Queensland Hunter
Gas Pipeline

Appendix J

Hazards and risks assessment

QUEENSLAND-HUNTER GAS PIPELINE

PRELIMINARY RISK ASSESSMENT

AS2885 RISK ASSESSMENT

MANIDIS ROBERTS

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CONTENTS

TABLES

FIGURES

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ABBREVIATIONS

AC	Alternating Current
ALARP	As Low as Reasonably Practicable
ALB	Automatic Line Break
API	American Petroleum Institute
AS	Australian Standard
CP	Cathodic protection
DC	Direct Current
DOC	Depth of Cover
DoP	NSW Department of Planning
EA	Environmental Assessment
ESAA	Energy Supply Association of Australia
HDD	Horizontal Directional Drill
HIPAP	Hazardous Industry Planning Advisory Paper
Kg/s	Kilograms per second
km	Kilometre
MAOP	Maximum Allowable Operating Pressure
MLV	Main Line Valve
mm	Millimetre
MPa(g)	Megapascal (gauge)
OH&S	Occupational Health and Safety
PRCI	Pipeline Research Council International
QHGP	Queensland-Hunter Gas Pipeline
QRA	Quantitative Risk Assessment
SCC	Stress Corrosion Cracking
SMP	Safety Management Plan
TSR	Travelling Stock Route
VCE	Vapour Cloud Explosion
WT	Wall Thickness

1. SUMMARY

1.1. General

The Hunter Gas Pipeline Pty Ltd (Hunter Gas) is proposing to construct the Queensland Hunter Gas Pipeline (QHGP) from Wallumbilla in Queensland to Newcastle, NSW. Natural gas will be sourced from coal seams in the Surat-Bowen basins fields and distributed through the Wallumbilla gas hub near Roma, Queensland. The pipeline will be approximately 825km long. Manidis Roberts were commissioned by Hunter Energy to prepare the environmental assessment for the project.

Manidis Roberts has commissioned Sherpa Consulting Pty Ltd (Sherpa) to undertake a preliminary risk assessment for the project. The analysis includes a qualitative risk assessment in accordance with AS2885-2007 (Ref. 1) and a quantitative assessment of the risk associated with the pipeline in accordance with the NSW Hazardous Industry Planning Advisory Paper (HIPAP) No. 6, 'Guidelines for Hazard Analysis' (Ref. 2) and HIPAP No. 4, 'Risk Criteria for Land Use Safety Planning' (Ref. 3).

1.2. AS2885 Risk Assessment Results

Based on the preliminary design details, potential threats to the pipeline were identified and qualitatively assessed using the guidelines of AS2885.1-2007. The hazard identification table is given in Table A2.1 of Appendix 2. There were no 'extreme' or 'high' level risk incidents identified. Additional risk reduction measures have been identified for 'intermediate' risk events but the mitigated risk levels incorporating these measures have not been assessed. It is recommended that the additional risk reduction measures be assessed by the pipeline designer during the detailed design stage for adequacy and suitability and the relevant measures incorporated into the final risk assessment.

A total of 54 incidents were identified in the hazard identification. The assessed risk levels for these were:

- No 'extreme' or 'high' risk level incidents
- 10 'intermediate' risk level incidents
- 33 'low' level risk incidents
- 11 'negligible' level risk incidents

Risk reduction measures should be implemented to reduce the 'intermediate' level risk events to 'As Low As Reasonably Practicable' (ALARP).

Once the design and operating procedures are finalised, all identified hazards should be reassessed, incorporating the relevant additional risk reduction measures.

1.2.1. AS2885 Risk Assessment Recommendations

Risk reduction measures should be put in place to reduce the risk of 'intermediate' risks to the ALARP level. The following recommendations have been made to ensure that the proposed design meets this requirement.

1. Scenarios assessed as being of a 'intermediate' risk in this preliminary assessment must be reviewed by the pipeline designer to establish what additional risk measures are suitable for these events. This review should consider the suggested risk reduction measures identified in the hazard identification table, in addition to other risk measures that may be identified during the detailed design stage.
2. The actions identified in Table A2.1 of Appendix 2 for 'low' risk events should be implemented in line with the ALARP principle to reduce the risk even further.
3. A detailed AS2885 risk assessment should be prepared during the detailed design, identifying location specific threats and proposed safeguards.
4. The proposed pipeline design should be assessed against the Pipeline Research Council International (PRCI) protocol for the assessment of likelihood of Stress Corrosion Cracking.

1.3. QRA Results

Risk transects showing the individual risk of fatality versus the distance from the centreline of the pipe were produced for a number of cases depending on the safeguards proposed (depth of cover, concrete capping).

The distances to the relevant risk criteria levels for each sensitivity case are summarised in Table 1.1.

Table 1.1 provides information to allow the pipeline designers to provide an appropriate level of safeguards to meet the HIPAP No. 4 risk criteria, taking into account the surrounding land uses at any particular location. If the separation distances to surrounding land uses in Table 1.1 can be achieved, then the risk from the pipeline will be within the ALARP range.

1.4. Recommendations Arising from QRA Results

The following recommendations are made as a result of the QRA:

1. The pipeline designers should use the distances summarised in Table 1.1 to determine an appropriate level of safeguards when finalising the pipeline route to ensure that the risk levels meets the HIPAP No. 4 risk criteria.
2. The QRA should be updated following the guidelines of HIPAP No.4 when details of the design and location of aboveground station are finalised.

