Mt Piper Power Station Extension Environmental Assessment

PRELIMINARY HAZARD ANALYSIS

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Sinclair Knight Merz
ABN 37 001 024 095
100 Christie Street
PO Box 164
St Leonards NSW
Australia 1590
Tel: +61 2 9928 2100
Fax: +61 2 9928 2500
Web: www.skmconsulting.com

EXECUTIVE SUMMARY

Introduction

As part of the Environmental Assessment (EA) of the proposed extension to Mt Piper Power Station a review was undertaken of the hazards that may be associated with the operation of the facility. Mt. Piper Power Station currently stores and handles a number of Dangerous Goods that are listed in the Australian Dangerous Goods Code. These goods are inherently hazardous to people and the environment and therefore in order to minimise the potential for impact to areas it is necessary to assess the storage and handling operations to ensure the risks associated with such operations are commensurate with the protection required for the surrounding land uses.

This paper details the objectives, scope of work, methodology, and study results for the of the hazard assessment of the Mt. Piper Power Station Extension Project. The Extension project involves two options to achieve up to 2000 MW of new generating capacity via an Ultra supercritical Coal Fired Extension or a Combined cycle gas turbine (CCGT).

Objectives

The objectives of the study are to:

- Identify hazards and risks associated with the operation of the Mt. Piper Power Station for the existing case* and for the two options abovementioned;
- Determine the risk impacts to the surrounding land uses;
- Assess the risk impacts to published risk criteria;
- Develop risk reduction measures where required;
- Report on the findings of the study.

Note*: A review of the historical risk studies for the site identified that a detailed land use planning hazard and risk study had not been conducted for the existing site. Hence, to allow an appropriate level of assessment the scope of work includes the assessment of risks associated with both the existing operations and proposed extension project.

Methodology

The Mt.Piper Power Station is located in NSW Central West region about 20 km northwest of Lithgow on land zoned Rural General (1a). The zoning does not prevent the development of hazardous and offensive industries, although it is prudent to review the potential hazards and ensure the power station facility has adequate safety features to minimise the risk to the environment and adjacent land uses. The methodology used for the study is that published in Hazardous Industry Planning Advisory Paper (HIPAP) No.6, Guidelines for Hazard Analysis (Ref.1).

A summary of the study approach is presented below:

- Hazard Identification – assessment of the hazards associated with the storage and handling of Dangerous Goods at the site;
- Consequence Analysis – analysis of the consequence severity and impact at adjacent land uses;
- Frequency Analysis – analysis of the frequency of incidents that have the potential to impact offsite;
- Risk Analysis – combination of the consequence and likelihood to determine the risk;
- Comparison with Risk Criteria – compare the assessed risks with those published by the regulatory authorities;
- Risk Reduction and Review – apply risk reduction solutions and review the risks to ensure risks are below criteria.

Summary Description of the Existing Proposed Mt. Piper Power Station and the Extension Project options

The existing Mt Piper Power Station was commissioned in 1992 and 1993, with the planning studies commencing in 1987. The station comprises two 700 megawatt (MW) generators (known as Units 1 and 2), driven by steam turbines (subcritical pressure cycle) that are supplied with steam from coal fired boilers.

The Mt Piper Extension Project – Option 1 – Coal Fired Extension will comprise the installation of two (up to) 1000 MW generators, adjacent to and on the western side of the existing Mt Piper Power Station. The generation of power by coal fired boilers and steam powered turbo generators would be essentially the same as that described above for the existing station, except for the use of two (up to) 1000 MW generators instead of the 700 MW generators, the use ultra-supercritical rather than subcritical technology for the boiler operation, and the use of air cooled condensers, rather than cooling towers, to minimise the consumption of water for steam cooling.

The second extension option, Option 2 – is a Combined Cycle Gas Turbine (CCGT) arrangement. The CCGT proposal will include up to six gas-fired combined cycle blocks with a total net capacity of nominally 2,000MW. The new units will employ combined cycle gas turbine technology as this is the most efficient power generation cycle commercially available for this size of plant. Each CCGT unit would include:

- Low pressure gas turbine / generator set;

- Heat recovery steam generator (HRSG) set;
- air cooled condensers (ACCs) would be used to condense the steam leaving the steam turbines in order to minimise water usage, and
- Ancillary items such as air inlet compressors and condensate pumps.

One of the key outcomes of selecting either of the above proposed technologies is that there will be few additional Dangerous Goods stored and handled on site. The air cooled condensers will eliminate the need for water treatment chemicals for the new facilities, whilst the existing facilities will retain the large quantities of water treatment chemicals.

Hazard Identification

The hazard identification commenced with a review of the existing and proposed Dangerous Goods stored and handled at the site. **Table 1** lists the classes of Dangerous Goods, their uses and the hazards associated with each Dangerous Good (DG) stored currently and inclusive of the storages under each extension option:

TABLE 1 - CLASS, NATURE AND HAZARDS OF DANGEROUS GOODS STORED AT MT PIPER POWER STATION

Class & Nature of DG	Material & Storage Type	Hazard
Class 2.1 Flammable Gas	Liquefied Petroleum Gas (LPG) stored in a horizontal tank Hydrogen/acetylene/LPG stored in cylinders Natural Gas transfer pipelines	- Gas Release and Ignition - Jet Fire / Flash fire - Gas cloud Explosion - Boiling Liquid Expanding Vapour Explosion (BLEVE)
Class 2.2 Non-Toxic/Non-Flammable Gas	Liquefied Refrigerated Carbon Dioxide stored in vertical tanks	- Gas Release - Asphyxiating Gas Cloud
Class 2.3 Toxic Gas	Anhydrous Ammonia stored in a horizontal tank and Liquid chlorine stored in drums	- Gas Release - Toxic Gas Cloud
Class 3 Flammable Liquid	Gasoline stored in an underground tank and kerosene/turpentine stored in drums and bottles	- Liquid Release and Ignition - Pool Fire
Class 8 Corrosive Substances	sulphuric acid stored in tanks and batteries, sodium hydroxide stored in tanks, ammonia solution stored in drums and hypochlorite solution stored in drums	- Liquid Release - Corrosion burns to people contacting the corrosives - Environmental Damage

TABLE 1 - CLASS, NATURE AND HAZARDS OF DANGEROUS GOODS STORED AT MT PIPER POWER STATION

Class & Nature of DG	Material & Storage Type	Hazard
Class C1 Combustible Liquid	Diesel fuel stored in above ground and underground tanks	- Liquid Release and Ignition - Pool Fire
Class C2 Combustible Liquid	Transformer oil stored in transformers; and Lube Oil stored adjacent to CCGT units	- Liquid Release and Ignition - Pool Fire

The Dangerous Goods listed in **Table 1** do not present a hazard unless released from the containment systems (e.g. tanks, pipework, etc.). A review of the storage facilities and their capacity to contain releases was conducted along with a qualitative assessment of the impact potential for hazardous incidents to offsite areas (i.e. heat radiation, discharge of drains, explosion overpressure, toxic gas concentration, etc.).

Based on the existing and proposed storages of Dangerous Goods the following hazardous incidents had the potential to impact offsite, these were:

- Transformer fire;
- Gasoline fuel spill during transfer to underground tanks and fire;
- Diesel fuel spill and bund fire;
- LPG tank BLEVE;
- Ammonia releases;
- Chlorine releases;
- Natural gas pipeline failure and jet fire; and
- Gas turbine enclosure leak and explosion.

These incidents were carried forward for consequence analysis.

Consequence Analysis

The consequence analysis identified the following potential releases from existing and proposed operations for both options:

- **Transformer fire** – the transformer fire is contained in the bunded area surrounding the transformer unit. The heat radiation impact from the fire reaches 4.7kW/m^2 at a distance of 29.4m (Note: the maximum permissible level of heat radiation impact at the site boundary is 4.7kW/m^2 –Ref.18). The distance from the transformers to the site boundary is 600m. Hence, there is no potential for impact offsite.
- **Gasoline fuel spill during transfer to underground tanks and fire** – the gasoline fuel spill is contained within the transfer area. The heat radiation impact from the fire reaches 4.7kW/m^2 at a distance of 15.5m. The distance from the gasoline transfer point to the site boundary is 350m. Hence, there is no potential for impact offsite.
- **Diesel fuel spill and bund fire** - the heat radiation impact from the fire reaches 4.7kW/m^2 at a distance of 35.4m. The distance from the diesel fuel tanks to the site boundary is 40m. Hence, there is no potential for impact offsite.
- **LPG tank BLEVE** – the BLEVE impact (fireball) was estimated to occur with a diameter of 147m (radius - 73.5m). The distance to the site boundary from the LPG storage is over 600m and hence there is no potential for impact offsite.
- **Ammonia releases** – the impact to people from ammonia (i.e. fatality/injury) was identified to occur at a concentration of 1000 parts per million (ppm) for exposures of 1 hour. A gas dispersion analysis was performed for postulated ammonia releases at the ammonia tank. It was identified that the ammonia concentration at 1000ppm (ERPG-3) reached 320m, in the worst case (F1) and did not extend to the boundary. For the same release scenario and under worst case conditions (F1) concentrations computed at the boundary were 460ppm. As this is between ERPG-3 and ERPG-2 levels, it can be concluded most individuals will not develop or experience irreversible or serious health effects. Daytime levels (D3) are considerably lower, around140 ppm and hence there is no fatality potential (fatality risk) for offsite impact from the postulated ammonia releases at the station.
- **Chlorine releases** - the impact to people from chlorine (i.e. fatality/injury) was identified to occur at a concentration of 20ppm (fatal) & 5ppm (injury). A gas dispersion analysis was performed for postulated chlorine releases at the chlorine storage area (drum storage). It was identified that the worst case chlorine concentrations for 20ppm (ERPG-3) and 3-5ppm (ERPG-2) occurred at 558m and 1558m respectively under F1 stability/wind conditions. The closest site boundary (Boulder Rd) to the chlorine storage is 900m. Hence, there is no potential for fatal offsite impact from the postulated chlorine releases at the station; however, there is a possibility for injury impact at the site boundary from the postulated releases.

- **Natural Gas Pipeline release and jet fire** – resultant heat flux levels of 4.7kW/m2 will extend beyond the easement boundary (inside the site), but may have an impact to offsite areas located around 105 m away. Hence, the impact to offsite facilities from a jet fire at the pipeline gantry/ metering station was carried forward for detailed analysis.

Gas Turbine Enclosure Explosion Risk - At the boundary close to Boulder Rd (500m away) the explosion overpressure is lower than 4 kpa (at 14kPa the risk of fatality to a person in the open is 0.01). Hence the effect is not significant. For the purpose of computation the risk of fatality will be taken as 0.01. Hence, this incident has been carried forward for further analysis (injury potential).

Risk Analysis Results

The land use safety implications for the proposed development are summarised in **Table ES1 – Overall Risk Evaluation**. The table summarises the events, event probability and risk. The parameters as provided in the table are defined as follows:

- Event – the events that may have an impact at the site boundary and comprise:
  - Gas fitting line incident leading to gas leak as a result of external interference ;
  - Gas leak into the gas turbine enclosure, ignition and explosion/jet fire;
  - Chlorine release from a pigtail failure in the chlorine storage area.
- Base Frequency x 10^{-6} – is the failure frequency of our events of interest (listed above).
- PF (E) – is the probability of fatality due to fire to a person on the boundary from the events above .
- CF-Risk – is the cumulative addition of the individual risk results.

Table ES1 - Overall Risk Evaluation

EVENT	Base Event Freq (x 10^{-6} pa)	Pf (Fatality)	Fatality Risk x 10^{-6} At Boundary (Boulder Rd)
1.Gas Pipeline jet fire	0.0375	0.5	0.02
2.Gas explosion Turbine Enclosure	1.6	0.01	0.016
3. Chlorine release from drum	5	0.06	0.3
Estimated RISK LEVEL at BOUNDARY (no more than 1 pmpy)			0.34

The risk levels expected at the boundary of the site are estimated to be around 0.34 pmpy.

Such risk levels are considered acceptable (Ref: NSW DEPT. OF PLANNING Risk Criteria at Boundary of site = 1 x 10^{-6} pa) under the NSW Department of Planning guidelines (Reference 11).

Notwithstanding the low risk levels estimated form this assessment, and to ensure the risks are maintained in the ALARP range, the following recommendations are made:

- The gas pipeline easement and the gas pipeline along the piperack should be clearly marked with "HIGH PRESSURE GAS PIPELINE" at regular intervals (20m) to ensure that personnel working in the area (especially on the piperacks) understand that a high pressure gas fitting line is present.
- A safety management system (SMS) be developed (in accordance with HIPAP # 9 – Safety Management System Guidelines) for the site, covering particularly the risk events that may have effects at the boundary, notably:
  - Gas fitting line incident leading to gas leak as a result of external interference
  - Gas leak into the gas turbine enclosure, ignition and explosion/jet fire;
  - Chlorine release from a pigtail failure in the chlorine storage area

The SMS should cover:

- Management of process changes (use of HAZOP critic methods);
- Accident / Incident reporting;
- Safety Training requirements;
- Emergency plans (based on risk assessment & HIPAP # 1);
- Site security and access;
- Audit program.

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ABBREVIATIONS

Abbreviation	Description
ACC	Air Cooled Condenser
ALARP	As Low As reasonably Practicable
AS	Australian Standard
BLEVE	Boling Liquid Expanding Vapour Explosion
CO_2	Carbon Dioxide
DG	Dangerous Goods
DIPNR	Department of Infrastructure Planning and Natural Resources
EIS	Environmental Impact Statement
HIPAP	Hazardous Industry Planning Advisory Paper
HP	High Pressure
Kg	Kilograms
Kms	Kilometres
kV	Kilovolts
kW/m^3	kilowatts per metre squared
LPG	Liquefied Petroleum Gas
M	Metres
m^3	Cubic metres
ML	Mega Litres
Mm	Millimetres
MW	Megawatts
p.a.	per annum
PHA	Preliminary Hazard Analysis
Ppm	parts per million
QRA	Quantitative Risk Assessment
RL	Relative Level
SEPP	State Environmental Planning Policy
STP	Standard Temperature and Pressure
UN	United Nations

1. INTRODUCTION

1.1 Background

Delta Electricity (Delta) operates a coal fired power station at Mt. Piper, about 20 kms North West of Lithgow, NSW. Power is generated using two 700MW steam turbine units.

Delta is seeking approval for an extension to the power generation capacity at the site by one of two options:

- Option 1 – New Coal Fired Boilers (CFB) and Steam Driven turbines with a total capacity of up to 2,000 MW. The exact size and capacity of the new generators would depend on their commercial availability at the time of tender; and
- Option 2 - A Combined Cycle Gas Turbine (CCGT) arrangement. The CCGT proposal will include up to six gas-fired combined cycle blocks with a total net capacity of nominally 2,000MW. The new units will employ combined cycle gas turbine technology as this is the most efficient power generation cycle commercially available for this size of plant.

As part of the power generation extension Delta is required to prepare an Environmental Assessment (EA), which must include *"a screening of potential hazards on site to determine the potential for off-site impacts and any requirement for a Preliminary Hazard Analysis (PHA)".*

The screening of potential hazards was undertaken using the application of State Environmental Planning Policy (SEPP) No.33 "Hazardous and Offensive Development" to determine whether the upgrade is potentially hazardous or offensive with respect to the surrounding land uses. Although SEPP33 does not apply to the proposed project, it was useful to assess the hazards and their potential effects as part of the EA process. This document details the objectives, scope of work, methodology, project description and study results for the hazard assessment of the Mt. Piper Power Station Extension Project. The scope of work includes an assessment of the existing facilities that will be used as part of the support to the new power generating units at the station.

1.2 Objectives

The objectives of the study are to:

- determine whether SEPP33 could apply to the proposed project;
- conduct a preliminary hazardous analysis (PHA), in accordance with Hazardous Industry Planning Advisory Paper (HIPAP) No.6, Guidelines for Hazard Analysis (Ref.1);
- Report on the findings of the PHA study for inclusion in the EA of the Mt.Piper Power Station Extension Project.

2. METHODOLOGY

2.1 Review of the Application of SEPP33

The Mt. Piper power station is located in land zoned Rural General (1a). This land zoning does not prohibit the development of hazardous and offensive industries. Hence, SEPP33 would not directly apply to this zoning. In addition, the assessment of the proposed extension is being undertaken under Part 3A of the EP&A Act and SEPP 33 does not generally apply. However, in order to ensure any such industry was provided with adequate safety features, it is regarded as prudent to assess the facility for hazardous impacts to people and the environment surrounding the site. This approach has been used for this assessment and a SEPP33 application review as been conducted to determine the nature of the Hazard assessment required for the site. This analysis is conducted below.

The NSW Department of Planning publishes a SEPP 33 application guideline document “Applying SEPP 33, Hazardous and Offensive Development Guidelines (Ref.2)”, which lists threshold levels that must be exceeded before SEPP 33 applies. Table 3.1 of that report lists the existing storage quantities of Dangerous Goods at the site. In addition, the proposed power station expansion project will require the addition of new Dangerous Goods storages. These are listed in Table 3.2 of the report.

There are a number of Dangerous Good (DG) stored at the existing Mt.Piper Power Station, and in the proposed extension project that exceed the threshold quantities listed in “Applying SEPP 33 – Hazardous and Offensive Development Application Guidelines” (Ref.2). These are listed in **Table 2.1**.

TABLE 2.1
DANGEROUS GOODS STORED AND HANDLED AT MT PIPER POWER STATION EXCEEDING THE SEPP33 THRESHOLD LEVEL

Name	Class	Packaging Group	Total Quantity Stored	SEPP33 Threshold
Existing Storage Facilities				
Corrosive Substances (acid/alkali)	8	II	256 m^3	25m^3
Corrosive Substances (acid/alkali)	8	III	73m^3	50m^3
Anhydrous Ammonia	2.3	-	30 tonnes	5 tonnes
Chlorine	2.3	-	10 tonnes	5 tonnes
Proposed Storage Facilities				
Corrosive Substances (acid/alkali)	8	II	36.4 m^3	25m^3

The flammable gases and liquids are all stored at sufficient distances from the site boundaries to result in SEPP33 not being applicable for these materials.

The fact that SEPP33 is not applicable to the flammable gases and liquids does not exclude the fact that the corrosive substances and toxic gases, in the existing storage areas, exceed the threshold quantities listed in "Applying SEPP 33 – Hazardous and Offensive Development Application Guidelines" (Ref.2). Hence, for a new facility, it would be a requirement (under SEPP33) that a preliminary hazard analysis (PHA) is performed to demonstrate that the proposed development is only potentially hazardous and not actually hazardous. Hence, although SEPP33 does not strictly apply to Rural General (1a) land zoning, it is considered prudent that a PHA be prepared for the site.

Mt.Piper Power Station is an existing facility and under these circumstances for additional storage facilities it would be prudent to perform an update of any PHA that was prepared earlier. However, when the initial planning studies were completed (around 1980) SEPP33 and the accompanying hazard analysis guidelines were not developed and a PHA has never been conducted for the facility.

Notwithstanding the fact that SEPP33 does not strictly apply, the proposed power station expansion project will store Dangerous Goods in excess of the threshold quantities in the document "Applying SEPP33" (Ref.2) (see **Table 2.1**). Hence, it is considered prudent to prepare a PHA for the proposed expansion project and, considering the fact that the existing power station has not been subjected to a PHA study, the storage within the existing site will be included in the assessment.

2.2 Multi Level Risk Assessment

A Multi Level Risk Assessment (Ref.3) approach was used for the SEPP 33 study of the Mt. Piper expansion project and existing Dangerous Goods storage facilities. The approach considered the development in context of its location, the quantity and type (i.e. hazardous nature) dangerous goods stored and used, and its technical and safety management control. The Multi Level Risk Assessment Guidelines are intended to assist industry, consultants and the consent authorities to carry out and evaluate risk assessments at an appropriate level for the facility being studied.

The Multi Level Risk Assessment approach is summarised in **Figure 2.1**. There are three levels of assessment, depending on the outcome of preliminary screening. These are:

- **Level 1 – Qualitative Analysis**, primarily based on the hazard identification techniques and qualitative risk assessment of consequences, frequency and risk;
- **Level 2 – Partially Quantitative Analysis**, using hazard identification and the focused quantification of key potential offsite risks; and
- **Level 3 – Quantitative Risk Analysis (QRA)**, based on the full detailed quantification of risks, consistent with Hazardous Industry Planning Advisory Paper No.6 – Guidelines for Hazard Analysis.

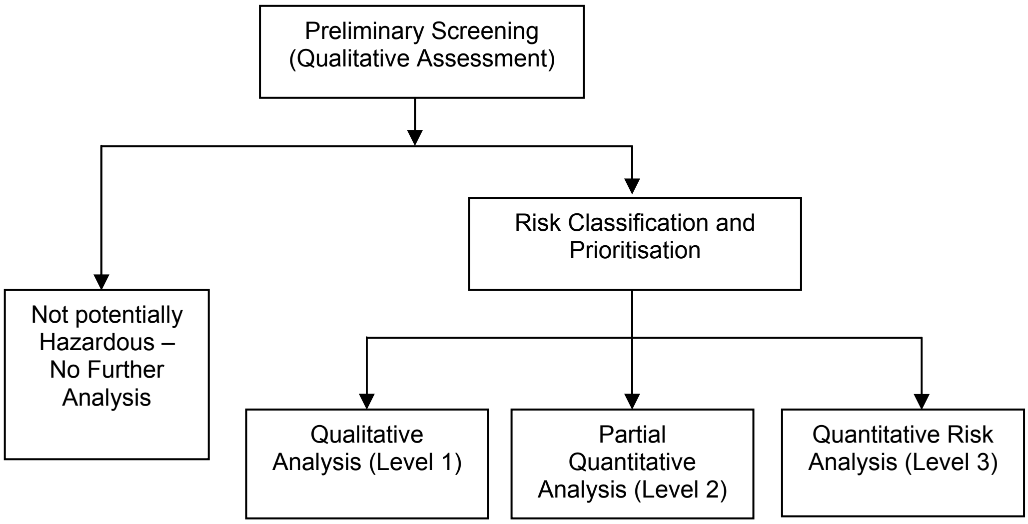

FIGURE 2.1
THE MULTI LEVEL RISK ASSESSMENT APPROACH

The “Applying SEPP 33” (Ref.2) guideline may also be used to assist in the selection of the appropriate level of assessment. This guideline states the following:

“It is considered that a qualitative PHA may be sufficient in the following circumstances:

- *where materials are relatively non-hazardous (for example corrosive substances and some classes of flammables);*
- *where the quantity of materials used are relatively small;*
- *where the technical and management safeguards are self-evident and readily implemented; and*
- *where the surrounding land uses are relatively non-sensitive.*

In these cases, it may be appropriate for a PHA to be relatively simple. Such a PHA should:

- *identify the types and quantities of all dangerous goods to be stored and used;*
- *describe the storage/processing activities that will involve these materials;*
- *identify accident scenarios and hazardous incidents that could occur (in some cases, it would also be appropriate to include consequence distances for hazardous events);*
- *consider surrounding land uses (identify any nearby uses of particular sensitivity); and*
- *identify safeguards that can be adopted (including technical, operational and organisational), and assess their adequacy (having regards to the above matters).*

A sound qualitative PHA which addresses the above matters could, for some proposals, provide the consent authority with sufficient information to form a judgement about the level of risk involved in a particular proposal”.

The Dangerous Goods stored at the Mt. Piper Power Station (existing and proposed) are, in the majority corrosive liquids used for water treatment. The number of flammable liquids is relatively low and the much of the flammable liquid (petroleum) is stored in an underground tank. However, there are two toxic gases stored in relatively high quantities (ammonia – 30 tonnes and chlorine 10 tonnes). Surrounding land uses (within 1km) are generally rural in nature.

Hence, based on the nature of the stored materials (i.e. corrosives, flammable gases/liquids and toxic gases) and that the adjacent land uses (i.e., within 1 km of the site) are rural in nature, a Level 2 assessment has been selected for this PHA. The Level 2 analysis will permit a qualitative assessment of the corrosive materials to be conducted along with a detailed consequence analysis for the flammable gases/liquids and toxic gases to determine the impact at the closest sensitive receptor.

3. BRIEF DESCRIPTION OF THE PROJECT

3.1 Land Zoning and Surrounding Land Uses

Figure 3.1 shows the regional location of the Mt. Piper Power Station west of Lithgow, NSW. The area is zoned Rural General (1a). **Figure 3.2** shows the existing power station site and nature of the surrounding land uses adjacent to the site.

3.2 Overview of the Existing Mount Piper Power Station

The existing Mt Piper Power Station was commissioned in 1992 and 1993, with the planning studies commencing in 1987. The station comprises two 700 megawatt (MW) generators (known as Units 1 and 2), driven by steam turbines (subcritical pressure cycle) that are supplied with steam from coal fired boilers.

The coal is delivered to the Power Station via conveyor or truck, and is ground in pulverising mills before injection into the boiler furnace chamber in a stream of preheated air. Maximum coal consumption is about 250 tonnes per hour. The boiler furnace heats purified fresh water to high pressure (HP) steam which is collected in a pressure vessel (steam drum) at the top of the boiler, before it passes through a superheater stage on route to the steam turbines. For each 700 MW turbo-generator, about 2 ML of water per hour is converted to steam.

Boiler exhaust gases pass through a series of fabric filters to trap ash particles and prevent their emissions from the boiler stack. The trapped ash particles are collected and disposed of in a designated ash disposal area.

The steam, which is injected at high pressure, spins the blades on the drive shaft of the turbine. The spent steam is cooled to water for re-use in the boiler as it passes over a series of condenser tubes, through which cold water from the cooling water system is circulated. The generation of electricity from Mt Piper Stages 1 and 2 requires significant volumes of water for both steam production and cooling. The fresh and recycled water is recirculated, while the heat is dissipated via the cooling towers.

