-02	2.38E-05	2.34E-02				2.93E-05				2.19E-03		
Boiler 5/6/7	138	4.37	9.2	18.58	2.30	2.352		4.03E-01	8.24E-02		6.11E-02	3.74E-02	4.96E-05	4.88E-02				6.11E-05				4.58E-03		
Gas Turbine 1	165	6.00	18.2	14.45	3.75	0.019		3.81E-01		7.25E-03	1.29E-01		2.18E-03	2.36E-02	1.16E-02			7.21E-05				5.41E-03		
Gas Turbine 2	165	6.00	18.2	14.45	3.75	0.019		3.81E-01		7.25E-03	1.29E-01		2.18E-03	2.36E-02	1.16E-02			7.21E-05				5.41E-03		
Non Combustion equipment Point Sources																								
OBF Vac Pump Stack	60	0.90	8.6					4.33E-02	3.28E-02	4.48E-03		4.48E-03		2.98E-04	8.95E-04									
Calciner Vac Pump West	50	0.60	2.5					1.77E-01	1.00E-01	3.84E-02		8.14E-03	9.88E-04	2.32E-03	1.98E-04	1.98E-05								
Calciner Vac Pump East	50	0.60	2.5					1.77E-01	1.00E-01	3.84E-02		8.14E-03	9.88E-04	2.32E-03	1.98E-04	1.98E-05								
ALD Vac Pump Stack	60	1.00	0.6					8.65E-02	4.95E-02	2.02E-02		4.28E-03	1.16E-05	1.22E-03	1.04E-04	2.41E-06								
45T Cooling Tower	30	17.00	12.8					1.57E+00	1.25E+00			2.51E-01		1.25E-03			5.79E-05							
ALD Cooling Tower	30	7.21	10.0					3.19E-01	2.35E-01	4.89E-02	2.22E-03	1.78E-02		2.53E-04										
44 Seed Filtration	50	1.80	0.0																					
Grouped Sources:																								
25A Tank Vents	90	0.255	18.5					6.44E-01	1.61E-01	2.44E-01		2.88E-02	1.99E-03	2.98E-02	1.59E-03	8.95E-04	1.13E-03		1.49E-04		1.91E-01	1.59E-03		2.49E-04
25A/C Droppers	100	0						5.61E-02	3.21E-02	1.31E-02		3.39E-03		7.78E-04	6.67E-05									
Excess BO - PRT & CT	100	0.755	3.5					5.50E-02	2.69E-02	1.21E-02		4.89E-03	1.19E-04	1.31E-03	1.19E-04		2.45E-04	2.39E-05	4.78E-05		3.70E-01	6.92E-03		5.13E-04
Dign. Vac Pump Stacks	50	0.154	7.0					8.96E-01	3.12E-02	6.60E-02		1.74E-02	9.52E-02	3.85E-01	4.55E-02	4.92E-04		3.58E-07	6.50E-05		8.80E-01	4.92E-07	4.92E-07	1.64E-06
B34 A-Rake Stacks	60	0.60	0.02					1.51E-02	7.39E-03	3.32E-03		1.35E-03	3.28E-05	3.61E-04	3.28E-05									
B40 Vac Pumps	50	0.154	4.0					5.94E-02	8.00E-03	7.52E-03		4.89E-03	4.30E-04	2.02E-02	2.27E-03	6.92E-04		4.67E-07	1.46E-05			5.26E-07	3.58E-07	1.24E-06
B42 Vac Pumps	55	0.078	13.1					3.14E-03	8.45E-04	6.16E-04		4.01E-04	8.45E-04	2.44E-04		1.86E-04		1.43E-07	2.44E-06					
35F & D Vents	98	0.255	6.9					1.95E-01	4.58E-02	1.97E-02		1.17E-02	2.63E-04	2.89E-02	1.57E-02	1.41E-03								
35A Vents	92	0.305	3.3					6.56E-02	1.51E-02	7.07E-03		4.21E-03	8.95E-05	1.02E-02	4.66E-03	4.57E-04								
Misc OC2 Liquor Tank Vents	97	0.248	20.9					2.19E-01	5.04E-02	2.36E-02		1.40E-02	2.98E-04	3.40E-02	1.55E-02	1.52E-03								
35C Washer Area Vents - Banks 1-2	97	0.255	15.0					1.73E-01	3.83E-02	1.79E-02		1.72E-02	2.27E-04	2.59E-02	1.18E-02	1.16E-03								
35C Washer Area Vents - Banks 3-5	97	0.255	15.0					2.59E-01	5.75E-02	2.69E-02		2.59E-02	3.40E-04	3.88E-02	1.77E-02	1.74E-03								
Fresh Water Storage Lake																	9.67E-03							
Total				**80.56**	**89.17**	**10.55**	**11.73**	**1.38E+01**	**5.78E+00**	**1.29E+00**	**2.45E+00**	**5.67E-01**	**1.81E-01**	**7.32E-01**	**1.43E-01**	**1.24E-02**	**1.40E-02**	**4.03E-03**	**2.98E-03**	**2.80E-10**	**1.44E+00**	**2.61E-02**	**8.57E-05**	**8.54E-04**

Note: For a discussion on the substances included under PAHs refer to Environ (2003).

▪ Table 4 Pinjarra Refinery Air Emissions - Baseline Case at Average Emissions

	Temp.	Stack Diameter	Velocity	NO_X	CO	SO_2	Dust	VOC	Acetone	Acetaldehyde	Formaldehyde	2-Butanone	Benzene	Toluene	Xylenes	PAHs	Mercury	Arsenic	Selenium	Dioxins & Furans(ITEQ)	Ammonia	Manganese & Compounds	Cadmium & Compounds	Nickel & Compounds
	(°C)	(m)	(m/s)	Emission Rate (g/s)																				
Combustion Equipment Point Sources:																								
Oxalate Kiln Stack	65	1.000	7.6	0.08	1.31	0.022	0.263	1.53E-01	1.05E-01	1.87E-02	1.04E-02	3.20E-03	2.10E-03	3.19E-03	3.41E-04	7.46E-05	1.62E-03	3.17E-03	2.27E-03	2.35E-10			7.13E-05	7.13E-05
Calciner 1	158	1.537	32.1	1.03	1.56	0.228	0.363	3.02E-01	1.16E-01	7.19E-02	8.15E-02	6.09E-03	3.18E-03	1.21E-03	2.31E-04	1.23E-04	1.35E-04							
Calciner 2	159	1.537	33.1	0.99	10.35	0.563	0.917	3.11E-01	1.20E-01	7.40E-02	8.39E-02	6.27E-03	3.27E-03	1.24E-03	2.38E-04	1.27E-04	1.35E-04							
Calciner 1 & 2	**158**	**2.090**	**32.6**	**2.02**	**11.91**	**0.791**	**1.280**	**6.13E-01**	**2.36E-01**	**1.46E-01**	**1.65E-01**	**1.24E-02**	**6.45E-03**	**2.45E-03**	**4.70E-04**	**2.50E-04**	**2.71E-04**							
Calciner 3	155	1.537	30.9	2.25	1.92	0.419	0.487	2.93E-01	1.13E-01	6.98E-02	7.91E-02	5.92E-03	3.08E-03	1.17E-03	2.25E-04	1.20E-04	1.35E-04							
Calciner 4	166	1.829	15.8	0.67	2.57	0.248	0.534	2.11E-01	8.11E-02	5.02E-02	5.68E-02	4.25E-03	2.22E-03	8.41E-04	1.62E-04	8.59E-05	1.35E-04							
Calciner 3 & 4	**160**	**2.090**	**26.3**	**2.92**	**4.49**	**0.668**	**1.021**	**5.04E-01**	**1.94E-01**	**1.20E-01**	**1.36E-01**	**1.02E-02**	**5.30E-03**	**2.01E-03**	**3.86E-04**	**2.05E-04**	**2.71E-04**							
Calciner 5	175	1.829	16.4	1.91	2.60	0.237	0.658	2.15E-01	8.28E-02	5.12E-02	5.80E-02	4.34E-03	2.26E-03	8.59E-04	1.65E-04	8.77E-05	1.35E-04							
Calciner 6	172	1.829	22.1	2.84	4.04	0.400	1.876	2.91E-01	1.12E-01	6.94E-02	7.87E-02	5.88E-03	3.07E-03	1.16E-03	2.24E-04	1.19E-04	1.35E-04							
Calciner 5 & 6	**173**	**2.490**	**19.3**	**4.76**	**6.64**	**0.637**	**2.534**	**5.06E-01**	**1.95E-01**	**1.21E-01**	**1.37E-01**	**1.02E-02**	**5.33E-03**	**2.02E-03**	**3.88E-04**	**2.07E-04**	**2.71E-04**							
ALD	77	1.500	15.0	1.41	0.09	0.054	1.014	2.47E-01	1.64E-01	1.55E-02	6.64E-03	4.18E-03	2.40E-05	1.17E-03										
Boiler 2	120	3.050	7.7	8.22	0.69	0.259		6.11E-02	1.45E-02		1.29E-02	2.88E-03	2.09E-05	7.89E-06				2.58E-05				1.93E-03		
Boiler 5/6/7	138	4.370	8.1	15.97	0.84	0.251		1.28E-01	3.02E-02		2.69E-02	6.01E-03	4.37E-05	1.65E-05				5.37E-05				4.03E-03		
Gas Turbine 1	165	6.000	18.2	14.45	3.75	0.019		3.81E-01		7.25E-03	1.29E-01		2.18E-03	2.36E-02	1.16E-02			7.21E-05				5.41E-03		
Gas Turbine 2	165	6.000	18.2	14.45	3.75	0.019		3.81E-01		7.25E-03	1.29E-01		2.18E-03	2.36E-02	1.16E-02			7.21E-05				5.41E-03		
Non Combustion equipment Point Sources																								
OBF Vac Pump Stack	60	0.90	8.0					3.94E-02	3.06E-02	4.03E-03		4.03E-03		1.39E-04	4.17E-04									
Calciner Vac Pump West	50	0.60	2.5					1.26E-01	7.46E-02	2.82E-02		5.46E-03	1.87E-04	1.45E-03	1.18E-04	6.04E-06								
Calciner Vac Pump East	50	0.60	2.5					1.26E-01	7.46E-02	2.82E-02		5.46E-03	1.87E-04	1.45E-03	1.18E-04	6.04E-06								
ALD Vac Pump Stack	60	1.00	0.6					8.14E-02	4.68E-02	1.89E-02		4.13E-03	1.16E-05	1.10E-03	9.47E-05	2.41E-06								
45T Cooling Tower	30	17.00	11.9					1.33E+00	1.05E+00			2.33E-01		9.22E-04			5.39E-05							
ALD Cooling Tower	30	7.21	10.0					2.90E-01	2.11E-01	4.89E-02	2.22E-03	1.78E-02	3.33E-05	2.00E-04										
44 Seed Filtration	50	1.800	0.0										3.33E-05											
Grouped Sources:																								
25A Tank Vents	90	0.255	15.5					2.45E-01	7.92E-02	7.41E-02		1.30E-02	1.47E-03	1.79E-02	1.21E-03	1.03E-04	9.48E-04		1.25E-04		1.60E-01	1.33E-03		2.08E-04
25A/C Droppers	100							4.39E-02	2.31E-02	1.26E-02		3.36E-03		6.94E-04	3.33E-05									
Excess BO - PRT & CT	100	0.755	3.2					3.95E-02	2.11E-02	8.97E-03		3.28E-03	5.56E-05	6.69E-04	6.25E-05		2.28E-04	2.22E-05	4.44E-05		3.44E-01	6.44E-03		4.78E-04
Dign. Vac Pump Stacks	50	0.154	6.5					5.27E-01	1.16E-02	3.69E-02		1.10E-02	7.34E-02	2.73E-01	3.20E-02	1.35E-04		3.34E-07	6.05E-05		8.19E-01	4.58E-07	4.58E-07	1.53E-06
B34 A-Rake Stacks	60	0.60	0.02					1.09E-02	5.81E-03	2.47E-03		9.01E-04	1.53E-05	1.84E-04	1.72E-05									
B40 Vac Pumps	50	0.154	4.0					3.70E-02	3.11E-03	4.12E-03		2.56E-03	2.13E-04	1.55E-02	1.78E-03	5.48E-04		4.35E-07	1.36E-05			4.90E-07	3.33E-07	1.16E-06
B42 Vac Pumps	55	0.078	13.1					2.92E-03	7.87E-04	5.73E-04		3.73E-04	7.87E-04	2.27E-04		1.73E-04		1.33E-07	2.27E-06					
35F & D Vents	98	0.255	6.4					1.09E-01	2.69E-02	1.14E-02		6.43E-03	1.14E-04	1.46E-02	8.81E-03	7.44E-04								
35A Vents	92	0.305	3.0					5.46E-02	1.34E-02	6.42E-03		3.58E-03	6.67E-05	7.54E-03	3.42E-03	3.33E-04								
Misc OC2 Liquor Tank Vents	97	0.248	19.5					1.82E-01	4.47E-02	2.14E-02		1.19E-02	2.22E-04	2.51E-02	1.14E-02	1.11E-03								
35C Washer Area Vents - Banks 1-2	97	0.255	14.0					7.58E-02	3.08E-02	9.45E-03		1.43E-02	1.32E-04	5.15E-03	2.16E-03	2.11E-04								
35C Washer Area Vents - Banks 3-5	97	0.255	14.0					1.14E-01	4.62E-02	1.42E-02		2.15E-02	1.99E-04	7.73E-03	3.25E-03	3.17E-04								
Fresh Water Storage Lake																	9.00E-03							
Total				**64.28**	**33.47**	**2.722**	**6.112**	**6.40E+00**	**2.73E+00**	**7.66E-01**	**7.55E-01**	**4.11E-01**	**1.01E-01**	**4.31E-01**	**8.97E-02**	**4.43E-03**	**1.27E-02**	**3.42E-03**	**2.52E-03**	**2.35E-10**	**1.32E+00**	**2.46E-02**	**7.21E-05**	**7.60E-04**

Note: For a discussion on the substances included under PAHs refer to Environ (2003).

▪ Table 5 Pinjarra Refinery Air Emissions - Upgrade Case at Peak Emissions

	Temp.	Stack Diameter	Velocity	NO_x	CO	SO_2	Dust	VOC	Acetone	Acetaldehyde	Formaldehyde	2-Butanone	Benzene	Toluene	Xylenes	PAHs	Mercury	Arsenic	Selenium	Dioxins & Furans(ITEQ)	Ammonia	Manganese & Compounds	Cadmium & Compounds	Nickel & Compounds
	(°C)	(m)	(m/s)	Emission Rate (g/s)																				
Combustion Equipment Point Sources:																								
Oxalate Kiln Stack	90	1.00	12.8	0.24	3.67	0.192	0.056	1.13E-02	8.21E-03	8.16E-04	4.25E-04	3.13E-04	2.12E-04	2.12E-04	2.24E-05	4.68E-05	2.54E-03	7.49E-04	3.56E-03	3.69E-10			1.68E-05	1.12E-04
Calciner 1	158	1.54	36.7	2.41	4.56	0.600	0.503	1.13E+00	4.69E-01	1.13E-01	3.77E-01	1.17E-02	1.22E-02	3.36E-03	5.45E-04	3.77E-04	1.55E-04							
Calciner 2	159	1.54	36.8	1.72	25.25	1.619	2.391	1.13E+00	4.69E-01	1.13E-01	3.77E-01	1.17E-02	1.22E-02	3.36E-03	5.45E-04	3.77E-04	1.50E-04							
Calciner 1 & 2	**158**	**2.09**	**36.7**	**4.13**	**29.81**	**2.218**	**2.894**	**2.27E+00**	**9.37E-01**	**2.27E-01**	**7.55E-01**	**2.35E-02**	**2.43E-02**	**6.71E-03**	**1.09E-03**	**7.55E-04**	**3.05E-04**							
Calciner 3	155	1.54	36.4	4.13	11.47	1.019	0.923	1.13E+00	4.69E-01	1.13E-01	3.77E-01	1.17E-02	1.22E-02	3.36E-03	5.45E-04	3.77E-04	1.60E-04							
Calciner 4	157	1.83	28.7	3.59	12.34	0.933	1.165	1.26E+00	5.21E-01	1.26E-01	4.19E-01	1.30E-02	1.35E-02	3.73E-03	6.06E-04	4.19E-04	2.47E-04							
Calciner 3 & 4	**155**	**2.09**	**36.9**	**7.72**	**23.81**	**1.952**	**2.088**	**2.40E+00**	**9.89E-01**	**2.39E-01**	**7.97E-01**	**2.48E-02**	**2.57E-02**	**7.08E-03**	**1.15E-03**	**7.97E-04**	**4.06E-04**							
Calciner 5	157	1.83	28.7	4.99	12.51	1.066	1.165	1.26E+00	5.21E-01	1.26E-01	4.19E-01	1.30E-02	1.35E-02	3.73E-03	6.06E-04	4.19E-04	2.42E-04							
Calciner 6	157	1.83	28.7	8.13	10.48	1.132	1.165	1.26E+00	5.21E-01	1.26E-01	4.19E-01	1.30E-02	1.35E-02	3.73E-03	6.06E-04	4.19E-04	1.78E-04							
Calciner 5 & 6	**159**	**2.49**	**28.7**	**13.12**	**22.99**	**2.198**	**2.330**	**2.52E+00**	**1.04E+00**	**2.52E-01**	**8.39E-01**	**2.61E-02**	**2.70E-02**	**7.46E-03**	**1.21E-03**	**8.39E-04**	**4.20E-04**							
ALD	77	1.50	17.2	1.93	0.42	0.332	2.485	7.12E-01	5.23E-01	2.47E-02	8.72E-03	7.26E-03	7.41E-05	2.91E-03										
Boiler 2	120	3.05	7.2	8.28	7.20	1.734		1.60E-01	3.28E-02	0.00E+00	2.43E-02	1.49E-02	1.97E-05	1.94E-02				2.43E-05				1.82E-03		
Boiler 5/6/7	133	4.37	7.5	15.42	1.91	1.951		3.34E-01	6.84E-02		5.07E-02	3.10E-02	4.12E-05	4.05E-02				5.07E-05				3.80E-03		
Gas Turbine 1	165	6.00	18.2	14.45	3.75	0.019		3.81E-01		7.25E-03	1.29E-01		2.18E-03	2.36E-02	1.16E-02			7.21E-05				5.41E-03		
Gas Turbine 2	165	6.00	18.2	14.45	3.75	0.006		3.81E-01		7.25E-03	1.29E-01		2.18E-03	2.36E-02	1.16E-02			7.21E-05				5.41E-03		
Non Combustion equipment Point Sources																								
OBF Vac Pump Stack	60	0.90	10.5					5.31E-02	4.03E-02	5.50E-03		5.50E-03		3.66E-04	1.10E-03									
Calciner Vac Pump West	50	0.60	2.5					2.04E-01	1.15E-01	4.41E-02		9.36E-03	1.14E-03	2.67E-03	2.27E-04	2.27E-05								
Calciner Vac Pump East	50	0.60	2.5					2.04E-01	1.15E-01	4.41E-02		9.36E-03	1.14E-03	2.67E-03	2.27E-04	2.27E-05								
ALD Vac Pump Stack	60	1.00	0.6					8.65E-02	4.95E-02	2.02E-02		4.28E-03	1.16E-05	1.22E-03	1.04E-04	2.41E-06								
45T Cooling Tower	30	19.01	11.9					1.83E+00	1.46E+00			2.92E-01		1.46E-03			6.74E-05							
ALD Cooling Tower	30	7.21	10.0					3.19E-01	2.35E-01	4.89E-02	2.22E-03	1.78E-02		2.53E-04										
44 Seed Filtration	50	1.800	19.3					1.31E-01	5.94E-02	1.07E-02		5.62E-03	8.88E-04	3.18E-03	1.08E-03									
Grouped Sources:																								
25A Tank Vents	90	0.255	21.5					3.75E-02	9.35E-03	1.42E-02		1.68E-03	1.16E-04	1.74E-03	9.26E-05	5.21E-05	1.32E-03		1.74E-04		2.22E-01	1.85E-03		2.89E-05
25A/C Droppers	100	0						2.81E-03	1.61E-03	6.56E-04		1.69E-04	0.00E+00	3.89E-05	3.33E-06									
Excess BO - PRT & CT	100	0.755	4.0					6.40E-03	3.13E-03	1.40E-03		5.69E-04	1.39E-05	1.53E-04	1.39E-05		2.85E-04	2.78E-05	5.56E-05		4.31E-01	8.06E-03		5.97E-05
Dign. Vac Pump Stacks	50	0.154	8.1					2.09E-02	7.26E-04	1.54E-03		4.05E-04	2.22E-03	8.95E-03	1.06E-03	1.15E-05		4.17E-07	7.57E-05		1.02E+00	5.73E-07	5.73E-07	1.91E-06
B34 A-Rake Stacks	60	0.60	0.03					1.76E-02	8.59E-03	3.86E-03		1.57E-03	3.82E-05	4.20E-04	3.82E-05									
B40 Vac Pumps	50	0.154	4.0					1.38E-03	1.86E-04	1.75E-04		1.14E-04	1.00E-05	4.69E-04	5.28E-05	1.61E-05		5.43E-07	1.70E-05			6.12E-07	4.17E-07	1.45E-06
B42 Vac Pumps	55	0.078	13.1					7.30E-05	1.97E-05	1.43E-05		9.33E-06	1.97E-05	5.67E-06	0.00E+00	4.33E-06		1.67E-07	2.83E-06					
35F & D Vents	98	0.255	8.0					2.27E-01	5.33E-02	2.30E-02		1.36E-02	3.06E-04	3.36E-02	1.83E-02	1.65E-03								
35A Vents	92	0.305	3.8					7.63E-02	1.76E-02	8.23E-03		4.90E-03	1.04E-04	1.19E-02	5.42E-03	5.31E-04								
Misc OC2 Liquor Tank Vents	97	0.248	25.7					2.68E-01	6.19E-02	2.89E-02		1.72E-02	3.66E-04	4.18E-02	1.91E-02	1.87E-03								
35C Washer Area Vents - Banks 1-2	97	0.255	14.0					1.61E-01	3.57E-02	1.67E-02		1.60E-02	2.11E-04	2.41E-02	1.10E-02	1.08E-03								
35C Washer Area Vents - Banks 3-5	97	0.255	19.8					3.42E-01	7.58E-02	3.54E-02		3.41E-02	4.49E-04	5.11E-02	2.33E-02	2.29E-03								
Fresh Water Storage Lake																	1.12E-02							
Total				**79.75**	**97.31**	**10.603**	**9.852**	**1.31E+01**	**5.94E+00**	**1.07E+00**	**2.73E+00**	**5.62E-01**	**8.88E-02**	**3.18E-01**	**1.08E-01**	**9.98E-03**	**1.66E-02**	**9.97E-04**	**3.89E-03**	**3.69E-10**	**1.68E+00**	**2.63E-02**	**1.78E-05**	**2.04E-04**

Note: For a discussion on the substances included under PAHs refer to Environ (2003).