TABLE 1.1: SUMMARY OF PIPELINE RISK ASSESSMENT RESULTS

Sensitivity Case	Distance to Individual Risk of Fatality (m)				
	0.5 x 10^{-6} per year (sensitive land use)	**1 x 10^{-6} per year (residential)**	**5 x 10^{-6} per year (commercial)**	**10 x 10^{-6} per year (Active Open Space)**	**50 x 10^{-6} per year (Industrial)**
Case 1 (Base Case, 750mm DOC)	140	105	Not Reached	Not Reached	Not Reached
Case 2 - 900mm DOC	132	103	Not Reached	Not Reached	Not Reached
Case 3 - 120mm DOC	121	92	Not Reached	Not Reached	Not Reached
Case 4 - marker tape, 750mm DOC	116	80	Not Reached	Not Reached	Not Reached
Case 5 - marker tape, 900mm DOC	112	60	Not Reached	Not Reached	Not Reached
Case 6 - marker tape, 1200mm DOC	106	35	Not Reached	Not Reached	Not Reached
Case 7 - marker tape, 1400mm DOC	104	17	Not Reached	Not Reached	Not Reached
Case 8 - marker tape, 900mm DOC, concrete capping	45	Not reached	Not Reached	Not Reached	Not Reached
Case 9 - marker tape, 1200mm DOC, concrete capping	35	Not reached	Not Reached	Not Reached	Not Reached
Case 10 - marker tape, 1400mm DOC, concrete capping	30	Not reached	Not Reached	Not Reached	Not Reached

2. INTRODUCTION

2.1. Background

The Hunter Gas Pipeline Pty Ltd (Hunter Gas) is proposing to construct the Queensland Hunter Gas Pipeline (QHGP) from Wallumbilla in Queensland to Newcastle, NSW. Natural gas will be sourced from coal seams in the Surat-Bowen basins fields and distributed through the Wallumbilla gas hub near Roma, Queensland. The pipeline will be approximately 825km long. Manidis Roberts were commissioned by Hunter Energy to prepare the environmental assessment for the project.

Manidis Roberts has commissioned Sherpa Consulting Pty Ltd (Sherpa) to undertake a preliminary risk assessment. The assessment includes a qualitative risk assessment in accordance with AS2885-2007 (Ref. 1) and a quantitatively assessment of the risk associated with the pipeline in accordance with the NSW Hazardous Industry Planning Advisory Paper (HIPAP) No. 6, 'Guidelines for Hazard Analysis' (Ref. 2) and HIPAP No. 4, 'Risk Criteria for Land Use Safety Planning' (Ref. 3).

The design of the pipeline has not yet been finalised but a preliminary pipeline route has been identified. A detailed design of pipeline stations has also not been undertaken. Therefore, only a preliminary risk assessment was carried out, based on this preliminary design. This risk assessment should be updated and finalised once the detailed design is available.

A previous version of this report (Ref. 4) was prepared and submitted for inclusion with the documentation submitted for approval. The government departments' review of the application raised concerns, requiring additional route and design information.

A preliminary environmental assessment (Ref. 5) was prepared by Manidis Roberts and submitted to the NSW Department of Planning (DoP) in November 2007. Manidis Roberts is preparing the Environmental Assessment, including additional route and design details for the project. An update to the preliminary risk assessment is to be included, taking into account revised pipeline design and to take account of the 2007 update to AS2885.

This report is the updated preliminary risk assessment and summarises the objectives, scope of work, methodology and results of the assessment.

2.2. Objectives of the AS2885 Risk Assessment

The high level objective of the study is to ensure that the design of the proposed pipeline incorporates adequate safety measures and minimises the risk of pipeline incidents during its operation.

The low level objectives of the study are to:

- Identify threats to the pipeline which could result in safety, environmental and supply impact.

- Assess whether the proposed physical and procedural operational measures are adequate to mitigate the identified pipeline threats.
- Identify, where required, additional safeguards to further minimise the risk to personnel, people and property.
- Prepare a report summarising the preliminary risk assessment and findings in a form suitable for use by the client and the regulatory authorities.

2.3. Objectives of the Quantitative Risk Assessment

The objectives of the QRA are to undertake a Quantitative Risk Assessment of the QHGP to meet the criteria of the NSW DoP Hazardous Industry Planning Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning'.

2.4. Scope

The scope of the study is the proposed high pressure gas pipeline from Wallumbilla, Queensland to Newcastle , NSW. The scope includes a preliminary risk assessment and was limited to the preliminary pipeline design and route selection. Details of the pipeline main line valve stations were not available and have not been assessed for the current report.

The scope of the preliminary risk assessment incorporated the design, construction, commissioning and operation stages of the proposed pipeline.

3. DESCRIPTION OF THE PROPOSED PIPELINE

3.1. Overview

The Hunter Gas Pipeline Pty Ltd (Hunter Gas) is proposing to construct the Queensland Hunter Gas Pipeline (QHGP) from Wallumbilla in Queensland to Newcastle, NSW. Natural gas will be sourced from coal seams in the Surat-Bowen basins fields and distributed through the Wallumbilla gas hub near Roma, Queensland.

The pipeline route will be about 825km long, with about 220km of pipeline within Queensland. The pipeline will provide an additional natural gas supply to the Newcastle and Hunter regions, with potential users including industrial and power generation industries. Future developments may include additional offtakes to local customers and additional coal seam gas sources located near the pipeline route.

Included in the current proposed pipeline route is a lateral pipeline from an offtake near the northern outskirts of Maitland to a proposed industrial facility (a tile factory) located near the industrial areas west of Maitland.

The NSW section of the pipeline is being assessed by the Department of Planning under Part 3A of the *Environmental Planning and Assessment Act 1979*. A preliminary environmental assessment (Ref. 5) was prepared by Manidis Roberts and was submitted to the Department of Planning in November 2007.

