INITIAL QUANTITATIVE RISK ASSESSMENT OF AGL'S PROPOSED TARRONE POWER STATION, VIC

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Prepared by: Karin Nilsson

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PO Box 1497
Lane Cove NSW 2066
Telephone: [02] 9427 7851
Facsimile: [02] 9427 7851
Email: karin@planager.com.au

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EXECUTIVE SUMMARY

E1 – General

To meet the rising demand for electricity in Australia, AGL Energy Limited (AGL) is proposing to build and operate a gas fired Power Station at Tarrone, south-west of Hawkesdale and south-east of Macarthur in Victoria.

Due to the potentially hazardous nature and quantities of hazardous materials stored and utilised on site, the facility itself is potentially hazardous.

The objective of this Initial Quantitative Risk Assessment (QRA) is to present the hazards and risks associated with the proposed Power Station at an early design stage. Through the evaluation of likelihood and consequence of the major hazards, the risks to the community associated with proposed Power Station may be estimated and compared to tolerability criteria in use in Victoria.

The aim of this Initial QRA is to:

- Identify and analyse the hazards and risks associated with all processes involved with the handling of potentially hazardous material which form part of the new development;
- Assess the findings against the tolerability criteria in use in Victoria
- Identify opportunities for risk reduction, and make recommendations as appropriate.

The risk assessment has quantitatively determined the risk of fatality and injury to the public associated with the handling of potentially hazardous material at the proposed development.

The report assesses the risks from the following facilities:

- The lateral supply pipeline carrying natural gas from the SEA Gas Pipeline to the Power Station.
- The Power Station itself.

The methodology for QRA is well established in Victoria. The assessment has been carried as per Victorian WorkSafe Victoria guidelines.

The risk assessment technique involves the following general steps:

- Identification of the hazards associated with the proposed project, including those which may potentially injure people off-site or damage the off-site environment;

- Identification of the proposed safeguards to mitigate the likelihood and consequences of the hazardous events;

- Estimation of the magnitude of the consequences of these incidents;

- Where the consequences may affect the land uses outside the site boundary, estimation of the probability with which these incidents may occur;

- Estimation of the risk by combining the frequency of the event occurring with the probability of an undesired consequence;

- Comparison of the risk estimated with the guidelines and criteria relevant to the proposal.

E2 Results

The main hazard associated with the proposed project is associated with the handling of natural gas, which is a flammable gas held under pressure.

Hazards may arise in fixed plant, storage, and pipelines. The failure modes assessed in the Initial QRA derived from historical failures of similar facilities and equipment. For the facilities which form part of the development, the predominant mode in which a hazardous incident may be generated is associated with a leak. This would generally only have the potential to cause injury or damage if there was ignition, which resulted in a fire or explosion incident. The factors involved are:

- Failure must occur causing a release. There are several possible causes of failure, with the main ones being corrosion and damage to the equipment by external agencies;

- The released material must come into contact with a source of ignition. In some cases this may be heat or sparks generated by mechanical damage while in others, the possible ignition source could include non-flame proof equipment, vehicles, or flames some distance from the release;

- Depending on the release conditions, including the mass of material involved and how rapidly it is ignited, the results may be a localised fire (a so called jet fire), a flash fire or an explosion of the vapour cloud formed through the release.

- Finally, for there to be a risk of injury or fatality, people must be present within the harmful range (consequence distance) of the fire or explosion. How close the people are will determine whether any injuries or fatalities result.

E3 Risk Assessment and Conclusions

The analysis showed that (as per risk criteria in use in Victoria):

- The 0.1 x 10^{-6} per year fatality risk contour does not extend beyond the Power Station site boundaries. This means that there are no requirements for restriction to residential development outside of the site.

- It then follows that the risk of fatality at the nearest residential area from the Power Station is extremely low.

- It also follows that the 10 x 10^{-6} per year fatality risk contour is not exceeded at the boundary of the Power Station site.

- As the risk of fatality does not extend outside the boundaries of the Power Station, it is considered that the proposed development does not have a significant impact on societal risk.

- The risk criterion *which must remain inside plant boundaries* (as per Victorian WorkSafe criteria) for the lateral gas supply pipeline (10 x 10^{-6} /yr) remains inside the pipeline easement provided the maximum operating pressure of the lateral gas pipeline does not exceed 12MPa. Hence, this criterion is adhered to. The maximum risk level experienced at 25 metres from the pipelines is less than 1 x 10^{-6} /yr. The 0.1 x 10^{-6} /yr risk contour extends 25 meters from the pipeline easement – residential development may need to be restricted in this area.

- The risk associated with the transport of dangerous goods and potentially hazardous material to the site is negligible.

E4 Recommendations

The risk assessment carried out in this study assumed that the facility will be operated with appropriate consideration to safety and safety management at all stages, throughout its design, construction and operation.

The following recommendations emphasise the assumptions made in this risk assessment. The recommendations are listed in the order in which they were listed in the body of the report.

Recommendation 1: It is recommended that an audit is carried out of the safety management system implemented at the site, specifically as it applies to the proposed hazardous materials handling, pipelining and storages. This audit should be carried out within the first year of operation.

Recommendation 2: High and low pressures of the natural gas supply are to be monitored during (and, if applicable, outside) operation of the Power Plant. These conditions will need to be associated with an automatic trip / shut down of the pipeline at the metering station in case of a major failure of the natural gas pipeline within the site boundary (as assumed in this QRA). The detection and subsequent closure at the SEA Gas pipeline in case of a major leak in the lateral pipeline is also required.

Recommendation 3: The use of fusible tubing around above ground high risk natural gas piping (e.g. within the turbine housing) to be investigated – such tubing would be linked to automatic shut down of the fuel source.

Recommendation 4: The detailed design of the turbine housing and associated equipment should clearly outline the basis of safety used to ensure that explosive situations do not arise (that the risk is rendered negligible). Reference should be made to European ATEX Directive and the UK HSE PM84 or other guidance / regulation of equivalent safety.

Recommendation 5: Fire protection inside the turbine housing to be determined during detailed design, including use of explosion panels and use of fire retardant material.

Recommendation 6: A system should be put in place to ensure that any removal of critical safety function (e.g. for repair or exchange) is subject to careful scrutiny by plant management (decisions on whether to allow continued operation of the plant or of a turbine if a critical safety function is removed need to be made by personnel with enough training and understanding of the safety implications of such decision).

Recommendation 7: Rotating machines to be designed such that the risk associated with projectile is minimised (gas pipelines protected or not in probable line of projectile; electrical switchyard protected or not in probably line of projectile; people protected etc.).

Recommendation 8: Loud alarm and visual indication (e.g. strobe light) to be installed within the turbine housing, alerting any persons within these housings of the pending discharge of asphyxiants (if such is used) and allowing escape.

Recommendation 9: As the project and design are still in the feasibility stage a number of assumptions needed to be made as part of this Initial QRA. While believed to be conservative, these assumptions should be verified at the detailed project and design stage to ensure that the results of the Initial QRA remain valid.

GLOSSARY

AGL	AGL Energy Limited
CBD	Central Business District
DLN	Dry Low NO_x
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HSE	Health and Safety Executive (UK)
LFL	Lower Flammable Limit
MAOP	Maximum Allowable Operating Pressure
MPa	Mega Pascal (unit for pressure)
MSDS	Material Safety Data Sheet
MW	Mega Watt (unit for energy output)
NG	Natural gas
NO_x	Nitrogen oxides
OH&S	Occupational Health and Safety
QRA	Preliminary Hazard Analysis
SCADA	Supervisory Control and Data Acquisition
SIL	Safety Integrity Level
UK	United Kingdom

REPORT

1 INTRODUCTION

1.1 BACKGROUND

To meet the rising demand for electricity in Australia, the Australian Gas Light Company (AGL) is proposing to build and operate a gas fired Power Station at Tarrone, south-west of Hawkesdale and south-east of Macarthur in Victoria. Due to the potentially hazardous nature and quantities of hazardous materials stored and utilised on site, the facility itself is potentially hazardous.

As one element of the planning approval process, WorkSafe Victoria requires a Quantitative Risk Assessment (QRA) to be prepared using the guidelines laid out in the *Risk Assessment Guidelines* prepared for the ACC and Victorian Government, 1995 (Ref 1).

1.2 SCOPE AND AIM OF STUDY

The objective of this QRA is to present the hazards and risks associated with the proposed Power Station. Through the evaluation of likelihood and consequence of the major hazards, the risks to the community associated with proposed Power Station may be estimated and compared to established risk criteria.

The scope of this report includes the following;

- Systematic identification and documentation of the major hazards, based on the information supplied and relevant experience with similar processes;

- Establishment of the consequence of each identified hazard and determination as to their offsite effects. This process is generally qualitative, with relevant quantitative calculations/modelling being completed where necessary;

- Where offsite effects are identified, the frequency of occurrence is estimated based on historical data. If such data is unavailable, assumptions and qualitative discussions are presented;

- Determination of the acceptability (or otherwise) risk by comparison of the qualitative or quantitative assessment of the identified risks with the criteria used by WorkSafe Victoria as presented in their Guidance for Risk Assessments (Ref 1) and referred to in their Guidance Note for Major Hazard Facilities MHF-GN-16 (Ref 2); and

- Identification of risk reduction measures as deemed necessary.

At the time this QRA was conducted, design of the Power Station was in its preliminary stages. Detailed plant information was therefore not available for review. In situations where such information could impact on the Initial QRA, assumptions have been made. These assumptions are intentionally conservative and have been stated in the report.

As a result of this conservatism, the results of the QRA are also inherently conservative, and this should be noted in their interpretation and application beyond the scope of this work.

The adherence to these assumptions should be verified at the detailed design stage to ensure that the results of the Initial QRA remain valid.

2 SITE AND PROCESS DESCRIPTION

2.1 SITE LOCATION AND SURROUNDING LAND USES

The site is located on the north-east corner of the intersection of Riordans Road and Landers Lane, in the locality of Tarrone, Victoria. A location map is presented in Figure 1 and more in details in Figure 2 below.

The site is rectangular in shape with a narrow on title access extending from the north-east corner of the site in an easterly direction for a distance of approximately 850m to Tarrone North Road.

Existing neighbouring land uses are agriculture and energy infrastructure. There are no existing residences on the subject site. The site is currently used for agricultural purposes, mainly the grazing of cattle.

The site is crossed by high-voltage powerlines from the north-east to the south-west. To the west of the site the powerline alignment is parallel to the east-west Riordans Road and within the site, the alignment direction alters to north-east-south-west, continuing north-east of the site.

2.2 LATERAL GAS SUPPLY PIPELINE

Two alternative pipelines are currently evaluated by AGL Energy, one which runs north east to south west and one which runs north south from the SEA Gas Pipeline.

The proposed (approximate) routes of these two alternative supply pipelines are presented in Figure 3, showing the valve station at the off-take from the SEA Gas Pipeline up to the gas receiving station within the Power Station site. The pipeline will run within an easement approximately 25 meter wide.

Only one pipeline route will be chosen.

Both pipelines run through mainly rural lands, to the Power Station located on Landers Lane.

The North-South Option traverses eight farming properties (including the subject site) and is aligned north-south. The pipeline runs from north of the proposed gas-fired power station site at Landers Lane, crosses over Woolsthorpe-Heywood Road, and terminates just north of Kangertong Road. It is approximately 10,000 m long and traverses numerous stony basalt knolls, drainage lines and low lying areas prone to seasonal inundation.

The East-West Option traverses six farming properties (including the subject site) and is aligned more or less east-west. It commences east of the proposed gas-fired power station site at Tarrone North Road, crosses over Coomete Road, and terminates just east of Willatook-Warrong Road. It is approximately

7,000 m long and traverses mostly improved pasture, but also includes two stony basalt knolls, several drainage lines and low lying areas prone to seasonal inundation.

2.3 SURROUNDING LANDUSE

The surrounding area is defined as the area within five kilometres of the subject site and pipeline alignment.

The area surrounding the Power Station site includes properties within the localities of Hawkesdale, Orford, Tarrone, Warrong and Willatook. The surrounding area is rural with no defined settlements. The nearest settlements are Hawkesdale and Orford, to the north-east and south-west of the surrounding area respectively.

The existing land uses within the surrounding area are predominantly rural with residences. There is also infrastructure including high-voltage power lines, the underground SEA Gas pipeline and numerous roads.

The site is located within the Moyne Shire in south-west Victoria. The major centre of the municipality is Port Fairy, with secondary centres at Koroit, Macarthur and Mortlake.

Figure 1 – Site Location (Overview)

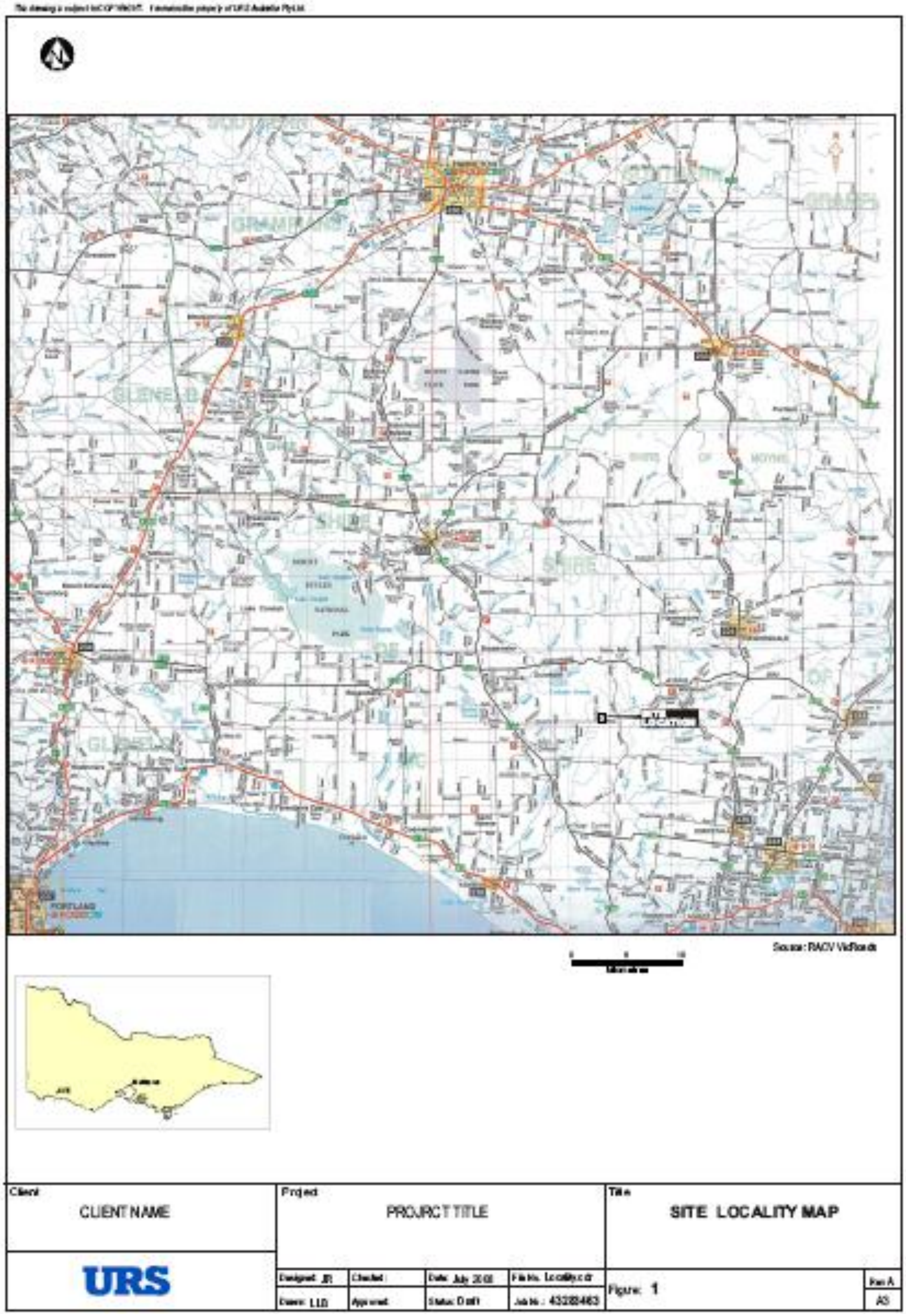
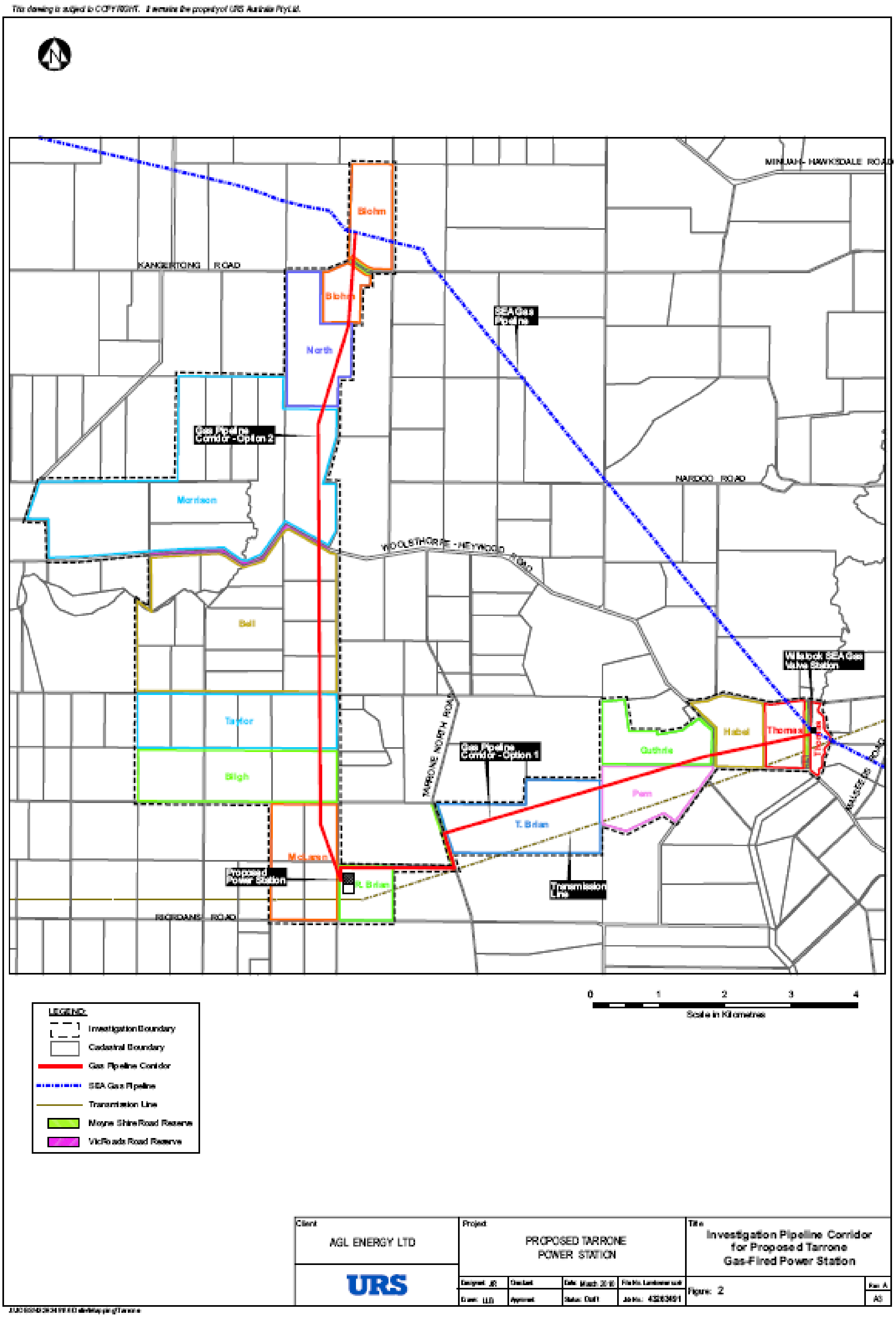


Figure 2 – Proposed Site Location (Detailed)

Figure 3 – Approximate Routes of the Lateral Gas Supply Pipeline



2.4 SITE LAYOUT

Three options are currently under review, depending on the choice of turbine supplier, as follows:

- Alsrom 13E2 as Option 1B;
- GE 9FA as Option 2B and
- Siemens as Option 3B.