■ Table 6 Pinjarra Refinery Air Emissions - Upgrade Case at Average Emissions

	Temp.	Stack Diameter	Velocity	NO_X	CO	SO_2	Dust	VOC	Acetone	Acetaldehyde	Formaldehyde	2-Butanone	Benzene	Toluene	Xylenes	PAHs	Mercury	Arsenic	Selenium	Dioxins & Furans(ITEQ)	Ammonia	Manganese & Compounds	Cadmium & Compounds	Nickel & Compounds
	(°C)	(m)	(m/s)	Emission Rate (g/s)																				
Combustion Equipment Point Sources:																								
Oxalate Kiln Stack	90	1.000	10.8	0.10	0.03	0.030	0.047	4.04E-03	2.76E-03	4.93E-04	2.75E-04	8.44E-05	5.53E-05	8.39E-05	8.97E-06	1.97E-06	2.13E-03	7.49E-04	3.00E-03	3.10E-10			1.68E-05	9.40E-05
Calciner 1	158	1.537	31.7	1.02	1.55	0.226	0.359	2.99E-01	1.15E-01	7.12E-02	8.07E-02	6.03E-03	3.14E-03	1.19E-03	2.29E-04	1.22E-04	1.34E-04							
Calciner 2	159	1.537	31.8	0.95	9.95	0.541	0.882	2.99E-01	1.15E-01	7.12E-02	8.07E-02	6.03E-03	3.14E-03	1.19E-03	2.29E-04	1.22E-04	1.30E-04							
Calciner 1 & 2	**158**	**2.090**	**31.7**	**1.97**	**11.49**	**0.767**	**1.241**	**5.98E-01**	**2.30E-01**	**1.42E-01**	**1.61E-01**	**1.21E-02**	**6.29E-03**	**2.39E-03**	**4.58E-04**	**2.44E-04**	**2.64E-04**							
Calciner 3	155	1.537	31.5	2.29	1.96	0.428	0.496	2.99E-01	1.15E-01	7.12E-02	8.07E-02	6.03E-03	3.14E-03	1.19E-03	2.29E-04	1.22E-04	1.38E-04							
Calciner 4	157	1.829	24.6	1.56	4.01	0.388	0.598	3.29E-01	1.27E-01	7.83E-02	8.87E-02	6.63E-03	3.46E-03	1.31E-03	2.52E-04	1.34E-04	2.11E-04							
Calciner 3 & 4	**155**	**2.090**	**31.5**	**3.85**	**5.97**	**0.815**	**1.095**	**6.28E-01**	**2.42E-01**	**1.49E-01**	**1.69E-01**	**1.27E-02**	**6.60E-03**	**2.51E-03**	**4.81E-04**	**2.56E-04**	**3.49E-04**							
Calciner 5	157	1.829	24.6	1.56	4.10	0.363	0.598	3.29E-01	1.27E-01	7.83E-02	8.87E-02	6.63E-03	3.46E-03	1.31E-03	2.52E-04	1.34E-04	2.07E-04							
Calciner 6	157	1.829	24.6	1.56	4.55	0.451	0.598	3.29E-01	1.27E-01	7.83E-02	8.87E-02	6.63E-03	3.46E-03	1.31E-03	2.52E-04	1.34E-04	1.53E-04							
Calciner 5 & 6	**157**	**2.490**	**24.6**	**3.12**	**8.65**	**0.814**	**1.197**	**6.57E-01**	**2.53E-01**	**1.57E-01**	**1.77E-01**	**1.33E-02**	**6.92E-03**	**2.63E-03**	**5.04E-04**	**2.68E-04**	**3.59E-04**							
ALD	77	1.500	15.0	1.41	0.09	0.054	1.014	2.47E-01	1.64E-01	1.55E-02	6.64E-03	4.18E-03	2.40E-05	1.17E-03										
Boiler 2	120	3.050	6.9	3.13	0.62	0.232		5.47E-02	1.30E-02		1.15E-02	2.58E-03	1.87E-05	7.06E-06				2.31E-05				1.73E-03		
Boiler 5/6/7	133	4.370	7.2	6.53	0.75	0.225		1.14E-01	2.71E-02		2.41E-02	5.38E-03	3.91E-05	1.47E-05				4.81E-05				3.61E-03		
Gas Turbine 1	165	6.000	18.2	14.45	3.75	0.019		3.81E-01		7.25E-03	1.29E-01		2.18E-03	2.36E-02	1.16E-02			7.21E-05				5.41E-03		
Gas Turbine 2	165	6.000	18.2	14.45	3.75	0.019		3.81E-01		7.25E-03	1.29E-01		2.18E-03	2.36E-02	1.16E-02			7.21E-05				5.41E-03		
Non Combustion equipment Point Sources																								
OBF Vac Pump Stack	60	0.90	10.0					4.94E-02	3.83E-02	5.04E-03		5.04E-03		1.74E-04	5.22E-04									
Calciner Vac Pump West	50	0.60	2.5					1.50E-01	8.86E-02	3.35E-02		6.49E-03	2.22E-04	1.72E-03	1.41E-04	7.17E-06								
Calciner Vac Pump East	50	0.60	2.5					1.50E-01	8.86E-02	3.35E-02		6.49E-03	2.22E-04	1.72E-03	1.41E-04	7.17E-06								
ALD Vac Pump Stack	60	1.00	0.6					8.14E-02	4.68E-02	1.89E-02		4.13E-03	1.16E-05	1.10E-03	9.47E-05	2.41E-06								
45T Cooling Tower	30	19.01	11.3					1.58E+00	1.25E+00			2.77E-01	0.00E+00	1.09E-03			6.40E-05							
ALD Cooling Tower	30	7.21	10.0					2.90E-01	2.11E-01	4.89E-02	2.22E-03	1.78E-02	3.33E-05	2.00E-04										
44 Seed Filtration	50	1.800	14.4					6.12E-02	2.89E-02	7.12E-03		4.44E-03	2.78E-04	1.45E-03	6.23E-04									
Grouped Sources:																								
25A Tank Vents	90	0.255	18.4					1.46E-02	4.70E-03	4.40E-03		7.69E-04	8.73E-05	1.06E-03	7.21E-05	6.13E-06	1.25E-03		1.65E-04		2.11E-01	1.76E-03		2.75E-05
25A/C Droppers	100							2.19E-03	1.16E-03	6.32E-04		1.68E-04	0.00E+00	3.47E-05	1.67E-06									
Excess BO - PRT & CT	100	0.755	3.8					4.69E-03	2.51E-03	1.07E-03		3.89E-04	6.60E-06	7.95E-05	7.42E-06		2.71E-04	2.64E-05	5.28E-05		4.09E-01	7.65E-03		5.67E-05
Dign. Vac Pump Stacks	50	0.154	7.7					1.25E-02	2.76E-04	8.77E-04		2.62E-04	1.74E-03	6.48E-03	7.61E-04	3.20E-06		3.96E-07	7.19E-05		9.73E-01	5.44E-07	5.44E-07	1.81E-06
B34 A-Rake Stacks	60	0.60	0.02					1.29E-02	6.89E-03	2.93E-03		1.07E-03	1.81E-05	2.19E-04	2.04E-05									
B40 Vac Pumps	50	0.154	4.0					8.78E-04	7.38E-05	9.78E-05		6.09E-05	5.05E-06	3.68E-04	4.22E-05	1.30E-05		5.16E-07	1.62E-05			5.82E-07	3.96E-07	1.38E-06
B42 Vac Pumps	55	0.078	13.1					6.94E-05	1.87E-05	1.36E-05		8.87E-06	1.87E-05	5.38E-06		4.12E-06		1.58E-07	2.69E-06					
35F & D Vents	98	0.255	7.6					1.29E-01	3.19E-02	1.36E-02		7.63E-03	1.35E-04	1.73E-02	1.05E-02	8.84E-04								
35A Vents	92	0.305	3.6					6.48E-02	1.59E-02	7.62E-03		4.26E-03	7.92E-05	8.96E-03	4.06E-03	3.96E-04								
Misc OC2 Liquor Tank Vents	97	0.248	24.4					2.28E-01	5.60E-02	2.68E-02		1.50E-02	2.78E-04	3.15E-02	1.43E-02	1.39E-03								
35C Washer Area Vents - Banks 1-2	97	0.255	14.0					7.58E-02	3.08E-02	9.45E-03		1.43E-02	1.32E-04	5.15E-03	2.16E-03	2.11E-04								
35C Washer Area Vents - Banks 3-5	97	0.255	18.4					1.49E-01	6.07E-02	1.86E-02		2.82E-02	2.61E-04	1.01E-02	4.26E-03	4.16E-04								
Fresh Water Storage Lake																	1.07E-02							
Total				**49.02**	**35.11**	**2.975**	**4.593**	**6.12E+00**	**2.89E+00**	**7.12E-01**	**8.11E-01**	**4.44E-01**	**2.78E-02**	**1.45E-01**	**6.23E-02**	**4.11E-03**	**1.54E-02**	**9.91E-04**	**3.30E-03**	**3.10E-10**	**1.59E+00**	**2.56E-02**	**1.78E-05**	**1.81E-04**

Note: For a discussion on the substances included under PAHs refer to Environ (2003).

- **Figure 26 Building 34Rake Vents. Modelled as One representative vent**

- Volume source, where the low level sources emitting from a building or tank were assumed initially to have dimensions of a cube to approximate the buildings that they are released next to. This is a standard procedure recommended within AUSPLUME as the initial dispersion of these low level vents is due to the plume being mixed around the building structure by the turbulence induced in the wind by the building. As such, if there are five small vents near or on this structure, they are modelled as one volume source with the dimensions derived from the structure, but with the emissions being the sum of the individual sources. Grouping of such sources into one will have no effect on ground level concentrations as the alternative is to model individual volume sources at the same location. An example of a grouped source modelled as a volume source are the building 42 vacuum pump vents shown in **Figure 27**.

Figure 27 Building 42, 3 & 4 Vacuum Pump Vents

Likewise for the modelling of the six calciner stacks, to account for plume merging of each of the three pairs of stacks that are separated by 8m (see **Figure 28**), the six calciner stacks were grouped into pairs of two following the procedure of Briggs (1974). The emission parameters for the combined calciner stacks are summarised in **Table 3** to **Table 6**.

SKM

Figure 28 Calciner Area

5.2 Modelling Particulate

Material in particulate form is released from the calciner stacks, ALD stack and oxalate kiln with small amounts of metals, dioxin and furans and PAHs which also may be emitted in particulate form from various stacks and vents. Particulate released from fugitive sources, most notably the bauxite stockpile area and residue drying area under strong winds, is not included in this assessment. Particulate from these sources has been addressed in Environ (2003).

To date there are no particle size distribution data for sources at the Pinjarra Refinery. The only applicable data available is from a stack test under normal operations from the Wagerup Refinery's calciner. The particle size distribution from the Wagerup calciner sample has a median physical diameter of 4.5 µm, with 69% of the particulate below 10µm and 88.6% below 20µm. From discussions with Alcoa personnel (Cox, 2003b) it is considered that the particle size after the electrostatic precipitators (ESPs) on the Pinjarra calciners will be similar to that from Wagerup due to the similar ESPs. This particulate consists primarily of alumina with a little alumina tri-hydrate and is considered to have a blocky/cubical shape. The particle density is estimated at around 2 g/cm^3 as it has a high surface area with a lot of micropores (the pores resulting from the removal of the water molecules from the alumina trihydrate within the calcining process which has a density of 2.4 g/cm^3).

For the ALD stack which primarily emits alumina after a wet scrubber, the same size distribution and density have been assumed. For the oxalate kiln which primarily emits sodium oxalate with a small amount of hydrate after being scrubbed with a wet scrubber, the same distribution and density has been assumed. For the oxalate kiln emissions which are emitted after passing through a cyclone, the sodium oxalate (which is needle like) is assumed to be broken down into smaller segments within the kiln process.

For the combustion sources (boilers and co-generation plant burning natural gas) the particulate should be sub-micron and has been treated as a gaseous emission.

Given the uncertainty in the particle size distributions, the following has been assumed in the modelling study:

- Modelling of PM2.5 and PM10 from the major sources listed in **Table 3** to **Table 6** were modelled using the particle size distribution and density from the calciner stack as described above;
- Dioxins and furans which are emitted only from the oxalate kiln stack were modelled both as gaseous and particulate (assuming the calciner size distribution). In the assessment both results are presented as well as the maximum predicted for each residential receptor from using either assumption of the size distribution;
- Arsenic (which of the metals has relatively high predicted ground level concentrations, see Toxikos, 2003) was modelled assuming that it is emitted either as very fine particulate (essentially a gas)or as particulate, with a calciner particulate distribution;
- All metal emissions from tanks and vents were assumed to be in either in gaseous form or be comprised of sub-micron particulate. For metals (other than arsenic) which are emitted from the tanks and vents, this assumption is not critical given that concentrations are relatively low and that modelling as either gas or calciner dust only typically results in 10 to 30% change in the concentrations. Note that annual concentrations offsite are generally higher when modelled as particulate (see **Section 6**); and
- PAHs from all sources were modelled assuming they occur as very fine particulate.

5.3 Building Effects

For many of the low stacks and vents at the refinery, nearby buildings can play a significant role in affecting the dispersion of the plumes, both by increasing the turbulence and decreasing the plume rise. To account for this, building dimensions for all buildings near the stacks and vents were entered into the respective models. These dimensions were developed from the refinery plans and heights of buildings supplied by Alcoa along with photographs of the buildings. These buildings dimensions are processed internally within TAPM and AUSPLUME to produce the required building projections, whilst CALPUFF required that the US EPA model BPIP be run, with the resultant building projections entered into the model.

5.4 Cooling Towers

Two of the sources where atmospheric emissions arise are mechanical draft cooling towers. Plumes from cooling towers are saturated with water vapour and also contain entrained water droplets. The plume rise from these saturated plumes is due to both momentum and buoyancy of the original plume and also to the heat released when water vapour condenses outside the cooling tower. As 80% of the total energy leaving a cooling tower is latent heat, there is the potential when condensation occurs, for the plume rise to be increased by more than 30% (Hanna, Briggs and Hosker, 1984). To model accurately the dispersion of such plumes, a model such as the seasonal and annual cooling tower impacts model (SACTI) is required (Policastro, 1994). In this assessment the cooling tower plumes were modelled as dry, which will be conservative in that it will under-predict plume rise (Hanna, Briggs and Hosker, 1984).

5.5 Upset conditions

Upset conditions that can occur at the Pinjarra Refinery relate to equipment failure or process upsets. Of the possible upset conditions that can lead to an increase in emissions, the most important is process failure within calcination or an ESP failure on the calciners. Both these events are monitored by dust concentration meters in the calciner stacks that sound an alarm to alert the control attendant of high levels. In the event of a total ESP failure, the control attendant responds by shutting feed off within 10 minutes if the ESP is not recovered. A countdown alarm is used to assist the Control Attendant to know when time is up. In the case of a partial failure, up to 60 minutes is allowed to trouble shoot before taking feed off. Higher levels of particulate are also released during start up and shut down. The effectiveness of the ESP is also reduced at lower temperatures, and for safety reasons the ESP cannot be online for the full duration of these processes to prevent explosion of unburnt gas. A normal start-up or shutdown process may result in elevated levels of dust for 2-4 hours. In the past at Pinjarra there has been one event where elevated dust emissions were emitted from one of the calciners for a period of up to 9 hours during a planned 'cool-down' shutdown during which problems occurred. Alumina blockages built up in the vessels, and on access after shutdown a hole was found in the fluidising air supply, which made the blockage difficult to clear. Normally vessels within the calciner are emptied prior to shutdown with the ESP still online. This event was reported to the Department of Environment, and a full investigation was carried out and submitted.

This event was modelled using CALPUFF with concentrations at distances greater than 1km from the stack predicted to be at most 20 and 0.5 $\mu g/m^3$ for a 15-minute and 24-hour average respectively (SKM, 2002).

SKM

5.6 Proportion of NO_2 in NO_X

To estimate the proportion of NO_X in the form of NO_2 (the species of concern to human health) the ozone limiting method (OLM) which is a conservative screening technique of the USEPA for short term NO_X impacts has been used (Cole and Sumerhays, 1979). Here the concentration of NO_2 is estimated as:

$NO_2 = NO_X$ if $O_3 > 0.9\ NO_X$ **Equation 1**

$NO_2 = O_3 + 0.1NO_X$ if $0.9\ NO_X > O_3$ **Equation 2**

and $NO_2\ (total) = NO_2 + NO_2\ (background)$ **Equation 3**

Where NO_X is the predicted NO_X concentration, O_3 is the background measured ozone and NO_2 (background) is background measured NO_2.

A coefficient of 0.1 has been used in equation 2 because NO_X emissions from gas fired boilers and gas turbines with standard burners and dry low NO_X burners is typically less than 10%. As reported in Environ (2002):

- Typically less than 5% of the NO_X is NO_2 at release from the current sources (power station and calciners) with greater than 95% nitric oxide; and
- Whilst the co-generation plant are anticipated to have NO_2 levels less than 25% NO_X at release (Environ, 2002). More recent data indicates that NO_X is expected to be less than 10% (Scherer, 2003).

This method is applied to the predictions for each hour of the year with background O_3 and NO_2 levels sourced from the monitoring that was undertaken at Wagerup that corresponded to the modelling period of 1 August 2002 to 31 July 2003.

5.7 Other Emissions

For most of the substances detailed in **Section 5.1** there are no other significant emissions in the Pinjarra area apart from the Pinjarra refinery. Therefore background concentrations of these substances in the region are assumed to be negligible. As such, predicted ground level concentrations of these substances from the refinery will represent the total ground level concentrations. Substances that may be emitted in appreciable quantities from other sources in the area and/or have appreciable concentrations are primarily particulate matter (PM10 and PM2.5) and NO_2.

PM10 and PM2.5 will arise from smoke from fires (burning off and wildfires), dust generated from agricultural activities such as cultivation, dust from dust storms and from fugitive dust sources at the refinery. Fugitive dust from the refinery can be a large source of dust and is associated generally with strong easterly winds being generated from the residue drying areas and bauxite stockpile areas. Such dust has not been included in the modelling as this is difficult to quantify. As such, the modelling assessment in this report only presents predictions from the point sources (stacks, vents, tanks) and not the fugitive sources from the refinery such as wind blown dust and dust generated by vehicles etc. An assessment of the existing dust levels in the region which includes background dust and the contribution from the fugitive and point sources at the refinery is presented in Environ (2003).

Concentrations of NO_X can also be present at significant levels in the Pinjarra area. An analysis of existing NO_X levels at Pinjarra is not presented here as only several weeks of data were available at the time this report was prepared. Instead an estimate of the background levels at Pinjarra (excluding the refineries contribution) is made from an analysis of the NO_X data at Wagerup. This data based on more than one years monitoring indicates that background NO_2 levels (the major species of concern) are up to 18.6ppb (38.2 $\mu g/m^3$) for the maximum 1-hour average and 1.75ppb (3.6 $\mu g/m^3$) for the annual average concentrations. These concentrations are 15.5% and 1.6% of the NEPM standard (see **Section 6**). These levels of NO_2 are considered to be primarily due to smoke from fires in the south west. Other sources of NO_X in the region are from the combustion activities in Pinjarra, from NO_X produced from the Perth region (including Kwinana), Collie (power stations) and Wagerup refinery and from agricultural activities. Again the sources from fires are very difficult to quantify. Instead of attempting to model these an assessment of the cumulative impacts has been undertaken by estimating background NO_2 concentrations and adding these to the predicted NO_X levels as detailed in **Section 5.6**.

6. Results

6.1 Predicted Concentrations at the Nearest Residences

A summary of the predicted ground level concentrations at the 14 nearest residences from the refinery alone is presented in **Table 7** and **Table 8**. These have been predicted using the model AUSPLUME, the 2002/2003 meteorological file and the model set up described in **Section 3**. For modelling concentrations for averaging periods less than or equal to 24 hours, the peak emissions (peak flows at the peak concentrations) have been used. It is noted that the peak concentrations measured may not have occurred at the times of the peak flows so that the peak emission rates (g/s) may be overly conservative. Additionally, the probability that the peak emissions from all sources occur at the same time is very low, such that the total peak emission estimates will generally be a conservative estimate. Annual average concentrations have been estimated based on average conditions, i.e. average flow rates and average concentrations.

Table 7 and **Table 8** indicate that the highest 1-hour concentrations always occur at locations 1 and 12, the two residences to the north east of the refinery on the side of the escarpment. Predicted concentrations at the residences in Pinjarra and North Pinjarra (monitors 3 and 4) are, on average 30% of the concentrations at these two residences.

For the predicted 24-hour average concentrations, the highest concentrations likewise occur at monitors 1 and 12, though location 11 (south of the refinery) is predicted to have slightly higher concentrations than location 1 and 12 for acetaldehyde, toluene and xylenes. At Pinjarra and North Pinjarra the 24-hour concentrations are on average 50% of those at location 1, 2 or 12.