The Queensland section of the pipeline was approved separately and a pipeline licence has been granted.

3.2. Pipeline Route

The following sections describe the proposed route for the main pipeline and the offtake at Maitland.

3.2.1. Main Pipeline Route

The pipeline route commences at the gas hub Wallumbilla, Queensland and proceeds to the Queensland/NSW border near Boomi, and continues in a south-easterly direction to Newcastle.

For the NSW section of the pipeline route, the pipeline passes the following major towns:

- Boomi
- Moree
- Narrabri
- Boggabri
- Gunnedah
- Quirindi

- Murrurundi
- Scone
- Muswellbrook
- Singleton
- Maitland

Figure 3.1 shows the preliminary pipeline route for the QHGP. Initially, the gas will be delivered via the pipeline to the Hunter Region for power generation and industry usage.

Gas for the Queensland Hunter Gas Pipeline will initially be extracted from Surat and Bowen basins in Queensland. The proposed pipeline will also enable the potential to source future natural gas from emerging coal seam gas reserves in regional NSW.

3.2.2. Lateral Pipeline

A small lateral (around 10.5km in length) will also extend from the main corridor to the Maitland area.

3.3. Pipeline Design

The proposed pipeline design parameters relevant to the risk assessment are given in Table 3.1.

TABLE 3.1: PIPELINE DESIGN DETAILS

Parameter	Main Pipeline	Lateral Pipeline
Length	825km	10.5km
Nominal Diameter	500mm	300mm
Wall thickness	12.7mm minimum for Rural Areas (Design Factor of 0.72)	Unspecified
Pipeline Specification	API5L-X65 or X70	Unspecified
Depth of Cover (DOC)	General – 750mm Deep cultivated areas – 1200mm Road/ Rail crossings – 1200-2000mm Watercourse crossings – 1200-2000mm	
MAOP	15.3 MPa	15.3 MPa

FIGURE 3.1: PIPELINE ROUTE

3.4. Pipeline Facilities

Details of pipeline facilities (delivery and offtake stations, main line valve stations, etc) have not been prepared yet, however the following typical pipeline station will be provided as required for the project:

- Mainline valves (MLVs) located at regular intervals, as per AS2885.1-2007, to allow isolation of the pipeline. Mainline valve stations will be provided with remote operation capability, as well as local manual operation. The Main Line Valve stations will be provided with Automatic Line Break (ALB) facilities which will, on detection of a pipeline break in a particular section of pipeline, initiate shutdown of the upstream and downstream valves. The pipeline and stations will be remotely monitored from a manned control centre.
- Scraper stations spaced at intervals of 100-150km for launching and retrieving 'pigs' which are used to clear and dewater the pipeline following construction and hydrostatic testing. 'Intelligent' pigs are periodically launched through the pipeline to monitor the pipewall for corrosion.
- Meter stations are generally provided at the offtake connection at the pipeline inlet and at the end of the pipeline, as well as any offtakes on the pipeline.

3.5. Review of Pipeline Route

A high level review of aerial photography for the proposed route was undertaken to identify significant features along the pipeline route, which may have a potential impact, either as a potential pipeline threat (such as a road crossing) or as a potential safety exposure (e.g. a dwelling). The major features identified from this preliminary review are summarised in Table 3.2 for the main pipeline and Table 3.3 for the lateral pipeline. A more detailed review of the route should be undertaken when the route is finalised.

3.5.1. Road Crossings

There are a large number of road crossings along the proposed pipeline route, ranging from local dirt roads and access tracks to major highway crossings. Major road crossings will be undertaken by boring or horizontal directional drilling to minimise impact on local traffic. Road crossings also result in an increased risk of third party impact resulting from construction activity near the pipeline for road and services maintenance. AS2885.1-2007 has specific requirements for safeguards at pipelines crossing and running within road reserves, including pipeline markers, minimum depth of cover under road surface and road drains

3.5.2. Rail Crossings

As for major road crossings, rail crossings would be undertaken by boring or horizontal directional drilling. As for road crossings, AS2885.1-2007 has specific requirements for safeguards at pipelines crossing and running within rail reserves, including pipeline markers, minimum depth of cover under rail surface and drains. There are also a large number of rail crossings with the following significant crossings identified from a review of the pipeline route:

- Three rail crossings near Moree
- Two rail crossings near Breeza

- Two rail crossings near Ardglen
- Railway crossing halfway between Ardglen and Murrurundi
- Railway crossing west of Murrurundi
- Railway crossing south of Scone
- Rail crossing east of Maitland
- Lateral crossing railway, west of Maitland

3.5.3. River Crossings

There are a large number of watercourse crossings, ranging from intermittent creeks to major rivers, such as the Hunter. The pipeline construction method required for each watercourse crossing will depend on the nature of each crossing. The crossing construction methods proposed may range from open trenching for dry creek beds, creek diversions to horizontal directional drilling for major river crossings. The following crossings of the Hunter River were identified:

- Three Hunter River crossings north of Maitland
- Hunter River crossing, Morpeth
- Two Hunter River crossings, Tomago
- Lateral pipeline crossing, north-west of Maitland