While the detailed layout will vary depending on the final choice of turbine supplier (and hence on the number of turbines used[1]), the basic site layout is presented in Figure 4 below.

Following completion of construction and commissioning, the major site features will include:

- The natural gas receiving station;
- Gas turbines (three to four, depending on the supplier of the turbine chosen), air compressors and electricity generators inside turbine enclosures (“housings”);
- Generator transformer for each turbine;
- Exhaust stack for each turbine; Inlet air evaporative cooler for each turbine;
- A control Building;
- Raw water storage tank with associated pump(s) – if required;
- An evaporation pond;
- A stormwater pond (for surface water management);
- A switchyard with service connections linked to the electricity transmission network, gas and water supplies;
- A maintenance building (*workshop and store* on the plan);
- An Administration Building with two uncovered separate parking areas; and
- Service roads.

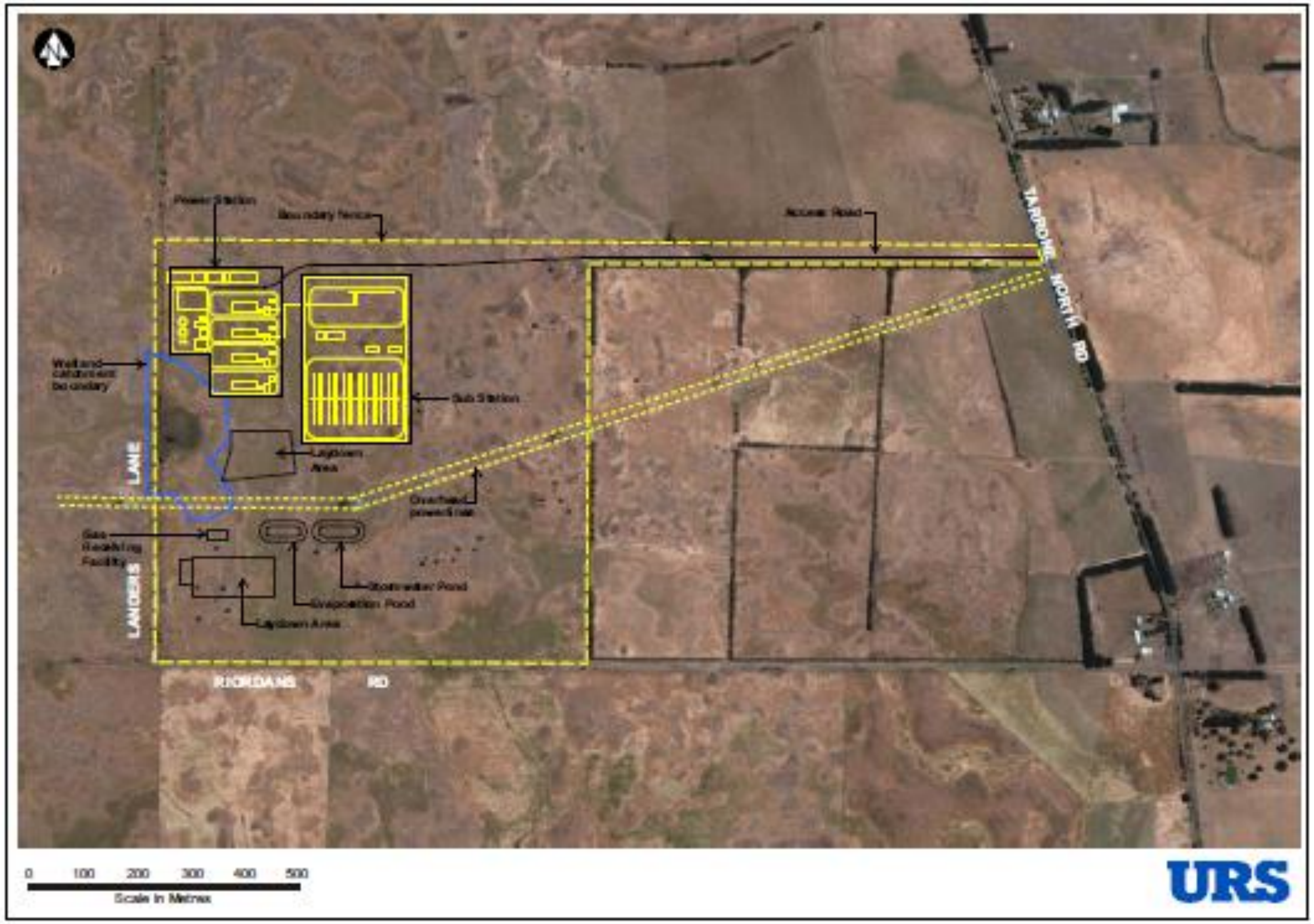
2.5 PROJECT PHASING

The Power Station will be constructed in two stages, with Stage 1 comprising of two gas turbines and Stage 2 of either one or two turbines depending on the supplier). The Power Station will operate in open cycle mode during times of peak electricity demand which is estimated to be less than 10% of the time[2].

[1] If Alstrom gas turbines are used, four turbines will be required to produce the electricity required. If General Electric (GE) or Siemens turbines are chosen, then three turbines will be required.

[2] The long term average operating hours are expected to be approximately 440 hours (approximately 5%) of the year operated to supply electricity at times of high demand.

Figure 4 – Preliminary Site Layout (Option 1B)



2.6 OPERATING HOURS AND STAFFING

Each phase of the proposed facility would be capable of operating for 24 hours per day. However, actual operational hours for each of the phases would be dependent upon periodic electricity demand and economic factors (the Power Station is designed for peaking demand only, generally operating less than 10% of the time on an annual basis).

It is expected that the facility would be staffed during day-shift only. 24-hour monitoring of the site may be provided from AGL's national control centre at Mt Beauty. Personnel could be called to the site at any time in case of a process upset.

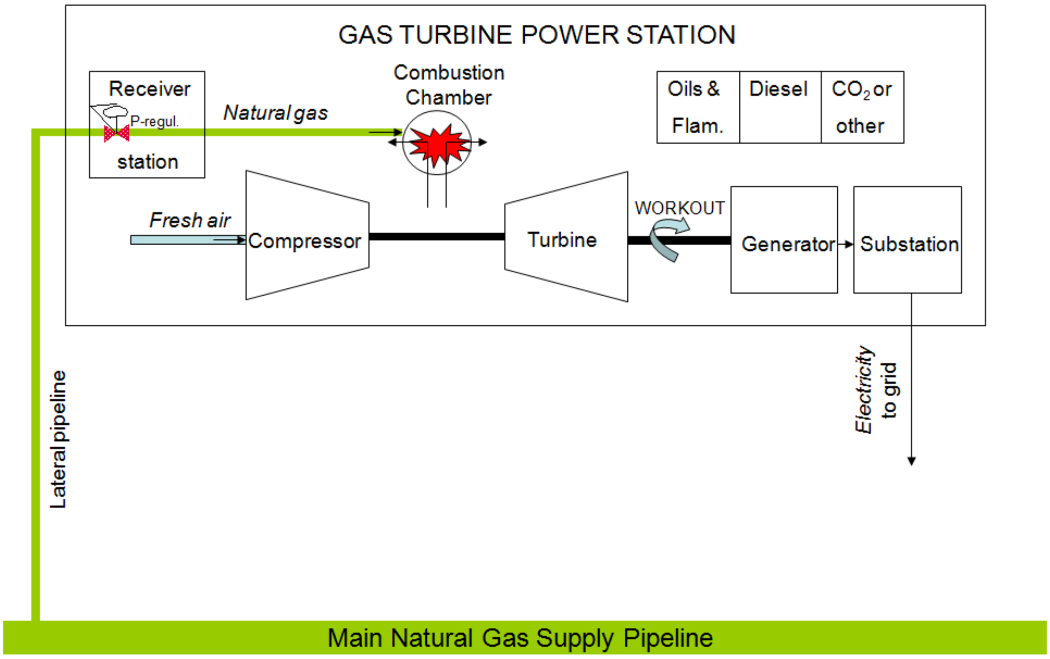
2.7 GAS TURBINE OPERATION

Gas turbines are rotary engines that extract energy from a flow of combustion gas (in this case natural gas). A gas turbine largely consists of an upstream air compressor coupled to a downstream gas turbine, and a combustion chamber in-between.

Energy is generated where air is mixed with the combustion gas and ignited in the combustion chamber. The heat produced by the burning fuel causes the air to expand and rush past the turbine causing it to spin. Energy is extracted in the form of shaft power, compressed air and thrust and used to generate electricity in the transformer.

A block diagram of the gas turbine station and gas supply is shown in Figure 5 below.

Figure 5 – Block Flow Diagram of Turbine Station and Gas Supply



2.8 ACCESS ROADS

The Power Station will be accessed from Tarrone North Road. Internal access roads will be constructed on hard surface inside the Power Station to allow vehicle and/or forklift access as required.

2.9 SECURITY

The Power Station, including the gas receiving and gas receiving stations, will be located within a fenced off area accessed through a security gate at the north eastern entrance of the site.

3 SAFETY MANAGEMENT SYSTEMS

3.1 SAFETY MANAGEMENT IN GENERAL

In quantitative risk assessments, incidents are assessed in terms of consequences and frequencies, leading to a measure of risk. Where possible, frequency data used in the analysis comes from actual experience, e.g. near misses or actual incidents. However, in many cases, the frequencies used are generic, based on historical information from a variety of plants and processes with different standards and designs.

As with any sample of a population, the quality of the management systems (referred to here as "safety software") in place in these historical plants will vary. Some will have little or no software, such as work permits, planned maintenance and modification procedures, in place. Others will have exemplary systems covering all issues of safe operation. Clearly, the generic frequencies derived from a wide sample represent the failure rates of an "average plant". This hypothetical average plant would have average hardware and software safety systems in place.

If an installation which has significantly below average safety software in place is assessed using the generic frequencies, it is likely that the risk will be underestimated.

Conversely, if a plant is significantly above average, the risk will probably be overestimated. However, it is extremely difficult to quantify the effect of software on plant safety.

Incorporating safety software as a means of mitigation has the potential to significantly reduce the frequency of incidents and also their consequences if rigorously developed and applied.

The risk could also be underestimated if safety software is factored into the risk assessment but is not properly implemented in practice.

Practical issues also arise when attempting to factor safety software into the risk assessment – applying a factor to the overall risk results could easily be misleading as in practice it may be the failure of one aspect of the safety software that causes the accident, while all other aspects are managed exemplarily.

In this study it is assumed that the generic failure frequencies used apply to installations which have safety software corresponding to accepted industry practice and that this site has similar management practices and systems. This assumption it is believed, will be conservative in that it will overstate the risk from well managed installations.

3.2 SAFETY MANAGEMENT SYSTEM AT THE POWER STATION

AGL and its operating entity have a commitment to Occupational Health and Safety (OH&S) and have numerous policies and procedures to achieve a safe workplace.

Written safety procedures will need to be established for the site.

An established incident reporting and response mechanism will need to be established, providing 24 hour coverage. Injury and incident management will need to be proceduralised and people will need to be trained in how to report incidents.

The plant will need to comply with all codes and statutory requirements with respect to work conditions.

In addition, special precautions will need to be observed as required by the site conditions, in particular, standards and requirement on the handling of pressurised, flammable gases.

All personnel required to work with these substances are required to be trained in their safe use and handling, and are provided with all the relevant safety equipment.

Emergency procedures will need to be developed. All staff will need to be trained in these procedures and they will incorporated in the plant's quality system. The emergency procedures will need to include responses to emergency evacuation, injury, major asset damage or failure, critical power failure, spillages, major fire, and threats.

A Permit to Work system (including Hot Work Permit) and a Control of Modification system will need to be in use on site to control work on existing plant and to control existing plant and structure from substandard and potentially hazardous modifications.

Protective Systems will need to be tested to ensure they are in a good state of repair and function reliably when required to do so. This should include scheduled testing of trips, alarms, gas detectors, relief devices and fire protection systems.

All persons working on the premises will need to be provided with appropriate personal protective equipment suitable for use with the specific corrosive substances.

A first aid station will need to be provided comprising an appropriate first aid kit and first aid instructions, i.e. MSDSs, for all substances kept or handled on the premises. At least one person on the premises will need to be trained in first aid.

Further, the relevant and up-to-date MSDS will need to be kept in safe location on the site (discussions with local fire brigades will determine preferred location).

3.3 RECOMMENDATIONS FOR SAFETY MANAGEMENT SYSTEM

It is recommended that an audit is carried out of the safety management system implemented at the site, specifically as it applies to the proposed hazardous materials handling, pipelining and storages. This audit should be carried out within the first year of operation.

The audit of the safety management system needs to be holistic and focus on the management of major hazards and risks associated with the operation of the Power Station.

This audit will in particular determine that the following systems are in place and working satisfactorily:

- Written safety procedures have been established for the site.
- Incident (and accident) reporting and response system has been established.
- Acceptable systems in place for the handling of potentially hazardous substances, including with pressurised, flammable gases.
- All personnel required to work with potentially hazardous substances are trained in their safe use and handling, and are provided with all the relevant safety equipment.
- Emergency procedures have been developed and people have been trained. The emergency plan has been incorporated in the plant's quality system. The emergency procedures include responses to emergency evacuation, injury, major asset damage or failure, critical power failure, spillages, major fire, and threats.
- A Permit to Work system (including Hot Work Permit) and a Control of Modification system is in use on site.
- Protective Systems are tested to ensure they are in a good state of repair and function reliably when required to do so.
- Persons working on the premises will need to be provided with appropriate personal protective equipment.
- One or several first aid station(s) are provided comprising an appropriate first aid kit and first aid instructions.
- The relevant and up-to-date MSDS are kept in safe location on the site (discussions with local fire brigades will determine preferred location).

4 DETAILS OF PLANT EQUIPMENT

Below is a brief explanation as to the operation of the equipment on site. Details of associated safeguards are presented in Section 7.2 below.

4.1 GAS TURBINES

The development will comprise three or four[3] industrial gas turbines with the electricity generated fed into the existing 500 kV transmission network via a new switchyard on the site that will include high voltage transformers and circuit breakers.

The nature of the proposed Power Station to meet peaking demand only largely determines the type of gas turbine selected. Required is a turbine that can handle intermittent operation, a high number of starts and stops and is reliable. As the plant will only run during high peak times, it is essential that multiple gas turbines are installed to increase reliability.

So called "E or F class industrial turbines" are usually selected for this type of duty. The gas turbines will already be largely assembled when they are transported to site.

Each gas turbine generator unit consists mainly of three heavy lift items namely the gas turbine, electricity generator and high voltage transformer. In each gas turbine generator, air is drawn in through filters to remove particulate matter and is compressed.

Following compression, the air flows into the combustion chambers where natural gas is injected and burnt, increasing the temperature to approximately 1100 – 13500 degrees Celsius.

The combustors feature Dry Low NO_x (DLN) technology is used to produce very low NO_x emissions. The combustion products from the combustion chambers enter the turbine area and expand to atmospheric pressure, reducing in temperature to around 550 degrees Celsius.

As the gas expands, it drives each turbine, which in turn drives the compressor and an electrical generator. From the turbine, the heated exhaust gases pass through a silencer unit and are discharged through a stack.

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[3] If Alstom gas turbines are used, four turbines will be required to produce the electricity required. If General Electric (GE) or Siemens turbines are chosen, then three turbines will be required.

4.2 ELECTRICAL GENERATORS

Attached to each gas turbine is an electrical generator that generates electricity when rotated by the turbine. The generators are large items of plant, assembled off site and delivered in one piece.

4.3 TRANSFORMERS

The electrical transformer step the voltage from the generator at around 22 kilovolts to 500 kilovolts in two stages with an intermediate voltage of 132 kilovolts. The transformer(s) will be located adjacent to the existing 500 kilovolt lines running through the site with appropriate switchgear to ensure safe and reliable connection to the electricity network.

4.4 LATERAL GAS SUPPLY PIPELINE

Natural gas is the fuel for the gas turbines. The plant will be designed such that the SEA Gas pipeline is used to source this gas.

The lateral gas supply pipeline will be designed to deliver gas at a rate of about 180 tonnes per hour[4] at a nominal maximum pressure of 12 MPa up to the gas receiving station where it will be reduced to approximately 3.4 MPa in the gas receiving station prior to use by the gas turbine facility. This can be achieved using a pipeline of approximately 400 mm diameter.

The lateral gas supply pipeline will be approximately 8km to 10km long (depending on the option chosen), as discussed in Section 2.2 above.

The gas supply to the plant will be controlled by the operator located remotely. Telemetered information will be received from the meter stations and from each valve. This data is recorded by a *Supervisory Control and Data Acquisition* (SCADA) system. The operator will be able to open and close valves and control the flow rate through the pipelines. AGL maintains regular contact with the operator of the SEA Gas pipeline. The operators of the SEA Gas pipeline will also monitor and control the flow of gas to the power station.

The lateral gas supply pipeline will be compliant with AS2885 (Ref 3). The detailed design of the lateral is not completed and the assumptions as to the technical details made in this Initial QRA are given in Table 1 below and further in the description below the table.

[4] Stage 1 will only require 120-135 tonnes/hour of gas delivered to the station.

Table 1 – Summary of Assumptions Made in the Initial QRA for the Lateral Gas Supply Pipelines Design

Item	Pipeline Design
Pipe Diameter	400 mm NB (nominal bore)
Pipe Length	8 or 10 kilometres depending on the option chosen (from the tie-off, at the SEA Gas pipeline through to the entrance of the gas receiving station at the Power Station (nominated in this Initial QRA as the upstream side of the first remote operated isolation valve)).
Number of flanges	10 flanges – assume no flanges on the actual lateral pipeline; assume 10 flanges at the valve station at the connection to the SEA Gas pipeline.
Design MAOP[5]	12 MPa up to the entrance of the pressure reduction valve at the gas receiving station
Temperature	25^{o}C
Class Location to AS2885[6]	R1 (broadly rural) with 40 hectare blocks
Pipe Thickness	12.7 mm
Depth of Cover	At least 750mm (or 450mm in rock)
Features	Valve station at SEA Gas pipeline off-take point (with remote controlled slam shut/emergency isolation valve).

- One remotely operable isolation valve will be installed at the valve station which is located at the SEA Gas pipeline connection.
- At the other end of the pipeline, within the Power Station site, the gas receiving station will include another remotely operable isolation valve, together with a non return valve, a pressure control valve and a remotely controlled slam shut off valve (or other type of emergency isolation valve).
- It is also assumed that there will be a bypass line around each valve station, which contains an isolation valve. This bypass is required for start-up and shutdown as well as for proof testing of the mainline valve while the pipeline is in operation.

