Appendix A Greenhouse Gas Assessment

Appendix A Greenhouse Gas Assessment

A.1 Summary

The principal greenhouse gas emission from the proposed Buronga facility is carbon dioxide (CO_2), which is the main product of fuel combustion. Minor quantities of other greenhouse gases may be emitted and have been represented in this assessment, as carbon dioxide equivalent (CO_2-e).

Due to the efficient combustion process inherent in modern gas turbine plant, the small scale of the plant, and the limited period of actual operations, total greenhouse gas emissions from the Buronga Peaking Power Plant relative to the emissions from base load power plants are low.

Based on a **typical operating scenario**, the Buronga Project is estimated to release 0.023 million tonnes of CO_2-e per year, which based on the 2005 inventory, represents 0.04% of the emissions from electricity generation in NSW, or 0.004% of all sources of greenhouse gas in Australia.

Based on the **theoretical upper limit of proposed operation**, total greenhouse gas emissions from the facility are estimated to be 0.098 Mt CO_2-e per year, which based on the 2005 inventory, will contribute 0.17% of the emissions from electricity generation in NSW, and up to 0.02% of the Australian emissions of greenhouse gases for all sectors. Due to the conservative assumptions made in this scenario, actual operation will most likely result in the release of less emissions.

Although there are currently no regulated limits on greenhouse gas emissions, there are a number of recent developments at the state, national and international levels to manage greenhouse gas emissions. IPRA will participate in State and National greenhouse gas emission programs to ensure effective monitoring and management processes are implemented.

The implementation of the National Emissions Trading Scheme (NETS) in 2010 will be a significant consideration in the selection of equipment to operate at best practice greenhouse gas emissions levels for the operational role and location at Buronga. It is understood that on implementation of NETS some of the existing greenhouse gas initiatives such as generator efficiency schemes may be replaced soon after commencement of the NETS.

IPRA will adopt an operations management approach for the Buronga Peaking Power Plant aimed at managing emissions in a manner consistent with the environmental objectives of all relevant programs, including the current Generator Efficiency Standards and the Greenhouse Challenge Plus program.

As part of these programs, IPRA will monitor GHG emissions and generator efficiency, and implement programs to improve operational performance of the generators, and reduce greenhouse emissions.

The Buronga Peaking Power Plant will contribute to the reduction of greenhouse gas emissions at the State level by potentially displacing additional generation by more carbon-intensive larger fossil fuelled power plant. Also, by injecting power at a regional level when high local demand requires it, electrical line loss inefficiencies associated with the long distance high voltage transmission network will be reduced.

Appendix A Greenhouse Gas Assessment

A.2 Introduction

Greenhouse gases absorb the infrared radiation reflected from the earth's surface and trap the heat in the atmosphere. The most abundant of these gases are carbon dioxide (CO_2) and water vapour (H_2O). Other greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) are present in much smaller amounts in the atmosphere. Naturally occurring greenhouse gases raise the Earth's global average temperature to approximately 15°C, approximately 33°C higher than without their presence.

The less abundant greenhouse gases (e.g. CH_4 and N_2O) are much more efficient in trapping infrared radiation than CO_2. The measure of how "efficient" a greenhouse gas in trapping heat is called the Global Warming Potential (GWP). GWP compares the heat absorbing ability of a greenhouse gas to that of the same mass of carbon dioxide over a given time frame. For example, over a 100 year time-frame, methane traps approximately 21 times as much infrared radiation from the earth as CO_2 and nitrous oxide approximately 310 times as much infrared radiation as CO_2. When compiling greenhouse gas inventories, this difference in Global Warming Potential is accounted for by converting one tonne of non-CO_2 greenhouse gas into a CO_2 equivalent (CO_2-e) amount using the Global Warming Potential for that particular non-CO_2 gas.

Since greenhouse gases trap heat in the atmosphere, scientists have suggested that there is a causal link between the rapid increases in the concentrations of greenhouse gases and the possibility of increased global temperatures. The best available scientific evidence suggests that the global average temperature has increased by approximately 0.76 ± 0.19 °C from 1850-1988 to 2001-2005[1]. Because of this, the accounting and management of greenhouse gases resulting from human activities are increasingly seen as an important issue by many governments and industrial companies. Furthermore, efficiencies in greenhouse gas emissions are often related to efficiencies in energy consumption.

This assessment includes a quantitative model of the tonnages of greenhouse gas produced by the Buronga Peaking Power Plant both annually and over the life of the project. These tonnages are also expressed as a percentage of the national and state inventories for greenhouse gases.

[1] Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis, Summary for Policymakers,* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, http://www.ipcc.ch.

A.3 Greenhouse Gas Policy

Global and national greenhouse gas policy is complex and despite the Kyoto protocol coming into force in 2005, remains uncertain. This section briefly summarises the policy issues.

A.3.1 International Policy

The Kyoto Protocol to the United Nations Framework Convention on Climate Change was signed in 1997 and entered into force in 2005. Its aim is to limit greenhouse gas emissions of countries that ratified the protocol by setting individual mandatory greenhouse gas emission targets in relation to those countries' 1990 greenhouse gas emissions. It sets out three "flexibility mechanisms" to allow greenhouse gas targets to be met:

- The Clean Development Mechanism.
- Joint Implementation.
- International Emissions Trading.

The definitions of the three mechanisms above are complex but effectively they allow greenhouse gas reductions to be made at the point where the marginal cost of that reduction is lowest. Essentially, an industrialised country sponsoring a greenhouse gas reduction project in a developing country can claim that reduction towards its Kyoto Protocol target and those greenhouse gas reductions can be traded.

A.3.2 Australian Policy

The Australian policy on climate change was released in July 2007[2] and sets out the Commonwealth Government's focus on reducing emissions, encouraging the development of low emissions and emission reduction technology, climate change adaptation, and setting Australia's policies and response to climate change within a global context. In December 2007, the Australian Government ratified the Kyoto Protocol which essentially states that greenhouse gas emissions not be more than 8% above 1990 levels. At the same time the Government announced its policy of implementing Australian National Emission Trading Scheme in 2010. However, the functional details of the Australian National Emission Trading Scheme are yet to be fully announced.

In addition to this policy, the Commonwealth Department of the Environment and Water Resources, through the Australian Greenhouse Office, manages programs that directly affect Australia's greenhouse gas inventory, including:

- Compiling and validating the National Greenhouse Gas Inventory;
- Delivery of the voluntary based Greenhouse Challenge Plus program, a vehicle for companies to report their greenhouse gas emissions annually; and
- Guiding a range of greenhouse gas mitigation initiatives.

Generator Efficiency Standards (GES)

The greenhouse gas initiative that is relevant to the stationary energy sector in Australia is the Generator Efficiency Standards (GES), launched in 2000 (see http://www.greenhouse.gov.au/ges/index.html for more information). The GES aims to work towards the best practice in the efficiency of fossil-fuelled electricity generation, and deliver reductions in the greenhouse gas intensity of energy supply.

2 *Australia's Climate Change Policy*, Department of the Prime Minister and Cabinet, Australian Government, July 2007.

Appendix A Greenhouse Gas Assessment

The GES applies to new and existing fossil-fuelled generators if they meet the following operational criteria[3]:

- 30MW electrical capacity or above; and
- 50GWh per annum electrical output; and
- A capacity factor of 5% or more in each of the last three years.

As the proposed maximum operating regime for the project falls within these criteria, the proposed plant will become a participant.

Energy Efficiency Opportunities (EEO)

The Energy Efficiency Opportunities legislation came into effect in 2006, and requires large energy users (over 0.5PJ of energy consumption per year) to participate in the program (see http://energyefficiencyopportunities.gov.au for program details). The objective of this program is to drive ongoing improvements in energy consumption amongst large users, and businesses are required to identify, evaluate and report publicly on cost effective energy savings opportunities.

Energy Efficiency Opportunities is designed to lead to:

- Improved identification and uptake of cost-effective energy efficiency opportunities;
- Improved productivity and reduced greenhouse gas emissions; and
- Greater scrutiny of energy use by large energy consumers.

Since the Buronga Peaking Power Plant is a minor consumer of energy when not operating, and is instead an electricity generator, it is not required to be a mandatory participant in the EEO program under the current EEO rules that exempt electricity generators.

National Emissions Trading Scheme

The Australian Government has announced adoption of Australian National Emissions Trading Scheme to come into effect by 2010. The Initial information is that this will be a "cap-and-trade" scheme, to be implemented by 2010.

Key features of the proposed scheme are:

- Setting of a long-term emissions abatement goal;
- Setting of an initial low target to establish a low starting price for carbon;
- Implementing progressively more stringent targets, to help drive deeper emission reductions and longer-term technology development;
- Establishing maximum practical coverage of all emission sources and sinks of all greenhouse gases;
- Permit liability placed on direct emissions from large facilities and on upstream fuel suppliers for other energy emissions;
- Practical considerations include initial exclusion of agriculture and land use emissions;
- Allocates permits for trade-exposed emission-intensive industries to reduce short-term impacts while encouraging abatement and energy efficiency;
- Recognition of a wide range of credible domestic and international carbon offset regimes; and
- Capacity, over time, to link to other national and regional schemes in order to provide the building blocks of a truly global emissions trading scheme.

The proposed Buronga facility, as for all of IPRA's portfolio of fossil-fuelled generating assets, will come under the emissions trading legislation when enacted.

---

3 *Technical Guidelines Generator Efficiency Standards, Section 4.1(ii),* Australian Greenhouse Office, Department of the Environment and Heritage, December 2006

A.3.3 State-based Initiatives

The NSW Greenhouse Gas Abatement Scheme (GGAS)

The NSW Greenhouse Gas Abatement Scheme (GGAS) commenced on 1 January 2003 with the aim of reducing greenhouse gas emissions from the production and use of electricity. It uses a “baseline and credit” approach to abatement, where project-based activities generate offsets that can be used to abate greenhouse gas emissions.

The tradable unit in the GGAS is a New South Wales Greenhouse Abatement Credit (NGAC), equivalent to one tonne of abated CO_2-e. A more generic name for these credits in GGAS is Abatement Certificate. Retailers are liable for a certain number of NGACs calculated on the basis of their share of the NSW electricity market. Therefore, retailers provide the demand for NGACs, and other parties supply NGACs into the market.

The proponent notes that the GGAS is likely to be subsumed by the federal government’s National Emissions Trading Scheme by the time the Buronga Peaking Power Plant is operational.

The NSW Energy Efficiency Program

This initiative was announced in early December 2007 by the NSW Premier, however functional details are as yet to be developed and announced.

A.4 Greenhouse Gas Assessment Methodology

The greenhouse gas emission inventory for the Buronga Peaking Power Plant is based on the methodology detailed in the Greenhouse Gas Protocol[4], and the relevant emission factors in the *National Greenhouse Accounts (NGA) Factors*[5] published in January 2008 and the *Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2005 – Energy (Stationary Sources)*[6]. The Protocol was first established in 1998 to develop internationally-accepted accounting and reporting standards for greenhouse gas emissions from companies.

The Greenhouse Gas Protocol is based on the concept of emission “scopes”.

- **Scope 1**: Direct greenhouse gas emissions. Direct greenhouse gas emissions occur from sources that are owned or controlled by a company. For example:
  - Emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.;
  - Emissions from chemical production in owned or controlled process equipment.
- **Scope 2**: Electricity indirect greenhouse gas emissions. This accounts for greenhouse gas emissions from the generation (elsewhere) of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organisational boundary of the company.
- **Scope 3**: Other Indirect greenhouse gas emissions. This is an optional reporting class that accounts for all other indirect greenhouse gas emissions resulting from a company’s activities, but occurring from sources not owned or controlled by the company. Examples include extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services.

The Director-General’s Environmental Assessment Requirements specify that both direct and indirect emissions from the project should be assessed. This greenhouse gas assessment has been conducted using the Australian Greenhouse Office’s quantitative methodology.

Individual contributions to the total site emissions were estimated from the use of distillate fuel for stationary energy generation. These were compared to the estimated annual power output from the Buronga Peaking Power Plant to assess the greenhouse gas contribution to the NSW and the Australian greenhouse gas inventories.

---

4 World Business Council For Sustainable Development & World Resources Institute (2004), The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard.

5 Australian Greenhouse Office *National Greenhouse Accounts (NGA) Factors* published in January 2008.

6 Australian Greenhouse Office (2006), *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2005: Energy (Stationary Sources)*.

A.4.1 Greenhouse Gas Inventory

This assessment encompasses the operational stage of the Buronga Peaking Power Project. The construction phase has not been included due to the small size of the project and short construction duration of 6-8 months.

The greenhouse gas inventory for the Buronga Peaking Power Plant reports Scope 1 and Scope 3 emissions to account for the direct (Scope 1) and indirect (Scope 3) emissions from the project. The operational boundary is defined as the boundary of the power station site. Scope 3 emissions are limited to upstream emissions from the production of distillate fuel used for electricity generation.

The Buronga facility will have three gas turbines with a total installed capacity of up to 150MW. The plant will operate as a peaking plant, with an operating time of up to 10% of the year. Plant operation will be on distillate fuel with the capability for conversion to use natural gas should a reliable source become economically available in the future. Estimated fuel consumption and power generated per year (power sent out) are presented in **Table 1** for both “Typical” and “Theoretical Maximum” scenarios.

Table 1: Estimated Distillate Consumption and Electricity Sent Out

Parameter	“Typical”	“Theoretical Maximum”	Units
Electricity Generation	22.5	105	GWh/yr
Fuel Consumption	0.30 (6,630)	1.31 (28,800)	PJ/yr (tonnes/yr)

There is a large difference in the two scenarios presented in **Table 1**. This difference illustrates the highly conservative assumptions made for the “Theoretical Maximum” scenario, and is a product of ranges in operational time (hours per year), and average operating loads between the two scenarios. The “Theoretical Maximum” scenario represents the distillate consumption and power generation that would result from running each turbine at full load, at all times during the licensed 10% of the year. This is highly conservative given the National Electricity Market support role environment in which the unit will operate. The “Typical” case is based on IPRA’s South Australian peaking plant experience and assessment of the NSW 2006 and 2007 peak demand going forward. In this scenario each turbine is operational for around 3% of the year, and operates at a range of loads, (using less fuel than constant operation at full load).

The following parameters were not included in the assessment as they contribute negligibly to the site’s GHG inventory:

- Liquid fuel combusted by off-site vehicles;
- Loss of biomass due to construction;
- Liquid refrigerant losses; and
- Electricity purchased from the grid.

Tables 2 and 3 show the GHG inventory for the Buronga Peaking Power Plant for both the “Typical” and “Theoretical Maximum” scenarios.

Appendix A Greenhouse Gas Assessment

Table 2 - Greenhouse Gas Inventory for Buronga Project - Direct Emissions – Scenario: "Typical"

Activity[1]	Scope	Emission Type	Emission Factor[2]	Greenhouse Gas Emissions t CO_2-e	Emissions Intensity kg CO_2-e/MWh	% of Total
Fuel Consumption: 0.30 PJ/yr Electricity Generation: 22.5 GWh/yr	1	Direct stationary combustion	69.5kgCO_2-e/GJ	20,931	932	93
	3	Indirect stationary combustion	5.3kgCO_2-e/GJ	1,596	71	7
	1 + 3	**Total**	**74.8kgCO_2-e/GJ**	**22,527**	**1003**	**(100)**

Notes:

1) Estimates of fuel consumption and electricity generation have been supplied by IPRA.

2) Emission factors for distillate combustion sourced from Table 1 of *"National Greenhouse Accounting (NGA) Factors"*, Department of Climate Change, January 2008. These emission factors incorporate the quantities of CO_2, N_2O and CH_4.emitted from distillate combustion.

Appendix A Greenhouse Gas Assessment

Table 3 - Greenhouse Gas Inventory for Buronga Project - Direct Emissions – Scenario: "Theoretical Maximum"

Activity[3]	Scope	Emission Type	Emission Factor[4]	Greenhouse Gas Emissions t CO_2-e	Emissions Intensity kg CO_2-e/MWh	% of Total
Fuel Consumption: 1.31 PJ/yr Electricity Generation: 105GWh/yr	1	Direct stationary combustion	69.5kgCO_2-e/GJ	90,876	864	93
	3	Indirect stationary combustion	5.3kgCO_2-e/GJ	6,930	66	7
	1 + 3	**Total**	**74.8kgCO_2-e/GJ**	**97,806**	**930**	**(100)**

Notes:

3) Estimates of fuel consumption and electricity generation have been supplied by IPRA.

4) Emission factors for distillate combustion sourced from Table 1 of *"National Greenhouse Accounting (NGA) Factors"*, Department of Climate Change, January 2008. These emission factors incorporate the quantities of CO_2, N_2O and CH_4.emitted from distillate combustion.

Appendix A Greenhouse Gas Assessment

A.4.2 Project Lifetime Emissions

Table 4 shows greenhouse gas emissions for the proposed plant on a project lifetime basis. The emissions presented in the three scenarios are derived from the product of the respective results presented in **Tables 2 and 3** and potential plant lifetime. Long term market trends define the operating duty, and ultimately the commercial life of the plant, hence there exist large uncertainties in potential emissions over the project lifetime.

Table 4: Estimated Greenhouse Gas Emissions on a Project Lifetime Basis

Scenario	Plant Life (years)	Annual Fuel Consumption (tonne)	Project Lifetime Emissions ($Mt\ CO_2$-e)		
			Direct	Indirect	Total
"Typical" Operation	20	6,630	0.42	0.03	0.45
"Typical" Operation	35	6,630	0.73	0.06	0.79
"Theoretical Maximum" Operation	35	28,800	3.2	0.2	3.4

A.4.3 Comparison to Australian and NSW GHG Inventories

Total greenhouse gas emissions in Australia for 2005 were estimated to be 559.1 million tonnes of CO_2-e (Australian Greenhouse Office 2005[7]), while NSW was estimated to emit 158.2 million tonnes CO_2-e from all sources (28.3% of emissions from all states). Most of the greenhouse gas emissions in NSW come from stationary energy sources (48% of NSW emissions).

Based on the "Typical" scenario, the Buronga Project is estimated to release 0.023 million tonnes of CO_2-e (includes direct and full fuel cycle emissions), representing 0.04% of emissions from electricity generation in NSW, or 0.004% of all sources of greenhouse gas in Australia in 2005.

Based on the "Theoretical Maximum" scenario, the Buronga Project is estimated to release 0.098 million tonnes of CO_2-e (includes direct and full fuel cycle emissions), representing 0.17% of the emissions from electricity generation in NSW, or 0.02% of all sources of greenhouse gas in Australia in 2005.

Quantitative greenhouse gas emissions from Buronga Peaking Plant and comparison with greenhouse gas generated from both "all sectors" and the electricity sector in both NSW and Australia are provided in **Table 5**.

[7] Australia's National Greenhouse Accounts, State and Territory Greenhouse Gas Inventories 2005, Australian Greenhouse Office, 2007

Table 5: Comparison of Proposal to State and National Greenhouse Gas Inventories

Greenhouse Gas Inventory Sector	CO_2-e emissions ($Mt\ CO_2$-e)	% Contribution represented by the Buronga Peaking Plant	
		"Typical"	"Theoretical Maximum"
Buronga Peaking Power Plant	0.023 ("Typical") 0.098 ("Theoretical Maximum")	-	-
NSW Electricity generation sector	57.8	0.04%	0.17%
Total NSW GHG emissions	158.2	0.01%	0.06%
Australia Electricity generation sector	194.3	0.01%	0.05%
Total Australian GHG emissions	559.1	0.004%	0.02%

Australia's future greenhouse gas inventory data are not possible to forecast with certainty. The 2005 inventory data shows that national emissions across all sectors rose by 2.2% from 1990 to 2005. The largest sector increase was the stationary energy sector, (followed by transport), showing a rise due to population growth and electricity demand for resources. The land use sector showed a decrease in emissions over this period, largely due to a reduction in vegetation clearing. Since future trends are unknown, the greenhouse gas emissions from the Buronga facility cannot be meaningfully compared to future emissions from other sources of greenhouse gases in Australia over the operational life of the plant. However, it can be stated that CO2-e emissions from Buronga facility would remain very low as a percentage of total NSW emissions from stationary electricity generation sector.

A.4.4 Impact of the Project on NSW Emissions Targets

The NSW government has proposed to reduce greenhouse gas emissions to 2000 levels by the year 2025 (NSW 2005 NSW Greenhouse Plan). This represents a reduction of 2.9% on 2005 levels, equating to 4.6Mt of CO_2. The NSW government aims to achieve this reduction through a range of measures including energy efficiency programs for both generators and consumers of electricity.

The impact of the proposal on this target is difficult to depict with confidence, given the uncertainties in:

- Operating duty and operating load;
- The style of plant that is displaced by the proposal (other styles of plant may be more carbon intensive, or have less efficient means of accommodating peak demand); and
- Transmission efficiency improvements brought about by generation close to demand.

Based on the "Typical" and "Theoretical Maximum" scenarios detailed in this assessment, the proposed plant was found to constitute emissions of around 0.01% (one in 10,000) and 0.06% (one in 1,550) of the total 2005 NSW inventory respectively. The opportunity for large greenhouse reductions in peaking applications is generally restricted by the technological limitations of equipment which is capable of responding to the infrequent and transient nature of peak load electricity demand, as well as the low (relative to baseload) amounts of emissions produced.

A.5 Generator Performance

As with any peaking plant, the proposed plant will be required to operate at a range of loads, as dictated by network and market demand. This range extends from full load, through to "no load", in which latter case the plant is employed to inject "reactive power" into the local high voltage transmission grid, thus maintaining the efficiency and stability of the transmission network.

Prior to plant selection, it is not possible to specify the proposed generator performance with certainty. On this basis, the worst case design emissions intensity has been presented for the range of plant types under consideration up to 50MW. The worst case emissions intensity by load is contained in **Table 6**.

As shown in **Table 6**, the design carbon intensity of these gas turbines is 864kgCO_2-e/MWh as a direct emission or 930kg CO_2-e/MWh in total emissions.

Table 6: Gas Turbine Generator Performance[1]

Load	Power Sent Out (MW)	Fuel Consumption (tonne/hr)	Emissions Intensity (kgCO_2-e/MWh)		
			Direct	Indirect	Total
100%	40	11.0	864	66	930
75%	30	9.3	893	68	961
50%	20	6.5	1020	78	1098
25%	10	4.7	1487	113	1600
0%	0	2.8	-	-	-
Typical Operation (Annualised)	-	-	932	71	1003

1: Based on Turbine Performance data supplied by IPRA

A.5.1 Comparison to Best Practice

As stated earlier, because the proposed maximum operating regime for the Buronga Project falls within the relevant criteria for fossil-fuelled plant, it is appropriate for the Generator Efficiency Standards (GES) to apply in a review of greenhouse gas emissions from the proposed Buronga facility.

One of the principles[8] driving the application and implementation of GES to proposed new plant is the comparison to "Best Practice".

The Buronga Peaking Power Plant Project has a range of technical and operational requirements which dictate the nature of the generation technology employed, some of which have implications on the greenhouse intensity achievable and the definition of best practice greenhouse performance for this application.

Importantly, the GES acknowledges that "best practice performance" is impacted by technical and commercial factors and that adjustment must be made to accommodate the specific operational *role* and operating *regime* of the plant to determine, in effect, the "best achievable performance".

[8] *Technical Guidelines Generator Efficiency Standards, Section 4.1(vii),* Australian Greenhouse Office, Department of the Environment and Heritage, December 2006

The GES specifically cites, for example, that frequent starts/stops and part load operation will impact on achievement of "best practice" performance. These and other key operational aspects are fundamental features of the proposed facility at Buronga as summarised below.

Chapters 1 to 4 of this Environmental Assessment have provided detail of the various drivers and objectives of the project together with the technical, environmental and commercial constraints, as well as alternatives which have been considered.

In summary the key aspects associated with the Buronga proposal as presented are:

- There is a need for a peaking power plant of up to 150MW maximum capacity at or near Buronga in the Wentworth/Mildura region;
- The plant will run on an as-required basis to satisfy short term peak electricity demands and provide market /system ancillary services;
- It is anticipated that the plant will generally operate for less than 5% of the time but depending on demand could operate up to 10% on an annual basis;
- Renewable energy technology is not a viable option given the demand profile and/or location;
- As there is no commercially available natural gas supply closer than Angaston in SA, the plant will be fuelled by distillate as the best alternative fuel from a technical and commercial perspective;
- Gas turbine generating technology utilising water injection for NOx control is the most appropriate combustion technology;
- Smaller plant size best mitigates the full range of environmental and community impacts associated with the project in particular air emissions;
- A single large generating unit will not satisfy the requirements for fast start capability, the short run durations, operations across the full load range - from "full speed, no load" injection of reactive power up to 150MW - and the requirement for high availability and reliability to manage commercial risk; and
- The use of three small gas turbines each of output up to 50MW (subject to final plant selection) is the optimum solution given the proposed location at Buronga and all technical, environmental and commercial factors associated with the project.

IPRA considers that its proposed Buronga Peaking Power Plant represents "best achievable performance" for GES best practice performance comparison purposes, given the location, technical and commercial factors and all environmental considerations.

The following section provides a description of the consideration of relevant best practice greenhouse performance factors.