TABLE 3.2: MAJOR FEATURES NEAR MAIN PIPELINE

Feature	Location	Co-ordinates		Distance From Pipeline	Comments
		Lat.	Long		
Farm Buildings	North of Boomi	28°37'5.97"S	149°34'1.87"E	122m	
Narrabri Airfield	East of Narrabri	30°18'59.10"S	149°49'29.06"E	400m	
Pullaming Stock Route	North of Breeza	31° 8'50.40"S	150°24'5.97"E	150m	
Farm Buildings	North West of Quirindi	31°28'5.89"S	150°37'0.38"E	40m from house	
Farm Buildings	Willow Tree	31°38'27.97"S	150°42'51.51"E	28m from house	
Farm Buildings	Willow Tree	31°38'40.51"S	150°42'51.89"E	3m from house	Not clear which buildings are houses or sheds
Wilson Memorial Hospital	Murrurundi	31°46'14.40"S	150°50'30.83"E	360m	
Farm buildings	West of Scone	32° 3'3.33"S	150°48'57.47"E	2m	Not clear if houses or shed
Muswellbrook No. 2 Open Cut Coal Mine	North-east of Muswellbrook	32°14'10.90"S	150°57'3.17"E	370m	
Mt Owen Open Cut Coal Mine	East of Liddell	32°22'38.34"S	151°6'59.88"E	4km	
Mt Pleasant Public School		32°24'29.67"S	151°11'16.19"E	1.2km	
Take off for lateral pipeline	North of Maitland	32°40'15.01"S	151°32'19.70"E	-	
Industrial Estates	Tomago	32°49'19.52"S	151°42'41.21"E	130m	
Kooragang Coal Terminal	Kooragang Island	32°52'38.57"S	151°45'57.07"E	40m	

TABLE 3.3: MAJOR FEATURES NEAR LATERAL PIPELINE

Feature	Location	Co-ordinates		Distance From Pipeline	Comments
		Lat.	Long		
Housing	North of Maitland	32°40'51.98"S	151°31'40.88"E	80-100m	
Housing (Resort) Melville Ford Road Maitland	Melville Ford Road, north-west of Maitland	32°41'13.62"S	151°31'3.40"E	100m	Large house, may be hotel or resort
Housing	West of Maitland	32°41'42.85"S	151°30'13.63"E	75m	
Maitland Airfield	West of Maitland	32°42'19.27"S	151°29'26.00"E	130m	

4. METHODOLOGY

4.1. Overview

The objective of the AS2885 assessment is to identify hazardous incidents that could affect the pipeline, resulting in a safety impact to people, loss of supply or affecting the environment. The previous risk assessment report (Ref. 4) was prepared with the previous version of AS2885.1-1997 (as amended in 2001). The current version of the standard, AS2885.1-2007 (Ref. 1) has undergone a major revision, including a revised risk assessment approach. AS2885.1-2007 provides guidelines for assessing the risk of potential hazardous incidents, either external or from the pipeline itself. This report update was prepared following the guidelines of the 2007 version of the standard.

The new revision of AS2885 requires consideration of potential design aspects and operating procedures to minimise the impact of potential hazardous incidents. The safety management process given in AS2885 provides guidelines to ensure that the following two key outcomes are achieved:

- Identification of potential threats to the pipeline to enable the pipeline designers and operators to clearly understand the nature of the hazards which could result from pipeline operation
- Development of an risk management plan to ensure appropriate risk treatment (both in terms of pipeline design and operational safeguards, i.e. both physical and procedural safeguards).

The risk assessment criteria given in AS2885.1-2007 have been revised to be consistent with the guidelines of AS4360 (Ref. 6).

4.2. AS 2885.1 Risk Assessment Methodology

The following tasks were undertaken during the hazard identification process:

- Identification of the hazardous event of interest.
- Identification of the consequences of the hazardous event and the proposed safeguards.
- Qualitative assessment of the severity (the magnitude of the effect) of the hazardous events.
- Qualitative assessment of the frequency (likelihood of occurrence) of the hazardous events.
- Qualitative assessment of the risk using a risk matrix.

The hazards associated with the operation of the pipeline were identified and the risk assessed following the guidelines of AS2885.1-2007. The pipeline safeguards proposed to mitigate the impact of the identified hazards were recorded and taken into account when evaluating the consequences and frequency of the incident. Appendix 1 shows the criteria for severity (consequence) and frequency (likelihood), as well as the risk matrix given in AS2885.1-2007.

From the qualitative assessment of the consequence and frequency of the hazardous event, the risk for each hazardous incident was allocated a risk score (derived from the risk matrix, as follows:

- 'extreme'
- 'high'
- 'intermediate'
- 'low'
- 'negligible'

'Extreme' and 'high' risk events require further risk reduction measures to ensure the risk is reduced to 'intermediate', typically by applying additional physical or operational measures to modify the threat, frequency or consequences.

'Intermediate' risk events require verification of the risk (typically by quantification). Where the risk is confirmed to be 'intermediate', further risk reduction measures are required to reduce the risk to 'low' or 'negligible'. Potential risk reduction measures should follow the 'As Low As Reasonably Practical (ALARP)' principle.

In Table A2.1, additional risk reduction measures were identified in a separate column in the hazard identification table. For each identified threat, the following details were recorded:

- The component or operation considered (design, construction, commissioning or operation).
- The threat (defined in AS2885.1-2007 as, 'any activity or condition that can adversely affect the pipeline, if not adequately controlled.')
- The consequence of the identified threats resulting from the failure.
- The proposed safeguards which will minimise the impact of the identified hazard.
- The severity; frequency and assessed risk levels for the hazard.
- Any recommendations for further risk reduction.

Table A2.1, Appendix 2 also provides for a reassessment of the risks, including the additional safeguards. It is anticipated that the final risk assessment will be updated once final design details are available.

4.2.1. Management of Hazards

AS 2885.1-2007 indicates the actions required to be taken for each risk category, as summarised in Table 4.1. The preliminary risk assessment identified ten events with an 'intermediate' risk level. In line with AS 2885.1, further risk reduction measures have been suggested for these incidents. However, the residual risk, incorporating these risk reduction measures has not been assessed but should be part of the scope for the final risk assessment at the detailed design stage.