For the annual average concentrations, highest concentrations again occur at residences 1 and 12 with concentrations at Pinjarra and North Pinjarra being 30% of these. The one exception to the above is for mercury where Fairbridge Farm (location 2) is predicted to have the highest concentrations. This is because the largest source of mercury is attributed to Alcoa's fresh water lake which is further north than the other sources of mercury.

Therefore, the two residences north east of the refinery (locations 1 and 12) are generally predicted to have the highest concentrations offsite, with Pinjarra and North Pinjarra (locations 3 and 4) having concentrations 30 to 50% of these. It is noted that the concentrations predicted by AUSPLUME at locations 1 and 12 are considered to be overestimates, based on the model comparisons presented in **Section 4**.

Table 7 Predicted Ground Level Concentrations from the Baseline Case

Location	NO_x	NO_2	CO	SO_2	PM2.5	PM10	VOC	Acetone	Acetaldehyde	Formaldehyde	2-Butanone	Benzene	Toluene	Xylenes	PAHs	Mercury	Arsenic modelled assuming fine particulate	Arsenic modelled using Calciner size distribution	Arsenic (max of both)	Selenium	Dioxins modelled as fine particulate	Dioxins modelled a using calciner size distribution	Dioxins modelled (max of both)	Ammonia	Manganese & Compounds	Cadmium & Compounds	Nickel & Compounds
												(µg/m³)									(pg/m³)				(µg/m³)		
Maximum 1-hour average																											
1	76.1	62.9	195	19.4	13.6	27.5	111.5	31.3	17.1	4.9	6.0	3.51	21.38	4.85	0.386	0.497	6.51E-02	6.32E-02	6.51E-02	4.90E-02	4.80E-03	4.69E-03	4.80E-03	8.69E+01	2.68E-01	1.47E-03	2.45E-02
2	36.3	36.3	79	8.2	4.9	11.2	64.7	13.9	9.9	2.2	3.2	2.37	13.38	2.80	0.206	0.432	1.86E-02	2.38E-02	2.38E-02	1.63E-02	1.34E-03	1.75E-03	1.75E-03	5.73E+01	1.52E-01	4.23E-04	1.40E-02
3	38.4	38.4	71	8.1	5.6	11.3	41.3	11.6	6.3	2.0	2.0	1.39	7.80	1.67	0.133	0.355	2.16E-02	1.92E-02	2.16E-02	1.75E-02	1.58E-03	1.42E-03	1.58E-03	3.27E+01	8.88E-02	4.88E-04	8.28E-03
4	32.3	32.0	56	6.6	4.5	9.8	42.1	12.5	6.4	1.5	2.1	1.29	7.43	1.57	0.130	0.303	1.54E-02	1.55E-02	1.55E-02	1.29E-02	1.12E-03	1.15E-03	1.15E-03	3.08E+01	8.79E-02	3.49E-04	8.17E-03
5	31.3	31.3	52	6.2	4.3	10.1	42.8	13.5	6.5	1.4	2.3	1.23	7.09	1.48	0.124	0.241	1.45E-02	1.41E-02	1.45E-02	1.22E-02	1.06E-03	1.05E-03	1.06E-03	2.90E+01	8.37E-02	3.29E-04	7.75E-03
6	34.1	33.5	78	7.9	4.8	9.8	53.6	14.8	8.1	2.2	2.7	1.58	9.50	2.13	0.173	0.245	1.62E-02	1.90E-02	1.90E-02	1.38E-02	1.18E-03	1.41E-03	1.41E-03	3.75E+01	1.07E-01	3.72E-04	9.87E-03
7	33.0	33.0	81	8.0	5.1	10.2	57.0	15.0	9.0	2.2	2.9	1.97	11.27	2.36	0.184	0.257	1.70E-02	2.00E-02	2.00E-02	1.37E-02	1.24E-03	1.48E-03	1.48E-03	4.76E+01	1.26E-01	3.87E-04	1.18E-02
8	33.2	33.2	68	7.6	4.5	9.4	52.8	12.7	8.3	1.9	2.6	1.82	10.34	2.15	0.164	0.209	1.68E-02	1.83E-02	1.83E-02	1.46E-02	1.22E-03	1.35E-03	1.35E-03	4.39E+01	1.19E-01	3.83E-04	1.11E-02
9	37.3	37.3	72	8.1	4.4	9.6	57.7	13.5	9.1	1.9	2.9	2.00	11.37	2.36	0.180	0.228	1.77E-02	2.00E-02	2.00E-02	1.54E-02	1.28E-03	1.48E-03	1.48E-03	4.82E+01	1.29E-01	4.04E-04	1.20E-02
10	33.4	33.4	72	7.6	4.5	9.2	56.0	13.0	8.8	2.1	2.8	1.99	11.28	2.33	0.176	0.224	1.71E-02	1.96E-02	1.96E-02	1.50E-02	1.24E-03	1.44E-03	1.44E-03	4.81E+01	1.29E-01	3.91E-04	1.20E-02
11	43.6	43.6	99	10.2	6.4	12.7	63.1	13.7	9.9	2.9	3.1	2.36	13.03	2.64	0.193	0.229	2.05E-02	2.24E-02	2.24E-02	1.78E-02	1.49E-03	1.65E-03	1.65E-03	5.71E+01	1.52E-01	4.68E-04	1.41E-02
12	142.8	103.3	288	32.9	20.5	43.6	110.4	41.4	15.3	6.9	5.5	2.91	16.86	3.76	0.329	0.369	8.05E-02	6.37E-02	8.05E-02	5.97E-02	5.93E-03	4.70E-03	5.93E-03	6.94E+01	2.34E-01	1.81E-03	2.06E-02
13	37.1	32.6	61	7.1	5.8	11.7	58.6	16.5	9.4	1.7	3.0	1.92	11.03	2.28	0.192	0.436	1.78E-02	2.21E-02	2.21E-02	1.51E-02	1.28E-03	1.64E-03	1.64E-03	4.60E+01	1.23E-01	4.06E-04	1.17E-02
14	35.4	34.9	53	6.4	5.9	11.9	68.1	18.3	10.8	1.5	3.5	2.23	12.73	2.62	0.220	0.474	1.81E-02	2.38E-02	2.38E-02	1.50E-02	1.30E-03	1.76E-03	1.76E-03	5.34E+01	1.41E-01	4.13E-04	1.35E-02
Maximum 24-hour Average																											
1				3.31	1.93	3.99			1.94	0.68			1.98	0.48													
2				2.08	1.08	2.05			1.04	0.45			1.39	0.31													
3				1.51	0.78	1.50			0.92	0.35			1.02	0.22													
4				1.47	0.88	1.77			1.04	0.35			1.10	0.25													
5				1.22	0.77	1.56			0.82	0.28			0.76	0.17													
6				2.72	1.44	2.81			1.08	0.60			1.05	0.23													
7				2.61	1.46	2.44			1.09	0.61			1.14	0.24													
8				1.95	1.01	1.93			0.83	0.44			0.79	0.17													
9				2.07	1.09	2.09			0.77	0.46			0.90	0.19													
10				2.04	1.04	2.01			0.98	0.45			0.88	0.19													
11				1.77	1.05	2.17			1.96	0.38			2.40	0.49													
12				3.91	2.25	4.63			1.67	0.81			1.51	0.36													
13				1.87	0.92	1.78			1.20	0.45			1.32	0.32													
14				1.67	0.84	1.55			1.64	0.38			1.73	0.35													
Annual Average																											
1	2.14	1.88	2.01	0.18	0.20	0.39	1.33	0.479	0.191	0.036	0.093	0.038	0.194	0.041	0.0028	0.0056	1.11E-03	9.73E-04	1.11E-03	8.87E-04	8.07E-05	7.09E-05	8.07E-05	6.10E-01	3.99E-03	2.48E-05	3.41E-04
2	0.89	0.85	0.83	0.08	0.09	0.18	0.65	0.218	0.092	0.016	0.042	0.023	0.109	0.021	0.0013	0.0077	2.84E-04	2.94E-04	2.94E-04	2.52E-04	2.05E-05	2.12E-05	2.12E-05	3.40E-01	1.82E-03	6.41E-06	1.53E-04
3	0.70	0.67	0.55	0.05	0.06	0.12	0.40	0.140	0.056	0.011	0.025	0.013	0.063	0.012	0.0008	0.0044	2.53E-04	2.12E-04	2.53E-04	2.10E-04	1.84E-05	1.54E-05	1.84E-05	1.94E-01	1.07E-03	5.70E-06	8.96E-05
4	1.13	1.09	0.80	0.07	0.08	0.15	0.53	0.193	0.077	0.016	0.034	0.016	0.077	0.015	0.0010	0.0042	2.67E-04	2.34E-04	2.67E-04	2.32E-04	1.93E-05	1.69E-05	1.93E-05	2.41E-01	1.49E-03	5.99E-06	1.22E-04
5	0.61	0.59	0.43	0.04	0.04	0.08	0.26	0.096	0.039	0.009	0.016	0.008	0.038	0.007	0.0005	0.0014	1.19E-04	1.03E-04	1.19E-04	1.07E-04	8.54E-06	7.40E-06	8.54E-06	1.22E-01	7.66E-04	2.66E-06	6.27E-05
6	0.99	0.96	0.88	0.09	0.09	0.16	0.33	0.131	0.049	0.018	0.020	0.009	0.041	0.008	0.0005	0.0017	1.81E-04	1.51E-04	1.81E-04	1.49E-04	1.31E-05	1.09E-05	1.31E-05	1.32E-01	8.95E-04	4.05E-06	6.79E-05
7	1.05	1.02	0.93	0.09	0.09	0.17	0.36	0.140	0.053	0.019	0.021	0.010	0.046	0.009	0.0006	0.0017	1.98E-04	1.66E-04	1.98E-04	1.63E-04	1.43E-05	1.19E-05	1.43E-05	1.48E-01	9.94E-04	4.43E-06	7.57E-05
8	0.75	0.74	0.54	0.05	0.05	0.09	0.27	0.095	0.039	0.011	0.016	0.009	0.043	0.008	0.0005	0.0011	1.55E-04	1.31E-04	1.55E-04	1.30E-04	1.11E-05	9.39E-06	1.11E-05	1.39E-01	8.73E-04	3.45E-06	6.69E-05
9	0.86	0.85	0.64	0.06	0.06	0.11	0.31	0.109	0.045	0.013	0.018	0.010	0.048	0.009	0.0005	0.0013	1.78E-04	1.51E-04	1.78E-04	1.49E-04	1.28E-05	1.08E-05	1.28E-05	1.58E-01	1.01E-03	3.97E-06	7.75E-05
10	0.76	0.75	0.55	0.05	0.05	0.10	0.29	0.101	0.043	0.011	0.017	0.010	0.047	0.009	0.0005	0.0012	1.64E-04	1.41E-04	1.64E-04	1.39E-04	1.18E-05	1.10E-05	1.18E-05	1.53E-01	9.47E-04	3.67E-06	7.37E-05
11	0.67	0.66	0.49	0.05	0.05	0.09	0.29	0.098	0.043	0.010	0.018	0.011	0.050	0.009	0.0005	0.0010	1.64E-04	1.43E-04	1.64E-04	1.41E-04	1.18E-05	1.03E-05	1.18E-05	1.63E-01	9.47E-04	3.68E-06	7.59E-05
12	2.60	1.90	2.09	0.20	0.20	0.39	0.99	0.386	0.142	0.039	0.068	0.025	0.126	0.026	0.0018	0.0037	8.58E-04	6.75E-04	8.58E-04	6.77E-04	6.25E-05	4.90E-05	6.25E-05	4.05E-01	2.95E-03	1.92E-05	2.37E-04
13	1.14	1.12	0.83	0.08	0.09	0.16	0.57	0.210	0.086	0.017	0.035	0.017	0.084	0.016	0.0010	0.0029	2.18E-04	2.13E-04	2.18E-04	2.04E-04	1.57E-05	1.53E-05	1.57E-05	2.68E-01	1.59E-03	4.91E-06	1.34E-04
14	1.06	1.04	0.78	0.08	0.09	0.15	0.55	0.201	0.084	0.016	0.033	0.017	0.082	0.016	0.0010	0.0027	1.95E-04	1.94E-04	1.95E-04	1.87E-04	1.40E-05	1.39E-05	1.40E-05	2.61E-01	1.53E-03	4.39E-06	1.30E-04

Note: For a discussion on the substances included under PAHs refer to Environ (2003)

Table 8 Predicted Ground Level Concentrations from the Upgraded Case

Location	NO_x	NO_2	CO	SO_2	PM2.5	PM10	VOC	Acetone	Acetaldehyde	Formaldehyde	2-Butanone	Benzene	Toluene	Xylenes	PAHs	Mercury	Arsenic modelled assuming fine particulate	Arsenic modelled using Calciner size distribution	Arsenic (max of both)	Selenium	Dioxins modelled as fine particulate	Dioxins modelled a using calciner size distribution	Dioxins and Furans modelled (max of both)	Ammonia	Manganese & Compounds	Cadmium & Compounds	Nickel & Compounds
												($\mu g/m^3$)									(pg/m^3)				($\mu g/m^3$)		
Maximum 1-hour average																											
1	77.9	64.0	205.7	19.9	10.4	21.0	67.1	25.3	7.9	5.06	4.86	0.20	8.62	3.93	0.37	0.5787	9.49E-03	1.07E-02	1.07E-02	4.74E-02	4.46E-03	5.04E-03	5.04E-03	1.01E+02	3.14E-01	2.22E-04	3.49E-03
2	36.8	36.8	82.9	8.4	4.0	8.5	31.9	11.3	3.7	2.32	2.38	0.10	4.49	2.04	0.19	0.5032	3.02E-03	4.27E-03	4.27E-03	1.73E-02	1.25E-03	1.87E-03	1.87E-03	6.60E+01	1.71E-01	7.32E-05	1.91E-03
3	39.5	39.5	76.4	8.3	4.5	9.1	21.5	9.1	2.5	2.19	1.51	0.09	2.72	1.24	0.12	0.4118	3.69E-03	3.64E-03	3.69E-03	1.96E-02	1.66E-03	1.65E-03	1.66E-03	3.76E+01	1.00E-01	8.65E-05	1.41E-03
4	35.8	34.8	64.7	7.2	3.7	8.4	23.8	9.8	2.9	1.82	1.66	0.08	2.73	1.25	0.12	0.3528	2.59E-03	2.90E-03	2.90E-03	1.41E-02	1.14E-03	1.30E-03	1.30E-03	3.55E+01	1.00E-01	6.10E-05	1.24E-03
5	30.5	30.5	52.4	5.9	3.7	8.5	27.3	10.7	3.1	1.42	1.83	0.08	2.62	1.18	0.11	0.2811	2.46E-03	2.66E-03	2.66E-03	1.34E-02	1.09E-03	1.20E-03	1.20E-03	3.35E+01	9.53E-02	5.79E-05	1.17E-03
6	35.3	34.9	83.4	8.2	4.2	8.2	32.8	11.7	4.1	2.30	2.17	0.10	3.70	1.67	0.16	0.2854	2.67E-03	3.49E-03	3.49E-03	1.48E-02	1.16E-03	1.57E-03	1.57E-03	4.35E+01	1.22E-01	6.79E-05	1.45E-03
7	33.7	33.7	83.7	8.2	4.5	9.1	32.6	13.6	4.2	2.31	2.27	0.10	3.96	1.79	0.17	0.2994	2.66E-03	3.54E-03	3.54E-03	1.49E-02	1.19E-03	1.63E-03	1.63E-03	5.47E+01	1.43E-01	6.52E-05	1.60E-03
8	33.0	32.8	72.1	7.6	3.6	7.5	27.6	9.5	3.3	2.06	1.91	0.09	3.43	1.54	0.15	0.2433	2.85E-03	3.44E-03	3.44E-03	1.62E-02	1.22E-03	1.51E-03	1.51E-03	5.07E+01	1.36E-01	7.06E-05	1.60E-03
9	38.0	38.0	76.7	8.1	3.5	7.1	29.6	10.1	3.5	2.08	2.08	0.10	3.77	1.70	0.16	0.2655	2.95E-03	3.72E-03	3.72E-03	1.68E-02	1.26E-03	1.64E-03	1.64E-03	5.56E+01	1.47E-01	7.26E-05	1.72E-03
10	33.9	33.7	77.5	7.7	3.7	7.3	28.4	9.9	3.4	2.23	2.01	0.09	3.70	1.67	0.16	0.2604	2.89E-03	3.65E-03	3.65E-03	1.67E-02	1.23E-03	1.61E-03	1.61E-03	5.56E+01	1.46E-01	7.11E-05	1.69E-03
11	44.1	43.7	105.7	10.3	5.2	10.5	29.4	12.4	3.5	3.14	2.18	0.11	4.07	1.83	0.17	0.2667	3.47E-03	4.21E-03	4.21E-03	1.98E-02	1.47E-03	1.84E-03	1.84E-03	6.59E+01	1.72E-01	8.47E-05	2.00E-03
12	144.1	103.6	310.3	33.4	15.4	32.7	84.9	34.4	9.4	7.38	4.99	0.31	6.94	3.10	0.30	0.4303	1.45E-02	1.23E-02	1.45E-02	7.03E-02	6.90E-03	5.83E-03	6.90E-03	8.05E+01	2.68E-01	3.27E-04	3.61E-03
13	37.9	34.2	67.1	7.8	4.5	8.9	33.4	12.2	4.0	1.96	2.44	0.10	4.09	1.87	0.18	0.5076	2.78E-03	3.89E-03	3.89E-03	1.58E-02	1.21E-03	1.79E-03	1.79E-03	5.28E+01	1.40E-01	6.71E-05	1.63E-03
14	40.2	36.9	59.5	7.0	4.9	9.9	39.8	13.6	4.7	1.82	2.84	0.12	4.71	2.17	0.21	0.5521	2.82E-03	4.13E-03	4.13E-03	1.58E-02	1.21E-03	1.87E-03	1.87E-03	6.13E+01	1.60E-01	7.03E-05	1.79E-03
Maximum 24-hour Average																											
1				3.36	1.46	3.01			1.03	0.72			0.89	0.40													
2				2.13	0.87	1.68			0.51	0.49			0.52	0.24													
3				1.55	0.63	1.18			0.41	0.38			0.35	0.16													
4				1.50	0.73	1.41			0.50	0.39			0.44	0.20													
5				1.26	0.60	1.21			0.37	0.31			0.28	0.13													
6				2.74	1.21	2.34			0.55	0.64			0.40	0.18													
7				2.66	1.22	2.06			0.53	0.64			0.40	0.18													
8				1.99	0.81	1.56			0.55	0.47			0.27	0.12													
9				2.11	0.88	1.69			0.48	0.50			0.30	0.13													
10				2.07	0.84	1.61			0.62	0.49			0.33	0.14													
11				1.77	0.79	1.62			0.75	0.37			0.76	0.34													
12				3.98	1.70	3.50			0.82	0.84			0.67	0.30													
13				1.73	0.76	1.54			0.59	0.50			0.60	0.27													
14				1.91	0.66	1.17			0.68	0.42			0.60	0.25													
Annual Average																											
1	1.43	1.33	1.69	0.19	0.14	0.27	1.01	0.430	0.141	0.034	0.090	0.003	0.069	0.031	0.0029	0.0066	2.26E-04	2.12E-04	2.26E-04	9.71E-04	8.64E-05	8.05E-05	8.64E-05	7.35E-01	4.75E-03	5.07E-06	6.63E-05
2	0.59	0.58	0.77	0.08	0.06	0.12	0.48	0.207	0.068	0.016	0.041	0.002	0.033	0.015	0.0013	0.0092	5.93E-05	6.45E-05	6.45E-05	2.74E-04	2.14E-05	2.36E-05	2.36E-05	4.02E-01	2.11E-03	1.39E-06	2.47E-05
3	0.46	0.45	0.47	0.05	0.04	0.08	0.29	0.125	0.041	0.010	0.024	0.001	0.019	0.008	0.0008	0.0052	5.47E-05	4.89E-05	5.47E-05	2.40E-04	2.06E-05	1.83E-05	2.06E-05	2.30E-01	1.23E-03	1.25E-06	1.67E-05
4	0.79	0.77	0.75	0.08	0.06	0.11	0.40	0.177	0.056	0.016	0.031	0.001	0.024	0.011	0.0010	0.0050	5.90E-05	5.50E-05	5.90E-05	2.65E-04	2.15E-05	1.99E-05	2.15E-05	2.88E-01	1.73E-03	1.34E-06	2.11E-05
5	0.43	0.42	0.41	0.04	0.03	0.06	0.20	0.088	0.028	0.009	0.015	0.001	0.011	0.005	0.0004	0.0016	2.70E-05	2.49E-05	2.70E-05	1.23E-04	9.66E-06	8.85E-06	9.66E-06	1.45E-01	8.81E-04	6.09E-07	1.04E-05
6	0.70	0.69	0.87	0.09	0.07	0.12	0.28	0.130	0.040	0.018	0.020	0.001	0.013	0.006	0.0005	0.0020	4.18E-05	3.60E-05	4.18E-05	1.76E-04	1.53E-05	1.30E-05	1.53E-05	1.59E-01	1.04E-03	9.22E-07	1.27E-05
7	0.74	0.73	0.92	0.09	0.07	0.12	0.30	0.142	0.043	0.019	0.023	0.001	0.014	0.006	0.0006	0.0021	4.56E-05	3.94E-05	4.56E-05	1.93E-04	1.67E-05	1.42E-05	1.67E-05	1.78E-01	1.16E-03	1.01E-06	1.41E-05
8	0.49	0.49	0.52	0.05	0.05	0.07	0.21	0.094	0.029	0.011	0.017	0.001	0.012	0.005	0.0005	0.0014	3.61E-05	3.16E-05	3.61E-05	1.55E-04	1.31E-05	1.13E-05	1.31E-05	1.66E-01	1.02E-03	7.99E-07	1.20E-05
9	0.57	0.56	0.61	0.06	0.04	0.08	0.24	0.109	0.033	0.013	0.019	0.001	0.013	0.006	0.0005	0.0016	4.14E-05	3.63E-05	4.14E-05	1.78E-04	1.50E-05	1.30E-05	1.50E-05	1.90E-01	1.17E-03	9.18E-07	1.38E-05
10	0.49	0.49	0.52	0.06	0.04	0.07	0.22	0.100	0.031	0.011	0.018	0.001	0.013	0.006	0.0005	0.0014	3.81E-05	3.38E-05	3.81E-05	1.65E-04	1.38E-05	1.21E-05	1.38E-05	1.84E-01	1.11E-03	8.47E-07	1.30E-05
11	0.44	0.43	0.46	0.05	0.03	0.06	0.22	0.095	0.030	0.010	0.018	0.001	0.013	0.006	0.0005	0.0012	3.79E-05	3.40E-05	3.79E-05	1.67E-04	1.37E-05	1.22E-05	1.37E-05	1.95E-01	1.11E-03	8.55E-07	1.33E-05
12	1.70	1.40	1.89	0.20	0.14	0.27	0.78	0.348	0.107	0.039	0.065	0.003	0.044	0.020	0.0018	0.0044	1.98E-04	1.63E-04	1.98E-04	8.26E-04	7.58E-05	6.16E-05	7.58E-05	4.87E-01	3.45E-03	4.37E-06	5.04E-05
13	0.80	0.79	0.81	0.08	0.07	0.12	0.43	0.191	0.062	0.017	0.031	0.001	0.025	0.011	0.0010	0.0034	4.87E-05	4.95E-05	4.95E-05	2.32E-04	1.72E-05	1.76E-05	1.76E-05	3.19E-01	1.84E-03	1.13E-06	2.14E-05
14	0.74	0.74	0.77	0.08	0.06	0.11	0.41	0.183	0.060	0.016	0.030	0.001	0.024	0.010	0.0010	0.0032	4.36E-05	4.48E-05	4.48E-05	2.12E-04	1.53E-05	1.58E-05	1.58E-05	3.10E-01	1.77E-03	1.01E-06	2.03E-05