[5] MAOP = maximum allowable operating pressure

[6] The more stringent requirement of T1 is applied for R2 areas

- The pressure tapping points associated with the remotely operated valves are assumed to allow a drop in line pressure (or other suitable process parameter) to be quickly ascertained. Closure of the valves at the entry to the Power Station or at the trunkline is either triggered automatically by the sensor upon low pressure, or is initiated by the operator in the control room (details to be determined in detailed design and reviewed in the HAZOP). The SCADA system, which includes telemetered data from the valve stations instrumentation, would give the operator sufficient details upon which to make a decision whether to close the isolation valve(s).

4.5 Gas Receiving Station and Gas Pipelines Within the Power Station

The design of the Power Station has not been finalised and accurate P&IDs are not available at the time of this Initial QRA. In such cases, conservative assumptions relating to the design need to be made, including the length of pipe, number of flanges required, operating pressures used etc.

The article by Professor Michael Valenti for The American Society of Mechanical Engineers (Ref 4) provides an estimate of the complexity of the pipework and flange-systems inside the acoustic housing of the turbines: *For example, a 250-megawatt turbine's pipework may have more than 200 flanges and 90 flexible joints*.

The following assumptions were made as to the design of the natural gas pipelines associated with the Power Station – these assumptions are believed to be conservative.

Table 2 – Summary of Assumptions Made in the Initial QRA for the Power Station Natural Gas Pipelines

Feature	Assumption(s)
General – Overall Power Plant	
Percent operational	The Power Plant is expected to be operational for only a fraction of the time (less than 10% of the time). All data used in the present risk assessment are however for a plant operating 100% of the time. The quantitative risk results are valid, though highly conservative, for the plant under the expected operating conditions. They are also valid for a plant operating 100% of the time.
Gas Pipelines Inside Power Station, including Gas Conditioning Station	
Length	10 metres upstream of the pressure regulator and 500 metres downstream of the pressure regulator, stretching from the gas receiving station through to each turbine.
Diameter	450 mm nominal diameter.
Number of flanges	20 flanges upstream of the pressure regulator valve and 200 flanges after (up to the entry of the turbine enclosure).

Feature	Assumption(s)
Pressure	12 MPa up to the pressure regulator, then 3.4 MPa.
Temperature	25^{o}C
Features	Gas receiving station with pressure regulator, by-pass valves, non return valves, pressure indication, flow indication and transmitter
Gas Piping to Turbine Inside Turbine Enclosure	
Length	10 metres for each turbine
Number of flanges	200 flanges inside each turbine housing, 90 flexible joints (modelled in this Initial QRA as flanges)
Pressure	3.4 MPa
Temperature	25^{o}C

Both the length of pipework and the number of flanges is believed to be conservative. Details as to pipework design will be available at detailed design.

4.6 ANCILLARY EQUIPMENT

To facilitate the extreme combustion conditions inside the combustion chambers associated with the turbines, air is compressed and cooled prior to entry into the combustion chamber of the gas turbine. This requires an air compressor attached to the turbine and an evaporative water cooling unit.

5 STUDY METHODOLOGY

5.1 INTRODUCTION

The methodology for QRAs is well established in Australia. The assessment has been carried as per the Victorian WorkSafe guidelines for risk assessment (Ref 1), including the “Interim” offsite individual risk criteria.

There are five stages in risk assessment:

Stage 1. Hazard Identification: The hazard identification includes a review of potential hazards associated with all dangerous and hazardous goods to be processed, used and handled at the Power Station and associated pipelines and facilities. The hazard identification includes a comprehensive identification of possible causes of potential incidents and their consequences to public safety and the environment, as well as an outline of the proposed operational and organisational safety controls required to mitigate the likelihood of the hazardous events from occurring.

The tasks involved in the hazard identification of the proposed facility included a review of all relevant data and information to highlight specific areas of potential concern and points of discussion, including drafting up of preliminary hazard identification (HAZID) word diagram. The HAZID word diagram is then reviewed and complete in a workshop which included people with operational / engineering / risk assessment expertise. The review takes into account both random and systematic errors, and gives emphasis not only to technical requirements, but also to the management of the safety activities and the competence of people involved in them.

The final HAZID word diagram is presented in Section 6.3.

Stage 2. Consequence and Effect Analysis: The consequences of identified hazards are assessed using current techniques for risk assessment. Well established and recognised correlations between exposure and effect on people are used to calculate impacts.

Stage 3. Frequency Analysis: For incidents with significant effects, whether on people, property or the biophysical environment, the incident frequency are estimated, based on historical data. A probabilistic approach to the failure of vessels and pipes is used to develop frequency data on potentially hazardous incidents.

Stage 4. Quantitative Risk Analysis: The combination of the probability of an outcome, such as injury or death, combined with the frequency of an event gives the risk from the event. In order to assess the merit of the proposal, it is necessary to calculate the risk at a number of locations so that the overall impact can be assessed. The risk for each incident is calculated according to:

Risk = Consequence x Frequency

Total risk is obtained by adding together the results from the risk calculations for each incident, i.e. the total risk is the sum of the risk calculated for each scenario.

The results of the risk analysis are presented in three forms:

- Individual Fatality Risk, i.e. the likelihood (or frequency) of fatality to notional individuals at locations around the site, as a result of any of the postulated fire and explosion events. The units for individual risk are probability (of fatality) per million per year. Typically, the result of individual risk calculations is shown in the form of risk contours overlaid on a map of the development area. For pipelines (as for other transport activities), the individual risk contours are best represented as risk transects, showing the risk as a function of the distance from the pipeline.

- Injury and irritation risk, i.e. the likelihood of injury to individuals at locations around the site as a result of the same scenarios used to calculate individual fatality risk.

- Societal risk takes into account the number of people exposed to risk. Whereas individual risk is concerned with the risk of fatality to a (notional) person at a particular location (person 'most at risk', i.e. outdoors), societal risk considers the likelihood of actual fatalities among any of the people exposed to the hazard. Societal risk are presented as so called *f-N curves*, showing the frequency of events (f) resulting in N or more fatalities. To determine societal risk, it is necessary to quantify the population within each zone of risk surrounding a facility. By combining the risk results with the population data, a societal risk curve can be produced

The risk results are then assessed against the criteria generally in use by Victorian WorkSafe (Ref 1).

Stage 5. Risk reduction: Where possible, risk reduction measures are identified throughout the course of the study in the form of recommendations.

5.2 RISK CRITERIA

Having determined the risk from a development, it must then be compared with accepted criteria in order to assess whether or not the risk level is tolerable. If not, specific measures must be taken to reduce the risk to a tolerable level.

Where this is not possible, it must then be concluded that the proposed development is not compatible with the existing surrounding land uses.

5.2.1 Individual Risk Criteria

The individual fatality risk is the probability of fatality to a person or a facility at a particular point. It is usually expressed as chances per million per year (pmpy). It is assumed that the person will be at the point of interest 24 hours per day for the whole year. By convention, no mitigation is allowed, i.e. any possible evasive action that could be taken by a person exposed to a hazardous event, e.g. by walking out of a toxic cloud or a heat radiation. The assessment of fatality, incident propagation and injury risk should include all components contributing to the total risk, i.e. fire and explosion.

Victorian WorkSafe uses a set of guidelines on acceptable levels or individual risk which are in line with the criteria used elsewhere in the world. These guidelines are published in the Risk Assessment Guidelines (Ref 1) and again referred to in the Guidance Note to Major Hazard Facilities MHD-GN-18 (Ref 2).

The criteria have been chosen so as not to impose a risk which is significant when compared to the background risk we are already exposed to.

The "Interim" criteria for maximum tolerable individual risk from a new development are shown in Table 3 below. Whilst these criteria do not have legal status, they are used in Victoria *for consideration as reference values* (Ref 2).

This table shows the criteria for individual risk of fatality, injury and propagation of an incident.

Table 3 – Criteria for Tolerable Individual Risk From A New Development

Land Use	Maximum Tolerable Risk (pmpy[7])
Fatality risk criteria:	
At Boundary (*Risk must not exceed 10 per million per year at the boundary of any new facility*).	10
If risk off-site is between 0.1 and 10 per million per year, all practicable risk reduction measures are to be taken, and residential developments are to be restricted.	0.1-10
Risk levels below 0.1 per million per year are broadly tolerable.	0.1

In order to put these risks into perspective, published information on the level of risk to which each of us may be exposed from day to day due to a variety of activities has been shown in Table 4 below. Some of these are voluntary, for which we may accept a higher level of risk due to a perceived benefit, while some are involuntary. Generally, we tend to expect a lower level of imposed or involuntary risk especially if we do not perceive a direct benefit.

Table 4 – Risk to Individuals

Activity / Type of Risk	Published levels of risk (pmpy[7])
VOLUNTARY RISKS (AVERAGED OVER ACTIVE PARTICIPANTS)	
Smoking	5,000
Drinking alcohol	380
Swimming	50
Playing rugby	30
Travelling by car	145
Travelling by train	30
Travelling by aeroplane	10
INVOLUNTARY RISKS (AVERAGED OVER WHOLE POPULATION)	
Cancer	1,800
Accidents at home	110
Struck by motor vehicle	35
Fires	10
Electrocution (non industrial)	3
Falling objects	3
Storms and floods	0.2
Lightning strikes	0.1

5.2.2 Societal Risk Criteria

Societal risk is concerned with the potential for an incident to coincide in time and space with a human population. Societal risk takes into account the potential for an incident to cause multiple fatalities. Therefore, two components are relevant, namely:

- The number of people exposed in an incident, and

[7] pmpy = per million per year

- The frequency of exposing a particular number of people.

The societal risk criteria specify levels of societal risk which must not be exceeded by a particular activity. The same criteria are currently used for existing and new developments. Two societal risk criteria are used, defining acceptable and unacceptable levels of risk due to a particular activity. The criteria in Table 5 above are represented on the societal risk (f-N) curve as two parallel lines. Three zones are thus defined:

- Above the unacceptable/intolerable limit the societal risk is not acceptable whatever the perceived benefits of the development.

- The area between the unacceptable and the acceptable limits is known as the ALARP (as low as reasonably possible) region. Risk reduction may be required for potential incidents in this area.

- Below the acceptable limit, the societal risk level is negligible regardless of the perceived value of the activity.

The interim criteria used by Victorian WorkSafe (Ref 2) are presented in Table 5 below.

Table 5 - Criteria for Tolerable Societal Risk

Number of fatalities (N) [-]	Acceptable limit of N or more fatalities per year	Unacceptable limit of N or more fatalities per year
1	1×10^{-4}	1×10^{-2}
10	1×10^{-6}	1×10^{-4}
100	3×10^{-8}	3×10^{-6}

5.3 RISK CALCULATIONS

In order to determine the cumulative risk from all identified hazards, the computer software tool ISORIS from the Warren Centre for Advanced Engineering (Ref 5) was used.

First, base information on the incidents, including type, location, processing conditions and frequency were entered into a spreadsheet. This spreadsheet calculates the leak rate for each incident using standard orifice flow equations for vapour or liquid, as appropriate. The spreadsheet also determines the base consequences for each incident in terms of total radiant heat release rate and TNT equivalent.

See Appendix 2 for a printout of the incident listing from the spreadsheet.

Information on the frequency, location and consequences of each incident was extracted from the spreadsheet and processed by the ISORIS program. This program is designed to take consequence and frequency information and determine risk levels to individuals at all locations within a user-defined grid.

From the output of ISORIS risk contours can be drawn and overlayed on a site map.

ISORIS can determine risks to persons in the open or in buildings. For this study, risks in the open have been determined. In the case of radiation, persons are more at risk in the open due to the lack of shelter, while for explosions the risk is greater inside due to the potential for the building to collapse.

To assess injury risk and the potential for knock-on or domino incidents, ISORIS can also determine the frequency of exceeding a given level of heat radiation or explosion overpressure.

6 HAZARD IDENTIFICATION

6.1 HAZARDOUS MATERIALS

A list of the types and storage quantities of materials that are likely to be found at the proposed site is included in the following table. Quantities are indicative only.

Table 6 - Typical Chemicals Stored Onsite

Plant Area / Use	Chemical/Product	Anticipated Storage Qty
Natural Gas supply	Natural gas	None stored on site. Supplied via pipeline system.
Turbines, pumps, air compressor, lubrication	Turbine oils (combustible oil)	1,000 L in small IBC
Transformers	Insulating oil (non PCB)	1,000 L in small IBC
Fire protection	Oil for fire pump	600 L in small IBC
	Carbon dioxide and/or other proprietary fire protection gases such as Inergen and/or FM200	If and as required, as determined by fire protection review.
Closed loop cooling system	Scale inhibitor	100 L
	Betz Foam-Trol	100 L
Chemicals for maintenance / repair work and clean-up	Carbon dioxide	As required for fuel line purging, in cylinders
	Nitrogen	As required for Gas line purging, in cylinders
	Acetone	100 L for miscellaneous cleaning

Note: Brand names are for example only

The natural gas is currently sourced from two off-shore Victorian gas fields-Minerva and Yolla in the Otway Basin. Natural gas is composed predominantly of methane gas. The typical composition of natural gas is shown in Table 7 below..

Table 7 – Approximate Composition of Natural Gas Supply

Component	Mole %
Methane	87
Ethane	8.46
Hydrogen	0.36
Nitrogen	3.61
carbon monoxide	0.09
carbon dioxide	0.34
Ethylene	0.03
hydrogen sulphide (H_2S)	0.04
Oxygen	0.07
TOTAL	**100**

Natural gas is composed predominantly of methane gas. The properties of methane gas are presented in Table 8 below.

Table 8 - Properties of Methane Gas

Molecular weight (g/mol)	17
Relative density of the gas (atmospheric temp. and pressure)	0.6
Heat of combustion (MJ/kg)	50
Flammable range (vol. % in air)	5 to 15
Ratio of specific heats (Cp + Cv)	1.31
Flash point	-218°C

6.2 Summary of Hazards Identified

The main hazard associated with the proposed site is related to a leak of flammable natural gas.

This would generally only have the potential to cause injury or damage if there was ignition, which resulted in a fire or explosion incident. The factors involved are:

- The pipelines, vessel or equipment must fail in a particular mode causing a release. There are several possible causes of failure, with the main ones being corrosion and damage by external agencies;

- The released material must come into contact with a source of ignition. In some cases this may be heat or sparks generated by mechanical damage while in others, the possible ignition source could include non-flame proof equipment, vehicles, or flames some distance from the release;

- Depending on the release conditions, including the mass of flammable material involved and how rapidly it ignited, the results may be a localised fire (for example a jet fire), a flash fire or an explosion of the vapour cloud formed through the release.;

- Finally, for there to be a risk, people must be present within the harmful range (consequence distance) of the fire or explosion. How close the people are will determine whether any injuries or fatalities result. Environmental damage from gas fire incidents are generally associated with a failure to control fire water used.

Natural gas is a buoyant, flammable gas which is lighter than air (relative density of 0.6). On release into the open the non-ignited gas tends to disperse rapidly at altitude. Ignition at the point of release is possible, in which case the gas would burn as a jet (or torch) flame. On release in an enclosed area (for example within the gas turbine housing) an explosion or a flash fire is possible.

The gas is non-toxic, posing only an asphyxiation hazard. Due to its buoyancy, any release of credible proportions from operations of this scale, in the open, would not present an asphyxiation hazard. With standard confined space entry procedures and appropriate security arrangements to prevent unauthorised access to any of the facilities the risk associated with asphyxiation from natural gas should be minimal.

Locally, the pressure of the compressed gas may be hazardous in case of an uncontrolled release. These hazards, while of importance for people working at the site, do not have implications beyond the immediate location of the release unless the released gas is ignited.

Therefore, the risk associated with of non-ignited compressed gas does not form part of the scope of the present risk assessment.

This potential risk would however need to be closely managed through job safety analysis (JSA) and/or other risk assessment practices used by management and operators of the facility (in accordance with Victorian Occupational Health and Safety Act and its associated legislation (Ref 6)).

Other potential hazards are associated with the handling and use of combustible liquids (i.e. the oils used for pumps, compressors, turbines etc.).

Minor quantities of flammable acetone (used for cleaning) will also introduce a potential fire hazard.

A total of 19 hazards were identified at the Power Station site, as listed in Table 9 below.

Table 9 - Summary of Identified Hazards

Number	Hazardous Event Potential	Offsite Impact Potential	Assessed in Section
1	Mechanical impact causes release of flammable gas	Y	7.2.1
2	Corrosion causes release of flammable gas	Y	7.2.1
3	Valve gland nut of flange leak causes release of flammable gas	Y	7.2.1
4	Terrorism / vandalism damages pipe or valve causing release of flammable gas	Y	7.2.1
5	Nearby explosion at neighbouring natural gas (SEA Gas) Trunkline causes damage to gas supply pipeline	Y	7.2.1
6	Pressure excursion leading to failure of the pipeline	Y	7.2.1
7	Spontaneous loss of integrity of pipe	Y	7.2.1
8	Land subsiding causes damage to pipe and release of flammable gas	Y	7.2.1
9	Leak of natural gas to atmosphere from gas pipes on-site (outside the turbine housing)	Y	7.2.2
10	Venting of gas from process	N	-
11	Explosion within piping or inside a vessel	N	-
12	Leak of natural gas to inside the turbine housing	Y	7.2.3
13	Leak of natural gas to inside of turbine housing due to projectile.	Y	7.2.3
14	Release of carbon dioxide (or of other fire quenching material to be used for fire protection)	N	7.2.4
15	Fire at transformers	N	7.2.6
16	Flooding	N	7.2.6
17	Land subsidence due to mining activity	N	7.2.6
18	Earthquake	N	7.2.6
19	Aircraft crash on Power Station site	N	7.2.6

6.3 Hazard Identification Word Diagram

The Hazard Identification Word Diagram, included in Table 10 below, provides a summary of the hazardous incidents identified for the proposed site and their associated mitigating features. Each section of the Power Station and associated pipelines was reviewed in turn in a workshop, to determine the potentially hazardous scenarios relevant to that section. The sections reviewed were:

- Natural gas lateral supply pipeline to the Power Station boundary (the "end point" of the lateral gas pipeline has been set, in this Initial QRA, as the upstream side of the first remote isolation valve which is assumed to be located just at the entry of the Power Station);
- Gas receiving station and on-site gas transport at the Power Station;
- Turbine enclosure;
- Carbon dioxide (or other asphyxiant fire quenching gas) storage;
- Storage and handling of combustible and flammable liquids (oils, diesel, acetone);
- Power generation;
- Finally, potential hazards that could affect the whole site (including supply pipeline) were reviewed.

While the table below provides an overview of the preventative and protective features proposed and recommended for the site, these safeguards are further detailed in Section 7 below.