TABLE 4.1: RISK TREATMENT ACTIONS

Risk Rank	Required Action
'Extreme'	Modify the threat, the frequency or the consequences so that the risk rank is reduced to 'intermediate' or lower For an in-service pipeline the risk shall be reduced immediately
'High'	Modify the threat, the frequency or the consequences so that the risk rank is reduced to 'intermediate' or lower. For an in-service pipeline the risk shall be reduced as soon as possible, typically within a timescale of not more than a few weeks.
'Intermediate'	Repeat threat identification and risk evaluation processes to verify and, where possible, quantify the risk estimation; determine the accuracy and uncertainty of the estimation. Where the risk rank is confirmed to be 'intermediate', if possible modify the threat, the frequency or the consequence to reduce the risk rank to 'low' or 'negligible' Where the risk rank cannot be reduced to 'low' or 'negligible', action shall be taken to: (a) remove threats, reduce frequencies and/or reduce severity of consequences to the extent practicable (b) demonstrate ALARP For an in-service pipeline, the reduction to 'low' or 'negligible' or demonstration of ALARP shall be completed as soon as possible, typically within a timescale of not more than a few months.
'Low'	Determine the management plan for the threat to prevent occurrence and to monitor changes that could affect the classification.
'Negligible'	Review at the next review interval.

4.3. QRA Methodology

The methodology for undertaking the QRA is as described in the NSW Department of Planning guidelines, HIPAP No. 6, 'Guidelines for Hazard Analysis' and HIPAP No.4. In addition, the level of assessment was determined by use of the advice document 'Multi-level Risk Assessment'. From the criteria set out in this document, the most rigorous, Quantitative Risk Assessment was chosen, referred to as a 'Level 3' assessment.

The hazard analysis process includes the following steps:

- Identification of potential hazardous incidents.
- Analysis of the consequences (magnitude of impact) of incidents
- Analysis of the frequency of possible hazardous incidents
- Assessment of the adequacy of proposed safeguards
- Assessment of the level of risk
- Comparison with risk criteria
- Recommendations for additional risk reduction where the risk levels were assessed to not meet the risk criteria.

The approach taken was to review the range of hazards that could occur and then to identify the significant risks. These were then carried forward for quantitative assessment. Resultant risk levels were compared with the criteria in HIPAP No. 4, summarised in Table 4.2.

TABLE 4.2: RISK CRITERIA FOR LAND USE SAFETY PLANNING (NSW DEPT. PLANNING GUIDELINES)

Land Use	Suggested Criteria (Fatality risk in a Million Per Year)
Sensitive developments (hospitals, schools, child care facilities, aged care housing)	0.5
Residential areas	1
Commercial areas (offices, retail centres, showrooms, restaurants etc)	5
Sporting complexes and active open spaces	10
Industrial facilities (reached at boundary)	50

5. HAZARD IDENTIFICATION

5.1. AS2885 Risk Assessment Results

Based on the preliminary design details, potential threats to the pipeline were identified and qualitatively assessed using the guidelines of AS2885.1-2007 (Ref. 1). The hazard identification table is given in Table A2.1 of Appendix 2. There were no ‘extreme’ or ‘high’ level risk incidents identified. Additional risk reduction measures have been identified for ‘intermediate’ risk events but the mitigated risk levels incorporating these measures have not been assessed. It is recommended that the additional risk reduction measures be assessed by the pipeline designer during the detailed design stage for adequacy and suitability and the relevant measures incorporated into the final risk assessment.

A total of 54 incidents were identified in the hazard identification. The assessed risk levels for these were:

- No ‘extreme’ or ‘high’ risk level incidents
- 10 ‘intermediate’ risk level incidents
- 33 ‘low’ level risk incidents
- 11 ‘negligible’ level risk incidents

Section 5.2 discusses the ‘intermediate’ risk events resulting from gas pipeline failures. Table 5.1 summarises the number of incidents for each stage of the pipeline project life.

TABLE 5.1: AS2885 RISK ASSESSMENT RESULTS

Project Stage	Number of Incidents					
	‘Extreme’	‘High’	‘Intermediate’	‘Low’	‘Negligible	Total
Design – General Locations	-	-	-	-	3	3
Construction – General Locations	-	-	2	7	-	9
Construction – Location Specific	-	-	4	13	1	18
Commissioning	-	-	-	1	-	1
Operational – General Locations	-	-	2	5	3	10
Operational – Location Specific	-	-	2	7	4	13
Total	**-**	**-**	**10**	**33**	**11**	**54**

5.2. Assessment Of 'Intermediate' Risk Events

5.2.1. Construction - Trench Digging (Incident No. 2.1)

Trench collapse during construction activity was identified to be an 'intermediate' risk event. There is an increased potential for this type of incident to occur during wet conditions. In the worst case, this incident could result in a potential fatality. The proposed safeguards identified which would manage the risk of the incident include:

- Development of a Construction Safety Management Plan incorporating safeguards associated with this incident.
- Undertaking an excavation risk assessment as required under NSW OH&S legislation.
- Shoring up of trenching, particularly where required to undertake welds at tie-in points.
- Safe Work Method Statements undertaken before entry to trenches.

As well, there will be little need for personnel to access the trench at most locations as trenching is undertaken remotely by trenching machine and the pipeline is strung out and welded up beside the trench before being remotely lowered by machine. The most likely time where access to the trench will be required is when the pipeline is to be connected to the tie-in points to the existing pipelines at the inlet and delivery stations. At these locations, additional excavation, shoring and alternative access points will be provided where required.