The electrical generator consists of the revolving section, called the rotor (which is directly coupled to the steam turbine main shaft), and the stator (which is a series of coils grouped around the rotor). The rotor revolves at high speed, generating electricity (alternating current) in the stator. The direct current supply to the rotor comes from a separate static exciter.

Electricity is produced in the 700 MW generators at 23 kilovolts (kV). It then passes through a step up transformer which increases the voltage to as high as 500 kV. From the transformer it passes via the high voltage switchyard to the electricity network.

3.3 Overview of the Proposed Mount Piper Power Station Expansion Project

The Mt Piper Extension Project will comprise two options.

3.3.1 Option 1 – 2 Coal Fired Boilers (CFB) and associated steam generators rated at 2000 MW

Option 1 comprises the installation of two (up to) 1,000 MW steam driven generators (Units 3 and 4) and coal fired boilers (CFB), adjacent to and on the western side of the existing Mt Piper Power Station. **Figure 3.3** shows the proposed expansion project and the location of the new generators and boilers. In addition to these units, new overland conveyors will be required to transport coal from a new rail siding to the existing, longterm coal stockpile or to a live coal storage area. The coal will be pulverised and used to fire two new boilers which will operate under an ultrasupercritical pressure cycle. Ash will be collected from the boiler furnace chamber, economiser airheater and fabric filter baghouse. The quantity of ash produced will depend on the ash content of the coal being used and the quantity of coal being burned. Flue gas will be emitted to the atmosphere via a single stack approximately 250m in height.

The steam generated by the boilers will be routed to the high pressure turbines where some of the heat energy will be converted to mechanical energy. The steam will then return to the boiler for reheating before it flows through the intermediate pressure turbine and then to the low pressure turbine to convert more of the heat energy into mechanical energy. Steam discharged from the low pressure turbines will pass to direct air cooled condensers (ACCs), which transfer steam from the turbine directly to heat exchanger modules. The steam will be condensed to water before it is returned to the boiler by way of feed heaters, which use steam extracted from the turbines. Heat will be dissipated to the atmosphere via air flow in the condensers located on the south west of the site.

The electrical power output of the power station will be delivered, via step up transformers, to a new 500kV switchyard which will be located adjacent to the existing switchyard. High voltage lines will connect the extended power station to the new switchyard.

A concept layout for the proposed plant extension is shown in **Figure 3.3**. The new plant (extension) differs from the existing plant in three major factors:

- It will use up to 1,000 MW generators;
- It will use ultrasupercritical rather than subcritical technology for the boiler operation, thereby reducing the level of greenhouse gas emissions per MW from coal burning; and
- It will use air cooled condensers, rather than cooling towers, to minimise the consumption of water for steam cooling.

3.3.2 Option 2 - Combined Cycle Gas Turbine blocks (CCGT units)

Option 2 comprises up to six gas-fired Combined Cycle Turbine blocks (CCGT units) with a rated capacity of around 2200 MW. The supplier is yet to be decided but the turbine units are likely to be Alstom, GE, Mitsubishi or Siemens. Regardless of the unit selection the technologies and ancillary systems are essentially the same, and one of the combinations as shown in **Table 3.1** – Estimated Site Based Performance by GT Unit, could be selected.

Table 3.1 – Estimated Site Based Performance by GT Unit

GT Model	GT26	9 FB	701 F	4000F	9H	701 G	8000H
Supplier	Alstom	GE	MHI	Siemens	GE	MHI	Siemens
Number of Units	6	6	5	6	5	5	5
Nominal Net Capacity (MW)	2,193	2,283	1,997	2,171	2,164	2,142	Not available
Net Efficiency (%, HHV)	51.5%	51.8%	51.3%	51.6%	52.9%	52.4%	Not available
Net Heat Rate (kJ/kWh, HHV)	6,990	6,940	7,020	6,980	6,810	6,880	Not available

Data from GTPro model, assuming multiple blocks of one gas turbine/HRSG/steam turbine and at 15°C, 940m, 70% relative humidity and an ACC.

It is assumed the combined cycle units will be built as single shaft blocks. This is the preferred design for this type of plant. The gas turbine and steam turbine drive a common generator, normally located between the two prime movers. This design delivers the lowest cost power and is the standard offering from the suppliers.

Alternatives are possible – most commonly where the steam from more than one gas turbine/HRSG train is sent to a single steam turbine. For a 2000MW plant at Mt Piper, the most likely alternative options are:

- Three blocks, each with 2 gas turbines, 2 HRSGs and a single steam turbine;
- Two blocks, each with 3 gas turbines, 3 HRSGs and a single steam turbine.

The turbines and generators will be located in turbine halls. The HRSGs, ACCs and step-up transformers will be located outdoors. Balance of plant equipment will generally be located in weather proof enclosures.

A potential layout of the new CCGT plant is shown in **Figure 3.4 - Existing Plant and Proposed CCGT extension.** The new plant would comprise the installation of up to six units in the benched area previously prepared for the extension during the construction of Units 1 and 2.

A summary of the typical main plant components is given below:

Gas Turbine Facility

- Air inlet filter
- Air compressor plant
- Combustors
- Gas Turbines
- Exhaust Stacks
- Power Generator
- Generator Circuit Breaker
- Mains Transformer (oil filled)

Gas Fitting line

- Fitting line inlet facility
- Fitting line delivery facility

Transmission Line

- Electrical substation complete with HV switching facility

Ancillary Services

- Backup fuel storage (diesel)/tanker unloading facility
- Station supply transformers (nominal 1500 kVA – dry type)
- Air compressor plant
- Lubricating and hydraulic oil system
- Stormwater system
- Fire protection
- Control Room, Workshop & Amenities

The facilities listed above are described in more detail in the following sections.

3.3.2.1 Gas Turbines

The proposed CCGT power station development is to comprise up to 6 x 400 MW combined cycle gas fired power generation facility. The station will utilise one closed cycle gas fired turbine unit (unit type yet to be determined). The turbine will normally operate on natural gas. The gas turbine will be installed within an acoustic enclosure that will limit noise on the outside of the enclosure to meet the regulatory requirements.

The gas turbine cycle operates by initially compressing air using a turbine fan which forces the air into a series of combustion chambers where the fuel is injected into the air stream and ignited. The combusted gas then passes across an expansion turbine, which is connected by shaft to the compressor and a generator or alternator that produces the power for the production of electricity.

The use of gas as the primary fuel supply does not require the storage of this fuel on site, and therefore the hazards are minimised.

The gas turbines and generator/alternator require lubrication (e.g. bearings) and each engine will be fitted with a lubricating oil tank of about 20,000L capacity. The tank will be installed on the outside of the gas turbine acoustic enclosure and will be fitted within a bunded area around the tank. Any leaks from the tank will be contained within the immediate area of the tank.

3.3.2.2 Gas supply infrastructure

Gas supply infrastructure will include:

- natural gas pipeline would be at least 457mm diameter and would be required to deliver approximately 133PJ per annum to Mt Piper for the CCGT plant operating at a 95% capacity factor.
- A Meter Pressure Regulating Station (MPRS) would be required comprising dry gas filtering, metering, water bath heating to maintain regulated outlet temperature, pressure regulation to 3-5MPa, pressure and temperature measurements, remote isolation valve, control hut to accommodate the communications, computing and auxiliary equipment, pipeline blowdown vent and remote control and monitoring.

3.3.2.3 Power Transmission

In both options the electrical power output of the power station would be delivered, via step up transformers, to a new station 500kV switchyard. High voltage transmission lines will connect this to TransGrid's existing 500kV switchyard.

One of the key outcomes of selecting either option is that the proposed requires few additional Dangerous Goods. The air cooled condensers will eliminate the need for water treatment chemicals for the new facilities, whilst the existing facilities will retain the large quantities of water treatment chemicals. A review of the Dangerous Goods stored and handled on site is conducted in **Section 3.4**.

3.4 Dangerous Goods Stored and Handled at the Mt. Piper Power Station

3.4.1 Existing Dangerous Goods Stored and Handled at the Mt. Piper Power Station

The Dangerous Goods stored and handled on site are mainly used for water treatment and conditioning in the water/steam circuit. Water used in the generation of steam must be essentially free from contaminants to minimise the potential for scaling and deposition on boiler and turbine parts. The water/steam must be pH neutral to minimise the potential for corrosion and there must be no algal growth in the water.

To minimise the potential for contaminants, corrosion products and algal growth, pH control chemicals are used (sulphuric acid and sodium hydroxide) and ammonia, chlorine and hypochlorites are used to prevent algae.

A number of additional chemicals, oils and fuels are stored and used in various location around the site. These storages include oil held in transformers, petroleum fuels (underground tanks) for vehicle fuelling, sulphuric acid for batteries and carbon dioxide for purging the generator.

Table 3.2 lists the Dangerous Goods stored and handled at the existing site.

3.4.2 Dangerous Goods Proposed for Storage at the Extension Project

Due to the proposed extension technology, the quantity of additional Dangerous Goods required for the station is relatively low. Air cooled condensers limit the requirement for additional water treatment chemicals. The only additional Dangerous Goods required for the project are related to transformers (oil), liquefied/refrigerated carbon dioxide, and sulphuric acid for batteries. The details of the Dangerous Goods proposed for storage in the expansion project are listed in **Tables 3.3 for Option 1 – Coal Fired DD Storage and Table 3.4 for Option 2 – CCGT DG Storage**. The locations of the existing Dangerous Goods depots are shown on **Figure 3.4**. The locations of the additional dangerous goods depots are shown on **Figure 3.5 for Option 1 – Coal Fired DD Storage and Figure 3.6 for Option 2 – CCGT DG Storage**.

TABLE 3.2
LIST OF EXISTING DANGEROUS GOODS STORED AND USED AT MT PIPER POWER STATION

Depot No.	Un.No.	Name	Class	Packaging Group	Maximum Qty Stored
1	-	Transformer Oil	C2	-	88,414 Litres
2	-	Transformer Oil	C2	-	88,414 Litres
3	-	Transformer Oil	C2	-	119,748 Litres
4	-	Transformer Oil	C2	-	135,660 Litres
5	-	Transformer Oil	C2	-	78,500 Litres
6	2187	Carbon Dioxide Refrigerated Liquid	2.2	-	6,500 Litres
7	2187	Carbon Dioxide Refrigerated Liquid	2.2	-	6,500 Litres
8	2796	Battery Fluid, Acid	8	II	18,193 Litres
9	2796	Battery Fluid, Acid	8	II	18,193 Litres
15	1824	Sodium Hydroxide Solution	8	II	6,000 Litres
16	1824	Sodium Hydroxide Solution	8	II	6,000 Litres
17	1049	Hydrogen, Compressed	2.1	-	2,756 m^3
18	1005	Ammonia, Anhydrous	2.3	-	30,000 kg
19	1017	Chlorine (Drums)	2.3	-	10,000 kg
21	1830	Sulphuric Acid	8	II	55,000 Litres
22	1830	Sulphuric Acid	8	II	55,000 Litres
23	1824	Sodium Hydroxide Solution	8	II	15,000 Litres
24	1824	Sodium Hydroxide Solution	8	II	40,000 Litres
25	1824	Sodium Hydroxide Solution	8	II	40,000 Litres
26	1830	Sulphuric Acid	8	II	32,000 Litres
27	1830	Sulphuric Acid	8	II	32,000 Litres
28	1760	Corrosive Liquid, NOS – (miscible with water)	8	III	24,000 Litres
29	1075	Petroleum Gases, Liquefied	2.1	-	30,000 kg
30	-	Diesel Fuel	C1	-	120,000 Litres
31	-	Diesel Fuel	C1	-	120,000 Litres
32	1223 1299	Kerosene Turpentine	3 3	III III	1500 Litres 1500 Litres
33	1001 1978	Acetylene, Dissolved Propane	2.1 2.1	- -	1000 kg 1000kg
34	2672	Ammonia Solution	8	III	3,200 Litres
35	1791	Hypochlorite Solution	8	III	5,600 Litres
36	1270	Petroleum Fuel [Aust.]	3	II	33,000 Litres

TABLE 3.3
LIST OF PROPOSED DANGEROUS GOODS TO BE STORED AND USED AT MT PIPER POWER STATION EXTENSION PROJECT under Option 1 Coal Fired Extension

Depot No.	Un.No.	Name	Class	Packaging Group	Maximum Qty Stored
37	-	Transformer Oil	C2	-	88,414 Litres
38	-	Transformer Oil	C2	-	88.414 Litres
39	-	Transformer Oil	C2	-	119,748 Litres
40	-	Transformer Oil	C2	-	135,660 Litres
41	2187	Carbon Dioxide Refrigerated Liquid	2.2	-	6,500 Litres
42	2187	Carbon Dioxide Refrigerated Liquid	2.2	-	6,500 Litres
43	2796	Battery Fluid, Acid	8	II	18,193 Litres
44	2796	Battery Fluid, Acid	8	II	18,193 Litres

Note: Class C1 & C2 Combustible liquids are not classed as dangerous Goods under the Australian DG Code ADG7, nor are they to be included in the SEPP33 inventory (unless they are contained in a bund with other tanks storing flammable liquids), and are only provided for completeness.

TABLE 3.4
LIST OF PROPOSED DANGEROUS GOODS TO BE STORED AND USED AT MT PIPER POWER STATION EXTENSION PROJECT under Option 2 CCGT Fired Extension

Depot No.	Un.No.	Name	Class	Packaging Group	Maximum Qty Stored
37	-	Transformer Oil	C2	-	88,414 Litres
38	-	Transformer Oil	C2	-	88.414 Litres
39	-	Transformer Oil	C2	-	119,748 Litres
40	-	Transformer Oil	C2	-	135,660 Litres
41	-	Lubricating Oil	C2	-	20,000 litres
42	-	Lubricating Oil	C2	-	20,000 litres
43	-	Lubricating Oil	C2	-	20,000 litres
44	-	Lubricating Oil	C2	-	20,000 litres
45	-	Lubricating Oil	C2	-	20,000 litres
46	-	Lubricating Oil	C2	-	20,000 litres
	-	Natural Gas	2.1	III	No storage

3.4.3 Operational and Site Safeguards

The power station is fitted with a number of safeguards to minimise the potential for incidents involving Dangerous Goods. These safeguards include prevention, detection, protection and mitigation systems, which are summarised below:

- **Fire main & Fire Hydrants** – a 250mm diameter fire main system is installed throughout the site. This will be expanded into the new boiler and turbine area. The fire main is supplied by high and low pressure fire water header tanks. Details of the tanks are presented below:
  - 2 x LP Fire water Tanks within the station, the bottom of the tanks at RL1047; and
  - 2 x 25ML HP tanks outside the station, the bottom of the tanks at RL1047.

  The tanks provide a head pressure to the fire main and maintain flow and pressure during fire main operation without the use of pumps.
- **Fire Extinguishers** – fire extinguishers are installed throughout the plant. Extinguishers have been selected and installed in accordance with AS2444 (Ref.4) and include dry chemical powder, foam and carbon dioxide, selected to address specific fire hazards around the site.
- **Chlorine** – the chlorine plant is fitted with a number of safeguards including gas detection, alarms and chlorguard fitted to the storage drum delivery valves. Chlorguard is a system for automatically isolating the chlorine delivery to the plant on the detection of gas release. The system closes the drum valve preventing gas continued release in the event of a leak.
- **Ammonia** – the ammonia tank is fitted with excess flow valves. In the event of a pipeline rupture, the excess flow valves will close, preventing continued release.
- **Corrosive Liquids** – all corrosive liquids (acid and alkali) are stored in tanks located in bunds. All bunds are designed to contain the full contents of the largest tank in the bund. All corrosive goods storages comply with the requirements of AS3780 (Ref.20).
- **Transformers** – all transformers are fitted with level detection (Bucholtz) to detect loss of oil level in the transformer. On detection of low oil level the transformer is “tripped” and an alarm raised. All transformers are installed in bunded areas with capacity to contain the full transformer oil contents. Transformers are also fitted with blast walls to prevent the potential for incident growth in the event of transformer fire and/or explosion. In addition to the blast walls, all transformers are fitted with deluge systems to apply fire water in the event of transformer fires. All the above safety features will be fitted to the new transformer units.

- **Site Containment –** the site is a zero discharge facility, with all water on site collected for re-use in a number of ponds. There are a series of water collection ponds located around the site these are summarised below:
  - Transformer Oil Containment Pond – 8 ML;
  - Ash and Washdown Ponds – 3 x 8ML each (total 24 ML); and
  - Water Treatment Plant, Ammonia area and general site drains – 120ML & 80ML site drainage ponds.

  The ponds contain all spills and stormwater on site and are sized to ensure pond freeboard is sufficient to contain likely storm events in the area.

- **Gas Detectors** – methane gas detectors will be installed in each of the gas turbine enclosures. The detection of gas in a specific enclosure will automatically shut the external gas feed valve to the gas turbine, shutting off gas supply to the enclosure itself. The gas detector will be calibrated to alarm as 5% of lower explosive limit (LEL) of gas in air and shut down gas supply at 50% LEL.
- **Bunding** – all dangerous goods and combustible liquids (lubricating oil, acids and alkalis) will be fitted with bunding to AS1940 (AS 2004a) to prevent spill release beyond the immediate area of the spill.
- **Gas Fitting Line Corrosion Protection** – the high pressure gas fitting line will be painted for corrosion protection.
- **External Interference Protection** –The fitting line will be installed in a sturdy pipe rack that is clear of through traffic.
- **Fitting Line Material** – the fitting line will be constructed from X42-grade steel, of at least 12 mm wall thickness which will minimise the potential for crack growth propagation in the event of a fitting line breach (i.e. impact). This minimises the potential for continued crack growth and incident propagation.