Table 10 – Hazard Identification Word Diagram

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
SECTION OF PLANT: Natural Gas Lateral Supply Pipeline (from SEA Gas Pipeline to the Site Boundary)			
1. Mechanical impact causes release of flammable gas.	3rd party involvement digging or trenching, or other earth work.	Massive release of natural gas (NG). If ignition, then possibility of flash or jet fire.	- Gas supply pipeline runs for its entirety within AGL pipeline easement. - Pipe is buried (minimum 750mm or 450mm in rock) - Signage along pipe route, including Dial Before You Dig information. Drawings available to Dial Before You Dig. - Resistance of pipelines to penetration through use of pipe thickness and low design factor. - Rapid shut down from low pressure trips if massive leak at pipelines prevents backflow from Plant and uncontrolled flow from SEA Gas pipeline. - Manual shut down (by isolating manually at the SEA Gas pipeline off-take point and/or at gas receiving station. - NG disperses readily upwards, minimising chances of ignition. Explosion not credible in unconfined situation. - Yearly landowner liaison as per AS2885 requirement. **The risk associated with this scenario is evaluated quantitatively.**

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
2. Corrosion causes release of flammable gas.	Damage of pipeline coating due to excavation inspection damage leads to corrosion	If ignition, a jet fire is possible.	- Cathodic protection for external corrosion with regular inspections and testing as per AS2885. - Internal corrosion virtually absent with clean hydrocarbon. - Coating on external surfaces of pipelines. - Regular patrolling of pipelines. Vegetation browning off around ground leak (lack of oxygen) aid detection. Further, a small hole will be sonic – possible detection through high pitched sound. - NG disperses readily upwards, minimising chances of ignition. **The risk associated with this scenario will be evaluated quantitatively.**
3. Valve gland nut of flange leak causes release of flammable gas.	Maintenance failure at valves. Wear and tear. Impact.	Release of natural gas. If ignition, then possibility of fire.	- Periodic surveillance of pipe and valve points. - Valves will be exercised periodically. - Gas detectors at valve stations. - Icing up at leak point improves detection. - Valve stations contained on site. - Minimum number of flanges. Welded connections wherever possible. **The risk associated with this scenario will be evaluated quantitatively.**

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
4. Terrorism / vandalism damages pipe or valve causing release of flammable gas.	Terrorism / vandalism	Massive release of natural gas. If ignition, then possibility of flash or jet fire.	- Terrorism and severe vandalism currently unlikely in Australia. - Buried pipelines and no valve points at public areas. - Valve station fenced. - Regular and periodic surveillance. - Intruder detection. **This scenario does not appear credible for this site.**
5. Nearby explosion at neighbouring natural gas (SEA Gas) Trunkline causes damage to gas supply pipeline.	Failure of maintenance of Trunkline. Hot tapping by error.	Massive release of natural gas (NG). If ignition, then possibility of flash or jet fire.	- Internal risk management procedures / systems by pipeline operators. - Pipeline integrity plan (incl. protection, pigging etc. to monitor integrity of pipeline and coating inspection). - 24 hour monitoring of natural gas and ethane pipelines. - NG disperses readily upwards, minimising chances of ignition. Explosion not credible in unconfined situation. - Buried natural gas Trunkline. - Thickness and grade of pipelines. - Hot tapping is a specialist field with highly trained personnel. **This scenario does not appear credible for this site.**

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
6. Pressure excursion leading to failure of the pipeline.	Operational error up or downstream of gas supply pipeline..	Release of natural gas. If ignition, then possibility of fire.	- The pipelines are to be hydrotested at a minimum of 1.4 times the MAOP (maximum allowable operating pressure). - The pipelines can operate against closed head (i.e. the main valve at the entrance to the site may be closed). - 24 hour monitoring of Trunkline and lateral supply gas pipeline. - Continuous monitoring of pressure of the pipelines supplying natural gas to the power plant. - High and low pressures of the natural gas supply will be monitored and if required (as defined in detailed HAZOP), associated with an automatic trip / shut down, see Recommendation. **The risk associated with this scenario will be evaluated quantitatively.**
7. Spontaneous loss of integrity of pipe.	Construction defect or operational error (repeated) .	Massive release of natural gas. If ignition, then possibility of flash or jet fire.	- All welds are x-rayed (100%). - Thickness of pipe material and temperature cycling make this scenario highly unlikely. - Cathodic protection. - Design for pipelines to prevent crack propagation. **This scenario does not appear credible for this site. As the likelihood data used in the Initial QRA is that from historical databases it is however included in the quantitative risk assessment.**
8. Land subsiding causes damage to pipe and release of flammable gas.	Mining activities in area or earthquake	Release of natural gas. If ignition, then possibility of flash or jet fire.	- See Event number 17 and 18 below (for the whole site)

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
SECTION OF PLANT: Gas Conditioning Station and On-Site Natural Gas Transport at the Power Station			
9. Leak of natural gas to atmosphere from gas pipes on-site (outside the turbine housings).	Mechanical impact, weld failure, operational error corrosion, sabotage etc.	Release of odourised natural gas. If ignition source available (or if ignited at source), then flash fire or jet fire possible.	- Use of fully welded pipework wherever possible. Minimise pipe-runs (pipe lengths). Pipes of robust design. - Detectors positioned strategically at high risk leak areas. - The use of fusible tubing around high risk leak piping to be investigated, see Recommendation. - Overpressure protection. - Communication systems. - Actuated isolation valve at receiving station inlet. - Fire protection system to be installed, incl. fixed sprinkler or water/hose system. **The risk associated with this scenario will be evaluated quantitatively.**
10. Venting of gas from process.	Maintenance work, shutdown, flaring.	Release of flammable gas or heat to process area. Fire hazard.	- Releases to be piped to safe area (flare). Vents to elevated point. **Standard design practices to be applied.**
11. An explosion within piping or inside a vessel.	Failure of maintenance activities creates ingress of air into natural gas piping and vessels and subsequent start-up without adequate purging.	Possible explosion. Due to the limited quantities of gas involved the effects of the explosion would however not be expected to pose a threat to nearby landuses.	- This scenario is only theoretically possible during start-up, shut-down and maintenance operations; - Piping normally operated at a positive pressure, preventing ingress of air; - Prevention of ingress of air will be considered throughout the design and operation of the facility (for example in the preparation of start-up, shut-down and maintenance procedures). **This scenario does not appear credible for this site.**

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
SECTION OF PLANT: Turbine Enclosure			
12. Leak of natural gas to inside of turbine housing due to failure of pipe.	Mechanical impact, weld failure, operational error corrosion, sabotage etc.	Release of odourised natural gas (NG). If ignition source available (or if ignited at source), then flash fire or jet fire possible. If confinement sufficient then an explosion is possible with overpressure effects and projectiles. Due to the limited quantities of gas involved and the size of the site, the effects of the explosion would however not be expected to pose a threat to nearby landuses.	- Control of ignition sources as per Australian Standard Hazardous Zone requirements. - The detailed design of the turbine housing and associated equipments need to demonstrate that explosive situations do not arise and need to clearly outline the basis of safety used to this end (see Recommendations). Generally, the basis of safety includes a combination of well controlled ventilation flows, flammable gas detection with automatic response, explosion relief and explosion suppression. - Preventative maintenance procedures and schedules will be developed. - Training of operators and maintenance workers. - System put in place to ensure removal of safety critical functions is subject to careful scrutiny (see Recommendation). - Permit to Work procedures, including for entry into Confined Space. - Emergency procedures and drills. **The risk associated with this scenario will be evaluated quantitatively.**

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
13. Leak of natural gas to inside of turbine housing due to projectile.	Violent mechanical failure of rotating machine (compressor, turbine) creates projectile.	Projectile would be ejected with high energy. Personnel hazard if in the vicinity. If a gas pipe is hit by the projectile or associated equipment / instrumentation then it may fail, causing gas release and fire / explosion if ignition source.	- Preventative maintenance of rotating machines. - Vibration monitoring. - Shut down of machine and repair if out of alignment. - Rotating machines to be designed such that risk associated with projectile is minimised (gas pipelines protected or not in probable line of projectile, people protected, substation and electricity facility not in direct line of projectile or protected etc.), see Recommendation 7. - Buried pipeline is not at risk from such projectiles. **The risk associated with this scenario will be evaluated quantitatively.**
SECTION OF PLANT: Carbon dioxide (or other asphyxiant fire quenching gas) Storage			
14. Release of carbon dioxide (or of other fire quenching material to be used for fire protection) into turbine housing.	Leaking cylinders, flanges, pipes into enclosed area.	Potential asphyxiation of person inside the enclosed area if concentrations reach hazardous levels.	- Small quantities, impact localised to enclosed area. - Permit to Work requirements. - Alarm (visual and audible) inside enclosed area allowing personnel escape prior to offloading carbon dioxide / other fire quenching material, see Recommendation 8. **The consequences of this scenario are local only to the immediate vicinity of the release. No off-site consequences expected.**
Power Generation			
15. Fire at transformers	Faulty connection, internal fault in transformer.	Fire in switchyard. Material damage.	- Gravel around switchyard provides separation distance from neighbouring combustible material (grass, bush, etc.) and ensures any oil spill seeps into the gravel and does no pool. - Fire remains localised to switchyard. **The consequences of this scenario are local only to the immediate vicinity of the release. No off-site consequences expected.**

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
SECTION OF PLANT: Whole Site (including supply pipeline)			
16. Flooding results in process upsets.	Uncontrolled flooding of site	Potential for damage to process / storage facilities resulting in release of hazardous material (particularly natural gas)	- Topography prevents flooding from any rivers or streams.
17. Land subsidence due to mining activity.	Land subsiding due to mining activities in area creates failure of pipes / pipeline resulting in potential for rupture or massive leak.	Release of natural gas. If ignition, then possibility of flash or jet fire.	- Thick walled pipe and pipe grade can withstand considerable plastic deformation. - Subsidence issue to be taken into account during detailed design, including requirements for thrust blocks on pipelines to be over-sized and prevented from separating from the pipe. - Pipelines located above ground where possible. **The risk associated with this scenario will need to be rendered negligible through design (i.e. inherent safety to be incorporated into the detailed design), as per Section 7.2.6.**
18. Earthquake results in process upsets, potential damage to process / storage facilities resulting in hazardous releases.	Earthquake	Potential damage to process / storage facilities resulting in hazardous releases, fire / explosion.	- Structures and plant are designed to withstand earthquake effects using well-established procedures in accordance with relevant Australian or international standards. The earthquake risk is not estimated in the present Initial QRA. Provided established Australian Standards are followed, the risk associated with this scenario should be able to be rendered negligible (refer to Section 7.2.6 below).

Event	Cause/Comments	Possible Consequences	Prevention/ Protection
19. Aircraft crash results in process upsets, potential damage to process / storage facilities resulting in hazardous releases.	Aircraft crash	Potential damage to process / storage facilities resulting in hazardous releases, fire / explosion. Relatively small quantities of gas held within the Power Station and very large site – effect unlikely to go off-site.	- Occupied site relatively small – aircraft crash unlikely. - Buried pipelines unlikely to be susceptible to aircraft crash. - Automatic slam shut valves or other type of emergency isolation valves at each end of the pipelines. This scenario, while theoretically possible, does not appear credible for the present site.

7 POTENTIAL HAZARDOUS INCIDENTS AND THEIR CONTROL

Safety management systems allow the risk from potentially hazardous installations to be minimised by a combination of hardware and software factors. It is essential to ensure that hardware systems and software procedures used are reliable and of the highest standard in order to assure safe operation of the facility.

Safety features of particular interest to the present project are detailed below.

7.1 HARDWARE SAFEGUARDS, GENERAL

Hardware safeguards include such factors as the layout and design of the plant and equipment, and their compliance with the relevant codes, technical standards, and industry best practice.

All systems handling dangerous goods will need to comply with the relevant Acts, Regulations and Codes in their latest edition. Compliance with these codes and standard is assumed in this Initial QRA.

Below are listed some of the most relevant for the present development:

- Victorian Occupational Health and Safety Act and its associated legislation including but not limited to the Dangerous Goods Regulations.
- NOHSC:1015(2001) - National Occupational Health & Safety Commission (NOHSC): Storage and Handling of Workplace Dangerous Goods.
- As2885 – Flammable and Combustible Pipelines
- AS 4041 - 1992 SAA Pressure Piping Code (was CB18).
- AS 1074 - Steel Tubes & Tubulars.
- AS 1836 - Welded Steel Tubes for Pressure Purposes.
- AS 1210 - Unfired Pressure Vessel Code.
- AS 2919, AS 3765.1 or AS 3765.2 - Protective clothing.
- AS3600 - Concrete Structures (for foundation and plinth).
- AS 1692 - Tanks for flammable and combustible liquids.
- API 620 - Design and construction of large welded low-pressure storage tanks.
- API 650 - Welded steel tanks for oil storage.
- AS1345 - Identification of the Contents of Pipes, Conduits and Ducts.

- ANSI Z 358.1 – For safety shower and eyewash facilities.

Pipe fittings, supports, and all other ancillary items will also need to comply with appropriate Australian Standards whether referenced above or not.

7.2 HARDWARE SAFEGUARDS, SPECIFIC

7.2.1 Leak of Natural Gas from the Supply Pipeline

Australian Standard AS2885 (Ref 3) sets the minimum standard for high-pressure pipelines in Australia. This code gives detailed requirements for the design, construction and operation of gas and liquid petroleum pipelines. It has gained wide acceptance in the Australian pipeline industry. AS2885 also sets the classification of locations which guide the designer in the assessment of potential risks to the integrity of the pipeline, the public, operating and maintenance personnel as well as property and the environment.

AS2885 accommodates changes in population density by its location classification scheme concept. The classification scheme allows broad division of the pipeline design requirements according to whether the pipeline is to be installed in rural, semi-rural, suburban or urban areas. For each of these classifications the minimum design requirements in terms of wall thickness and depth of cover are specified. The pipeline will run in areas classified as *Class R1 - Broadly Rural* for the entire length of the run.

Allowance is made in AS2885 for the improvement in safety performance possible through the use of thick walled pipe with a low design factor. AS2885 also mandates that the integrity of the pipeline be maintained throughout the pipeline operating life.

The proposed safeguards for the supply pipeline are detailed below. The safeguards have been grouped together under the potential hazardous events associated with the pipeline (as defined in the Hazard Identification Word Diagram in Table 10 above). These incidents have been collated by a group of six European gas transmission companies, based on pipeline incidents relevant to pipeline design and operation in Europe (Ref 7). The data was collated covers a length-time of more than 970,000 km-yrs. Experience within Australia (APA, AGL etc.) indicates that the learning from these incidents can be directly translated to the Australian conditions.

- External interference is historically by far the main cause of loss of gas and accounts for about 40% of all incidents leading to a release of gas.

  This potential is minimised in the present development through the fact that AS2885 requires the pipeline to be buried to 750mm (or 450mm in rock).

  Further, signage will be provided along the pipe route, including Dial Before You Dig information.

The pipeline presents a certain resistance to penetration through use of pipe thickness and low design factor.

In the very unlikely event of a damage to a pipeline which causes a leak, a slam shut valve (or other form of emergency isolation valve) would be activated at the Power Station (preventing back flow from the plant) and another one at the supply pipeline off-take at the SEA Gas Pipeline end (preventing uncontrolled flow from these pipelines). If the leak is substantial, the activation would be manual. If the automatic trip is not activated then shut down would be manual by closing the slam shut valve(s)/emergency isolation valve(s).

Note also that natural gas disperses readily upwards, reducing chances of ignition. Explosion does not appear to be credible in an unconfined situation.

Valve stations are potentially more at risk of a loss of containment due to the presence of small bore attached piping, which is required for pressure tappings. These small-bore pipes are historically known to be more vulnerable to failure.

The major mitigating features at valve stations are firstly the fact that the valve site is conspicuous and therefore reduces significantly the accidental mechanical interference for which a buried pipe is vulnerable. Secondly, the instrumentation off-take line will most likely be installed with a restriction orifice, which would severely restrict the potential outflow caused by damage to the instrumentation. Thirdly, the layout and siting of the valve stations will be subjected to a rigorous Hazard and Operability Study (HAZOP) which will result in improvements to the design to limit their hazard potential.

- *Construction defect / material failure:* This is a known cause of failure of pipelines and accounts for approximately 15% of all incidents. The Australian Pipelines Code (AS2885) will be adopted as a minimum requirement for the design and construction of the pipelines. The pipelines will be constructed of seamless piping of 400 mm diameter (NB) and will be 100% radiographed (including all welds).

  Further, inherent design safeguards will be provided by ensuring that the piping is manufactured from high tensile steel of known quality, and subject to quality control inspections to ensure high standard.

- *Corrosion:* Corrosion accounts for approximately 15% of all historical incidents. The result of the corrosion is mainly pinholes and cracks.

  The gas supply pipelines will be coated with polyethylene (or other) coating. A corrosion protection team will survey the pipeline each year to identify any areas where cathodic protection has become ineffective. Potential corrosion leaks will be detected by visual inspection and protected against by cathodic protection systems. Note that internal corrosion virtually absent with clean hydrocarbon.

In the unlikely event of a corrosion leak, it can be detected through the fact that the vegetation is browning off around ground leak (lack of oxygen) and that a small hole will be sonic – possible detection through high pitched sound.

- *Hot tap by error*: Hot-tapping or hot tapping by error (i.e. hot-tapping the wrong pipeline) is possible and has occurred in the past in the world (approximately 15% of all incidents). Further, hot tapping is a highly specialised field in Australia and only very few, highly trained, groups can perform this task.

- *Ground movement.* Earthquakes account for about 5% of all historical incidents could potentially cause a failure of a pipeline due to the high forces involved. Earthquakes are not particularly common in this area. This scenario is further discussed in Section 7.2.6 below.

- *Other / unknown causes.* Rare or unknown causes form about 10% of all historical incidents. They are mainly of the pinhole crack category. The following potential incidents have been canvassed for the present development:

    - *Valve gland nut leak or flange leak or maintenance failure at valves and scraper stations.* The pipeline is designed with the minimum number of flanges and welded connections are used wherever possible. Periodic surveillance will be carried out of the pipe and valve points. All valves will be exercised periodically. There are no valves in public areas. Icing up at leak point improves detection.

    - *Nearby explosion.* The potential for a domino incident due to an incident at neighbouring natural gas or ethane pipeline or tie-offs was canvassed. The preventative features for this type of incident include internal risk management procedures / systems in use by the natural gas / ethane pipeline owners and operators; the pipelines integrity plans (incl. systems in use to monitor integrity of pipeline and coating inspection); their thickness and grade; and the 24 hour monitoring of natural gas and ethane pipelines. Further, natural gas disperses readily upwards, minimising chances of ignition and making explosion not credible in unconfined situation; and the fact that all pipelines will be buried at a depth of at least 750mm (450mm in rock).

    - *Terrorism / vandalism.* Terrorism and severe vandalism are currently unlikely in Australia and the pipeline is subject to regular and periodic surveillance. Further, the pipeline is buried and no valve points at public areas. Valve systems are surrounded by security fencing.

    - *Operational error causes pressure excursion leading to failure of the pipeline*. The pipeline is to be hydrotested at a minimum of 1.4 times the

MAOP (maximum allowable operating pressure) and can operate against closed head (i.e. the main isolating valve at the entrance to the Power Station may be closed). There is 24hour monitoring of the natural gas pipeline (SEA Gas). Continuous observation of pressure of the gas supply pipeline from the Camden Plant Control Room or from the control room at Mount Beauty.

Recommendation 2: High and low pressures of the natural gas supply are to be monitored during (and, if applicable, outside) operation of the Power Plant. These conditions will need to be associated with an automatic trip / shut down of the pipeline at the metering station in case of a major failure of the natural gas pipeline within the site boundary (as assumed in this Initial QRA). The detection and subsequent closure at the SEA Gas pipeline in case of a major leak in the lateral pipeline is also required.

7.2.2 Gas Conditioning Station and Gas Pipes Within the Power Station

A. Pipeline / Vessel Leaks

Hazards at the gas treatment plant may arise in the following: fixed plant, storage, and pipelines. The failure modes are derived from historical failures of similar equipment and are described in the following sections.

- **Piping Failures:** Pressure piping may fail as a result of corrosion, erosion, mechanical impact damage, pressure surge ("water hammer") or operation outside design limitations of pressure and temperature. Pressure surge or significant deviations of pressure or temperature may cause a flanged joint to be overstressed, resulting in a small leak. Larger holes through to complete line fracture may conceivably result from mechanical impact or pressure surge.