Appendix A Greenhouse Gas Assessment

Technology Type

The role of peaking power plants (fast starts, a range of loads, relatively short run duration etc.) within the electricity generation market dictates the style of technology suitable for use. The style of peaking plant defined in the project need must be able to ensure the security of the network, and must be able to be deployed in a short amount of time (usually around ten minutes), with a high degree of reliability. **Table 7** provides consideration of a range of generating technologies, with respect to their suitability to the project need.

Table 7: Comparison of alternate generation technologies

Generation Technology	Operational and commercial Constraints
Wind turbine	Lacks reliability, availability and consistent generating strength requirements to generate to the level required. Not suitable for peaking power generation as it is affected by adverse weather conditions. Wind turbines also suffer from the need to impose automatic "output de-rating" as plant protection measures from the heat in the peak summer periods.
Solar Array	Not considered a reliable option with current technology as the requirements for peaking power and network support can span 24-hours and solar is effected by adverse weather conditions. Solar generators have very large ground area footprint for the output - for example a 50MW array would indicatively occupy an area of approx 1.5km x 1.5km
Hydro-electric	No suitable water resource exists in the Wentworth/Mildura region nor is the terrain suitable for alternate cost-effective "pumped-storage" generation.
Coal-Fired	Coal-fired power stations typically require 8 hours to start up and therefore are unable to respond to unforeseen load peaks. Consequently, coal is not suitable for this application.
Combined cycle gas turbine (CCGT)	CCGT technology is more suited to intermediate or base load operations as they require longer start-up and shut down periods than open cycle gas turbines.
Compression Ignition Engines (or reciprocating gas engines)	These smaller size gas and diesel generators (up to 10MW) are traditionally used for and are better suited to the lower end "distributed energy" market and not for the intended larger scale peaking power and network support role.
Open cycle gas turbine (OCGT)	Modern open cycle gas turbines can be established quickly, reach full capacity within 10 minutes from cold start, meet short duration peak load demand and generally represent best practice technology for this use.

As detailed in **Table 7**, open cycle gas turbine technology is considered to represent the only feasible generator type for the scale and location of the project. Open cycle gas turbines are available in the appropriate capacity size, have the ability to reach full load in the short amount of time needed for peaking applications and the reliability required for ancillary services.

OCGT technology has gained increased world-wide acceptance for their unique network support and rapid grid support capability in times of peak demand.

Appendix A Greenhouse Gas Assessment

Fuel Type

Geographic isolation from existing gas infrastructure of any significance compels that some alternative fuel must be utilised. **Chapter 3.3** provides explanation of why distillate represents the only feasible source of fuel for the project.

Given the structure of the electricity network in the region, the siting of the proposed plant close to gas infrastructure would conflict with the project objective to embed generation in the Buronga region.

Hence natural gas does not constitute a valid alternative and has been consequently dismissed from the direct best practice comparison.

Whilst distillate-fired generation technologies are the only appropriate solution for this project at this time, should natural gas become commercially available locally in the future, the proposed gas turbine units would be capable of conversion to use natural gas.

Gas Turbine Performance

In order to give a meaningful comparison of the Buronga Project to best practice emissions intensity a clear understanding of the relationship between gas turbine performance and greenhouse gas emissions estimates is required.

Gas turbines convert fuel to useful electrical energy. The better the “efficiency” of this process, the better the “performance” of the generating plant. Typical open cycle capacity and efficiency ratings for a range of commercially available distillate-fired gas turbine units are shown in **Table 8**

Table 8: Gas Turbine Efficiency with Turbine Size

Unit Size	Turbine Unit (Full Load) Efficiency (HHV basis)
290MW	36.9%
180MW	34.8%
125MW	31.9%
40MW to 50MW	30.3 % to 36.8%

Source: *Gas Turbine World 2007-2008 GTW Handbook (Low Heat Values LHV)*
Adjusted to High Heat Values (HHV)

Over time the evolution of gas turbine combustion technology has seen the achievement of higher plant efficiencies in increasingly larger (MW) capacity gas turbine units.

Generating plant efficiency can be described as the relationship between energy obtained and fuel used:

$$\textbf{Efficiency,} \quad \eta = \frac{\textbf{Electrical Output}}{\textbf{Fuel Used}} \qquad \textit{generally expressed as a \%}$$

Each class and size of gas turbine has different MW output ratings and combustion efficiencies depending upon the plant size and its effectiveness in converting fuel into electrical energy.

Greenhouse gas emissions assessments use the relationship between generated electrical energy output (MWh) and the type and quantity of fuel consumed to determine an equivalent tonnage of greenhouse gas production in kgCO_2-e/GJ. Using the methodologies cited by the AGO[9], this can then be related to the specific generating facility under review and expressed in the commonly used formats of **kgCO_2e/MWh** or **t CO_2-e per year**.

[9] AGO, *National Greenhouse Accounts (NGA) Factors, January 2008*

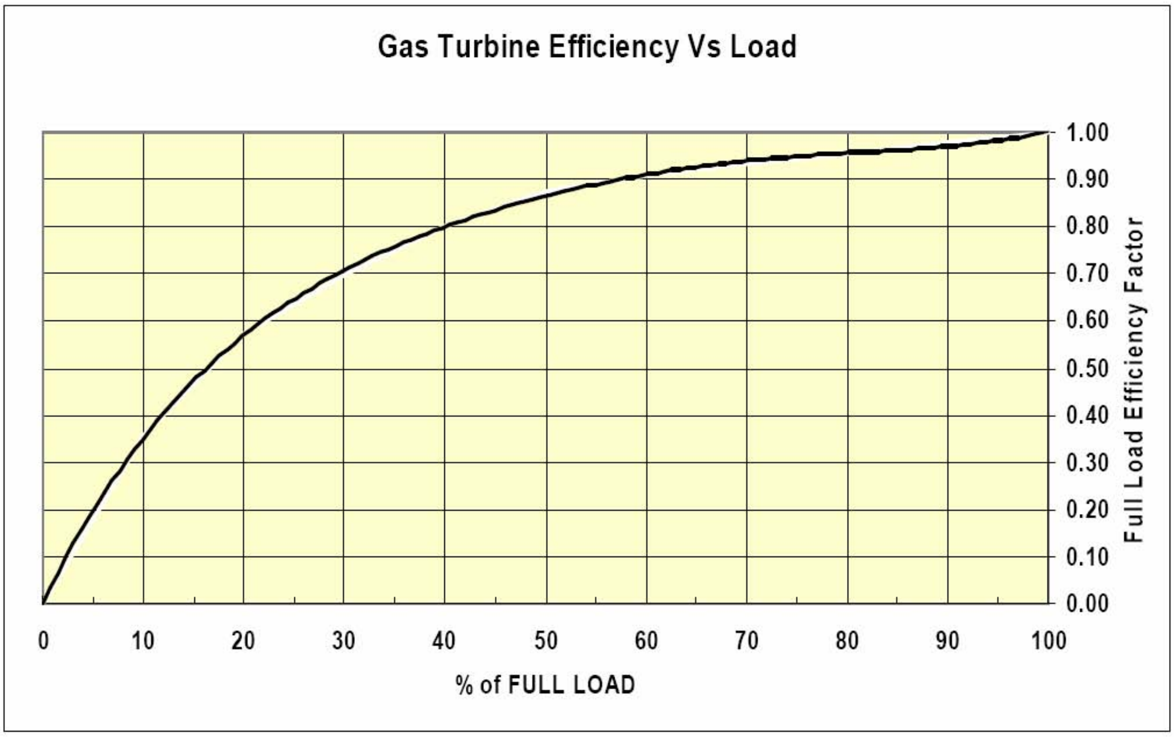
Appendix A Greenhouse Gas Assessment

The GES[10] does qualify its best practice requirements for comparison purposes with specific plant. Therefore it is critical to the assessment of greenhouse gas emissions from the proposed Buronga facility that gas turbine performance efficiency be clearly understood in the context of the specific plant market role and operational regime.

It is a fundamental premise of combustion technology that all gas turbine units operate at their highest level of combustion efficiency when operating at their respective full (100%) load rating. That is, each gas turbine of a specific size or capacity rating will burn fuel (and convert it to electrical energy) at its highest efficiency when operating at full load.

Figure 1 illustrates how gas turbine efficiency reduces when not running at full load. This "Full Load Efficiency Factor" curve applies for both gas and distillate fired gas turbines, but given that distillate is the only viable fuel for use at Buronga, the further discussion below is based upon distillate fuel.

Figure 1: Gas Turbine Full Load Efficiency Factor



Source: Figure compiled by IPRA using data sourced from gas turbine manufacturers' data sheets

It follows that greenhouse gas emissions intensity is *minimised* when a gas turbine is operating at its greatest combustion efficiency. **Figure 1** shows why, prima facie, the GES cites[11] the 290MW Alstom GT26 operating at full load as "base line" best practice for open cycle plant.

---

10 *Technical Guidelines Generator Efficiency Standards, Section 4.1(vii),* Australian Greenhouse Office, Department of the Environment and Heritage, December 2006

11 *Technical Guidelines Generator Efficiency Standards, Appendix F (Section F.2.3.7)* Australian Greenhouse Office, Department of the Environment and Heritage, December 2006

Appendix A Greenhouse Gas Assessment

The GT26 gas turbine is rated[12] at around 290MW with an optimum efficiency of 36.9% using distillate fuel. That is, the GT26 will operate at 36.9% efficiency when running at 290MW. However if the GT26 is run at 50% load (ie 145MW), from **Figure 1** it can be seen that its efficiency is reduced to 0.86 of its full load efficiency - that is to around 31.7% efficiency. This loss of efficiency is compounded by running the plant at even lower loads – at 25% load (73MW) and at 10% load (29MW) its efficiency drops to 24.0% and 12.9% respectively.

Similar reductions would apply to other smaller plant types with different full load outputs and associated maximum efficiencies.

This is the fundamental reason that power plant designers/developers tailor their plant specifications to meet the targeted market role and operational regime.

The major issues associated with poor plant fuel efficiency are:

- Increased fuel costs per MW generated;
- Increased maintenance costs per MW generated;
- Inability to meet environmental licence conditions; and
- Problematic combustion stability and plant control across some load range operations.

Gas Turbine Greenhouse Gas Performance Comparisons

Following the methodology required by the GES and applying the appropriate NGA Factors[13] based upon the relevant data[14] for each type of generating unit it is possible to create the greenhouse gas emissions profiles in $kgCO_2$-e/MWh for a range of plant types as shown in **Figure 2**.

These curves represent the total emissions for the “Scope1” (direct) and “Scope 3” (indirect) emissions as required under the Greenhouse Gas Protocol outlined in **Section A.4** above.

It is clear that, for the lower end (40MW - 50MW) output requirements the greenhouse gas emissions of the smaller plant are significantly lower on an electricity production (MWh) basis.

The proposed plant at Buronga will be required to operate at a range of loads, for which the emissions intensity of generation varies. Whilst there exists some uncertainty of the actual loads at which the market will require the plant to operate, the emissions *intensity* of the proposed plant operating from “full speed, no load” to full load will still be significantly less than attempting to use a single larger plant operating well down its load range design efficiency curve with consequent performance inefficiencies and larger greenhouse gas emission footprint.

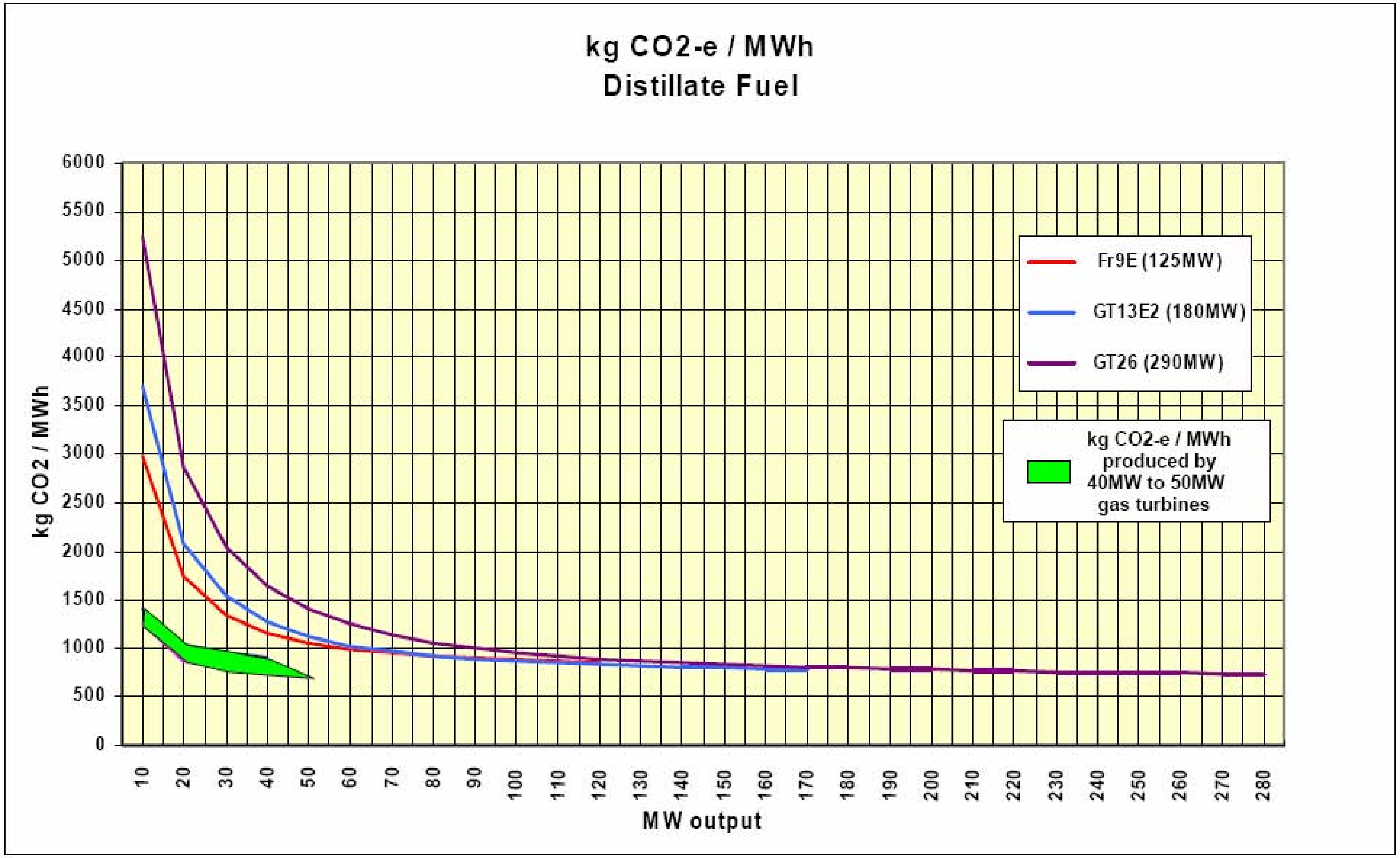
---

[12] *Gas Turbine World 2007-2008 GTW Handbook*

[13] Fuel Combustion Emission Factors from *Table 1 of the National Greenhouse Accounts Factors, January 2008*

[14] *Gas Turbine World 2007-2008 GTW Handbook*

Figure 2: Greenhouse Gas Emissions for Gas Turbines Operating Across their Capacity Range



Source: *Figure compiled by IPRA using (a) fuel heat rate and GT capacity data sourced from Gas Turbine World 2007-2008 GTW Handbook and (b) Fuel Combustion Emission Factors from Table 1 of the National Greenhouse Accounts Factors, January 2008*

Appendix A Greenhouse Gas Assessment

Best Practice

In July 2001, the Australian Greenhouse Office (AGO) released the Generator Efficiency Standards (GES). This program, updated in 2006, is designed to achieve movement towards best practice in the efficiency of electricity generation from fossil fuels, with a subsequent reduction in greenhouse gas emissions.

Natural gas-fired Open Cycle Gas Turbine (OCGT) technology represents best practice for a peaking plant servicing network support. However, as noted above, until natural gas capacity becomes commercially available in the Wentworth/Mildura region, the next most appropriate best practice is distillate-fired OCGT.

As clearly illustrated in **Figure 2** above the proposed use of three small gas turbines up to 50MW (subject to final plant tendering and selection processes) is clearly the best greenhouse gas and overall environmental performance outcome that can be achieved at Buronga for the peaking operational role intended.

This multi-unit proposal also satisfies IPRA's need to manage its commercial risk associated with fast start requirements and maintaining high plant availability and reliability.

Even if considered solely from a greenhouse gas perspective, **Figure 2** also illustrates that establishing a single unit facility to satisfy:

- A maximum load demand of say 120MW would still result in an adverse outcome unless the smallest alternative single unit (a 125MW Frame 9E) was always running at full load - which, in the proponents experience, it would not; and
- A maximum load demand of 150MW would always result in an adverse outcome.

Conclusion

For the above reasons, IPRA maintains that open cycle gas turbine technology utilising three small generating units each up to 50MW as proposed is best greenhouse gas practice and environmental performance outcomes for the operational role and location of the proposed Buronga Peaking Power Plant.

A.5.2 Alternative Project Siting Utilising Natural Gas as Fuel

The nearest significant source of natural gas is at Angaston in South Australia, some 325km distant. Alternatively the closest point on Moomba to Sydney gas pipeline is some 400km from Buronga at Bulla Park in the far northwest of NSW.

This study cannot objectively analyse the theoretical alternative of comparing greenhouse gas emissions if the best practice plant (that is three small gas turbines up to 50MW fired on distillate as established in **Section A5.1** above) for Buronga were to be located at the nearest source of natural gas and fired on natural gas.

Firstly, the comparison would be theoretical because existing transmission infrastructure is not adequate to carry this additional generation from Angaston and there is no transmission infrastructure at all at Bulla Park. In both instances alternative generation is not a feasible option given that the fundamental basis for proposing the siting of the facility at Buronga is to mitigate seasonal regional peak demands and transmission system security concerns.

Secondly, a correct and objective comparison of the alternative insofar as the total greenhouse gas emissions and its impacts is beyond the scope of this Environmental Assessment as the proponent cannot quantify the additional greenhouse gas generated by the construction and maintenance of new or upgraded transmission assets.

However, what can be stated with objectivity is that theoretical transmission losses[15] between either Angaston or Bulla Park and Buronga would be between 8% and 12%. Taking the lower figure as a best case comparison would mean that as an example, 150MW generated elsewhere would reduce electricity *delivered* to Buronga to 138MW.

Based on the “typical” scenario detailed in this assessment, total emissions from operation on natural gas at Angaston would be 21,442 tonnes (includes additional fuel consumption to account for additional transmission losses of 8%). This compares to total greenhouse gas emissions from operation on distillate at Buronga of 22,527 tonnes. This “gross” differential of 1,085 tonnes would need to be reduced by the unquantified factors identified above.

[15] Interpolated by IPRA from NEMMCO’s *Marginal Loss Factors* (MLF) published annually

A.6 Management of Greenhouse Gases

A.6.1 Greenhouse Gas Programs

International Power (Australia) Pty Ltd (IPRA) has committed to meeting the State and Federal greenhouse gas programs that are applicable to the site.

All IPRA assets operating in Australia are participants in the Greenhouse Challenge Plus program, and the vast majority have either committed or are in process of committing to the legally binding targets under the Commonwealth Government's Generator Efficiency Standards.

As part of these programs, IPRA monitors GHG emissions, thermal efficiency and heat rate at each of its power plant sites, and implements programs to improve operational performance and reduce emissions.

The Buronga Peaking Power Plant will also become a participant in these programs including:

- Greenhouse Change Plus program;
- Generator Efficiency Standard (GES) (if continued after implementation of NETS);
- Energy Efficiency Opportunity (EEO) program; and
- Environmental Management System ISO 14001:2004 standard; and
- National Greenhouse & Energy Reporting (NGER).

In addition to the above, IPRA is working with the Commonwealth and the Victorian Governments to trial carbon dioxide capture and storage in Victoria. IPRA is not proposing to implement greenhouse gas offsets for this project as IPRA consider that the National Emissions Trading Scheme when implemented in July 2010 will be the most efficient incentive for efficient operations of IPRA generation portfolio in NSW and Australia.

Appendix B Meteorological Data Discussion

Appendix B Meteorological Data Discussion

B.1 Assessment of Meteorological Data – 2000 - 2005

The meteorological data needed for dispersion modelling is required to be site representative. The closest weather stations were found to be located at Mildura Airport (Station 076031) and Mildura Post Office (Station 076077) which are understood to conform to relevant Australian Standards. The Mildura Airport weather station, which produces hourly averaged data, is located approximately 22km SW of the proposed development site. Meteorological monitoring at Mildura Post Office ceased in 1949, hence this assessment has utilised the data from Mildura Airport.

A review of air quality in the area showed that particulate matter from dust storms posed the greatest air pollution problem. Given the need to utilise the limited background data in a contemporaneous manner, 2005 was the preferred year for the air quality assessment.

URS also examined six years: 2000 through to 2005, inclusive. This methodology is consistent with the requirements contained in DEC (2005) *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales.*

The Mildura Airport wind roses for 2000–2005 are shown in **Figure B.1**. The examination of the six years of meteorological data was summarised with the "All years" windrose and wind speed plot shown in **Figure B.1**.

The wind roses for the individual years appear to be fairly consistent, showing winds from the south west quadrant to be dominant. The average wind speed for the years showed little difference from year to year, with a range between 3.53 m/s in 2001 to 3.75 m/s in 2002. Calms showed some variation with the calm periods ranging from 2.74% in 2004 to 5.89% in 2001. The most recent year assessed, 2005, appears to be consistent with other years and does not show anomalous results in terms of wind directions or average wind speeds.

In order to ensure local meteorological conditions were represented in the dispersion modelling, The Air Pollution Model (TAPM) was used to generate local wind fields. Given the lack of strong terrain features in the area, the Mildura Airport meteorological data for 2005 was assimilated into TAPM, re-located to the project site, with a radius of influence of 35km.

B.2 Meteorological modelling

TAPM was run to calculate meteorological fields for the modelling domain. Through a number of verification studies (e.g. CSIRO 2005), TAPM has been identified as a suitable model of choice to simulate meteorological fields in a number of situations[1].

TAPM is an incompressible, non-hydrostatic, primitive equation model with a terrain-following vertical co-ordinate for three-dimensional simulations. It includes parameterisations for cloud/rain micro-physical processes, turbulence closure, urban/vegetative canopy and soil, and radiative fluxes.

TAPM, with the use of the input databases provided by CSIRO, was used to generate a meteorological dataset for the year 2005 based on actual synoptic data. The following TAPM settings and input files were used to generate the meteorological file for the Buronga site for the year 2005.

[1] CSIRO, 2005. The Air Pollution Model (TAPM) Version 3. Part 2: Summary of Some Verification Studies. CSIRO Atmospheric Research Technical Paper 72, 2005.

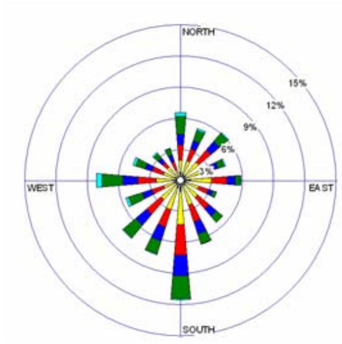
Appendix B Meteorological Data Discussion

Default options were selected, except where noted otherwise below:

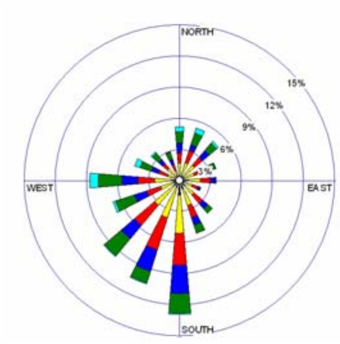
- Grid centre coordinates –34°06’00’’ latitude, 142°15’30’’ longitude (MGA94: 616071mE, 6226041mN);
- Meteorological grid consisting of four nests of 25 x 25 grid points at 30, 10, 3 and 1 km spacing, with 25 vertical grid levels from 10 to 8000 m;
- Terrain at 9 arc-second (approximately 270m) resolution from the Geoscience Australia terrain database. Land characterisation data at approximately 1km resolution, sourced from the US geological Survey, Earth Resources Observation System (EROS) Data Centre Distributed Active Archive Centre (EDC DAAC). Sea surface temperature data at 100 km grid intervals from the US National Centre for Atmospheric Research (NCAR);
- Six hourly synoptic scale meteorology from the BoM on a 75 to 100 km grid. This data is derived from the BoM LAPS (Limited Area Prediction System) output;
- Mildura Airport meteorological data for the year 2005 was assimilated into the model predictions on a radius of influence of 35km. The centre of influence was also relocated to the project site and configured to affect the lowest two levels of TAPM generated wind fields (9.8 and 24.8m);

The annual and seasonal windroses for the TAPM generated meteorological data are provided in **Figure B.2**. These wind roses show the dominance of winds from the south, south west and north east. Summer shows winds to be primarily from the south west, with autumn showing a distinct southerly component. Winter, however, shows the presence of a high proportion of winds from the north with Spring showing a more uniformly spread of winds with a slight dominance of winds from the south west and north east quadrants.