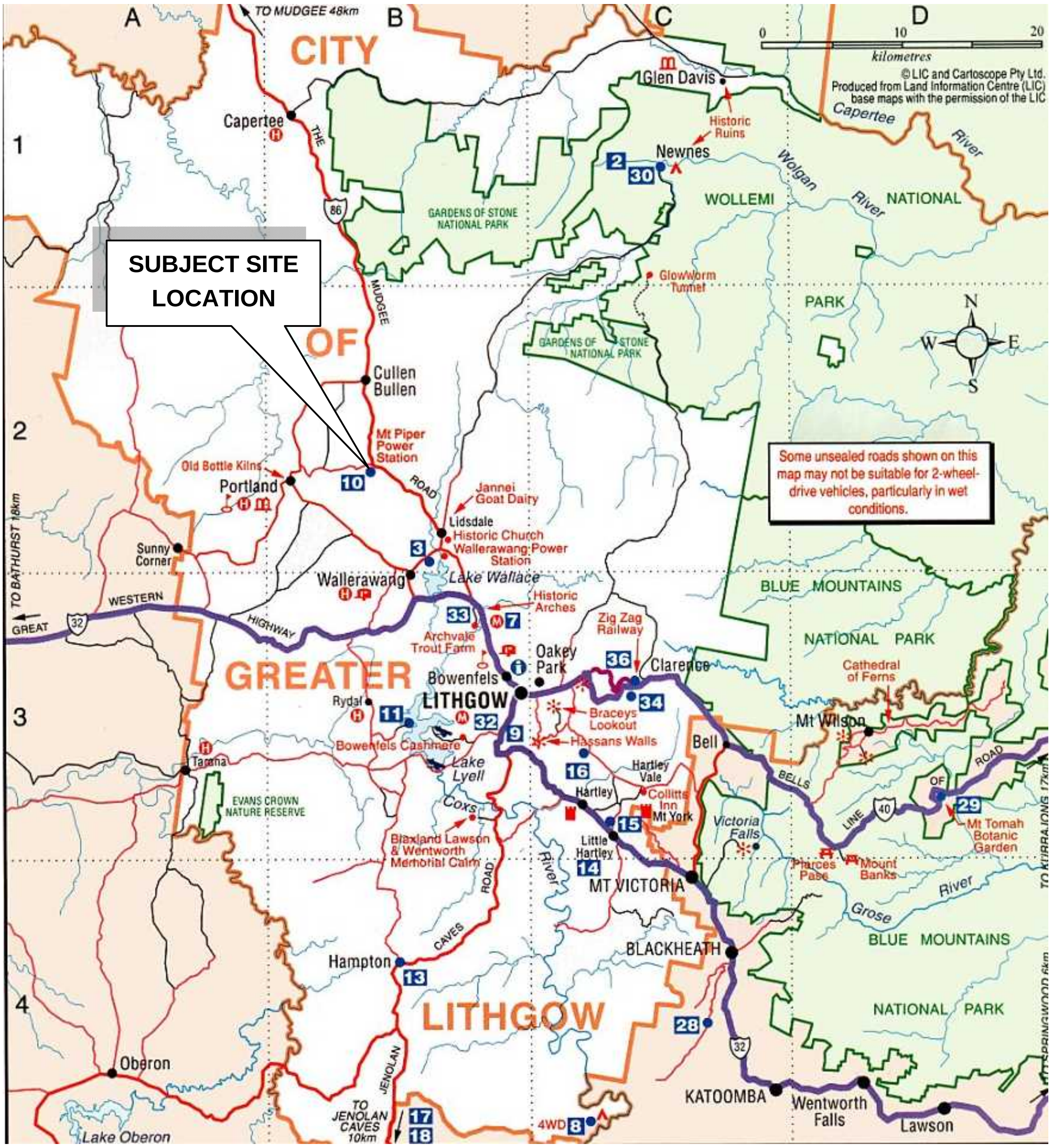

FIGURE 3.1

REGIONAL LOCATION OF THE MT.PIPER POWER STATION

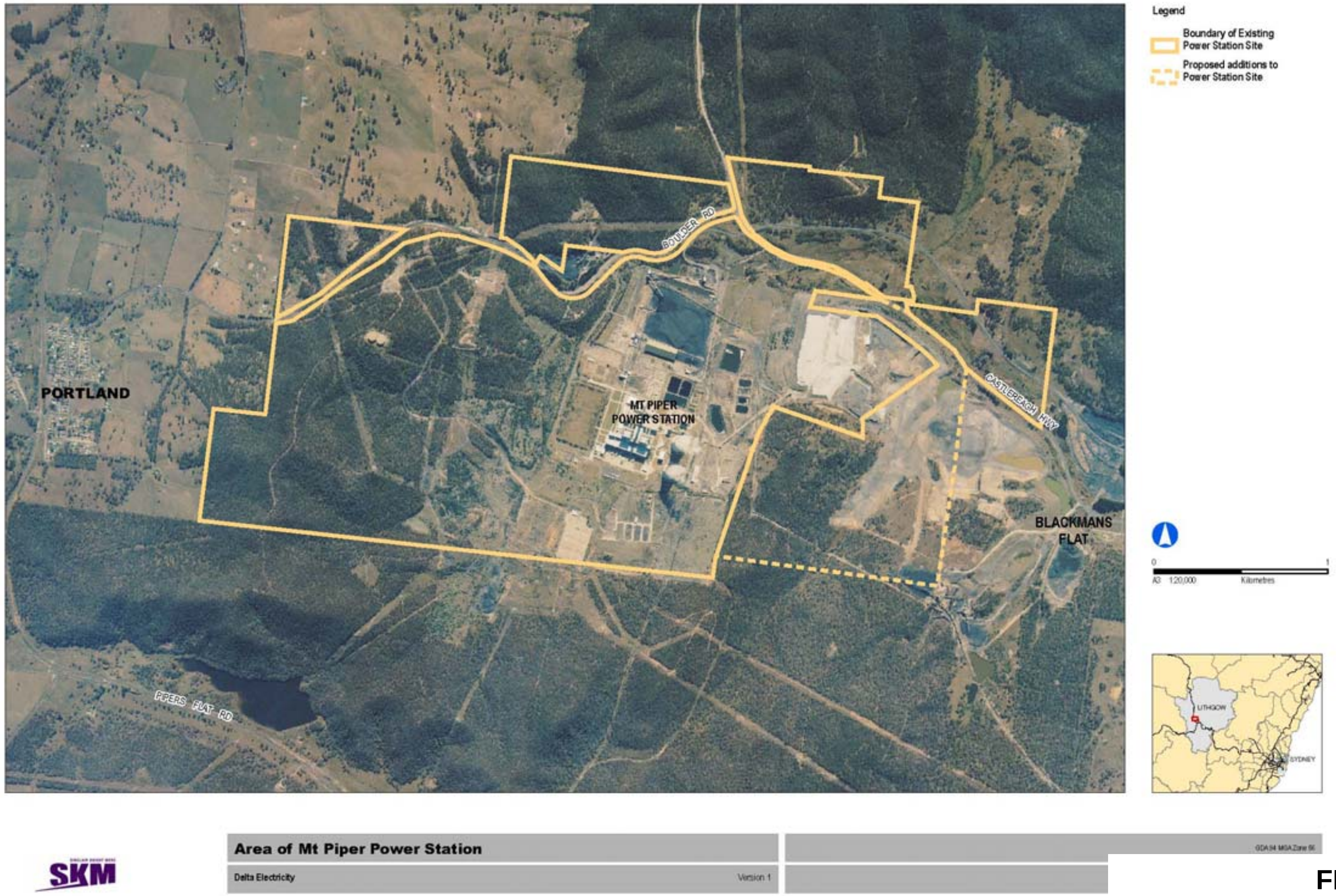

FIGURE 3.2

EXISTING MT.PIPER POWER STATION

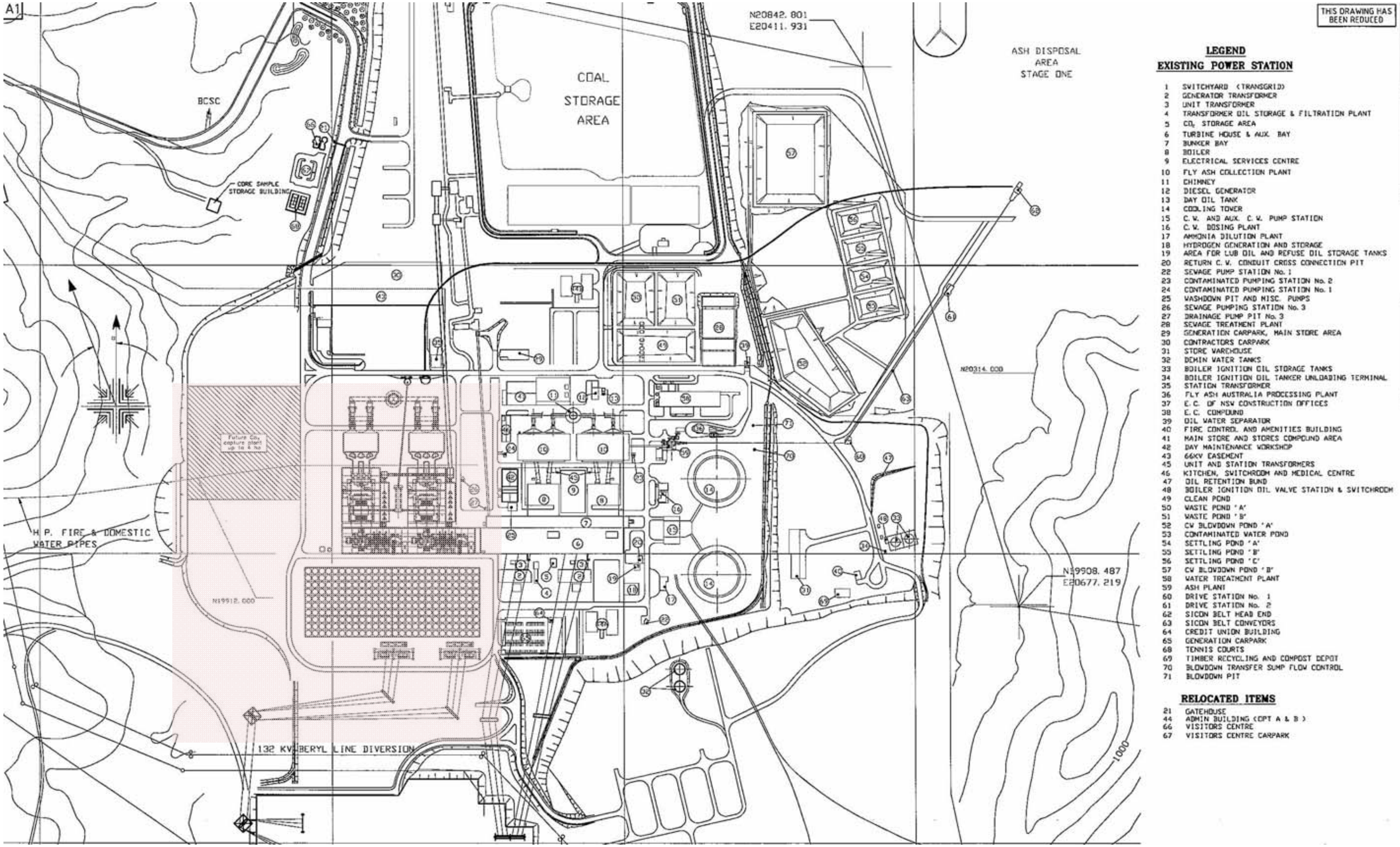

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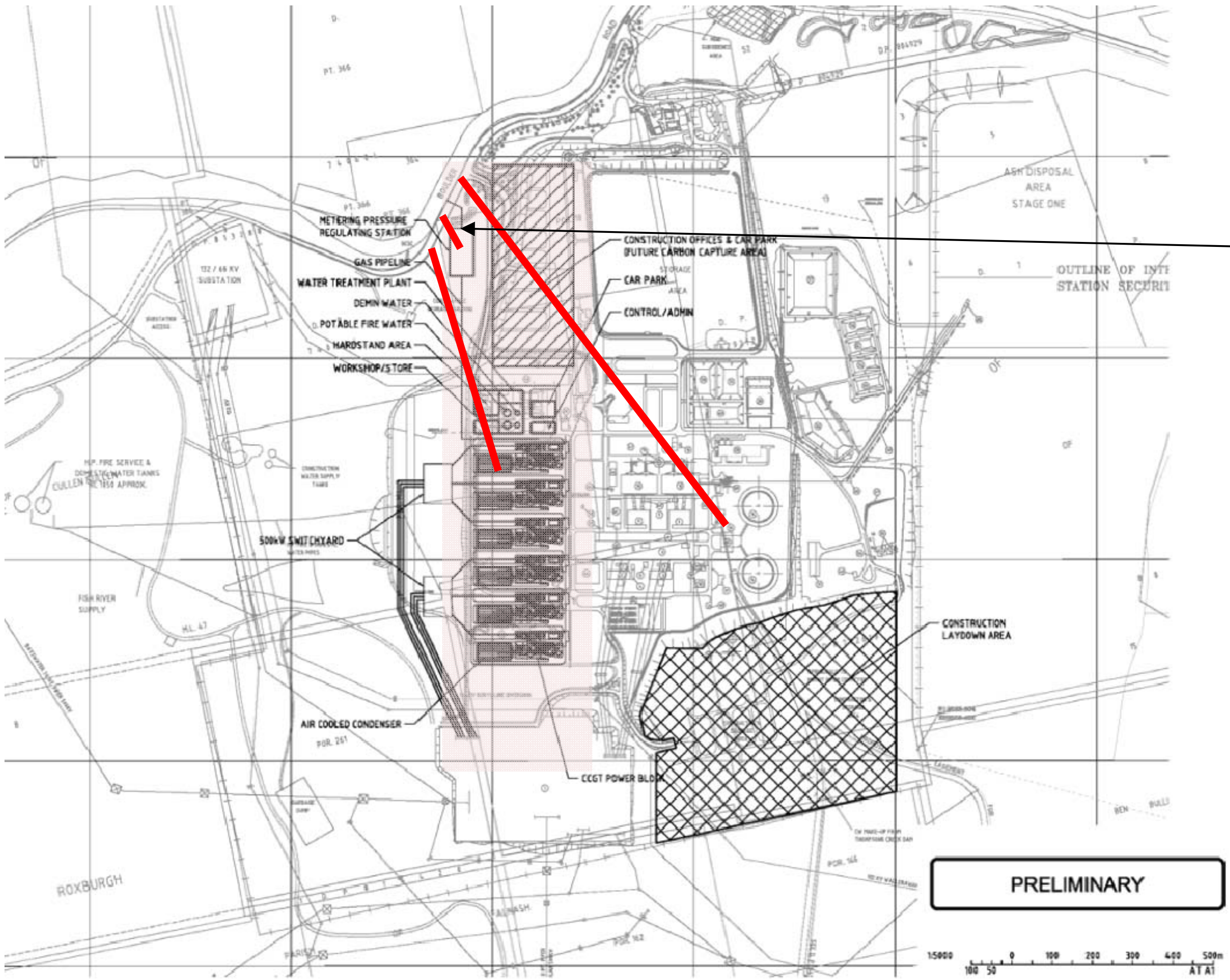
FIGURE 3.3 - EXISTING PLANT AND PROPOSED CFB EXTENSION TO Mt PIPER PS



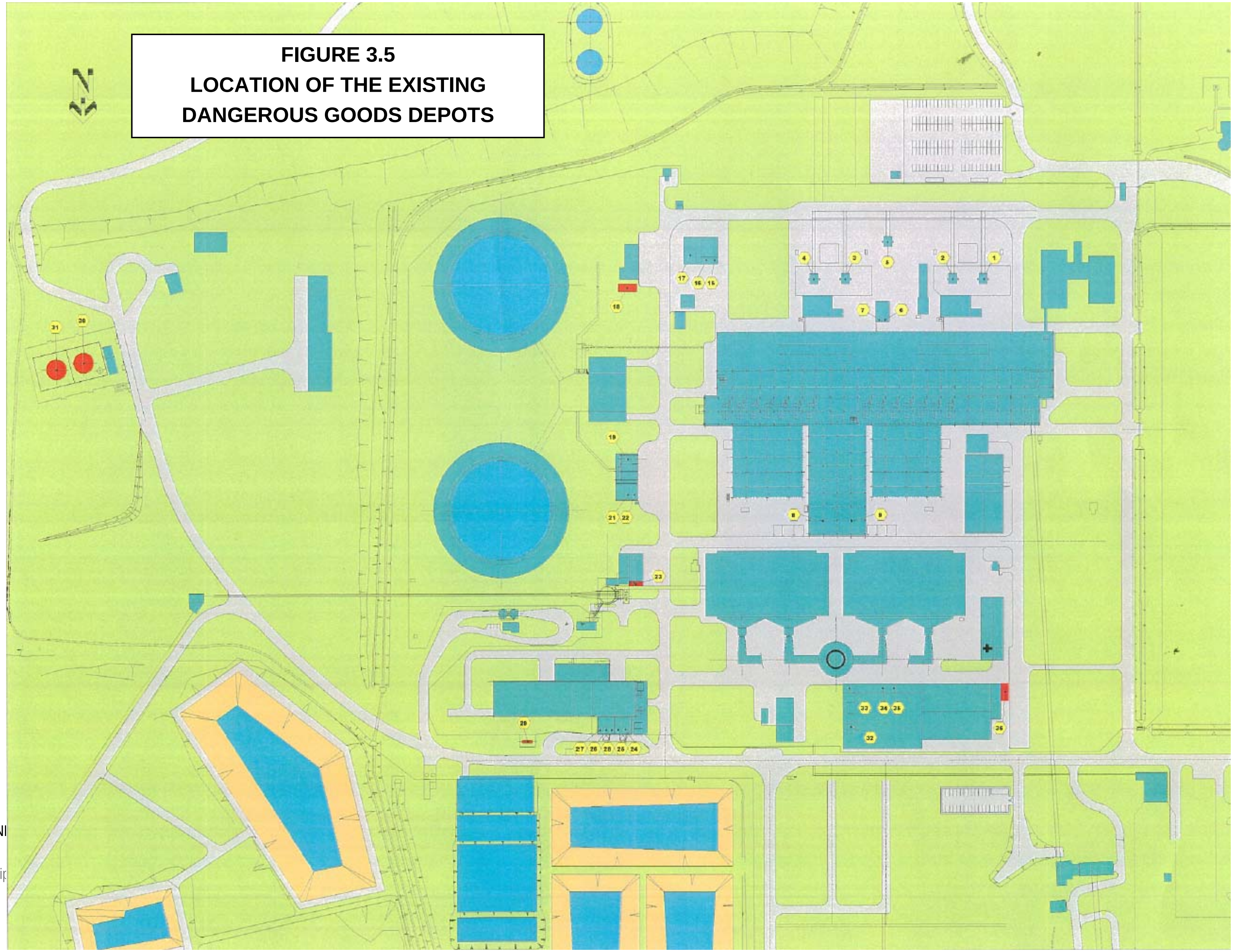
Event 1 – Gas Pipeline rupture (100m to boundary)

Event 2 – Gas Explosion turbine enclosure (500m to boundary)

Event 3 – Chlorine release (900m to boundary)

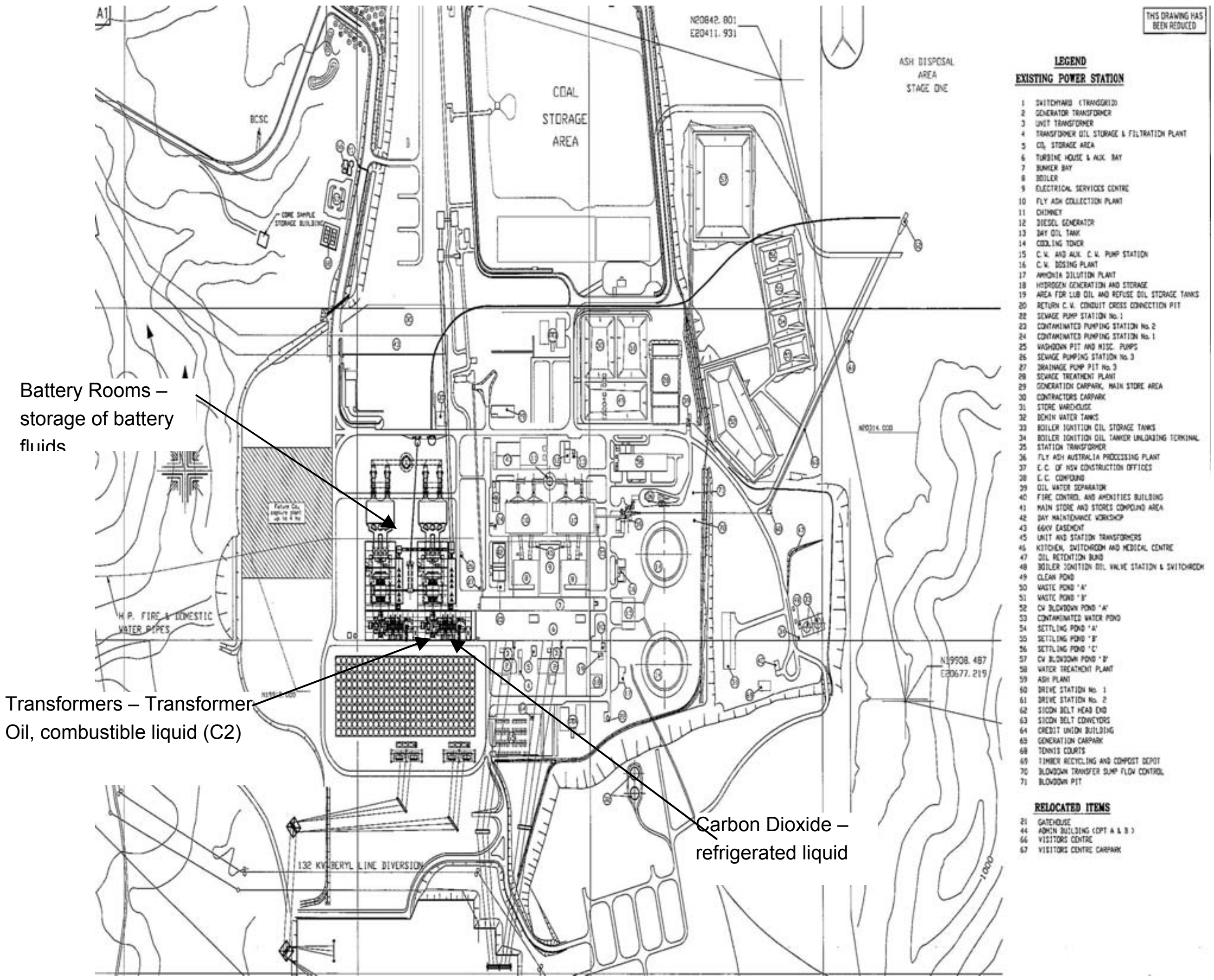
FIGURE 3.4 - EXISTING PLANT AND PROPOSED CC Gas Turbine EXTENSION TO Mt PIPER PS

FIGURE 3.5
LOCATION OF THE EXISTING DANGEROUS GOODS DEPOTS



Note:
See Table 3.1 for Depot details

FIGURE 3.6
LOCATION OF THE ADDITIONAL DANGEROUS GOODS DEPOTS



4. HAZARD ANALYSIS

4.1 General Hazard Identification

A hazard identification table has been developed and is presented at **Appendix A**. Those hazards identified to have a potential impact offsite are detailed in the following section of this document.

4.2 Hazardous Properties of Materials Stored and Used

Tables 3.1 & 3.2 list all the hazardous materials and dangerous goods - existing and proposed - at the Mt.Piper Power Station. **Table 4.1** lists the nature of the Dangerous Goods stored and used at the site to enable an effective hazard analysis to be conducted.

TABLE 4.1
NATURE OF THE DANGEROUS GOODS STORED AND USED AT MT.PIPER POWER STATION

DG Class	Packaging Group*	Chemical Name	Hazardous Nature	Type of Storage
8	III	Sodium Hydroxide	Corrosive alkali, low risk, damaging to the environment, causes visible necrosis of the skin within 1 to four hours of exposure.	Above Ground Tank
8	II	Sulphuric Acid	Corrosive acid, damaging to the environment, causes visible necrosis of the skin within 3 to 60 minutes of exposure, exothermic reaction with water.	Above Ground Tank
8	III	Hypochlorite Solution	Mildly corrosive to metals, liquid chlorine odour, evolves very toxic gases on contact with acid, impact to the biophysical environment.	205 Litre Drums
8	III	Ammonia Solution	Colourless liquid with pungent odour, corrosive to noble metals (zinc, copper, tin, etc.) but low corrosion to steel/iron. Harmful if swallowed or inhaled, vapours corrosive to mucous membranes in nose, throat and eyes. Minor impact to the environment.	205 Litre Drums
C2	-	Transformer Oil / Lubricating Oils	Combustible liquids, burns with significant quantities of smoke, acute environmental contamination of soils, potential for long term environmental impact for large spills, minimal acute impact to people.	Transformer Tanks /Lube Oil Tanks
2.1	-	Petroleum Gas,	Heavier than air flammable gas,	Above

TABLE 4.1
NATURE OF THE DANGEROUS GOODS STORED AND USED AT MT.PIPER POWER STATION

DG Class	Packaging Group*	Chemical Name	Hazardous Nature	Type of Storage
		Liquefied	explodes if ignited in a confined area, burns with a jet fire if a leak is ignited under pressure, burns with flash fire if gas cloud is ignited unconfined. No impact to environment.	Ground Tank (pressure vessel)
2.1	-	Hydrogen Compressed	Very light gas, rises rapidly when release, burns with a clear jet flame if leak is ignited under pressure, difficult to contain and does not readily form a gas cloud.	Cylinders
2.1	-	Acetylene/ Propane	Heavier than air flammable gases, explodes if ignited in a confined area, burns with a jet fire if a leak is ignited under pressure, burns with flash fire if gas cloud is ignited unconfined. No impact to environment.	Cylinders
2.1	III	Natural Gas (methane)	Very light gas, rises rapidly when release, burns with a clear jet flame if leak is ignited under pressure, difficult to contain and does not readily form a gas cloud.	No storage Pipeline only
3	III	Kerosene/ Turpentine/ Gasoline	Flammable liquid, forms a pool if released, pool fire if ignited, acute impact to the environment, potential long term contamination of soil. Irritation if contact with skin.	20L Drums Underground Tank
2.2	-	Caron Dioxide (liquefied)	Non Toxic/Non Flammable heavier than air Gas, asphyxiant gas if forming a cloud. Extremely cold in liquid form.	Refrigerated Above Ground Tanks
2.3	-	Ammonia (anhydrous)	Toxic gas, hygroscopic, severe impact to people in low concentrations, severe damage to mucous membranes (eyes, nose, throat), explosive at concentrations in excess of 27% in air if confined. Low impact on the environment.	30 MT Above Ground Tank
2.3	-	Chlorine	Non-flammable yellow toxic gas, heavier than air, severe impact to	Drums (1700kg)

TABLE 4.1
NATURE OF THE DANGEROUS GOODS STORED AND USED AT MT.PIPER POWER STATION

DG Class	Packaging Group*	Chemical Name	Hazardous Nature	Type of Storage
			people at very low concentrations, detectable by smell at less than 2 parts per million (ppm), fatal at concentrations in excess of 20ppm. Corrosive in presence of moisture, sever impact to mucous membranes (eyes, nose, throat).	
C1	-	Diesel Fuel	Combustible liquid, burns with significant quantities of smoke, acute environmental contamination of soils, potential for long term environmental impact for large spills, minimal acute impact to people.	Above Ground Tanks & Underground Tanks
8	III	Alumn(aluminium sulphate)	Corrosive alkali, low risk, mildly damaging to the environment, causes visible necrosis of the skin within 1 to four hours of exposure.	Above Ground Tank

*Packaging Group indicates risk: I – High Risk, II – Medium Risk, III – Lo Risk

4.3 Detailed Hazard Identification

The following section constitutes a detailed, qualitative hazard identification for those incidents listed in **Appendix A**. Each Dangerous Good has been selected in turn and the potential hazards and safeguards discussed. Where there is a potential for offsite impact the incident was been selected for consequence analysis and carried forward to **Section 5**.

4.3.1 Sulphuric Acid

Sulphuric Acid is stored in a number of locations around the site. Each location is analysed separately below:

- **Batteries** – Two existing battery rooms are located in the Electrical Services Centre and contain a total of around 360 batteries. This facility would be reproduced in the proposed extension project. Batteries are used for uninterruptible power supply (UPS) to the computer and critical systems (e.g. turbine oil pumps, emergency lighting, critical controls, etc.) in the station that must be supplied with power in the event of a "blackout" situation. Batteries are different voltages and sizes and range from 24Volts to 240Volts. Battery fluid is mainly sulphuric acid based. A total of about 360 batteries are stored in each battery room. Battery fluid volumes range from around 25 Litres to 60 Litres. Whilst the battery fluid is contained within the battery cell, there is no hazard. In the event the battery leaks or a spill occurs during battery maintenance (filling) there is a potential for the fluid to escape to drains, releasing off site and impacting the environment. However, the battery rooms are fully bunded and contain an internal drainage system that collects any spills and directs them to a collection and neutralisation pit. The pit uses magnesium carbonate chips to neutralise the acid spill and then discharge the neutralised acid to the site drainage system. The site is fully contained and spills cannot escape beyond the site drainage and pond system. The potential for release of sulphuric acid beyond the confines of the battery room and site is negligible. Hence, this incident has not been carried forward for further analysis as the existing hazard control measures are considered adequate for this section of the plant.

- **Sulphuric Acid Tanks** (Cooling Water Treatment) – Sulphuric Acid is used for the pH control of the cooling water circuit (cooling towers). Two 55,000 litre sulphuric acid tanks are located on the western side of the cooling water towers, between the towers and the main turbine hall at the station. The two tanks are located in a common bunded area. The bund will contain the full contents of one of the tanks in the event of a tank leak. Sulphuric acid is delivered to site in 20,000 litre tankers. The acid is transferred from the tanker to the tank(s) by flexible hose and truck mounted pump. The tank facility is fitted with an unloading bay which is bunded to contain any spills that may occur during the transfer operation. The unloading bay drain runs to a pit which will contain the full contents of the tanker. In addition to the local spill containment, the site is fully contained and all drains report to the site collection ponds. The first flush or holding pond has a freeboard capacity of 10ML (10 million litres). Hence, the potential for offsite release is negligible. This incident has not been carried forward for further analysis as the existing hazard control measures are considered adequate for this section of the plant.
- **Sulphuric Acid Tanks** (Water Treatment Plant) – sulphuric acid is used for pH control in the site water treatment plant located on the northern side of the cooling towers. Two 32,000 litre sulphuric acid tanks are located on the northern side of the water treatment plant. The two tanks are located in a common bunded area. The bund will contain the full contents of one of the tanks in the event of a tank leak. Sulphuric acid is delivered to site in 20,000 litre tankers. The acid is transferred from the tanker to the tank(s) by flexible hose and truck mounted pump. The tank facility is fitted with an unloading bay which is bunded to contain any spills that may occur during the transfer operation. The unloading bay drain runs to a pit which will contain the full contents of the tanker. In addition to the local spill containment, the site is fully contained and all drains report to the site collection ponds. The first flush, or holding pond has a freeboard capacity of 10ML (10 million litres). Hence, the potential for offsite release is negligible. This incident has not been carried forward for further

analysis as the existing hazard control measures are considered adequate for this section of the plant.

4.3.2 Sodium Hydroxide

Sodium Hydroxide is stored in a number of locations around the site. Each storage is analysed in detail below.

- **Sodium Hydroxide Tanks** (Cooling Water Treatment) – Sodium Hydroxide is used for the pH control of the cooling water circuit (cooling towers). A single 15,000 litre sodium hydroxide tank is located between the northern cooling tower and the boilers. The tank is located in a bund, which has the capacity to contain the full contents of the tank in the event of a tank leak. Sodium Hydroxide is delivered to site in 20,000 litre tankers. The alkali is transferred from the tanker to the tank by flexible hose and truck mounted pump. The tank is located adjacent to a site road and the tanker parks on the road, adjacent to the tank, transfers the liquid via a flexible hose. The road area is graded to collect any spills and direct them to a pit, which has the capacity to contain the tanker contents. In addition to the local spill containment, the site is fully contained and all drains report to the site collection ponds. The first flush, or holding pond has a freeboard capacity of 10ML (10 million litres). Hence, the potential for offsite release is negligible. This incident has not been carried forward for further analysis as the existing hazard control measures are considered adequate for this section of the plant.
- **Sodium Hydroxide Tanks** (Water Treatment Plant) – Sodium Hydroxide is used for the pH control in the site water treatment plant. Two 40,000 litre sodium hydroxide tanks are located on the northern side of the water treatment plant. The tanks are located in a common bund, which has the capacity to contain the full contents of one of the tanks in the event of a tank leak. Sodium Hydroxide is delivered to site in 20,000 litre tankers. The alkali is transferred from the tanker to the tank by flexible hose and truck mounted pump. The tank farm, in which the tanks are located, is fitted with a dedicated loading bay which is fully bunded to contain the full contents of the tanker in the event of a spill. In addition to the local spill containment, the site is fully contained and all drains report to the site collection ponds. The first flush or holding pond has a freeboard capacity of 10ML (10 million litres). Hence, the potential for offsite release is negligible. This incident has not been carried forward for further analysis as the existing hazard control measures are considered adequate for this section of the plant.

4.3.3 Alum (Aluminium Sulphate)

Aluminium sulphate (Alum) is used for water treatment on site. The material is stored as a liquid in a single 24,000 Litre tank, which is bunded to contain the full tank contents. Alumn is delivered to site in 20,000 Litre road tankers and is transferred to the tank via a flexible hose and tanker mounted pump.