- **Pressure Vessel Failures:** Storage and processing equipment in pressurised gas service will be operating at pressures of between 0.2–12 MPa (normal operating pressure at the turbines is 4.2 MPa). Vessels, such as the filter, may suffer from failure due to corrosion, erosion or mechanical impact. Major incidents involving the vessels include catastrophic failure and smaller leaks.

Corrosion and erosion caused failures usually result in small leaks which are detected early and corrected. Leak duration may be of the order of ten minutes for such events. Further, pressure surge or significant deviations of pressure or temperature may cause a flanged joint to be overstressed, resulting in a small leak.

Larger holes through to complete nozzle / pipe fracture may conceivably result from mechanical impact or pressure surge. These events are likely to be detected more rapidly, resulting in quicker isolation of the leak. These events are likely to be detected more rapidly, resulting in quicker isolation of the leak.

The potential to release natural gas will be minimised by:

- Use of fully welded pipework wherever possible;
- Minimizing pipe-runs (pipe lengths);
- Pipes of robust design (designed to comply with the requirements of Australian Standard AS4041 - Pressure piping);
- Detectors positioned strategically;
- Overpressure protection provided by three methods:
    - Rapid control valve closure under alarm conditions;
    - Slam shut isolation valve (or other emergency isolation valve) installed at the inlet to each control valve run; and
    - Pressure relief valve.
- An actuated isolation valve will be installed at the inlet to the Power Station; and
- Control and communications equipment to provide remote monitoring and central control of system by operating staff.

Recommendation 3: The use of fusible tubing around above ground high risk natural gas piping (e.g. within the turbine housing) to be investigated – such tubing would be linked to automatic shut down of the fuel source.

A fire protection system will be installed in the facility. The fire control system will be developed to meet all requirements of Building Code of Australia and the Victorian Fire Brigade. Elements of the system will include:

- Provision of potable water supply to the boundary of the site;
- Provision of booster pumps – duty and standby, if required, to meet the specified pressure objectives;
- Provision of permanent water storage, if required, to meet the supply volume objectives;
- Provision of a dedicated fire water ring main system through the facility; and
- Provision of fire hydrants and hose reels as nominated by above requirements.

B. Pipe / Vessel Internal Explosion

An explosion within piping or inside a vessel is theoretically possible during start-up, shut-down and maintenance operations.

Due to the limited quantities of gas involved the effects of the explosion would however not be expected to pose a threat to nearby businesses or to any residential areas in the vicinity.

Therefore, the probability of an explosion due to ignition of an explosive mixture within piping and vessels is considered negligible and will not be analysed further in this Initial QRA.

This conclusion is based on the following observations:

- All piping will normally operate at a positive pressure, thereby preventing ingress of air in the event of a pipe or other equipment failure;

- Prevention of ingress of air will be considered throughout the design and operation of the facility (for example in the preparation of start-up, shut-down and maintenance procedures).

7.2.3 Turbine Enclosure

A. Introduction and legislative framework

Despite the best efforts during design and management of the gas turbine Power Station, natural gas turbines are not beyond mishap.

Assuming that the gas turbines will be housed in acoustic chambers to reduce noise and permit turbine cooling by ventilation, a degree of confinement would be introduced.

Ignition of fuels released into the turbine housing can cause fire and, because of the confinement, even explosions.

Note that the explosive event is not credible in an unconfined scenario, where the turbines are not housed inside acoustic chambers.

Turbines typically rely on complex fuel supply pipes with multiple high-pressure joints to deliver the primary fuel, natural gas. *The large number of flanges and joints, combined with high pressures, presents an explosion hazard within the housing in the event of fuel leaks,* noted Mr Hunt, a chemical engineer at Eutech who led the risk assessment study[8] undertaken as a result of an explosion in a gas turbine acoustic housing at Teeside Power Station, UK in 1996 (Ref 4).

Since the Teeside explosion, guidelines and codes of practice have been developed, and are now in use, notably the European ATEX Directive (Ref 8) and the UK Health and Safety Executive's Guidance Note PM84: *Control of*

[8] At 12:25 a.m. on July 17, 1996, a fire and explosion occurred in the unit 106 turbine housing (enclosure) at the Teeside Power Station.

safety risks at gas turbines used for power generation (Ref 9), both which are gaining wide acceptance in Australia.

The HSE Guidance Note PM84 covers the design and operation of gas turbine installations, making specific and practical recommendations with regard to operational functions such as alarm and engine trip conditions, and the maximum acceptable volume of clouds of explosive mixtures of gas and air.

Although it is not a specific legislative requirement to comply with these guidelines, they provide plant operators and legislators with a framework for assessing whether operation of a plant is satisfactory from a general Health and Safety standpoint (Ref 10). It is therefore appropriate for installations to adhere to the guidelines as far as is reasonably practicable, or other guidance / regulation of equivalent safety.

B. Basis of safety requirements

Basis of safety of turbine housings is generally achieved through a combination of:

- Elimination or control of sources of ignition as far as reasonably possible, following legislative requirements and Australian Standard requirement (e.g. for control of sources of ignition in potentially explosive atmosphere). Note that it may not be technically possible to reduce the temperature of all hot surfaces to eliminate the potential for an ignition of natural gas released into the turbine housing; and
- Limitation of the volume of the explosive atmosphere by the application of all or a combination of:
    - Dilution ventilation. Note that dilution ventilation reduces the size of any flammable cloud to below that which would result in a hazardous explosion if ignited. In order that the dilution ventilation ensures a negligible risk of an explosive atmosphere at all times, the ventilation system should have additional safety features such as e.g.: a 100% standby fan; an uninterruptible power supply to the ventilation fans; interlocks so that the gas turbine cannot start without sufficient ventilation; proven automatic isolation of fuel supply if ventilation fails;
    - Flammable gas detection combined with automatic shut-down of turbine and alarms;
    - Explosion relief,
    - Explosion suppression.

Preventative maintenance procedures and schedules will be developed for the proposed site, covering all critical safety functions such as leak detectors, ventilation fans, alarm systems etc. as appropriate.

Operators and maintenance workers at the plant will be trained to recognise the critical nature of critical safety functions (such as a leak detector, ventilation fan etc.).

Permit to Work systems will be put in place for work inside enclosed areas (including turbine housing).

Emergency procedures and drills for personnel will be developed.

A fire protection system will be installed in the facility, including inside the turbine hall, the generator transformers, as discussed under Section 7.2.2 above.

Recommendation 4: The detailed design of the turbine housing and associated equipments should clearly outline the basis of safety used to ensure that explosive situations do not arise (/the risk is rendered negligible). Reference should be made to European ATEX Directive (Ref 8) and the UK HSE PM84 (Ref 9) or other guidance / regulation of equivalent safety.

Recommendation 5: Fire protection inside the turbine housing to be determined, including use of explosion panels and/or use of fire retardant material.

Recommendation 6: A system should be put in place to ensure that any removal of critical safety function (e.g. for repair or exchange) is subject to careful scrutiny by plant management (decisions on whether to allow continued operation of the plant or of a turbine if a critical safety function is removed need to be made by personnel with enough training and understanding of the safety implications of such decision).

C. Assumptions Used for this Initial QRA

It is assumed that the basis of safety design for the turbine will include:

- A highly reliable ventilation system, designed to remove even small leaks before lower flammable limits are reached,,
- A number of gas detectors linked to automatic shut off of the gas supply,
- Automatic quenching using carbon dioxide or other,
- Separation distance between each turbine of at least 30 meters,

D. Other Hazards Associated with the Enclosure

Two other hazards associated with the enclosure were identified, namely:

- Violent mechanical failure of rotating machine (compressor, turbine) creates projectile(s).
- Release of carbon dioxide (or of other fire quenching material to be used for fire protection) into turbine housing creates risk of asphyxiation of person inside the enclosed area if concentrations reach hazardous levels.

The risk associated with the release of carbon dioxide is discussed under Section 7.2.4 below.

The risk associated with the rotating machines is discussed below.

In case of a mechanical failure of the turbine, projectile may be ejected with high energy, creating a personnel hazard if in the vicinity. Further, if a gas pipe is hit by the projectile or associated equipment / instrumentation then it may fail, causing gas release and fire / explosion if ignition source present.

All rotating machines will be subject to regular and periodic preventative maintenance, including vibration monitoring. If any issues are identified, the machine would be shut down and repaired (as required).

Recommendation 7: Rotating machines to be designed such that the risk associated with projectile is minimised (gas pipelines protected or not in probable line of projectile; electrical switchyard protected or not in probably line of projectile; people protected etc.).

Note that buried pipelines to AS2885 requirements are not generally at risk from such projectiles.

7.2.4 Carbon dioxide Storage (or other asphyxiant fire quenching gas)

The turbine housings, electrical rooms and control rooms will contain fire suppressants, such as carbon dioxide or other fire quenching material.

Carbon dioxide is also anticipated to be required on site for purging purposes during maintenance work.

These materials may pose an asphyxiation hazard to people working within the housings. However, the quantities are relatively small, ensuring that any impact is localised to the enclosed area.

Permit to Work requirements will need to be established and adhered to when people are working inside the housings.

Recommendation 8: Loud alarm and visual indication (e.g. strobe light) to be installed within the housing, alerting any persons within these housings of the pending discharge of asphyxiants (if such is used) and allowing escape.

7.2.5 Storage and Handling of Combustible and Flammable Liquids (combustible diesel and oils or flammable acetone)

The following combustible and flammable liquids are likely to be stored and handled on site:

- Combustible oils (3 x 1,000 litres) will be used in the pumps and turbines;
- Flammable acetone (100 litres) will be used for cleaning.

All the requirements for risk management of these flammable and combustible materials will be as per AS1940 (*Storage and handling of flammable and combustible liquids,* Ref 11), including:

- Bunding requirements as per AS1940, i.e. 100% of the largest tank, with bunding design and construction as per Section 5.9.3 in AS1940.
- Any valve controlling the drainage from the bunds is to be located outside the bund.
- Overflow line from all tanks is / will be open to atmosphere and directed to bund.
- Run-off from external (unbunded) areas would be captured in the first flush stormwater system which is designed to retain the first flush runoff from these areas.
- Fire protection (fire extinguishers, foam, hose reel requirements, separation distances etc) as per AS1940.
- Design of ventilation of building as per AS1940 Section 4.4 with regards to flammable vapours.
- Valving and piping associated with the storage as per AS1940 Section 7.
- Control of ignition sources as per AS1940 Section 9.7.6.
- Communication systems.
- Visual inspection of tanks, lines and equipment. Preventative maintenance program.
- Overflow line and vent line on top of diesel tank to minimise risk of ovepressurisation of tank.
- Foundations, supports, bearing etc. designed and constructed in accordance with AS1940. Tanks and associated equipment are protected from external impact by the bund wall (concrete) which is designed to comply with criteria in AS1940.
- Disposal of spills in accordance with established procedures.

Provided the requirements from AS1940 and the above recommendations are adhered to, the risk of an incident involving the combustible (and small quantities of flammable) material stored and handled is very small.

7.2.6 Whole Site

Flooding: The topography of the site prevents flooding from any rivers or streams.

Mine Subsidence: The risk of mine subsidence will need to be evaluated as part of the design and was not included in the present Initial QRA. The Initial QRA assumes that the risk associated with mine subsidence has been rendered negligible. (Note that geological stability has not been assessed as part of the present Initial QRA).

Earthquake: Structures and plant will be designed to withstand earthquake effects using well-established procedures in accordance with relevant Australian or international standards (Note that geological stability has not been assessed as part of the present Initial QRA).

Aircraft crash on Power Station site: The gas supply pipelines, being buried, are unlikely to be damaged even in case of an aircraft crash. The preventative and protective features of this site makes the risk of an aircraft crash negligible. This scenario, while theoretically possible, does not appear credible for the present site.

7.2.7 Road Transport Risks

Once the site has been built and put into operation, the frequency of road transportation to the site of potentially hazardous material will be minimal.

It is expected that one delivery (up to a maximum of three deliveries) per year will be sufficient for the operation of the site, consisting of the oil top up and possibly the transport of some other material used for maintenance or cleaning (e.g. acetone). Note that oil will be transported to the site in relatively small quantities. Oils are used to top up the gear boxes of the turbines, pumps, air compressors etc.

Road transportation would use Landers Lane and then turn into the site. The access road to the site is to be of adequate construction for the use and to be maintained and repaired as required.

General transport risks of these materials are handled by transport companies' internal safety requirements. Clean up and incident management will be as per the transport company's procedures.

The review of road transport risks concludes that the risk associated with the transport of potentially hazardous material to the site is negligible.

8 CONSEQUENCE ANALYSIS

8.1 EVALUATION TECHNIQUES

As none of the material used, produced or handled are toxic, the evaluation of consequences requires only the determination of fire radiation and explosion overpressure.

For both fires and explosions, it is necessary to determine the leak rate and duration for each incident.

Radiation effects are then determined using the point source method while overpressure effects are determined using the TNT equivalent model in Ref 12.

The explanation of the nomenclature used in the equations below is listed in Table 13 at the end of this Chapter.

8.1.1 Leak Rates

The rate at which a liquid leaks from a hole can be determined using a standard orifice flow equation:

$$\dot{m} = 0.8A\sqrt{(2\rho deltaP)}$$

For the case where two-phase flow occurs, the calculation technique is much more involved. An acceptable approximation is to divide the liquid flow rate determined in the equation by 3 to allow for two-phase flow.

For gas or vapour flows (as for natural gas), the appropriate equation is:

$$\dot{m} = 0.8AP\sqrt{\frac{M\gamma}{zRT}(\sqrt{\frac{2}{\lambda+1}}^{\frac{\gamma+1}{\gamma-1}}}$$

Note that this applies to the condition known as critical or choked flow, which applies when the internal pressure is more than double the atmospheric pressure (approximately).

8.1.2 Duration

The duration of a leak will depend on the hardware systems available to isolate the source of the leak, the nature of the leak itself and the training, procedures and management of the facility. While in some cases it may be argued that a leak will be isolated within one minute, the same leak under different circumstances may take 10 minutes to isolate.

The approach used in this study for failure scenarios identified is to assume three possible event durations and to assign to each the same probability of occurrence. For this analysis, the three leak durations considered were 1 minute, 5 minutes and 10 minutes for manual responses to leaks.

Where automatic response has been designed into the plant (e.g. in the form of process trips) such response has been taken into account (with the relevant probability of failure of the trip etc.). The trips associated with the site, as relevant for the present Initial QRA are the two trips actuated in case of a major leak at the supply pipeline or within the Power Station (see Section 7.2.1 above).

Leak from vessels are assumed to last until the inventory of the vessel has been released, up to a maximum duration of one hour.

The mass of flammable gas contained in a cloud which could flash or explode is set at the total amount which would leak out in 3 minutes. This is based on the assumption that a cloud travelling in the direction of the wind will either encounter a source of ignition within this time[9] or would disperse to concentrations below the Lower Flammable Limit (LFL).

8.1.3 Radiation Effects - The Point Source Method

Radiation effects are evaluated using the point source method, which assumes that a fire is a point source of heat, located at the centre of the flame, and radiating a proportion of the heat of combustion. The radiation intensity at any distance is then determined according to the inverse square law, making allowance for the attenuating effect of atmospheric water vapour over significant distances (e.g. 100m or more).

$$I = \frac{Qf\tau}{4\Pi r^2}$$

The rate of heat release, Q, is given by:

$$Q = \dot{m}H_C$$

8.1.4 Explosion Effects - The TNT Model

For explosions, the amount of gas or vapour resulting from the leak is important. For gases this is the total quantity leaking out for the duration of interest.

The equivalent mass of TNT is then determined using the following relationship:

[9] In a relatively moderate wind force of say 4 m/s, the cloud would after 3 minutes have covered a distance of 240 metres.

$$m_{TNT} = \frac{\alpha H_C m_V}{4600}$$

The overpressure effect from the vapour cloud is determined using a correlation developed for TNT, which relates the scaled distance (a function of actual distance and mass of TNT) to the overpressure. The scaled distance is given by the relationship in equation:

$$\lambda = \frac{r}{(m_{TNT})^{1/3}}$$

8.2 IMPACT ASSESSMENT

The above techniques allow the level of radiation or overpressure resulting from fires and explosions to be determined at any distance from the source. The effect or impact of heat radiation on people is shown in Table 11 while Table 12 shows the effects of explosion overpressure.

Table 11 - Effects of Heat Radiation

Radiant Heat Level (kW/m^2)	Physical Effect (effect depends on exposure duration)
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds' exposure
12.6	Significant chance of fatality for extended exposure High chance of injury
23	Likely fatality for extended exposure and chance of fatality for instantaneous (short) exposure
35	Significant chance of fatality for people exposed instantaneously

Table 12 – Effect of Explosion Overpressure

Overpressure (kPa)	Physical Effect
3.5	90% glass breakage. No fatality, very low probability of injury
7	Damage to internal partitions & joinery 10% probability of injury, no fatality
14	Houses uninhabitable and badly cracked
21	Reinforced structures distort, storage tanks fail 20% chance of fatality to person in building
35	Houses uninhabitable, rail wagons & plant items overturned. Threshold of eardrum damage, 50% chance of fatality for a person in a building, 15% in the open
70	Complete demolition of houses Threshold of lung damage, 100% chance of fatality for a person in a building or in the open

For jet flames and fireballs the effect of heat radiation is constant in every direction, hence they are omni-directional in effect. The probability of affecting a target at a location within the effect distance away from the location of the incident is equal in all directions.

The relationship between exposure and effect was estimated based on the probit equation for heat radiation. In the case of flash fires, 100% fatality was assumed for anyone engulfed within the flaming cloud, and 0% probability outside it. In the case of a Vapour Cloud Explosion, the relationship between overpressure and probability of fatality to people in a building as defined in the Orica course material in Ref 12 is taken as defining the lethal zone.

For the case of pipelines, the hazard must be treated as a linear hazard in the respect that it remains constant along the length of the route, and it only changes if there are special features in the pipeline such as valve stations. For a given location (at a distance **d** away from the fire), the heat radiation could exceed specified levels if **d** is less than, or equal to, the hazard range (or in this case the "effect distance"). Hence, this Initial QRA has determined the hazard range of incident scenarios occurring anywhere along the interaction length of the pipeline.

Table 13 – Nomenclature for Section 8

Label	Explanation
A	Area of hole, m^2
C_p	Average liquid heat capacity, kJ/kg.K
f	Fraction of heat radiated
H_c	Heat of combustion, kJ/kg
H_v	Heat of vaporisation, kJ/kg
I	Radiant heat intensity kW/m^2
M	Molecular weight
m	Mass, kg
m_v	Mass of vapour (in cloud), kg
m_{TNT}	Equivalent mass of TNT, kg
$\dot{m}$	Mass flow rate of leak, kg/s
P	Pressure, Pa
P_1	Upstream absolute pressure, Pa
Q	Heat release rate, kW
R	Universal gas constant, 8.314 J.K/mol
r	Distance from fire/explosion, m
T	Temperature, K
T_1	Storage temperature, K
T_b	Boiling point, K
t	Duration of leak/time, seconds
z	Gas compressibility factor
α	Explosion efficiency factor
γ	Ratio of specific heats (~1.4)
λ	Scaled distance
ρ	Density, kg/m^3
τ	Atmospheric transmissivity

8.3 CONSEQUENCE CALCULATIONS

This initial outflow rates estimated for natural gas releases are shown in Table 14. The results predict that the rate of decrease in outflow rate for a full bore rupture is dramatic with a drop to less than half of the initial flow within seconds and further rapid decay. However, the present Initial QRA has assumed that the initial release rate remains until isolation can be achieved - this is a highly conservative approach. Further details, refer to Appendix 1.