Note: For a discussion on the substances included under PAHs refer to Environ (2003)

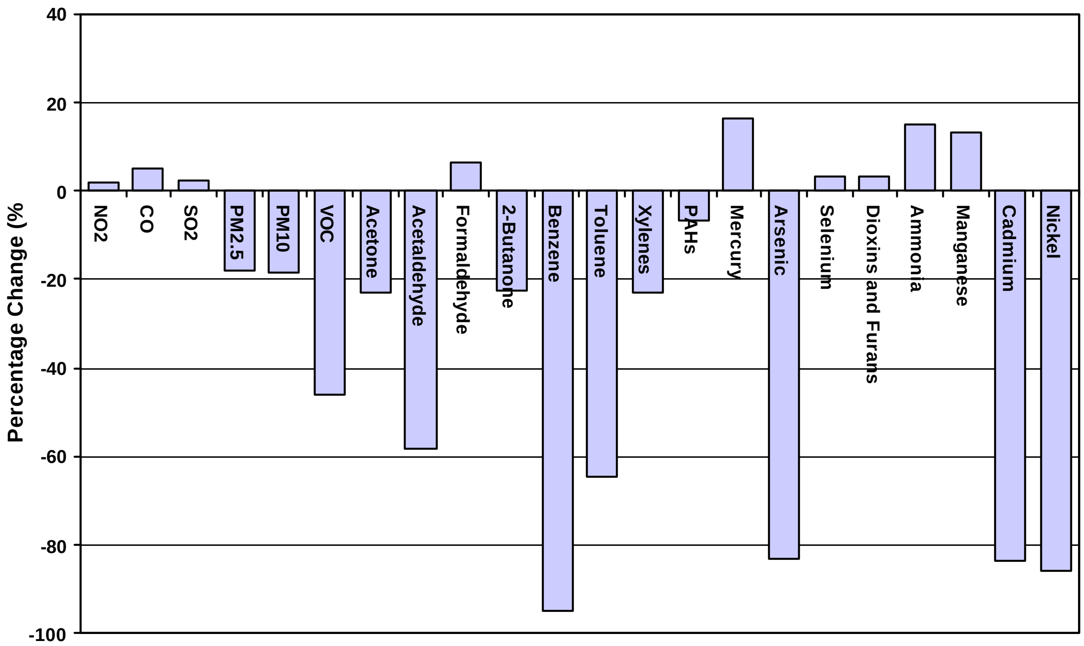
Given the uncertainty in the phase that some of the emitted metals may be in (either vapour or solid) and limitations in the particle size distribution data (see **Section 5.2**), a sensitivity analysis of the results was conducted for two substances, arsenic and dioxins and furans. Both arsenic and dioxins and furans were modelled as being either very fine particulate (modelled as a vapour) or using the calciner particle size distribution, assuming uniform mass distribution across the particulate. The results (see **Table 7** and **Table 8**) indicate that by assuming the calciner particle distribution the 1-hour concentrations at the nearest residences are generally higher by around 30% (maximum of 62%), whilst the annual average concentrations are generally lower by 10% (maximum 19%).

Given the uncertainty in the phase of the metals emitted and the particle size distribution, the majority of the metals and PAH have been modelled assuming a very fine particle distribution (i.e. behaves as a gas). This will result in the annual average concentrations being conservative and likely overstating the actual concentrations. For 1-hour average concentrations, it is noted that the concentrations for these substances will be understated by generally 30%. For arsenic and dioxins and furans the results have been presented as the maximum of the two assumptions and therefore should be conservative. A comparison of predicted concentrations of metals and VOCs against criteria is found in Toxikos (2003). More accurate predictions of these substance concentrations would require further details on the phase of the metals from the sources and the particulate particle size distributions for each source.

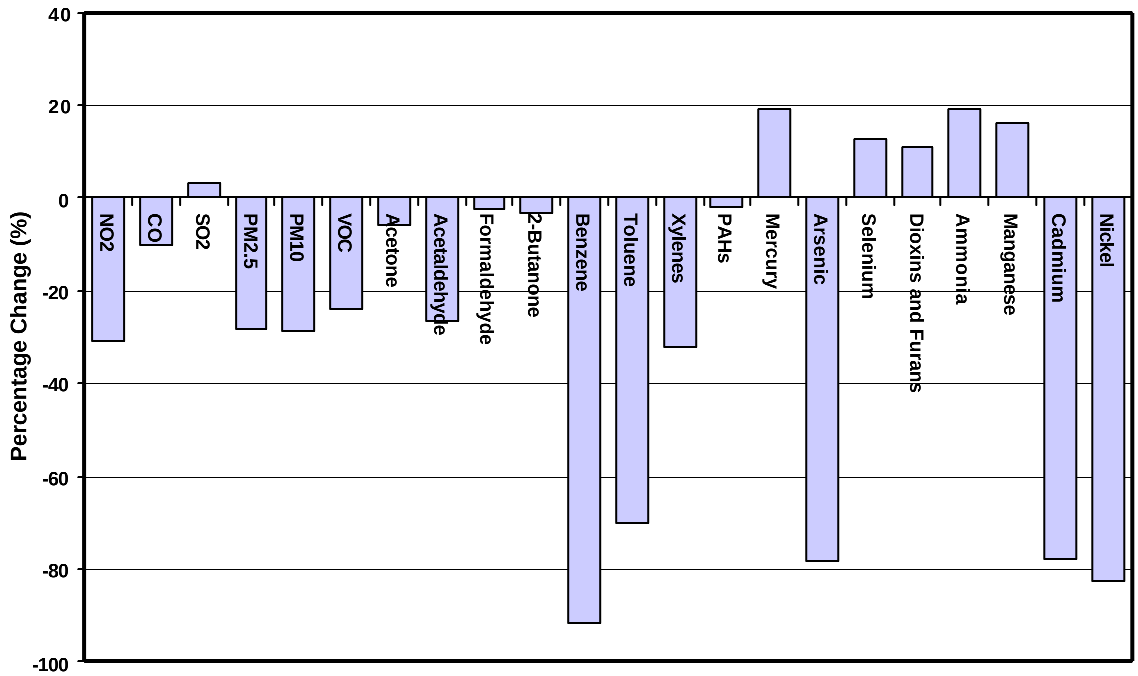
The percentage changes from baseline case to upgrade case in the predicted 1-hour maximum and annual average concentrations are summarised in **Figure 29** and **Figure 30**. Here the percentage change is the average change from all the 14 nearest residences. **Figure 29** and **Figure 30** indicate that there would be:

- Large reductions in ground level concentrations of benzene (-92 to -95%), arsenic (-78 to -83%), cadmium (-78 to -84%), acetaldehyde (-26 to –58%), toluene (-65 to -70%) and nickel (-86 to -83%);
- Moderate increases in some metals, including mercury (15 to 19%), selenium (15 to 19%) and manganese (13 to 16%), dioxins and furans (3 to 11%), ammonia (15 to 19%) and SO_2 (2 to 3%); and
- Moderate decreases in substances such as PM10 (-18 to -29%), PM2.5 (-18 to -28%), VOC (-24 to -46%), acetone (-6 to -23%), xylenes (-23 to -30%), 2-Butanone (-3 to -23%) and PAHs (-2 to -7%).

Depending on the averaging period, the remaining three substances were predicted to either increase or decrease, such as NO_2 (+2 to –31%), CO (+5 to –10%), and formaldehyde (+6 to –2%). This difference in the relative change from the baseline to upgrade case with averaging



- **Figure 29 Predicted change in maximum 1-hour ground level concentration from the baseline to upgrade case**



SKM

- **Figure 30 Predicted change in the average ground level concentration from the baseline to upgrade case**

period is due to the different assumptions used in estimating the emissions in the peak and average emission case for each source. In particular for some sources such as the Boiler stack 5,6 and 7 where reductions in emissions are planned, the peak emissions were estimated assuming the same maximum concentrations, whilst the average emissions were estimated based on the anticipated decrease in concentrations.

6.2 Comparison to NEPM criteria

A comparison of the maximum concentrations at the nearest residences for the substances listed in the various air NEPMs is presented in **Table 9**. These comparisons are for the:

- Substances listed in the 1998 air NEPM which include standards for NO_2, SO_2, PM10 and CO (NEPC, 1998).
- PM2.5, where the "standard" listed is an advisory reporting standards where the goal is to gather sufficient data to facilitate a review of the advisory standard by 2005 (NEPC, 2003a).
- The air toxics listed in the draft air toxics NEPM that was released in May 2003 (NEPC, 2003b). This air toxics NEPM specifies investigation levels "for use in assessing any air monitoring data collected for the purpose of this measure. The investigation levels are established for use in establishing the significance of the monitored levels of air toxics with respect to protection of human health. If the investigation levels are exceeded then some form of further investigation by the relevant jurisdiction of the cause of the exceedance is appropriate." (NEPC, 2003b).

SKM

- **Table 9 Summary of the Predicted NEPM Pollutant Concentrations at the Nearest Residences from the Pinjarra Refinery for the Baseline and Upgrade Case**

Pollutant	Averaging Time	Level (mg/m^3)	Highest Concentration @ Nearest Residences		Percentage of NEPM @ Nearest Residences	
			Baseline Refinery	Upgraded Refinery	Baseline Refinery	Upgraded Refinery
Standards (NEPC, 1998)						
NO_2	1 hour	246	103.3 (108.5)	103.6 (108.8)	42.0 (44.1)	42.1 (44.2)
NO_2	Annual	61.6	1.90 (5.5)	1.40 (5.0)	3.1 (8.9)	2.3 (8.1)
SO_2	1 hour	570	32.9	33.4	5.8	5.9
SO_2	24 hour	228	3.91	3.98	1.7	1.7
SO_2	Annual	57	0.20	0.20	0.35	0.35
PM10	24 hour	50	4.63	3.5	9.3	7.0
CO	8 hour	11,240	91.5	95	0.81	0.85
Advisory Reporting Standard and Goal (NEPC, 2003a)						
PM2.5	24 hour	25	2.25	1.70	9.0	6.8
PM2.5	Annual	8	0.20	0.14	2.5	1.8
Investigation Levels (NEPC, 2003b)						
Benzene	Annual	9.57	0.038	0.003	0.40	0.03
Formaldehyde	24 hour	18.45	0.81	0.84	4.4	4.6
Toluene	24 hour	7540	2.40	0.89	0.032	0.012
Xylenes	24 hour	868	0.49	0.40	0.056	0.046

Notes:

1) The NEPM pollutants of NO_2, SO_2 and CO have been converted to $\mu g/m^3$ using reference conditions of 101.3kPa and 0 deg C.

2) The investigation levels for benzene, benzo[a]pyrene, formaldehyde, toluene and xylenes have been converted at 25 degrees Celsius using the conversion factors on page 55 of (NEPC, 2003c).

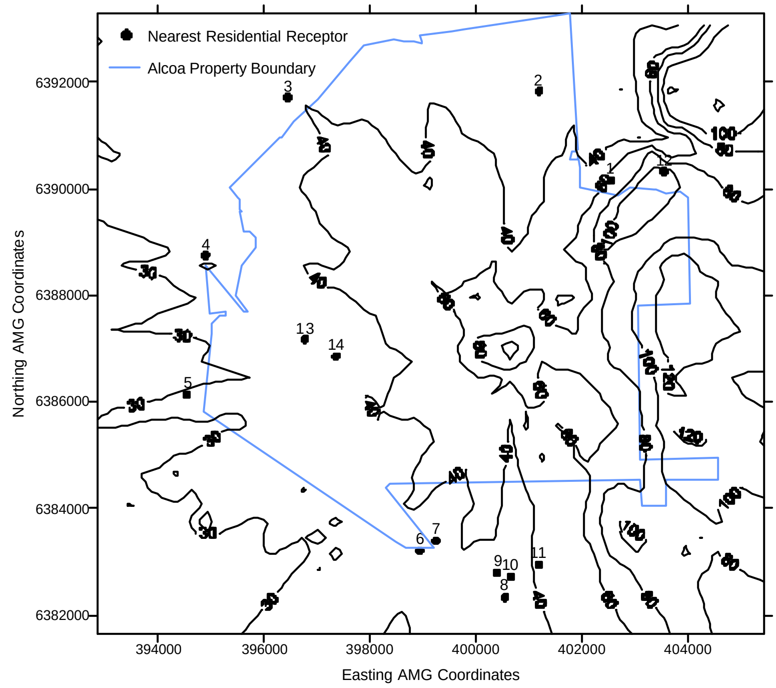
3) The values in brackets for NO_2 are the cumulative contribution from predicted concentrations and background NO_2 concentrations. For the maximum 1-hour cumulative concentrations the refinery is predicted to not increase the levels as the highest background occurred in the early morning where the plumes containing NO_X remained above ground level.

4) Benzene[a]pyrene has been omitted from this table and is discussed in Toxikos (2003).

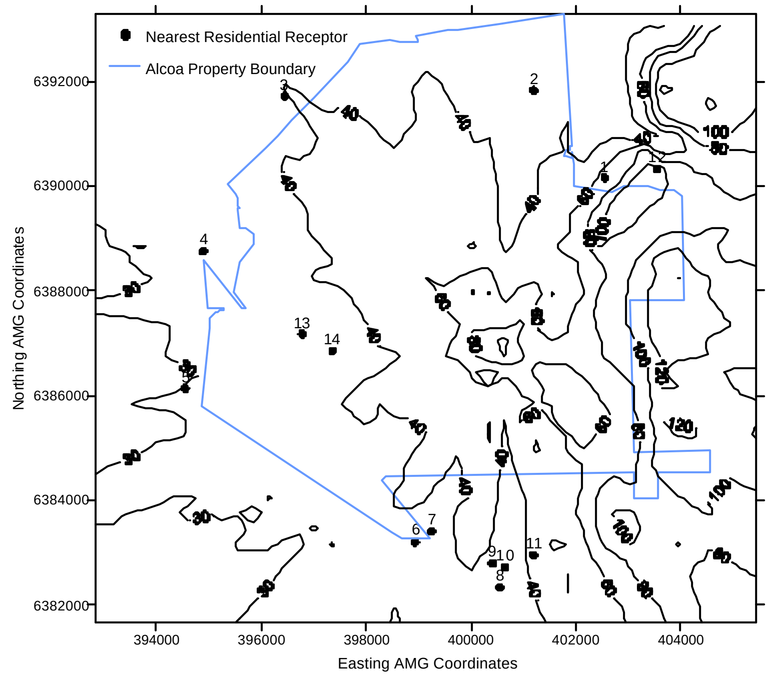
5) CO 8-hour predictions are not presented in Table 7 and 8.

Table 9 indicates that for the criteria pollutants the concentrations are below the respective standards with NO_2 being the closest at 42.0 and 42.1% of the NEPM criteria for the baseline and upgrade case respectively. The maximum NO_2 concentrations occur at location 12, on the side of the scarp, where it is noted that the concentrations predicted from AUSPLUME are considered to be conservative due to the simple terrain scheme used (see **Section 3** and **Figure 31**, **Figure 32** and **Figure 33)**. Additionally, the NO_2 concentrations have been estimated from the NO_X concentrations using the OLM (see **Section 5.6**) which is a conservative screening technique. As such the NO_2 are considered to be over estimates.

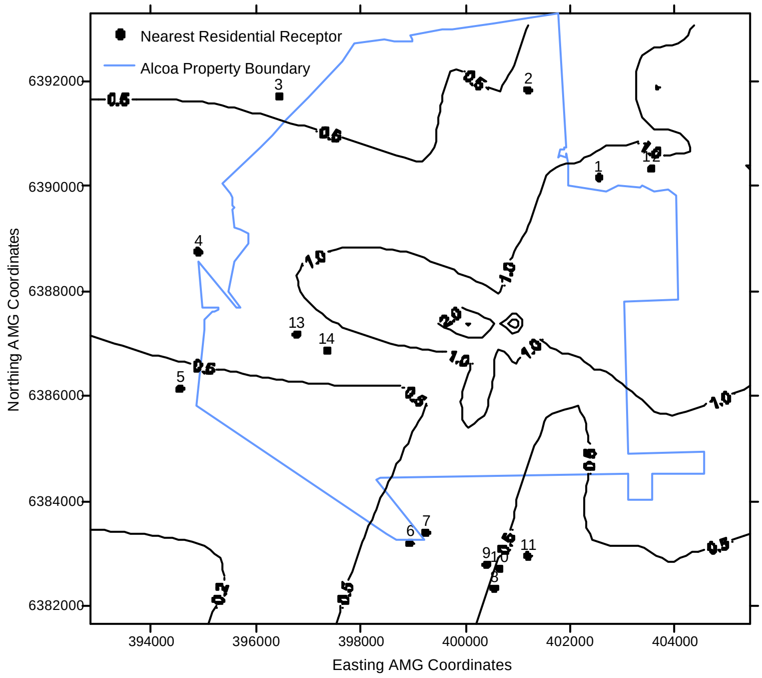
SKM



- **Figure 31 Predicted maximum 1-hour average ground level concentration ($\mu g/m^3$) of NO_2 from the Baseline Case**



- **Figure 32 Predicted maximum 1-hour average ground level concentration ($\mu g/m^3$) of NO_2 from the Upgrade Case**



- **Figure 33 Predicted annual average ground level concentration (μg/m^3) of NO_2 from the Upgrade Case**

The next highest relative concentrations are those from PM10 and PM2.5 with maximum 24-hour concentrations of 9.3% of the standard (a goal of no more than 5 exceedances per year) and 9% of the advisory reporting standard respectively.

6.3 Predicted NO_2 Concentrations with Existing Background Levels

As discussed in **Section 5.7**, apart from PM10, PM2.5 and NO_2, background levels of the substances modelled are expected to be negligible and therefore the predictions from the refinery for these substances will represent the total concentrations. For PM10 and PM2.5 due to the difficulty in modelling these, no assessment of the total cumulative concentrations has been done. However, an analysis of the existing levels including the present refinery are presented in Environ (2003) along with historical trends in dust levels.

For NO_2, predicted cumulative levels are summarised in **Table 9**. This indicates that for the maximum 1-hour average concentration, consideration of the background NO_2 concentrations will make little difference. This is due to the background maximum 1-hour levels being relatively low (38.2μg/m^3) and that the highest predicted concentrations do not occur at the time of highest background concentrations. For the annual concentrations, it is seen that the refinery contributes up to an additional 41% of the annual concentrations with these still remaining low at 8.9% of the NEPM.

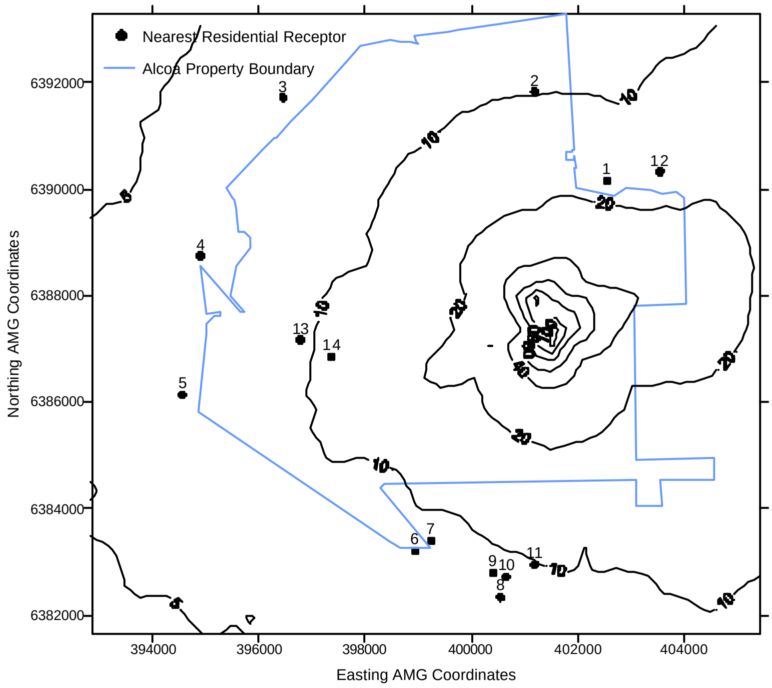
6.4 Other VOCs and Metals

An evaluation of the significance of the predicted ground level concentrations of the other VOCs and metals predicted in this report is presented in the health risk assessment by Toxikos (Toxikos, 2003). **Figure 34** to **Figure 38** presents predicted ground level concentrations for selected substances and averaging periods for this assessment although interpretation of these is provided by others (Toxikos, 2003). Modelling of arsenic was also performed using the model CALPUFF to provide more realistic predictions at locations 1 and 12 where it is considered that AUSPLUME over-predicts ground level concentrations(see **Section 4**). The results are presented in **Table 10** and indicate that CALPUFF predicts lower concentrations of arsenic by 1.85 to 2.97 times than those predicted from AUSPLUME.