The tank farm, in which the tanks are located, is fitted with a dedicated loading bay which is fully bunded to contain the full contents of the tanker in the event of a spill. In addition to the local spill containment, the site is fully contained and all drains report to the site collection ponds. The first flush, or holding pond has a freeboard capacity of 10ML (10 million litres). Hence, the potential for offsite release is negligible. This incident has not been carried forward for further analysis as the existing hazard control measures are considered adequate for this section of the plant.

4.3.4 Hypochlorite Solution

Hypochlorite solution is stored in a number of location around the site; each storage depot is assessed in detail below.

- **Hypochlorite Solution Tanks** (Cooling Water Treatment) – Hypochlorite solution for the treatment of cooling tower water is stored in two individual plastic tanks located adjacent to the cooling towers and is used for the pH control in the site water treatment plant. Two 40,000 litre sodium hydroxide tanks are located on the northern side of the water treatment plant. The tanks are located in individual bunds which have the capacity to contain the full contents of each tank in the event of a tank leak. Hypochlorite solution is prepared in the tanks by mixing a concentrated solution of hypochlorite with water. The hypochlorite is loaded to the tanks from 200 litre drums using a drum transfer pump. Water is added to form the required solution concentration. Tank leaks will be contained within the bunded area and will not escape beyond the storage. Spills during the tank mixing operation could occur as a result of a drum leak, dripped drum or transfer hose failure. However, the spill quantity will be limited to a maximum of 200 litres (i.e. maximum drum capacity). Spill in the area adjacent to the cooling tower would fall directly to the ground and spread around the drum handling area. There are no drains located in this area, hence, the spill will not immediately enter the drainage system on site. In the event of rain during a spill the spillage may be carried with rainwater to a drain point, however, the site is fully contained and all drains report to the site collection ponds. The first flush, or holding pond has a freeboard capacity of 10ML (10 million litres). Hence, the potential for offsite release is negligible. Further, the spill of 200 litres into the large capacity ponds would result in dilution to a point where the hypochlorite would not be detectable. This incident has not been carried forward for further analysis as the existing hazard control measures are considered adequate for this section of the plant.

- **Hypochlorite Solution Drums** (Cooling Water Treatment) – Hypochlorite solution used for the preparation of the cooling tower treatment solution is stored in 200 litre drums in a drum store in the main stores compound on the northern side of the site. The drums store is located within the main stores compound and is fully bunded to contain 25% of the capacity of liquids stored in the depot. In the event of a drum leak, the spillage would be fully contained by the bund. The store is fitted with a roof, which prevents the ingress of rainwater into the bund and the potential for overfilling of the bund and escape to the site drainage system. During drum loading and unloading there is a potential for a drum to fall from a truck, resulting in split and spill outside the containment of the depot. In this case there is a potential for liquid to reach drains. However, personnel would be in attendance during drum handling and spill containment equipment is provided in the stores compound. Use of this equipment would minimise the spill quantity. Notwithstanding this, there is a potential for some liquid to enter drains, however, the site is fully contained and all drains report to the site collection ponds. The first flush, or holding pond has a freeboard capacity of 10ML (10 million litres). Hence, the potential for offsite release is negligible. Further, the spill of 200 litres into the large capacity ponds would result in dilution to a point where the hypochlorite would not be detectable. This incident has not been carried forward for further analysis as the existing hazard control measures are considered adequate for this section of the plant.

4.3.5 Ammonia Solution

Ammonia solution is used as a back up for the main ammonia dilution plant in the event of ammonia dilution plant failure or failure of ammonia supply. The ammonia solution is held in drums in the main site storage compound. The storage design and operation is identical to that described above for the hypochlorite solution. The depot is bunded to contain any spills and handling incidents are managed using spill containment equipment. The site is fully contained and spills entering drains report to the site first flush pond (10ML). This incident has not been carried forward for further analysis as the existing hazard control measures are considered adequate for this section of the plant.

4.3.6 Transformer Oil / Lubricating Oils

There are 4 main transformers and a spare transformer on site (total 5), each holding between 78,500 and 135,660 litres of transformer oil. The operating transformer units (4 in number) will be duplicated in the expansion project. In addition should the gas turbine option proceed up to 6 x 20kL Lube oil tanks will be required (one per gas turbine unit).
Transformer oils/ Lube Oils are classified as a C2 combustible liquid by the Australian Dangerous Goods Code (Ref.11) and AS1940-2004 (Ref.10). However, oil is not classified as a Dangerous Good under the NSW Occupational Health and Safety Dangerous Goods Amendment Regulation (2005) (Ref.12).

Notwithstanding this, oil is combustible and if heated and ignited can result in a severe fire which is difficult to extinguish. Whilst contained within the transformer casing the oil presents no hazard, however, in the event of a release, there is a potential for ignition of the oil and fire in the bunded area under the transformers. Transformer casing and pipework leaks may occur in the transformer equipment leading to a loss in oil to the transformer bund. Loss of oil level could result in exposure of internal windings, spark, ignition and fire.

Whilst it is recognised that a low oil level switch is installed in the transformers, and power to the unit will be cut on low level, failure of the switch could lead to ignition of the oil and bund fire. Noting that the transformers bunds are a significant distance from the site boundary, there is little chance that heat radiation will impact beyond the site boundary. For the lube oil tanks associated with the CCGT units the conclusions are the same. However, to confirm this, this incident has been carried forward to the consequence assessment section for further analysis.

4.3.7 Petroleum Gas, Liquefied (LPG)

LPG is stored in a 64,100 litre pressure vessel (tank) located on the northern side of the water treatment plant. The LPG is filled from a 25,000 litre LPG tanker which attends the site once every two years. The LPG is transferred from the road tanker to the vessel via a flexible hose and truck mounted pump. A review of the LPG tank and associated equipment indicated that the facility complies with the requirements of AS1596-2002 (Ref.13). The LPG is used as a fuel supply for a boiler which is used to supply steam to a desalination unit (or brine concentrator). The brine concentrator is used infrequently.

Whilst contained in the tank, the LPG presents little hazard to the surrounding facilities. However, in the event of a leak at flanges, valves, pipework or during vessel filling, the gas may find an ignition source and if ignited after a time may result in a gas cloud explosion, flash fire and/or jet fire at the leak source. Incidents such as these result in heat radiation or explosion overpressure that if impacting people may result in injuries or fatalities.

In the event a jet flame impinges on the vessel side for an extended period, the flame may weaken the vessel structure resulting in premature failure and catastrophic release of gas. As an ignition source is immediately present, the gas expands and burns rapidly. This incident is known as a Boiling Liquid Expanding Vapour Explosion (BLEVE) and would be considered the worst case incident for this vessel. Hence, to determine whether such an incident could have potential offsite impacts the BLEVE scenario has been carried forward for consequence analysis.

4.3.8 Compressed Hydrogen

In the past, hydrogen was manufactured by hydrolysis in a cell plant located on the south east corner of the plant. The hydrogen was compressed and stored in cylinders located on the eastern side of the cell plant. The maximum quantity of hydrogen gas in the cylinders is 2,756m^3 (at Standard Temperature & Pressure or STP). The hydrogen is used in the main generators as a circulating fluid between the generator and heat exchangers. Hydrogen is an effective heat transfer medium for this purpose.

Currently, the hydrogen cell plant is offline and under repair. The aim is to re-commission the cell plant and then place it on stand-by, continuing the current practice of bringing hydrogen to site by tanker truck. The cell plants will be kept on stand-by in the event of interrupted hydrogen supply. In addition to the current cylinder storage, it is proposed to install additional cylinders for hydrogen storage and a 14,000 Litre medium pressure tank for tanker unloading. The tankers will unload the hydrogen into the medium pressure tank, where compressors will transfer the hydrogen to the cylinders.

Whilst the hydrogen is contained within the medium pressure tank and cylinders it presents no hazard. However, in the event of a gas release there is a potential for the gas to ignite, resulting in a jet fire. As hydrogen is a very light gas, and as the tank and cylinders are located externally, the formation of a cloud is highly improbable. The more likely scenario is an immediate ignition and jet fire.

Hydrogen jet fires are intense and invisible. The danger is localised around the leak with heat radiation only projecting a relatively short distance beyond the flame surface. The hydrogen cylinder and tank storage area is located about 620m from the site boundary. Pipework and fittings in the hydrogen storage area are relatively small bore (less than 25mm), hence, hydrogen flame dimensions are limited and it would not be possible for a hydrogen flame, nor the heat radiation from that flame, to reach the site boundary as a result of fires from 25mm diameter pipework.

The location of the hydrogen plant on site provides a significant separation between it and other site facilities. The closest facility on site is the anhydrous ammonia storage area, which is about 35m from the hydrogen storage area. A release of hydrogen from a failure (rupture) of a 25mm hydrogen pipe would not result in a jet flame or heat radiation impact at a distance of 35m. In addition, the area is fitted with a full deluge system, which is activated on flame detection (heat). The deluge provides cooling to the area, preventing potential fire growth by flame impact on adjacent cylinders.

Whilst incidents at the hydrogen plant have been assessed to have little potential to result in impact to adjacent plants, incidents at those plants could affect the hydrogen storage, resulting in cylinder and tank heating from external fire. As noted above, the closest facility to the hydrogen storage is the ammonia tank. Ammonia is generally not considered flammable in the sense that it burns in a jet flame or pool fire. Whilst the gas is explosive in certain concentrations, there is no confinement in the area of the ammonia tank, hence, fire and explosion in the ammonia storage area is not feasible. Hence, there will be no equipment impact from incidents at the ammonia storage on the hydrogen plant.

The risk of incident growth from incidents at the hydrogen storage facility, both on and offsite, is negligible. There is no risk of incident escalation between the hydrogen plant and other plants or as a result of incidents at other plants impacting the hydrogen plant. Hence, incidents in this area have not been carried forward for further analysis, the existing separation distances and safety systems (i.e. deluge) are considered sufficient to maintain the risks in the as low as reasonably practicable (ALARP) range. Notwithstanding this, it is recommended that the existing sprinkler/deluge system, installed over the current cylinder storage, be extended to cover the new cylinder banks and medium pressure storage tank. This will minimise the potential for any incident growth between cylinders/tank.

4.3.9 Acetylene/Propane

Acetylene and propane cylinders are stored in a cylinder store located in the m ain stores compound. The materials are used as fuels (propane) for vehicles on site (i.e. forklift trucks) and for maintenance purposes (acetylene). Whilst the Dangerous Goods licence states the maximum storage quantity as 2000kg, typical storage quantities are much less (100kg of each gas). This equates to about 6 x G size cylinders of each gas. A “G” size cylinder stores about 6m^3 of the gas at STP.

Leaks of gas from stored cylinders may occur around the valves at the cylinder top. Ignition of such leaks would result in a jet flame at the cylinder valve. This flame would be limited in duration as the cylinder stores a finite quantity. Whilst this scenario is feasible, the likelihood is low due to the cylinder store being located in a remote area away from ignition sources and secured by a wire mesh cage. The facility complies with the requirements of AS4332 (Ref.16).

The closest site boundary to this facility is about 650m to the east. Incidents in the cylinder store would have no offsite impact and little if any onsite impact. Incidents in the cylinder store have not been carried forward for further analysis due to the relatively small quantities stored and the separation distances provided by the store location.

4.3.10 Natural Gas Pipeline Release

Natural gas would be delivered to the site via dedicated pipeline and regulated down to around 5 Mpa (50 bar). The gas pipeline would be at least 457mm diameter and would be required to deliver approximately 133PJ per annum to Mt Piper for the CCGT plant operating at a 95% capacity factor.

A Meter Pressure Regulating Station (MPRS) would be located about 100 m from Boulder Rd, at the northwest corner of the site. The Metering Station would comprise dry gas filtering, metering, water bath heating systems (to maintain regulated outlet temperature), pressure regulation to 5MPa (max), pressure and temperature measuring systems, remote isolation systems, control hut to accommodate the communications, computing and auxiliary equipment, pipeline blowdown vent and remote control and monitoring systems.

The inherent hazards of the gas transmission line include the flammability of the natural gas, and the pressure at which it is transmitted and processed in the station. The types of hazardous incident which may occur, in theory at least, would all require a leak in the fitting line or associated equipment (e.g. valves, meters, flanges, etc.). They are:

- fire;
- flash fire; and/or
- explosion.

There is historical evidence of gas transmission pipeline failure both in Australia and overseas. Historical evidence (Bolt, R. & Horalek, V. 2004) indicates that there are a number of factors that can lead to fitting line leak and subsequent release of gas. The details below summarise those incidents that have historically led to fitting line failure and gas release:

- **External Interference** – external interference accounts for the majority of release incidents in gas transmission fitting lines (Bolt, R. & Horalek, V. 2004)). Forklifts, excavators, front end loaders, and other mechanical equipment can strike fitting lines in pipe racks leading to gas release, ignition and jet fire. At this stage of development in the area there are few if any adjacent operations. Hence, there is a low likelihood of external impact. However, as the area develops there is a higher likelihood that excavation or other contact will occur in the area and the pipeline may be affected. The fitting line is internal to the power station and of least 12.7mm wall thickness that will withstand external interference. All work carried out at site will be controlled by a permit system and will be supervised. The pipe rack would be of robust design and would be clear of any through traffic. However, external impact has been carried forward for further analysis.

- **Flood Damage –** this may occur where the fitting line traverses river beds or water courses. The potential for fast running water could lead to scouring above the fitting line exposing the pipe to potential impact from rocks and debris moving in the water stream. In addition, surface flooding could lead to the fitting line floating from the trench, leading to fitting line damage. A review of the fitting line route (shown in Figure 3-3) indicates that the fitting line will be laid away from water courses on the existing Stage A above ground pipe rack corridor. Hence, this hazard has not been carried forward for further analysis.

- **Subsidence Damage** – where fitting lines are installed near or in banks and levees, wash away may expose the fitting line and uneven weight could cause severe fitting line damage. However, the fitting line is not installed in a bank or levee and therefore, incidents resulting from subsidence have not been carried forward for further analysis.

- **External Corrosion Damage** – many soils are acidic and fitting lines installed without external protection are susceptible to corrosion and eventual failure (leaks). The fitting line is not installed underground and hence is not exposed to acidic soils reducing the potential for external corrosion to negligible levels. Incidents involving external corrosion (excluding impact) have not been carried forward for further analysis.

- **Internal Corrosion Damage** – the introduction of corrosive gas to the fitting line could result in accelerated corrosion or moisture in the gas could lead to corrosion impact on the pipe internal surface. However, gas is fed from the EGP and the gas is dry and non-corrosive, having passed over 1000kms through this line. Hence, the likelihood of corrosion from this source is considered negligible. Incidents as a result of corrosion have therefore not been carried forward for further analysis.

- **Faulty Material** – the use of faulty materials, such as fitting line with manufacturing defects, could lead to premature fitting line failure resulting in rupture. However, pipe material will be purchased from a quality assured organisation (i.e. ISO9001, AS (2004c), which minimises the potential for faulty materials. Further, the fitting line will be fully tested in accordance with the requirements of AS2885 (AS 2007), including a pressure test to prove fitting line will operate safely and without failure at maximum allowable operating pressure (MAOP). The quality assurance testing regime required under AS2885 minimises the potential for fitting line failure as a result of material defects. Hence, these potential incidents have not been carried forward for further analysis.

- **Faulty Construction** – like the faulty materials incidents detailed above, faulty construction can also lead to failure of the fitting line. For example, faulty welding can lead to premature failure and gas release. However, fitting line welds will be subjected to X-Ray inspection minimising the potential for failure from this source. Further, the fitting line will be subjected to a testing regime required by AS2885 (AS 2007), further minimising the potential for faulty construction failure. Additional construction problems, such as poor support or alignment in the pipe rack will be minimised by strictly following the requirements of AS2885 (AS 2007). Hence, incidents as a result of faulty construction have not been carried forward for further analysis.

- **Ground Movement** – this may occur where fitting lines are installed in an earthquake zone. Earthquakes and excessive ground movement may lead to damaged pipe racks and buckled pipework or, in the worst case, rupture. However, the fitting line would not be installed in an earthquake zone. The Lithgow area is relatively stable and earthquakes of the magnitude that could result in fitting line rupture are rare and, hence, the risk is considered negligible. Incidents as a result of earthquake of excessive ground movement have not been carried forward for further analysis.

- **"Hot Tap" by Error** "– "hot tap" is the connection to a live gas line during operation. When this is conducted by expert personnel the risk is negligible. However, failure to identify a live gas fitting line and attempts, by error, to connect to this fitting line could lead to fitting line breach and gas release. To identify gas fitting line, marker signs will be installed on the fitting line in accordance with AS2885.1. This incident has, therefore, not been carried forward for further analysis.

The above analysis is supported by the results of studies conducted by the European Gas Pipeline Incident Data Base (Bolt, R. & Horalek, V. 2004), which conducts research into gas pipeline incidents both in Europe and overseas. The results of these studies indicate that the majority of pipeline incidents (50%) occur as a result of external interference.

However, it is noted that natural gas is lighter than air (i.e. a buoyant gas) and if released tends to rise and disperse rather than accumulate forming a flammable cloud.

4.3.11 Natural Gas Release in the Gas Turbine Enclosure

Natural gas fuel, supplied by a fitting line from the main supply line, would be used to supply the gas turbines. The fuel is piped internally within the turbine enclosure and, hence, any leaks of gas would have the potential to accumulate within the enclosure resulting in the formation of a flammable gas cloud. Ignition of such a cloud could result in explosion and significant damage to the enclosure as well as offsite impact from explosion overpressure and/or “missiles” projected from the destruction of parts of the enclosure.

To minimise the potential for such an incident, the gas turbine enclosure will be fitted with ventilation, which will continually provide air exchange within the enclosure. Hence, any leaks will be diluted to below lower flammable limits (LEL) and discharged from the enclosure. Further, the enclosure will be fitted with a hydrocarbon detector, which will activate level alarms and initiate gas turbine fuel supply shut down (from outside the enclosure). Hence, any leaks will either be diluted and or isolated before reaching potentially hazardous levels.

Notwithstanding the fact that detection and protection measures would be installed, in the event such measures fail, there is a potential for an explosion within the enclosure and jet fire at the leak source. Hence, explosion and fire incidents at the gas turbine enclosure have been carried forward for further analysis.

4.3.12 Kerosene/Turpentine

Kerosene and turpentine are used on site for maintenance purposes (i.e. paint thinners, etc.). They are stored in a variety of containers in the flammable liquids store located in the main stores compound. The flammable liquids are stored in a dedicated Dangerous Goods store which is bunded and separated from the surrounding storages to prevent the potential for incident growth to adjoining storages.

The maximum quantity of flammable material stored in the flammable liquids depot is listed as 3000 Litres, although typical quantities are 200 litres or less. A leak of flammable liquid in the storage area will be contained within the bund and will not escape beyond the immediate confines of the store. Ignition of leaks would lead to a fire in the store, but the limited quantity of stored materials (200 Litres) would not result in a severe fire. The separation of the store from the surrounding dangerous goods storage areas in the main stores compound (i.e. cylinders store, ammonia solution, hypochlorite solution, etc.) exceeds 5m and fires in the flammable liquids store would not grow to or involve adjacent storages. Further, incidents at the flammable liquids store would not have any impact on offsite areas. Hence, this incident has not been carried forward for further analysis.

4.3.13 Gasoline

Gasoline is used for fuelling site vehicles and is stored in a 32,000 litres underground storage tank. Fuel is delivered to site in 20,000 Litres road tankers. Incidents involving underground tanks are limited, as the fuel is stored away from potential external impact. The major hazard occurs during the transfer of fuel from the tanker to the tank. The tanker is located over the filling point and the tanker delivery connection is joined to the underground tank filling point by a flexible hose. The tanker driver/operator then transfers the fuel to the tank by gravity.

In the event of a hose failure, fuel may leak into the area surrounding the tanker/filling point. As a tanker driver will be present during the operation, transfer can be stopped immediately, preventing further leak and pool formation. An error by the tanker driver may also occur such that the truck is driven away whilst still connected, however tankers are fitted with driveaway protection in the form of a bar across the loading connections. The bar must be moved down to access the connection, which in turn applies the truck brakes, preventing driveaway.

A spill from a hose would be minimal and would be collected in the site drainage system, reporting to the site first flush pond (10ML). There would be no impact offsite as a result of a spill in the gasoline delivery area. In the event of an ignition of a spill a pool fire would form and radiate heat to the area surrounding the spill. As indicated above, the spill would be limited and would consist mainly of the hose contents.

This incident has been carried forward for further analysis to determine whether a fire at the underground gasoline tank loading area could impact offsite facilities.

4.3.14 Diesel Fuel

Diesel fuel is held at the station in two locations; underground storage tanks (2) and above ground tanks.

The diesel fuel stored in the two x 1.2ML above ground tanks is used for boiler start-up from a “cold start” condition. The tanks are located close to the eastern boundary of the site and are fully bunded in individual bunds, each bund with the capacity to contain the full tank contents.

Leaks of fuel from the tanks or associated pipework will be contained within the bunded area and will not be released into the site drainage system. However, ignition of leaks in the bund would result in a bund fire, which would radiate heat to the surrounding area. The tanks are located about 40m from the site boundary, and fires may have an impact offsite in this area.

The diesel fuel is pumped to the power station buildings via underground pipework. In the event of a pump leak, the fuel will be retained in the pump bunded area. However, in the event the leak continues, the pump bund may overflow resulting in diesel fuel spill to the drainage system. The fuel spill would then report to the first flush pond where the spill would be contained. As the first flush pond is 10ML in capacity, there would be more than sufficient quantity of storage in this area to eliminate the potential for offsite release.

Notwithstanding this, there is a potential for fire at the diesel storage, which could impact offsite. Hence, this incident has been carried forward for consequence analysis.

Diesel fuel stored in the underground tanks, located adjacent to the main stores area, is used for fuelling vehicles and as a fuel supply for the site generator. The hazards of diesel fuel stored in underground tanks are the same as those detailed in **Section 4.3.11** for gasoline. Hence, the results of the assessment conducted in **Section 4.3.11** can be applied to the diesel fuel storage and handling risks. Diesel storage handling risks have therefore not been carried forward in this study.

4.3.15 Ammonia (anhydrous)

Anhydrous Ammonia is stored in a pressurised above ground steel tank (vessel) located on the western side of the main cooling towers (between the towers and the turbine halls) on site. A review of the ammonia system indicated that the facility complies with the requirements of AS2022-2003 (Ref.14). The tank stores a maximum of 30,000kg or 44,000 litres and is filled by a 20-25 tonne road tanker once every 12 months.

A dedicated filling point adjacent to the tank (western side) is installed, which incorporates dedicated filling lines, a filling connection and Armco protection around the filling points. A concrete driveway, off the main site road, is also provided for location of the trucks during the tank filling operation. A dedicated ammonia delivery driver/operator is used for the deliver transfer operation. The driver connects the flexible delivery hose from the tanker to the filling point and the liquid anhydrous ammonia is transferred by pump to the tank.

The plant uses the ammonia for water treatment. Gaseous ammonia is drawn from the top of the tank and is delivered to the water treatment (addition) facilities by 50mm pipeline. The pipeline initially runs from the top of the tank into a dosing building adjacent to the plant (on the southern side). Pipework also runs underground from the ammonia tank to the turbine building (ground floor) where it is dosed to water tanks.

Whilst contained within the tank and pipework system the ammonia does not present a hazard. However, the gas is toxic and in the event a release occurs, there is a potential for the gas to form a cloud. Injury of fatality may occur where personnel are exposed to high concentrations of the gas. An ammonia gas cloud could be carried downwind and impact areas offsite at concentrations that could result in injury of fatality.

As the ammonia is stored under pressure in liquefied form, releases will evaporate and eventually return to the gaseous state, hence, there will be no impact to the environment around the storage area.

As there is a potential for offsite impact to people from this incident it has been carried forward for consequence analysis.

4.3.16 Chlorine

Chlorine is stored in 1700kg drums in a dedicated chlorine storage building on the western side of the cooling towers at the site. Four drums are delivered to site once every ten days. A review of the chlorine storage indicated that the facility complies with the requirements of AS2927-1002 (Ref.15). Chlorine is used for water treatment (control of marine growth) and is dosed to the water cooling circuit. There are two sets of four drums each, each set connected to a manifold, which delivers the chlorine to the water dosing system. Only one set of four drums is connected to the plant at any one time. As the chlorine is used and the drums empty in one set, the second set is automatically brought on line. The change-over is triggered by a low chlorine flow.

Once a set of drums is empty, the manifold is automatically isolated and an alarm raised in the plant control room, notifying the operators of the need to order a new set of drums. Drums are delivered to site by flatbed truck from Orica in Sydney. The drums are lifted from the truck using the overhead monorail crane arrangement. The trucks draw alongside the delivery area and the mono-rail is used to lift the empty drums from the plant to the truck and then install the new drums.

Whilst the chlorine is contained within the drums and pipework it does not present a hazard. However, the gas is toxic and in the event a release occurs, there is a potential for the gas to form a cloud. Injury of fatality may occur where personnel are exposed to high concentrations of the gas. A chlorine gas cloud could be carried downwind and impact areas offsite at concentrations that could result in injury of fatality.

As the chlorine is stored in liquefied form under pressure, releases will eventually evaporate and return to the gaseous state, hence, there will be no impact to the environment around the storage area.

As there is a potential for offsite impact from this incident it has been carried forward for consequence analysis.