Table 14 – Release Rates

Release rate [kg/s]	Hole Size					
	Small leak (5mm)	**Flange leak (13 m)**	**Interme-diate leak (25 mm)**	**Major leak (80 mm)**	**Massive leak (100 mm)**	**Full bore (guilo-tine)**
Upstream of the Pressure Regulator						
Instantaneous	0.4 kg/s	2.8 kg/s	6.5	104	163 kg/s	2,600 kg/s (first few seconds)
Downstream of the Pressure Regulator						
Instantaneous	0.1 kg/s	0.8 kg/s	2	30	47 kg/s	946 kg/s (first few seconds)

The distance from the source of the fire to the specified heat radiation for jet fire scenarios is listed in Table 15 below.

Table 15 – Heat Radiation from Jet Fires

Hole size	Distance to Heat radiation (metres)		
	$4.7kW/m^2$	**$12.5kW/m^2$**	**$23.5kW/m^2$**
Upstream of the Pressure Regulator			
Small leak (5mm)	7	4	3
Intermediate leak (25 mm)	40	25	15
Massive leak (100 mm)	145	90	65
Full bore (guillotine)	575	350	260
Downstream of the Pressure Regulator			
Small leak (5mm)	4	2	1.5
Intermediate leak (25 mm)	20	12	9
Massive leak (100 mm)	80	50	35

Hole size	Distance to Heat radiation (metres)		
	4.7kW/m^2	12.5kW/m^2	23.5kW/m^2
Full bore (guillotine)	350	215	155

The distance to 100% chance of fatality from a jet fire is shown in Table 16 below.

Table 16 – Distance to 100% Chance of Fatality

Hole size	Distance to 100% Fatality (metres)		
	Jet Fire	Flash Fire	Vapour Cloud Explosion
Upstream of the Pressure Regulator			
Small leak (5mm)	5	15	15
Intermediate leak (25 mm)	15	40	40
Massive leak (100 mm)	75	75	150
Full bore (guillotine)	220	220	250
Downstream of the Pressure Regulator			
Small leak (5mm)	2	10	10
Intermediate leak (25 mm)	10	25	25
Massive leak (100 mm)	30	60	75
Full bore (guillotine)	120	120	150

9 FREQUENCY ANALYSIS

9.1 GENERIC EQUIPMENT FAILURES

A summary of all incident scenarios that are incorporated into the Initial QRA are listed in Appendix 2. The frequency of each postulated equipment failure was determined using the data in the table below.

The frequencies used for on-site fixed plant are those that have been in use by Orica Engineering for over 15 years of risk assessments in Australia. These frequencies are based on Orica Engineering's interpretation of published and unpublished (internal ICI and Orica) data and have been used in QRAs for potentially hazardous industry in Victoria (and in other states of Australia) for over 20 years.

The frequencies used for the gas supply pipeline are based on information from the US Dept of Transportation Office of Pipeline Safety. This data source is widely recognised in gas pipeline operation throughout the world.

Table 17 - Equipment Failures and Associated Frequencies

Type of Failure	Failure Rate (pmpy)
PIPELINES WITHIN FIXED PLANT (POWER PLANT)	
3 mm hole	9 / m
13 mm hole	3 / m
50 mm hole	0.3 / m
3 mm gasket (13 mm hole equivalent)	5 / joint
Guillotine fracture (full bore):	
< 50 mm	0.6 / m
> 50 mm but < 100 mm	0.3 / m
> 100 mm	0.1 / m
GAS SUPPLY PIPELINES (>100mm NB)	
<20 mm hole – steel pipeline	0.23 / m
<80 mm hole – steel pipeline	0.03 / m
Guillotine fracture (full bore) – steel pipeline	0.009 / m

9.2 FAILURE OF AUTOMATIC PROTECTION

Slam shut isolation or emergency isolation valves will be positioned on either end of the lateral supply pipeline. These valves will close automatically in case of a major leak at the lateral pipeline. The following estimates of probabilities have been used for the purposes of determining the reliability of the automatic protection (Ref 13). While the design of the control system is not finalised, it is assumed that the protective systems will be designed to SIL 1 requirements.

Table 18 - Probability of Human Error

Safety Integrity Level (SIL)	Low Demand Mode of Operation (probability of failure to perform as intended on demand)
4	>=10^{-5} to < 10^{-4}
3	>=10^{-4} to < 10^{-3}
2	>=10^{-3} to < 10^{-2}
1	>=10^{-2} to < 10^{-1}

9.3 HUMAN ERROR

The following estimates of human error have been used as a guide for the purposes of determining human responses (Ref 14):

Table 19 - Probability of Human Error

ACTIVITY	Probability of error
Probability of failing to take correct action in high stress situations with one minute in which to act	0.9-1.0
Error in non-routine operation when other duties required	0.1
Error in routine operation where some care is needed	0.01
Error in routine simple operation	0.001

9.4 PROBABILITY OF FLAMMABLE OUTCOME

The probability of ignition if leak were based on the British Gas Corporation as reported in FP Lees (*Loss Prevention in the Process Industries*) (Ref 14) as follows:

Table 20 – Ignition Probability

Leak size (mm)	**Probability of ignition**
<20mm	0.2
20 to 100 mm	0.32
>100 mm	0.37

The probability of an explosion is virtually zero for a natural gas leak out in the open, such as for the gas supply pipeline. The probability of an explosion for the fixed plant (where there may be some confinement) is taken as 0.9M (in %), with M being the mass of flammable vapour in the cloud (Ref 15). This equation was used to determine the probability of a flash fire for the gas supply pipelines. This equation is believed to be highly conservative when used for natural gas plant because of the gas' propensity to rise high up in the air and disperse to below flammable limits without encountering an ignition source. The probability of a jet fire was taken as:

$$P_{\text{jet fire}} = P_{\text{ignition}} - P_{\text{explosion}} - P_{\text{flash fire}}$$

The frequency of outcome of each individual incident scenario is listed in the spreadsheet in Appendix 2.

10 RISK RESULTS AND COMPARISON WITH RISK CRITERIA

10.1 RISK CALCULATIONS FOR NATURAL GAS PIPELINES OUTSIDE OF THE TURBINE ENCLOSURES

10.1.1 Results

Risk contours for the site are shown in the following figures:

- Figure 6 shows the individual fatality contours for risk associated with the Power Station.

Note that all data used in this assessment are for a site operating 100% of the time with the natural gas pipelines pressurised 100% of the time. The quantitative risk results are valid, though conservative, for the plant under the expected operating conditions, which are for the Power Plant expected to operate less than 10% of the time.

In this study the risk of fatality of 0.1 pmpy does not extend beyond the site boundaries and is therefore well away from the residential areas.

The concept of societal risk is not applicable for the proposed development and has not been calculated further.

10.1.2 Discussions

The interim risk criteria in use by Victorian WorkSafe states that: *Risk must not exceed 10 per million per year at the boundary of any new facility.* In the case of the power station, the 10 pmpy risk contour remains within the site boundary.

The criteria further states that: *If risk off-site is between 0.1 and 10 per million per year, all practicable risk reduction measures are to be taken, and residential developments are to be restricted.*

The distance to the 0.1 pmpy risk contour from natural gas receiving station is 95 meters. The buffer provided between the gas receiving station and the closest (western) boundary is 100 meters. The 0.1 pmpy criterion is hence adhered to.

The distance to the 0.1 pmpy risk contour from above ground (on-site) natural gas pipes is 10 metres. Following the requirements in the criteria, residential area should be restricted for an area of about 10 metres from the centre point of the gas pipeline supplying natural gas into the turbines (i.e. to pipelines operating at 3.4MPa). This is easily achieved at the site by ensuring that the on-site pipe runs are located at least 10 meters from the site boundary. In the layout provided in Figure 4 the buffer provided between above ground piping on the site exceeds by far 10 meters (it is closer to 100 metres) and the 0.1 pmpy criterion is hence adhered to.

Figure 6 - Individual Fatality Risk Contours, Power Station Site

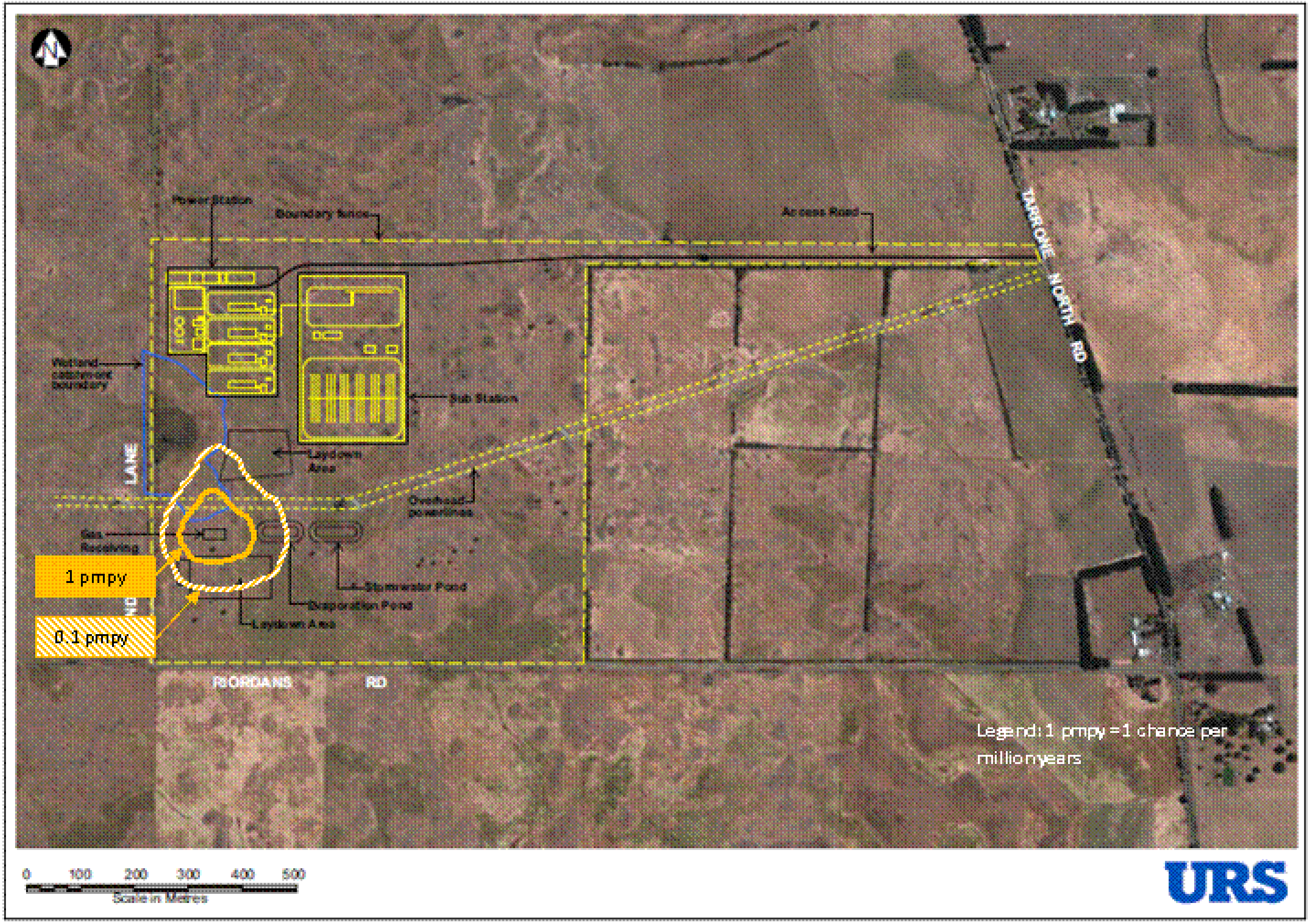


Table 21 – Distance to Risk Contours (Above Ground Pipeline at Power Station)

Risk Contour	Maximum Distance to Risk Contour metres)
General Pipeline Distributing Natural Gas to Gas Turbines	
Individual Fatality Risk – 0.1 pmpy	10
Individual Fatality Risk – 10 pmpy	5
Gas Receiving Station	
Individual Fatality Risk – 0.1 pmpy	95
Individual Fatality Risk – 10 pmpy	20

10.2 Risk of Natural Gas Explosion in Turbine Housing

The likelihood of a confined explosion inside the turbine housing was estimated taking into account that the basis of safety would include in the minimum (see Recommendations 4 and 5):

- Highly reliable ventilation fan system,
- Gas detection linked to automatic emergency shutdown system,
- Prevention of ignition sources within the housing,
- Explosion panel (to minimize effect of confinement) and fire quenching (e.g. carbon dioxide), and
- Separation distances or explosion resistant wall to nearby turbines and pressure piping.

The frequency of explosion inside the turbine housing can be estimated as follows:

Explosion frequency = (Gas release frequency within enclosure) x (Ventilation fan failure probability) x (Gas detection and emergency shutdown failure probability) x (Ignition probability of accumulated gas) x (Explosion if ignition probability).

With the following assumptions:

- Gas leak frequency = 1.4 x 10^{-3} t/yr (assuming equipment failure frequencies as per Table 17 and 290 flanges and flexible joints as per Table 2 above).

- Ventilation fan failure probability, allowing accumulation of gas = 0.1 (taken as the failure of one or the other of two automated protective systems of SIL 1, i.e. P = 0.05 + 0.05 = 0.1). This is believed to be a highly conservative assumption, particularly taking into account the requirement to provide reliable ventilation, see recommendation 4.

- Gas detection failure and failure of the emergency shutdown = 0.05 per gas detector, assume two independent detectors [and that both have to fail or fail to pick up the leak]. Also, taken into account is a 0.0025 probability of common mode failure for gas detectors (e.g. due to maintenance failure affecting detector system).

- Ignition probability of accumulated gas = 0.1. Even though all equipment and instrumented protective equipment used in the enclosure need to be designed for the hazardous zone requirements, a gas turbine could have hot surfaces above the auto ignition temperature of the fluids used even in normal circumstances (operation under fault conditions may increase surface temperatures).

- Explosion if ignition probability = 1 (i.e. assuming that all ignitions of flammable gases inside the enclosure would lead to an explosion. This is highly conservative).

Calculations show:

> Explosion frequency = $(1.45 \times 10^{-3}) \times (0.1) \times (0.05 \times 0.05 + 0.0025) \times (0.1) \times (1) = 7.2 \times 10^{-8}$ per year per housing.

With four enclosures, the total frequency of explosion inside turbine enclosures is:

F(explosion in turbine housing, 4 turbines) = 2.9×10^{-7} per year.

With three enclosures, the total frequency of explosion inside turbine enclosures is:

F(explosion in turbine housing, 3 turbines) = 2.2×10^{-7} per year.

This frequency is very low.

A confined explosion may generate high over pressures which could damage neighbouring equipment and turbines. It is however understood that the enclosures will be designed with explosions vents (/ panels) which would blow out in case of a pressure event, thereby reducing the effect of the confinement. Further, the turbines will be separated from each other by a 10 meters buffer zone and will be separated from each other by an explosion resistant wall.

With proper design it is unlikely that an explosion at one turbine would have serious effect at a neighbouring turbine.

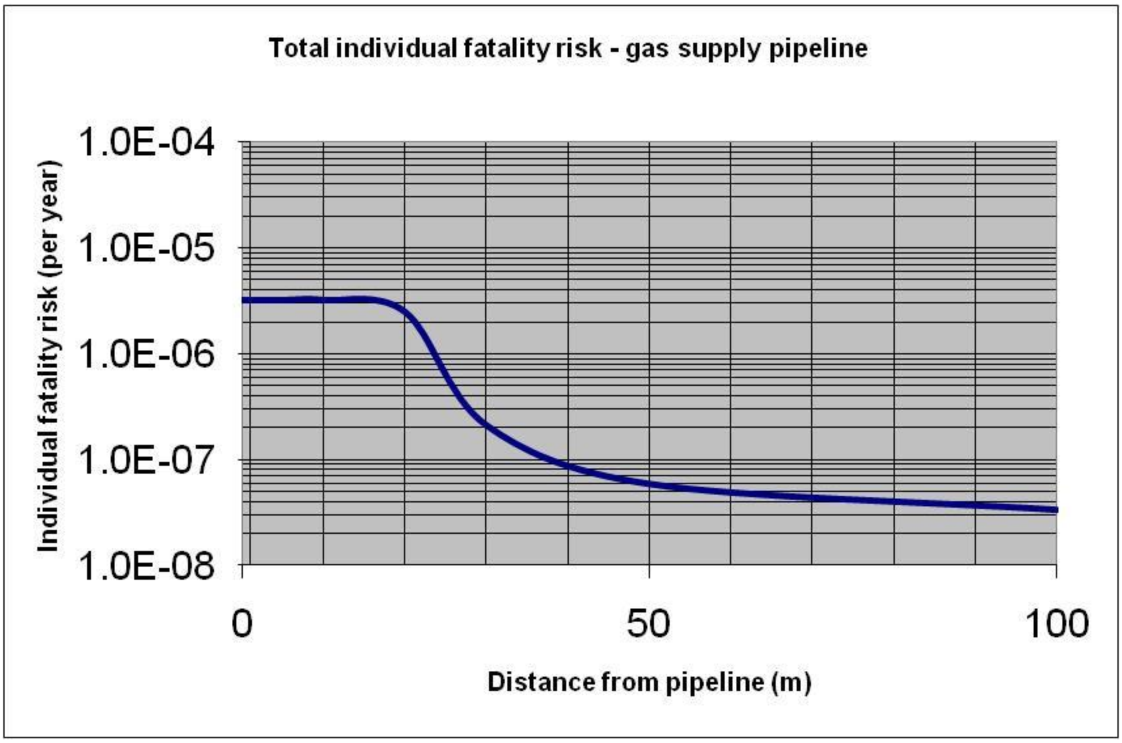
The separation distance to the site boundary is very large for this development. Providing recommendations 4 and 5 are carried out, the risk from an explosion at turbine enclosures will be contained well within the site boundary.

10.3 LATERAL GAS SUPPLY PIPELINE

10.3.1 Results

Figure 7 shows the risk-transect for individual fatality at the natural gas lateral supply pipeline.

Figure 7 – Individual Risk Transects for the Lateral Gas Supply Pipeline



10.3.2 Discussions

The interim risk criteria in use by Victorian WorkSafe states that: *Risk must not exceed 10 per million per year at the boundary of any new facility.* In the case of the lateral gas supply pipeline, the 10 pmpy risk contour is never reached and the risk remains below this level at all distances from the pipeline (and well within the pipeline easement).

The criteria further states that: *If risk off-site is between 0.1 and 10 per million per year, all practicable risk reduction measures are to be taken, and residential developments are to be restricted.*

The distance to the 1 pmpy risk contour is 25 meters from the centre of the pipeline and the distance to the 0.1 pmpy contour is 40 meters from the centre of the pipeline. With an easement of 25 meters (i.e. about 12.5 meters on either side of the pipeline) it then follows that residential development may need to be restricted for a distance of 27.5 meters from the easement, as determined through Council consultation.

Note that the 0.1 pmpy criteria is very low compared with criteria in other States in Australia and internationally where the 1 pmpy risk contour is generally stated as the criteria for residential area.

10.4 TRANSPORT RISK

The review of road transport risks concludes that the risk associated with the transport of dangerous goods and potentially hazardous material to the site is negligible.