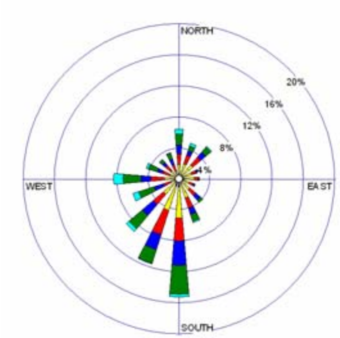
Appendix B Meteorological Data Discussion



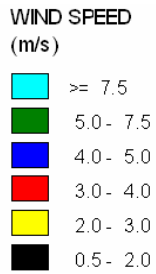
2000
Average wind speed: 3.54 m/s
Calms: 4.36 %



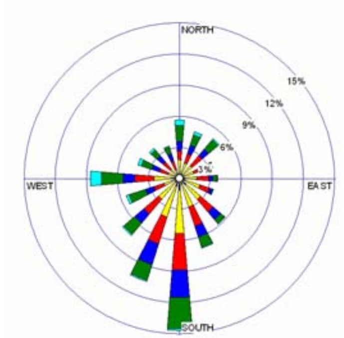
2001
Average wind speed: 3.53 m/s
Calms: 5.89 %



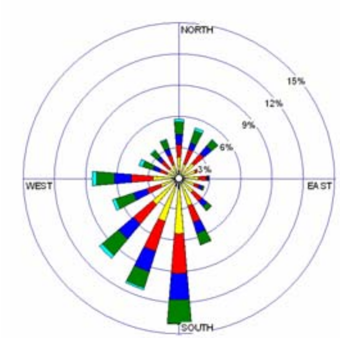
2002
Average wind speed: 3.75 m/s
Calms: 3.85 %



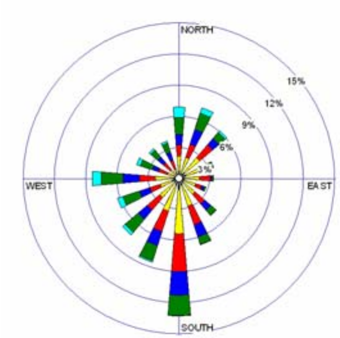
Wind Speed Legend



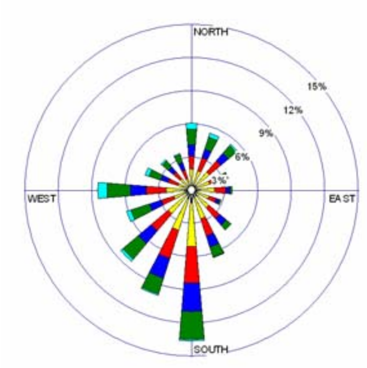
2003
Average wind speed: 3.69 m/s
Calms: 3.23 %



2004
Average wind speed: 3.62 m/s
Calms: 2.74 %



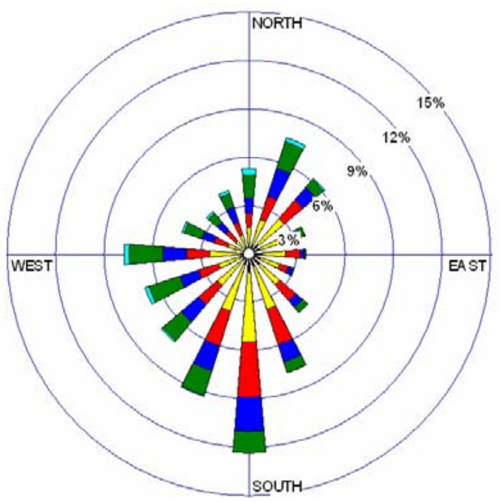
2005
Average wind speed: 3.69 m/s
Calms: 3.32 %



2000 - 2005
Average wind speed: 3.64m/s
Calms3.90%

Figure B.1: Mildura Airport Wind Roses 2000 – 2005

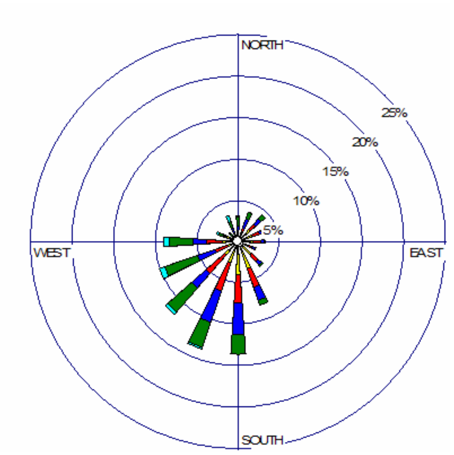
Appendix B Meteorological Data Discussion



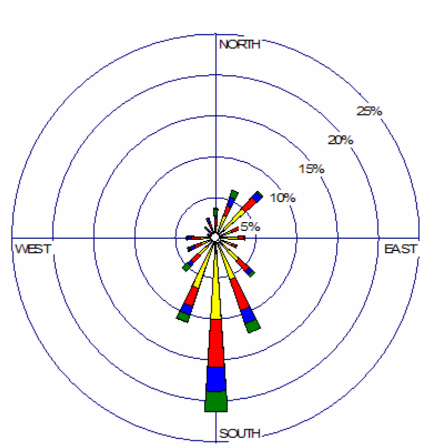
Annual Average wind speed: 3.48m/s

Annual Calms: 2.83%

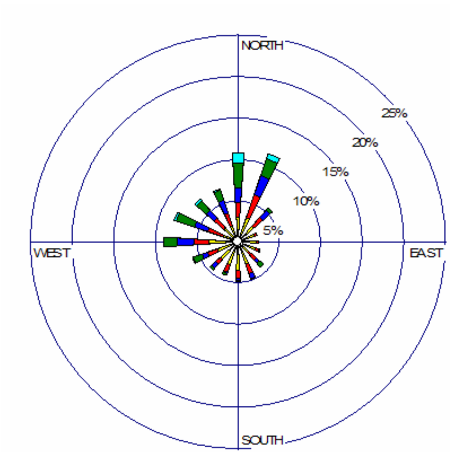
Annual Wind Rose



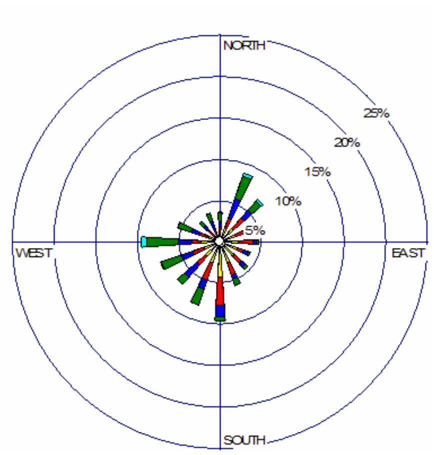
Summer



Autumn



Winter



Spring

Figure B.2: Seasonal TAPM generated wind roses for the proposed development site

Appendix B Meteorological Data Discussion

B.3 Mixing Height

Figure B.3 shows the Mixing Height (m) vs Time of Day (Hour) generated from TAPM data at the development site for 2005. The figure shows that the TAPM predicted mixing height increases with increasing solar radiation as a function of time of day. This is consistent with general atmospheric processes that show increased vertical mixing during the daytime associated with the increasing thermal radiation. Nightime conditions are cooler, more stable and, as expected, winds are generally lighter thus vertical mixing is reduced leading to a lower mixing height.

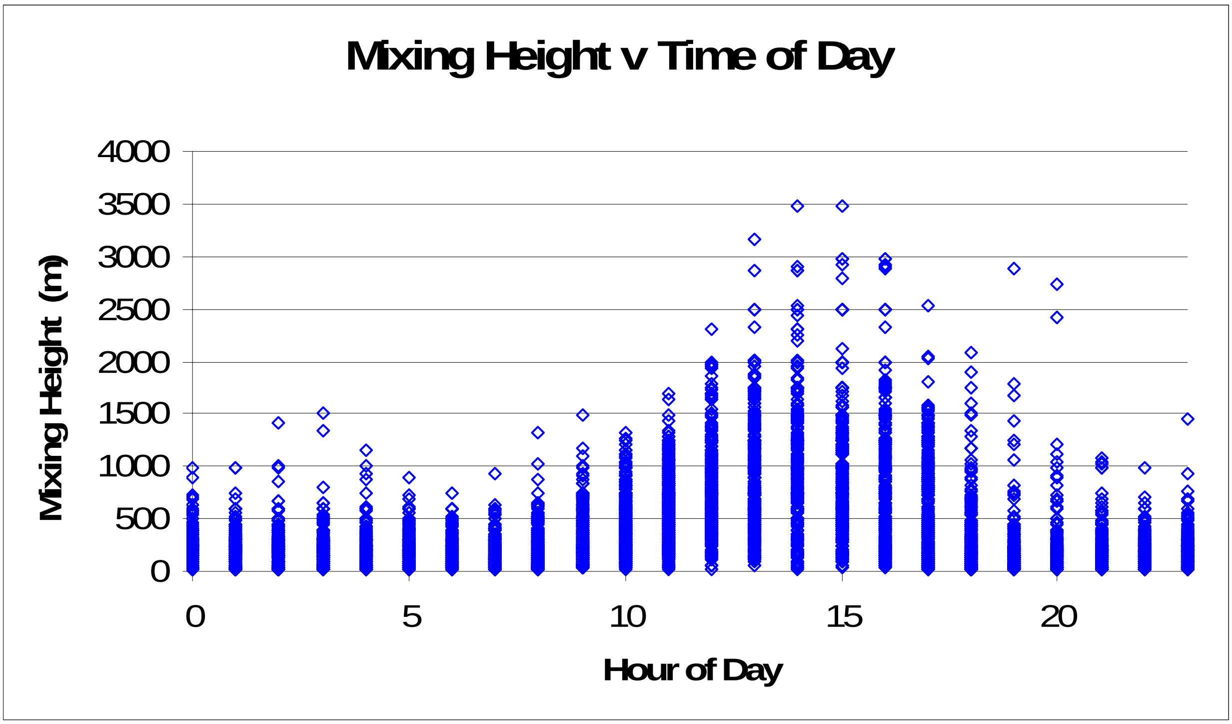


Figure B.3 Mixing Height (m) vs Time of Day (Hour of Day) – TAPM predicted, Buronga Site 2005

B.4 Atmospheric Stability

Stability class is used as an indicator of atmospheric turbulence for use in meteorological models. The class of atmospheric stability generally used in these types of assessments is based on the Pasquill-Gifford-Turner scheme where six categories are used (A to F) which represent atmospheric stability from extremely unstable to moderately stable conditions. The stability class of the atmosphere is based on three main characteristics, these being:

- Static stability (vertical temperature profile/structure);
- Convective turbulence (caused by radiative heating of the ground); and
- Mechanical turbulence (caused by surface roughness).

The Pasquill Gifford Stability classes are provided in **Table B.1**.

The stability classes for the site have been extracted from a TAPM generated meteorological file and are shown in **Table B.2**.

Appendix B Meteorological Data Discussion

Table B.1: Modified Pasquill-Gifford Stability Classes (adapted from Turner, 1994[2])

Surface Wind Speed at 10m (m/s)	Insolation			Night-time cloud (Oktas)	
	Strong	Moderate	Slight	Thinly overcast of > 4/8 low cloud	< 3/8 Cloud
≤ 2	A	A-B	B	-	-
2 - 3	A-B	B	C	E	F
3 - 5	B	B-C	C	D	E
5 - 6	C	C-D	D	D	D
> 6	C	D	D	D	D

Notes:
- : Generally referred to as strongly stable conditions.

The Pasquill Gifford Stability Classes, shown in **Table B.2** shows neutral atmospheric conditions (Stability Class D) is the most prevalent Stability Class of the area, with the extreme stability classes, namely Extremely Unstable (Stability Class A) being the least prevalent.

Table B.2: Site Representative Pasquill-Gifford Stability Classes

Stability Class	% of year
A (Extremely Unstable)	1.8%
B (Moderately Unstable)	8.7%
C (Slightly Unstable)	16.8%
D (neutral)	33.1%
E (Slightly Stable)	17.6%
F (Moderately Stable)	22.0%

[2] Turner B 1994 *Workbook of Atmospheric Dispersion Estimates: An Introduction to Dispersion Modelling*. 2nd Edition. CRC Press Inc

Appendix B Meteorological Data Discussion

In addition to their composition, Stability Classes were also predicted by TAPM for the site as a function of time of day, as shown in **Figure B.4**. As expected, the Stability Classes show a tendency for the unstable classes (Stability Classes A, B and C) to occur during daytime, whilst the more stable conditions (Stability Classes D,E and F) are shown to occur primarily during night time. This is consistent with the values contained in **Table B.1**.

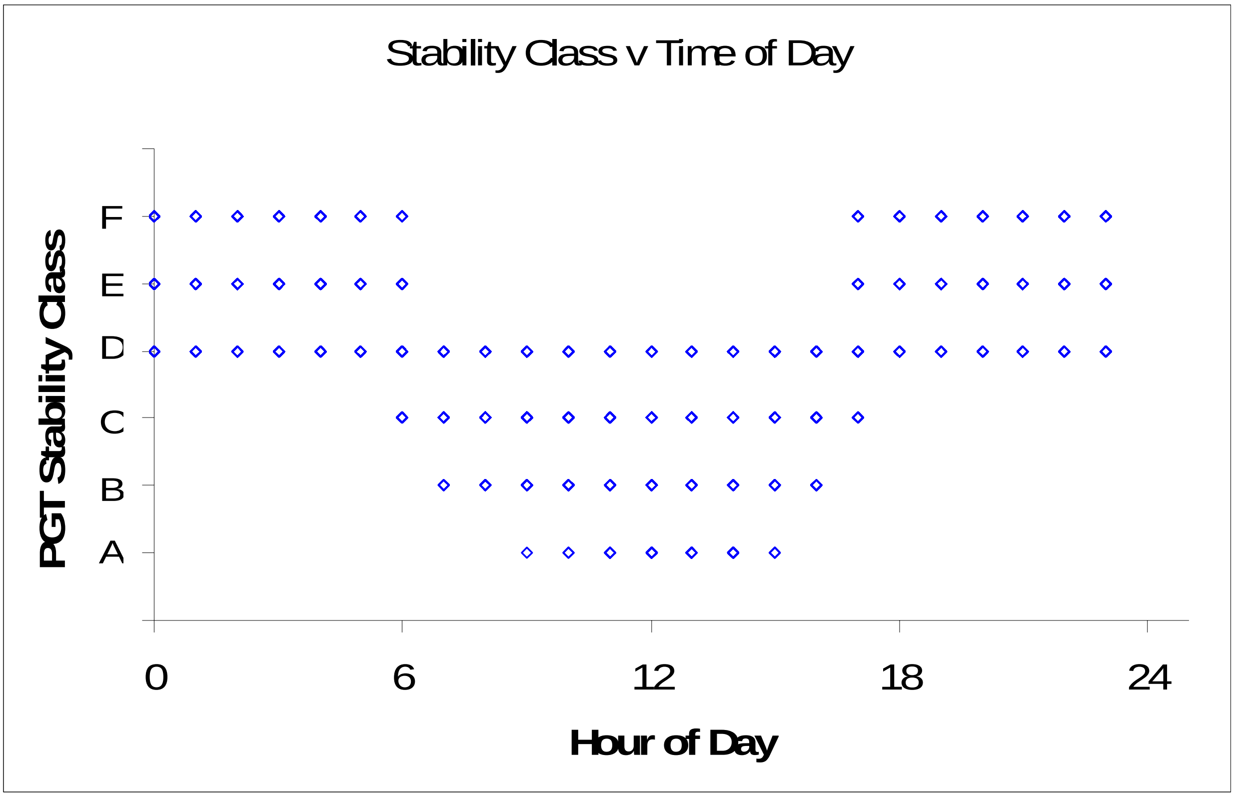


Figure B.4: Stability Class vs Time of Day – TAPM predicted, Buronga Site 2005

Appendix B Meteorological Data Discussion

Stability Classes were also measured against wind speed, as shown in **Figure B.5**. As expected, the highest wind speeds are associated with Stability Classes C and D. The more unstable conditions (Stability Classes A and B) are associated with lower wind speeds, as it is under low winds (coupled with insolation) where thermal turbulence is able to dominate. The more stable conditions (Stability Classes E and F) are also associated with low wind speeds. These data are consistent with the values contained in **Table B.1.**

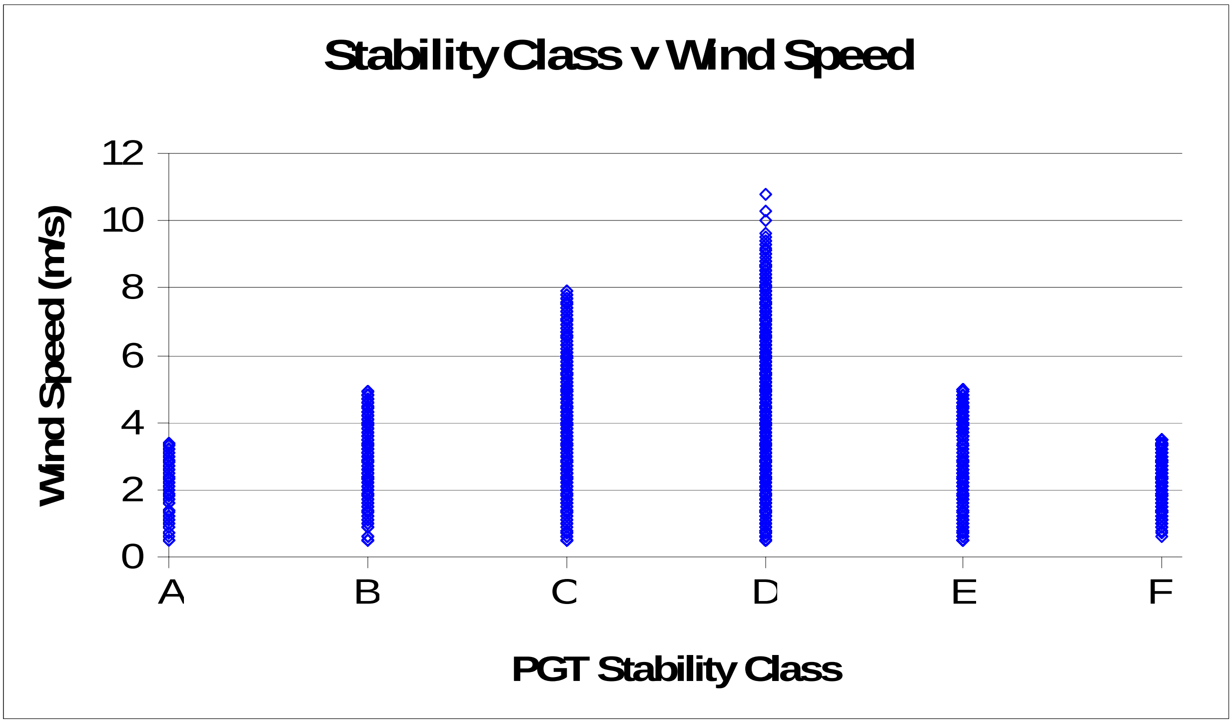


Figure B.5: Stability Class vs Wind Speed – TAPM predicted, Buronga Site 2005

B.5 Conclusion

Where site specific dispersion meteorological data does not exist, as is the case for the proposed Buronga development site, the predicted meteorological data used in the dispersion modelling is required to be representative of the surrounding area. It is accepted standard Australian practice, that in situations where adequate site-specific meteorological data does not exist, TAPM is used to synthetically generate meteorological data. TAPM is a sophisticated, 3D meteorological model that has been extensively validated. In order to better represent the meteorology of the proposed development site, Mildura airport data was incorporated into the predicted TAPM meteorology.

The assessment of the predicted meteorology at the proposed Buronga development site was discussed and was shown to be consistent with general atmospheric parameters. It is therefore considered that the meteorological data used in dispersion modelling is appropriate.

Appendix C Plume Rise Assessment

R E P O R T

Appendix C

Plume Rise Assessment for the Proposed Buronga Peaking Power Plant

Prepared for

International Power (Australia) Pty Ltd

Level 37, Rialto North Tower
525 Collins Street
Melbourne VIC 3000

28 April 2008

43177457

Project Manager:	William Barrett Associate	URS Australia Pty Ltd	
Project Director:	Matt Coetzee NSW Manager	Level 3, 116 Miller Street North Sydney NSW 2060 Australia Tel: 61 2 8925 5500 Fax: 61 2 8925 5555	
Author:	James Grieve Air Quality Engineer	Date: Reference: Status:	28 April 2008 43177455 Final Report

Contents

Executive Summary

The proposed Buronga Peaking Power Plant has been assessed for its potential impact on aviation safety. As operational times for peaking plants cannot be predicted, the assessment was performed on the basis that the plant would be operating continuously at full load (3 turbines operating). The actual operation of the plant is expected to be up to 10% of the year per turbine.

Based on the assessment for one year of modelled data using TAPM, the Obstacle Limitation Surface is exceeded during approximately 3% of the year, with an average vertical velocity of 4.3m/s at 44m above ground level.

Whilst this assessment is considered conservative with respect to the modelled operating times and operating conditions, the Civil Aviation Safety Authority (CASA) at its discretion may opt to designate this to be a potential hazard to aircraft operators in the area.

Section 1 Introduction

International Power (Australia) Pty Ltd (IPRA) proposes to build an open cycle gas turbine power plant for peaking operation, with a capacity in the range of up to 150MW.

The proposed facility is to be located at Buronga in south western New South Wales, approximately 21km north east of Mildura Airport, and will comprise three gas turbines - each up to 50MW nominal capacity depending upon final plant selection.

Operating duty of the plant would be determined by daily fluctuations in market demand, however IPRA estimates that the operating duty will consist of short run periods totalling up to 10% of the year for any one gas turbine.

This plume rise assessment is based upon information provided by IPRA as being typical of the types of gas turbine plant under consideration.

Given the quantity, velocity and temperature of the exhaust gases emitted from the exhaust stacks, open cycle gas turbine plumes can travel at high velocities through the atmosphere. Exhaust temperatures upwards of 500 degrees Celsius and exit velocities of around 25 metres per second enhance the dispersion characteristics of the plume and reduce the ground level impacts of pollutants. However, this factor presents issues for aviation safety, where the high velocity of the exhaust gases can potentially affect the handling characteristics of aircraft, with the risk of airframe damage in extreme cases.

The purpose of this report is to present the information required to perform an aviation hazard analysis based on the predicted impacts of the proposed facility. The statistics have been compiled in coordination with the Civil Aviation Safety Authority's (CASA) Advisory Circular "Guidelines for Conducting Plume Rise Assessments" (June, 2004). This involved use of the CSIRO's The Air Pollution Model (TAPM) model which was used to create site-specific meteorological data, including meteorology for the upper atmosphere. TAPM was also used to calculate plume rise trajectories for the gas turbine emissions.

CASA considers an exhaust plume with a vertical velocity component of greater than 4.3m/s to be a potential hazard to aircraft stability during approach, landing, take-off and for low level manoeuvring in general. At these stages of flight the stability of the aircraft is critical, especially in situations where visibility is extremely poor, such that potentially hazardous areas cannot be identified visually, and pilots are reliant on instruments for navigation.

Such plumes also potentially create risks to the structure of the aircraft, where the transient nature of the plume has the potential to overstress the frame.

Therefore, industrial sources that may release exhaust plumes with a vertical velocity greater than 4.3m/s at the Obstacle Limitation Surface (OLS) of 110m, must undergo a hazard analysis, such that suitable measures can be taken to prevent the hazards described above.

Section 2 Background

2.1 Proposed Plant Location

The proposed plant is to be located at Buronga, approximately 21km north east from Mildura Airport. A gliding airfield is also located 25km SSE of the proposed plant.

The three exhaust stacks are located in a single line running north west to south east, with approximately 40m spacing between each stack. **Table 2.1** presents the locations of the three stacks. **Figure 2.1** presents the location of the proposed plant relative to nearby aerodromes.