4.3.17 Carbon Dioxide

Carbon dioxide is stored in two refrigerated liquid tanks, each of 6,500 Litre capacity. The tanks are located on the southern side of the turbine hall building, adjacent to the transformers. The expansion project will require an additional two tanks of equal capacity and design to the existing tanks. These will be located in the same configuration in the expanded site as the existing storages. The tanks are double walled to ensure the refrigerated nature of the gas is maintained. Carbon Dioxide (CO_2) is not a toxic gas, but significant release quantities may exclude oxygen, resulting in the potential for an asphyxiating atmosphere to be present.

As the CO_2 is stored as a refrigerated liquid, releases (both from the static tank and during tank filling) will not result in an immediate and massive expansion of gas. Refrigerated liquid will release and form a pool under the release point. The liquid will then absorb the heat from the surrounding area releasing CO_2 gas at the liquid surface.

As CO_2 is heavier than air, the gas will disperse slowly and be dissipated by air movements and wind. As the closest site boundary is over 700m from the CO_2 tanks (including the new storage tanks) the likelihood of impact at the site boundary is low. This incident has not been carried forward for further analysis as the risk of offsite impact is low and there will be minimal environmental impact (as a result of an accidental release) as CO_2 is a normal constituent of air.

4.4 Assumptions Made in the PHA Review Study

As the PHA study is preliminary in nature, many of the detailed designs are not yet complete. Hence, the PHA study has made a number of assumptions in order to complete the analysis, these include the effectiveness of the fire safety and gas detection systems, the construction of the facility and adequacy of the location of the safety systems, the operability of the equipment and interaction with operators on site and the central control room, response to emergencies (both when the site is staffed and un-staffed) and adequacy of control systems (hardware and software).

As plant design firms, it will be necessary assess the effectiveness of the proposed designs in relation to the PHA assumptions. It is therefore recommended that the following studies be completed as part of the ongoing assessment prior to commencement of operations:

- Hazard and Operability Study, in accordance with HIPAP No.8 (DoP 1995a) - on completion of the final system design;
- Fire Safety Study, in accordance with HIPAP No.2 (DIPNR 1992d) - prior to commencement of operations;
- Emergency Response Planning in accordance with HIPAP No.1 (DIPNR 1992e) - prior to commencement of operations;
- Final Hazard Analysis (DIPNR 1992b) – on completion of final design and prior to commencement of operations;
- Safety Management System assessment in accordance with HIPAP No.9 (DIPNR 1992f) - prior to the commencement of operations; and
- Hazard Audit within 12 months of commencement of operations in accordance with HIPAP No.5 (DoP 1995b).

4.5 Incidents Carried Forward for Consequence Analysis

The following incidents have been identified to have the potential to impact offsite:

- Transformer fire;
- Gasoline fuel spill during transfer to underground tanks and fire;
- Diesel fuel spill and bund fire;
- LPG tank BLEVE;
- Ammonia releases;
- Chlorine releases;
- Natural Gas pipeline release and jet fire;
- Gas Turbine Enclosure Explosion Risk.

These incidents have been carried forward for consequence analysis and have been subjected to a detailed analysis of impacts in **Section 5**.

5. CONSEQUENCE ASSESSMENT

5.1 Incidents Carried Forward for Consequence Assessment

The hazardous analysis conducted in Section 4 identified a number of hazards that have the potential to impact upon adjacent offsite areas. These incidents have been carried forward for consequence analysis to determine whether incident impacts have the potential to exceed consequence criteria published in HIPAP No.4 (DIPNR 1992c). Those incidents carried forward for consequence analysis are:

- Transformer fire;
- Gasoline fuel spill during transfer to underground tanks and fire;
- Diesel fuel spill and bund fire;
- LPG tank BLEVE;
- Ammonia releases;
- Chlorine releases;
- Gas fitting line incident leading to gas leak as a result of external interference and jet fire (i.e. impact or other contact with machinery or plant);
- Gas leak into the gas turbine enclosure, ignition and explosion.

Each incident is assessed in detail in Appendix B. Each incident may occur as a result of a number of scenarios, the worst case scenario in each area was assessed in details and the potential for impact offsite reviewed. Where the incident was identified to have no offsite impact, it was not carried forward for further assessment. Where an incident was identified to have a potential for offsite impact it was carried forward for frequency and risk assessment. A summary of each incident, including assessment results, is presented in the following sections.

5.2 Transformer Fire

Transformers are located on the southern side of the main turbine hall. Each transformer is located in its own bunded area, with the capacity to contain the full contents of the transformer. In the event of a transformer leak, the contents of the transformer (oil) will spill to the bund and be contained. However, as the oil level falls in the transformer there is a potential for the windings to become exposed resulting in overheating, sparking and ignition of the oil. Whilst it is recognised that a low level oil switch is fitted to the transformer (Buckholz switch), which cuts power to the unit in the event of a low oil level, in the event this switch fails and the oil is ignited, a bund fire will result.

The transformer bund dimensions (length by width) are 17m x 17m, hence, in the worst case scenario the bund would be full of oil resulting in a full bund fire. It is noted that each transformer is fitted with a deluge system which would activate in the event of a fire mitigating the heat radiation within the bund and protecting the remaining transformer components. However, heat radiated beyond the bund has the potential to impact adjacent equipment and offsite areas. Notwithstanding the fact that the distance to the closest site boundary from the transformers is in the order of 600m, to demonstrate that there will be limited heat radiation impact a pool fire analysis was conducted. The detailed analysis is presented in **Appendix B**. A summary of the results of the analysis are presented in **Table 5.1**.

TABLE 5.1
HEAT RADIATION IMPACT FROM A TRANSFORMER BUND FIRE

Heat Flux (kW/m^2)	Distance to Heat Flux (m)*
23	13.7
15	16.6
12.5	18.2
10	20.2
8	22.6
6	26
4.7	29.4
2.1	44.5
1.2	60

* Distance is calculated from the centre of the bund

It can be seen that at 60m there is a very low impact of heat radiation. This distance is well within the site boundary and there is no impact offsite.

The distance from the transformer bund closest to the main turbine hall building is about 10m and, from the bund centre, the distance is 18.5m. The heat radiation impact at this distance is 12.5kW/m^2. The adjacent turbine hall building is constructed from steel sheet over steel framework and at a level of 15kW/m^2 there is a potential for weakening of the structure over an extended period of time (Ref.18). However, at 12.5kW/m^2, the potential for weakening of the structure in the turbine hall is diminished and, although there may be signs of heat damage to the adjacent structure, there would be no potential for building collapse and incident escalation to the adjacent turbine hall.

As there is no potential for offsite impact or onsite incident growth, this incident has not been carried forward for further analysis.

5.3 Gasoline Fuel Spill and Fire

In the event of a fuel spill, whilst filling the gasoline underground storage tank, the spill will collect in the spoon drain located adjacent to the tanker unloading area. A speed-hump style bund is provided on the southern side of the filling point to prevent fuel running in this direction. The drain is about 2m wide and runs north from the filling point to a site drain (about 8m). Hence there would be an area 2m wide by 8m long which if ignited would form a pool fire. Heat would be radiated to the surrounding area with the potential for impact on adjacent structures (the main store).

A detailed consequence analysis has been conducted in **Appendix B**. The results of the analysis are presented in **Table 5.2**.

TABLE 5.2
HEAT RADIATION IMPACT FROM A GASOLINE FUEL SPILL FIRE

Heat Flux (kW/m^2)	Distance to Heat Flux (m)
35	6
23	7.3
15	8.9
12.5	9.7
10	10.8
8	12
6	13.7
4.7	15.5
2.1	23
1.2	29

It can be seen that at 29m there is a very low impact of heat radiation. This distance to the site boundary is about 350m and therefore the incident is contained well within the site boundary and there is no impact offsite.

The distance from the centre of the pool fire (fuel spill) to the adjacent main stores building is about 9m. The heat radiation impact at this distance is 14.5kW/m^2. The adjacent main stores building is constructed from steel sheet over steel framework and at a level of 15kW/m^2 there is a potential for weakening of the structure over an extended period of time (Ref.18). However, at 14.5kW/m^2, the potential for weakening of the structure in the turbine hall is diminished and, although there may be signs of heat damage to the adjacent structure, there would be no potential for building collapse and incident escalation to the adjacent turbine hall.

As there is no potential for offsite impact or onsite incident growth, this incident has not been carried forward for further analysis.

5.4 Diesel Fuel Spill and Bund Fire

In the event of an ignited diesel spill into the bund, surrounding the diesel tanks, a bund fire would result. The heat would radiate into the areas surrounding the bund and may project offsite as the site boundary at this point is only 40m from the bund edge.

A detailed consequence analysis has been conducted in **Appendix B**. The results of the analysis are presented in **Table 5.3**.

TABLE 5.3
HEAT RADIATION IMPACT FROM A DIESEL FUEL BUND FIRE

Heat Flux (kW/m^2)	Distance to Heat Flux (m)
23	16.6
15	20.1
12.5	21.9
10	24.4
8	27.1
6	31.4
4.7	35.4
2.1	52.8
1.2	69.5

It can be seen that at 35.4m the heat radiation level is $4.7kW/m^2$. HIPAP No.4 (Ref.19) states that levels of heat radiation in excess of $4.7kW/m^2$ at the site boundary exceed the permissible risk criteria and the site could be classified as hazardous. However, the Diesel fuel tanks are located 40m from the site boundary and, hence, heat radiation at $4.7kW/m^2$ is contained within the site boundary, therefore in the worst case incident the risk criteria are not exceeded at these tanks.

The closest structures to the diesel fuel tanks are the concrete cooling towers. These are located over 200m from the diesel storage tanks. There will be no heat radiation impact on the closest adjacent buildings on site. Hence, there will be no potential for fire growth to other areas of the site from fires at the diesel storage tank.

As the risk criteria at the site boundary is not exceeded for this incident and as there is no potential for onsite incident growth, this incident has not been carried forward for further analysis.

5.5 LPG Tank BLEVE

In the event of an ignited gas release from a flange adjacent to the LPG tank, the resultant jet flame could impact the tank and after a time cause weakening of the tank shell. This could lead to premature tank failure and release of the gas boiling gas in the presence of an ignition source. The resultant expanding gas will burn causing a fireball (or BLEVE).

Whilst the gas tank is located well clear of the boundary (over 600m) it is necessary to demonstrate that such an incident would not impact beyond the site boundary, as it is well documented that BLEVEs can create large diameter fire balls. To calculate the magnitude and duration of the BLEVE the following formulae are used:

$D = 6.48\ (M)^{0.325}$ (metres)

$T = 0.852\ (M)^{0.26}$ (seconds)

Where M = the mass of liquefied gas remaining in the vessel at the point of vessel failure

A BLEVE detailed analysis is conducted in **Appendix B**. The results of the analysis indicate that the fireball diameter will be 147m and the duration of the fireball 10.2 seconds.

Hence, the fireball impacts up to a distance of 73.5m from the LPG tank. This would impact the adjacent water treatment plant to the south and corrosive goods storage tanks to the west. However, there will be no offsite impact as the site boundary is over 600m to the east.

Noting that the BLEVE does not have a percussive impact, there will be little explosion damage to adjacent facilities. Hence, fire impact is the only potential hazard from the BLEVE. In addition, once the fuel has been consumed, the fire ball diminishes and extinguishes. Hence, steel structures, such as the water treatment building will not be severely damaged by the incident. Whilst the structure may be heat damaged, the likelihood of incident growth to the sheet steel walls is low.

The corrosive goods tanks contain a large quantity of liquids at ambient temperature. Hence, a short duration fire impact (i.e. for 10 seconds) would not cause tank failure. Whilst there may be some external fire damage to the tank paintwork, tanks would not be breached as a result of the BLEVE incident.

As there is no potential for offsite impact and limited risk for incident growth on site. Incidents at the LPG storage have not been carried forward for further analysis.

5.6 Ammonia Storage and Handling Incident Consequences

Anhydrous Ammonia is stored in liquefied form in a tank (pressure vessel). The tank is located on the western side of the main site cooling towers, between the towers and the main turbine hall/boiler building. This is an existing facility and will not be duplicated as part of site expansion project.

During normal operations the ammonia is contained within the tank and associated pipework. However, a release may occur as a result of tank or line corrosion, gasket failure, or transfer operation incident. A number of postulated release incidents at the ammonia tank are listed below:

- Pipeline corrosion – external/internal corrosion leading to a hole in the pipework;
- Gasket failure – gasket or joint material splits leading to a release at the flange;
- Weld failure (corrosion) on the vessel – crack in the weld leading to a release at the vessel nozzle;
- Transfer hose split – wear on the hose leading to release at a point along the hose length; and
- Driveaway whilst connected – operator drives away from the delivery point whilst still connected by the flexible hose.

Of the above incidents a number have been eliminated as negligible risk due to the operating age of the facility, these are:

- Driveaway whilst connected – delivery trucks are fitted with driveaway protection. The truck transfer point connections are fitted with a drop down bar, which activates the truck brakes when the bar is lowered to access the fill connection. Hence, this scenario is eliminated from the assessment.
- Weld failure on the vessel – the ammonia vessel has been operating successfully for nearly 20 years without sign of leak or failure. Vessel inspections are conducted as part of the site maintenance program and regulatory requirements, hence, the likelihood of failure of the vessel as a result of weld or shell corrosion is very low.

The incidents most likely to occur are pipeline failure, gasket/joint failure or transfer hose failure. A detailed consequence analysis for an ammonia release has been conducted in **Appendix B**.

A conservative concentration level of 1000ppm (ERPG-3), and 250 ppm (ERPG-2) of ammonia was selected as concentrations of interest to determine whether there is a potential for impact at the site boundary (i.e. fatality or injury). The results of this analysis show that the maximum downwind distance for a concentration level of 1000ppm of ammonia is 320m.

The site boundary is located over 600m from the ammonia storage and hence, there is no potential fatality impact offsite as a result of the postulated incidents at the ammonia storage.

The concentrations at the boundary (600m away) under daytime (D3) and night-time (F1) conditions are 140ppm and 460ppm respectively. Hence there is no fatality potential (fatality risk) for offsite impact from the postulated ammonia releases at the station, and therefore this incident has not been carried forward for further analysis.

5.7 Chlorine Storage and Handling Incident Consequences

Chlorine is stored in liquefied form in a drum. The drum storage is located on the western side of the main site cooling towers, between the towers and the main turbine hall/boiler building. This is an existing facility and will not be duplicated as part of site expansion project.

During normal operations the chlorine is contained within the drums and associated pipework. However, a release may occur as a result of drum or pipeline leak, joint failure, or transfer operation incident. A number of postulated release incidents at the chlorine storage are listed below:

- Drum failure – external/internal corrosion leading to a hole in the drum;
- Joint failure –joint material splits leading to a release at the joint;
- Pigtail line failure – crack in the small bore pipeline leading to a release from the line connecting the drum to the plant;
- Manifold Failure – corrosion of the manifold leading to hole and chlorine release; and
- Dropped drum – drum is dropped during unloading leading to drum split and release;

Of the above incidents a number have been eliminated as negligible risk due to the equipment design, these are:

- Dropped Drum Incident – chlorine drums are specifically manufactured for the storage and transport of chlorine. Drums are designed to withstand being dropped from typical heights associated with delivery vehicles. A drum dropped from the top of a flatbed truck has been designed and tested to withstand the drop loads and will not fail under these circumstances. Drum valves are located inside the concave ends of the drum and are protected by a valve cover. Based on these facts, this incident has been eliminated from the assessment.
- Drum Failure (corrosion) – chlorine drums are owned and managed by Orica, the chlorine supplier. Each drum is a registered item in the Orica organisation and is tracked by a drum management system. Drums are regularly inspected and tested to ensure their integrity. Discussion with Orica (Ref.5) indicates that there have been no drum failure incidents as a result of corrosion or leak. Hence, this incident has been eliminated from the assessment due to the low risk potential.
- Joint failure – chlorine pipework and joints are all metallic design (nut and tail joints). There are no gasket materials used in the joints and, hence, leaks via gaskets are eliminated. Whilst leaks may still occur these are minimal and are minor in comparison to other postulated incidents. Minor releases from metallic style joints would not result in the formation of a gas cloud that would impact offsite areas. Hence, this incident has been eliminated from the analysis.

The incidents most likely to occur are manifold leak and pigtail failure. A detailed consequence analysis has been conducted in **Appendix B**. Concentration levels of 20ppm (ERPG – 3 levels are the max airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects) and 3-5ppm (injurious ERPG-2 - levels are the max airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individuals ability to take preventative action) of chlorine were selected as a concentration of interest to determine whether there is a potential for impact at the site boundary (i.e. fatality or injury). The results of this analysis show that the maximum downwind distance for a concentration level of 20ppm of chlorine is 558m under F1 (night-time wind /stability conditions) and for a concentration level of 3-5ppm of chlorine is 1,558ppm.

The site boundary adjoining Boulder Rd is located over 900m from the chlorine storage areas and hence, there is no fatality impact offsite (as ERPG 3 levels are not exceeded) as a result of the postulated incidents at the chlorine storage area. However, there is a potential for injury as a result of the postulated incident. Hence, the potential for injury/ inhalation risk has been carried forward for frequency and risk analysis.

5.8 Natural Gas Pipeline Leak

The fitting line hazard analysis conducted in Section 4 identified that external impact was the most likely source of gas pipeline breach. A detailed consequence analysis for pipeline impact failure is conducted in Appendix B of this report; this study identified that external impact (punctures from external interference) on the fitting line could initially result in a hole, with a diameter of 20mm – 80 mm . In the event that the fitting line was breached, at a pressure of 5M Pa (or 50 bar), the pressure would result in continued crack propagation leading to fitting line rupture.

Based on statistical data reviewed (Reference 22) three hole sizes have been selected:

- 10mm for pinholes and pipe defects, corrosion and valves
- 50 mm for puncturing or impact style events, and
- 100 mm for large release (deemed to represent rupture)

If ignited immediately, a jet fire would result projecting from the fitting line and radiating heat into the surrounding area. Figure 5-1 shows a typical jet fire schematic, showing flame layout and dimensions.

A heat radiation analysis was conducted and the impacts identified at various distances from the fitting line for hole sizes of 10mm, 50mm, and 100mm and at an angle of 45 degrees under daytime conditions (D stability and 1.5 m/s wind speed) are reported in

Table 5-1. Figure 5-1 may be used to aid in understanding the flame dimensions listed in this table.

Table 5-1 – Heat Radiation and LFL distances based on hole size.

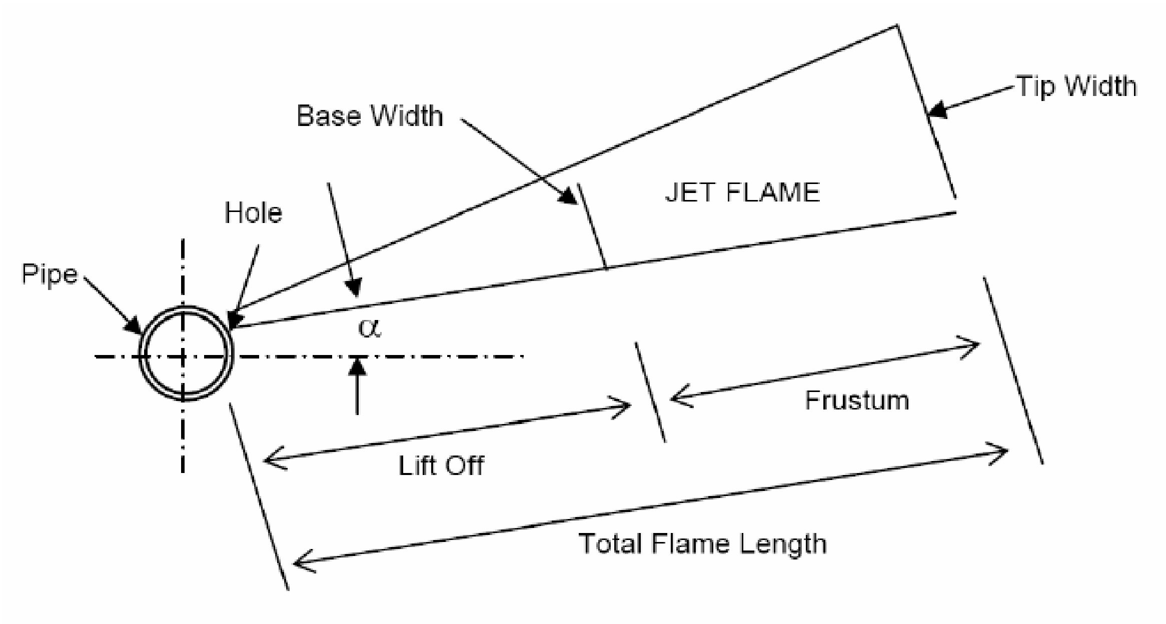
Hole Size(mm)	Initial release rate (kg/s)	LFL distance (m)	Flame Length
10	0.67	4	7
50	13.3	16	30
100	53.4	32	55

Based on the rupture scenario, and a surface flux for methane of 95 kW /m2 the distance to radiant heat fluxes of concern is given in Table 5.2. The heat flux at the closest boundary from the pipeline (105m away based on the location of the metering station) is estimated at 4.7 kW/ m^2 intensity.

Table 5-2 – Heat Radiation distances based on 100mm hole (rupture).

Heat Flux	Distance (m)
95	55
35	65
23	70
12.6	82
4.7	105
4.7 (Boundary)	105

- **Figure 5-1 Jet fire schematic**



HIPAP No.4 (AS 2004a) indicates that heat radiation exceeding 4.7kW/m^2 should not impact beyond the site boundary. The nominal easement for the fitting line was considered to be 10m wide; however, the closest site boundary to the metering station is around 105m. Hence, based on the values in Table 5-1, the heat radiation impact to 4.7kW/m^2 will extend beyond the easement boundary (inside the site), but may have an impact to offsite areas located around 105 m away. Hence, the impact to offsite facilities from a jet fire at the pipeline gantry/ metering station has been carried forward for further analysis.

The detailed analysis in Appendix B of this report identified that in the event a fitting line breach and subsequent rupture occurred, the gas released from the fitting line may immediately ignite forming a gas cloud that if ignited at a distance and after a time would result in a flash fire, where the cloud burns at subsonic speeds but does not explode.

The distance to LFL does not extend to the boundary of the site and hence a flash fire incident has not been carried forward for further analysis.

5.9 Gas Leak into the Turbine Enclosure

In the event of gas leak into the CCGT turbine enclosure, there is a potential for a confined flammable gas cloud to from within the enclosure itself. Ignition of the cloud could lead to explosion due to the confined nature of the enclosure. The detailed consequence analysis conducted in Appendix B calculated the explosion overpressure at specific distances from the gas turbine enclosures at the site. Table 5-3 summarises the results of the explosion overpressure analysis.

I

Table 5.3 Explosion Overpressure versus distance for the Gas Turbine Enclosure explosion

Overpressure kPa	Results	Distance to Overpressure (m)	Risk of Fatality	
			Conventional Building	Open in Chemical Plant
4	90% window breakage, some damage to cladding.	277.5	0.01	0.00
7	Glass fragments fly with sufficient force to injure. Damage to cladding, roof tiles removed	195.6	0.02	0.00
14	Houses uninhabitable but not totally irreparable. Cement block buildings may be flattened. Roofs of oil storage tanks would be damaged.	126.8	0.08	0.01
20		101.5	0.16	0.03
35	Onset of severe general structural damage. Houses severely damaged, needed demolition. Serious damage could occur to items of plant equipment and possibly initiation of leaks and fires. Oil storage tanks could rupture.	71.5	0.48	0.12
70	Almost complete demolition of all ordinary structures. Assumed edge of cloud. Damage to most chemical plants would be severe although some compressors, pumps and heat exchangers could be salvaged.	46.4	1.00	1.00

At the boundary close to Boulder Road (500m away) the explosion overpressure is lower than 4 kpa (at 14kPa the risk of fatality to a person in the open is 0.01). Hence the effect is not significant. For the purpose off computation the risk of fatality will be taken as 0.01.

Hence, this incident has been carried forward for further analysis (injury potential).

6. FREQUENCY ANALYSIS

6.1 Incidents Carried Forward for Frequency Analysis

The consequence analysis indicates that the following incidents have the potential to have an impact on offsite areas with severity levels exceeding the criteria published in HIPAP No.4 (DIPNR 1992c). Those incidents carried forward for frequency analysis are:

- Gas fitting line incident leading to gas leak as a result of external interference ; and
- Gas leak into the gas turbine enclosure, ignition and explosion/jet fire;
- Chlorine release from a pigtail failure in the chlorine storage area

6.2 Natural Gas Pipeline Failure

A review of the pipeline installation and design indicates that the use of data for high pressure gas pipelines may not be prudent, as the pipeline is installed above ground and within a plant area. Hence, the pipeline failure frequency has been assessed using two data sources, including CCPS (CCPS 1989) and University of Sydney (Tweeddale, H.M. 1993). The pipeline failure frequency rate from each data source is:

- In the medium to low range of 0.004 to 0.00006 per section of pipe (per annum) between connections. It is noted that the pipeline will be fully welded along its length, from the point where it enters the plant (metering station) and where it is connected at the gas turbines (CCPS 1989).
- 2x10-8 L/D per annum (where L = length and D = diameter). Based on a pipeline diameter of 0.47 and a length of pipeline on site of 250m, the failure rate is 2x10-8 x 250/0.273 = 2.1 x 10-5 p.a. (Tweeddale, H.M. 1993).

A review of the two sets of data indicates that there is some commonality in the failure rate in the range of 10-5. To ensure a conservative assessment, a value of 1x10-4 has been selected as a pipeline rupture failure rate.

6.3 Gas Turbine Explosion Frequency Analysis

The gas fitting lines inside the gas turbine enclosures deliver fuel to the combustion chambers. The pipework is fully welded, with the exception of sections where valves are installed. At these locations flanges are used to fit the valve into the pipe. Whilst there is negligible likelihood of failure of the pipe (i.e. hole), due to the dry gas, it was identified in the consequence analysis that leaks from flanges and valves could result in build up of gas in the turbine enclosure. However, this would require failure of the gas detection and isolation system and failure of the ventilation fans in the enclosure. In addition, ignition of the gas would also be required. The following failure frequencies have been developed for this analysis.