10.5 ADHERENCE TO RISK CRITERIA

The quantitative analysis showed that:

Individual Risk of Fatality: The risk of fatality at the boundary to this site (and hence also at the nearest residential area) is below the criterion for new installations of 0.1 chance in a million per year (0.1×10^{-6}/yr). The 0.1×10^{-6}/yr individual fatality risk for the Power Plant is contained within the site boundaries.

The risk criterion which must remain inside plant boundaries for the lateral gas supply pipeline (10×10^{-6}/yr) remains inside the pipeline easement. The maximum risk level experienced at 25 metres from the pipelines is less than 1×10^{-6}/yr. The 0.1×10^{-6}/yr risk contour extends 25 meters from the pipeline easement – residential development may need to be restricted in this area.

Societal Risk: The risk of fatality does not extend anywhere close to any residential and is well within the criteria for business / industrial areas. It is therefore considered that the current installation does not have a significant impact on societal risk.

11 CONCLUSION AND RECOMMENDATIONS

11.1 OVERVIEW OF RISK

The main hazard associated with the proposed project is associated with the production and handling of natural gas (predominantly composed of methane gas), which is a flammable gas held under pressure. Other, less significant hazards, are associated with the handling of flammable and combustible liquids.

Hazards may arise in fixed plant, storage, and pipelines. The predominant mode in which a hazardous incident may be generated is associated with a leak. This would generally only have the potential to cause injury or damage if there was ignition, which resulted in a fire or explosion incident. The factors involved are:

- Failure must occur causing a release. There are several possible causes of failure, with the main ones being corrosion and damage to the equipment by external agencies;

- The released material must come into contact with a source of ignition. In some cases this may be heat or sparks generated by mechanical damage while in others, the possible ignition source could include non-flame proof equipment, vehicles, or flames some distance from the release;

- Depending on the release conditions, including the mass of material involved and how rapidly it is ignited, the results may be a localised fire (for example a so called jet fire), a flash fire or an explosion of the vapour cloud formed through the release.

- Finally, for there to be a risk, people must be present within the harmful range (consequence distance) of the fire or explosion. How close the people are will determine whether any injuries or fatalities result.

11.2 SUMMARY OF RISK RESULTS

The detailed design has not been completed as yet for this development. A set of very conservative assumptions as to the design and operation of the plant have been made, including a 100% on-line operation of the plant (despite the fact that it is expected that the plant will be operational for less than 10% of the time only, with appropriate fire proof isolation valves separating the plant from pressurised gas supplies).

Despite the fact that many of the assumptions in this Initial QRA are conservative, the results show that the risk associated with this development is very low. The most stringent risk criteria, as required by Victorian WorkSafe are adhered to for the Power Station.

The lateral gas supply pipeline will run in a 30 meter wide easement. The risk criterion which must remain within plant boundary is adhered to. Residential development may need to be restricted within 25 meters from the edge of the easement (to allow for the 0.1 pmpy risk contour not to be reached).

11.3 RECOMMENDATIONS

The risk assessment carried out in this study assumed that the facility will be operated with appropriate consideration to safety and safety management at all stages.

The following recommendations emphasise the assumptions made in this risk assessment:

Recommendation 1: It is recommended that an audit is carried out of the safety management system implemented at the site, specifically as it applies to the proposed hazardous materials handling, pipelining and storages. This audit should be carried out within the first year of operation.

Recommendation 2: High and low pressures of the natural gas supply are to be monitored during (and, if applicable, outside) operation of the Power Plant. These conditions will need to be associated with an automatic trip / shut down of the pipeline at the metering station in case of a major failure of the natural gas pipeline within the site boundary (as assumed in this Initial QRA). The detection and subsequent closure at the SEA Gas pipeline in case of a major leak in the lateral pipeline is also required.

Recommendation 3: The use of fusible tubing around above ground high risk natural gas piping (e.g. within the turbine housing) to be investigated – such tubing would be linked to automatic shut down of the fuel source.

Recommendation 4: The detailed design of the turbine housing and associated equipment should clearly outline the basis of safety used to ensure that explosive situations do not arise (/the risk is rendered negligible). Reference should be made to European ATEX Directive and the UK HSE PM84 or other guidance / regulation of equivalent safety.

Recommendation 5: Fire protection inside the turbine housing to be determined, including use of explosion panels and use of fire retardant material.

Recommendation 6: A system should be put in place to ensure that any removal of critical safety function (e.g. for repair or exchange) is subject to careful scrutiny by plant management (decisions on whether to allow continued operation of the plant or of a turbine if a critical safety function is removed need to be made by personnel with enough training and understanding of the safety implications of such decision).

Recommendation 7: Rotating machines to be designed such that the risk associated with projectile is minimised (gas pipelines protected or not in probable line of projectile; electrical switchyard protected or not in probably line of projectile; people protected etc.).

Recommendation 8: Loud alarm and visual indication (e.g. strobe light) to be installed within the turbine housing, alerting any persons within these housings of the pending discharge of asphyxiants (if such is used) and allowing escape.

Recommendation 9: As the project and design are still in the feasibility stage a number of assumptions needed to be made as part of this Initial QRA. While believed to be conservative, these assumptions should be verified at the detailed project and design stage to ensure that the results of the Initial QRA remain valid.

Appendix 1

Consequence Assessment

Appendix 1 - Consequence Assessment

OUTFLOW RATES

Gas flow rate = 0.8 x A x P {M/zRT x [(2/gamma + 1)$^{0.5}$]$^{(gamma+1)/(gamma-1)}$}$^{0.5}$

R =	8.314	J.K/mol	
T =	293	K	
gamma =	1.31	ratio of specific heat	
z =	1	assume ideal gas	
M =	18	g/mol	
P =	1.20E+07	Pa	Upstream of regulator
P =	3.44E+06	Pa	Downstream of regulator

GAS SUPPLY PIPELINE RISK ASSESSMENT

Leak size (m)	Cross section	Flow rate (kg/s)	
5.00E-03	1.96E-05	4.07E-01	Upstream of regulator
2.50E-02	4.91E-04	1.02E+01	Upstream of regulator
1.00E-01	7.85E-03	1.63E+02	Upstream of regulator
4.00E-01	1.26E-01	2.60E+03	Upstream of regulator
5.00E-03	1.96E-05	1.17E-01	Downstream of regulator
2.50E-02	4.91E-04	2.92E+00	Downstream of regulator
1.00E-01	7.85E-03	4.67E+01	Downstream of regulator
4.50E-01	1.59E-01	9.46E+02	Downstream of regulator

ONSITE PIPE FAILURES - RISK ASSESSMENT

Leak size (m)	Cross section	Flow rate (kg/s)	
3.00E-03	7.07E-06	1.46E-01	Upstream of regulator
1.30E-02	1.33E-04	2.75E+00	Upstream of regulator
5.00E-02	1.96E-03	4.07E+01	Upstream of regulator
4.00E-01	1.26E-01	2.60E+03	Upstream of regulator
3.00E-03	7.07E-06	4.20E-02	Downstream of regulator
1.30E-02	1.33E-04	7.89E-01	Downstream of regulator
5.00E-02	1.96E-03	1.17E+01	Downstream of regulator
4.50E-01	1.59E-01	9.46E+02	Downstream of regulator

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JET FIRE - POINT SOURCE METHOD

Assume :		*Probit Y = -A + B x ln(Q x t^n^)*		Length of jet		
Heat of combustion Hc=	50000 kJ/kg	A	-14.9	*F. P. Lees*	$L = 6M^{0.5}$	for 0<M<50 kg/s
Radiation efficiency =	0.15	B	2.56		(M = mass flow rate, kg/s)	
Transmissivity =	1	n	1.333			
Duration of exposure =	60 s					for M>50 kg/s
Duration for total mass of vapour in cloud	180 s					
1 Mass burn rate = outflow rate						

Jet Fire

Leak size(mm)	Location	Burn rate (kg/s)	Heat rad (kW)	Length of jet flame metres	Distance to Heat Radiation (m) 4.7kW/m²	12.5kW/m²	23.5kW/m²	Probit value Y = -14.9 + 2.56 ln(I^1.333^ t) 4.7kW/m²	12.5kW/m²	23.5kW/m²	Probability of fatality 4.7kW/m²	12.5kW/m²	23.5kW/m²
5.00E-03	Upstream of regulator	4.07E-01	3.05E+03	3.83	7.2	4.4	3.3	0.9	4.2	6.3	0	0.28	0.96
2.50E-02	Upstream of regulator	1.02E+01	7.63E+04	19.14	35.9	22.0	16.3	0.9	4.2	6.3	0	0.28	0.96
1.00E-01	Upstream of regulator	1.63E+02	1.22E+06	76.55	143.8	88.2	65.0	0.9	4.2	6.3	0	0.28	0.96
4.00E-01	Upstream of regulator	2.60E+03	1.95E+07	761.99	575.2	352.7	260.0	0.9	4.2	6.3	0	0.28	0.96
5.00E-03	Downstream of regulator	1.17E-01	8.76E+02	2.05	3.9	2.4	1.7	0.9	4.2	6.3	0	0.28	0.96
2.50E-02	Downstream of regulator	2.92E+00	2.19E+04	10.25	19.3	11.8	8.7	0.9	4.2	6.3	0	0.28	0.96
1.00E-01	Downstream of regulator	4.67E+01	3.50E+05	41.01	77.0	47.2	34.8	0.9	4.2	6.3	0	0.28	0.96
4.50E-01	Downstream of regulator	9.46E+02	7.09E+06	255.26	346.7	212.6	156.7	0.9	4.2	6.3	0	0.28	0.96

Leak size(mm)	Location	Burn rate (kg/s)	Heat rad (kW)	Length of jet flame metres	Heat radiation (kW/m2) at Distance from Centre of Flame (in metres). 1	2	5	10	20	30	50	100	200	300
5.00E-03	Upstream of regulator	4.07E-01	3.05E+03	3.83	243	61	10	2	1	0	0	0	0	0
2.50E-02	Upstream of regulator	1.02E+01	7.63E+04	19.14	6074	1519	243	61	15	7	2	1	0	0
1.00E-01	Upstream of regulator	1.63E+02	1.22E+06	76.55	97187	24297	3887	972	243	108	39	10	2	1
4.00E-01	Upstream of regulator	2.60E+03	1.95E+07	761.99	1554995	388749	62200	15550	3887	1728	622	155	39	17
5.00E-03	Downstream of regulator	1.17E-01	8.76E+02	2.05	70	17	3	1	0	0	0	0	0	0
2.50E-02	Downstream of regulator	2.92E+00	2.19E+04	10.25	1743	436	70	17	4	2	1	0	0	0
1.00E-01	Downstream of regulator	4.67E+01	3.50E+05	41.01	27894	6974	1116	279	70	31	11	3	1	0
4.50E-01	Downstream of regulator	9.46E+02	7.09E+06	255.26	564860	141215	22594	5649	1412	628	226	56	14	6

Leak size(mm)	Location	Burn rate (kg/s)	Heat rad (kW)	Length of jet flame metres	Distance to this heat radiation from the source (in metres) 1	2	5	10	20	30	(takes into account the length of the flame) 50	100	200	300
5.00E-03	Upstream of regulator	4.07E-01	3.05E+03	3.83	3	4	7	12	22	32	52	102	202	302
2.50E-02	Upstream of regulator	1.02E+01	7.63E+04	19.14	11	12	15	20	30	40	60	110	210	310
1.00E-01	Upstream of regulator	1.63E+02	1.22E+06	76.55	39	40	43	48	58	68	88	138	238	338
4.00E-01	Upstream of regulator	2.60E+03	1.95E+07	761.99	382	383	386	391	401	411	431	481	581	681
5.00E-03	Downstream of regulator	1.17E-01	8.76E+02	2.05	2	3	6	11	21	31	51	101	201	301
2.50E-02	Downstream of regulator	2.92E+00	2.19E+04	10.25	6	7	10	15	25	35	55	105	205	305
1.00E-01	Downstream of regulator	4.67E+01	3.50E+05	41.01	22	23	26	31	41	51	71	121	221	321
4.50E-01	Downstream of regulator	9.46E+02	7.09E+06	255.26	129	130	133	138	148	158	178	228	328	428

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Leak size(mm)	Location	Burn rate (kg/s)	Heat rad (kW)	Length of jet flame	Probit									
				metres	1	2	5	10	20	30	50	100	200	300
5.00E-03	Upstream of regulator	4.07E-01	3.05E+03	3.83	14	10	3	-1	-6	-9	-12	-17	-22	-25
2.50E-02	Upstream of regulator	1.02E+01	7.63E+04	19.14	25	21	14	10	5	2	-1	-6	-11	-14
1.00E-01	Upstream of regulator	1.63E+02	1.22E+06	76.55	35	30	24	19	14	12	8	3	-1	-4
4.00E-01	Upstream of regulator	2.60E+03	1.95E+07	761.99	44	39	33	28	24	21	17	13	8	5
5.00E-03	Downstream of regulator	1.17E-01	8.76E+02	2.05	10	5	-1	-6	-10	-13	-17	-21	-26	-29
2.50E-02	Downstream of regulator	2.92E+00	2.19E+04	10.25	21	16	10	5	1	-2	-6	-10	-15	-18
1.00E-01	Downstream of regulator	4.67E+01	3.50E+05	41.01	30	26	19	15	10	7	4	-1	-6	-8
4.50E-01	Downstream of regulator	9.46E+02	7.09E+06	255.26	41	36	30	25	20	18	14	9	5	2
Leak size(mm)	Location	Burn rate (kg/s)	Heat rad (kW)	Length of jet flame		Probability of fatality								
5.00E-03	Upstream of regulator	4.07E-01	3.05E+03	3.83	1.00	1.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.50E-02	Upstream of regulator	1.02E+01	7.63E+04	19.14	1.00	1.00	1.00	1.00	0.50	0.00	0.00	0.00	0.00	0.00
1.00E-01	Upstream of regulator	1.63E+02	1.22E+06	76.55	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.03	0.00	0.00
4.00E-01	Upstream of regulator	2.60E+03	1.95E+07	761.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50
5.00E-03	Downstream of regulator	1.17E-01	8.76E+02	2.05	1.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.50E-02	Downstream of regulator	2.92E+00	2.19E+04	10.25	1.00	1.00	1.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
1.00E-01	Downstream of regulator	4.67E+01	3.50E+05	41.01	1.00	1.00	1.00	1.00	1.00	0.98	0.16	0.00	0.00	0.00
4.50E-01	Downstream of regulator	9.46E+02	7.09E+06	255.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.01

FLASH FIRE

Distance to fatality for flash fires= dist. To 70kPa = scaled distance of 4

Leak size(mm)	Location	Burn rate (kg/s)	Mass in cloud (	Flash fire	Probability of Fatality							
(m)			(kg)	danger zone (m)	5 m	10 m	20 m	30 m	50 m	100 m	200 m	300 m
5.00E-03	Upstream of regulator	4.07E-01	7.32E+01	10	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
2.50E-02	Upstream of regulator	1.02E+01	1.83E+03	30	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
1.00E-01	Upstream of regulator	1.63E+02	2.93E+04	80	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00
4.00E-01	Upstream of regulator	2.60E+03	4.69E+05	180	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
5.00E-03	Downstream of regulator	1.17E-01	2.10E+01	12	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
2.50E-02	Downstream of regulator	2.92E+00	5.26E+02	25	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
1.00E-01	Downstream of regulator	4.67E+01	8.41E+03	75	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00
4.50E-01	Downstream of regulator	9.46E+02	1.70E+05	170	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00

VCE - TNT METHOD													
Equivalent mass TNT = [Explosion efficiency compared with TNT] x [Mass of vapour in cloud] x [Heat of combustion of vapour] / 4,600 =													
Scaled distance = Radius [metres] / (MTNT)0.333													
Explosion efficiency =		4%											
Hc =		50000	kJ/kg										
Mass in cloud after (s) =		180											
	Leak size(mm)	**Location**	**Burn rate (kg/s)**	**Mass in cloud (**	**M(TNT)**	**Scaled distance**							
	(m)			**(kg)**	**(kg)**	**5 m**	**10 m**	**20 m**	**30 m**	**50 m**	**100 m**	**200 m**	**300 m**
	5.00E-03	Upstream of regulator	4.07E-01	7.32E+01	3.18E+01	1.6	**3.2**	**6.3**	9.5	15.8	31.6	63.2	94.8
	2.50E-02	Upstream of regulator	1.02E+01	1.83E+03	7.96E+02	0.5	1.1	2.2	**3.2**	**5.4**	10.8	21.6	32.4
	1.00E-01	Upstream of regulator	1.63E+02	2.93E+04	1.27E+04	0.2	0.4	0.9	1.3	2.1	**4.3**	8.6	12.9
	4.00E-01	Upstream of regulator	2.60E+03	4.69E+05	2.04E+05	0.1	0.2	0.3	0.5	0.9	1.7	**3.4**	**5.1**
	5.00E-03	Downstream of regulator	1.17E-01	2.10E+01	9.14E+00	**2.4**	**4.8**	9.6	14.4	23.9	47.9	95.7	143.6
	2.50E-02	Downstream of regulator	2.92E+00	5.26E+02	2.28E+02	0.8	1.6	**3.3**	**4.9**	8.2	16.4	32.8	49.2
	1.00E-01	Downstream of regulator	4.67E+01	8.41E+03	3.66E+03	0.3	0.7	1.3	2.0	**3.3**	6.5	13.0	19.5
	4.50E-01	Downstream of regulator	9.46E+02	1.70E+05	7.40E+04	0.1	0.2	0.5	0.7	1.2	2.4	**4.8**	7.2
	Leak size(mm)	**Location**	**Burn rate (kg/s)**	**Mass in cloud (**	**M(TNT)**	**Overpresure (kPa)**							
	(m)			**(kg)**	**(kg)**	**5 m**	**10 m**	**20 m**	**30 m**	**50 m**	**100 m**	**200 m**	**300 m**
	5.00E-03	Upstream of regulator	4.07E-01	7.32E+01	3.18E+01	100	90.0	35.0	20.0	10.0	3.0	0.0	0.0
	2.50E-02	Upstream of regulator	1.02E+01	1.83E+03	7.96E+02	100	100	100	90	40	15	6	1
	1.00E-01	Upstream of regulator	1.63E+02	2.93E+04	1.27E+04	100	100	100	100	100	65	20	15
	4.00E-01	Upstream of regulator	2.60E+03	4.69E+05	2.04E+05	100	100	100	100	100	100	90	40
	5.00E-03	Downstream of regulat	1.17E-01	2.10E+01	9.14E+00	90	40.0	17.0	10.0	4.5	0.8	0.0	0.0
	2.50E-02	Downstream of regulat	2.92E+00	5.26E+02	2.28E+02	100	100	100	45	20	10	3	1
	1.00E-01	Downstream of regulat	4.67E+01	8.41E+03	3.66E+03	100	100	100	100	85	30	10	6
	4.50E-01	Downstream of regulat	9.46E+02	1.70E+05	7.40E+04	100	100	100	100	100	90	40	20
	Leak size(mm)	**Location**	**Burn rate (kg/s)**	**Mass in cloud (**	**M(TNT)**	**Probability of fatality**							
	(m)			**(kg)**	**(kg)**	**5 m**	**10 m**	**20 m**	**30 m**	**50 m**	**100 m**	**200 m**	**300 m**
	5.00E-03	Upstream of regulator	4.07E-01	7.32E+01	3.18E+01	1.00	1.00	0.50	0.15	0.05	0.01	0.00	0.00
	2.50E-02	Upstream of regulator	1.02E+01	1.83E+03	7.96E+02	1.00	1.00	1.00	1.00	0.65	0.10	0.06	0.01
	1.00E-01	Upstream of regulator	1.63E+02	2.93E+04	1.27E+04	1.00	1.00	1.00	1.00	1.00	1.00	0.16	0.10
	4.00E-01	Upstream of regulator	2.60E+03	4.69E+05	2.04E+05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.65
	5.00E-03	Downstream of regulat	1.17E-01	2.10E+01	9.14E+00	1.00	0.62	0.15	0.08	0.02	0.00	0.00	0.00
	2.50E-02	Downstream of regulat	2.92E+00	5.26E+02	2.28E+02	1.00	1.00	1.00	0.80	0.17	0.04	0.02	0.00
	1.00E-01	Downstream of regulat	4.67E+01	8.41E+03	3.66E+03	1.00	1.00	1.00	1.00	1.00	0.35	0.08	0.04
	4.50E-01	Downstream of regulat	9.46E+02	1.70E+05	7.40E+04	1.00	1.00	1.00	1.00	1.00	1.00	0.62	0.17