Further risk reduction measures to be considered include:

- Implementation of a competency and certification scheme for supervisors and excavation inspectors.
- Inclusion of criteria for when trenching activities cannot occur, e.g. wet weather or other conditions as determined as a result of a risk assessment.

5.2.2. Construction – Unsafe Work Practices (Incident No. 2.3)

These scenarios describes the type of hazard that may arise during construction activities as a result of equipment failure, inadequate supervision, inadequate procedures, inexperienced or poorly trained staff, etc.

The proposed safeguards for these general incidents are the controlled safe work procedures for the type of construction work undertaken. The proposed risk reduction measures include:

- Specification of safety requirements as part of contractor selection process
- Implementation of a Safety Management Plan (SMP) for construction activities including contractor management
- Audit of worksites and contractor's SMP

- Regular safety audits/inspections of workplaces as part of SMP
- Approval of equipment to be used for construction work
- Competency system implemented for relevant tasks
- Safe Work Method Statements for relevant tasks

Further improvements to the management of the OH&S risk exposures include:

- Regular safety audits (management system and workplace inspections) carried out by independent party
- A risk register and risk minimisation process as part of SMP

5.2.3. Construction – Construction Along Roads (Incident Nos. 3.1 and 3.2)

Impact on members of the public, construction workers, contractor or visitor during construction activity on or near roads was identified as an 'intermediate' risk incident. These incidents could occur due to the proximity of vehicle traffic near construction work. People may be impacted by vehicle incidents or impact could occur as a result of a person being distracted during construction.

Similarly, a member of the public may be impacted by vehicles, construction equipment or falling into the trench while passing the construction site. This incident could result in a potential fatality.

The proposed safeguards identified which would manage the risk of such incidents include:

- Development of a Traffic Management Plan incorporating requirements for traffic management during construction work and after hours
- Access barriers, warning signs at construction areas and access points and/ or separation distances between construction areas and roadways
- Awareness training prior to commencement of construction activity

The risk reduction measures identified to manage this risk include:

- Liaison with local councils and roads authorities to review Traffic Management Plan and proposed construction activities
- Review requirements for single lane operation where required during periods of construction activity.

5.2.4. Construction in Forest, Bushfires (Incident No. 3.3)

This incident has been assessed as 'intermediate'. Construction activity such as welding and grinding activity, vehicle use or personnel smoking could result in bushfires if not controlled. This is especially important during hot days with very high and extreme bush fire danger and could potentially result in a major bushfire.

The proposed safeguards include:

- Restriction and control of all ignition sources
- Fire fighting capabilities, both physical equipment and competent operators
- Minimisation of combustion material in the vicinity
- Equipment maintenance

Further risk reduction of such events includes:

- Liaison with local fire authorities to establish daily fire danger
- Restriction of work activity during high fire danger periods
- Liaison with local fire authorities and review and approval of proposed fire fighting controls

5.2.5. Construction Near Powerlines (Incident No. 3.4)

This incident has been assessed as 'intermediate'. Construction activity such as crane lifts could result in contact or arcing at powerlines if safe clearances are not maintained.

The proposed safeguards include:

- Restriction on the type of equipment allowed on the corridor
- Training and certification of equipment operators

Further risk reduction of such events includes:

- Construction work is to comply with the Energy Supply Association of Australia guidelines for Safe Approach Distance to Electrical Apparatus and/ or WorkCover Code of Practice for Work near Overhead Powerlines, Catalogue No. 1394, 2006
- Hazard to be included in Construction Safety Management Plan
- Liaison with local fire authorities and review and approval of proposed fire fighting controls.

5.2.6. Operation - Third Party Impact (Incident No. 5.2)

This incident has been assessed as 'intermediate'. Construction and farming activity (e.g. fence post digging, deep ploughing, roadworks) could result in damage to the pipeline, potentially leading to a major release and fatality if people are in the area. This is the most common mode of pipeline incidents.

This hazard is one of the key issues for design, construction, operation and maintenance addressed in AS2885.1-2007.

5.2.7. Operation – Seismic Activity (Incident No. 5.3)

This incident has been assessed as an 'intermediate' risk. It is assumed that the Hunter Valley region is a seismic active area, considering earthquakes have struck in the Newcastle area. Although an earthquake rarely results in pipe failures, it is a possible outcome. To better understand the possibility of earthquake in the area and its potential impact, the operator should contact relevant authorities to evaluate this and, consequently, review this risk issue as part of the final risk assessment.

Proposed safeguards include:

- Physical integrity of pipe line (wall thickness, etc.)
- Depth of cover
- Emergency response plan with regular drills

To reduce the impact of this event, appropriate siting of valve stations will be required to meet the requirements of AS2885.1-2007.

5.2.8. Operation - Pipeline Near Mining Leases (Incident No. 6.3)

Mining activity at leases located near the pipeline could result in impact on the pipeline. This could be due to mine subsidence or seismic impact from blasting activity.

The safeguards proposed to be in place include:

- Pipeline route selection to avoid mining leases
- Pipeline integrity (wall thickness, etc.)
- Liaison with local mining companies to establish extent and timing of mining activity near pipeline
- Pipeline surveillance
- Emergency response plan with regular drills

The Mines Subsidence Board has provided the project team with their requirements for the proposed pipeline (Ref. 7). This includes requirements to identify coal resources and old mining areas along the pipeline route, as well as the need to demonstrate the structural integrity of the pipeline is adequate near known subsidence areas.