6.3.1 Flange & Valve Leaks

As this is a preliminary analysis since the detailed design of the gas turbine installation is not yet complete, the number of valves and flanges has been assumed to be 10 valves and 20 flanges, based on similar facilities.

The failure frequency for an external leak in a valve is given as 3.7x10-3 per annum (p.a.) (OREDA 2003, Taxonomy 4.3.1.3).

The failure frequency for a leak in a flange is given as 5x10-3 p.a. (CCPS 1989, Taxonomy 3.2.1.4).

Total valve leak frequency = single valve leak frequency x no. valves
= 3.7x10-3 x 10
= 3.6 x 10-2 p.a.

Total flange leak frequency = single flange leak frequency x no. flanges
= 5x10-3 x 20
= 0.1 p.a.

Total leak frequency in the enclosure = flange leak frequency + valve leak frequency
= 0.1 + 0.036
= 0.136 p.a

6.3.2 Fan Failure Frequency

The failure frequency for a fan is given as 2.2x10-3 p.a. (NPRD 1995, page 2-92, Fan Exhaust). Assuming the fan is tested every 6 months (i.e. electrical test, inspection and planned maintenance), the failure probability during operation is estimated using fractional dead time (FDT) theory where:

FDT = ½ λ t
Where: λ = failure rate p.a. (0.0022)
t = 1/no. tests p.a. (1/2)
FDT of fan = ½ x 0.0022 x ½ = 5.5x10-4

6.3.3 Gas detector & Isolation Valve Failure Frequency

The failure frequency for a gas detector is given as 0.0125 p.a. (OREDA 2003, Taxonomy 4.1.4)
Assuming the gas detector is tested every 6 months, the failure on demand is estimated using fractional dead time (FDT) theory:

FDT of gas detector = ½ x 0.0125 x ½ = 3.125x10-3

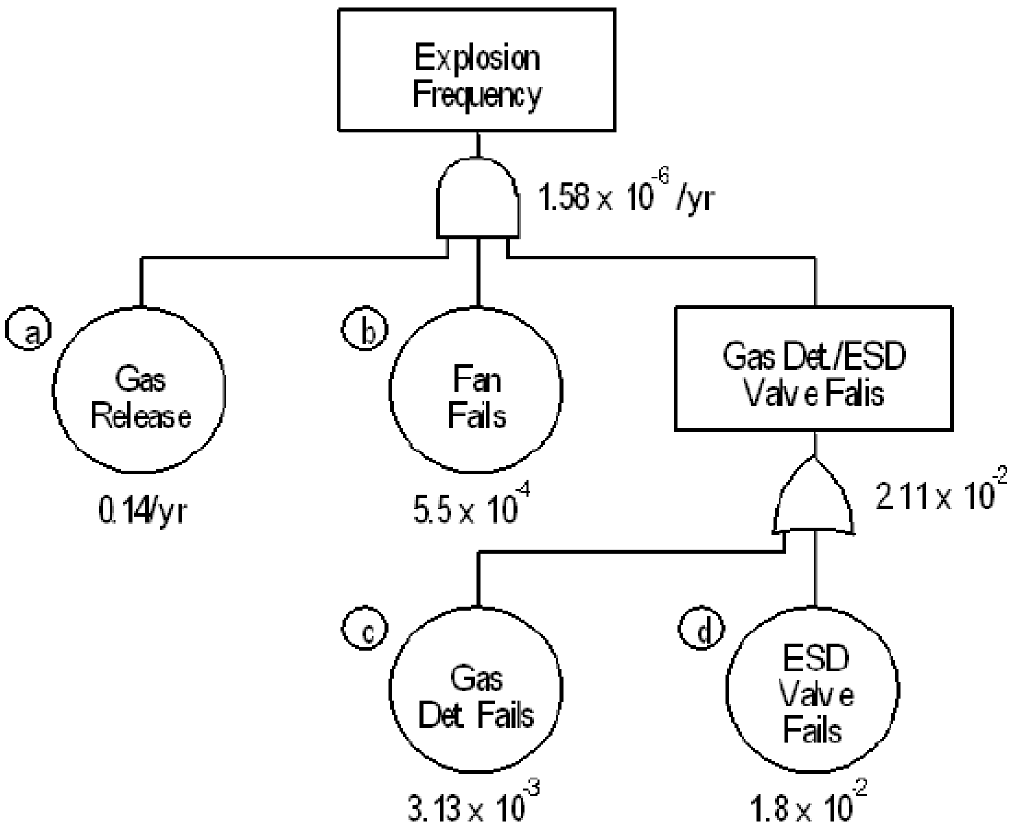
The failure frequency for an isolation valve to close on demand (i.e. the emergency shut down or ESD valve outside the enclosure) is given as 0.075 p.a. (OREDA 2003, Taxonomy 4.3.5.4). Assuming the ESD valve is tested every 6 months, the failure on demand is estimated using fractional dead time (FDT) theory:
FDT of ESD valve = ½ x 0.075 x ½ = 1.8x10-2

6.3.4 Ignition & Explosion Frequency

The ignition frequency in an enclosed space is given as 0.3 for large releases in excess of 50kg of gas (Cox, A.W. Lees, GF.P. & Ang, M.L. 1991).

The explosion frequency is estimated using a fault tree analysis. Figure 6-1 shows the fault tree for explosion in the turbine enclosure. The fault tree analysis was conducted using the proprietary software “Faultrease©”, which was developed by Arthur.D.Little in the US. The results of the analysis indicates the explosion frequency (per turbine) to be 1.58x10-6p.a. For the one CCGT turbine the frequency is 1.58x10-6p.a. For the two OCGT turbines the frequency is 3.16x10-6p.a. These values have been carried forward for risk analysis.

- **Figure 6-1 Fault tree analysis – turbine enclosure explosion**



6.4 Chlorine Release Frequency

The postulated release occurs as a result of a pigtail failure in the line from the drum to the manifold. In the event of a chlorine release, the chlorine room is fitted with a gas detector system which activates a chlorine shut down system (chlorguard) attached to the chlorine drum valve.

The frequency of failure of the chlorine pigtail has been estimated to be 0.01 per annum. This is based on the frequency of pigtail failure of at least one in the plants life. This is conservative as the pigtails are replaced regularly (once every 6 months) to minimise the potential for premature failure.

The probability of failure of the gas detector system is estimated below:

Gas detector Failure Rate = 0.22 per 10^6 hours (Ref.19)

Fail Rate per annum (p.a.) = (0.22 x 8760 hrs/yr)/10^6 = $2x10^{-3}$

Fractional Dead Time (FDT) = ½ λ t

where λ = failure rate p.a. and t = test interval (1/tests p.a.)

Four tests of the gas detector system are conducted p.a. (i.e. once every three months), FDT is estimated as:

FDT = 0.5 x $2x10^{-3}$ x ¼ = $2.5x10^{-4}$

Hence, the probability that a gas detector will fail to detect the chlorine gas when it is released is $2.5x10^{-4}$.

The probability of failure of the emergency shut down system (chlorguard) is estimated below:

Emergency Valve Failure Rate = 2.88 per 10^6 hours (Ref.19)

Fail Rate per annum (p.a.) = (2.88 x 8760 hrs/yr)/10^6 = $2.5x10^{-2}$

Fractional Dead Time (FDT) = ½ λ t

where λ = failure rate p.a. and t = test interval (1/tests p.a.)

Assuming the chlorguard system is tested when the drums are replaced (once every two weeks), FDT is estimated as:

FDT = 0.5 x $2x10^{-3}$ x 1/26 = $4.8x10^{-4}$

Hence, the probability that the Chlorguard system will fail isolate a chlorine leak when activated from a chlorine gas detection is 4.8×10^{-4}.

A fault tree has been developed to determine the failure of the chlorguard system and, hence, the failure to shut down the gas release. The fault tree is shown in **Figure 6.1**.

Legend

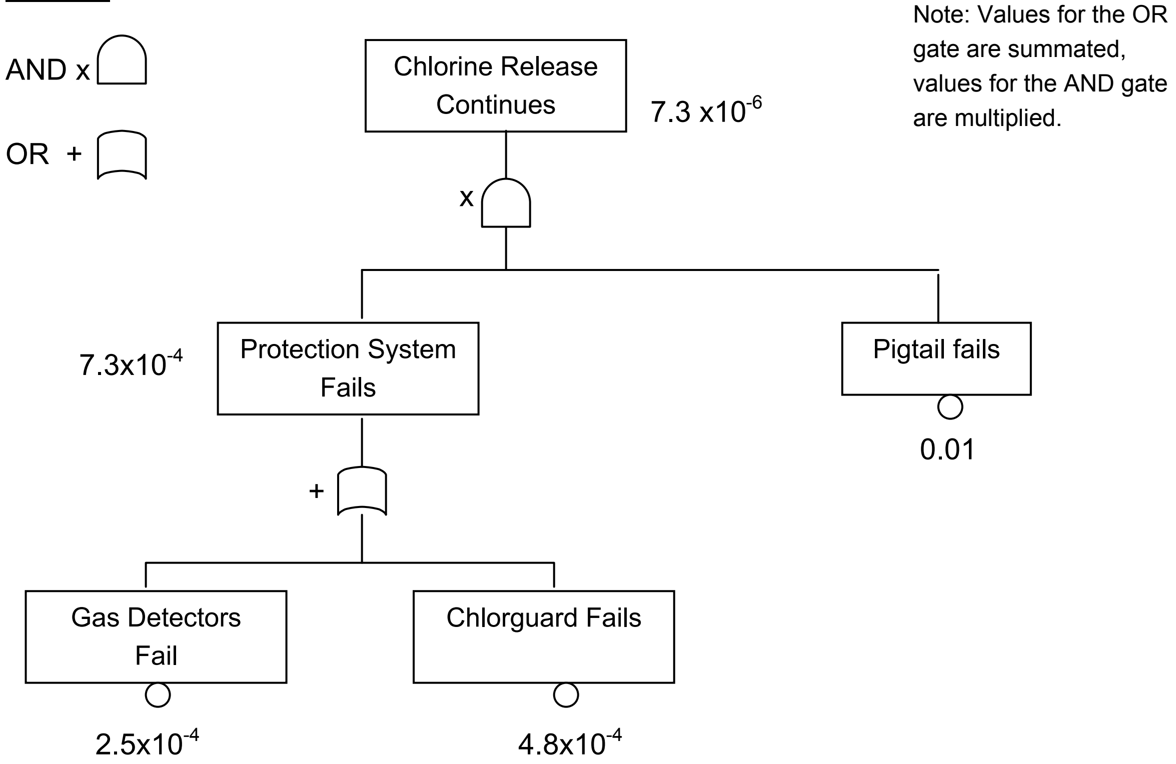


FIGURE 6.1
FAULT TREE – CHLORINE RELEASE

The fault tree analysis shows that the frequency of chlorine release is in the order of 7.3×10^{-6} per annum (p.a.), which is conservative as the analysis has not taken account of the potential for manual isolation of the chlorine drums using breathing apparatus to access the leak area.

The chlorine release frequency has been carried forward for risk analysis.

7. RISK ANALYSIS

7.1 Incidents Carried forward for Risk Analysis

Those incidents carried forward for frequency analysis are:

- Gas fitting line incident leading to gas leak as a result of external interference ; and
- Gas leak into the gas turbine enclosure, ignition and explosion/jet fire;
- Chlorine release from a pigtail failure in the chlorine storage area.

7.2 Natural Gas Pipeline Rupture

The gas fitting line incidents would occur in the nominal fitting line easement to the south of the turbine area. A pipeline failure (rupture), and ignition, would result in the jet flame being directed perpendicular to the pipeline, with heat radiated from the flame towards the areas adjacent to the piperack. The heat radiation impact at the boundary for the site is estimated at 0.7 kW /m^2 and is considered insignificant is risk terms.

The probability a jet fire is dependent on the ignition probability and the failure of the isolation valve to activate.

The failure rate of a shut down valve to close on demand has been estimated to be 2.5x10-3p.a. (OREDA 2003, Taxonomy 4.4.11). To determine the failure probability of the valve to close on demand, Fractional Dead Time (FDT) theory is used, where:

FDT = ½ λ t where: λ = component failure rate (p.a.)
t = test period (1/no.tests per annum), assumed 1 in this case
Hence, FDT = 0.5 x 2.5x10-3 x 1 = 1.25x10-3

For this study, the ignition probability has been selected as 0.3 (Cox et al 1991) for massive leaks (>50kg/s) and therefore the failure rate is = Ignition probability x leak frequency x probability valve fails to close
= 0.3 x 1x10-4 p.a. x 1.25x10-3
= 3.75 x 10-8 per year.

7.3 Gas Turbine Enclosure Explosion Risk

A review of the distance from the turbines to the fenced site boundaries indicates that, as a result of the postulated explosion in the turbine enclosure, explosion overpressure at the fence line surrounding the site exceeds 100kPa (see Table 5-2). However, the power station site boundaries extend well beyond the fenced area and a buffer zone has been established around these sites such that no industrial, residential or commercial developments can be established within a specific distance of the power station site. The analysis conducted in the study identified that in the event of an explosion, there would be insufficient overpressure at the buffer zone boundary to cause fatalities. However, the analysis indicated that there would be sufficient pressure to cause injuries.

The explosion assessment conducted in Section 5 indicates that at the closest residential area on the boundary of the buffer zone, the explosion overpressure would result in an injury probability of 10% (0.1) (DIPNR 1992c). The explosion frequency has been estimated to be 1.58x10-6 p.a.

Fatality Risk (Turbine Enclosure Explosion) = 0.1 x 1.58x10-6 = 0.158 pmpy.
HIPAP No.4 (DIPNR 1997) indicates that the accepted injury risk at residential areas is 1 pmpy(taken as the nearest boundary of the site), hence, the criteria is not exceeded in this case.

7.4 Chlorine Release Risks

The only incident carried forward for risk analysis was the postulated release of chlorine from a pigtail failure in the chlorine drum storage area. The consequence analysis indicated that injury was the maximum consequence severity that could occur at the site boundary from postulated releases at the chlorine storage.

The frequency of chlorine release was estimated to be $5x10^{-6}$p.a. Hence, the risk of injury as a result of the postulated chlorine release is $5x10^{-6}$ p.a. or 5 chances in a million per year.

7.5 Risk Evaluation

7.5.1 Fatality risk

The land use safety implications for the proposed development are summarised in **Table 7-1 – Overall Risk Evaluation**.

The table summarises the events, event probability and risk. The parameters as provided in the table are defined as follows:

Event – the events that may have an impact at the site boundary and comprise:

- Gas fitting line incident leading to gas leak as a result of external interference ; and
- Gas leak into the gas turbine enclosure, ignition and explosion/jet fire;
- Chlorine release from a pigtail failure in the chlorine storage area

Base Frequency x 10^{-6} – is the failure frequency of our events of interest (listed above).

PF (E) – is the probability of fatality due to fire to a person on the boundary from the events above.

Event 1 – Gas Pipeline Jet Fire - Based on a heat flux 4.7 kW / m2 for 5 minute exposure gives PF(E) = 0.01 (Based on $Pr = -14.9 + 2.56 \ln (t \times I^{4/3})$)

Event 2 – Gas explosion Turbine Enclosure - Based on a explosion overpressure of 10 kPA gives PF (E) = 0.01

Event 3 – C - Based on a chlorine drum release concentrations of around 20 ppm may reach the boundary of the site and gives PF(E) = 0.06 for a 5 min release.

Risk x 10^{-6} – is the product of the frequency x probability of injury and is defined as the risk of exposure from the event

CF-Risk – is the cumulative addition of the individual risk results.

TABLE 7-1 - OVERALL RISK EVALUATION

EVENT	Base Event Freq (x 10-6 pa)	Pf(Fatality)	Fatality Risk x 10-6 At Boundary (Boulder Rd)
1.Gas Pipeline jet fire	0.0375	0.5	0.02
2.Gas explosion Turbine Enclosure	1.6	0.01	0.016
3. Chlorine release from drum	5	0.06	0.3
Estimated RISK LEVEL at BOUNDARY (no more than 1 pmpy)			0.3

The risk levels expected at the boundary of the site are around 0.3 pmpy.

Such risk levels are considered acceptable (Ref: NSW DEPT. OF PLANNING Risk Criteria at Boundary of site = 1 x 10^{-6} pa) under the NSW Department of Planning guidelines (Reference 11).

Notwithstanding the low risk levels estimated form this assessment, and to ensure the risks are maintained in the ALARP range, the following recommendations are made:

- The gas pipeline easement and the gas pipeline along the piperack are clearly marked with "HIGH PRESSURE GAS PIPELINE" at regular intervals (20m) to ensure that personnel working in the area (especially on the piperacks) understand that a high pressure gas fitting line is present.
- A safety management system be developed (in accordance with HIPAP # 9 – Safety Management System Guidelines) for the site as part of the current proposal, covering particularly the risk events that may have effects at the boundary, notably:
  - Gas fitting line incident leading to gas leak as a result of external interference
  - Gas leak into the gas turbine enclosure, ignition and explosion/jet fire;
  - Chlorine release from a pigtail failure in the chlorine storage area

The SMS covers:

- Management of process changes (use of HAZOP critic methods);
- Accident / Incident reporting;
- Safety Training requirements;
- Emergency plans (based on risk assessment & HIPAP # 1);
- Site security and access;
- Audit program;

8. REFERENCES

1. Hazardous Industry Planning Advisory Paper No.6 (1992) – Guidelines for Hazard Analysis, Department of Infrastructure Planning and Natural Resources (formerly planningnsw, Department of Urban Affairs and Panning and Department of Planning).

2. Applying SEPP 33 (1994), "Hazardous and Offensive Development Application Guidelines", Department of Infrastructure, Planning and Natural Resources, NSW.

3. Multi-Level Risk Assessment (1997), Department of Infrastructure, Planning and Natural Resources, NSW.

4. AS2444-2001, "Portable Fire Extinguishers and Fire Blankets – Selection and Location", Standards Association of Australia, Sydney

5. Private Communication – S.Sylvester (SKM)/C.Gent(Orica Chloralkali Manager, Botany).

6. Townsend, N.A & Fearnehough, G.D (1986), Control of Risks from UK Gas Transmission Pipelines, proceedings 7th symposium on line pipe research, American Gas Association, Oct.1986, Houston, USA.

7. Tweeddale, H.M.(1993), "Hazard Assessment and Reduction", Department of Chemical Engineering, University of Sydney.

8. Withers, J. et.al. (1988), Ammonia Toxicity Monograph", IChemE, Rugby UK

9. Withers, J. et.al. (1987), "Chlorine Toxicity Monograph", IChemE, Rugby, UK

10. AS1940-2004, "The storage and handling of flammable and combustible liquids", Standards Association of Australia, Sydney

11. The Australian Dangerous Goods Code (ADG) (1998), "The Australian Code for the Transport of Dangerous Goods by Road and Rail", Federal Office of Road Safety, Canberra, ACT

12. NSW OH&S Dangerous Goods Amendment Regulation-2005, under the NSW OH&S Dangerous Goods Amendment Act 2003, WorkCover NSW, Gosford.

13. AS1596-2002, "The Storage and Handling of LP Gas", Standards Association of Australia, Sydney

14. AS2022-2003, "Anhydrous Ammonia – Storage and Handling", Standards Association of Australia, Sydney

15. AS2927-2001, "The Storage and Handling of Liquefied Chlorine Gas, Standards Association of Australia, Sydney

16. AS4332-1995,"The storage and handling of gases in cylinders", Standards Association of Australia

17. Lees, F.P. (1996), "Loss Prevention in the Process Industries", Butterworth-Heinemann, London.

18. Hazardous Industry Planning Advisory Paper No.4, "Risk Criteria for Land Use Safety Planning", Department of Infrastructure Planning and Natural Resources, NSW (1992).

19. Hazardous Industry Planning Advisory Paper No.4 (1992) – Risk Criteria for Land Use Safety Planning, Department of Infrastructure Planning and Natural Resources (formerly planningnsw, Department of Urban Affairs and Panning and Department of Planning).

20. AS3780-1994, "The storage and handling of corrosive substances", Standards Association of Australia

21. OREDA – 2003, Offshore Reliability Data, 4th ed., prepared by SINTEF Industrial management, Trondheim, Norway

22. Fearnehough, G.D (1990) Pipeline Ssafety, Pipeline Technology Conference, Royal Flemish Society of Engineers, Oostende, Belgium, 1990.

APPENDIX A

HAZARD IDENTIFICATION TABLE

Hazard Identification Table – Mt.Piper Power Station and Extension Project

Incident	Cause	Consequence	Safeguards (Prevention, Protection, Detection)
Corrosive Materials – Class 8			
Leak and spill from a tank or pipe in the storage area	Gasket fails, tank hole, pipe damage (physical), internal/ external corrosion of storage	Leak from tank into the surrounding area, potential impact on the environment	- All corrosive material storage tanks are fully bunded (100% of the largest tank in the bund) - Tanks are regularly inspected - Corrosion resistant materials selected for tank and equipment components - Site is bunded (zero release)
Leak during unloading of corrosive materials	Flexible transfer hose leak/failure, driveaway whilst connected,	Spill of corrosive material in areas adjacent to the corrosive materials storage and potential release to the environment Corrosive materials impact to operators transferring from road tankers to tanks	- All corrosive material unloading/transfer areas are bunded to prevent release beyond immediate area of the spill - Operator is present during transfer operations - Regular testing of hoses - Operator wears PPE - Site is bunded (zero release) - Driveaway protection provided on delivery vehicles
Delivery of acid into alkali tank or vice versa	Operator error	Exothermic reaction, excessive heat in the tank, tank failure, release of acid/alkali from tank containment (Note: no toxic gas developed from this reaction)	- Clear signage provides at all delivery points - DG Placards located adjacent to the delivery connections - Single truck delivery only (i.e. mixed products not delivered in a single truck) - Tanks are bunded to contain 100% of tank contents - Dedicated acid/alkali drivers, trained in product transfer operations

Hazard Identification Table – Mt.Piper Power Station and Extension Project

Incident	Cause	Consequence	Safeguards (Prevention, Protection, Detection)
Transformer Oil – C2 Combustible Liquid			
Oil Leak from Transformer	Leaking join, pipe, casing	Level of oil falls in the transformer exposing the windings, overheating the transformer and igniting the oil resulting in a pool fire in the bund	- Low oil level switch, alarm and automatic transformer shut down (Buckholtz Protection) - Bunded area around transformer, drain to collection pits (full transformer contents) - Deluge system over transformer - Fire main, hydrants and hoses
Oil Leak from Transformer	Leaking join, pipe, casing	Level of oil falls in the transformer exposing the windings, overheating the transformer and igniting the oil resulting in transformer explosion and projectiles impacting adjacent transformers – incident growth	- Low oil level switch, alarm and automatic transformer shut down (Buckholtz Protection) - Blast walls between transformers - Deluge system over transformer - Fire main, hydrants and hoses
Carbon Dioxide – Class 2.2			
Leak and spill from a tank or pipe in the storage area	Joint fails, tank hole, pipe damage (physical), internal/ external corrosion of storage	Leak from tank into the surrounding area, potential for asphyxiant cloud developing impacting personnel in the surrounding area No impact to the environment	- CO_2 is stored as a refrigerated liquid (i.e. does not rapidly form a gas cloud) - Tank is double walled with insulation between - Tanks are regularly inspected - Corrosion resistant materials selected for tank and equipment components - Joints are metal to metal face (no gaskets) - Storage area is open with little confinement (i.e. good dispersion of gas)
Leak during unloading of corrosive materials	Flexible transfer hose leak/failure, driveaway whilst	Leak from hose or transfer fitting into the surrounding area, potential for	- Operator is present during transfer operations - Regular testing of hoses

Hazard Identification Table – Mt.Piper Power Station and Extension Project

Incident	Cause	Consequence	Safeguards (Prevention, Protection, Detection)
	connected,	asphyxiant cloud developing impacting personnel in the surrounding area No impact to the environment	- Operator wears PPE (i.e. protection against impact of refrigerated liquid) - Emergency shut of systems available of tanker transfer systems - Driveaway protection provided on delivery vehicles
Battery Fluid (Corrosives) – Class 8			
Leak in a battery cell	Cracked battery casing	Spill into the battery room	- Battery room is fitted with drains to collect and contain spills - Battery room drains report to neutralisation pit (magnesium carbonate) - Single cells are between 25-60 Litres, relatively minor spill volume
Spill whilst replenishing battery acid in cells	Operator error	Spill of battery acid to the floor of the battery room	- Battery room is fitted with drains to collect and contain spills - Battery room drains report to neutralisation pit (magnesium carbonate) - Operator is present during battery “top-up” - Operator wear PPE (gloves, apron, face shield, etc.) - “Top-up” volume is relatively small (<1 litre) minimising spill potential in the area