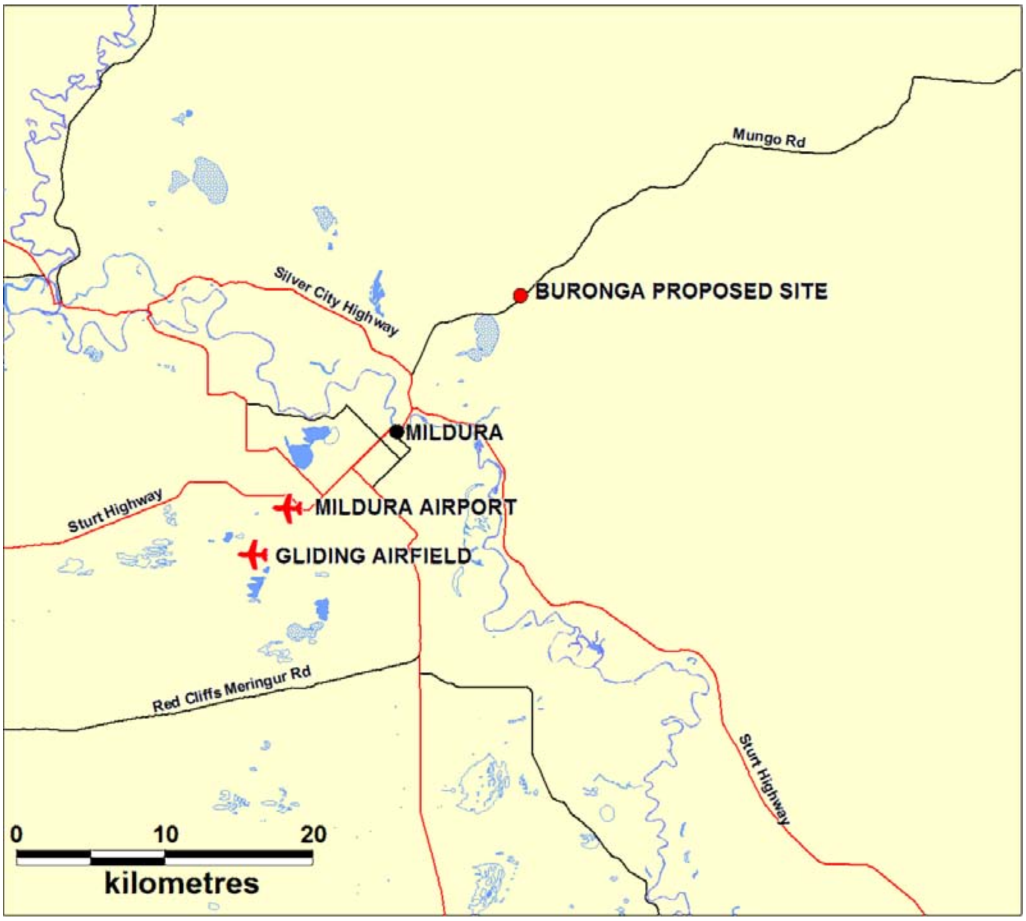
The final stack height is subject to final plant selection, and will fall between a height of 13 and 20m. The analysis contained in this report has been performed for a 20m stack.

Table 2.1: Gas Turbine Stack locations

Stack	Location (MGA94)		Base Elevation (mAHD)	Stack Height (m)
Stack 1	616340mE	6225879mN	50	13-20
Stack 2	616363mE	6225850mN	50	13-20
Stack 3	616387mE	6225821mN	50	13-20

Note: For the purposes of this report, Stack Height was presumed to be 20m.

Figure 2.1 Plant Location and Nearby Aerodromes



2.2 Operating Scenario

The operating scenario in this assessment considers the three gas turbines running for every hour of the year at full operating load and temperature.

Given the expected total operating time of the plant is for up to 10% per year per turbine, this represents a conservative scenario, whilst still remaining relevant to the needs of the aviation safety assessment, recognising that the plant may operate at full load for extended periods and during any hour of the day.

2.3 Exit parameters

As the power plant is configured in an open cycle arrangement, the exhaust gases exit the gas turbine with considerable amounts of energy, relative to the ambient air. The exit parameters on which this assessment is based are shown in **Table 2-2**.

Table 2.2: Modelled Exhaust Stack Parameters

Exit Parameter	Units	
Stack Height (above ground level)	(m)	20
Stack Diameter	(m)	4
Exit Temperature	(°C)	541
Exit Velocity	(m/s)	26

The analysis performed in this report was conducted using The Air Pollution Model (TAPM). TAPM was used in conjunction with meteorological data from Mildura Airport to generate site-specific meteorology for the proposed plant. The model was also set to produce an output of the plume rise from the exhaust stacks. This output consists of vertical velocity, plume centreline elevation and radius of the plume. The plume elevation and radius are measured from the plume's point of release, until it stabilises in the atmosphere. TAPM produces this output in intervals ranging from 1 to 5 seconds, for each source (exhaust stack), for every hour of the modelling period. This allows the elevation of the plume at the point at which it reaches 4.3m/s to be interpolated.

Section 3 Modelling Methodology

3.1 Model Setup

3.1.1 TAPM Configuration

The configuration of TAPM used in this assessment was based on the guidelines included in Attachment A of the Advisory Circular “Guidelines for Conducting Plume Rise Assessments” (CASA –AC139-05(0) – June 2004). This is with the exception of the specified modelling period of 5 years. The year 2005 was used in this assessment. Details of the TAPM configuration are given below:

- Grid centre coordinates –34°06’00’’ latitude, 142°15’30’’ longitude (MGA94: 616071mE, 6226041mN);
- Meteorological grid consisting of four nests of 25 x 25 grid points at 30, 10, 3 and 1 km spacing, with 25 vertical grid levels from 10 to 8000 m;
- Mildura Airport meteorological data for the year 2005 was assimilated into the model predictions on a radius of influence of 35km. The centre of influence was also relocated to the project site and configured to affect the lowest two levels of TAPM generated wind fields (9.8 and 24.8m);
- Eulerian dispersion was used on the outer nests, whilst Lagrangian dispersion was used on the innermost nest;
- Buoyancy enhancement from multiple stacks was calculated according to the method described in Manins et al. 1992;
- Terrain at 9 arc-second (approximately 270m) resolution from the Geoscience Australia terrain database. Land characterisation data at approximately 1km resolution, sourced from the US geological Survey, Earth Resources Observation System (EROS) Data Centre Distributed Active Archive Centre (EDC DAAC). Sea surface temperature data at 100 km grid intervals from the US National Centre for Atmospheric Research (NCAR);
- Six hourly synoptic scale meteorology from the BoM on a 75 to 100 km grid. This data is derived from the Bureau of Meteorology LAPS (Limited Area Prediction System) output;

3.1.2 Plume Merging

TAPM does not account for interaction between sources with regards to plume dynamics. Every source is treated separately, with its trajectory defined by its individual exit parameters and the surrounding meteorology. This is an inadequate representation for cases where, due to the presence of multiple exhaust stacks, the plumes merge and experience enhanced buoyancy. Contact between plumes results in a reduction of the entrainment of cooler static air, thus increasing the extent and rate of plume rise.

In this assessment, the ‘Buoyancy Enhancement Factor’ parameter in TAPM has been used in accordance with the methodology of Manins (1992) and Hurley (2005) to account for the additional plume rise due to the merging of the plumes. This methodology takes into account the number of exhaust stacks present, their separation, as well as the exit parameters of the exhaust gas, thus arriving at a buoyancy enhancement factor for use in TAPM.

In TAPM this enhancement factor is used to scale the initial condition for buoyancy flux, thus increasing the magnitude of the plume velocity throughout its rise. A buoyancy enhancement factor of 1.43 was used in this assessment.

3.1.3 Meteorological Data Assimilation

The TAPM generated wind fields were influenced by Bureau of Meteorology data for 2005, from the Mildura Airport Automatic Weather Station (AWS). The Mildura Airport AWS is located 21km south west of the site (600201mE, 6211329mN). The Mildura Airport AWS data was used with the centre of influence moved to the proposed site, and with a radius of influence of 35km, and configured to affect the lowest two levels of TAPM generated wind fields (9.8 and 24.8m). This was performed to better represent local meteorological conditions.

Section 3 Modelling Methodology

3.2 Statistical Analysis

Plume rise statistics were developed using the TAPM gradual plume rise output in accompaniment with the upper air data derived from TAPM (at heights of 9.8 to1468 m above ground level). This data was processed to give the statistical representation of the plume's vertical and horizontal plume extent required for the assessment.

The height at which the plume velocity decreases to 4.3m/s was calculated through linear interpolation of the TAPM gradual plume rise output. This gives the critical vertical extent of the plume for each hour of the modelling period (i.e. the height at which the vertical velocity reaches 4.3m/s).

The critical horizontal plume extent was calculated using the TAPM gradual plume rise output, in conjunction with the TAPM generated upper air data. The plume is assumed to adopt the ambient horizontal wind velocity immediately (Hurley, 2005).

i.e. $$\frac{dx_p}{dt} = u$$

where x_p = horizontal plume velocity;

t = time;

u = horizontal component of wind speed.

For each time step of the gradual plume rise file that is output from TAPM, the upper air data was linearly interpolated to give the horizontal wind speed at that point. The horizontal translation of the plume during this time step was calculated as a product of the interpolated wind speed, and the length of the time step. These were summed for each time step until the critical vertical velocity of 4.3m/s was reached. The plume radius (Ry) at this height was then added to the total to give the horizontal distance from the source to the extremity of the plume boundary, at the point at which a vertical velocity of 4.3 m/s was reached (i.e. critical horizontal extent).

Statistics for wind speed at specific elevations were calculated through linear interpolation of the upper air data, which was given at 15 heights (between 9.8, 24.5, 48.9, 97.9, 146.8, 195.8, 244.7, 293.6, 391.5, 489.4, 587.3, 734.1, 978.8, 1223.5 and 1468.2 m). Whilst this profile follows a power-law trend, the error of linear interpolation is considered to be negligible, considering that the intervals between lower levels are smaller where change in wind speed with elevation is greatest. These results were then manipulated to give the various statistical representations required for the hazard assessment.

Section 4 Results

4.1 Local meteorology

Bureau of meteorology data from the Mildura Airport Automatic Weather Station indicates that the region experiences light to moderate wind speeds, primarily from the south to south west, with an average wind speed of 3.77m/s, and 2.8% calms (wind speeds less than 0.5m/s) recorded for the year 2005 inclusive.

The TAPM predicted wind rose is consistent with data from Mildura Airport and is provided in **Figure 4-1**.

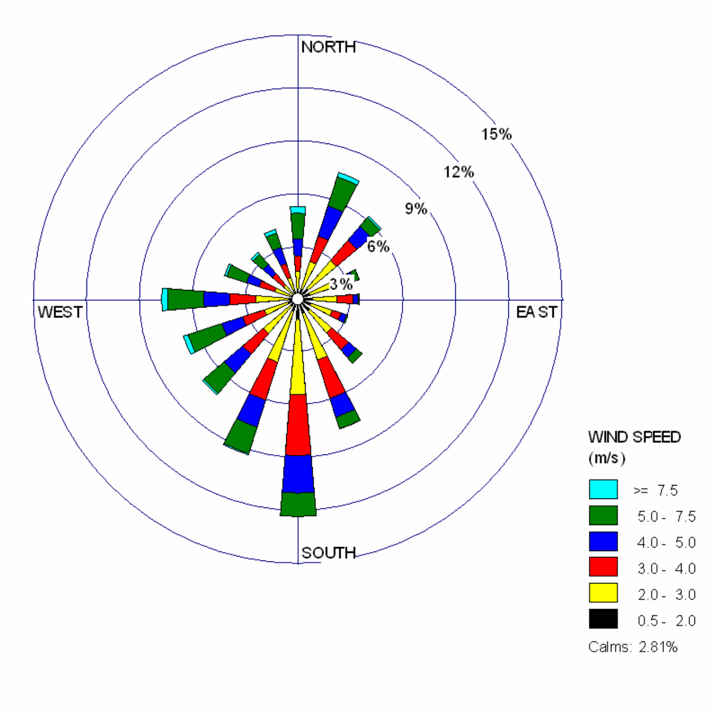
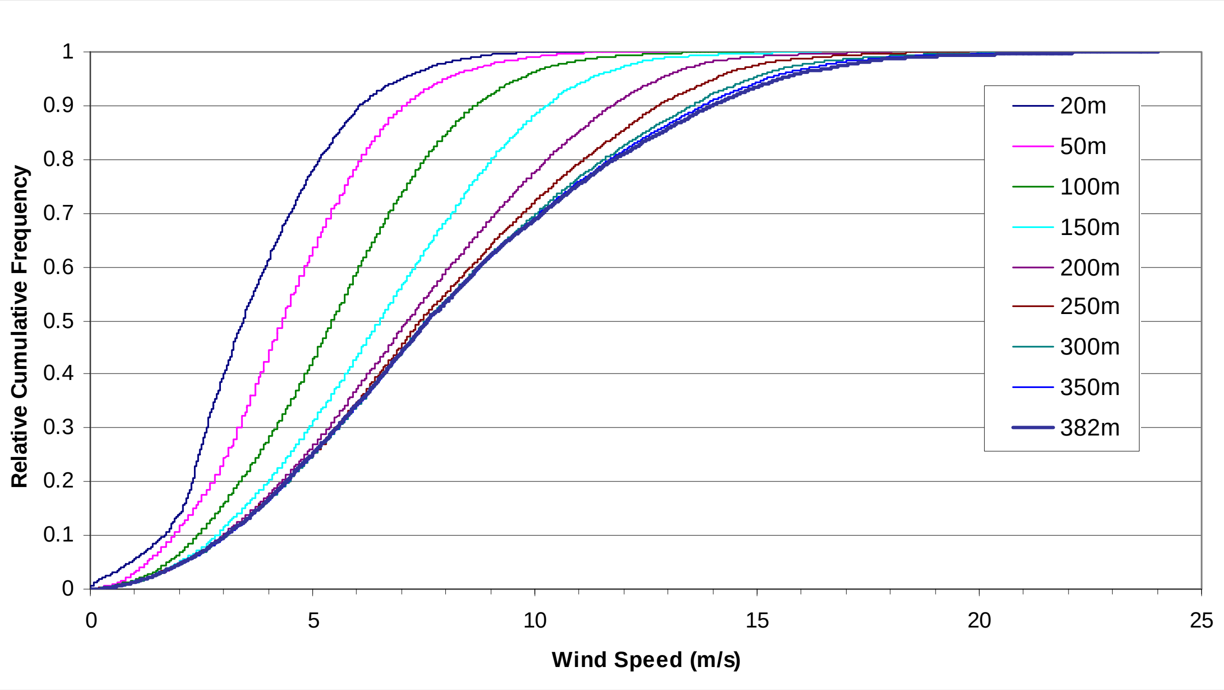


Figure 4.1 – TAPM generated wind rose for Buronga 2005, all hours, 10 m elevation

Figure 4.2 shows the relative cumulative frequency for wind speeds at various elevations. This figure represents the probability (at various elevations) of experiencing a wind speed less than or equal to a given value, based on the TAPM results for 2005. For example, at 50m elevation, there is approximately 60% probability that the wind speed for a given hour is less than or equal to 5m/s. The decreasing probability of low wind speeds with increasing elevation is indicated by rightward trend as elevation increases.

Figure 4.2: TAPM upper air wind speed relative cumulative frequency



Each row of **Table 4.1** displays the percentage of the year for which winds are less than the wind speed noted at the left of the row. The heights included range from the point of release (top of exhaust stack), to the highest point during the modelling period at which the plume velocity depreciates below 4.3m/s.

Table 4.1: TAPM upper air wind speeds by percentage

Elevation Wind Speed	20m	50m	100m	150m	200m	250m	300m	350m	382m
<=0.1m/s	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
<=0.2m/s	1.6%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
<=0.3m/s	2.1%	0.3%	0.2%	0.1%	0.2%	0.2%	0.2%	0.1%	0.1%
<=0.4m/s	2.4%	0.6%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%
<=0.5m/s	2.7%	0.8%	0.5%	0.4%	0.4%	0.4%	0.4%	0.3%	0.3%
<=1.0m/s	5.3%	2.8%	1.6%	1.3%	1.2%	1.2%	1.3%	1.3%	1.3%
<=1.5m/s	8.7%	6.4%	3.5%	2.7%	2.6%	2.6%	2.7%	2.7%	2.7%
<=3.0m/s	39.3%	23.1%	15.5%	11.1%	9.8%	9.4%	9.4%	9.6%	9.6%
<=5.0m/s	77.7%	62.0%	41.7%	30.5%	26.2%	24.8%	24.8%	24.9%	25.1%

4.2 Plume Rise Statistics

The modelling results show that, as expected for an open cycle gas turbine facility, the plant will produce exhaust plumes with vertical velocities that exceed 4.3m/s above the OLS. **Table 4.2** displays the maximum, minimum and average critical plume extents. The critical vertical plume extent is the height (for a given hour modelled) at and below which, the vertical velocity (w) of the plume exceeds 4.3m/s. The maximum critical vertical plume extent (based on the 2005 meteorology) was 382m, which occurred during extremely calm conditions with a neutral atmospheric temperature profile, where low wind speeds resulted in minimal entrainment of cooler ambient air into the plume. This allowed the plume to conserve its buoyancy to a greater degree, causing it to rise at a greater velocity, and to a greater extent.

The critical horizontal plume extent is the total downwind translation of the plume centreline at the point at which the vertical velocity decreases to 4.3m/s. The maximum critical horizontal plume extent of 84m occurs at a height of approximately 310m (see outermost contour of **Figure 4.4** for detail of variation of maximum critical horizontal plume extent with altitude).

Table 4.2: Maximum, Minimum and Average Critical Plume Extents

	Critical Vertical Plume Extent (m)	Critical Horizontal Plume Extent (m)
Maximum	382	84
Minimum	28	15
Average	46	24

Section 4 Results

Table 4.3 shows the critical vertical plume extent by percentage of time, for the year 2005. The result of 315m for 0.05% indicates that for 1 in every 2000 hours, the plume velocity exceeds 4.3m/s at a height greater than or equal to 315m. The OLS of 110m is achieved for approximately 2.5% of the year, assuming that the power plant operates full time, under full load and under all possible meteorological conditions.

Table 4.3: Heights below which the vertical velocity exceeds 4.3m/s by percentage of 2005

Percentage of time, 2005	Height below which *w* >4.3m/s: (m)
100%	28
90%	30
80%	33
70%	34
60%	36
50%	39
40%	42
30%	46
20%	52
10%	69
9%	73
8%	77
7%	80
6%	85
5%	89
4%	96
3%	105
2%	118
1%	148
0.5%	178
0.3%	208
0.2%	223
0.1%	259
0.05%	315

Section 4 Results

Figure 4.3 is another representation of the data contained in Table 4.3 and provides the critical vertical plume extent by percentile. For example, this figure indicates that for approximately 97% of the time, the vertical velocity of the plume decreases to 4.3m/s at or below 110m elevation.

Figure 4.3: Critical vertical plume extent by percentile

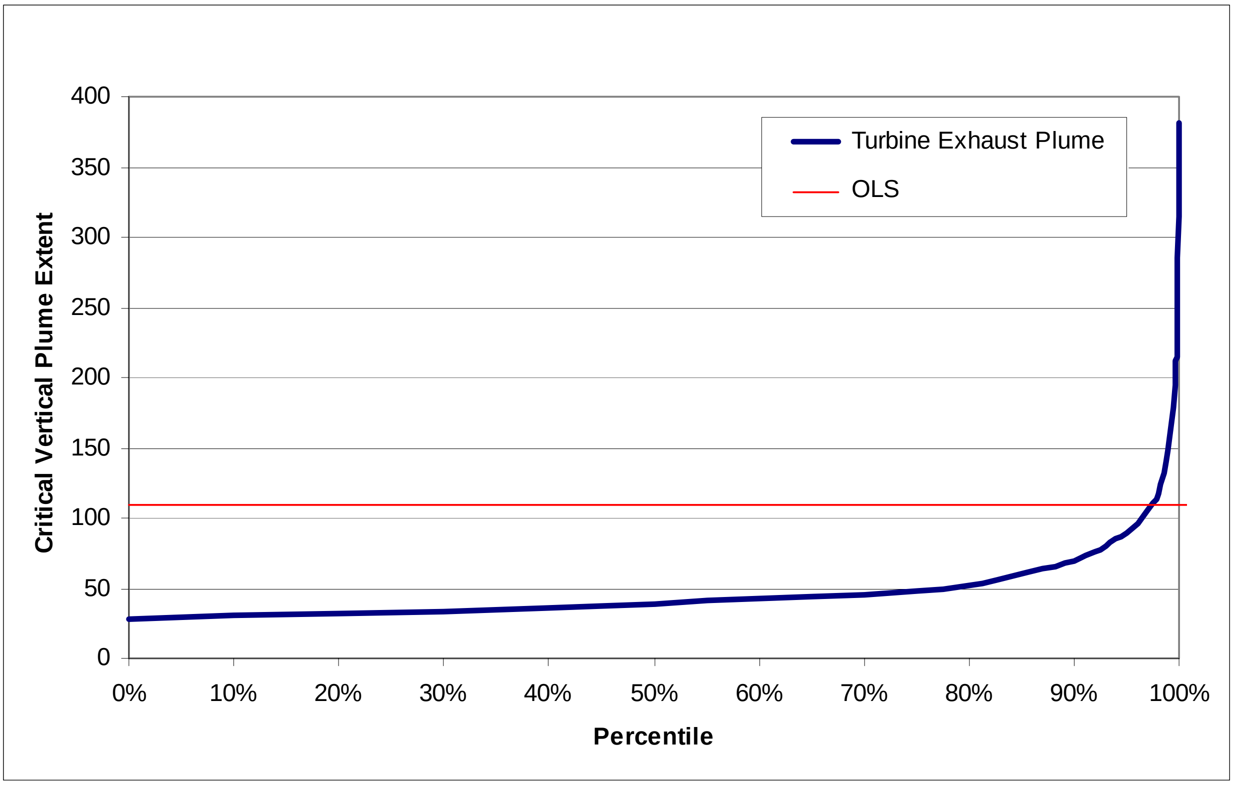
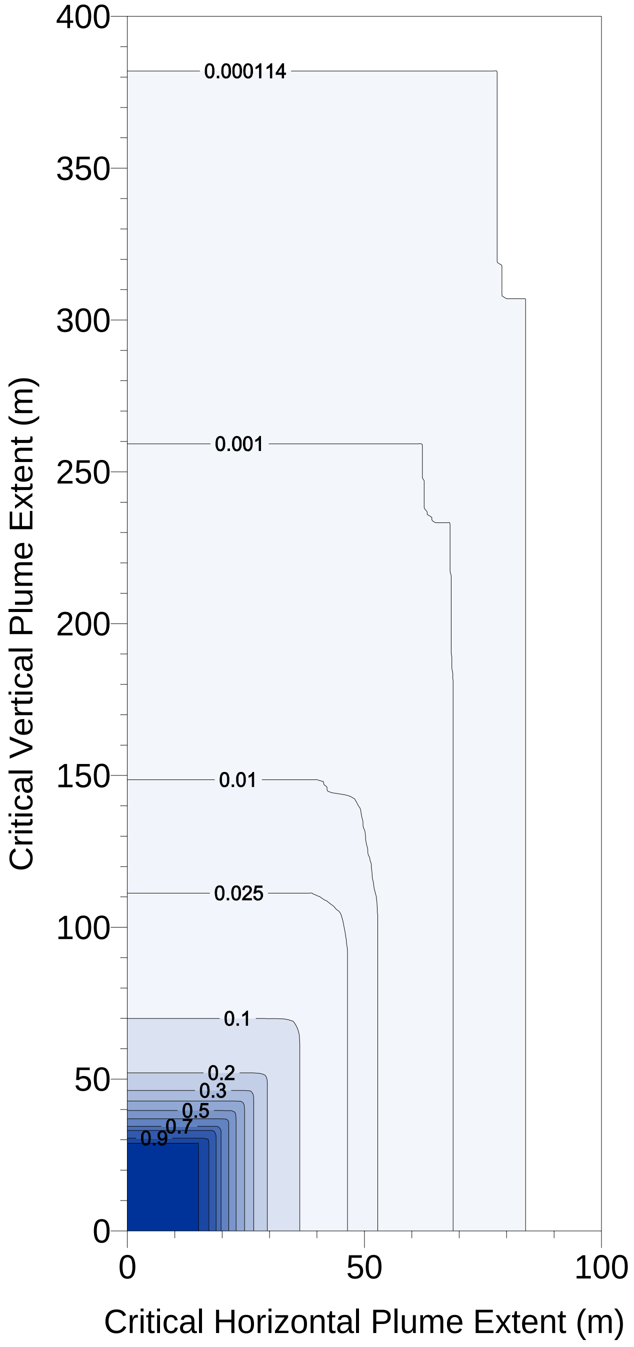


Figure 4.4 illustrates the vertical and horizontal extent of the critical plume, giving the fraction of time that the plume vertical velocity exceeds 4.3 m/s. For example, for contour level 0.01 (1% of the time, or 87 hours per year), the plume height is approximately 148 m and the corresponding total horizontal extent is 53m. It should be noted that the contour of 0.000114 is representative of the worst hour (1/8760 = 0.000114) and thus indicates entire region of space at which the vertical velocity was predicted to be greater than 4.3m/s for any instance during the year of 2005.

Figure 4.4: Probability density plot representing the region of space for which the plume velocity exceeds the critical velocity of 4.3m/s.



Section 5 Conclusion

The proposed Buronga Peaking Power Plant has been assessed for its impact on aviation safety. As operational times for peaking plants cannot be predicted, the assessment was performed on the basis that the plant would be operating continuously at full load (3 gas turbines operating). The actual operation of the plant is expected occur for up to 10% of the year.

Based on the assessment for one year of modelled data using TAPM, the OLS is exceeded during approximately 2.5% of the year, with an average vertical velocity of 4.3 m/s at 46m above ground level. Whilst this assessment is considered conservative with respect to the modelled operating times and operating conditions, the Civil Aviation Safety Authority (CASA) at its discretion may opt to designate this to be a potential hazard to aircraft operators in the area.