5.3. Other Issues

5.3.1. Stress Corrosion Cracking (Incident No. 5.5)

Stress corrosion cracking is a phenomenon which can occur in pipelines that are subject to pressure cycles under high operating temperatures and in soil conditions which are conducive to corrosion. If detected, stress corrosion cracking may require pipeline repairs or may require derating of the pipeline. If undetected, stress corrosion cracking may lead to pipeline failure.

The detailed pipeline design will make allowance to minimise the impact of stress corrosion cracking. This will be provided by selecting an appropriate pipeline coating which will minimise the impact of external corrosion and by an appropriate design for the cathodic protection system.

It is recommended that the proposed pipeline design be assessed against the Pipeline Research Council International (PRCI) protocol for the assessment of likelihood of SCC (Ref. 8).

Because of the proposed safeguards and the low likelihood of SCC impact, no increase in the failure rate for stress corrosion cracking was included in the frequency analysis.

5.3.2. Acid Sulphate Soils

Acid sulphate soils occur predominantly in coastal areas where the soils formed underwater and the sea level later receded, leaving behind underground concentrations of iron sulphide rich soil. Acid sulphate soils are typically found in coastal plains, wetlands and mangroves.

When the soils remain in an undisturbed and waterlogged state these soils remain relatively inactive. However, when the soil is excavated and exposed to oxygen through drainage or excavation, sulphuric acid is produced in large quantities. This results in an environmental impact from releases of concentrated acid. During the operational phase of the pipeline, residual acid may result in pipeline corrosion.

The effect of acid sulphate soils is mitigated by appropriate management procedures, including:

- Limited excavation to minimise the length of open trenches and the time exposed in affected areas
- Lime neutralisation
- Spoil management, including segregated storage of acidic spoil stockpiles away from watercourses and appropriate treatment and disposal methods

5.4. Location Specific Hazards

Other hazards specific to the locations where the pipeline crosses include the following:

- Impact from vehicle loading or construction work near road and rail crossings
- AC induction effects from powerlines near the pipeline
- AC corrosion
- Stray currents from high voltage DC traction lines

These issues are commonly encountered in pipeline designs in Australia and there are adequate safeguards to mitigate the hazard. The most significant of these are the impact of AC induction and AC corrosion which is discussed in more detail in the next sections.

5.4.1. Powerline Impacts

The impact of powerlines near gas pipelines is a well known hazard and can give rise to additional hazards to the pipeline and to personnel constructing the pipeline or operating and maintaining equipment.

The potential hazards include:

- During construction of the pipeline, mobile equipment (such as cranes) could approach too close to overhead power cables resulting in direct contact or arcing to earth. This would result in the equipment becoming energised and lead to shock and electrocution hazard to personnel operating the equipment.
- Voltage caused by capacitance effects between the powerline and the pipeline. This effect is usually most significant during construction of the pipeline when the pipeline is located above the ground prior to installation in the trench. The voltage can result in a shock hazard to personnel working on the pipeline.
- Fault conditions on the powerline could result in arcing between the tower/pole earth and the pipeline leading to damage to the pipe coating, the pipe wall and to electrical equipment associated with the pipeline. In addition, personnel working on the pipeline or at test points for the cathodic protection system at the time of the fault could be impacted by high potential differences between the pipeline and earth resulting in exposure to shock and electrocution hazards. This could also impact on the test points for the cathodic protection system.
- Induced voltage in the pipeline could also occur due to the electromagnetic field generated by the normal operating current in the power cables. This is most significant in pipelines which run parallel to the power cables. The induced voltage could lead to shock and electrocution hazards to personnel working on the pipeline, and can lead to corrosion of the pipeline which may not be mitigated by cathodic protection.

The following safeguards were identified to minimise the risk of the identified hazards.

Construction Period

The Contractor will be responsible for providing a safe working environment for personnel and complying with the appropriate safety requirements for work near overhead powerlines, e.g. the Energy Supply Association of Australia (ESAA) National Guidelines for Safe Approach Distances for Electrical Apparatus and/ or WorkCover Code of Practice for Work near Overhead Powerlines, Catalogue No. 1394, 2006.

Operational Period

Appropriate safety measures will be designed and adopted to ensure the safety of personnel and equipment. Typical mitigation measures include selective earthing at particular positions on the pipeline, zinc ribbon installed in the trench with the pipeline, inline isolation installed in the pipeline, restricted access to the pipeline and its facilities, and the use of equipotential grids or other safety equipment during maintenance of the pipeline. The test points for the cathodic protection system may also be made lockable at all locations depending on final requirements.

Given the safeguards proposed in the design basis document and corrosion protection reports, the impact of AC induction effects near powerlines will be minimised and an allowance for an increased failure rate has not been included in the frequency analysis.

5.4.2. AC Corrosion

AC corrosion occurs at 'holidays' (exclusions or defects in the pipeline coating) as a result of the impact of AC induction near powerlines. The mechanism for the process is not clearly understood, but is more likely to occur under the presence of specific conditions including:

- High current density
- Low soil resistivity.

The impact of AC corrosion should be assessed in the detailed design to verify that load current levels are mitigated to values that are below the critical value which would result in a high likelihood of impact. Given the low likelihood of AC corrosion, no increase in the failure rate for this failure mode was included in the frequency analysis.

6. HAZARD IDENTIFICATION FOR QRA

6.1. Hazardous Incidents

The hazard identification given in Appendix 2 was used to identify a set of potential hazardous incidents for carrying forward to the QRA. The major hazards with the potential for offsite impact are discussed in the following sections.

6.2. Releases from Pipeline

The main incident of concern that could result from the operation of the pipeline is a loss of containment, release of high pressure natural gas to the atmosphere and subsequent ignition. The range of release sizes may range from a small leak to a full bore rupture.