Hazard Identification Table – Mt.Piper Power Station and Extension Project

Incident	Cause	Consequence	Safeguards (Prevention, Protection, Detection)
Hydrogen Storage – Class 2.1			
Leak of hydrogen, ignition and fire	Hydrogen line failure, joint failure	Jet fire impinging on adjacent lines/cylinders resulting in fire growth, cylinder explosion Personnel walk through clear hydrogen flame resulting in burns	- Joints and cylinder equipment is located at the top of the cylinders minimising potential for jet fire impact on adjacent cylinders - Pipework and equipment is located at top of cylinders, about 5m above grade - Area us fenced with 2m chainwire mesh preventing unauthorised personnel access - Cylinders are deluged (sprinklers) used to cool the area in the event of fire - Area is located in a isolated section of the site
Leak of hydrogen from transfer pipework, ignition and fire	Hydrogen line failure, joint failure	Jet fire impinging on areas adjacent to the transfer pipework	- Pipework is fully welded along the transfer pipework route - Pipework is located in an underground trench, minimising impact to adjacent equipment - No ignition sources in the trench - Trench is located in open areas (no potential for containment of hydrogen)
Natural Gas – Class 2.1			
Natural Gas Pipeline leak	External interference Construction error, corrosion, earthquake, subsidence	Leak/rupture, ignition, jet fire, flash, explosion	- pipeline marker signs to be installed at regular intervals) - pressure testing of fitting line after construction - external paint system corrosion protection - land is flat with no subsidence potential - fitting line is installed in a pipe rack of substantial construction and remote from through traffic

Hazard Identification Table – Mt.Piper Power Station and Extension Project

Incident	Cause	Consequence	Safeguards (Prevention, Protection, Detection)
			- site work using mechanical equipment will be subject to a permit system and supervision.
Turbine Enclosure Leak	Gas fitting line failure Valve, or pipe failure	Leak / rupture. If ignited may result in jet fire, flash fire or explosion	- gas detection within the enclosure - automatic isolation valve located at gas entry point to the enclosure (linked to gas detection to operate at 50% LEL) - enclosure is vented with fans - alarms linked to gas detection - fire detection installed in the enclosure (linked to fire fighting system) - fire hydrants, hose reels and extinguishers available on site - - inert gas fire suppression installed in the gas turbine enclosure - site is fully staffed during all operational periods (i.e. no fuel in the turbine when site is unstaffed - -
LPG Storage – Class 2.1			
LPG leak	Gasket/valve leak, Line failure, PSV leak,	Gas cloud, delayed ignition and explosion Gas cloud delayed ignition and flash fire Gas release and immediate ignition – jet fire	- Fire detectors (plastic air lines on valve actuators) - Auto isolation valves on all tanks - Manual isolation valves on all tanks - Excess flow valves on all liquid outlets on all tanks - fire alarms linked to site alarms - Tank installed in the open, well clear of adjacent

Hazard Identification Table – Mt.Piper Power Station and Extension Project

Incident	Cause	Consequence	Safeguards (Prevention, Protection, Detection)
			facilities - All electrical equipment installed in accordance with AS2430 hazardous area requirements
Ignited LPG Leak	Gasket/valve leak, Line failure, PSV leak, ignition from passing vehicles	Jet flame impinges on vessel shell resulting in eventual BLEVE	- as above, plus - Fire fighting equipment available (hydrants) and fire main for cooling water supply
Ignition of LPG leak during delivery	Pipework, flexible hose, coupling failure, driveaway whilst connected, ignition from passing vehicles	Gas cloud, delayed ignition and explosion Gas cloud delayed ignition and flash fire Gas release and immediate ignition – jet fire	- as for LPG Storage, plus - operator in attendance during all transfer operations; - LPG deliveries performed by a registered LPG transport and delivery company - Tanker driver has emergency response plan - Tanker driver is trained in LPG deliveries and transfers - Driveaway protection installed on all tankers - First attack fire fighting equipment provided on the tanker
Kerosene/Turpentine – Class 3			
Leak of flammable liquid during storage or handling	- Corroded drum or container - Dropped drum	Spill leaks in the immediate area of the drum	- Quantities are minor in nature (typically 200L in 20L drums and small containers) - Flammable liquids stored in a dedicated & secured DG store - DG Store is bunded to contain a minimum of 1000 L spilled materials (no release to the environment) - DG Store is separated from adjacent facilities by a minimum of 3m - DG Store complies with the requirements of

Hazard Identification Table – Mt.Piper Power Station and Extension Project

Incident	Cause	Consequence	Safeguards (Prevention, Protection, Detection)
			AS1940-2004 (Ref.5) - Fire extinguishers, fire hydrants, hose reels are provided adjacent to the storage - All drums inspected on arrival, damaged drums are quarantined for return to the supplier - Site is bunded (zero release facility)
Leak of flammable liquid during storage or handling – ignition of leak	- Corroded drum or container - Dropped drum - Ignition from faulty electrical fitting near the store		- As above, plus - Electrical systems comply with the requirements of AS2430 (Ref.6) - Personnel present during transfer and handling (i.e.raise the alarm/response) - Spill quantities are small and do not project beyond the immediate spill area
Acetylene/Propane Cylinders – Class 2.1			
Ignition of a leak of gas from cylinder valve	Dropped cylinder, Leak from faulty valve, valve not closed correctly (human error), crack in valve body Ignition from faulty electrical fittings adjacent to the store	Jet fire impinges on adjacent cylinders resulting in cylinder rupture and BLEVE (no impact to the environment)	- Typical quantities of gas stored are minor (<200kg) - Area is well ventilated - Cylinders are stored in a secured caged area - Store is constructed from non-combustible materials - Electrical equipment complies with the requirements of AS2430 (Ref.6) - The storage area complies with the requirements of AS4332 (Ref.7)
Ammonia Solution – Class 8			
Leak from drum	Dropped drum, corroded drum	Spill of material in the leak area,	- Drum size limits spill (200L)

Hazard Identification Table – Mt.Piper Power Station and Extension Project

Incident	Cause	Consequence	Safeguards (Prevention, Protection, Detection)
		potential for run off into the environment (Note: vapours from the ammonia solution will not have significant respiratory impacts on personnel)	- DG Store is bunded to contain a minimum of 1000 L spilled materials (no release to the environment) - DG Store is separated from adjacent facilities by vapour barrier (fire wall FRL240/240/240) - DG Store complies with the requirements of AS3780-1994 (Ref.8) - All drums inspected on arrival, damaged drums are quarantined for return to the supplier - Site is bunded (zero release facility) - PPE work during handling (i.e. gloves, face shield, apron, etc.)
Hypochlorite Solution			
Leak from drum	Dropped drum, corroded drum	Spill of material in the leak area, potential for run off into the environment (Note: vapours from the hypochlorite solution will not have significant respiratory impacts on personnel)	- Drum size limits spill (200L) - DG Store is bunded to contain a minimum of 1000 L spilled materials (no release to the environment) - DG Store is separated from adjacent facilities by vapour barrier (fire wall FRL240/240/240) - DG Store complies with the requirements of AS3780-1994 (Ref.8) - All drums inspected on arrival, damaged drums are quarantined for return to the supplier - Site is bunded (zero release facility) - PPE work during handling (i.e. gloves, face shield, apron, etc.)
Petroleum Fuel – Class 3 & Diesel Fuel - Class C2			
Leak of gasoline/Diesel	Tank corrosion (internal from	Gasoline/Diesel contaminates the soil	- Tanks are corrosion protected externally, not

Hazard Identification Table – Mt.Piper Power Station and Extension Project

Incident	Cause	Consequence	Safeguards (Prevention, Protection, Detection)
	water in fuel/external from moisture in the soil) Uneven pressure on tank external surface from compacted soil	surrounding the tank resulting in chronic contamination over a long period of time	contact between tank and soil - Tanks are surrounded by sand - Tanks are pressure tested regularly (last test Feb 2004) - Regular ground water sampling conducted at the station from dedicated bore holes
Spill of fuel during delivery	Transfer hose failure, operator error, driveaway whilst still connected	Fuel spill in the area surrounding the tank fill point & bowsers, potential for gasoline/diesel to enter the drains and release to the environment	- Driver/operator is in attendance during full delivery operation (emergency response activated by driver) - Driver/operator has an emergency response plan as part of the delivery safety management systems - Drivers are registered DG transport contractors - Driveaway protection fitted to delivery tankers - Drains report to the site containment pond (no offsite release) - Site containment pond capacity is 200ML
Ignition of a spill during delivery	Transfer hose failure, operator error, driveaway whilst still connected, fuel runs into gutters and drains and is ignited at a distance from the release by vehicles or electrical systems	Pool fire adjacent to the transfer area, impact on adjacent structures and delivery vehicle	- Driver/operator is in attendance during full delivery operation (emergency response activated by driver) - Driver/operator has an emergency response plan as part of the delivery safety management systems - Drivers are registered DG transport contractors - Driveaway protection fitted to delivery tankers - First attack fire fighting equipment fitted to the fuel

Hazard Identification Table – Mt.Piper Power Station and Extension Project

Incident	Cause	Consequence	Safeguards (Prevention, Protection, Detection)
			delivery tanker (dry chemical powder extinguishers) - Fire hydrants and hoses available on site for fire response
Anhydrous Ammonia – Class 2.3			
Ammonia leak	Flange failure, valve stem failure, pipeline corrosion, nozzle leak (weld), PSV release	Toxic cloud forms and is dispersed downwind Concentrations of ammonia exceed injurious and/or fatal levels Injurious/fatal levels of ammonia extend offsite impacting adjacent facilities	- Facility complies with AS2022 (Ref.14)] - Excess flow valves installed internally on the tank (close automatically on pipeline rupture) - All liquid lines on the tank are isolated after delivery - PSV are fitted with extension tubes (discharge at 5m) - Delivery lines are vapour only (i.e. minimise release quantities) - Delivery lines are welded from the tank to the process
Ammonia leak during delivery	Hose leak/failure, connection failure, driveaway whilst connected	Toxic cloud forms and is dispersed downwind Concentrations of ammonia exceed injurious and/or fatal levels Injurious/fatal levels of ammonia extend offsite impacting adjacent facilities	- Operator is in attendance during full delivery cycle - Operator has access to an emergency shut down "button" (stops transfer and isolates valves) - Globe vales used on delivery system (these valves act as non-return valves) - Regular testing of hoses - Fire hoses close to the transfer point (fog spray application to prevent toxic cloud formation)
Chlorine Storage – Class 2.3			
Chlorine leak	Pigtail line failure, valve stem	Toxic cloud forms and is dispersed	- Facility complies with AS2927 (Ref.15)]

Hazard Identification Table – Mt.Piper Power Station and Extension Project

Incident	Cause	Consequence	Safeguards (Prevention, Protection, Detection)
	failure, delivery pipeline corrosion (weld/gasket), Drum failure (corrosion/impact)	downwind Concentrations of ammonia exceed injurious and/or fatal levels Injurious/fatal levels of ammonia extend offsite impacting adjacent facilities	- Drums are installed in a building - Gas detectors installed in the building - Gas detectors regularly tested (every 3 months) - Chlorguard automatic shut down system installed on all drums - Chlorine alarms attached to gas detectors - Small bore lines used to transfer chlorine (6mm NB)
Chlorine leak from damaged drum during delivery	Dropped drum	Toxic cloud forms and is dispersed downwind Concentrations of ammonia exceed injurious and/or fatal levels Injurious/fatal levels of ammonia extend offsite impacting adjacent facilities	- Robust drums used for chlorine transport - Chlorine delivered and handled by Orica - Orica personnel are experienced in drum handling - Drum delivery personnel have emergency plans and procedures for responding to damaged drums - Drum valves are protected by an external cap and within the concave dished ends of the drum

APPENDIX B

DETAILED CONSEQUENCE ANALYSIS

B1 Consequence Analysis

The following incidents were carried forward for detailed consequence analysis:

- Ammonia releases involving gasket/joint leaks, pipework corrosion leaks, flexible transfer hose leaks;
- Chlorine releases involving failure of pigtail lines between the drums and manifolds and leaks in the manifolds;

B2 Transformer Bund Fire

A bund fire in a transformer is modelled as a pool fire involving the full bund area. The bund is 17m x 17m, hence the equivalent pool diameter is calculated by:

$\pi/4 \times D^2 = 17 \times 17$

$D = (289 \times 4/\pi)^{0.5} = 19.2\text{m}$

Flame Dimensions

Figure B.1 shows the cylindrical flame as a result of a pool fire in the transformer bund.

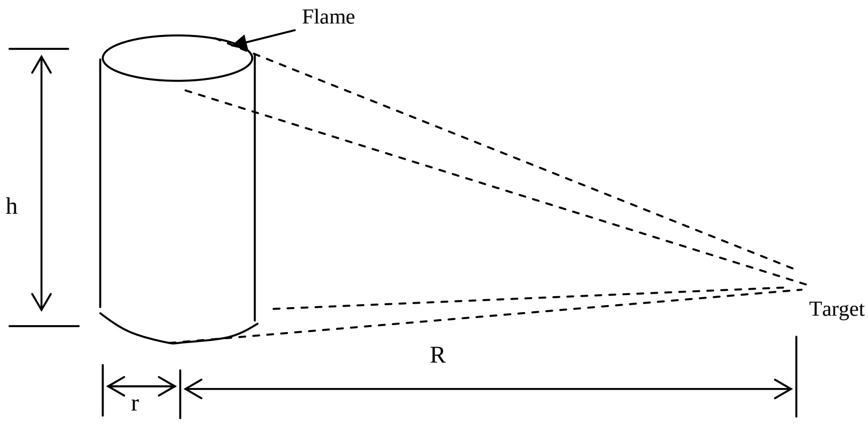


FIGURE B.1
DRUM SPILL INCIDENT AND POOL FIRE

The flame height of a pool fire is given by the following correlation of Thomas (Ref.17-Main Report):

-----------------(B1.1)

where: L= mean flame height (m)
D= pool diameter (m)
ρ_o= ambient air density (typically 1.2 kg/m^3)
m= mass burning rate (kg/m^{2}s) = 0.087, based on 6mm/min burn down rate (Ref.10-Main Report)
g= acceleration due to gravity (9.81 m/s^2)

From formula B1.1 above, flame height is calculated as:

$L = 42 \times 19.2\ (0.087/(1.2(9.81 \times 19.2)^{0.5}))^{0.61} =$ 28m

Heat radiation (I_r) at the target can be estimated using the following formula:

$I_r = I_e \times F \times \tau$ -------(B1.2)

Where: I_r = Target Heat (kW/m^2).
I_e= Flame Heat (kW/m^2) or surface emissive power (SEP).
τ = Transmissivity.
F = View Factor

The calculation of the view factor (F) in **Formula B1.2** depends upon the shape of the flame and the location of the flame to the receiver. F is calculated using an integral over the surface of the flame, S. The formula can be shown as:

$$F = \int\int_S \frac{\cos\beta_1 \cos\beta_2}{\pi d^2}$$

The above formula may be solved using the double integral or using a numerical integration method in spread sheet form. This is explained below.

A spreadsheet calculator (SSC)* has been developed to determine the radiation flux experienced at a "target" originating from a cylindrical fire in a circular tank, bund, flammable liquid storage depot with fire walls or where the shape of a cone jet fire approaches a cylinder. It is intended typically for fires of petroleum liquids though it can be used with any material so long as the "emissivity" of the flame is known. This is the heat flux at the surface of the flame and is given in kiloWatts per square metre (kW/m^2). The other parameters needed are: diameter of tank/bund or flame dimension, height of tank/walls (if any), distance to target, height of flame, tilt of flame caused by wind (if any). It is assumed that the tank/walls have some height although

* The Spread Sheet Calculator was developed by Dr Wayne Davies of the Chemical Engineering Faculty, Sydney University

there is no reason not to use the calculator for pool or jet fires at ground level by entering a zero height.

The SSC is designed on the basis of finite elements. The fire is assumed to be in the shape of a cylinder of the same diameter as the tank at its roof, the bund or the cone end for a jet fire. Once the flame height is known, the surface of the cylinder can be divided into many separate plane surfaces.

To do this, a plan view of the tank/bund was drawn and the relevant distances and angles allocated. The plan view is for the target and the tank in the same horizontal plane.

The angle "theta" is varied from zero to 90 degrees in intervals of 2.5 degrees. Zero deg. represents the straight line joining the centre of the tank/bund to the target (x0, x1,x2) while 90 deg. is the point at the extreme left hand side of the tank/bund. In this way the fire surface is divided up into elements of the same angular displacement. Note the tangent to the circle in plan. This tangent lies at an angle, gamma, with the line joining the target to where the tangent touches the circle (x4). This angle varies from 90 deg at the closest distance between the tank /bund and the target (x0) and gets progressively smaller as theta increases. As theta increases, the line x4 subtends an angle phi with x0. By similar triangles we see that the angle gamma is equal to 90-theta-phi. This angle is important because the sine of the angle give us the proportion of the projected area of the plane. When gamma is 90 deg, sin(gamma) is 1.0, meaning that the projected area is 100% of the actual area.

Before the value of theta reaches 90 degrees the line x4 becomes tangential to the circle. The fire cannot be seen from the rear and negative values appear in the view factors to reflect this. The SSC filters out all negative contributions.

For the simple case, where the fire is of unit height, the view factor of an element is simply given by the expression:

VF = ΔA. sin(gamma)/(π. x4. x4) .... Eq 1

where ΔA is the area of an individual element at ground level.

Note the denominator (π. x4. x4) is a term that describes the inverse square law for radiation assumed to be distributed evenly over the surface of a sphere.

As we see the value of x4 increases as theta increase and the value of sin(gamma) decreases as theta increase. This means that the contribution of the radiation from the edge of the circular fire drops off quite suddenly compared to a view normal to the fire. Note that the SSC adds up the separate contributions of Eq 1 for values of theta between zero until x4 makes a tangent to the circle.

It is now necessary to do two things: (i) to regard the actual fire as occurring on top of a tank/bund/fire wall and (ii) to calculate and sum all of the view factors over the surface of the fire from its base to its top. The overall height of the flame is divided into 10 equal segments. The same geometric technique is used. The value of x4 is used as the base of the triangle and the height of the flame plus the tank, as the height. The hypotenuse is the distance from target to the face of the flame (called X4'). The angle of elevation to the element of the fire (alpha) is the arctangent of the height over the ground distance. From the cos(alpha) we get the projected area for radiation. Thus there is a new combined distance and an overall equation becomes:

$VF = \Delta A. \sin(gamma).\cos(alpha)/(\pi. x4'. x4')$ .... Eq 2

The SSC now turns three dimensional. The vertical axis represents the variation in theta from 0 to 90 deg representing half a projected circle. The horizontal axis represents increasing values of flame height in increments of 10%. The average of the extremes is used. e.g. if the fire were 10 m high then the first point would be the average of 0 and 1 i.e. 0.5 m. The next point would be 1.5 m and so on.

Thus the surface of the flame is divided into 360 equal area increments per half cylinder making 720 increments for the whole cylinder. Some of these go negative as described above and are not counted because they are not visible. Negative values are removed automatically.

The sum is taken of the View Factors in Eq.2. Actually the sum is taken without the ΔA term. This sum is then multiplied by ΔA which is constant. The value is then multiplied by 2 to give both sides of the cylinder. This is now the integral of the incremental view factors. It is dimensionless so when we multiply by the emissivity at the "face" of the flame, which occurs at the same diameter as the tank/bund, we get the radiation flux at the target.

The following data was input to the spread sheet calculator for a full bund fire at the transformers:

- Flame Cylinder diameter – 19.2m
- Flame height – 28m
- Transmissivity – 0.79
- SEP – 32 kW/m^2
- Angle of flame tilt – 15^o

The results of the analysis indicated that the distance to a heat radiation of 4.7kW/m^2 was 29.4m from the centre of the fire.

An analysis was conducted, using the SCC, for various levels of heat radiation to determine the distances to the selected levels of heat radiation. **Table B1** presents the result of this analysis.

TABLE B.2
HEAT RADIATION IMPACT FROM A TRANSFORMER BUND FIRE

Heat Flux (kW/m^2)	Distance to Heat Flux (m)
23	13.7
15	16.6
12.5	18.2
10	20.2
8	22.6
6	26
4.7	29.4
2.1	44.5
1.2	60

B3 Gasoline Fuel Spill Incident

The transfer of fuel from a road tanker to the underground storage tanks (gasoline) occurs adjacent to the main site store on the north western corner of the plant. The identified hazardous scenario involves the failure of a hose and the leak of fuel into the area adjacent to the tanker transfer point. The area is covered with concrete, which slopes away from the main site store building. A pipe trench is located adjacent to the tanker unloading area, however this trench is covered with steel plates to prevent fluids from flowing into the trench. Adjacent to the pipe trench is a spoon drain, which is about 2, wide and runs north to a site drain (about 8m).

Hence, the equivalent diameter of the spill is calculated as shown below:

$\pi/4 \times D^2 = 2 \times 8$

$D = (16 \times 4/\pi)^{0.5} = 4.5m$

By the same analysis conducted in **Section B2**, the following flame dimensions and properties were developed:

- Flame Cylinder diameter – 4.5m
- Flame height – 10.2m
- Transmissivity – 0.83
- SEP – 90 kW/m^2
- Angle of flame tilt – 15^o

The SCC program was used and the results of the analysis indicated that the distance to a heat radiation of 4.7kW/m^2 was 15.5m from the centre of the fire.

An analysis was conducted, using the SCC, for various levels of heat radiation to determine the distances to the selected levels of heat radiation. **Table B2** presents the result of this analysis.

TABLE B.2
HEAT RADIATION IMPACT FROM A GASOLINE FUEL SPILL FIRE

Heat Flux (kW/m^2)	Distance to Heat Flux (m)
35	6
23	7.3
15	8.9
12.5	9.7
10	10.8
8	12
6	13.7
4.7	15.5
2.1	23
1.2	29

B4 Diesel Fuel Spill Bund Fire

A spill and ignition of fuel in the diesel storage tank bund was identified to be the worst case incident at the diesel fuel tanks. The ignition of a spill of fuel into the bund of the diesel storage area would result in a pool fire. The bund is 26m x 27m, hence, the equivalent pool diameter is:

$\pi/4 \times D^2 = 26 \times 27$

$D = (702 \times 4/\pi)^{0.5} = 30m$

By the same analysis conducted in **Section B2**, the following flame dimensions and properties were developed:

- Flame Cylinder diameter – 30m
- Flame height – 38.2m
- Transmissivity – 0.77
- SEP – 23.3 kW/m^2
- Angle of flame tilt – 15^o

The SCC program was used and the results of the analysis indicated that the distance to a heat radiation of 4.7kW/m^2 was 35.4 m from the centre of the fire.

An analysis was conducted, using the SCC, for various levels of heat radiation to determine the distances to the selected levels of heat radiation. **Table B3** presents the result of this analysis.

TABLE B3
HEAT RADIATION IMPACT FROM A DIESEL FUEL BUND FIRE

Heat Flux (kW/m^2)	Distance to Heat Flux (m)
23	16.6
15	20.1
12.5	21.9
10	24.4
8	27.1
6	31.4
4.7	35.4
2.1	52.8
1.2	69.5

B5 LPG Tank BLEVE

The capacity of the LPG tank is 30,000 kg (50m^3). With a density of 560 kg/m^3, the volume of LPG in a full tank is 30,000/560 kg/m^3 = 53.6kg. In the event of a release and fire, the BLEVE will not occur immediately. It will take considerable time to heat the tank and its contents to a point where the weakened vessel will fail releasing the "boiling" gas contents. A conservative estimate of 60 minutes impingement before failure has been assumed. This is based on BLEVE experience, for example the BLEVE at St.Peters (Sydney) in 1989, occurred after the vessel has been impinged by fire for well in excess of 60 minutes. Tweeddale (Ref.7 – main report) explains the BLEVE phenomena in detail, indicting the process to take considerable time. Hence, in the event a release and fire occurs with a full tank, a conservative estimate is that half the gas is released at the leak, and via the pressure relief valves (which will have lifted due to the heating of the gas). The remaining gas available to fuel the BLEVE is therefore 30,000/2 = 15,000kg.

Based on a mass of fuel of 15,000kg the fireball characteristics are:

Fireball Diameter (D) = 6.48 $(15{,}000)^{0.325}$ = 147.5m

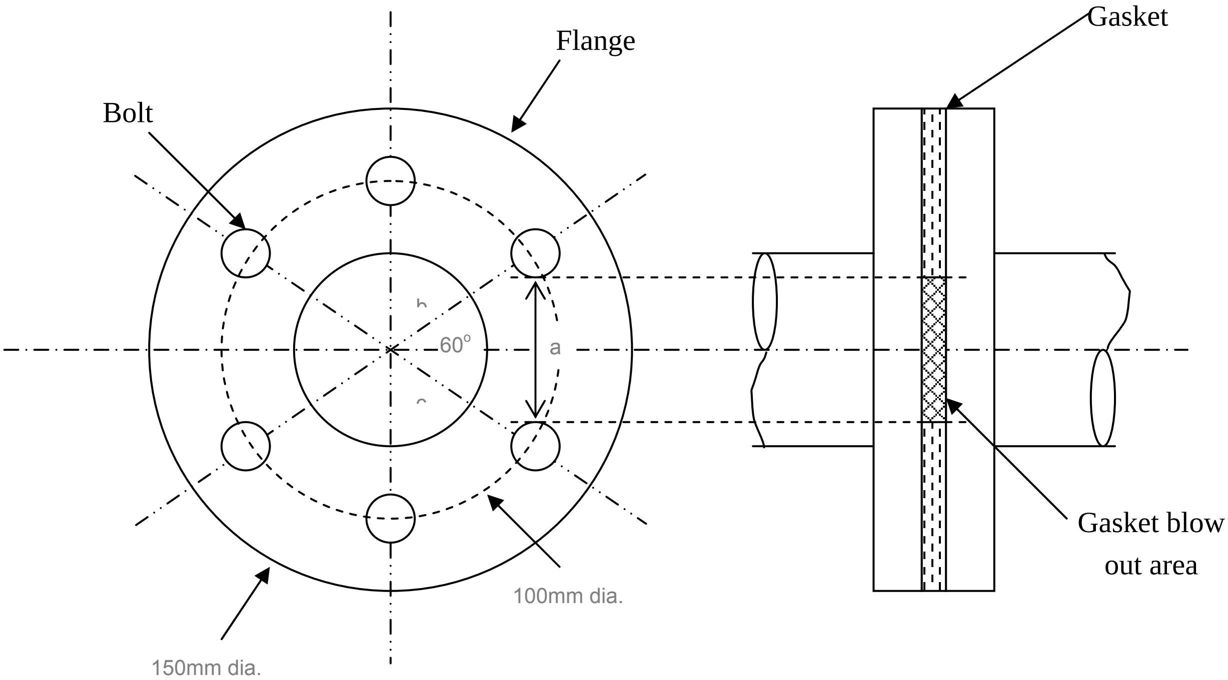
Fireball Duration (T) = 0.852 $(15{,}000)^{0.26}$ = 10.4 seconds

B6 Ammonia Incidents

The hazard analysis identified that there is a potential for leaks to occur in the ammonia storage and handling system. Leaks were identified to have the potential to occur in gaskets, pipework or flexible transfer hoses (during tank filling).