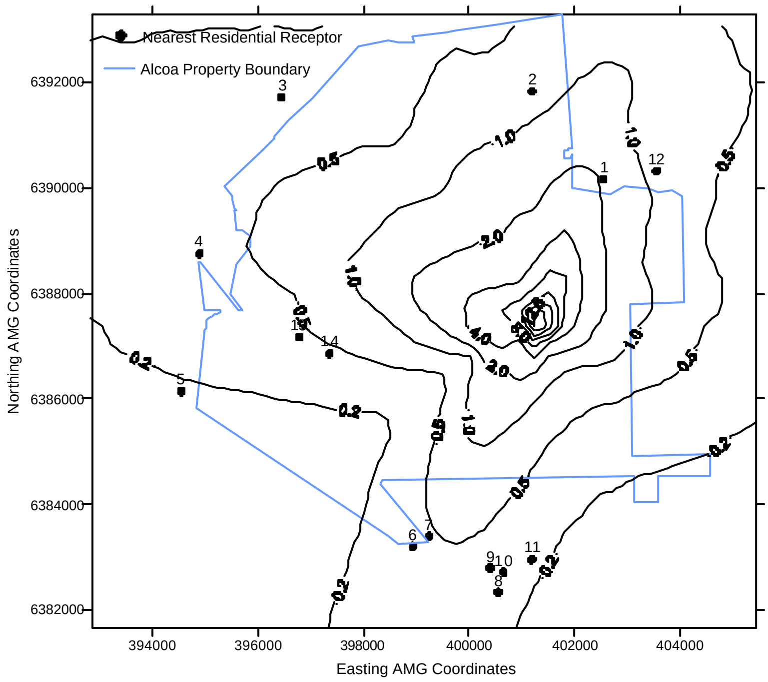
- **Table 10 Predicted Annual Average Concentrations of Arsenic from AUSPLUME and CALPUFF**

Refinery	Location	AUSPLUME ($\mu g/m^3$)	CALPUFF ($\mu g/m^3$)
Baseline	1	0.00111	0.00037
	12	0.00086	0.000465
Upgrade Case	1	0.00023	0.0000796
	12	0.00020	0.000092

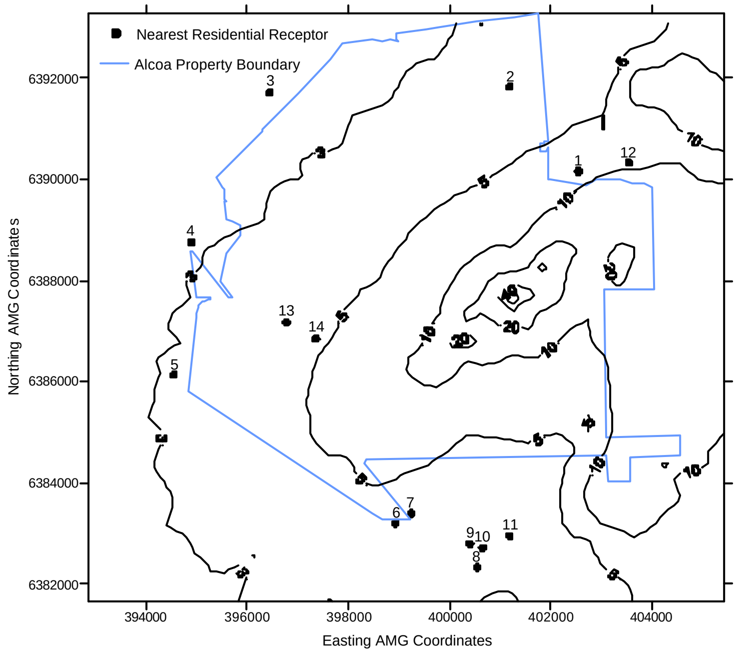
Note: The results are presented from modelling as very fine particulate.



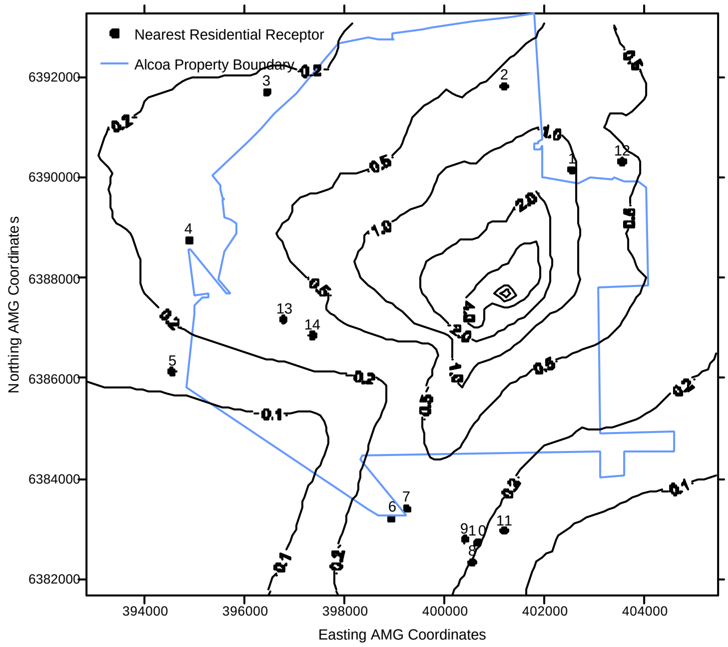
- **Figure 34 Predicted maximum 1-hour average concentration (mg/m³) of acetaldehyde from the Baseline Case**



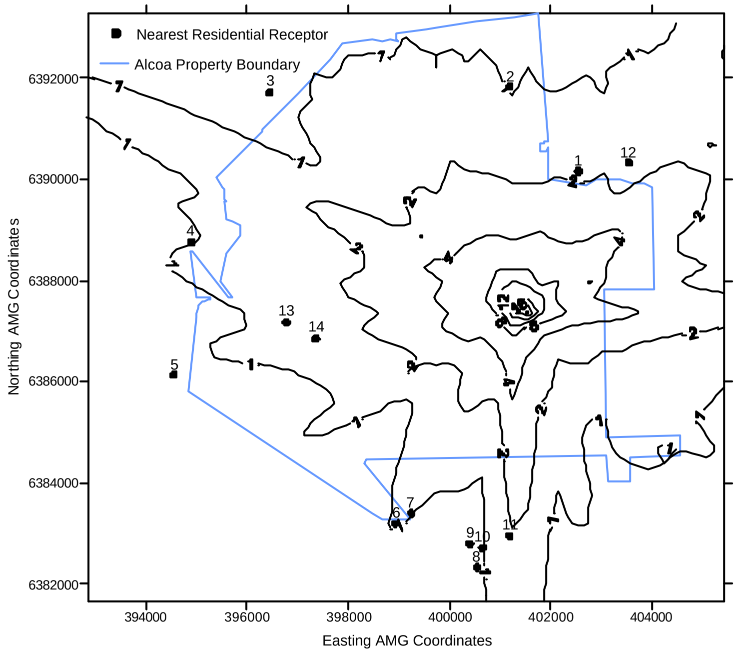
- **Figure 35 Predicted 95 percentile1-hour average concentration (mg/m³) of acetaldehyde from the Baseline Case**



- **Figure 36 Predicted maximum 1-hour average concentration (µg/m^3) of acetaldehyde from the Upgrade Case**



- **Figure 37 Predicted 95 percentile1-hour average concentration (µg/m^3) of acetaldehyde from the Upgrade Case**



- **Figure 38 Predicted maximum 24-hour average concentration (mg/m^3) of acetaldehyde from the Baseline Case**

6.5 Vegetation Impacts

Predicted 24-hour and annual average ground level concentrations of NO_X from the baseline case are presented in **Figure 39** and **Figure 40** along with the predicted annual average concentration of SO_2 in **Figure 41.** The maximum concentrations outside the Pinjarra refinery property for these averaging periods along with the WHO vegetation guidelines are also presented in **Table 11.**

SKM

- **Table 11 Predicted Maximum Concentrations of NO_X and SO_2 Outside the Refinery Property for the Baseline Case and the Respective WHO Vegetation Guidelines**

Vegetation Category	Time Period	WHO European Guideline (mg/m^3)	Predicted Maximum Outside Refinery Boundary (mg/m^3)	Percentage of WHO Guideline (%)
SO_2				
Agricultural Crops	Annual or winter mean	30	0.46	1.5
Forests and natural Vegetation	Annual or winter mean	20	0.46	2.3
Lichens	Annual mean	10	0.46	4.6
NO_X				
Not Specified	24-hour	75	119 AUSPLUME	159
			31 CALPUFF	41
Not Specified	Annual mean	30	9.9 AUSPLUME	33

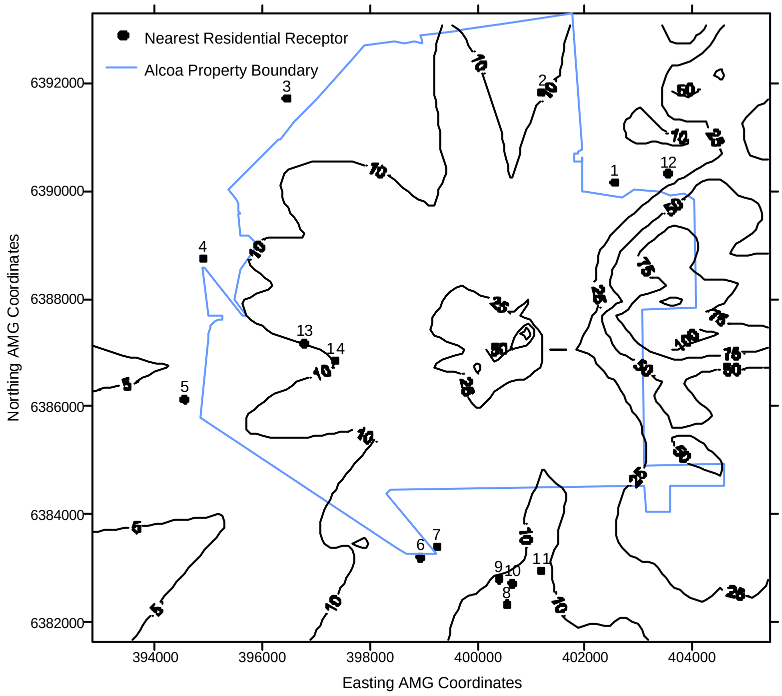
Notes

1) Source WHO (2000)

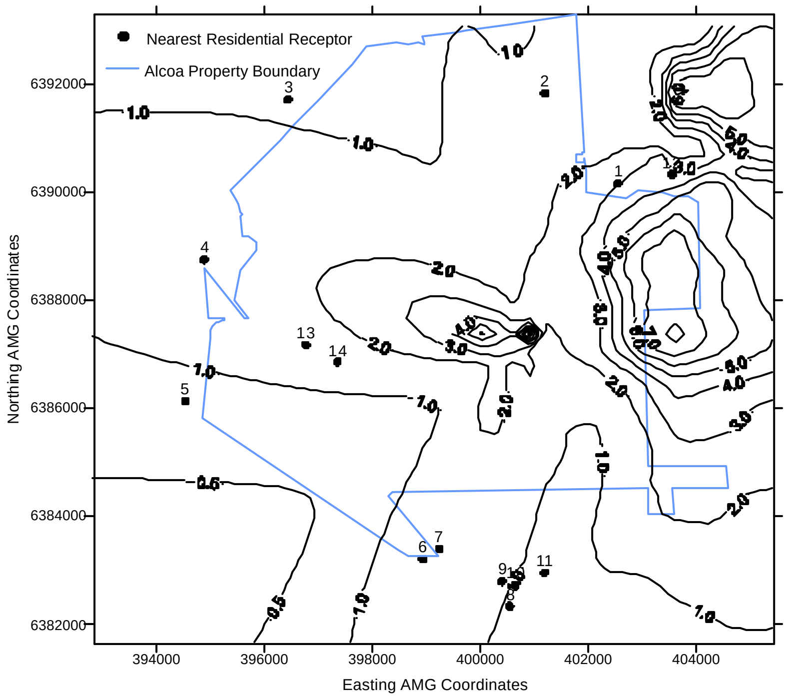
2) Winter is defined as October to March for Europe (i.e 5 months)

3) Annual means have only been estimated for SO_2.

Table 11 indicates that the annual NO_X and SO_2 concentrations are at most 33 and 4.6% of the WHO guidelines respectively. The 24-hour NO_X concentrations however are predicted to exceed the guideline. These high concentrations are predicted to occur on the escarpment where it is shown that AUSPLUME predicts concentrations 3 to 4 times higher than the other two models. As these models have a more rigorous treatment of terrain effects they are considered to provide more realistic predictions on the escarpment. Using the model CALPUFF, a maximum 24-hour concentration outside the refinery boundary of 31 $\mu g/m^3$ (41% of the guideline) is predicted (**Table 11**) which occurs due east of the refinery on the escarpment (**Figure 42**). Therefore, it is considered that the actual 24-hour NO_X concentrations will be below the guidelines. This will be confirmed by the ongoing measurements conducted and the model validation to be performed in 2004.

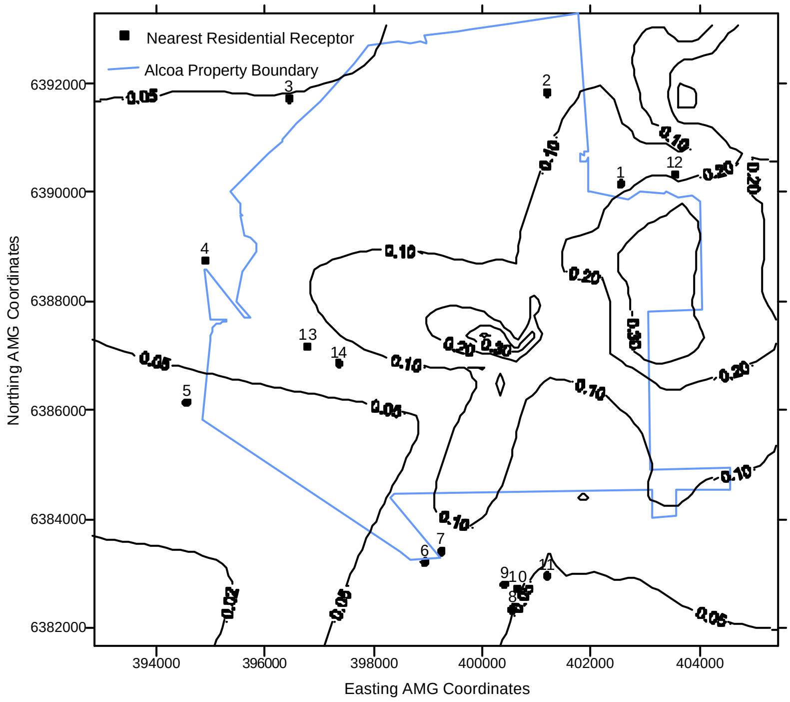


- **Figure 39 Predicted maximum 24-hour average ground level concentration (μg/m^3) of NO_X from the Baseline case (Predicted by AUSPLUME)**

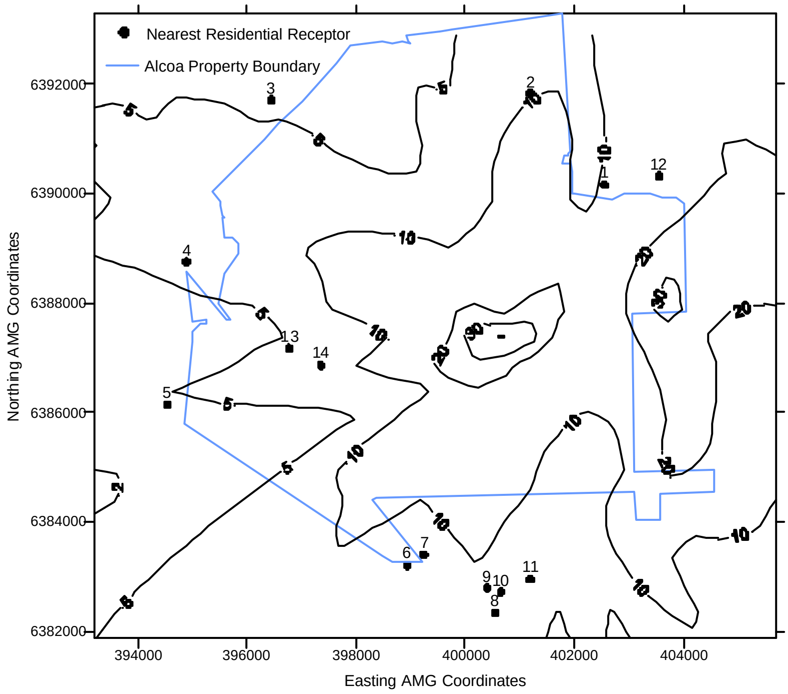


- **Figure 40 Predicted annual average ground level concentration (μg/m^3) of NO_X from the Baseline case (Predicted by AUSPLUME)**

SKM



- **Figure 41 Predicted annual average ground level concentrations of SO_2 from the Baseline case (Predicted by AUSPLUME)**



- **Figure 42 Predicted maximum 24-hour average ground level concentration (mg/m^3) of NO_X from the Baseline case (Predicted by CALPUFF)**

6.6 Calciner Upset Conditions

An assessment of the maximum concentrations from the calciners for the duration of a 'cool-down' shutdown event on the night of the 14 to 15 July 2002 was conducted by SKM (2002). This found low concentrations offsite. As this event occurred on a night with light winds where the plumes from the calciners tend to remain elevated, this previous assessment does not represent the maximum ground level concentrations that could occur if this event were to happen during worst case dispersive conditions. To estimate the potential highest concentrations from a calciner upset, AUSPLUME was used to predict concentrations assuming that these upset emissions occurred for the entire year. Model parameters used were:

- Maximum particulate concentration of 700 mg/m^3;
- Particulate emissions of 13.8 g/s;
- Velocity of 37.7 m/s;
- Temperature of 107 degrees;
- 45% of the particulate below 10 µm and 20% below 2.5µm; and
- Other calciners operating normally at the baseline peak emission case.

The results of this modelling indicate that the maximum 24-hour PM10 and PM2.5 concentrations offsite would be 32.3 and 21.2 µg/m^3 respectively (occurring at location 5) with the next highest concentrations at a residence predicted to be 14.8 and 6.9 µg/m^3 (occurring at location 2). Given that this condition would have to occur for 24-hours, that the original event lasted for 9 hours and that Alcoa has implemented systems and processes to ensure that it does not occur again, it is reasonable to assume that the hypothetical worst case PM10 concentrations would be substantially less than these. As such, even if this emission scenario occurred under the worst dispersive conditions the concentrations at the nearest residences should be well below the NEPM PM10 and PM2.5 standards.

SKM

7. Conclusions and Recommendations

This report presents an assessment of the ground level concentrations from the major air pollutants around the Pinjarra refinery.

Predicted concentrations have been undertaken using the dispersion model AUSPLUME, and an annual meteorological file from Pinjarra. AUSPLUME was selected as the basis of modelling based on a comparison of three models (TAPM, CALPUFF and AUSPLUME) as it provides generally the highest (most conservative) estimates at all the nearest residences and particularly at the residences predicted to receive highest concentrations. It is considered that, at the locations predicted to receive the highest concentrations (on the escarpment), AUSPLUME over- predicts due to its simple method for modelling the impacts of terrain. A complete comparison of the models is scheduled for 2004 upon completion of an ambient monitoring programme currently being undertaken.

The results of AUSPLUME modelling indicate the following:

- The highest concentrations outside the refinery property boundary are predicted to occur on the escarpment to the east of the refinery;
- The highest concentrations at the nearest residences are predicted to occur at locations 1 and 12. Concentrations in the more populated areas of Pinjarra and North Pinjarra are predicted to be only 30 to 50% of these concentrations;
- Of the NEPM pollutants, the concentrations of NO_2 are closest to the NEPM standards at 42.0 and 42.1% for the baseline and upgrade case respectively. These concentrations are considered to be over-estimates as they occur on the scarp (location 12) where AUSPLUME is considered to over-predict and the conversion of NO to NO_2 has been made using the OLM which is a conservative screening technique. The next highest relative concentrations are those from PM10 and PM2.5 with maximum 24-hour concentrations of 9.3% of the standard (a goal of no more than 5 exceedances per year) and 9% of the advisory reporting standard respectively. These concentrations are predicted to decrease to 7.0 and 6.8% of the standard for PM10 and PM2.5 following the upgrade; and
- Predicted 1-hour average and annual average concentrations at the nearest residential sites will decrease substantially for 6 substances including: benzene (decreases by 92 to 95%), arsenic (decreases by 78 to 83%) and cadmium (decreased by 78 to 84%), nickel (decreased by 83 to 86%), acetaldehyde (decreased by 26 to 58%) and toluene (decreased by 65 to 70%). Of the other 16 substances modelled, seven will show moderate decreases (up to a 50% decrease), three will be indeterminate with both an increase and decrease in concentrations, and six will show moderate increases ranging from 2 to 3% for SO_2 and up to a 15 to 19% increase for mercury.

Further validation of the dispersion models is scheduled for 2004 after completion of the ambient monitoring programme. This will compare the model predictions against observational data and allow the sensitivity of the models (especially CALPUFF) to be tested for a range of model parameters. When available, it is also recommended that actual particle size and shape data be utilised for the particulate sources to improve the predictions of PM10, PM2.5, metals, dioxins and furans and PAHs. Additionally, further data is needed to confirm which phase (either particulate or vapour) of metals are emitted from some of the sources.