Section 6 References

Hurley, Peter J, CSIRO (2005) *The Air Pollution Model (TAPM) Version 3: Technical Description;*

Manins, P C, (1992) *Plume Rise from Multiple stacks*, *Clean Air* (Australia) May 1992 Vol 26 Part2 pp 65-68;

CASA (2004) *Advisory Circular AC 139-05(0) Guidelines for conducting Plume Rise Assessments.*

Section 7 Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of International Power (Australia) Pty Ltd and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared in April 2008 and is based on the information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix D Health Risk Assessment

Appendix D Health Risk Assessment

EXECUTIVE SUMMARY

The Air Quality Impact Assessment presents a review of potential emissions to air associated with the operation of the proposed Buronga Peaking Power Plant. This includes a review of criteria pollutants (NOx, PM_{10}, SO_2, CO and lead) and a range of other hazardous pollutants (benzene, formaldehyde, polycyclic aromatic hydrocarbons (PAHs), arsenic, beryllium, cadmium, chromium, manganese, mercury and nickel).

All pollutants assessed, including background contributions (where available) were shown to fall within or meet Air Impact Assessment Criteria and Air Quality guidelines published by DECC.

Inhalation exposures to these chemicals in the off-site environment typically dominate any multi-pathway exposure assessment. The predicted maximum ground level concentrations associated with emissions from the proposed peaking power plant have been compared with relevant air criteria (protective of inhalation exposures). As the concentrations (for all chemicals including persistent chemicals such as arsenic and mercury) are significantly less than the criteria, any contribution from multi-pathway exposures is considered to be negligible.

In assessing the potential for PAHs to accumulate in soils surrounding the proposed facility, the assessment of total PAH as a BaP (benzo(a)pyrene) equivalent can be directly compared with the Health Based Soil Investigation Level (HIL) for BaP (the lower of the HIL levels presented). The estimated maximum concentration of PAH as a BaP equivalent in surface soil is 0.00012mg/kg, approximately 0.01% of the relevant HIL. The estimated maximum concentration of PAH as a BaP equivalent in soils in the root zone of plants and crops is even lower at 0.0000080mg/kg, approximately 0.0008% of the relevant HIL.

It is noted that background concentrations of BaP in soils in rural areas reported by the WHO (1998) range from 0.006 to 0.022mg/kg, well above the concentrations estimated from the proposed facility. Concentrations of BaP in soils near industrial facilities (WHO, 1998) are significantly higher, with levels up to 38mg/kg.

Regardless of the conservative approach adopted in this assessment, the concentration of PAHs (as BaP equivalent) estimated in soils is negligible with respect to relevant HILs and background concentrations and are likely to be so low that they are less than the analytical limit of reporting for soil analysis. On this basis the potential for PAHs to impact on the amenity of surrounding areas (soil, crops or within rainwater tanks) is considered negligible and does not warrant further detailed assessment.

This study has considered the short and long term health impacts of pollutants, including particulate and PAH emissions, from the proposed Buronga distillate-fired peaking power plant.

This assessment demonstrates that emissions from the peaking power plant are low and not of significance with respect to health in areas surrounding the peaking power plant. In addition emissions of PAHs are considered negligible and do not warrant detailed multi-pathway exposure assessment.

The potential for the deposition of persistent and/or accumulative chemicals in the off-site soil and water environment by the gas turbine plant operation is considered to be at a negligible level.

Appendix D Health Risk Assessment

D.1 Introduction

The results of the Air Quality Assessment (to which this is an Appendix) have been reviewed further with respect to potential health impacts that may be associated with the operation of the proposed Buronga Peaking Power Plant. The assessment has been undertaken in response to a request made by the Department of Environment and Climate Change (DECC) and NSW Health that the Environmental Assessment for the project should include a review of the potential for the facility to release particulates and polycyclic aromatic hydrocarbons (PAHs) into the surrounding environment with the use of low sulphur distillate as a fuel for the proposed gas turbines.

Any emission to air has the potential to result in exposures by the general population in areas surrounding the source. With respect to emissions to air, the most significant exposure is associated with directly inhaling the pollutants in the air. Some pollutants are also considered persistent and bio-accumulative and have the potential to deposit onto and mix with soils and water to result in other indirect exposures (for example exposures associated with the ingestion of soils, dermal contact with soils and accumulation in produce and consumption of the produce).

Taking these issues into consideration, the health risk assessment undertaken has:

- provided a review of the Air Quality Assessment with respect to the protection of human health. This is of particular relevance to the assessment of direct inhalation exposures;
- provided additional discussion on issues that may be associated with particulate emissions; and
- provided additional discussion on issues that may be associated with emissions of PAHs.

The calculations utilised and presented in this assessment have been based on a conservative approach (as outlined in the Air Quality Report), including:

- the assumption that the plant will operate at full load throughout the whole year when actual operation will range across the load spectrum;
- the assumption that the plant will operate continuously throughout the whole year when actual operation will be limited to up to 10% of the year;
- PAH emission rates have been assumed to be higher than the NPI Emission Estimation Methodology;
- the assumption of much lower exhaust temperature and velocity characteristics than will be encountered in practice therefore “forcing” the exhaust plume to ground more quickly; and
- the assumption of a 70-year period for soil accumulation calculations, when the operational life expectancy of the plant is estimated at between 35 to 40 years.

Full details on the proposed peaking power plant are presented in the Environmental Assessment (**Main Report Volume 1**). Details associated with the air modelling undertaken as part of the air quality impact assessment, including assumptions and modelling parameters, are presented in **Appendix C** Air Quality Assessment (**Appendices Volume 2** of the Environmental Assessment).

Appendix D Health Risk Assessment

D.2 Overview of Air Quality Assessment

The Air Quality Assessment has presented a review of potential emissions to air associated with the operation of the proposed peaking power plant. This included a review of criteria pollutants (NOx, PM_{10}, SO_2, CO and lead) and a range of other hazardous pollutants (benzene, formaldehyde, PAHs, arsenic, beryllium, cadmium, chromium, manganese, mercury and nickel). Excluding PM_{10}, all pollutants assessed, including background contributions (where available) were less than the Air Impact Assessment Criteria available from DECC. Due to dust storms in the area, elevated concentrations of PM_{10} were found to occur on a regular basis. However, the Air Quality Assessment showed that additional exceedances of PM_{10} above regulatory criteria, would not occur due to the operation of the proposed peaking power plant.

The Impact Assessment Criteria (presented in **Table 2-2** of the Air Quality Assessment) relevant to the criteria pollutants are derived from the National Environmental Protection Council (NEPC) National Environment Protection (Ambient Air Quality) Measure (2003). These criteria are relevant to the protection of human health and well-being. As predicted, worst-case concentrations, including background, are less than these guidelines, exposures by the general public are considered to be low and acceptable.

The Impact Assessment Criteria (presented in **Table 2-3** of the Air Quality Assessment) relevant for the hazardous pollutants identified are the same as those presented in the Victorian Government Gazette (2001). The criteria are based on inhalation exposures and relevant to the protection of the general population from exposure to these pollutants every day over a lifetime. Hence, from the perspective of direct inhalation exposures, emissions to air of the hazardous pollutants considered in this assessment are considered to be low and therefore public exposure risk is low and acceptable.

D.3 Review of Particulate Emissions

Particulate matter and its size is an important parameter in reviewing issues that may be associated with the emission of particulates to air from the proposed peaking power plant. The following provides a general review of the key issues that may be associated with suspended particulates and deposited particulates in relation to the proposed Buronga Peaking Power Plant Project.

D.3.1 Suspended Particulates

Suspended particulate matter is dust or aerosol that stays suspended in the atmosphere for significant periods. A range of different suspended particle sizes occur, which can be measured with different monitoring procedures. Although some particulate matter up to about 50µm can be measured with high volume sampling, generally suspended particulate matter has a diameter of less than 20µm. Particles in the size range of 0.1µm and 1µm can stay in the atmosphere for days or weeks and be transported over long distances. The more coarse particles are more easily deposited and typically travel less than 10km from their source.

Major natural sources of background particulate levels include forest fires, pollen and wind-blown dust. Background levels vary widely depending on location, meteorology and proximity of major point or area sources. Man-made sources include stationary and mobile combustion sources, road dust, agriculture, major fires and emissions from industrial processes.

Respirable particles are those particles in the 1-10µm size range (PM_{10}) that have the potential to penetrate deep into the lungs and reach the fine bronchioles and alveoli where they are deposited and can cause local irritation and tissue damage.

Further discussion of these issues is available in the 2001 report presented by the Risk Assessment Taskforce commissioned under the NEPM (Ambient Air Quality) Measure to the NEPC which provides detail on the establishment of the guidelines presented in the NEPM (Ambient Air Quality). The report provides a critical review of the data available overseas and within Australia which relates to potential health effects of particulates.

Appendix D Health Risk Assessment

In addition reviews of particulates and health effects are presented by the WHO (2000, 2005 and 2006).

The following points can be noted from these documents with respect to health effects and the available guideline:

- Particulates are a broad class of chemically and physically diverse substances unlike the other air pollutants. Health effects what have been associated with short-term (acute) exposure to PM include increased total mortality, increased hospital admissions for respiratory and cardiovascular conditions, increased respiratory symptoms, increased incidence of asthma conditions (i.e. exacerbation of existing conditions). These health effects, even at low PM concentrations, have been noted primarily from epidemiological studies (from both acute and chronic studies) conducted on large population groups overseas and within some areas of Australia. The health effects observed in different areas throughout the world in the epidemiological studies suggests that dose response relationships obtained in a particular country may not be readily transferable to other countries. Hence, overseas data may not be relevant to the assessment of particulates in Australia.

- It is noted that there are population subgroups that are more sensitive to acute PM exposure. These groups include the elderly and those suffering from pre-existing lung or heart disease. In addition, children may be more sensitive. Health effects have been observed at all levels of exposure in large populations reflecting the wide range of susceptibility in a population.

- There is no clear data which describes the role of particle composition in observed health effects, hence no distinction between crustal particulates and other particulates (such as those from combustion source) can be determined at this point in time. In addition, the biological mechanisms (i.e. toxicology) associated with the observed effects from epidemiological studies are not well understood.

- There is no evidence from the studies undertaken that a threshold concentration can be determined for PM_{10} exposure and the related health effects. Hence linear dose-response curves have been developed for the assessment of potential health effects associated with acute exposure to PM_{10}. These dose-response curves relate potential increase in PM_{10} concentration to a potential increase in health effects of a statistical population group, not individuals. No toxicological or dose-response data is available for the assessment of potential health effects to an individual or small group.

Available data suggests that the short-term PM_{10} guideline of 50µg/m^3 (24hour average) would be exceeded on occasions within major airsheds in most years (these cover large industrial/residential areas such as the greater Sydney Region or the greater Melbourne Region and include regional areas where bushfires are significant). The assessment of particulate matter presented in **Section 6.1** and **Section 6.1.5** of the **Air Quality Assessment** has noted that the occurrence of dust storms (most significant on some days) and bush fires has resulted in relatively high background levels of PM_{10}.

The more detailed review of short-term PM_{10} concentrations associated with background sources and emissions from the proposed peaking power plant (based on conservative operating conditions) indicate that the maximum ground level concentrations are below the NEPC and WHO short-term guideline of 50µg/m^3 (24 hour average). The contribution to the total PM_{10} associated with emissions from the proposed peaking power plant (based on conservative operating conditions) is less than 1%, which is considered low.

As with the short-term assessment, the estimated annual average PM_{10} concentration is dominated by background sources, in particular dust storms and bushfires, with emissions from the proposed peaking power plant (based on conservative operating conditions) contributing less than 0.5% of the total PM_{10} concentration. This contribution is considered negligible.

On the basis of the above, the operation of the proposed peaking power plant is not considered to result in increases in total PM_{10} in the offsite areas that are considered of significance with respect to health effects.

D.3.2 Deposited Particulates

Deposited particulate matter is dust, which, because of its aerodynamic diameter and density, falls rapidly from the air. In general terms, deposited particulate has a diameter of greater than about 20µm, however there is no sharp dividing line between these particles and the smaller particles of suspended matter that fall more slowly out of the air. Because of the size of the particulate matter, most of this material does not enter the lungs.

Hence the common effects of deposited particulate are primarily nuisance, and may only affect health via annoyance reactions.

Deposited particulate matter arises from both natural and man-made sources. The most important global sources are probably volcanoes and wind-blown dust, whilst on a local level, stationary and mobile combustion sources, road dust, wind-blown soil, and emissions from industrial processes are important.

With respect to pollutants that may be emitted to air from the proposed peaking power plant the following can be noted:

- Deposition of larger particulates is not considered to be of significance with respect to nuisance effects as, in general, low levels of particulates would be emitted from the facility, much of which is expected to be < PM_{10}.
- The potential for the deposition of persistent and/or accumulative chemicals in the off-site environment (soils and water) is considered to be negligible. Inhalation exposures to these chemicals in the off-site environment typically dominate any multi-pathway exposure assessment. The predicted maximum ground level concentrations associated with emissions from the proposed peaking power plant have been compared with relevant air criteria (protective of inhalation exposures). As the concentrations (for all chemicals including persistent chemicals such as arsenic and mercury) are significantly less than the criteria, any contribution from multi-pathway exposures is considered to be essentially negligible.
- A more detailed assessment of PAHs, with respect to deposition, is presented in the following section. The assessment presented highlights that the potential for multi-pathway exposures is negligible.

D.4 Review of PAH Emissions

D.4.3 General

Further review of PAH emissions has been undertaken. A number of PAHs are listed on the UN/ECE's Persistent Organic Pollutants (POP) Protocol (1998) and the WHO (2003) lists all PAHs as POP. Hence the potential for PAHs to be present in the off-site environment (air, water and soils) has been assessed further. Accumulation of any chemical in the off-site environment via deposition has the potential to result in multi-pathway exposures such as ingestion and dermal contact with pollutants in soil; and uptake and accumulation of pollutants in produce (milk, meat, fruit, and vegetables) and consumption of the produce.

The estimated emission of PAHs assessed are low, based on the highly conservative peaking power plant operating regime assumed and adverse weather conditions, and it is considered that the potential for PAHs to accumulate in the environment will negligible.

To determine this, a preliminary assessment has been undertaken adopting the following process:

- Calculation of maximum ground level concentrations and deposition rates (for long-term emissions, annual average) for PAHs that may be emitted from the operation of the proposed peaking power plant;

- Calculation of maximum concentrations of PAHs that may deposit to and accumulate in soils. The assessment of PAHs has been undertaken on the basis of a benzo(a)pyrene toxicity equivalent. The maximum concentration in soil can then be reviewed against relevant health based soil investigation levels to determine the potential significance of the emission of PAH particulates;
- Review of the maximum ground level concentration of PAHs on the basis of a benzo(a)pyrene toxicity equivalent such that the maximum concentration in air can be directly compared against ambient air criteria protective of human health.

The maximum ground level concentration and deposition rate of PAHs has been estimated using the approach presented in the Air Quality Assessment. In summary, the following has been undertaken:

- Maximum ground level concentrations and deposition rates of PAHs that may be emitted from the operation of the distillate fired gas turbines has been estimated using the Ausplume dispersion model with meteorological data generated using the CSIRO's prognostic meteorological model TAPM. Ausplume was chosen for use in this component of the Assessment, given it's ability to account for particle size distribution and density, as opposed to TAPM which only accounts for broad particle size fractions, Modelling files are included in **Attachment 1** of this report. The methodology has followed a similar approach to that presented in the Air Quality Assessment for the project, except with some highly conservative simplifications made, given the nature of this specific screening assessment.
- Emission rates of PAHs have been derived on the basis of a paper titled *"Exhaust Emissions from High Speed Passenger Ferries"* D.A.Cooper (2001). This paper contains test data from a passenger ferry operating on two 17MW distillate oil-fired gas turbines.
- Use of data from this paper provides a consistent, slightly conservative estimate of total PAH emissions against emission factors supplied in the DEH (2005) National Pollution Inventory Emission Estimation Technique Manual *"NPI Fossil Fuel Electric Power Generation Version 2.4 15 March 2005"* (Cooper: 4.2mg/s Vs NPI: 3.4mg/s), however Cooper's study also includes speciation of the PAH's which is not available in the NPI emission factors. The results detailed in the paper also incorporate sampling conducted during a range of operating conditions including a cold start of the turbines, and full and part-load operation. This is useful given the peaking nature of the proposed power plant
- In calculating worst case annual impacts, it has been assumed that:
  - all three gas turbines are operating at full load for every hour of the year. This is highly conservative as the turbines will only operate for up to 10% of the year and across a range of loads, thus producing annual emissions less than 10% of those resulting from this assessment.
  - exhaust stack temperature would be 200^{o}C (whereas actual exhaust temperatures will be in the range 400-540^{o}C) and a lower exit velocity of 18m/s (whereas actual exit velocity is around 26m/s). These conservative assumptions result in an approximately twofold increase in the worst case annual impacts over those predicted using actual operating conditions.

D.5 Assessment of the Potential for PAHs to Deposit to Soils

D.5.4 Calculation of a Benzo(a)pyrene Equivalent

To enable this preliminary assessment to provide a review of PAH emissions with respect to potential health end points, PAHs have been assessed on the basis of a benzo(a)pyrene (BaP) toxicity equivalent (**Table D1**).

PAHs are a group of chemicals that are formed during the incomplete combustion of coal, oil and gas, garbage or other organic substances. PAHs can be man-made, but also occur naturally from sources such as volcanoes and bushfires. More than 100 different naturally occurring PAH compounds are found throughout the environment in the air, water, and soil.

Appendix D Health Risk Assessment

PAHs are a major contaminant at several important land sites in Australia (CSMS, 1998). In the US, several carcinogenic PAHs appear on the ATSDR/EPA Priority List of Hazardous Substances, with BaP ranking the highest. Several PAHs have been studied in experimental animals and shown to be mutagenic and carcinogenic, BaP being the most potent and the most widely studied PAH member. To provide a simplified evaluation, all PAHs have been evaluated using a BaP equivalence methodology outlined by the WHO (1998).

Table D1 Toxicity Equivalency Factors (TEF) for PAHs

PAH	TEF	PAH	TEF
Benzo(a)anthracene	0.145	Naphthalene	0.001
Benzo(a)pyrene	1	2-Methylnaphthalene*	0.001
Benzo(e)pyrene	0.01	1-Methylnaphthalene*	0.001
Benzo(b)fluoranthene	0.141	2,6-Dimethylnaphthalene*	0.001
Benzo(k)fluoranthene	0.1	Acenaphthylene	0.01
Chrysene	0.1	Acenaphthene	0.001
Dibenz(a,h)anthracene	5	2,3,5-Trimethylnaphthalene*	0.001
Indeno(1,2,3-cd)pyrene	0.232	1-Methylphenanthrene	0.001
Benzo(g,h,i)perylene	0.022	Anthracene	0.01
Perylene	0.001	Fluorene	0.001
Phenanthrene	0.001	Fluoranthene	0.01
Pyrene	0.81		

Note the following key principal assumptions are made in the use of TEFs:

1. Consistent relative toxicity is observed amongst different cancer bioassays in animal models and by different exposure routes, suggesting similar mechanisms. There is sufficient evidence to suggest this is reasonable for carcinogenic PAHs. It is noted that a number of the individual PAHs listed above are not carcinogenic; and
2. The toxic effects of different PAH compounds in a mixture are additive. Experimental evidence suggests that this is a fair assumption.

* The toxic effect of these individual PAHs is unknown, however it has been conservatively assumed that they are no more toxic than naphthalene and hence the TEF adopted for naphthalene has also been adopted for these compounds.

This methodology references the toxicity of individual PAHs to BaP using relative potency factors (or toxicity equivalence factors). This allows for total PAHs to be assessed on the basis of its overall equivalence to BaP (where the total BaP equivalent is calculated as the sum of the individual PAHs expressed on the basis of toxicity equivalence). BaP is typically used as the reference PAH since it is considered to be the PAH which has been best characterised in the class of PAHs.

The toxicity equivalency factors (TEF) utilised are the maximum values listed in a number of studies presented by the WHO (1998). This provides a conservative assessment of overall toxicity equivalence. The toxicity equivalence factors adopted are listed below.

The TEFs shown in **Table D1** have been applied to the maximum calculated concentration (annual average) and deposition rates for each individual PAH resulting in the calculation of a total maximum concentration and deposition rate as a BaP equivalent as follows:

- Maximum total PAH deposition rate (as BaP equivalent) = 0.15 µg/m^2/year
- Maximum total PAH concentration in air (as BaP equivalent) = 0.000012 µg/m^3

Note that the PAH concentrations presented in the Air Quality Assessment is based on a maximum 1hour average as required for comparison with the DECC Assessment Criteria. The assessment presented here has focused on long term (lifetime) exposures associated with annual averages.

D.5.5 Calculation of Maximum PAH Concentration in Soil

The potential accumulation of PAHs (that are considered persistent in the environment) chemicals in soils, which may be the result of deposition from the proposed facility, can be estimated using a soil accumulation model (Stevens 1991).

The concentration in soil, which may be the result of deposition following emission of PAHs, can be calculated using **Equation 1**.

$$C_s = \frac{DR \bullet \left[1 - e^{-k \bullet t}\right]}{d \bullet \rho \bullet k} \bullet 1000 \qquad \text{(mg/kg)} \qquad \text{....Equation 1}$$

where:

DR = Particle deposition rate – maximum estimated (mg/m^2/year)

k = Chemical-specific soil-loss constant (1/year) = ln(2)/T$^{0.5}$

T$^{0.5}$ = Chemical half-life in soil (years)

t = Accumulation time (years)

d = Soil mixing depth (m)

ρ = Soil bulk-density (g/m^3)

and 1000 = Conversion from g to kg

The maximum particle deposition rate of PAHs expressed as a total BaP equivalent from all off-site receptor locations based has been used in this calculation. In addition the following has been assumed:

- Emissions may occur for a lifetime which is assumed to be 70 years (as per enHealth, 2004) (considered to be the accumulation time). It is considered overly conservative to assume that the proposed peaking power plant will operate for all hours continuously over a 70 year period when the operational life expectancy of the power plant is estimated at between 35 to 40 years.
- Soil half-life for PAHs has been taken to be 9 years. This is the maximum half-life listed from a range of studies presented by the WHO (1998) for BaP and other individual PAHs. The half-life adopted is considered representative of all PAHs expressed as a BaP equivalent.
- It is assumed that the soil where deposition occurs is not well mixed (as would be the case in a garden or cultivated bed), and hence the mixing depth for deposited soils and dusts has been taken to be 1cm, with a soil bulk density of 1.6g/cm^3 (typical of more loose top soils). For the assessment of areas where plants may be grown, including crops a, a soil mixing zone of 15cm has been assumed within the root zone of plants.

Following this approach, the following conservative soil concentrations have been estimated:

- Maximum concentration of PAHs in surface soils and dusts (as BaP equivalent) = 0.00012 mg/kg
- Maximum concentration of PAHs in the root zone of plants (as BaP equivalent) = 0.0000080 mg/kg

D.5.6 Review of Significance of PAH Concentrations in Soils

The National Environment Protection Council (NEPC, 1999) has established a Health-Based Soil Investigation Level (HIL) for both BaP and total PAHs (as a total). The HIL has been derived to be protective of the health of all individuals who may be exposed to the presence of chemicals in soils at the HIL associated with exposure over a lifetime. The HIL is a conservative value that can be applied to any site and can be considered to be a level above which further investigation and assessment would be warranted. For the most sensitive land-use scenario, low density residential, the HIL for BaP is 1 mg/kg and for total PAHs is 20 mg/kg.

In assessing the potential PAHs to accumulate in soils surrounding the proposed facility, the assessment of total PAH as a BaP equivalent can be directly compared with the HIL for BaP (the lower of the HIL levels presented). The estimated maximum concentration of PAH as a BaP equivalent in surface soil is 0.00012 mg/kg, approximately 0.01% of the relevant HIL. The estimated maximum concentration of PAH as a BaP equivalent in soils in the root zone of plants and crops is even lower at 0.0000080 mg/kg, approximately 0.0008% of the relevant HIL.

It is noted that background concentrations of BaP in soils in rural areas reported by the WHO (1998) range from 0.006 to 0.022 mg/kg, well above the soil concentrations estimated based on accumulation of deposited particulates from the proposed facility. Concentrations of BaP in soils near industrial facilities (WHO, 1998) are significantly higher, with levels up to 38 mg/kg.

Regardless of the overly conservative approach adopted, the concentration of PAHs (as BaP equivalent) estimated in soils is considered negligible with respect to relevant HILs and background concentrations and are likely to be so low that they are less than the analytical limit of reporting for soil analysis. On this basis the potential for PAHs to impact on the amenity of surrounding areas (soil, crops or within rainwater tanks) is considered negligible and does not warrant further detailed assessment.

D.5.7 Review of Significance of PAHs in Air

In June 1998 (with variations to 2003), the NEPC released a National Environment Protection Measure (NEPM) for Ambient Air Quality, setting out national levels for criteria pollutants. This did not include any guidelines for PAHs or other VOCs in ambient air. In April 2004 the NEPC released the Air Toxics NEPM that presented a number of air investigation levels for some key air toxics. The air investigation levels were derived on the basis of the long term protection of human health within regional areas. An air investigation level for BaP as a marker for PAHs in air has been established at 0.3 ng/m^3 expressed as an annual average. The air investigation level is protective of the health of all individuals associated with exposure every day for a lifetime. As with the HIL, the air investigation level is considered to be a conservative value that represents a level at which further investigation or assessment is required.