B2.1 Gasket Leaks

The maximum pipework size on the vessel is be 50mm. The first flange attached to a nozzle on the vessel would be 150mm diameter and contain six bolts. A weak gasket may blow out under pressure between the bolts in the flange. **Figure B2** shows a bolted flange and the cross sectional area between the flange bolts.



By the cosine rule: $a^2=b^2+c^2 - 2.b.c.\text{Cos}$

$a = (50^2 + 50^2 - (2 \times 50 \times 50\ \text{Cos}60))^{0.5}$

a = 50mm

FIGURE B2
LPG FLANGE – GASKET LEAK AREA

A gasket for the liquefied gas flange would be 3mm thick. Hence, the total area of release would be 0.05m x 0.003m = $1.5 \times 10^{-4} m^2$.

The equivalent release diameter is:

$1.5 \times 10^{-4} m^2 = \pi/4\ D^2$

D = 14mm

B2.2 Pipework Leaks

Leaks from pipework could occur as a result of corrosion. This would commence as a pinhole leak, growing to a hole over a short period. However, continued growth of the hole would be limited as the pressure in the ammonia system is not sufficient to propagate the hole and rupture the pipe (Ref.6-main report). Hole diameter of a leak would be in the order of 5% of the cross sectional area of the pipe (Ref.7-main report).

Cross Sectional Area of the pipe = $\pi/4\ D^2 = \pi/4\ (0.05)^2 = 1.96 \times 10^{-3} m^2$

5% cross section area = $0.05 \times 1.96 \times 10^{-3} m^2 = 9.8 \times 10^{-5} m^2$

Diameter of hole = $(4/\pi \times 9.8 \times 10^{-5})^2$ = 11mm

B2.3 Hose Leaks

Continued use of hoses (i.e. loading on and off trucks) can lad to wear on the external surface of the hose and potential for puncture and gas release. Hoses are steel braided and reinforced, preventing rupture and major release. Hence, release magnitude would be similar in size to that detailed in **Section B2.2** (i.e. 11mm hole diam.). Release incidents would be limited by the attendance of the driver at the transfer operation, who would activate the emergency shut down of the transfer in the event of a leak.

B2.4 Incident Selected for Modelling

Of the above incidents, the worst case incident is the leak at the gasket or flange. This could occur at a liquid flange releasing liquid ammonia from a hole of equivalent diameter 14mm.

Release rate from a 14mm hole is estimated as follows.

Liquid Release rate $G_L = C_d A(2.\rho.\delta P)^{0.5}$

Where: C_d = Co-efficient of discharge (0.6)
A = cross sectional area of the release hole (m^2)
ρ = density of the liquid (kg/m^3)
δP= pressure difference across the hole (Pa)

Hence, for a 14mm hole, the cross sectional area = $1.54 x 10^{-4} m^2$

Density of anhydrous ammonia = $682 kg/m^3$

Pressure differential = 8.8 bar (or $8.8x10^5$ Pa)

$G_L = 0.6 \times 1.45x10^{-4} \times (2 \times 682 \times 8.8x10^5)^{0.5}$ = 3kg/s

To calculate the adiabatic flash rate (i.e. the quantity of vapour formed from a liquid release, the following formula is used:

$V = (W.C_{p(mean)}.(T_1-T_2))/H_v$

Where: V = weight of the flash vapour produced (
W = weight of liquid spilled (kg/s)
$C_{p(mean)}$ = geometric mean of the specific heats over a range between T_1 & T_2
T_1 = Temperature of the liquid in the process (°C)
T_2= Atmospheric pressure boiling temperature of the liquid (°C)
H_v = Latent Heat of Vaporisation (kj/kg)

V = 3 x 1.37 x (21 – (-33))/287.84

Vapour Release Rate = 0.77 kg/s

A dispersion analysis was conducted using the gas release rate estimated above. When a gas is released, the downwind dispersion is a function of wind speed and weather conditions. In bright sunny conditions, with high wind, the gas disperses readily, but in light wind and overcast conditions the cloud tends to disperse slowly. To model such releases dispersion analysis analyse weather conditions in 6 classes:

A – Bright sunny conditions, highly unstable air streams;
B – Bright sunny conditions, moderately stable air streams;
C – Partial cloud, moderately stable air streams;
D – Mostly cloudy, some patches of sun, moderately stable air;

E – Full cloud cover, very light to stable air streams;
F – Full cloud, virtually no wind, very stable air streams.

To the values above, a wind speed is added to estimate the dispersion at the selected wind weather condition. For example, D5 represents partial cloud with moderate air stream and a wind speed of 5m per second. The selected values are input to a computer model that assesses the dispersion of the release and estimates the downwind concentration of the gas over a range of distances from the release source. The results are read in parts per million (ppm) of gas content in air.

The model used for the analysis was SLAB. This model was developed by the University of California (Lawrence Livermore Laboratories) for the US Department of Energy. The model was applied for each of the release scenario detailed above.

For ammonia, the concentration levels of interest are:

- Lowest reported lethal concentrations for any species for 30 minutes exposure (Ref.8) – 5000 ppm
- Injuriuos (50% of lowest reported lethal concentrations) – 2500 ppm
- ERPG-3 – 1000ppm - The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.
- ERPG-2 – 200 ppm - The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual’s ability to take protective action.
- ERPG-1 – 25 ppm - The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

For conservatism, the SLAB model was run using a concentration level of interest of 1000 ppm (ERPG-3) to determine the impact distance at the lower level of concentration. Model simulations were undertaken for time averaging periods of 1 second and 900 seconds to represent peak and typical short term (STEL) exposures. Runs were also conducted to check ammonia concentrations at the boundary during daytime (D3) and night time (F1) conditions. The source and meteorological parameters used in the model are presented in **Table B4** & **B5**.

TABLE B4
SOURCE PARAMETERS

Parameter	Ammonia
Spill source type	Stack
Source duration (seconds)	3600
Source height (metres)	0.3
Storage temperature (K)	288
Source Area (m^2)	0.000028
Averaging Time (seconds)	1, 900
Emission Rate (kg/s)	0.77
Analysis level of interest (ppm)	1000

TABLE B5
METEOROLOGICAL PARAMETERS

Parameter	Value
Surface Roughness (metres)	0.05
Temperature (K)	288
Relative Humidity (%)	40
Wind Speed and Stability Scenarios (PG stab, m/s)	B3, B5, D3, D5, D9, E1.5, F1

The result of the analysis is shown in **Tables B6** & **B7**.

TABLE B6
AMMONIA 1000 PPM MAXIMUM DISTANCE FORM SOURCE (METRES) – 1 SECOND AVERAGING PERIOD

Met Condition	Height (m) Above Ground Level			
	0.01	1.5	1.8	2.5
B3	88	87	87	86
B5	75	74	74	73
D3	167	163	161	155
D5	148	145	144	139
D9	121	119	118	113
E1.5	223	213	210	199
F1	320	300	291	260

TABLE B7
AMMONIA 1000 PPM MAXIMUM DISTANCE FORM SOURCE (METRES) – 900 SECOND AVERAGING PERIOD

Met Condition	Height (m) Above Ground Level			
	0.01	1.5	1.8	2.5
B3	73	72	72	71
B5	57	56	55	54
D3	146	143	141	135
D5	120	117	115	110
D9	89	86	85	80
E1.5	212	206	202	191
F1	314	294	286	256

It can be seen from Tables B6 & B7 that the maximum downwind distance for a concentration level of ammonia of 1000 ppm is 320 m. This occurs using a 1 second averaging period, at 0.01 m above ground level, and under F class stability 1 m/s conditions.

Boundary Concentrations

The following results show the predicted concentrations at distances of 600 m (the closest boundary) and 900 m from the source, which are representative of the site boundary. Results for 1 s and 900 s averaging periods are given and the highest concentrations were found to occur at 0.01 m above ground level under F class stability with 1 m/s wind.
Results indicate that, for a 1 s averaging period, the concentration should be 483 ppm and 304 ppm at a distance of 600 m and 900 m respectively. Concentrations for a 900 s averaging period are expected to be 262 ppm and 283ppm at a distance of 600 m and 900 m respectively.

Table B8: Ammonia concentration at 600m boundary – 1 s averaging period

Met Condition	Concentration (ppm) ant Height (m) Above Ground Level			
	0.01	1.5	1.8	2.5
B3	33	33	33	33
B5	20	20	20	20
D3	138	137	137	136
D5	100	99	99	99
D9	62	62	62	62
E1.5	273	270	269	265
F1	483	469	463	446

Table B9: Ammonia concentration at 900m boundary – 1 s averaging period

Met Condition	Concentration (ppm) ant Height (m) Above Ground Level			
	0.01	1.5	1.8	2.5
B3	16	16	16	16
B5	10	10	10	10
D3	72	72	72	72
D5	50	50	50	50
D9	30	30	30	30
E1.5	160	159	158	157
F1	304	299	296	290

Table B10: Ammonia concentration at 600m boundary – 900 s averaging period

Met Condition	Concentration (ppm) ant Height (m) Above Ground Level			
	0.01	1.5	1.8	2.5
B3	16	16	16	16
B5	9	9	9	9
D3	85	85	84	84
D5	52	51	51	51
D9	28	28	28	28
E1.5	231	229	228	225
F1	262	249	433	426

Table 1: Ammonia concentration at 900m boundary – 900 s averaging period

Met Condition	Concentration (ppm) ant Height (m) Above Ground Level			
	0.01	1.5	1.8	2.5
B3	7	7	7	7
B5	4	4	4	4
D3	41	41	41	41
D5	24	24	24	24
D9	13	13	13	13
E1.5	126	126	125	124
F1	283	278	276	270

B3 Chlorine Incidents

Chlorine incidents were identified to occur as a result of a manifold leak or failure of a pigtail line. Noting that the pigtail line is installed between the drum and the manifold, holes in the manifold, larger than the pigtail diameter would be limited by the flow restriction down the pigtail line. Hence, the governing factor in the chlorine release is the pigtail line diameter.

The worst case incident is therefore a pigtail line failure releasing into the storage building and escaping through the vents in the building. Pigtail lines are nominally 6mm NB, hence, this diameter has been used to estimate the chlorine release rate for this scenario. The release rate calculation is as follows.

Liquid Release rate $G_L = C_d A(2.\rho.\delta P)^{0.5}$

Where: C_d = Co-efficient of discharge (0.6)
A = cross sectional area of the release hole (m^2)
ρ = density of the liquid (kg/m^3)
δP= pressure difference across the hole (Pa)

Hence, for a 6mm hole, the cross sectional area = $1.54 \times 10^{-4} m^2$

Density of chlorine = $1.56 kg/m^3$

Pressure differential = 6.95 bar (or 6.95×10^5 Pa)

$G_L = 0.6 \times 2.83 \times 10^{-5} \times (2 \times 1560 \times 6.95 \times 10^5)^{0.5} = 0.79 kg/s$

To calculate the adiabatic flash rate (i.e. the quantity of vapour formed from a liquid release, the following formula is used:

$V = (W.C_{p(mean)}.(T_1\text{-}T_2))/H_v$

Where: V = weight of the flash vapour produced (
W = weight of liquid spilled (kg/s)
$C_{p(mean)}$ = geometric mean of the specific heats over a range between T_1 & T_2
T_1 = Temperature of the liquid in the process (^oC)
T_2= Atmospheric pressure boiling temperature of the liquid (^oC)
H_v = Latent Heat of Vaporisation (kj/kg)

V = 0.79 x 1.3 x (21 –(-34.6))/1370.84

Vapour Release Rate = 0.041kg/s

The model used for the analysis was SLAB (see details listed in **Section 2.4**). This model was developed by the University of California (Lawrence Livermore Laboratories) for the US Department of Energy. The model was applied for the release scenarios detailed above.

For chlorine, the concentration levels of interest are:

- Fatality potential (Ref.9) – 20 ppm
- Injurious (50% of lowest reported lethal concentrations) – 5 ppm

The SLAB model was run using the two concentration levels above (20 & 5 ppm) to determine the impact distance at these levels of concentration. Model simulations were undertaken for time averaging periods of 1 second and 900 seconds to represent peak and typical short term (STEL) exposures. The source and meteorological parameters used in the model are presented in **Table B8** & **B9**.

TABLE B8
SOURCE PARAMETERS

Parameter	Chlorine
Spill source type	Stack
Source duration (seconds)	3600
Source height (metres)	0.3
Storage temperature (K)	288
Source Area (m^2)	0.000028

Parameter	Chlorine
Averaging Time (seconds)	1s, 900s
Emission Rate (kg/s)	0.041
Analysis level of interest (ppm)	5, 20

TABLE B9
METEOROLOGICAL PARAMETERS

Parameter	Value
Surface Roughness (metres)	0.05
Temperature (K)	288
Relative Humidity (%)	40
Wind Speed and Stability Scenarios (PG stab, m/s)	B3, B5, D3, D5, D9, E1.5, F1

The result of the analysis is shown in **Tables B10** & **B11**, for 5ppm and **B12** & **B13** for 20ppm.

TABLE B10
CHLORINE 5 PPM MAXIMUM DISTANCE FORM SOURCE (METRES) – 1 SECOND AVERAGING PERIOD

Met Condition	Height (m)			
	0.01	1.5	1.8	2.5
B3	175	175	175	174
B5	136	136	136	135
D3	402	401	400	389
D5	308	307	307	305
D9	225	225	224	223
E1.5	786	783	782	778
F1	1570	1561	1558	1546

TABLE B11
CHLORINE 5 PPM MAXIMUM DISTANCE FORM SOURCE (METRES) – 900 SECOND AVERAGING PERIOD

Met Condition	Height (m)			
	0.01	1.5	1.8	2.5
B3	115	114	114	113
B5	90	90	89	89
D3	261	260	259	258
D5	197	196	195	192
D9	143	141	140	137
E1.5	536	533	531	526
F1	1135	1127	1124	1111

It can be seen from Tables B10 & B11 that the maximum downwind distance for a concentration level of chlorine of 5 ppm is 1,558m. This occurs using a 1 second averaging period, at 1.8m above ground level, and under F class stability 1 m/s conditions.

TABLE B12
CHLORINE 20 PPM MAXIMUM DISTANCE FORM SOURCE (METRES) – 1 SECOND AVERAGING PERIOD

Met Condition	Height (m)			
	0.01	1.5	1.8	2.5
B3	84	83	83	83
B5	68	67	67	66
D3	182	180	179	176
D5	142	140	138	136
D9	106	104	103	100
E1.5	326	321	319	313
F1	576	563	558	540

TABLE 13
CHLORINE 20 PPM MAXIMUM DISTANCE FORM SOURCE (METRES) – 900 SECOND AVERAGING PERIOD

Met Condition	Height (m)			
	0.01	1.5	1.8	2.5
B3	58	57	57	56
B5	46	45	45	43
D3	124	121	120	117
D5	94	92	91	87
D9	69	66	65	61
E1.5	243	239	237	230
F1	464	453	446	432

It can be seen from **Tables B10** & **B11** that the maximum downwind distance for a concentration level of chlorine of 20 ppm is 558m. This occurs using a 1 second averaging period, at 1.8m above ground level, and under F class stability 1 m/s conditions.

Based on a 5min release and a concentration of 20 ppm at the boundary the probability of fatality is given by;

Pr = -8.29 + 0.92 ln (c^n t) = 3.4, form the graph a Pr value of 3.4 equates to a probability of fatality of 0.06 for this event.

Table B.1 Relation Between Probits and Probabilities

%	0	1	2	3	4	5	6	7	8	9
0	-	2.67	2.95	3.12	3.25	3.36	3.45	3.52	3.59	3.66
10	3.72	3.77	3.82	3.897	3.92	3.96	4.01	4.05	4.08	4.12
20	4.16	4.19	4.23	4.26	4.29	4.33	4.36	4.39	4.42	4.45
30	4.48	4.50	4.53	4.56	4.59	4.61	4.64	4.67	4.69	4.72
40	4.75	4.77	4.80	4.82	4.85	4.87	4.90	4.92	4.95	4.97
50	5.00	5.03	5.05	5.08	5.10	5.13	5.15	5.18	5.20	5.23
60	5.25	5.28	5.31	5.33	5.36	5.39	5.41	5.44	5.47	5.50
70	5.52	5.55	5.58	5.61	5.64	5.67	5.71	5.74	5.77	5.81
80	5.84	5.88	5.92	5.95	5.99	6.04	6.08	6.13	6.18	6.23
90	6.28	6.34	6.41	6.48	6.55	6.64	6.75	6.88	7.05	7.33

B4 Natural Gas Pipeline Consequence Analysis

A review of the hazard identification section indicates that the only gas fitting line incidents carried forward for further analysis are related to external impact and the potential for fitting line breach from mobile equipment (e.g. cranes, vehicles, etc.) striking the fitting line. It is noted that the fitting line is manufactured from X42 grade steel and that the pressure is about 5,300kPa or 53bar. Hence, propagation of a breach (i.e. hole created by an external impact) would not occur (SKM & Agility Communication 2005) at this pressure using "X" grade steel pipe.

Based on the above information, an external impact from mobile equipment (e.g. crane, vehicles, etc.) on a steel fitting line, with diameter 470 mm and wall thickness 12.7mm, would cause fitting line rupture. Hence, to determine the leak rate from a 10, 40, and 100 mm hole in the fitting line (i.e. rupture), the EFFECTS© model was used. EFFECTS© is a series of loss estimation programs developed by the TNO Organisation in the Netherlands (TNO Safety Software 2003). In the event of a rupture in the fitting line, the release would commence with a significant surge of gas, reducing with time as the flow in the fitting line was restricted as a result of flow friction, etc.

It is noted that the gas supply to the site enters via an isolation and metering station, where a number of manual and automatic isolation valves are installed. In the event of a major leak (i.e. rupture), the rapid de-pressuring would be detected and the isolation valve closed automatically. This would isolate the flow of gas to the leak resulting in extinguishing of the fire due to lack of fuel source.

In the event of immediate ignition, the release would burn as a jet fire in the form shown in Figure B1. Much research has been conducted on the shape of jet fires, the most appropriate modelling shape being the frustum of a cone (Lees, F.P. 2001). An analysis of the fire shape and impact was performed using the EFFECTS© model, the results of the analysis are summarised in Table B1. A horizontal release will be directed upwards at an angle of about 45o.

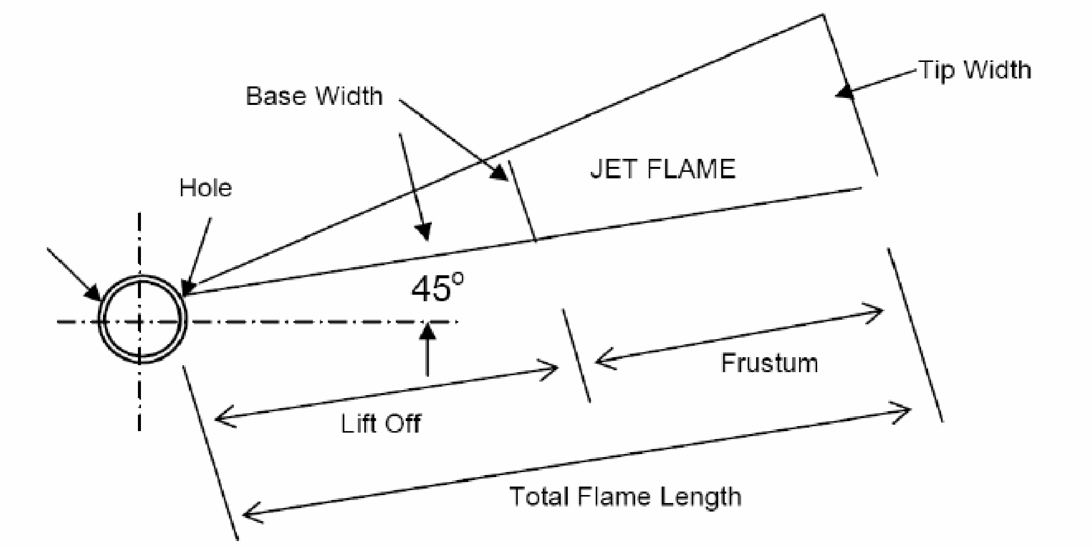
The EFFECTS© model has therefore used an angle of 45o for assessment of impacts to the surrounding areas.

Noting that the flow rate is constantly changing, due to de-pressuring, the flow rate used in the analysis of the jet fire has been selected based on the impact criteria published in HIPAP No.4 (DIPNR 1992b). HIPAP No.4 indicates that people impacted by more than 4.7kW/m2 for over 30 seconds would feel pain and therefore need to move from the area. An average value of 30kg/sec has therefore been used, which is conservative, as the majority of gas has been released within the first few seconds of the incident.

Table B1 Heat radiation impacts from fitting line incidents as a result of jet fire from an external impact breach

Hole Diameter (m)	Rupture (100 mm)
Jet Fire Length-Total (m)	59.13
Width of Flame at End (m)	15.96
Width of Flame at Base (m)	2.26
Flame Lift Off (m)	10.9
Angle of Flame from Horizontal	45^o
Heat Radiation Level (kW/m2)	Distance (m)
35	52.5
23	54.5
15	56
12.5	57
8	59
4.7	61
2	68

Figure B1 Jet flame schematic



In the event a gas release from a hole does not immediately ignite, the gas will escape from the fitting line and be released as a gas jet, dispersing in the area surrounding the fitting line. It is noted that the fitting line will be installed in an easement, well clear of surrounding areas. The easement will not contain any structures that could confine the gas and, hence, in the event of an ignition, explosion is not likely in this area (Kletz, T 2006). The more likely scenario, in the event of an ignition, is a flash fire, whereby the gas cloud developed as a result of the release will burn rapidly but without deflagration (explosion).

A rupture of the fitting line in the easement will see a significant quantity of gas released, resulting a gas cloud of many tonnes. This will extend well beyond the easement boundary. Hence, ignition of the cloud would result in flash fire outside the confines of the fitting line easement.

Notwithstanding the large quantity of gas released, it is noted that the gas is considerably lighter than air and releases would rise and disperse above the plant.

Gas Leak into the Turbine Enclosure

In the event a gas leak occurs within the gas turbine enclosure, under normal circumstances the enclosure ventilation fan would extract the gas and disperse it externally. However, in the event the ventilation fan is shut down or in a failed condition, the gas would build up in the enclosure. Under these circumstances the gas will eventually reach the lower flammable limit and if ignited a gas explosion would occur. This explosion would result in destruction of the gas turbine enclosure and blast impact towards the site boundary.
To estimate the magnitude of the blast wave the TNT equivalence method was used. This method estimated the quantity of gas within an explosive cloud and equates the mass of gas to an equivalent mass of TNT. Empirical analysis can then be performed to estimate the blast pressure at specific distances from the blast centre.

To estimate the quantity of gas at LEL in the gas turbine enclosure, the volume of the enclosure is first calculated. The gas turbine enclosure dimensions have been assumed as (final designs have not yet been selected): 20m long x 4.2m wide x 4.4m high. Whilst the volume of the enclosure can be calculated as: 20x4.2x4.4 = 369.6m3, the enclosure is fitted with equipment and the gas turbine unit itself. This reduces the free volume in the enclosure to below 50%. However, for this analysis a free volume of 50% has been assumed.

Hence, the volume of gas (at LEL) that would explode if ignited is 369.6/2 = 184.8m3.
The mass of methane, at LEL, within 184.8m3 of gas is calculated as follows:
1 mole of gas is contained within each 22.4L. Hence, for 184,800 of gas the number of moles = 184,800/22.4 = 8,250 mole

At LEL there is a 5% mixture of methane gas in air. Hence, the total number of mole of methane = 8,250 x 0.05 = 412.5 mole. The molecular weight of methane is 16. Hence, the total mass of methane in the enclosure is 6,600kg.

Table B2 summarises the results of the analysis.

Overpressure kPa	Results	Distance to Overpressure (m)	Risk of Fatality	
			Conventional Building	Open in Chemical Plant
4	90% window breakage, some damage to cladding.	277.5	0.01	0.00
7	Glass fragments fly with sufficient force to injure. Damage to cladding, roof tiles removed	195.6	0.02	0.00
14	Houses uninhabitable but not totally irreparable. Cement block buildings may be flattened. Roofs of oil storage tanks would be damaged.	126.8	0.08	0.01
20		101.5	0.16	0.03
35	Onset of severe general structural damage. Houses severely damaged, needed demolition. Serious damage could occur to items of plant equipment and possibly initiation of leaks and fires. Oil storage tanks could rupture.	71.5	0.48	0.12
70	Almost complete demolition of all ordinary structures. Assumed edge of cloud. Damage to most chemical plants would be severe although some compressors, pumps and heat exchangers could be salvaged.	46.4	1.00	1.00

At the boundary close to Boulder Rd (500m away) the explosion overpressure is around is lower than 4 kpa (at 14kPa the risk of fatality to a person in the open is 0.01). Hence the effect is not significant . For the purpose off computation the risk of fatality will be taken as 0.01.