8. References

Alcoa (2003). Air Quality Data - Environmental Protection Statement, Pinjarra Refinery Efficiency Upgrade. October 2003. Alcoa World Alumina Australia.

Briggs, G.A. (1974). Plume rise from multiple sources. *In Cooling Tower Environment – 1974*, S.R Hanna and J.Pells (Eds), University of Maryland Education Center, 4-6 March 1974, NTIS CONF – 740302, pp161-179.

Cole, H.S. and Summerhays, J.E. (1979). A review if techniques available for estimating short-term NO_2 concentrations. Journal of the Air Pollution Control Association. 29, 812-817.

Cox, S. (2003a). E-mails of 8 October 2003.

Cox, S. (2003b). Personnel communication of 23 September 2003 with Stephen Cox, Process Engineer, Alcoa.

Dames & Moore (1977). Atmospheric Dispersion and Recommended Chimney Heights, Pinjarra, WA. Report to Alcoa Australia.

Environ (2002). Air dispersion modelling. Pinjarra cogeneration project for Alcoa World Alumina Australia Pty Ltd.

Environ (2003). Pinjarra Refinery Efficiency Upgrade Alcoa World Alumina Australia: Air Quality Data Environmental Protection Statement.

Hanna, S.R., Briggs, G.A, and Hosker, R.P. (1984). Handbook on Atmospheric Diffusion. Technical Information Center. U.S. Department of Energy. pp 102.

NEPC (1998). National Environment Protection Measure for Ambient Air Quality. 26 June 1998. National Environment Protection Council.

NEPC (2003a). Variation to the National Environment Protection (Ambient Air Quality) Measure for Particles as PM2.5. National Environment Protection Council. 23 May 2003.

NEPC (2003b). National Environment Protection (Air Toxics) Measure. Draft NEPM for Public Consultation. Draft NEPM for Public Consultation, May 2003.

Pitts, R.O. and Lyons, T.J. (1988). The influence of topography on Perth radiosonde observations. Australian Meteorological Magazine., 36, 17-23.

Pitts, R.O. and Lyons, T.J. (1989). Airflow over a two dimensional escarpment. I. Observations. Q.J.. Meteorol Soc, 965 – 981.

Policastro, A.J., Dunn W.E., and Carhart, R.A. (1994). A model for seasonal and annual cooling tower impacts. Atmospheric Environment, 28, 379-395.

Ray, D.K., Nair, U.S., Welch, R.M., Han, Q., Zeng, J., Su, W., Kikuchi, T., and Lyons, T.J. (2003). Effects of land use in Southwest Australia. 1. Observations of cumulus cloudiness and energy fluxes.

Scherer, T. (2003). E-mail from Thomas Scherer of Siemans of 22 October 2003.

SKM (2001). Wind Erosion over Future Wagerup Residue Area. Report prepared for Alcoa World Alumina.

SKM (2002). Particulate Emissions Modelling. Pinjarra Refinery – Calciner 3 Emission Modelling. Report prepared for Alcoa World Alumina Australia. 24 July 2002.

Toxikos (2003). Health Risk and Toxicological Assessment of Emissions from the Upgraded Alcoa Pinjarra Alumina Refinery, Dr Roger Drew, Toxikos Pty Ltd, 2003.

USEPA. (1998). Revised draft user's guide for the AERMOD meteorological pre-processor (AERMET). U.S. Environmental Protection Agency. November 1998.

Appendix A Typical AUSPLUME Output File

1

Pinjarra Refinery Base VOC

```
Concentration or deposition                          Concentration
Emission rate units                                  grams/second
Concentration units                                  microgram/m3
Units conversion factor                              1.00E+06
Constant background concentration                             0.00E+00
Terrain effects                                      Egan method
Smooth stability class changes?                      No
Other stability class adjustments ("urban modes")    None
Ignore building wake effects?                        No
Decay coefficient (unless overridden by met. file)   0.000
Anemometer height                                    10 m
Roughness height at the wind vane site               0.100 m

                   DISPERSION CURVES
Horizontal dispersion curves for sources <100m high  Pasquill-Gifford
Vertical  dispersion  curves for sources <100m high  Pasquill-Gifford
Horizontal dispersion curves for sources >100m high  Briggs Rural
Vertical  dispersion  curves for sources >100m high  Briggs Rural
Enhance horizontal plume spreads for buoyancy?       Yes
Enhance  vertical  plume spreads for buoyancy?       Yes
Adjust horizontal P-G formulae for roughness height? Yes
Adjust  vertical  P-G formulae for roughness height? Yes
Roughness height                                     0.400m

Horizontal plume spreads will be adjusted taking into account
the default wind directional shear values.

                    PLUME RISE OPTIONS
Gradual plume rise?                                  Yes
Stack-tip downwash included?                         Yes
Building downwash algorithm:                        PRIME method.
Entrainment coeff. for neutral & stable lapse rates 0.60,0.60
Partial penetration of elevated inversions?          No
Disregard temp. gradients in the hourly met. file?   No

and in the absence of boundary-layer potential temperature gradients
given by the hourly met. file, a value from the following table
(in K/m) is used:
```

Wind Speed Category	Stability Class A	B	C	D	E	F
1	0.000	0.000	0.000	0.000	0.020	0.035
2	0.000	0.000	0.000	0.000	0.020	0.035
3	0.000	0.000	0.000	0.000	0.020	0.035
4	0.000	0.000	0.000	0.000	0.020	0.035
5	0.000	0.000	0.000	0.000	0.020	0.035
6	0.000	0.000	0.000	0.000	0.020	0.035

```
WIND SPEED CATEGORIES
Boundaries between categories (in m/s) are:  1.54,  3.09,  5.14,  8.23, 10.80

WIND PROFILE EXPONENTS: "Irwin Rural" values (unless overridden by met. file)

AVERAGING TIMES
 1 hour
 average over all hours
```

1

Pinjarra Refinery Base VOC

SOURCE CHARACTERISTICS

STACK SOURCE: BS567

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
400994	6387248	42m	75m	4.37m	138C	9.2m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	123	123	119	111	100	86	70	0	0	0	0	40
Effective building height	21	21	21	21	21	21	21	0	0	0	0	16
Along-flow building length	51	70	86	100	112	119	123	0	0	0	0	45
Along-flow distance from stack	40	36	30	25	18	11	3	0	0	0	0	-40
Across-flow distance from stack	-37	-26	-13	0	13	26	37	0	0	0	0	24

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	43	45	119	123	123	120	123	123	119	111	100	86
Effective building height	16	16	21	21	21	21	21	21	21	21	21	21
Along-flow building length	44	43	86	69	51	30	50	70	86	101	111	119
Along-flow distance from stack	-44	-46	-69	-72	-73	-72	-90	-105	-117	-125	-129	-130
Across-flow distance from stack	20	16	70	65	57	48	37	26	13	0	-13	-26

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	70	0	0	0	22	22	21	45	119	123	124	120
Effective building height	21	0	0	0	28	28	28	16	21	21	21	21
Along-flow building length	123	0	0	0	16	18	20	43	86	70	51	30
Along-flow distance from stack	-126	0	0	0	-98	-101	-100	3	-18	3	23	42
Across-flow distance from stack	-37	0	0	0	18	2	-14	-16	-70	-65	-57	-48

(Constant) emission rate = 4.03E-01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: BS3&4

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401074	6387263	42m	31m	3.77m	0C	0.0m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	123	123	119	111	100	86	24	23	20	51	69	86
Effective building height	21	21	21	21	21	21	20	20	20	21	21	21
Along-flow building length	51	70	86	100	112	119	21	18	15	123	123	119
Along-flow distance from stack	11	-6	-23	-39	-53	-66	20	20	19	-101	-106	-108
Across-flow distance from stack	39	44	49	52	53	53	7	12	17	36	29	21

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	100	111	119	123	123	120	123	123	119	111	100	86
Effective building height	21	21	21	21	21	21	21	21	21	21	21	21
Along-flow building length	111	100	86	69	51	30	50	70	86	101	111	119
Along-flow distance from stack	-107	-103	-96	-85	-72	-57	-61	-63	-64	-62	-58	-53
Across-flow distance from stack	12	3	-7	-16	-24	-32	-39	-45	-49	-51	-53	-53

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	24	23	20	51	69	86	21	20	18	123	124	120
Effective building height	20	20	20	21	21	21	28	28	28	21	21	21
Along-flow building length	21	18	15	123	123	119	20	21	22	70	51	30
Along-flow distance from stack	-41	-38	-34	-23	-17	-11	20	-90	-89	16	22	27
Across-flow distance from stack	-7	-12	-17	-36	-29	-21	20	4	-10	16	24	32

(Constant) emission rate = 0.00E+00 grams/second
No gravitational settling or scavenging.

STACK SOURCE: CALC12

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
400675	6387129	39m	41m	2.09m	161C	37.3m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	88	86	81	74	40	41	41	26	54	26	41	53
Effective building height	31	31	31	31	38	38	38	31	26	31	31	31
Along-flow building length	26	40	53	64	39	35	31	88	87	88	86	81
Along-flow distance from stack	-18	-31	-43	-54	-139	-139	-136	-79	-79	-79	-77	-72
Across-flow distance from stack	35	34	31	28	23	2	-19	8	-14	-5	-11	-17

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	64	74	81	86	88	87	88	86	81	74	64	53
Effective building height	31	31	31	31	31	31	31	31	31	31	31	31
Along-flow building length	74	65	53	40	26	11	26	41	53	65	74	81

SKM

Along-flow distance from stack	-65	-56	-46	-34	-21	-7	-8	-10	-10	-11	-11	-11
Across-flow distance from stack	-22	-26	-30	-33	-35	-36	-35	-34	-31	-28	-24	-19

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	40	26	54	26	40	53	65	74	81	86	88	87
Effective building height	31	31	26	31	31	31	31	31	31	31	31	31
Along-flow building length	86	88	87	88	86	81	74	65	53	40	26	11
Along-flow distance from stack	-10	-9	-8	-9	-9	-9	-9	-8	-8	-7	-5	-4
Across-flow distance from stack	-14	-8	14	5	11	17	22	26	30	33	35	36

(Constant) emission rate = 2.33E+00 grams/second
No gravitational settling or scavenging.

STACK SOURCE: CALC34

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
400644	6387128	39m	41m	2.09m	160C	32.6m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	88	86	81	39	40	41	41	26	54	26	41	53
Effective building height	31	31	31	38	38	38	38	31	26	31	31	31
Along-flow building length	26	40	53	41	39	35	31	88	87	88	86	81
Along-flow distance from stack	-12	-20	-27	-113	-114	-112	-106	-48	-48	-49	-48	-46
Across-flow distance from stack	5	5	5	20	4	-13	-29	3	-13	2	1	-1

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	64	74	81	86	88	87	88	86	81	39	41	53
Effective building height	31	31	31	31	31	31	31	31	31	38	38	31
Along-flow building length	74	65	53	40	26	11	26	41	53	41	39	81
Along-flow distance from stack	-42	-37	-31	-24	-17	-8	-15	-21	-26	73	76	-38
Across-flow distance from stack	-1	-2	-3	-3	-4	-5	-5	-5	-5	-20	-4	-5

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	41	26	54	26	40	53	65	74	81	86	88	87
Effective building height	38	31	26	31	31	31	31	31	31	31	31	31
Along-flow building length	31	88	87	88	86	81	74	65	53	40	26	11
Along-flow distance from stack	75	-40	-39	-39	-38	-35	-32	-28	-23	-16	-10	-3
Across-flow distance from stack	29	-3	13	-2	-1	0	1	2	3	4	4	5

(Constant) emission rate = 2.04E+00 grams/second
No gravitational settling or scavenging.

STACK SOURCE: OXL

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401145	6387751	42m	37m	1.00m	65C	9.1m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	0	30	34	36	39	39	0	0	0	0	107	102
Effective building height	0	18	18	18	18	18	0	0	0	0	23	23
Along-flow building length	0	39	39	39	36	34	0	0	0	0	53	69
Along-flow distance from stack	0	-76	-79	-79	-76	-71	0	0	0	0	38	39
Across-flow distance from stack	0	16	6	-4	-15	-24	0	0	0	0	-57	-45

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	94	83	69	53	36	0	0	0	0	0	0	0
Effective building height	23	23	23	23	23	0	0	0	0	0	0	0
Along-flow building length	82	94	102	108	109	0	0	0	0	0	0	0
Along-flow distance from stack	39	37	35	31	27	0	0	0	0	0	0	0
Across-flow distance from stack	-31	-16	-2	13	28	0	0	0	0	0	0	0

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	0	0	0	0	108	102	94	82	69	53	36	0
Effective building height	0	0	0	0	23	23	23	23	23	23	23	0
Along-flow building length	0	0	0	0	53	69	82	94	102	107	109	0
Along-flow distance from stack	0	0	0	0	-91	-108	-121	-131	-137	-138	-136	0
Across-flow distance from stack	0	0	0	0	56	44	31	17	2	-13	-28	0

(Constant) emission rate = 4.30E-01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: CALC56

SKM

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
400614	6387129	39m	38m	2.49m	179C	22.1m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	88	31	36	39	40	41	40	26	54	26	41	53
Effective building height	31	38	38	38	38	38	31	31	26	31	31	31
Along-flow building length	26	41	42	41	39	35	86	88	87	88	86	81
Along-flow distance from stack	-7	-91	-95	-95	-92	-86	-19	-19	-18	-19	-19	-19
Across-flow distance from stack	-25	22	10	-4	-16	-29	-7	-3	-14	6	10	14

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	64	74	81	86	88	87	88	31	35	39	41	41
Effective building height	31	31	31	31	31	31	31	38	38	38	38	38
Along-flow building length	74	65	53	40	26	11	26	41	41	41	39	36
Along-flow distance from stack	-19	-17	-15	-13	-10	-7	-19	51	53	54	53	51
Across-flow distance from stack	18	21	23	25	25	26	25	-22	-9	4	16	29

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	40	26	54	26	40	53	65	74	81	86	88	87
Effective building height	31	31	26	31	31	31	31	31	31	31	31	31
Along-flow building length	86	88	87	88	86	81	74	65	53	40	26	11
Along-flow distance from stack	-67	-69	-69	-69	-66	-62	-56	-48	-38	-28	-16	-4
Across-flow distance from stack	8	3	14	-6	-10	-14	-18	-20	-23	-25	-25	-26

(Constant) emission rate = 1.88E+00 grams/second
No gravitational settling or scavenging.

STACK SOURCE: ALD

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
400557	6387077	39m	45m	1.50m	77C	17.2m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	26	31	36	39	40	41	41	39	36	39	41	41
Effective building height	38	38	38	38	38	38	38	38	38	38	38	38
Along-flow building length	39	41	42	41	39	35	31	26	20	26	31	36
Along-flow distance from stack	-25	-23	-21	-18	-15	-11	-7	-2	2	0	-2	-4
Across-flow distance from stack	-13	-14	-14	-14	-13	-12	-11	-9	-7	-5	-3	0

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	41	39	35	31	26	20	26	31	35	39	41	41
Effective building height	38	38	38	38	38	38	38	38	38	38	38	38
Along-flow building length	39	41	41	41	39	36	39	41	41	41	39	36
Along-flow distance from stack	-6	-7	-9	-10	-11	-11	-15	-18	-21	-23	-24	-25
Across-flow distance from stack	2	5	7	9	11	12	13	14	14	14	13	12

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	41	39	36	39	41	42	41	39	35	31	26	20
Effective building height	38	38	38	38	38	38	38	38	38	38	38	38
Along-flow building length	31	26	20	26	31	36	39	41	41	41	39	36
Along-flow distance from stack	-24	-24	-22	-26	-29	-32	-33	-34	-33	-31	-29	-25
Across-flow distance from stack	11	9	7	5	3	0	-2	-4	-7	-9	-11	-12

(Constant) emission rate = 7.12E-01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: BS-2

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401105	6387266	42m	35m	3.05m	120C	8.7m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	123	16	18	23	25	25	24	23	20	51	69	86
Effective building height	21	28	28	23	20	20	20	20	20	21	21	21
Along-flow building length	51	22	22	21	24	23	21	18	15	123	123	119
Along-flow distance from stack	3	-84	-84	21	-7	-8	-10	-11	-12	-131	-134	-134
Across-flow distance from stack	69	9	-4	21	14	15	15	15	14	28	15	2

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	100	111	119	123	123	120	123	21	23	24	25	25
Effective building height	21	21	21	21	21	21	21	20	20	20	20	20

Along-flow building length	111	100	86	69	51	30	50	24	25	25	25	23
Along-flow distance from stack	-129	-120	-108	-93	-75	-54	-53	-24	-22	-20	-18	-15
Across-flow distance from stack	-11	-23	-35	-46	-55	-63	-69	-9	-11	-12	-14	-15

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	24	23	20	51	69	86	100	112	18	123	124	120
Effective building height	20	20	20	21	21	21	21	21	28	21	21	21
Along-flow building length	21	18	15	123	123	119	111	100	22	70	51	30
Along-flow distance from stack	-11	-7	-3	7	11	15	18	20	-76	24	24	24
Across-flow distance from stack	-15	-15	-14	-27	-15	-3	11	23	18	46	55	63

(Constant) emission rate = 1.93E-01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: COGEN1

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401122	6387207	42m	40m	6.00m	165C	18.2m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	11	16	18	20	21	22	22	21	19	21	21	22
Effective building height	33	28	28	28	28	28	28	28	28	28	28	28
Along-flow building length	10	21	22	21	20	18	16	13	10	13	16	18
Along-flow distance from stack	-17	-17	-17	-16	-14	-12	-10	-8	-5	-5	-6	-6
Across-flow distance from stack	-2	-2	-3	-4	-5	-6	-6	-6	-7	-6	-6	-5

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	21	20	18	123	123	10	11	16	18	20	21	21
Effective building height	28	28	28	21	21	33	33	28	28	28	28	28
Along-flow building length	20	21	22	69	51	8	10	21	22	21	20	18
Along-flow distance from stack	-6	-6	-6	-154	-136	8	7	-5	-6	-6	-6	-6
Across-flow distance from stack	-5	-4	-3	-42	-62	0	2	2	3	4	5	6

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	22	21	19	21	22	22	21	20	18	16	11	10
Effective building height	28	28	28	28	28	28	28	28	28	28	33	33
Along-flow building length	16	13	10	13	16	18	20	21	22	22	10	8
Along-flow distance from stack	-6	-6	-5	-8	-10	-12	-14	-16	-16	-17	-17	-16
Across-flow distance from stack	6	6	7	7	6	6	5	4	3	2	2	0

(Constant) emission rate = 3.81E-01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: COGEN2

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401072	6387207	42m	40m	6.00m	165C	18.2m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	11	16	18	20	21	22	22	21	19	21	21	22
Effective building height	33	28	28	28	28	28	28	28	28	28	28	28
Along-flow building length	10	22	22	21	20	18	16	13	10	13	16	18
Along-flow distance from stack	-17	-17	-17	-16	-14	-12	-10	-8	-5	-5	41	38
Across-flow distance from stack	-2	-2	-3	-4	-5	-6	-6	-7	-7	-7	11	20

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	21	20	18	123	123	120	123	123	18	20	21	21
Effective building height	28	28	28	21	21	21	21	21	28	28	28	28
Along-flow building length	20	21	22	69	51	30	50	70	22	21	20	18
Along-flow distance from stack	-6	-6	-6	-137	-127	-113	-117	-117	-6	-6	-6	-6
Across-flow distance from stack	-5	-4	-3	5	-12	-30	-47	-62	3	4	5	6

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	21	21	19	21	22	22	21	20	18	16	11	10
Effective building height	28	28	28	28	28	28	28	28	28	28	33	33
Along-flow building length	16	13	10	13	16	18	20	21	22	22	10	8
Along-flow distance from stack	-6	-55	-55	-57	-57	-56	-14	-16	-16	-17	-17	-16
Across-flow distance from stack	6	15	7	-2	-11	-19	5	5	3	2	2	0

(Constant) emission rate = 3.81E-01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: 25AAS1

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401364	6387360	45m	24m	0.25m	90C	18.5m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	68	67	64	59	52	22	21	19	16	19	33	43
Effective building height	30	30	30	30	30	21	21	21	21	21	30	30
Along-flow building length	22	33	43	52	59	22	21	19	16	19	67	64
Along-flow distance from stack	-41	-41	-40	-38	-34	-7	-8	-8	-8	-11	-2	4
Across-flow distance from stack	-27	-32	-35	-38	-39	7	7	8	8	8	-24	-18

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	52	59	64	67	68	67	68	67	64	58	52	22
Effective building height	30	30	30	30	30	30	30	30	30	30	30	21
Along-flow building length	59	52	43	34	23	11	23	33	43	52	59	22
Along-flow distance from stack	9	14	18	22	26	28	18	8	-4	-14	-25	-15
Across-flow distance from stack	-12	-5	2	9	15	22	27	32	36	38	39	-7

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	21	19	16	19	34	43	52	59	64	67	68	67
Effective building height	21	21	21	21	30	30	30	30	30	30	30	30
Along-flow building length	21	19	16	19	67	64	59	52	43	33	23	11
Along-flow distance from stack	-13	-11	-8	-8	-65	-67	-67	-66	-61	-56	-48	-39
Across-flow distance from stack	-7	-8	-8	-8	24	19	12	5	-2	-9	-15	-22

(Constant) emission rate = 6.44E-01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: DGCT3

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401365	6387437	45m	24m	0.75m	100C	3.5m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	68	105	102	97	88	77	64	48	31	48	63	77
Effective building height	30	16	16	16	16	16	16	16	16	16	16	16
Along-flow building length	22	64	77	88	97	102	105	104	100	104	105	102
Along-flow distance from stack	-117	-8	-15	-22	-29	-34	-39	-42	-44	-50	-55	-58
Across-flow distance from stack	-39	2	7	11	14	18	20	22	24	25	24	23

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	88	97	102	51	52	50	104	105	102	97	88	77
Effective building height	16	16	16	26	26	26	16	16	16	16	16	16
Along-flow building length	97	88	77	30	22	13	48	63	77	88	97	102
Along-flow distance from stack	-59	-59	-56	-129	-127	-120	-48	-56	-62	-66	-68	-68
Across-flow distance from stack	22	20	17	19	-1	-21	2	-2	-7	-11	-14	-17

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	63	48	31	48	64	22	23	23	64	67	68	67
Effective building height	16	16	16	16	16	21	21	21	30	30	30	30
Along-flow building length	105	104	100	104	105	22	23	23	43	33	23	11
Along-flow distance from stack	-66	-62	-56	-54	-50	-75	-77	-78	-128	-128	-124	-116
Across-flow distance from stack	-20	-22	-24	-24	-24	20	8	-3	38	18	-1	-21

(Constant) emission rate = 5.50E-02 grams/second
No gravitational settling or scavenging.