The maximum concentration of PAHs as a BaP equivalent (which is directly comparable to the air investigation level) is 0.012 ng/m^3, approximately 4% of the air investigation level. Background average concentrations of BaP detected in air in a number of cities in Australia (WA DEP, 1999) range from 0.03 to 1.88 ng/m^3. The maximum PAH concentration as BaP equivalent estimated from the proposed facility is less than the lower end of these background concentrations.

Given the conservative approach adopted in the estimation of the maximum concentration of PAHs in air associated with emissions from the proposed peaking power plant, this is considered to be low and essentially negligible.

D.6 Conclusions

This study has considered the short and long term impacts of pollutants, including particulate and PAH emissions, from the proposed Buronga distillate-fired peaking power plant.

This assessment demonstrates that emissions from the peaking power plant are considered to be low and not of significance with respect to long term health in areas surrounding the peaking power plant. In addition emissions of PAHs are considered negligible and do not warrant detailed multi-pathway exposure assessment.

D.7 References

Cooper D.A., 2001. Exhaust Emissions from High Speed Passenger Ferries. *Atmospheric Environment* 35, p4189-4200.

CSMS, 1998. The Benchmark Dose Approach and Health-Based Investigation Levels for Polycyclic Aromatic Hydrocarbons (PAHs). Prepared by J Fitzgerald, published in the Contaminated Sited Monograph Series, No. 7, 1998.

DEH 2005 *National Pollutant Inventory. Emission Estimation Technique Manual for Fossil Fuel Electric Power Generation Version 2.4*. 15 March 2005. Australian Government.

enHealth, 2004. Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards, June 2004.

National Environment Protection Council (NEPC), 1999. National Environment Protection Measure (Assessment of Site Contamination), Schedule B(7a), Guideline on Health-Based Investigation Levels, 1999

National Environment Protection Council (NEPC), 2001. National Environment Protection (Ambient Air Quality) Measure. Report for the Risk Assessment Taskforce, Appendix 4, Health Effects of Criteria Pollutants.

National Environment Protection Council (NEPC), 2003. National Environment Protection (Ambient Air Quality) Measure, Variation 2003.

National Environment Protection Council (NEPC), 2004. National Environment Protection (Air Toxics) Measure. April 2004.

Stevens B. 2,3,7,8-Tetrachlorobenzo-p-Dioxin in the Agricultural Food Chain: Potential Impact of MSW Incineration on Human Health. Presented In: Health Effects of Municipal Waste Incineration, Edited by Holly A. Hattemer-Frey and Curtis Travis, CRC Press 1991.

UN/ECE, 1998. *Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Persistent Organic Pollutants*.

Victoria Government Gazette 2001 *State Environment Protection Policy (Air Quality Management)*. Victorian Government Printer.

Western Australia Department of Environmental Protection, State of Knowledge Report on PAHs in Australia, 1999.

WHO, 1998. Environmental Health Criteria 202, Selected Non-Hetrocyclic Polycyclic Aromatic Hydrocarbons. World Health Organisation, International Programme of Chemical Safety, 1998.

WHO, 2000. Guidelines for Air Quality. World Health Organisation, 2000.

WHO, 2003. *Health Risks of Persistent Organic Pollutants from Long-Range Transboundary Air Pollution*. Joint WHO/Convention Task Force on the Health Aspects of Air Pollution, WHO Regional Office for Europe.

WHO, 2005. WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide, Global Update 2005. World Health Organisation, 2005.

WHO, 2006. Health Risks of Particulate Matter from Long-Range Transboundary Air Pollution, World Health Organisation 2006.

Attachment 1 – Modelling Files

Calculation of Total PAHs Emission Rate using NPI data

Fuel Usage	15.3	tonnes/hour
Fuel S.G	0.84	
Fuel Usage	18.21	kL/hour
Fuel Usage	0.0051	kL/s
	5.1	(L/s)
Emission Factor	6.8E-04	kg/kL_fuel_usage*
Total PAH Emission Rate	**3.44**	mg/s/turbine

(Hence on a Total PAH basis the test data is consisent (if not slightly conservative) against the NPI emission factor)

* *"NPI Fossil Fuel Electric Power Generation Version 2.4 15 March 2005"*, pg.50

1

IPRA Buronga Inhalation Calculation

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	0.300 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	0.200m
Adjustment for wind directional shear	None

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

IPRA Buronga Inhalation Calculation

SOURCE CHARACTERISTICS

STACK SOURCE: 1

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
616340	6225879	50m	13m	4.00m	200C	18.0m/s

No building wake effects.
(Constant) emission rate = 1.00E+00 grams/second
No gravitational settling or scavenging.

STACK SOURCE: 2

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
616363	6225850	50m	13m	4.00m	200C	18.0m/s

No building wake effects.
(Constant) emission rate = 1.00E+00 grams/second
No gravitational settling or scavenging.

STACK SOURCE: 3

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
616387	6225821	50m	13m	4.00m	200C	18.0m/s

No building wake effects.
(Constant) emission rate = 1.00E+00 grams/second
No gravitational settling or scavenging.

1

IPRA Buronga Inhalation Calculation

RECEPTOR LOCATIONS

The Cartesian receptor grid has the following x-values (or eastings):

```
604071.m  604321.m  604571.m  604821.m  605071.m  605321.m  605571.m
605821.m  606071.m  606321.m  606571.m  606821.m  607071.m  607321.m
607571.m  607821.m  608071.m  608321.m  608571.m  608821.m  609071.m
609321.m  609571.m  609821.m  610071.m  610321.m  610571.m  610821.m
611071.m  611321.m  611571.m  611821.m  612071.m  612321.m  612571.m
612821.m  613071.m  613321.m  613571.m  613821.m  614071.m  614321.m
614571.m  614821.m  615071.m  615321.m  615571.m  615821.m  616071.m
616321.m  616571.m  616821.m  617071.m  617321.m  617571.m  617821.m
618071.m  618321.m  618571.m  618821.m  619071.m  619321.m  619571.m
619821.m  620071.m  620321.m  620571.m  620821.m  621071.m  621321.m
621571.m  621821.m  622071.m  622321.m  622571.m  622821.m  623071.m
623321.m  623571.m  623821.m  624071.m  624321.m  624571.m  624821.m
625071.m  625321.m  625571.m  625821.m  626071.m  626321.m  626571.m
626821.m  627071.m  627321.m  627571.m  627821.m  628071.m
```

and these y-values (or northings):

```
6214041.m 6214291.m 6214541.m 6214791.m 6215041.m 6215291.m 6215541.m
6215791.m 6216041.m 6216291.m 6216541.m 6216791.m 6217041.m 6217291.m
6217541.m 6217791.m 6218041.m 6218291.m 6218541.m 6218791.m 6219041.m
6219291.m 6219541.m 6219791.m 6220041.m 6220291.m 6220541.m 6220791.m
6221041.m 6221291.m 6221541.m 6221791.m 6222041.m 6222291.m 6222541.m
6222791.m 6223041.m 6223291.m 6223541.m 6223791.m 6224041.m 6224291.m
6224541.m 6224791.m 6225041.m 6225291.m 6225541.m 6225791.m 6226041.m
6226291.m 6226541.m 6226791.m 6227041.m 6227291.m 6227541.m 6227791.m
6228041.m 6228291.m 6228541.m 6228791.m 6229041.m 6229291.m 6229541.m
6229791.m 6230041.m 6230291.m 6230541.m 6230791.m 6231041.m 6231291.m
6231541.m 6231791.m 6232041.m 6232291.m 6232541.m 6232791.m 6233041.m
6233291.m 6233541.m 6233791.m 6234041.m 6234291.m 6234541.m 6234791.m
6235041.m 6235291.m 6235541.m 6235791.m 6236041.m 6236291.m 6236541.m
6236791.m 6237041.m 6237291.m 6237541.m 6237791.m 6238041.m
```

METEOROLOGICAL DATA : AUSPLUME METFILE

AVERAGE OVER ALL HOURS AND FOR ALL SOURCES
in microgram/m3

Y (km) \ X (km):	604.071	604.321	604.571	604.821	605.071	605.321
6238.041	1.15E-02	1.17E-02	1.19E-02	1.21E-02	1.24E-02	1.26E-02
6237.791	1.10E-02	1.12E-02	1.16E-02	1.19E-02	1.23E-02	1.27E-02
6237.541	1.08E-02	1.08E-02	1.13E-02	1.18E-02	1.23E-02	1.27E-02
6237.291	1.09E-02	1.10E-02	1.14E-02	1.18E-02	1.23E-02	1.27E-02
6237.041	1.10E-02	1.11E-02	1.16E-02	1.19E-02	1.22E-02	1.27E-02
6236.791	1.11E-02	1.14E-02	1.16E-02	1.20E-02	1.23E-02	1.27E-02
6236.541	1.12E-02	1.16E-02	1.18E-02	1.21E-02	1.24E-02	1.26E-02
6236.291	1.11E-02	1.15E-02	1.18E-02	1.21E-02	1.24E-02	1.26E-02
6236.041	1.09E-02	1.13E-02	1.18E-02	1.21E-02	1.24E-02	1.27E-02
6235.791	1.09E-02	1.13E-02	1.17E-02	1.21E-02	1.24E-02	1.26E-02
6235.541	1.08E-02	1.14E-02	1.18E-02	1.21E-02	1.25E-02	1.27E-02
6235.291	1.09E-02	1.14E-02	1.19E-02	1.23E-02	1.27E-02	1.29E-02
6235.041	1.11E-02	1.16E-02	1.22E-02	1.25E-02	1.29E-02	1.31E-02
6234.791	1.13E-02	1.17E-02	1.23E-02	1.28E-02	1.31E-02	1.34E-02
6234.541	1.14E-02	1.19E-02	1.25E-02	1.30E-02	1.33E-02	1.36E-02
6234.291	1.14E-02	1.19E-02	1.24E-02	1.29E-02	1.33E-02	1.35E-02
6234.041	1.13E-02	1.18E-02	1.23E-02	1.28E-02	1.32E-02	1.35E-02
6233.791	1.11E-02	1.16E-02	1.20E-02	1.26E-02	1.30E-02	1.34E-02
6233.541	1.09E-02	1.15E-02	1.19E-02	1.23E-02	1.28E-02	1.33E-02
6233.291	1.09E-02	1.14E-02	1.19E-02	1.22E-02	1.27E-02	1.31E-02
6233.041	1.08E-02	1.13E-02	1.17E-02	1.21E-02	1.25E-02	1.29E-02
6232.791	1.07E-02	1.11E-02	1.15E-02	1.20E-02	1.25E-02	1.28E-02
6232.541	1.06E-02	1.10E-02	1.14E-02	1.18E-02	1.23E-02	1.26E-02
6232.291	1.05E-02	1.08E-02	1.12E-02	1.16E-02	1.21E-02	1.25E-02
6232.041	1.02E-02	1.07E-02	1.10E-02	1.15E-02	1.19E-02	1.25E-02
6231.791	1.01E-02	1.05E-02	1.09E-02	1.13E-02	1.18E-02	1.24E-02
6231.541	9.89E-03	1.03E-02	1.09E-02	1.13E-02	1.18E-02	1.23E-02
6231.291	9.84E-03	1.04E-02	1.08E-02	1.13E-02	1.18E-02	1.25E-02
6231.041	9.82E-03	1.03E-02	1.09E-02	1.14E-02	1.20E-02	1.27E-02
6230.791	1.00E-02	1.06E-02	1.11E-02	1.17E-02	1.23E-02	1.29E-02
6230.541	1.02E-02	1.07E-02	1.13E-02	1.19E-02	1.25E-02	1.33E-02
6230.291	1.01E-02	1.07E-02	1.14E-02	1.20E-02	1.28E-02	1.35E-02
6230.041	1.03E-02	1.08E-02	1.15E-02	1.23E-02	1.30E-02	1.39E-02
6229.791	1.04E-02	1.10E-02	1.16E-02	1.25E-02	1.34E-02	1.43E-02
6229.541	1.04E-02	1.10E-02	1.16E-02	1.25E-02	1.35E-02	1.43E-02
6229.291	1.05E-02	1.10E-02	1.18E-02	1.25E-02	1.35E-02	1.44E-02
6229.041	1.04E-02	1.10E-02	1.17E-02	1.25E-02	1.35E-02	1.42E-02
6228.791	1.04E-02	1.11E-02	1.18E-02	1.26E-02	1.34E-02	1.41E-02
6228.541	1.04E-02	1.12E-02	1.20E-02	1.28E-02	1.35E-02	1.40E-02
6228.291	1.04E-02	1.12E-02	1.19E-02	1.27E-02	1.35E-02	1.40E-02
6228.041	1.09E-02	1.14E-02	1.22E-02	1.29E-02	1.36E-02	1.40E-02
6227.791	1.14E-02	1.20E-02	1.27E-02	1.32E-02	1.37E-02	1.41E-02
6227.541	1.21E-02	1.27E-02	1.32E-02	1.37E-02	1.39E-02	1.39E-02
6227.291	1.29E-02	1.35E-02	1.39E-02	1.40E-02	1.42E-02	1.39E-02
6227.041	1.39E-02	1.43E-02	1.47E-02	1.46E-02	1.44E-02	1.42E-02
6226.791	1.48E-02	1.54E-02	1.53E-02	1.53E-02	1.50E-02	1.46E-02
6226.541	1.55E-02	1.59E-02	1.59E-02	1.56E-02	1.54E-02	1.47E-02
6226.291	1.61E-02	1.63E-02	1.62E-02	1.60E-02	1.55E-02	1.48E-02
6226.041	1.65E-02	1.67E-02	1.67E-02	1.64E-02	1.57E-02	1.49E-02
6225.791	1.68E-02	1.70E-02	1.70E-02	1.67E-02	1.59E-02	1.52E-02
6225.541	1.69E-02	1.71E-02	1.70E-02	1.65E-02	1.60E-02	1.50E-02
6225.291	1.69E-02	1.69E-02	1.68E-02	1.63E-02	1.58E-02	1.48E-02
6225.041	1.68E-02	1.68E-02	1.65E-02	1.62E-02	1.56E-02	1.45E-02
6224.791	1.66E-02	1.65E-02	1.63E-02	1.57E-02	1.52E-02	1.42E-02
6224.541	1.63E-02	1.61E-02	1.58E-02	1.55E-02	1.50E-02	1.40E-02
6224.291	1.57E-02	1.56E-02	1.55E-02	1.50E-02	1.47E-02	1.39E-02
6224.041	1.50E-02	1.51E-02	1.48E-02	1.47E-02	1.44E-02	1.38E-02
6223.791	1.42E-02	1.45E-02	1.44E-02	1.43E-02	1.40E-02	1.34E-02
6223.541	1.36E-02	1.39E-02	1.39E-02	1.37E-02	1.34E-02	1.30E-02
6223.291	1.32E-02	1.35E-02	1.35E-02	1.33E-02	1.30E-02	1.26E-02
6223.041	1.27E-02	1.29E-02	1.30E-02	1.29E-02	1.29E-02	1.24E-02

6222.791	1.21E-02	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.25E-02
6222.541	1.16E-02	1.22E-02	1.24E-02	1.25E-02	1.25E-02	1.26E-02
6222.291	1.05E-02	1.05E-02	1.16E-02	1.23E-02	1.28E-02	1.28E-02
6222.041	1.04E-02	1.07E-02	1.17E-02	1.27E-02	1.29E-02	1.30E-02
6221.791	1.04E-02	1.09E-02	1.19E-02	1.29E-02	1.27E-02	1.28E-02
6221.541	1.01E-02	1.07E-02	1.12E-02	1.15E-02	1.15E-02	1.20E-02
6221.291	9.77E-03	9.99E-03	1.02E-02	1.05E-02	1.07E-02	1.12E-02
6221.041	9.98E-03	1.03E-02	1.06E-02	1.08E-02	1.10E-02	1.12E-02
6220.791	1.03E-02	1.06E-02	1.09E-02	1.11E-02	1.13E-02	1.15E-02
6220.541	1.03E-02	1.07E-02	1.09E-02	1.11E-02	1.15E-02	1.16E-02
6220.291	1.03E-02	1.06E-02	1.08E-02	1.10E-02	1.11E-02	1.12E-02
6220.041	1.02E-02	1.05E-02	1.07E-02	1.08E-02	1.08E-02	1.07E-02
6219.791	1.01E-02	1.03E-02	1.05E-02	1.06E-02	1.08E-02	1.08E-02
6219.541	1.02E-02	1.03E-02	1.05E-02	1.06E-02	1.08E-02	1.13E-02
6219.291	1.08E-02	1.04E-02	1.06E-02	1.07E-02	1.11E-02	1.14E-02
6219.041	1.15E-02	1.12E-02	1.14E-02	1.21E-02	1.21E-02	1.22E-02
6218.791	1.18E-02	1.18E-02	1.20E-02	1.25E-02	1.26E-02	1.27E-02
6218.541	1.19E-02	1.21E-02	1.23E-02	1.27E-02	1.29E-02	1.30E-02
6218.291	1.20E-02	1.22E-02	1.25E-02	1.29E-02	1.31E-02	1.33E-02
6218.041	1.22E-02	1.24E-02	1.26E-02	1.31E-02	1.33E-02	1.35E-02
6217.791	1.23E-02	1.26E-02	1.28E-02	1.31E-02	1.34E-02	1.37E-02
6217.541	1.25E-02	1.27E-02	1.30E-02	1.33E-02	1.36E-02	1.39E-02
6217.291	1.27E-02	1.29E-02	1.32E-02	1.35E-02	1.39E-02	1.42E-02
6217.041	1.28E-02	1.33E-02	1.36E-02	1.39E-02	1.41E-02	1.44E-02
6216.791	1.32E-02	1.35E-02	1.40E-02	1.42E-02	1.45E-02	1.47E-02
6216.541	1.35E-02	1.39E-02	1.46E-02	1.49E-02	1.53E-02	1.50E-02
6216.291	1.37E-02	1.42E-02	1.48E-02	1.51E-02	1.55E-02	1.56E-02
6216.041	1.39E-02	1.44E-02	1.49E-02	1.53E-02	1.56E-02	1.58E-02
6215.791	1.43E-02	1.48E-02	1.53E-02	1.54E-02	1.60E-02	1.63E-02
6215.541	1.46E-02	1.51E-02	1.56E-02	1.59E-02	1.65E-02	1.68E-02
6215.291	1.49E-02	1.54E-02	1.59E-02	1.65E-02	1.68E-02	1.73E-02
6215.041	1.54E-02	1.57E-02	1.62E-02	1.67E-02	1.73E-02	1.76E-02
6214.791	1.55E-02	1.60E-02	1.65E-02	1.70E-02	1.76E-02	1.79E-02
6214.541	1.58E-02	1.61E-02	1.66E-02	1.71E-02	1.77E-02	1.80E-02
6214.291	1.59E-02	1.62E-02	1.67E-02	1.72E-02	1.78E-02	1.82E-02
6214.041	1.59E-02	1.63E-02	1.68E-02	1.73E-02	1.77E-02	1.83E-02

Y (km) \ X (km):	605.571	605.821	606.071	606.321	606.571	606.821
6238.041	1.28E-02	1.32E-02	1.35E-02	1.35E-02	1.36E-02	1.40E-02
6237.791	1.29E-02	1.35E-02	1.39E-02	1.37E-02	1.39E-02	1.43E-02
6237.541	1.32E-02	1.37E-02	1.43E-02	1.40E-02	1.41E-02	1.43E-02
6237.291	1.31E-02	1.37E-02	1.41E-02	1.40E-02	1.43E-02	1.45E-02
6237.041	1.31E-02	1.35E-02	1.38E-02	1.39E-02	1.42E-02	1.47E-02
6236.791	1.29E-02	1.33E-02	1.36E-02	1.38E-02	1.42E-02	1.48E-02
6236.541	1.29E-02	1.32E-02	1.34E-02	1.36E-02	1.41E-02	1.47E-02
6236.291	1.28E-02	1.31E-02	1.32E-02	1.35E-02	1.41E-02	1.48E-02
6236.041	1.29E-02	1.30E-02	1.32E-02	1.36E-02	1.42E-02	1.48E-02
6235.791	1.29E-02	1.30E-02	1.31E-02	1.35E-02	1.41E-02	1.47E-02
6235.541	1.30E-02	1.31E-02	1.32E-02	1.36E-02	1.42E-02	1.48E-02
6235.291	1.30E-02	1.32E-02	1.34E-02	1.38E-02	1.43E-02	1.49E-02
6235.041	1.33E-02	1.35E-02	1.36E-02	1.41E-02	1.45E-02	1.51E-02
6234.791	1.35E-02	1.38E-02	1.39E-02	1.43E-02	1.48E-02	1.53E-02
6234.541	1.37E-02	1.38E-02	1.41E-02	1.46E-02	1.50E-02	1.54E-02
6234.291	1.38E-02	1.41E-02	1.44E-02	1.47E-02	1.51E-02	1.57E-02
6234.041	1.38E-02	1.41E-02	1.44E-02	1.49E-02	1.53E-02	1.58E-02
6233.791	1.37E-02	1.40E-02	1.45E-02	1.50E-02	1.53E-02	1.57E-02
6233.541	1.36E-02	1.41E-02	1.44E-02	1.49E-02	1.54E-02	1.58E-02
6233.291	1.34E-02	1.39E-02	1.43E-02	1.48E-02	1.53E-02	1.57E-02
6233.041	1.33E-02	1.38E-02	1.43E-02	1.48E-02	1.51E-02	1.55E-02
6232.791	1.32E-02	1.37E-02	1.41E-02	1.45E-02	1.48E-02	1.52E-02
6232.541	1.31E-02	1.36E-02	1.39E-02	1.43E-02	1.47E-02	1.49E-02
6232.291	1.29E-02	1.33E-02	1.38E-02	1.41E-02	1.44E-02	1.45E-02
6232.041	1.29E-02	1.33E-02	1.37E-02	1.40E-02	1.40E-02	1.42E-02
6231.791	1.28E-02	1.33E-02	1.37E-02	1.39E-02	1.38E-02	1.39E-02
6231.541	1.29E-02	1.33E-02	1.39E-02	1.37E-02	1.38E-02	1.37E-02
6231.291	1.30E-02	1.37E-02	1.40E-02	1.36E-02	1.35E-02	1.33E-02
6231.041	1.32E-02	1.36E-02	1.40E-02	1.36E-02	1.34E-02	1.31E-02
6230.791	1.35E-02	1.39E-02	1.42E-02	1.37E-02	1.35E-02	1.31E-02
6230.541	1.38E-02	1.42E-02	1.45E-02	1.38E-02	1.34E-02	1.30E-02
6230.291	1.42E-02	1.48E-02	1.49E-02	1.40E-02	1.33E-02	1.27E-02

1

IPRA Buronga Deposition calculation

Concentration or deposition	Dry deposition only
Emission load units	grams/second
Deposition units	microgram/m2
Units conversion factor	1.00E+06
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	0.300 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	0.200m
Adjustment for wind directional shear	None

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

IPRA Buronga Deposition calculation

SOURCE CHARACTERISTICS

STACK SOURCE: 1

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
616340	6225879	50m	13m	4.00m	200C	18.0m/s

No building wake effects.
(Constant) emission rate = 1.00E+00 grams/second

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
0.0700	1.0	2.20
0.0800	0.3	2.20
0.1300	0.2	2.20
0.2400	0.2	2.20
0.4800	0.1	2.20

STACK SOURCE: 2

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
616363	6225850	50m	13m	4.00m	200C	18.0m/s

No building wake effects.
(Constant) emission rate = 1.00E+00 grams/second

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
0.0700	1.0	2.20
0.0800	0.3	2.20
0.1300	0.2	2.20
0.2400	0.2	2.20
0.4800	0.1	2.20

STACK SOURCE: 3

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
616387	6225821	50m	13m	4.00m	200C	18.0m/s

No building wake effects.
(Constant) emission rate = 1.00E+00 grams/second

Particle Mass fraction	Particle Size (micron)	Particle Density (g/cm3)
0.0700	1.0	2.20
0.0800	0.3	2.20
0.1300	0.2	2.20
0.2400	0.2	2.20
0.4800	0.1	2.20

1

IPRA Buronga Deposition calculation

RECEPTOR LOCATIONS

The Cartesian receptor grid has the following x-values (or eastings):

604071.m	604321.m	604571.m	604821.m	605071.m	605321.m	605571.m
605821.m	606071.m	606321.m	606571.m	606821.m	607071.m	607321.m
607571.m	607821.m	608071.m	608321.m	608571.m	608821.m	609071.m
609321.m	609571.m	609821.m	610071.m	610321.m	610571.m	610821.m
611071.m	611321.m	611571.m	611821.m	612071.m	612321.m	612571.m
612821.m	613071.m	613321.m	613571.m	613821.m	614071.m	614321.m
614571.m	614821.m	615071.m	615321.m	615571.m	615821.m	616071.m
616321.m	616571.m	616821.m	617071.m	617321.m	617571.m	617821.m
618071.m	618321.m	618571.m	618821.m	619071.m	619321.m	619571.m