Appendix 2

Release Scenarios and Frequency / Probability Calculations

Preliminary Hazard Analysis of AGL's Proposed

Tarrone Power Station, Vic

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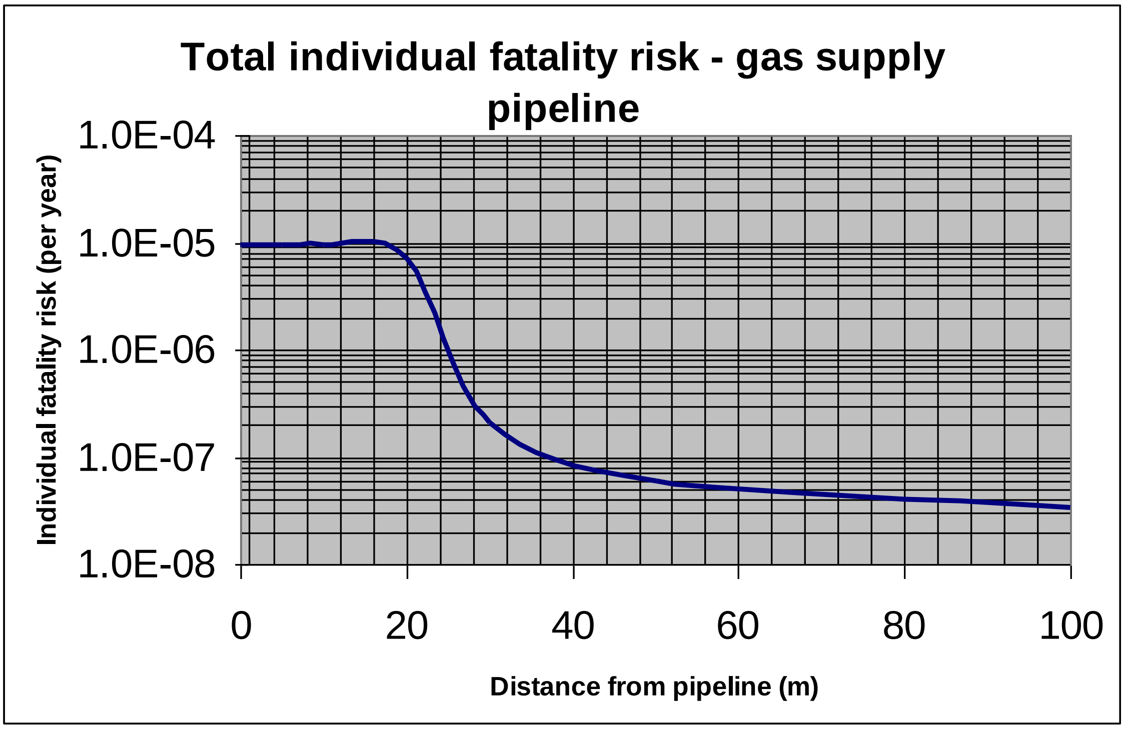
Appendix 2 - Release Scenarios and Frequency / Probability Calculations.

A. Lateral Gas Supply Pipeline

FREQUENCY ASSESSMENT				
Steel Pipe				
Leak size (m)	**Frequency of failure (per km per year)**	**Probability of failure of slam shut/emergency isolation valve [-]**	**Probability of ignition**	**Freq. of flammable outcome (per km per year)**
<20mm	2.30E-04	1.00E+00	0.2	4.60E-05
20 to 100 mm	3.00E-05	5.00E-02	0.32	4.80E-07
>100 mm	9.00E-06	5.00E-02	0.37	1.67E-07
Reference:	US Dept of Transportation Office of Pipeline Safety		FP Lees (*Loss Prevention in the Process Industries*)	

Mass in Flammable cloud (tonnes)	**Probability of flash fire if ignited [-]**	**Freq. of flash fire (per km per year)**	**Freq. of jet fire (per km/yr)**
1.83E+00	1.65E-02	7.58E-07	4.52E-05
2.93E+01	2.64E-01	1.27E-07	3.53E-07
4.69E+02	4.22E+00	1.67E-07	0.00E+00
Hazard Analysis Course Notes, Risk Management Group, SHE Pacific, 1999	Tweeddale, *Managing Risks and Reliability in Process Plants: P(exp) = 0.9M, with = ass cloud in tonnes [%]*	*Prob explosion = Pign x 0.9M (in tonnes)*	

RISK ASSESSMENT GAS SUPPLY PIPELINE UPSTREAM OF REGULATOR									
	Frequency (per metre per year)								
	Jet fire	Flash fire	Explosion						
<20mm	4.52E-08	7.58E-10	0						
20 to 100 mm	3.53E-10	1.27E-10	0						
>100 mm	0.00E+00	1.67E-10	0						
Risk of fatality from jet fires (per m per yr)		Note: The calculation uses the distance from the source of the release (not the centre of the flame)							
		5 m	**10 m**	**20 m**	**30 m**	**50 m**	**100 m**	**200 m**	**300 m**
<20mm		4.52E-08	4.52E-08	4.52E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20 to 100 mm		3.53E-10	3.53E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>100 mm		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Risk of fatality from flash fires (per m per yr)									
		5 m	**10 m**	**20 m**	**30 m**	**50 m**	**100 m**	**200 m**	**300 m**
<20mm		7.58E-10	7.58E-10	7.58E-10	7.58E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20 to 100 mm		1.27E-10	1.27E-10	1.27E-10	1.27E-10	1.27E-10	0.00E+00	0.00E+00	0.00E+00
>100 mm		1.67E-10	1.67E-10	1.67E-10	1.67E-10	1.67E-10	1.67E-10	1.67E-10	0.00E+00
Risk of fatality from explosions (per m per yr)									
		5 m	**10 m**	**20 m**	**30 m**	**50 m**	**100 m**	**200 m**	**300 m**
<20mm		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20 to 100 mm		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>100 mm		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total fatality (per m per yr)									
		5 m	**10 m**	**20 m**	**30 m**	**50 m**	**100 m**	**200 m**	**300 m**
<20mm		4.6E-08	4.6E-08	4.6E-08	7.6E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00
20 to 100 mm		4.8E-10	4.8E-10	1.3E-10	1.3E-10	1.3E-10	0.0E+00	0.0E+00	0.0E+00
>100 mm		1.7E-10	1.7E-10	1.7E-10	1.7E-10	1.7E-10	1.7E-10	1.7E-10	0.0E+00
Total risk of fatality (per metre per year)		**4.7E-08**	**4.7E-08**	**4.6E-08**	**1.1E-09**	**2.9E-10**	**1.7E-10**	**1.7E-10**	**0.0E+00**
not taking into account any overlapping effect									
Divide pipeline into segments of 200 metres each.									
In this particular case there is almost no overlapping of the effect zones, so no adjustment needs to be made for overlapping effect zones.									
Total risk of fatality (per pipeline effect zone)		**9.3E-06**	**9.3E-06**	**9.3E-06**	**2.1E-07**	**5.9E-08**	**3.3E-08**	**3.3E-08**	**0.0E+00**



B. Power Plant

EQUIP.	EAST	NORTH	TYPE	LENGTH metres	#JOINTS	TRIP	LEAK FREQ. /yr	FLASH FIRE FREQ. /yr	GAS PRES. Pa	DIAM ORIF. Metres	MW (megawatts)	TNT 4%
BATREG	50	0	PI	100	20	NO	9.00E-04	1.80E-04	1.20E+07	3.00E-03	1.10E+00	4.78E-01
BATREG	50	0	PI	100	20	NO	3.00E-04	6.00E-05	1.20E+07	1.30E-02	2.06E+01	8.97E+00
BATREG	50	0	PI	100	20	YES	1.50E-06	3.00E-07	1.20E+07	5.00E-02	3.05E+02	1.33E+02
BATREG	50	0	PI	100	20	YES	5.00E-07	1.00E-07	1.20E+07	4.00E-01	1.95E+04	8.49E+03
BATREG	50	0	PI	100	20	NO	1.00E-04	2.00E-05	1.20E+07	1.30E-02	2.06E+01	8.97E+00
REGTU1A	95	70	PI	70	10	NO	2.25E-05	4.50E-06	3.44E+06	3.00E-03	3.15E-01	1.37E-01
REGTU1A	95	70	PI	70	10	NO	5.25E-05	1.05E-05	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU1A	95	70	PI	70	10	YES	2.63E-07	5.25E-08	3.44E+06	5.00E-02	8.76E+01	3.81E+01
REGTU1A	95	70	PI	70	10	YES	8.75E-08	1.75E-08	3.44E+06	4.00E-01	7.09E+03	3.08E+03
REGTU1A	95	70	PI	70	10	NO	7.50E-06	1.50E-06	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU1B	95	140	PI	70	0	NO	0.00E+00	0.00E+00	3.44E+06	3.00E-03	3.15E-01	1.37E-01
REGTU1B	95	140	PI	70	0	NO	5.25E-05	1.05E-05	3.44E+06	1.30E-02	5.92E+00	2.57E+00

EQUIP.	EAST	NORTH	TYPE	LENGTH metres	#JOINTS	TRIP	LEAK FREQ. /yr	FLASH FIRE FREQ. /yr	GAS PRES. Pa	DIAM ORIF. Metres	MW (megawatts)	TNT 4%
REGTU1B	95	140	PI	70	0	YES	3.71E-11	7.42E-12	3.44E+06	5.00E-02	8.76E+01	3.81E+01
REGTU1B	95	140	PI	70	0	YES	1.24E-11	2.47E-12	3.44E+06	4.00E-01	7.09E+03	3.08E+03
REGTU1B	95	140	PI	70	0	NO	0.00E+00	0.00E+00	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU1C	25	210	PI	70	0	NO	0.00E+00	0.00E+00	3.44E+06	3.00E-03	3.15E-01	1.37E-01
REGTU1C	25	210	PI	70	0	NO	5.25E-05	1.05E-05	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU1C	25	210	PI	70	0	YES	3.71E-11	7.42E-12	3.44E+06	5.00E-02	8.76E+01	3.81E+01
REGTU1C	25	210	PI	70	0	YES	1.24E-11	2.47E-12	3.44E+06	4.00E-01	7.09E+03	3.08E+03
REGTU1C	25	210	PI	70	0	NO	0.00E+00	0.00E+00	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU1D	50	280	PI	70	4	NO	9.00E-06	1.80E-06	3.44E+06	3.00E-03	3.15E-01	1.37E-01
REGTU1D	50	280	PI	70	4	NO	5.25E-05	1.05E-05	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU1D	50	280	PI	70	4	YES	3.71E-11	7.42E-12	3.44E+06	5.00E-02	8.76E+01	3.81E+01
REGTU1D	50	280	PI	70	4	YES	1.24E-11	2.47E-12	3.44E+06	4.00E-01	7.09E+03	3.08E+03
REGTU1D	50	280	PI	70	4	NO	3.00E-06	6.00E-07	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU2	95	305	PI	50	4	NO	3.60E-05	7.20E-06	3.44E+06	3.00E-03	3.15E-	1.37E-

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EQUIP.	EAST	NORTH	TYPE	LENGTH metres	#JOINTS	TRIP	LEAK FREQ. /yr	FLASH FIRE FREQ. /yr	GAS PRES. Pa	DIAM ORIF. Metres	MW (megawatts)	TNT 4%
											01	01
REGTU2	95	305	PI	50	4	NO	1.50E-04	3.00E-05	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU2	95	305	PI	50	4	YES	1.06E-10	2.12E-11	3.44E+06	5.00E-02	8.76E+01	3.81E+01
REGTU2	95	305	PI	50	4	YES	3.53E-11	7.07E-12	3.44E+06	4.00E-01	7.09E+03	3.08E+03
REGTU2	95	305	PI	50	4	NO	1.20E-05	2.40E-06	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU3	95	355	PI	50	4	NO	3.60E-05	7.20E-06	3.44E+06	3.00E-03	3.15E-01	1.37E-01
REGTU3	95	355	PI	50	4	NO	1.50E-04	3.00E-05	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU3	95	355	PI	50	4	YES	1.06E-10	2.12E-11	3.44E+06	5.00E-02	8.76E+01	3.81E+01
REGTU3	95	355	PI	50	4	YES	3.53E-11	7.07E-12	3.44E+06	4.00E-01	7.09E+03	3.08E+03
REGTU3	95	355	PI	50	4	NO	1.20E-05	2.40E-06	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU4	25	405	PI	50	4	NO	3.60E-05	7.20E-06	3.44E+06	3.00E-03	3.15E-01	1.37E-01
REGTU4	25	405	PI	50	4	NO	1.50E-04	3.00E-05	3.44E+06	1.30E-02	5.92E+00	2.57E+00
REGTU4	25	405	PI	50	4	YES	1.06E-10	2.12E-11	3.44E+06	5.00E-02	8.76E+01	3.81E+01
REGTU4	25	405	PI	50	4	YES	3.53E-11	7.07E-12	3.44E+06	4.00E-01	7.09E+03	3.08E+03

EQUIP.	EAST	NORTH	TYPE	LENGTH metres	#JOINTS	TRIP	LEAK FREQ. /yr	FLASH FIRE FREQ. /yr	GAS PRES. Pa	DIAM ORIF. Metres	MW (megawatts)	TNT 4%
REGTU4	25	405	PI	50	4	NO	1.20E-05	2.40E-06	3.44E+06	1.30E-02	5.92E+00	2.57E+00

BATREG	Line from battery limit to the pressure regulator
REGTU1A	Line from pressure regulator to the gas turbine 1
REGTU1B	Line from pressure regulator to the gas turbine 1
REGTU1C	Line from pressure regulator to the gas turbine 1
REGTU1D	Line from pressure regulator to the gas turbine 1
REGTU2	Line from gas turbine 1 to gas turbine 2
REGTU3	Line from gas turbine 2 to gas turbine 3
REGTU4	Line from gas turbine 3 to gas turbine 4

C. Inside Turbine Housing – Calculation Sheet

Number flanges	2.00E+02	
Number flexible joints	9.00E+01	model as flanges
Total	2.90E+02	
Frequency of leak per flange	5.00E-06	per flange / joint
Leaks per enclosure	1.45E-03	
Probability of failure of fan, allowing accumulation of gas	1.00E-01	conservative
Failure to detect leak, each detector	5.00E-02	SIL4
Number of detectors	2.00E+00	
Common mode failure, gas detectors	2.50E-03	
Probability of ignition	1.00E-01	
Frequency if igniton (per enclosure)	7.25E-08	t/yr
Number of enclosures	4.00E+00	
Total frequency of ignition on site	2.90E-07	
Probability of explosion if igniton	1.00E+00	
Frequency of explosion inside one of the turbine enclosures	**2.90E-07**	**t/yr**

Appendix 3

QRA Assumptions

Preliminary Hazard Analysis of AGL's Proposed

Tarrone Power Station, Vic

Appendix 3 – QRA Assumptions

The assumptions made in this QRA are listed below. These are critical for the results of this QRA. Should the final design and operation of the Power Station and associated lateral gas supply pipeline differ substantially from these assumptions then the results of this QRA may not be valid.

Item / Subject Matter	Assumption
Safety Management System	In this study it is assumed that the generic failure frequencies used apply to installations which have safety software corresponding to accepted industry practice and that this site has similar management practices and systems. This assumption it is believed, will be conservative in that it will overstate the risk from well managed installations.
Gas rate through lateral gas supply pipeline	180 tonnes per hour or less
Operating conditions and design of Power Station	The Power Station will operate in open cycle mode during times of peak electricity demand which is estimated to be less than 10% of the time. Up to four operational gas turbines on site. Gas reduced to (up to) 3.4MPa for use in Power Station. Power Station conditions monitored 24hr/24 via SCADA. The gas receiving station will include a remote operated isolation valve, together with a non return valve, a pressure control valve and a remotely controlled slam shut off valve (or other type of emergency isolation valve). Length of pipe 10 metres upstream of the pressure regulator and 500 metres downstream of the pressure regulator, stretching from the gas receiving station through to each turbine. Onsite pipe diameter: 450mm.

Item / Subject Matter	Assumption
Operating conditions and design of lateral gas supply pipeline	Operational pressure up to 12MPa up to gas receiving station. Pipeline diameter 400mm. Pipeline minimum wall thickness: 12.7mm. Lateral pipeline conditions monitored 24hr/24 via SCADA. Compliant with AS2885.1-3. 8 or 10 kilometres depending on the option chosen. Welded connections wherever possible. Minimum number of flanges. Valve station at SEA Gas pipeline off-take point (with remote controlled slam shut/emergency isolation valve).
Remote operated valves	At least the following remote operated valves are assumed to be included: one at the valve station at the SEA Gas pipeline off-take; one at the entrance to the Power Station. The final design will determine if the valve at the SEA Gas pipeline is automatic or manual. If it are to be manually operated only then it's rapid closure in case of a major leak at gas pipeline needs to be assured at all times. The valve at the entrance to the site (at the metering station) has been assumed to close automatically in the case of a major failure (exceeding 50mm diameter hole in the pipe). This is necessary to allow the 0.1 pmpy risk contour to remain within the site boundary. Further details refer to Section 4.4.
Operation of site	Site will be monitored using a SCADA system. The operator will be able to open and close valves and control the flow rate through the pipelines on site and in the lateral pipeline.

Item / Subject Matter	Assumption
Types of chemicals on-site	Small quantities of combustibles, as follows: Turbine oils (combustible oil) : 1,000 L in small IBC; Insulating oil (non PCB): 1,000 L in small IBC; Oil for fire pump: 600 L in small IBC; Small quantities of chemicals used in cooling systems loop: Scale inhibitor : 100 L Betz Foam-Trol: 100 L Small quantities of chemicals used for maintenance: Carbon dioxide Nitrogen Acetone
Preventative and protective features in place (on-site and lateral pipeline)	Preventative maintenance of rotating machines.; Vibration monitoring; Shut down of machine and repair if out of alignment Subsidence issues are taken into account through design. Structures and plant are designed to withstand earthquake effects using well-established procedures in accordance with relevant Australian or international standards Topography prevents flooding from any rivers or streams. All welds are x-rayed (100%). A detailed Hazard and Operability study will be carried out covering at least the natural gas transport and handing at the lateral pipeline and the Power Station. Monitoring requirements of the lateral pipeline to be established and to comprise patrolling and regular monitoring of cathodic protection. The turbine housings, electrical rooms and control rooms will contain fire suppressants, such as carbon dioxide or other fire quenching material.

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