STACK SOURCE: DGVACP

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401367	6387439	45m	24m	0.15m	50C	7.0m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	68	105	102	97	88	77	64	48	31	48	63	77
Effective building height	30	16	16	16	16	16	16	16	16	16	16	16
Along-flow building length	22	64	77	88	97	102	105	104	100	104	105	102
Along-flow distance from stack	-119	-11	-18	-25	-32	-37	-41	-44	-46	-52	-56	-58
Across-flow distance from stack	-38	4	7	11	14	17	19	21	22	22	22	21

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	88	97	50	51	52	50	104	105	102	97	88	77

Effective building height	16	16	26	26	26	26	16	16	16	16	16	16
Along-flow building length	97	88	37	30	22	13	48	63	77	88	97	102
Along-flow distance from stack	-59	-58	-127	-128	-125	-118	-46	-53	-59	-63	-66	-65
Across-flow distance from stack	19	17	36	17	-3	-23	0	-4	-7	-11	-14	-17

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	63	48	31	48	64	77	23	23	64	67	68	67
Effective building height	16	16	16	16	16	16	21	21	30	30	30	30
Along-flow building length	105	104	100	104	105	102	23	23	43	33	23	11
Along-flow distance from stack	-63	-60	-54	-52	-49	-44	-77	-78	-128	-129	-126	-118
Across-flow distance from stack	-19	-21	-22	-22	-22	-21	11	0	40	21	1	-19

(Constant) emission rate = 8.96E-01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: RAKE12

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401326	6387557	45m	34m	0.60m	60C	0.0m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	52	52	50	47	42	36	30	22	13	22	29	37
Effective building height	26	26	26	26	26	26	26	26	26	26	26	26
Along-flow building length	22	30	37	42	47	50	52	52	50	52	52	50
Along-flow distance from stack	-14	-15	-15	-15	-14	-13	-11	-9	-7	-7	-7	-6
Across-flow distance from stack	-19	-19	-19	-18	-17	-15	-12	-10	-7	-3	0	3

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	42	21	21	51	52	50	52	52	50	47	42	36
Effective building height	26	37	37	26	26	26	26	26	26	26	26	26
Along-flow building length	47	21	21	30	22	13	22	30	37	42	47	50
Along-flow distance from stack	-6	-112	-113	-3	-2	0	-8	-15	-22	-28	-33	-37
Across-flow distance from stack	7	18	0	15	17	18	19	19	19	18	17	15

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	30	22	13	22	29	36	42	47	50	52	52	50
Effective building height	26	26	26	26	26	26	26	26	26	26	26	26
Along-flow building length	51	52	50	52	52	50	47	42	37	30	22	13
Along-flow distance from stack	-40	-42	-43	-45	-45	-44	-41	-38	-33	-27	-20	-13
Across-flow distance from stack	12	10	7	3	0	-4	-7	-10	-12	-15	-17	-18

(Constant) emission rate = 1.51E-02 grams/second
No gravitational settling or scavenging.

STACK SOURCE: 35AVNT

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401172	6387669	42m	19m	0.31m	92C	3.3m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	36	53	69	83	94	102	107	110	108	109	107	102
Effective building height	23	23	23	23	23	23	23	23	23	23	23	23
Along-flow building length	110	108	102	94	83	69	53	36	17	36	53	69
Along-flow distance from stack	-45	-42	-38	-33	-26	-18	-11	-2	6	-5	-15	-25
Across-flow distance from stack	-13	-11	-9	-7	-4	-1	2	4	7	10	12	13

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	94	83	69	53	36	17	36	53	69	83	94	102
Effective building height	23	23	23	23	23	23	23	23	23	23	23	23
Along-flow building length	82	94	102	108	109	108	109	107	102	94	83	69
Along-flow distance from stack	-35	-43	-50	-56	-59	-61	-64	-65	-64	-62	-57	-51
Across-flow distance from stack	15	16	16	16	16	15	13	11	9	7	4	1

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	107	110	108	110	108	102	94	82	69	53	36	17
Effective building height	23	23	23	23	23	23	23	23	23	23	23	23
Along-flow building length	53	36	17	36	53	69	82	94	102	107	109	108
Along-flow distance from stack	-43	-33	-23	-31	-38	-43	-48	-51	-53	-52	-50	-47
Across-flow distance from stack	-2	-4	-7	-9	-12	-14	-15	-16	-16	-16	-16	-15

(Constant) emission rate = 6.56E-02 grams/second
No gravitational settling or scavenging.

SKM

STACK SOURCE: OBFVAC

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401101	6387723	42m	19m	0.90m	60C	8.6m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	25	30	34	36	39	39	39	37	34	37	39	39
Effective building height	18	18	18	18	18	18	18	18	18	18	18	18
Along-flow building length	37	39	39	39	36	34	30	25	19	25	30	34
Along-flow distance from stack	-37	-35	-32	-29	-24	-19	-13	-7	0	1	1	2
Across-flow distance from stack	-13	-16	-18	-20	-21	-22	-22	-22	-20	-18	-16	-13

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	39	83	33	30	25	19	25	30	34	37	39	39
Effective building height	18	23	18	18	18	18	18	18	18	18	18	18
Along-flow building length	37	94	39	38	37	34	37	39	39	39	37	34
Along-flow distance from stack	2	44	3	3	3	3	0	-4	-7	-10	-13	-15
Across-flow distance from stack	-9	35	-2	2	6	10	13	16	18	20	21	22

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	39	110	108	110	108	102	94	82	22	19	25	19
Effective building height	18	23	23	23	23	23	23	23	20	20	18	18
Along-flow building length	30	36	17	36	53	69	82	94	27	27	37	34
Along-flow distance from stack	-17	-94	-94	-110	-123	-132	-137	-138	-110	-112	-40	-37
Across-flow distance from stack	22	61	47	32	15	-2	-19	-36	19	2	-6	-10

(Constant) emission rate = 4.33E-02 grams/second
No gravitational settling or scavenging.

STACK SOURCE: B40VAC

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
401042	6387444	42m	24m	0.15m	50C	4.0m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	66	66	65	61	56	49	41	31	20	31	41	49
Effective building height	22	22	22	22	22	22	22	22	22	22	22	22
Along-flow building length	31	41	49	56	61	65	66	66	63	66	66	65
Along-flow distance from stack	-18	-23	-26	-29	-31	-32	-32	-31	-29	-30	-30	-29
Across-flow distance from stack	-3	-3	-4	-4	-4	-4	-4	-3	-3	-3	-2	-2

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	56	62	65	66	66	63	66	66	65	61	56	49
Effective building height	22	22	22	22	22	22	22	22	22	22	22	22
Along-flow building length	61	56	49	41	31	20	31	40	49	56	61	65
Along-flow distance from stack	-27	-24	-21	-17	-12	-7	-13	-18	-23	-28	-31	-33
Across-flow distance from stack	-1	0	1	1	2	3	3	3	4	4	4	4

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	41	31	20	31	41	49	56	61	65	66	66	63
Effective building height	22	22	22	22	22	22	22	22	22	22	22	22
Along-flow building length	66	66	63	66	66	65	61	56	49	41	31	20
Along-flow distance from stack	-34	-35	-34	-36	-36	-36	-35	-32	-29	-24	-19	-13
Across-flow distance from stack	4	4	3	3	2	1	1	0	-1	-1	-2	-3

(Constant) emission rate = 5.94E-02 grams/second
No gravitational settling or scavenging.

STACK SOURCE: CVACW

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
400619	6387131	39m	41m	0.60m	50C	2.5m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	88	31	36	39	40	41	40	26	54	26	41	53
Effective building height	31	38	38	38	38	38	31	31	26	31	31	31
Along-flow building length	26	41	42	41	39	35	86	88	87	88	86	81
Along-flow distance from stack	-10	-95	-99	-100	-97	-92	-24	-24	-23	-24	-23	-23
Across-flow distance from stack	-20	26	13	-1	-15	-28	-8	-4	-16	3	6	10

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°

Effective building width	64	74	81	86	88	87	88	31	35	39	41	41
Effective building height	31	31	31	31	31	31	31	38	38	38	38	38
Along-flow building length	74	65	53	40	26	11	26	41	41	41	39	36
Along-flow distance from stack	-21	-19	-16	-13	-9	-5	-16	54	58	59	58	56
Across-flow distance from stack	13	16	18	19	20	21	20	-26	-13	1	15	28

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	40	26	54	26	40	53	65	74	81	86	88	87
Effective building height	31	31	26	31	31	31	31	31	31	31	31	31
Along-flow building length	86	88	87	88	86	81	74	65	53	40	26	11
Along-flow distance from stack	-62	-64	-64	-64	-62	-59	-53	-46	-38	-28	-17	-6
Across-flow distance from stack	8	4	16	-3	-7	-10	-13	-15	-17	-19	-20	-21

(Constant) emission rate = 1.77E-01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: CVACE

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
400661	6387131	39m	41m	0.60m	50C	2.5m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	88	86	81	39	40	41	41	26	54	26	41	53
Effective building height	31	31	31	38	38	38	38	31	26	31	31	31
Along-flow building length	26	40	53	41	39	35	31	88	87	88	86	81
Along-flow distance from stack	-17	-28	-38	-127	-129	-128	-123	-65	-65	-65	-63	-59
Across-flow distance from stack	21	20	18	31	13	-7	-26	3	-16	-4	-8	-12

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	64	74	81	86	88	87	88	86	81	74	64	53
Effective building height	31	31	31	31	31	31	31	31	31	31	31	31
Along-flow building length	74	65	53	40	26	11	26	41	53	65	74	81
Along-flow distance from stack	-53	-46	-37	-27	-17	-5	-9	-13	-15	-18	-20	-22
Across-flow distance from stack	-14	-17	-19	-20	-21	-22	-21	-20	-18	-16	-14	-10

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	40	26	54	26	40	53	65	74	81	86	88	87
Effective building height	31	31	26	31	31	31	31	31	31	31	31	31
Along-flow building length	86	88	87	88	86	81	74	65	53	40	26	11
Along-flow distance from stack	-23	-23	-22	-23	-23	-22	-21	-19	-17	-13	-10	-6
Across-flow distance from stack	-7	-3	16	5	8	11	14	17	19	21	21	22

(Constant) emission rate = 1.77E-01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: ALDVAC

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
400562	6387078	39m	41m	1.00m	60C	0.6m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	26	31	36	39	40	41	41	39	36	39	41	41
Effective building height	38	38	38	38	38	38	38	38	38	38	38	38
Along-flow building length	39	41	42	41	39	35	31	26	20	26	31	36
Along-flow distance from stack	-27	-25	-24	-22	-19	-16	-12	-7	-3	-5	-6	-8
Across-flow distance from stack	-8	-9	-10	-11	-11	-11	-10	-9	-8	-7	-5	-4

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	41	39	35	31	26	20	26	31	35	39	41	41
Effective building height	38	38	38	38	38	38	38	38	38	38	38	38
Along-flow building length	39	41	41	41	39	36	39	41	41	41	39	36
Along-flow distance from stack	-9	-10	-10	-10	-11	-10	-13	-15	-17	-19	-20	-20
Across-flow distance from stack	-2	0	2	4	6	7	8	9	10	11	11	11

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	41	39	36	39	41	42	41	39	35	31	26	20
Effective building height	38	38	38	38	38	38	38	38	38	38	38	38
Along-flow building length	31	26	20	26	31	36	39	41	41	41	39	36
Along-flow distance from stack	-19	-19	-17	-21	-25	-28	-30	-31	-31	-30	-29	-26
Across-flow distance from stack	10	9	8	7	5	3	2	0	-2	-4	-6	-7

(Constant) emission rate = 8.65E-02 grams/second
No gravitational settling or scavenging.

STACK SOURCE: 45TCOO

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
400436	6387373	39m	21m	17.00m	30C	12.8m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	18	23	28	32	35	37	37	37	35	37	37	37
Effective building height	19	19	19	19	19	19	19	19	19	19	19	19
Along-flow building length	37	37	36	35	32	28	23	18	12	18	23	28
Along-flow distance from stack	-18	-18	-18	-17	-16	-14	-12	-9	-6	-9	-12	-14
Across-flow distance from stack	0	0	0	0	0	0	1	0	1	0	1	0

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	35	261	28	23	18	12	18	23	28	32	35	37
Effective building height	19	26	19	19	19	19	19	19	19	19	19	19
Along-flow building length	32	255	37	37	37	35	37	37	36	35	32	28
Along-flow distance from stack	-16	52	-19	-19	-19	-18	-19	-19	-19	-18	-16	-14
Across-flow distance from stack	0	119	0	0	0	0	0	0	0	0	0	0

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	37	194	160	194	221	242	255	261	28	23	18	12
Effective building height	19	26	26	26	26	26	26	26	19	19	19	19
Along-flow building length	23	231	206	231	248	259	261	255	37	37	37	35
Along-flow distance from stack	-12	-308	-309	-329	-339	-338	-327	-307	-18	-18	-18	-17
Across-flow distance from stack	-1	96	61	24	-13	-50	-86	-118	0	0	0	0

(Constant) emission rate = 1.57E+00 grams/second
No gravitational settling or scavenging.

STACK SOURCE: ALDCOO

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
400534	6387105	39m	12m	7.21m	30C	10.0m/s

______ Effective building dimensions (in metres) ______

Flow direction	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
Effective building width	16	17	17	16	98	91	81	86	36	39	41	41
Effective building height	9	9	9	9	26	26	26	26	38	38	38	38
Along-flow building length	10	12	14	15	102	102	148	138	20	26	31	36
Along-flow distance from stack	-5	-6	-7	-7	37	45	5	16	25	28	29	30
Across-flow distance from stack	1	1	1	1	-60	-44	-27	-17	-35	-29	-21	-13

Flow direction	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°
Effective building width	41	39	35	31	16	206	231	248	259	261	61	53
Effective building height	38	38	38	38	9	26	26	26	26	26	28	31
Along-flow building length	39	41	41	41	10	160	193	221	242	255	71	81
Along-flow distance from stack	30	29	28	25	-6	-287	-319	-342	-354	-356	-138	-145
Across-flow distance from stack	-4	5	13	21	0	108	70	31	-10	-50	42	31

Flow direction	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°	360°
Effective building width	40	26	36	39	41	42	41	39	35	31	16	15
Effective building height	31	31	38	38	38	38	38	38	38	38	9	9
Along-flow building length	86	88	20	26	31	36	39	41	41	41	10	7
Along-flow distance from stack	-151	-152	-45	-54	-60	-66	-69	-70	-69	-65	-4	-3
Across-flow distance from stack	12	-7	35	28	21	13	5	-4	-13	-21	0	1

(Constant) emission rate = 3.19E-01 grams/second
No gravitational settling or scavenging.

VOLUME SOURCE: ACDROP

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
401375	6387375	45m	1m	15m	1m

(Constant) emission rate = 5.61E-02 grams/second
No gravitational settling or scavenging.

VOLUME SOURCE: 35DF

X(m)	Y(m)	Ground Elevation	Height	Hor. spread	Vert. spread
401375	6387698	45m	17m	33m	3m

```
              (Constant) emission rate = 1.95E-01 grams/second
                  No gravitational settling or scavenging.


                       VOLUME SOURCE: 35C3-5

     X(m)      Y(m)      Ground Elevation     Height    Hor. spread    Vert. spread
   401612   6388022             51m             17m          19m             3m

              (Constant) emission rate = 2.59E-01 grams/second
                  No gravitational settling or scavenging.


                       VOLUME SOURCE: 35C1-2

     X(m)      Y(m)      Ground Elevation     Height    Hor. spread    Vert. spread
   401642   6387668             51m             17m          15m             3m

              (Constant) emission rate = 1.73E-01 grams/second
                  No gravitational settling or scavenging.


                       VOLUME SOURCE: B42VAC

     X(m)      Y(m)      Ground Elevation     Height    Hor. spread    Vert. spread
   401049   6387543             42m              5m          15m             2m

              (Constant) emission rate = 3.10E-03 grams/second
                  No gravitational settling or scavenging.


                       VOLUME SOURCE: OC2

     X(m)      Y(m)      Ground Elevation     Height    Hor. spread    Vert. spread
   401200   6387617             42m             11m           8m             3m

              (Constant) emission rate = 6.56E-02 grams/second
                  No gravitational settling or scavenging.
______________________________________________________________________________

1                        ______________________________

                           Pinjarra Refinery Base VOC

                               RECEPTOR LOCATIONS

                         ______________________________

 The Cartesian receptor grid has the following x-values (or eastings):
 392850.m  393150.m  393450.m  393750.m  394050.m  394350.m  394650.m
 394950.m  395250.m  395550.m  395850.m  396150.m  396450.m  396750.m
 397050.m  397350.m  397650.m  397950.m  398250.m  398550.m  398850.m
 399150.m  399450.m  399750.m  400050.m  400350.m  400650.m  400950.m
 401250.m  401550.m  401850.m  402150.m  402450.m  402750.m  403050.m
 403350.m  403650.m  403950.m  404250.m  404550.m  404850.m  405150.m
 405450.m

 and these y-values (or northings):
6381650.m 6381950.m 6382250.m 6382550.m 6382850.m 6383150.m 6383450.m
6383750.m 6384050.m 6384350.m 6384650.m 6384950.m 6385250.m 6385550.m
6385850.m 6386150.m 6386450.m 6386750.m 6387050.m 6387350.m 6387650.m
6387950.m 6388250.m 6388550.m 6388850.m 6389150.m 6389450.m 6389750.m
6390050.m 6390350.m 6390650.m 6390950.m 6391250.m 6391550.m 6391850.m
6392150.m 6392450.m 6392750.m 6393050.m

 at a height above ground level of  1.0 metres


 DISCRETE RECEPTOR LOCATIONS (in metres)

 No.      X        Y     ELEVN  HEIGHT        No.      X        Y     ELEVN  HEIGHT
  1   401707 6388310     60.0     1.0         12   399244 6383394     44.0     1.0
  2   400844 6388289     44.0     1.0         13   400550 6382332     46.0     1.0
  3   402153 6386857     75.0     1.0         14   401190 6382950     53.0     1.0
  4   400127 6389902     44.0     1.0         15   400404 6382790     46.0     1.0
```

5	400201	6386947	44.0	1.0	16	400653	6382715	46.0	1.0
6	402549	6390156	75.0	1.0	17	397688	6387220	44.0	1.0
7	401193	6391826	44.0	1.0	18	403550	6390322	105.0	1.0
8	396448	6391713	44.0	1.0	19	394550	6386133	44.0	1.0
9	397755	6389885	44.0	1.0	20	402009	6390041	57.0	1.0
10	394894	6388746	44.0	1.0	21	396778	6387170	44.0	1.0
11	398938	6383200	44.0	1.0	22	397359	6386852	44.0	1.0

METEOROLOGICAL DATA : Ausplume file from CALMET,,,,,,

Appendix B Summary of AUSPLUME Meteorological Data

Pinjarra 2002/2003 File

Stability Classes

	A	B	C	D	E	F	Total
Number	189	1023	1610	2460	671	2807	8760
Percent	2.16	11.68	18.38	28.08	7.66	32.04	

Wind Speed (m/s)	Stability Class A	B	C	D	E	F
0.0 - 1.99	1.06	4.21	5.00	1.87	0.26	25.62
2.0 - 4.99	1.10	7.47	10.80	12.19	6.70	6.43
>5.0	0.00	0.00	2.58	14.02	0.70	0.00

Stability Class by Wind direction

	A	B	C	D	E	F
N	2.0	10.5	14.8	33.6	15.8	23.3
NE	1.1	7.8	14.9	29.4	17.8	29.0
E	1.1	7.9	14.5	42.8	5.8	28.0
SE	3.2	13.3	16.2	18.7	7.6	41.0
S	2.0	6.7	12.8	13.8	7.2	57.5
SW	3.1	15.6	25.2	22.1	3.3	30.6
W	2.6	18.1	26.4	28.7	4.9	19.3
NW	1.8	14.4	23.3	41.3	4.4	14.8

Stabilty Class by Hour of Day

Hour	A	B	C	D	E	F
1	0	0	0	93	59	213
2	0	0	0	100	52	213
3	0	0	0	100	57	208
4	0	0	0	94	48	223
5	0	0	0	98	50	217
6	0	0	0	91	59	215
7	0	0	60	146	40	119
8	0	28	120	155	17	45
9	1	65	145	154	0	0
10	4	122	108	131	0	0
11	19	119	121	106	0	0
12	57	121	96	91	0	0
13	55	131	96	83	0	0
14	37	145	103	80	0	0
15	15	135	125	90	0	0
16	1	94	168	102	0	0
17	0	56	193	116	0	0
18	0	6	214	145	0	0
19	0	1	46	166	19	133
20	0	0	15	85	39	226
21	0	0	0	35	61	269
22	0	0	0	55	59	251
23	0	0	0	62	53	250
24	0	0	0	82	58	225

Mixing heights — Time (hr)