619821.m 620071.m 620321.m 620571.m 620821.m 621071.m 621321.m
621571.m 621821.m 622071.m 622321.m 622571.m 622821.m 623071.m
623321.m 623571.m 623821.m 624071.m 624321.m 624571.m 624821.m
625071.m 625321.m 625571.m 625821.m 626071.m 626321.m 626571.m
626821.m 627071.m 627321.m 627571.m 627821.m 628071.m

and these y-values (or northings):
6214041.m 6214291.m 6214541.m 6214791.m 6215041.m 6215291.m 6215541.m
6215791.m 6216041.m 6216291.m 6216541.m 6216791.m 6217041.m 6217291.m
6217541.m 6217791.m 6218041.m 6218291.m 6218541.m 6218791.m 6219041.m
6219291.m 6219541.m 6219791.m 6220041.m 6220291.m 6220541.m 6220791.m
6221041.m 6221291.m 6221541.m 6221791.m 6222041.m 6222291.m 6222541.m
6222791.m 6223041.m 6223291.m 6223541.m 6223791.m 6224041.m 6224291.m
6224541.m 6224791.m 6225041.m 6225291.m 6225541.m 6225791.m 6226041.m
6226291.m 6226541.m 6226791.m 6227041.m 6227291.m 6227541.m 6227791.m
6228041.m 6228291.m 6228541.m 6228791.m 6229041.m 6229291.m 6229541.m
6229791.m 6230041.m 6230291.m 6230541.m 6230791.m 6231041.m 6231291.m
6231541.m 6231791.m 6232041.m 6232291.m 6232541.m 6232791.m 6233041.m
6233291.m 6233541.m 6233791.m 6234041.m 6234291.m 6234541.m 6234791.m
6235041.m 6235291.m 6235541.m 6235791.m 6236041.m 6236291.m 6236541.m
6236791.m 6237041.m 6237291.m 6237541.m 6237791.m 6238041.m

METEOROLOGICAL DATA : AUSPLUME METFILE

AVERAGE OVER ALL HOURS AND FOR ALL SOURCES
in microgram/m2

Y (km) \ X (km):	604.071	604.321	604.571	604.821	605.071	605.321
6238.041	1.13E+02	1.16E+02	1.18E+02	1.21E+02	1.23E+02	1.26E+02
6237.791	1.09E+02	1.12E+02	1.15E+02	1.18E+02	1.23E+02	1.26E+02
6237.541	1.07E+02	1.08E+02	1.13E+02	1.18E+02	1.22E+02	1.26E+02
6237.291	1.07E+02	1.09E+02	1.13E+02	1.17E+02	1.22E+02	1.26E+02
6237.041	1.08E+02	1.10E+02	1.14E+02	1.18E+02	1.21E+02	1.26E+02
6236.791	1.09E+02	1.12E+02	1.14E+02	1.18E+02	1.21E+02	1.25E+02
6236.541	1.09E+02	1.13E+02	1.15E+02	1.18E+02	1.22E+02	1.24E+02
6236.291	1.08E+02	1.11E+02	1.15E+02	1.18E+02	1.21E+02	1.24E+02
6236.041	1.06E+02	1.10E+02	1.14E+02	1.18E+02	1.21E+02	1.24E+02
6235.791	1.05E+02	1.09E+02	1.13E+02	1.17E+02	1.20E+02	1.23E+02
6235.541	1.05E+02	1.10E+02	1.14E+02	1.17E+02	1.21E+02	1.23E+02
6235.291	1.05E+02	1.10E+02	1.14E+02	1.18E+02	1.22E+02	1.25E+02
6235.041	1.06E+02	1.11E+02	1.16E+02	1.19E+02	1.23E+02	1.26E+02
6234.791	1.07E+02	1.11E+02	1.17E+02	1.21E+02	1.24E+02	1.27E+02
6234.541	1.08E+02	1.12E+02	1.18E+02	1.22E+02	1.25E+02	1.28E+02
6234.291	1.08E+02	1.12E+02	1.17E+02	1.21E+02	1.25E+02	1.27E+02
6234.041	1.07E+02	1.11E+02	1.15E+02	1.20E+02	1.24E+02	1.27E+02
6233.791	1.05E+02	1.09E+02	1.13E+02	1.18E+02	1.22E+02	1.26E+02
6233.541	1.03E+02	1.08E+02	1.12E+02	1.16E+02	1.20E+02	1.24E+02
6233.291	1.02E+02	1.07E+02	1.11E+02	1.15E+02	1.19E+02	1.23E+02
6233.041	1.01E+02	1.05E+02	1.09E+02	1.14E+02	1.17E+02	1.21E+02
6232.791	9.95E+01	1.04E+02	1.08E+02	1.12E+02	1.16E+02	1.20E+02
6232.541	9.82E+01	1.03E+02	1.06E+02	1.10E+02	1.14E+02	1.18E+02
6232.291	9.72E+01	1.00E+02	1.04E+02	1.08E+02	1.13E+02	1.16E+02
6232.041	9.45E+01	9.85E+01	1.02E+02	1.06E+02	1.10E+02	1.15E+02
6231.791	9.30E+01	9.69E+01	1.00E+02	1.04E+02	1.09E+02	1.14E+02
6231.541	9.09E+01	9.45E+01	9.94E+01	1.04E+02	1.08E+02	1.13E+02
6231.291	9.00E+01	9.44E+01	9.81E+01	1.03E+02	1.07E+02	1.13E+02
6231.041	8.93E+01	9.36E+01	9.82E+01	1.03E+02	1.08E+02	1.14E+02
6230.791	9.06E+01	9.51E+01	9.97E+01	1.05E+02	1.10E+02	1.15E+02
6230.541	9.12E+01	9.57E+01	1.00E+02	1.05E+02	1.11E+02	1.17E+02
6230.291	9.07E+01	9.53E+01	1.01E+02	1.06E+02	1.13E+02	1.19E+02
6230.041	9.21E+01	9.58E+01	1.02E+02	1.08E+02	1.14E+02	1.21E+02
6229.791	9.22E+01	9.72E+01	1.02E+02	1.09E+02	1.16E+02	1.24E+02
6229.541	9.21E+01	9.72E+01	1.03E+02	1.10E+02	1.17E+02	1.24E+02
6229.291	9.29E+01	9.70E+01	1.04E+02	1.10E+02	1.17E+02	1.24E+02
6229.041	9.24E+01	9.77E+01	1.03E+02	1.09E+02	1.17E+02	1.23E+02

6228.791	9.29E+01	9.83E+01	1.04E+02	1.10E+02	1.17E+02	1.22E+02
6228.541	9.33E+01	9.99E+01	1.06E+02	1.12E+02	1.18E+02	1.22E+02
6228.291	9.34E+01	1.00E+02	1.06E+02	1.13E+02	1.18E+02	1.22E+02
6228.041	9.80E+01	1.03E+02	1.09E+02	1.14E+02	1.20E+02	1.23E+02
6227.791	1.03E+02	1.08E+02	1.13E+02	1.17E+02	1.21E+02	1.25E+02
6227.541	1.09E+02	1.14E+02	1.18E+02	1.22E+02	1.24E+02	1.24E+02
6227.291	1.15E+02	1.21E+02	1.23E+02	1.25E+02	1.26E+02	1.25E+02
6227.041	1.23E+02	1.27E+02	1.30E+02	1.30E+02	1.29E+02	1.27E+02
6226.791	1.31E+02	1.36E+02	1.36E+02	1.36E+02	1.34E+02	1.31E+02
6226.541	1.37E+02	1.40E+02	1.40E+02	1.38E+02	1.37E+02	1.32E+02
6226.291	1.41E+02	1.42E+02	1.43E+02	1.41E+02	1.37E+02	1.32E+02
6226.041	1.44E+02	1.45E+02	1.46E+02	1.44E+02	1.39E+02	1.33E+02
6225.791	1.45E+02	1.47E+02	1.47E+02	1.45E+02	1.40E+02	1.34E+02
6225.541	1.44E+02	1.46E+02	1.46E+02	1.43E+02	1.39E+02	1.32E+02
6225.291	1.44E+02	1.44E+02	1.43E+02	1.40E+02	1.36E+02	1.29E+02
6225.041	1.42E+02	1.41E+02	1.40E+02	1.38E+02	1.34E+02	1.25E+02
6224.791	1.39E+02	1.38E+02	1.37E+02	1.33E+02	1.29E+02	1.23E+02
6224.541	1.36E+02	1.34E+02	1.32E+02	1.30E+02	1.26E+02	1.20E+02
6224.291	1.30E+02	1.29E+02	1.29E+02	1.26E+02	1.24E+02	1.19E+02
6224.041	1.24E+02	1.25E+02	1.24E+02	1.23E+02	1.21E+02	1.18E+02
6223.791	1.18E+02	1.21E+02	1.20E+02	1.20E+02	1.18E+02	1.15E+02
6223.541	1.14E+02	1.16E+02	1.17E+02	1.16E+02	1.14E+02	1.12E+02
6223.291	1.11E+02	1.14E+02	1.15E+02	1.13E+02	1.12E+02	1.10E+02
6223.041	1.08E+02	1.10E+02	1.12E+02	1.12E+02	1.12E+02	1.09E+02
6222.791	1.05E+02	1.10E+02	1.11E+02	1.11E+02	1.12E+02	1.11E+02
6222.541	1.02E+02	1.07E+02	1.09E+02	1.11E+02	1.12E+02	1.13E+02
6222.291	9.53E+01	9.59E+01	1.05E+02	1.11E+02	1.15E+02	1.16E+02
6222.041	9.52E+01	9.83E+01	1.07E+02	1.14E+02	1.17E+02	1.19E+02
6221.791	9.59E+01	1.00E+02	1.09E+02	1.17E+02	1.17E+02	1.19E+02
6221.541	9.49E+01	1.01E+02	1.05E+02	1.07E+02	1.09E+02	1.14E+02
6221.291	9.31E+01	9.55E+01	9.80E+01	1.01E+02	1.03E+02	1.08E+02
6221.041	9.55E+01	9.90E+01	1.01E+02	1.04E+02	1.07E+02	1.09E+02
6220.791	9.86E+01	1.02E+02	1.04E+02	1.07E+02	1.09E+02	1.12E+02
6220.541	9.91E+01	1.04E+02	1.06E+02	1.08E+02	1.12E+02	1.14E+02
6220.291	1.00E+02	1.03E+02	1.06E+02	1.08E+02	1.10E+02	1.11E+02
6220.041	1.00E+02	1.03E+02	1.05E+02	1.07E+02	1.08E+02	1.08E+02
6219.791	9.96E+01	1.03E+02	1.05E+02	1.07E+02	1.09E+02	1.10E+02
6219.541	1.01E+02	1.03E+02	1.05E+02	1.07E+02	1.10E+02	1.14E+02
6219.291	1.07E+02	1.05E+02	1.07E+02	1.09E+02	1.13E+02	1.16E+02
6219.041	1.13E+02	1.12E+02	1.14E+02	1.21E+02	1.22E+02	1.24E+02
6218.791	1.16E+02	1.17E+02	1.20E+02	1.25E+02	1.27E+02	1.28E+02
6218.541	1.18E+02	1.20E+02	1.23E+02	1.27E+02	1.30E+02	1.32E+02
6218.291	1.20E+02	1.22E+02	1.25E+02	1.29E+02	1.32E+02	1.34E+02
6218.041	1.21E+02	1.24E+02	1.27E+02	1.31E+02	1.35E+02	1.37E+02
6217.791	1.23E+02	1.26E+02	1.29E+02	1.32E+02	1.36E+02	1.39E+02
6217.541	1.25E+02	1.28E+02	1.31E+02	1.35E+02	1.38E+02	1.42E+02
6217.291	1.27E+02	1.30E+02	1.33E+02	1.37E+02	1.41E+02	1.45E+02
6217.041	1.29E+02	1.34E+02	1.37E+02	1.41E+02	1.43E+02	1.47E+02
6216.791	1.32E+02	1.36E+02	1.41E+02	1.43E+02	1.47E+02	1.50E+02
6216.541	1.36E+02	1.39E+02	1.46E+02	1.50E+02	1.54E+02	1.54E+02
6216.291	1.38E+02	1.43E+02	1.48E+02	1.52E+02	1.56E+02	1.59E+02
6216.041	1.40E+02	1.45E+02	1.50E+02	1.54E+02	1.58E+02	1.61E+02
6215.791	1.43E+02	1.48E+02	1.54E+02	1.56E+02	1.62E+02	1.66E+02
6215.541	1.47E+02	1.52E+02	1.57E+02	1.61E+02	1.67E+02	1.71E+02
6215.291	1.50E+02	1.55E+02	1.60E+02	1.66E+02	1.70E+02	1.76E+02
6215.041	1.54E+02	1.58E+02	1.63E+02	1.69E+02	1.75E+02	1.80E+02
6214.791	1.56E+02	1.61E+02	1.66E+02	1.72E+02	1.78E+02	1.83E+02
6214.541	1.59E+02	1.62E+02	1.68E+02	1.74E+02	1.80E+02	1.85E+02
6214.291	1.60E+02	1.64E+02	1.69E+02	1.75E+02	1.82E+02	1.87E+02
6214.041	1.61E+02	1.65E+02	1.71E+02	1.77E+02	1.82E+02	1.89E+02

Y (km) \ X (km):	605.571	605.821	606.071	606.321	606.571	606.821
6238.041	1.28E+02	1.32E+02	1.35E+02	1.36E+02	1.37E+02	1.41E+02
6237.791	1.29E+02	1.34E+02	1.38E+02	1.38E+02	1.39E+02	1.44E+02
6237.541	1.31E+02	1.36E+02	1.41E+02	1.40E+02	1.41E+02	1.43E+02
6237.291	1.30E+02	1.35E+02	1.39E+02	1.39E+02	1.42E+02	1.46E+02
6237.041	1.30E+02	1.34E+02	1.37E+02	1.39E+02	1.42E+02	1.47E+02
6236.791	1.28E+02	1.32E+02	1.35E+02	1.38E+02	1.42E+02	1.47E+02
6236.541	1.28E+02	1.31E+02	1.34E+02	1.36E+02	1.41E+02	1.47E+02
6236.291	1.27E+02	1.30E+02	1.32E+02	1.35E+02	1.41E+02	1.48E+02

IPRA Buronga PAH Inhalation Calculations - Based upon emission rates for a 17MW distillate oil-fired gas turbine from "Exhaust Emissions from High Speed Passenger Ferries" * - D.A.Cooper (2001)

Annual 1g/s/turbine Concentration: **0.09** µg/m³ - Ausplume 1g/s/turbine worst point on 24 x 24km (250m Resolution) grid: three turbines running all hours with plume reduced to 200deg.C and 18m/s, dry deposition TAPM meteorology with assimilation of wind data from Mildura Airport for the year 2005, Particle density of elemental carbon, Particle size distribution from USEPA-AP42 Distillate fired turbines (1998)

Frame 6 turbine flow rate: **97** Nm³/s (dry) - Based on 141kg/s mass flow rate,12% exhaust moisture content, standard air assumptions

Species	Whole Voyage* (µg/Nm³,dry)	Manouevreing* (µg/Nm³,dry)	MAX (µg/Nm³,dry)	Emission Rate (mg/s)	Annual Average Ambient Conc. (µg/m³)
Naphthalene	11	11	11	1.07	9.60E-05
2-Methyl-Naphthalene	7.3	7.5	7.5	0.73	6.55E-05
1-Methyl-Naphthalene	4.7	5.1	5.1	0.49	4.45E-05
Biphenyl	1.4	1.4	1.4	0.14	1.22E-05
2,6-Dimethyl-naphthalene	1.1	1.1	1.1	0.11	9.60E-06
Acenaphtylene	0.9	0.6	0.9	0.09	7.86E-06
Acenaphtene	0.5	0.5	0.5	0.05	4.37E-06
2,3,5-Trimethyl-naphthalene	0.8	0.8	0.8	0.08	6.98E-06
Fluorene	1.2	1.1	1.2	0.12	1.05E-05
Phenanthrene	6.3	6.4	6.4	0.62	5.59E-05
Anthracene	0.4	0.1	0.4	0.04	3.49E-06
1-Methyl-phenanthrene	4.4	4.3	4.4	0.43	3.84E-05
Fluoranthene	0.4	0.4	0.4	0.04	3.49E-06
Pyrene	0.6	0.8	0.8	0.08	6.98E-06
Benz(a)anthracene	0.1	0.1	0.1	0.01	8.73E-07
Chrysene	0.5	0.7	0.7	0.07	6.11E-06
Benzo(b)fluoranthene	0.04	0.04	0.04	0.00	3.49E-07
Benzo(k)fluoranthene	0.04	0.04	0.04	0.00	3.49E-07
Benzo(e)pyrene	0.04	0.09	0.09	0.01	7.86E-07
Benzo(a)pyrene	0.04	0.09	0.09	0.01	7.86E-07
Perylene	0.07	0.09	0.09	0.01	7.86E-07
Indeno(1,2,3-c,d)pyrene	0.07	0.09	0.09	0.01	7.86E-07
Dibenzo(a,h)anthracene	0.07	0.09	0.09	0.01	7.86E-07
Benzo(g,h,i)perylene	0.07	0.09	0.09	0.01	7.86E-07
			TOTAL:	**4.20**	**3.78E-04**

shaded indicates below detection limit

IPRA Buronga PAH Deposition Calculations - Based upon emission rates for a 17MW distillate oil-fired gas turbine from "Exhaust Emissions from High Speed Passenger Ferries" * - D.A.Cooper (2001)

Annual 1g/s/turbine Deposition: **1128** μg/m²/year - Ausplume 1g/s/turbine worst point on 24 x 24km (250m Resolution) grid: three turbines running all hours with plume reduced to 200deg.C and 18m/s, dry deposition TAPM meteorology with assimilation of wind data from Mildura Airport for the year 2005, Particle density of elemental carbon, Particle size distribution from USEPA-AP42 Distillate fired turbines (1998)

Frame 6 turbine flow rate: **97** Nm³/s (dry) - Based on 141kg/s mass flow rate,12% exhaust moisture content, standard air assumptions

Species	Whole Voyage* (μg/Nm³,dry)	Manouevreing* (μg/Nm³,dry)	MAX (μg/Nm³,dry)	Emission Rate (mg/s)	Annual Deposition (μg/m²/year)
Naphthalene	11	11	11	1.07	1.2E+00
2-Methyl-Naphthalene	7.3	7.5	7.5	0.73	8.2E-01
1-Methyl-Naphthalene	4.7	5.1	5.1	0.49	5.6E-01
Biphenyl	1.4	1.4	1.4	0.14	1.5E-01
2,6-Dimethyl-naphthalene	1.1	1.1	1.1	0.11	1.2E-01
Acenaphtylene	0.9	0.6	0.9	0.09	9.8E-02
Acenaphtene	0.5	0.5	0.5	0.05	5.5E-02
2,3,5-Trimethyl-naphthalene	0.8	0.8	0.8	0.08	8.8E-02
Fluorene	1.2	1.1	1.2	0.12	1.3E-01
Phenanthrene	6.3	6.4	6.4	0.62	7.0E-01
Anthracene	0.4	0.1	0.4	0.04	4.4E-02
1-Methyl-phenanthrene	4.4	4.3	4.4	0.43	4.8E-01
Fluoranthene	0.4	0.4	0.4	0.04	4.4E-02
Pyrene	0.6	0.8	0.8	0.08	8.8E-02
Benz(a)anthracene	0.1	0.1	0.1	0.01	1.1E-02
Chrysene	0.5	0.7	0.7	0.07	7.7E-02
Benzo(b)fluoranthene	0.04	0.04	0.04	0.00	4.4E-03
Benzo(k)fluoranthene	0.04	0.04	0.04	0.00	4.4E-03
Benzo(e)pyrene	0.04	0.09	0.09	0.01	9.8E-03
Benzo(a)pyrene	0.04	0.09	0.09	0.01	9.8E-03
Perylene	0.07	0.09	0.09	0.01	9.8E-03
Indeno(1,2,3-c,d)pyrene	0.07	0.09	0.09	0.01	9.8E-03
Dibenzo(a,h)anthracene	0.07	0.09	0.09	0.01	9.8E-03
Benzo(g,h,i)perylene	0.07	0.09	0.09	0.01	9.8E-03
			TOTAL:	**4.20**	**4.74**

shaded indicates below detection limit

Appendix E Ausplume Assessment

Appendix E Worst Case Ausplume Assessment

E.1 Evaluation of Worst Case Impacts using Ausplume

A screening study of potential impacts from the proposed Buronga Peaking Power Plant has been performed using the Victorian EPA's (EPAV) regulatory dispersion model Ausplume. This screening validation has been performed in order to evaluate the scale of the TAPM predictions against Ausplume predictions when running both worst case synthetic meteorology, and TAPM generated meteorology. In performing this analysis, both the dispersion and meteorological components of TAPM have been evaluated against Ausplume.

Given that ground level concentrations associated with emissions of oxides of nitrogen (NO_X) and particulate matter are of interest, the assessment looked at peak impacts for these species.

The following scenarios were modelled and the modelling parameters are further discussed in the subsequent sections:

- 1 hour NO_x using Ausplume with TAPM meteorology;
- 1 hour NO_x using Ausplume with standard metsamp;
- 1 hour NO_x using Ausplume with optimised metsamp; and
- 24 hour PM_{10} using Ausplume with TAPM meteorology.

Both the Ausplume and TAPM assessments have assumed that pollutants are conserved in the atmosphere. Therefore the predicted impacts of two different pollutants for a particular averaging time are directly proportional to their relative emission rates.

Hence, this appendix also validates the Air Quality Assessment, (which used TAPM), for all other chemical species with 1 hour and 24 hour regulatory criteria. 10 and 15 minute impacts are also validated by this study, as they are scaled from the 1 hour impacts.

E.2 The Metsamp Meteorological Data File

For analysis of NO_X, Ausplume was run using the Metsamp screening meteorological data file. This file contains a range of permutations of meteorological parameters. With reference to Metsamp, the Victorian EPA Ausplume guidance material states:

"Licence applications may only require that predicted pollution levels be less than some threshold under all conceivable meteorological conditions. Because of the conservative assumptions involved, the use of an artificial screening file is often sufficient to ensure that regulatory requirements are met."

(EPAV,2004[1])

In this case however, the Ausplume screening procedure has been used to augment the comprehensive TAPM study included in the main report. It should be noted that metsamp is consists of synthetic hourly meteorological parameters, and is not suitable for the calculation of impacts for periods greater than one hour. Hence in this appendix, TAPM generated meteorology has been used in Ausplume to assess the peak impact for particulate matter.

[1] EPA Victoria, June 2004, *AUSPLUME Gaussian Dispersion Model – Technical User Manual*

Appendix E Worst Case Ausplume Assessment

The Metsamp screening file contains meteorological data for a single wind direction, hence the file was configured to contain the standard Metsamp data at 5° increments in wind direction. This in turn allows terrain effects to be incorporated into the model, resulting in over 19,000 hour cases of synthetic meteorology.

Once worst case parameters were identified (using Metsamp in this form), the file was further refined to investigate sensitivity to other parameters, beyond the range and resolution of the standard Metsamp file. The parameters investigated were wind speed, ambient temperature and wind direction.

E.3 Model Configuration

Ausplume was run using the following settings. Default parameters were used elsewhere:

- 97 x 97 gridded receptors, at 250m resolution
- Terrain Effects were incorporated using the 'Egan Half Height' option with terrain data sourced from the TAPM 9 arc-second terrain database;
- Pasquill Gifford dispersion coefficients were used for both horizontal and vertical dispersion;
- Irwin Rural wind profile exponents were used;
- The 'Adjust PG curves for roughness' option was selected;
- A roughness height of 0.2m was used;
- The 'Enhance Plume for Buoyancy' option was selected;
- Both the 'Gradual Plume Rise' and 'Partial Penetration of Elevated inversions' options were trialled;
- Stack parameters, emission rates and locations were input as detailed in the main report, with the exception of neglecting buoyancy enhancement due to plume merging. The modelling was performed for a stack height of 13m, which represents the worst case for steady state models.

These details are also contained in the Ausplume output file which is included in **Attachment A**.

E.4 Worst Case Impacts

Table 1 shows the results of the scenarios modelled. As presented, Ausplume using worst-case optimised synthetic meteorological data has produced a lower peak impact than that predicted by TAPM.

Table 1 – Worst Case Impacts

Modelling Scenario	Predicted Worst Case Impact (µg/m³)	Percent of Maximum Prediction
Peak 1 hour Oxides of Nitrogen Impact (All NO_x as NO_2)		
TAPM (as presented in main report)	67.6	100
Ausplume using TAPM Meteorology	26.0	38
Ausplume using standard Metsamp (at 325°)	44.3	67
Ausplume using optimised Metsamp	46.5	69
Peak 24 hour PM_{10} Impact		
TAPM (as presented in main report)	1.4	100
Ausplume (using TAPM Meteorology)	0.75	54

Appendix E Worst Case Ausplume Assessment

E.5 Worst Case Model Meteorology

This section details the influence of various meteorological parameters in producing the worst case 1 hour impact, which are presented in **Table 2**.

Table 2 – Worst Case Model Meteorology

Parameter	Value
Temperature	47deg.C
Wind Speed	20m/s
Wind Direction	326
Stability Class	D
Mixing Height	-

Temperature

The worst case impact was largely insensitive to changes in ambient temperature. The model was run using Metsamp at approximately 10°C increments across the temperature range experienced for the region. An increase of NO_X from 42.1 µg/m³ to 46.5 µg/m³ occurred over the -4°C to 47°C temperature range recorded in the area, with the peak being recorded at an ambient temperature of 47°C.