Mixing heights	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
> 2000 m	22	28	32	36	31	27	18	1	0	0	0	9	23	42	51	57	63	60	42	0	2	7	11	19
1800 to 2000 m	11	6	8	5	4	7	7	4	0	0	3	14	22	20	26	33	29	29	14	1	2	2	5	5
1600 to 1800 m	4	10	7	5	6	6	5	3	0	1	19	22	23	42	52	56	59	51	24	0	0	3	5	7
1400 to 1600 m	9	11	6	7	7	8	4	6	0	12	18	39	51	65	62	56	55	44	17	0	3	4	4	6
1200 to 1400 m	10	6	7	4	8	6	9	9	8	29	39	51	70	56	63	55	54	38	13	4	1	5	2	4
1000 to 1200 m	8	6	9	11	10	6	17	9	31	37	59	54	56	49	41	43	37	20	10	4	6	5	6	10
800 to 1000 m	5	8	5	7	8	9	7	40	50	55	57	61	44	37	32	37	35	8	7	3	3	9	8	13
600 to 800 m	13	11	13	7	9	14	16	48	69	64	60	47	37	35	24	15	19	11	8	7	11	10	12	12
400 to 600 m	18	19	21	21	18	16	38	59	63	72	57	46	31	16	12	11	12	7	12	18	16	16	15	11
200 to 400 m	44	43	44	42	38	44	61	67	72	61	48	20	8	3	2	2	2	14	29	37	37	38	40	38
0 to 200 m	221	217	213	220	226	222	183	119	72	34	5	2	0	0	0	0	0	83	189	291	284	266	257	240

Wind Occurence Matrix

Speed (m/s)	N	NE	E	SE	S	SW	W	NW	Total
<0.5 (calm)									11.70
0.5 - 1.9	2.27	1.59	2.89	3.76	6.47	5.22	2.60	1.53	26.32
2.0 - 3.9	4.47	3.24	3.36	4.37	4.94	7.61	4.21	1.95	34.17
4.0 - 5.9	2.29	1.78	3.09	1.80	0.55	2.90	2.93	1.76	17.11
6.0 - 7.9	0.59	0.95	2.77	0.59	0.00	0.05	0.55	0.57	6.07
8.0 - 9.9	0.07	0.08	2.28	0.38	0.00	0.00	0.15	0.14	3.09
10.0 - 11.9	0.01	0.00	0.98	0.09	0.00	0.00	0.00	0.00	1.08
12.0 - 13.9	0.00	0.00	0.34	0.02	0.00	0.00	0.00	0.00	0.37
14.0 - 15.9	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.08
16.0 - 17.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>18.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.71	7.64	15.80	11.02	11.96	15.78	10.45	5.95	100.00

Ave wind speed = 3.06

SKM

Wind Speed range (m/s)	Count	Percentage (%)
0.00 - 0.99	1663	18.98
1.00 - 1.99	1668	19.04
2.00 - 2.99	1629	18.60
3.00 - 3.99	1364	15.57
4.00 - 4.99	921	10.51
5.00 - 5.99	578	6.60
6.00 - 6.99	339	3.87
7.00 - 7.99	193	2.20
8.00 - 8.99	152	1.74
9.00 - 9.99	119	1.36
10.00 - 10.99	62	0.71
11.00 - 11.99	33	0.38
12.00 - 12.99	24	0.27
13.00 - 13.99	8	0.09
14.00 - 14.99	3	0.03
15.00 - 15.99	4	0.05
16.00 - 16.99	0	0.00
17.00 - 17.99	0	0.00
18.00 - 18.99	0	0.00
19.00 - 19.99	0	0.00

Pinjarra 1987/1988 File

Stability Classes

	A	B	C	D	E	F	Total
Number	629	1608	1294	1243	1113	2297	8184
Percent	7.69	19.65	15.81	15.19	13.60	28.07	

Wind Speed (m/s)	Stability Class A	B	C	D	E	F
0.0 - 1.99	2.97	1.63	0.00	0.00	0.00	15.26
2.0 - 4.99	4.72	17.52	6.98	0.00	13.25	12.81
>5.0	0.00	0.50	8.83	15.19	0.35	0.00

Stability Class by Wind direction

	A	B	C	D	E	F
N	12.9	23.6	11.7	5.6	9.5	36.7
NE	7.6	18.2	7.8	4.5	11.7	50.3
E	5.2	14.6	17.0	40.6	10.6	11.9
SE	6.6	23.6	15.1	23.1	16.5	15.2
S	4.1	15.0	10.1	6.1	24.4	40.3
SW	6.2	18.0	28.0	13.4	11.3	23.0
W	14.3	35.5	17.3	4.5	6.6	21.7
NW	14.3	24.0	20.5	8.7	11.3	21.2

Stabilty Class by Hour of Day

Hour	A	B	C	D	E	F
1	0	0	0	90	87	164
2	0	0	0	98	83	160
3	0	0	0	108	74	159
4	0	0	0	100	87	154
5	0	0	0	95	91	155
6	0	0	1	72	95	173
7	0	22	78	74	54	113
8	12	122	75	66	25	41
9	58	141	115	27	0	0
10	92	157	82	10	0	0
11	89	160	87	5	0	0
12	90	171	77	3	0	0
13	105	155	78	3	0	0
14	84	161	92	4	0	0
15	54	190	86	11	0	0
16	35	157	131	18	0	0
17	9	112	153	67	0	0
18	1	50	148	73	22	47
19	0	10	89	58	60	124
20	0	0	2	27	122	190
21	0	0	0	42	87	212
22	0	0	0	56	72	213
23	0	0	0	66	66	209
24	0	0	0	70	88	183

Mixing heights	Time (hr) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
> 2000 m	0	0	0	0	0	0	0	0	3	9	14	36	54	66	69	73	73	62	0	0	0	0	0	0
1800 to 2000 m	0	0	0	0	0	0	0	1	2	3	15	18	25	29	36	33	31	23	0	0	0	0	0	0
1600 to 1800 m	0	0	0	0	0	0	0	2	7	7	16	37	44	46	52	55	51	24	0	0	0	0	0	0
1400 to 1600 m	0	0	0	0	0	0	0	2	5	17	33	41	44	51	48	47	45	17	0	0	0	0	0	0
1200 to 1400 m	0	0	0	0	0	0	2	5	8	19	34	38	40	37	26	26	22	8	0	0	0	0	0	0
1000 to 1200 m	0	0	0	0	0	0	0	4	16	26	26	28	26	23	28	25	17	5	0	0	0	0	0	0
800 to 1000 m	341	341	341	341	329	272	80	34	18	23	34	41	36	27	29	28	61	191	341	341	341	341	341	341
600 to 800 m	0	0	0	0	2	2	6	20	36	52	63	44	29	26	24	24	20	9	0	0	0	0	0	0
400 to 600 m	0	0	0	0	0	1	10	37	70	81	49	26	20	15	13	14	9	1	0	0	0	0	0	0

200 to 400 m	0	0	0	0	0	4	43	69	79	70	39	21	13	15	12	12	9	1	0	0	0	0	0	0
0 to 200 m	0	0	0	0	10	62	200	167	97	34	18	11	10	6	4	4	3	0	0	0	0	0	0	0

Wind Occurence Matrix

Speed (m/s)	N	NE	E	SE	S	SW	W	NW	Total
<0.5 (calm)									1.17
0.5 - 1.9	3.04	4.69	1.27	0.86	3.07	2.27	1.81	1.67	18.68
2.0 - 3.9	4.03	6.16	4.97	3.68	10.07	5.80	2.55	2.16	39.43
4.0 - 5.9	1.98	1.98	4.69	3.32	4.37	4.90	2.46	2.20	25.90
6.0 - 7.9	0.28	0.31	3.18	0.98	0.66	2.59	0.43	0.59	9.01
8.0 - 9.9	0.05	0.00	2.58	0.54	0.01	0.13	0.06	0.11	3.48
10.0 - 11.9	0.00	0.00	1.58	0.17	0.00	0.00	0.00	0.02	1.77
12.0 - 13.9	0.00	0.00	0.48	0.01	0.00	0.00	0.00	0.00	0.49
14.0 - 15.9	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.06
16.0 - 17.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>18.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.38	13.14	18.80	9.56	18.18	15.70	7.31	6.76	100.00

Ave wind speed = 3.84

Wind Speed range (m/s)	Count	Percentage (%)
0.00 - 0.99	415	5.07
1.00 - 1.99	1210	14.78
2.00 - 2.99	1667	20.37
3.00 - 3.99	1560	19.06
4.00 - 4.99	1296	15.84
5.00 - 5.99	824	10.07
6.00 - 6.99	439	5.36
7.00 - 7.99	298	3.64
8.00 - 8.99	164	2.00
9.00 - 9.99	121	1.48
10.00 - 10.99	90	1.10
11.00 - 11.99	55	0.67
12.00 - 12.99	30	0.37
13.00 - 13.99	10	0.12
14.00 - 14.99	5	0.06
15.00 - 15.99	0	0.00
16.00 - 16.99	0	0.00
17.00 - 17.99	0	0.00
18.00 - 18.99	0	0.00
19.00 - 19.99	0	0.00

Appendix C Comparison of Winds and Mixing Heights from TAPM and CALMET

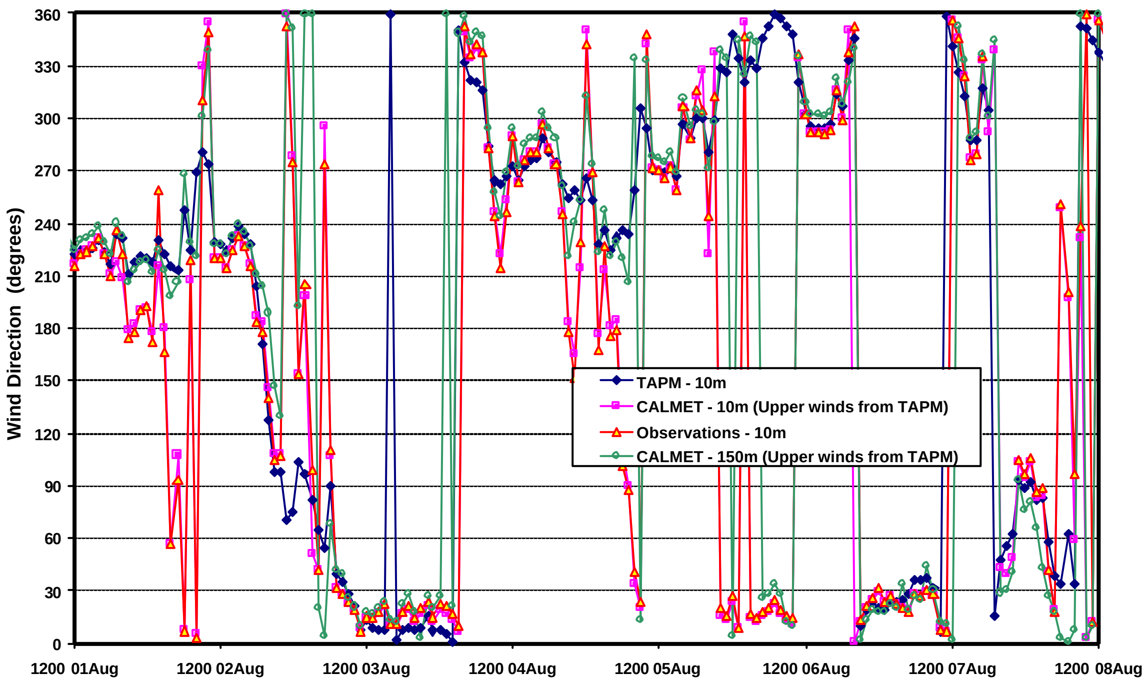
C.1 Comparison of the Winds

Figure C-1 presents the wind directions:

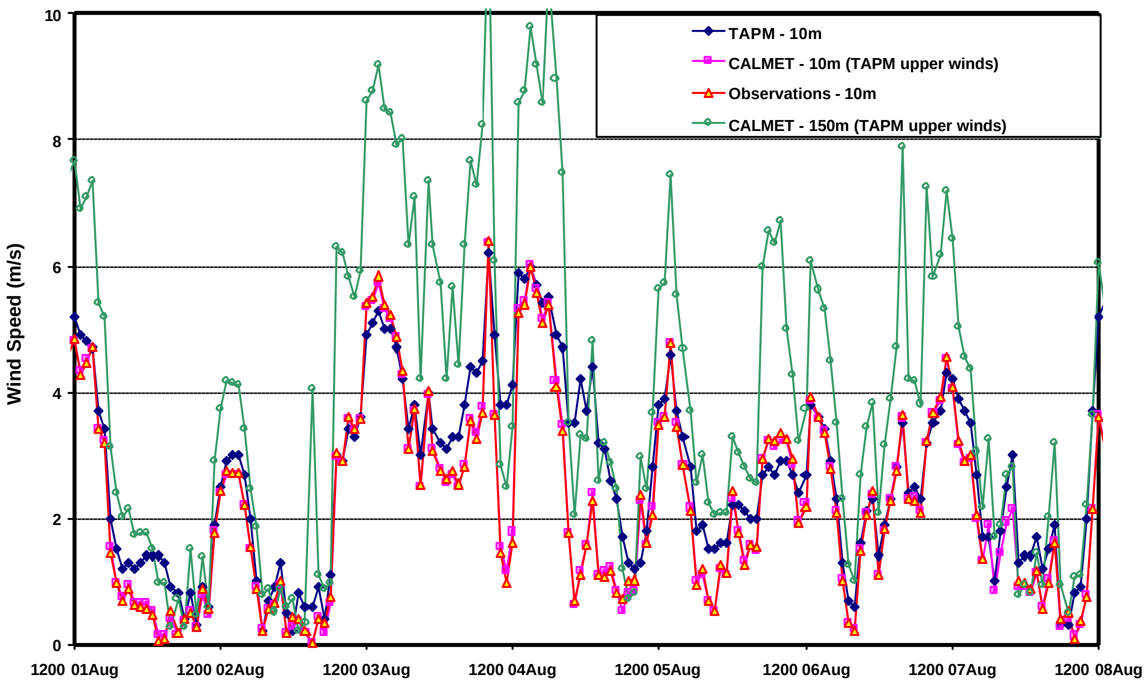
- Observed at 10m at the Pinjarra refinery meteorological station;
- Predicted by TAPM (as per the set up described in **Section 3** along with meteorological data assimilation from the Pinjarra meteorological station for the first two levels);
- Predicted by CALMET using the Pinjarra 10m winds as the surface observations and the TAPM predicted upper winds; and
- Predicted by CALMET using the Pinjarra 10m winds as the surface observations and the Perth airport upper winds.

Figure C-1 indicates that the TAPM predicted 10 m winds are generally in good agreement with the observations, although these can differ significantly from the surface observations under light winds at night (see **Figure C-2** for the wind speeds). Under these light wind conditions the TAPM 10m winds follow the TAPM predicted 150m winds, which are considered to be representative of the synoptic winds. This difference in the observed and predicted 10m winds is considered to result from TAPM (as configured here) not resolving the light wind fluctuations from the synoptic pattern, which is thought to be due to the development of slight surface drainage winds at night.

The derived CALMET winds using the TAPM on the other hand are predicted to follow the observations at 10m winds at the surface and the TAPM winds at 150m. That is, at night the CALMET file predicts a region where there is a marked wind shear from the surface to 150m winds. This wind shear (up to 180 degrees) may or may not be important in dispersal of the plumes, as plumes at heights of 50 to 100m at night will probably not be dispersed to the ground.



■ **Figure C-1 Wind Directions Observed and Predicted at Pinjarra**

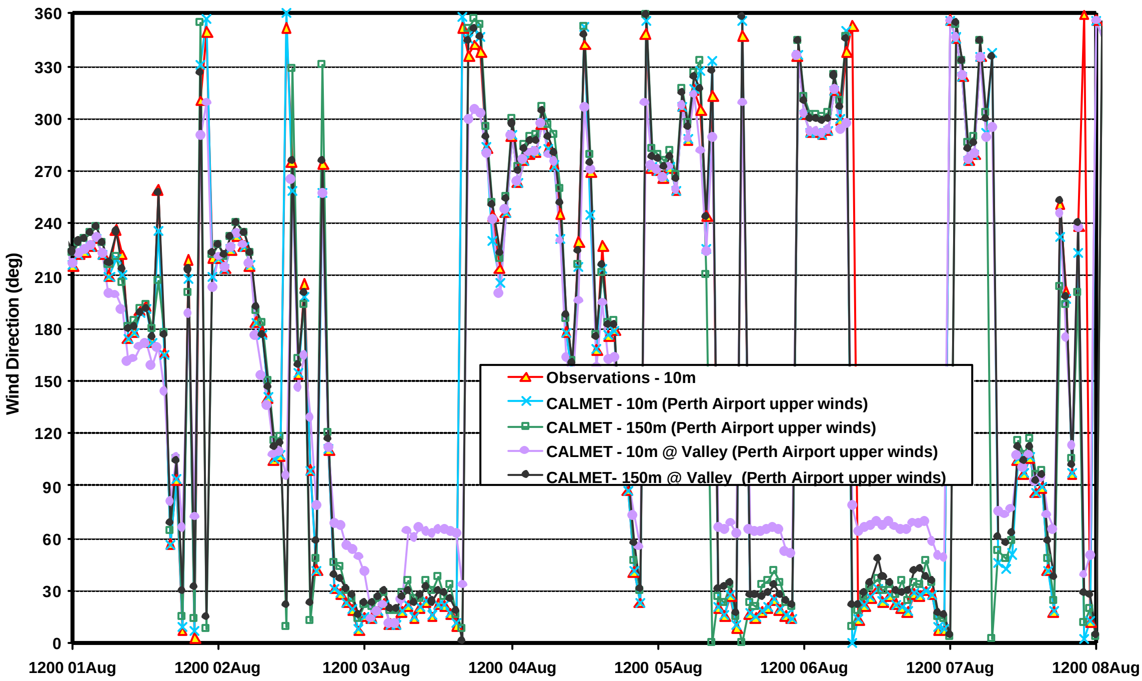


■ **Figure C-2 Wind Speeds Observed and Predicted at Pinjarra**

SKM

Besides the meteorological file developed by CALMET using upper winds from TAPM, upper winds and temperatures were sourced from the Perth airport. The advantage of this data is that the data is from observations. The disadvantage is that the temperature and wind profiles are only available twice daily. As such, features that may only last for six hours or less (such as afternoon sea breezes and strong easterlies at night) may not be resolved. **Figure C-3** presents the observed wind directions at 10m at Pinjarra along with CALMET predicted wind directions at 10 and 150m at the Pinjarra meteorological site. This Figure indicates that the 10m winds follow the Pinjarra 10m winds whilst the 150m winds follow the surface winds much more closely.

Additionally presented in **Figure C-3** are the winds predicted at the head of the South Dandalup river valley as it enters the Darling escarpment. This indicates that, under these light wind conditions, an east/north easterly drainage flow consistently develops. This is a local shallow drainage flow out of the valley onto the coastal plain and is not detected at the 150m level at this location. This indicates that CALMET is producing local wind drainage winds under light wind night time conditions which is as expected, but can not be verified due to the lack of surface measurements.

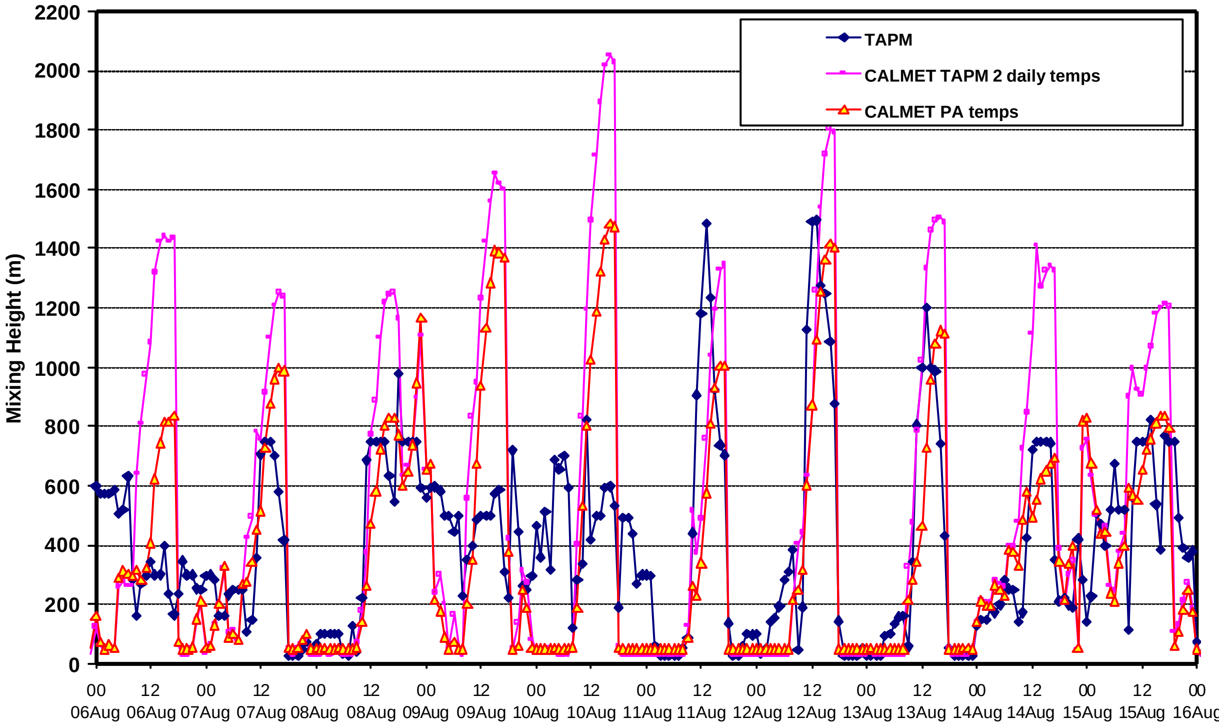


- **Figure C-3 Observed and Predicted winds at the Pinjarra refinery and at the mouth of the South Dandalup river (east of Fairbridge) labelled valley winds**

SKM

C.2 Mixing Heights

A comparison of the mixing heights predicted from TAPM and CALMET is presented in **Figure C-4**. This indicates significant differences between the CALMET predicted mixing heights derived using the temperature profile sourced from either TAPM or from Perth airport. This is primarily due to the result that TAPM predicted temperature profiles are not as sharply resolved as the observational data. TAPM mixing heights are also different for this period due in part to the differences in the amount of clouds predicted by TAPM and the observed cloud cover.



▪ **Figure C-4 Predicted Mixing Heights from TAPM and CALMET**