Wind Speed

The predicted impact was found to increase with wind speed. Due to the lack of terrain features in the surrounding region, the peak impact is primarily a result of rapid entrainment of ambient air, which cools the plume (reducing the effects of buoyancy) and allowing it to ground sooner. Metsamp includes a maximum hourly averaged windspeed of 20m/s. This is an extremely high wind speed, and is greater than the maximum hourly averaged wind speed of 15m/s observed at Mildura in the period 2000-2005 inclusive. The use of this wind speed is the premise for the TAPM predicted meteorology producing a lower impact (in Ausplume), where the greatest wind speed for 2005 was predicted to be 10.8m/s.

Stability Class

The worst case impacts occurred under the Pasquill Gifford stability class D, which is representative of "neutral" conditions. Whilst stability classes E and F are associated with poorer plume dispersion than stability class D, the mechanical turbulence associated with high wind speeds (which are required to bring the plume down close to the plant) is incongruous with the meteorological conditions under which E and F stabilities are found to occur. Hence, of the stability classes under which high wind speeds can occur, (as required to bring the plume down close to the plant), stability class D features the poorest dispersion.

Mixing Height

The worst case impact occurred irrespective of mixing height, as the peak impact was found to occur near to the plant. In this case vertical transport of the plume was not significant enough for the mixing height would form a restriction on the plume.

Plume Rise Option

The worst case impact was also found to occur irrespective of whether or not the *'Partial Penetration of Elevated Inversions option'* is selected. This is as expected, given that the plume is not present at the mixing height for this near plant impact.

Appendix E Worst Case Ausplume Assessment

E.6 Conclusion

The results of this screening study indicate that the TAPM methodology is conservative against worst-case Ausplume predictions.

In conjunction with the extremely conservative nature of the TAPM assessment, which has assessed NO_2 using peak background / peak impact / operation all hours / all NO_x as NO_2 and has also assessed PM_{10} under 24 hour constant operation of all three turbines, this validation assessment implies with a high level of confidence that air impact assessment criteria will not be breached by the proposed plant.

Appendix E Worst Case Ausplume Assessment

Attachment A: Ausplume Output File

1

IPRA Buronga Worst Case Ausplume Assessment

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	0.300 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	0.200m
Adjustment for wind directional shear	None

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	Stability Class					
Category	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
24 hours

1

IPRA Buronga Worst Case Ausplume Assessment

SOURCE CHARACTERISTICS

STACK SOURCE: 1

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
616340	6225879	50m	13m	4.00m	541C	26.0m/s

No building wake effects.
(Constant) emission rate = 1.50E+01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: 2

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
616363	6225850	50m	13m	4.00m	541C	26.0m/s

No building wake effects.
(Constant) emission rate = 1.50E+01 grams/second
No gravitational settling or scavenging.

STACK SOURCE: 3

X(m)	Y(m)	Ground Elev.	Stack Height	Diameter	Temperature	Speed
616387	6225821	50m	13m	4.00m	541C	26.0m/s

No building wake effects.
(Constant) emission rate = 1.50E+01 grams/second
No gravitational settling or scavenging.

1

IPRA Buronga Worst Case Ausplume Assessment

RECEPTOR LOCATIONS

The Cartesian receptor grid has the following x-values (or eastings):

604071.m	604321.m	604571.m	604821.m	605071.m	605321.m	605571.m
605821.m	606071.m	606321.m	606571.m	606821.m	607071.m	607321.m
607571.m	607821.m	608071.m	608321.m	608571.m	608821.m	609071.m
609321.m	609571.m	609821.m	610071.m	610321.m	610571.m	610821.m
611071.m	611321.m	611571.m	611821.m	612071.m	612321.m	612571.m
612821.m	613071.m	613321.m	613571.m	613821.m	614071.m	614321.m
614571.m	614821.m	615071.m	615321.m	615571.m	615821.m	616071.m
616321.m	616571.m	616821.m	617071.m	617321.m	617571.m	617821.m
618071.m	618321.m	618571.m	618821.m	619071.m	619321.m	619571.m
619821.m	620071.m	620321.m	620571.m	620821.m	621071.m	621321.m
621571.m	621821.m	622071.m	622321.m	622571.m	622821.m	623071.m
623321.m	623571.m	623821.m	624071.m	624321.m	624571.m	624821.m
625071.m	625321.m	625571.m	625821.m	626071.m	626321.m	626571.m
626821.m	627071.m	627321.m	627571.m	627821.m	628071.m	

and these y-values (or northings):

6214041.m	6214291.m	6214541.m	6214791.m	6215041.m	6215291.m	6215541.m
6215791.m	6216041.m	6216291.m	6216541.m	6216791.m	6217041.m	6217291.m
6217541.m	6217791.m	6218041.m	6218291.m	6218541.m	6218791.m	6219041.m
6219291.m	6219541.m	6219791.m	6220041.m	6220291.m	6220541.m	6220791.m
6221041.m	6221291.m	6221541.m	6221791.m	6222041.m	6222291.m	6222541.m
6222791.m	6223041.m	6223291.m	6223541.m	6223791.m	6224041.m	6224291.m
6224541.m	6224791.m	6225041.m	6225291.m	6225541.m	6225791.m	6226041.m
6226291.m	6226541.m	6226791.m	6227041.m	6227291.m	6227541.m	6227791.m
6228041.m	6228291.m	6228541.m	6228791.m	6229041.m	6229291.m	6229541.m
6229791.m	6230041.m	6230291.m	6230541.m	6230791.m	6231041.m	6231291.m
6231541.m	6231791.m	6232041.m	6232291.m	6232541.m	6232791.m	6233041.m
6233291.m	6233541.m	6233791.m	6234041.m	6234291.m	6234541.m	6234791.m
6235041.m	6235291.m	6235541.m	6235791.m	6236041.m	6236291.m	6236541.m
6236791.m	6237041.m	6237291.m	6237541.m	6237791.m	6238041.m	

METEOROLOGICAL DATA : "METSAMP" test meteorological file

1 Peak values for the 100 worst cases (in microgram/m3)
Averaging time = 1 hour

Rank	Value	Time Recorded hour,date	Coordinates (* denotes polar)
1	4.65E+01	06,02/01/00	(616571, 6225541, 0.0)
2	4.65E+01	07,02/01/00	(616571, 6225541, 0.0)
3	4.65E+01	08,02/01/00	(616571, 6225541, 0.0)
4	4.65E+01	09,02/01/00	(616571, 6225541, 0.0)
5	4.65E+01	10,02/01/00	(616571, 6225541, 0.0)
6	4.65E+01	10,04/01/00	(616571, 6225541, 0.0)
7	4.65E+01	20,05/01/00	(616571, 6225541, 0.0)
8	4.65E+01	06,07/01/00	(616571, 6225541, 0.0)
9	4.65E+01	16,08/01/00	(616571, 6225541, 0.0)
10	4.65E+01	02,10/01/00	(616571, 6225541, 0.0)
11	4.65E+01	12,11/01/00	(616571, 6225541, 0.0)
12	4.65E+01	24,11/01/00	(616571, 6225541, 0.0)
13	4.65E+01	05,02/01/00	(616571, 6225541, 0.0)
14	2.45E+01	09,04/01/00	(616571, 6225541, 0.0)
15	2.45E+01	19,05/01/00	(616571, 6225541, 0.0)
16	2.45E+01	05,07/01/00	(616571, 6225541, 0.0)
17	2.45E+01	15,08/01/00	(616571, 6225541, 0.0)
18	2.45E+01	01,10/01/00	(616571, 6225541, 0.0)
19	2.45E+01	11,11/01/00	(616571, 6225541, 0.0)
20	2.45E+01	23,11/01/00	(616571, 6225541, 0.0)
21	2.35E+01	11,07/01/00	(616821, 6225291, 0.0)
22	2.16E+01	12,07/01/00	(616821, 6225041, 0.0)
23	1.80E+01	20,08/01/00	(617071, 6225041, 0.0)
24	1.70E+01	22,08/01/00	(616821, 6225291, 0.0)
25	1.69E+01	08,10/01/00	(616821, 6225291, 0.0)
26	1.65E+01	19,02/01/00	(616571, 6225541, 0.0)
27	1.54E+01	21,08/01/00	(616821, 6225041, 0.0)
28	1.50E+01	09,06/01/00	(617071, 6225041, 0.0)
29	1.50E+01	05,10/01/00	(617071, 6225041, 0.0)
30	1.50E+01	07,10/01/00	(616821, 6225291, 0.0)
31	1.36E+01	11,02/01/00	(624321, 6214041, 0.0)
32	1.30E+01	20,02/01/00	(624321, 6214041, 0.0)
33	1.30E+01	21,02/01/00	(624321, 6214041, 0.0)
34	1.30E+01	12,02/01/00	(624321, 6214041, 0.0)
35	1.28E+01	05,05/01/00	(616821, 6225041, 0.0)
36	1.28E+01	22,02/01/00	(624321, 6214041, 0.0)
37	1.25E+01	23,02/01/00	(624321, 6214041, 0.0)
38	1.23E+01	06,10/01/00	(617071, 6225041, 0.0)
39	1.22E+01	24,02/01/00	(624321, 6214041, 0.0)
40	1.20E+01	13,02/01/00	(624321, 6214041, 0.0)
41	1.17E+01	08,04/01/00	(616571, 6225541, 0.0)
42	1.17E+01	18,05/01/00	(616571, 6225541, 0.0)
43	1.17E+01	04,07/01/00	(616571, 6225541, 0.0)
44	1.17E+01	14,08/01/00	(616571, 6225541, 0.0)
45	1.17E+01	24,09/01/00	(616571, 6225541, 0.0)
46	1.17E+01	10,11/01/00	(616571, 6225541, 0.0)
47	1.17E+01	22,11/01/00	(616571, 6225541, 0.0)
48	1.15E+01	14,02/01/00	(622321, 6217041, 0.0)
49	1.10E+01	15,02/01/00	(618821, 6222041, 0.0)
50	1.09E+01	16,02/01/00	(618821, 6222041, 0.0)
51	1.07E+01	17,02/01/00	(618821, 6222041, 0.0)
52	1.05E+01	18,02/01/00	(618821, 6222041, 0.0)
53	1.00E+01	19,07/01/00	(616821, 6225291, 0.0)
54	1.00E+01	05,09/01/00	(616821, 6225291, 0.0)
55	1.00E+01	15,10/01/00	(616821, 6225291, 0.0)
56	9.88E+00	15,06/01/00	(617821, 6223791, 0.0)
57	9.50E+00	23,04/01/00	(616821, 6225541, 0.0)
58	8.91E+00	02,06/01/00	(616571, 6225541, 0.0)
59	8.75E+00	07,04/01/00	(617071, 6224791, 0.0)
60	8.74E+00	18,07/01/00	(617571, 6224041, 0.0)
61	8.33E+00	08,06/01/00	(616821, 6225291, 0.0)
62	8.11E+00	01,08/01/00	(616821, 6225291, 0.0)

Appendix F Stack Emission Calculations

Appendix F Stack Emission Calculations

NO2 Emissions (all Nox as NO2)

Exhaust mass flow rate[1]	141	kg/s
Exhaust oxygen content	14	% vol
Exhaust moisture content	12	% vol
Exhaust volumetric flow rate[2]	109.0	Nm^3/sec
	96.0	Nm^3/sec (dry)
Manufacturer's guarantee[3]	65	ppm,dry,15%O2
In-stack concentration	133.3	mg/Nm^3,dry,15%O2
	155.8	mg/Nm^3,dry,stackO2
Emission rate	**15.0**	g/s

[1]GE Energy Brochure, *"Gas Turbine and Combined Cycle Products"*
[2]Assuming exhaust M.W. is equal to that of dry air which has a density of 1.293kg/m^3 at NTP
[3]Supplied by IPRA

SO2 Emissions (all SOx as SO2)

Fuel Consumption[1]	15.3	Tonne/hr
	4.25	kg/sec
Fuel-bound Sulphur Content[2]	50	mg/kg
Sulphur emission rate	0.21	g/s
Sulphur dioxide emission rate[3]	**0.42**	g/s

[1]Supplied by IPRA - updated information has indicated peak fuel consumption to be 11.0 Tonne/hr, hence calculated emission rate is considered conservative
[2]Upper Limit as specified in Standard (Automotive Diesel) Determination 2001
[3]Assuming all fuel bound sulphur is oxidised to sulphur dioxide

Appendix F Stack Emission Calculations

Hazardous Air Pollutants (all values in HHV)

Fuel Consumption[1]	15.3	Tonne/hr
	4.25	kg/sec
Energy density of fuel[2]	45.6	MJ/kg (HHV)
Energy Input	193.8	MW (HHV)
	0.184	MMBtu/sec (HHV)

Emission Factors[3]		**lb/MMBtu (HHV)**	**Emission Rates**	
Benzene		5.50E-05	4.58E-03	g/s
Formaldehyde		2.80E-04	2.33E-02	g/s
PAH		4.00E-05	3.33E-03	g/s
Arsenic	<	1.10E-05	9.17E-04	g/s
Beryllium	<	3.10E-07	2.58E-05	g/s
Cadmium		4.80E-06	4.00E-04	g/s
Chromium (total)		1.10E-05	9.17E-04	g/s
Lead		1.40E-05	1.17E-03	g/s
Manganese		7.90E-04	6.58E-02	g/s
Mercury		1.20E-06	1.00E-04	g/s
Nickel	<	4.60E-06	3.83E-04	g/s

[1]Supplied by IPRA - updated information has indicated peak fuel consumption to be 11.0 Tonne/hr, hence calculated emission rates are considered conservative

[2]ABARE/ Australia Government Department of Industry Tourism and Resources, *energy in australia 2006*

[3]USEPA, 1995, AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources
-Total chromium divided into Chromium III to Chromium VI at ratio of 3.3:1.4, as suggested in DEH (2005)

Appendix G TAPM Peak Impact Analysis

Appendix G TAPM Peak Impact Analysis

G.1 Introduction

This section contains a brief discussion of atmospheric mechanisms under which TAPM has predicted the peak hourly impact of the year. Higher short term (1 hour and less) impacts were predicted for a 20m stack as compared to the 13m stack. Given the counter-intuitive nature of this prediction, further investigation into this result was made.

G.2 Analysis

The peak impact has occurred under complex meteorological conditions, where the atmosphere is highly stratified, with the cumulative effect of plant emissions over several hours contributing to the peak impact during the breakup of the ground based inversion.

The peak was found to occur during the 12th hour of the day (using hour ending convention, i.e. 11am-12pm - hereafter referred to as 12pm) on 13/05/05. A strong ground based inversion has restricted plume rise, whilst low wind speeds coupled with wind shear, and changes in wind direction (with time) have restricted advection and promoted circulation of plant emissions.

The atmospheric conditions leading up the peak impact are discussed in the following sections.

Wind Speed

At the time of the peak impact, TAPM has predicted low wind speeds at a range of levels in the atmosphere. As can be seen in **Figure G-1**, near-zero upper air wind speeds extending up to approximately 500m elevation were present in the hours before the peak occurred. The 9am wind speed profile is consistent with available wind finding radar data collected during this time at Mildura Airport[1]. At 9am a wind speed of 2.0m/s was recorded at 600m and 3.0m/s at 900m. Wind speeds of 1.5m/s at 600m and 2.0m/s at 900m were also reported in the 3am wind finding data further indicating the presence of low wind speeds at height during the day. The wind finding data does not include any measurements below 600m.

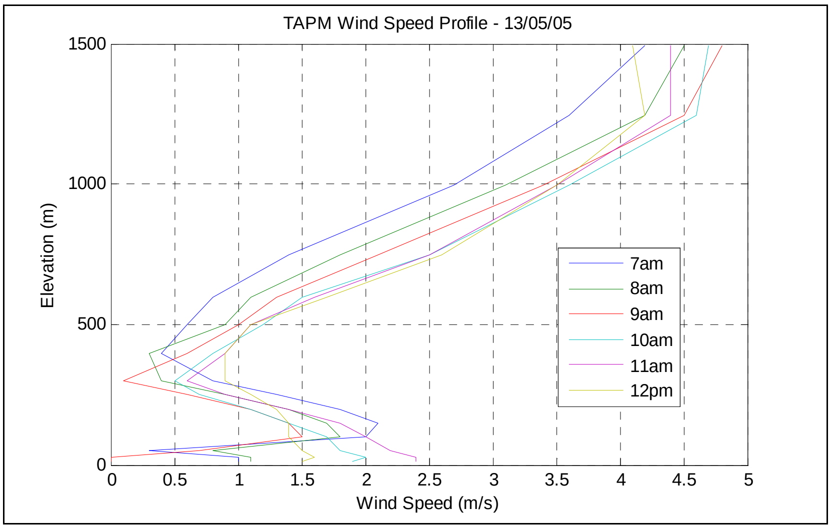


Figure G-1 TAPM wind speed profile during worst case impact

[1] Sourced from http://www.ncdc.noaa.gov/oa/climate/igra/index.php

Appendix G TAPM Peak Impact Analysis

Temperature

Figure G-2 shows the ambient temperature profile for the hours before the peak occurred. During the earlier hours, a strong ground-based inversion is responsible for suppressing the plume rise, which in conjunction with low wind speeds retains the pollutants in the region.

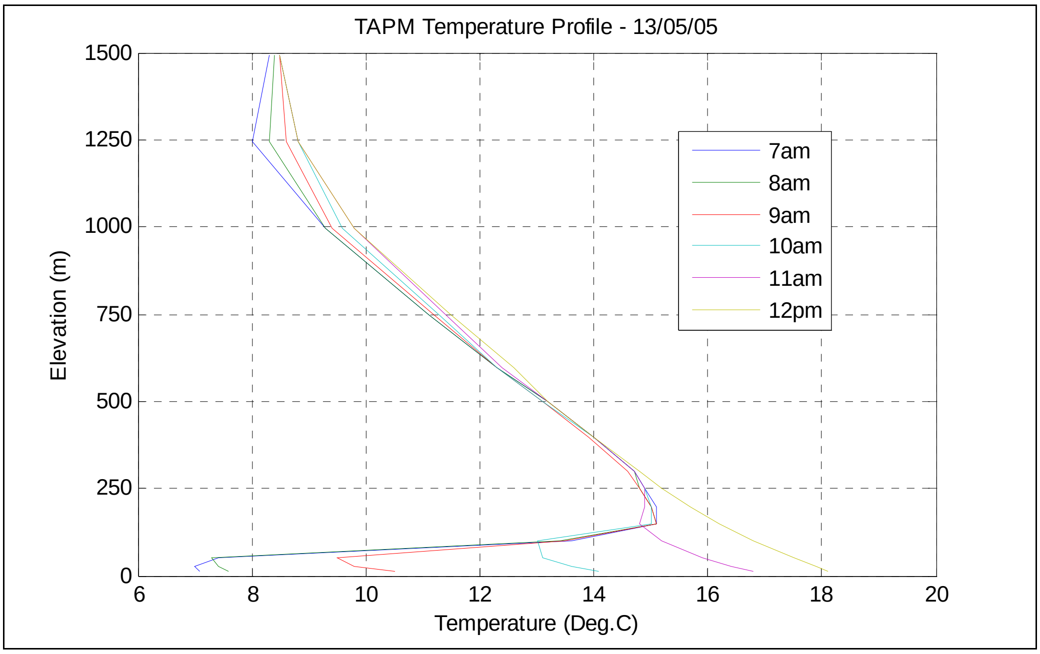


Figure G-2 TAPM temperature profile during worst case 1 hour impact

Plume Rise

Table G.1 shows the final plume (centreline) height for the period. A comparison between 9am and 10am results indicates that despite the presence of a stronger inversion at 9am, the 9am plume has risen further than the 10am plume. This is due to the predicted wind speeds at the surface (which are based on data assimilation from Mildura Airport AWS), where at 10am, the higher surface wind speeds mean that air is entrained into the plume more rapidly, suppressing the plume rise to a greater extent. Most importantly, **Table G-1** in conjunction with **Figure G-1** support reasoning as to why the impacts are higher from the higher (20m) stack, as the higher stack has allowed the plume to rise further, into a more stagnant level of the atmosphere.

Table G-1 Final plume height

Time	Final Plume height (m)	
	13m	20m
7am	258	284
8am	230	269
9am	357	423
10am	275	301
11am	391	428
12pm	672	693

Appendix G TAPM Peak Impact Analysis

Wind Direction

Figure G-3 shows the strong wind shear present, indicating stratification of the atmosphere associated with cooling in the surface layer overnight. In the case of wind shear under light winds, plume trajectories are heavily affected by the level of plume rise. This is considered to be the primary mechanism for the counter-intuitive prediction, where a higher stack has produced a marginally higher impact, in a marginally different location (as detailed in the contour plots included prior to this appendix). In this case, strong wind shear in the vicinity of the plume centreline (300m as detailed in **Table G-1**) during 10am has modified the trajectory of the 20m plume relative to the 13m plume.

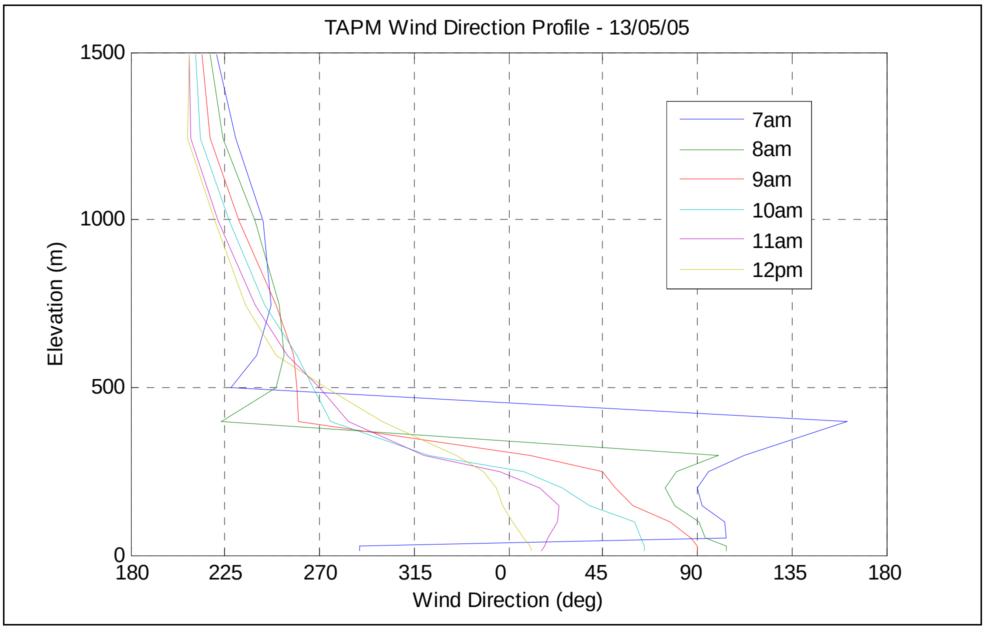


Figure G-3 TAPM wind direction profile during worst case 1 hour impact

Hourly Contribution of Emissions at Peak Impact Location

Table G-2 contains the results for a TAPM simulation which began on the previous day (12/05/05). The run was configured for 20m stacks, with unity emissions (1 g/s) occurring for separate tracers for each of the separate hours, 9am through to 12pm, on the 13/05/05. The data indicates that the peak concentration was heavily dependent on plant emissions from previous hours, (which is a mechanism that steady state models are not able to replicate). For this model run, 75% of the peak impact is attributable to material released two hours earlier, under a strong inversion and low wind speeds, where vertical diffusion through inversion breakup has permitted transport of contaminants to ground level.

Table G-2 Contribution of plant emissions at peak impact location by hour

Hour of Day	Concentration at Peak Location (µg/m³)				
	Material Emitted during 9am	Material Emitted during 10am	Material Emitted during 11am	Material Emitted during 12pm	Peak (Total) Impact
9am	0.00	-	-	-	0.00
10am	0.00	0.00	-	-	0.00
11am	0.06	0.14	0.000001	-	0.20
12pm	0.39	2.49	0.44	0.000001	3.31
Percentage of Peak Impact	12%	75%	13%	0%	100%

Appendix G TAPM Peak Impact Analysis

G.3 Conclusion

The brief analysis contained in this appendix has revealed the complexity of the dispersion mechanisms which are present in TAPM's peak prediction.

This analysis also provides reasoning for higher ground level concentrations resulting from the higher (20m) stack, where plume trajectories through the non-uniform atmosphere are dependent on the level to which the plume is predicted to rise. In this case, the higher stack has allowed the plume to reach a slightly higher elevation, at which lower wind speeds were predicted. This has in turn allowed the higher plume to accumulate in the upper atmosphere to a greater extent, before diffusing to the surface, with the onset of vertical mixing.

Whilst no contemporaneous upper air data was available to validate the unusually low wind speeds predicted around 400m, this analysis illustrates that non-steady state (e.g. Lagrangian or Eulerian) models may be more appropriate for handling the high volume, high buoyancy plumes that emanate from open cycle gas turbine plants.