Ignited gas release from the pipeline could result in:

- Jet fires
- Flash fire
- Vapour Cloud Explosion (VCE).

Gas release would result in a jet fire if ignited immediately, resulting in a jet flame. Heat radiation from the jet fire will impact people within the vicinity of the release.

If ignition is delayed, a vapour cloud may form, however as natural gas is buoyant and will disperse easily, the potential for a significant cloud buildup is low. If the vapour cloud reached an ignition source, a flash fire or a vapour cloud explosion could result.

In the event of a flash fire, the vapour cloud burns rapidly without a blast wave and will then continue to burn as a jet flame from the release point. There is a high (100%) chance of a fatality within the radius of the flash fire, but due to the short duration of the flame, there is a low chance of significant impact outside the vapour cloud radius. However, the impact from the jet fire that continues after the flash fire remains.

A vapour cloud explosion could occur if there is a potential for buildup of natural gas in congested areas, which restricts the flame front and results in an explosive overpressure which will impact people in the area. As there are no major structures near the pipeline, there is a very low likelihood of congestion and resulting vapour cloud explosion.

Therefore explosion events (e.g. VCEs) from pipeline releases have not been considered further in this analysis and jet fires and flash fires were considered as the most significant scenarios.

The main types of failure incident reported by the various sources (both overseas and Australian) are:

- External interference from heavy equipment (e.g. mechanical damage to pipe during excavation by third parties)

- Scour damage (e.g. river bed scouring, exposing and damaging pipes).
- Construction and material defect
- Internal and external corrosion and stress corrosion cracking
- Subsidence damage (e.g. banks and levees washing away, exposing and damaging pipes, mine subsidence, construction work near the pipeline)
- Faulty construction (e.g. welding defects, lack of weld testing)
- Ground movement (e.g. buckled pipework from excessive ground movement from earthquakes, slips and ground subsidence)
- Error during 'hot tapping'

6.3. Pipeline Safeguards

The proposed pipeline will be designed and operated in accordance with AS 2885.1-2007. The pipeline design must meet the requirements for the appropriate location class as per Clause 4.3.4 of AS2885.1-2007. These location classes are summarised as follows:

- Rural (R1) – typically undeveloped land or land used for rural activities such as grazing or agriculture, with isolated dwellings and infrastructure serving the local land uses
- Rural Residential (R2) – typically land occupied by single residence blocks typically in the range 1 ha to 5 ha or which is zoned rural residential
- Residential (T1) – typically land developed for community living, with multiple dwellings in close proximity
- High Density (T2) – typically land developed for high density community living, with multiple dwellings and multi-storey development

The pipeline route passes near regions that range from R1 (open isolated rural areas with limited dwellings) to T1 areas. However, the pipeline generally avoids built-up residential areas, even at the Tomago and Kooragang Island areas, where the pipeline route is near industrial areas.

The selection and design of the safeguards for protection of pipelines are based on the requirements of AS2885.1-2007 and from previous experience. The following engineered and procedural safeguards are typical of pipeline designs and will be included in the design as appropriate to the location class.

6.3.1. Protection against External Damage

- Marker signs
- 'One-Call'/ 'Dial-before-dig' services
- Pipeline patrols

- Marker tape

6.3.2. Corrosion Protection

- External coating of pipeline
- 'Holiday' detection (testing of coating integrity) prior to burial
- Impressed current cathodic protection system
- Gas quality with minimal corrosion enhancing components
- Intelligent pigging to assess pipeline condition

6.3.3. Ground Movement/Subsidence

- The pipeline will be regularly patrolled to facilitate detection of any ground movement or land subsidence so that investigation can be carried out.
- Pipeline design to make provision for current subsidence parameters for the location (provided by Mine Subsidence Board).
- Liaison with Mine Subsidence Board to determine likely future mining activity.
- Where significant ground movement has been detected and stresses are determined to be high, the ground around the pipeline will be dug up to relieve the stresses on the pipe as an additional precautionary measure to mitigate the effect of subsidence.

6.4. Incidents Carried Forward for Pipeline Risk Assessment

Based on the above review, the incidents carried forward for risk assessment are pipeline releases resulting in release of gas with the potential for ignition. The potential hole sizes, release rates and consequences of pipeline releases are assessed in Section 7. The likelihood of incidents resulting from the main causes of release are discussed in Section 8.

7. CONSEQUENCE ASSESSMENT FOR QRA

7.1. Jet Fire Scenarios

The proposed pipeline design remains unchanged since the previous version of preliminary risk assessment report (Ref. 4). The details of the consequence assessment are summarised below.

7.2. Hole Sizes

The following hole sizes were selected for release incidents resulting in jet fires:

- 10mm diameter for pinholes and small holes
- 50mm for medium holes
- one pipe diameter for rupture (508mm).

7.3. Isolation of Pipeline Releases

The pipeline will be provided with mainline valves located at a spacing as required by AS2885.1-2007, as follows for gas pipelines:

- Rural (R1) – as required
- Rural residential (R2) – 30km
- Residential (T1) and High Density (T2) – 15km

A general spacing of 50km spacing for mainline valves has been adopted for rural (R1) areas.

A depressurising curve was generated to show the release rate profile following pipeline isolation. When calculating the release rate following pipeline rupture, two cases were considered:

- Pipeline rupture followed by operation of the isolation system at an average release rate derived from the depressurising curve
- Pipeline rupture followed by failure of the isolation system resulting in a continuous release at a release rate determined by the maximum allowable operating pressure (MAOP)

7.4. Release Rates and Jet Fire Modelling

The release rates for pipeline failures were calculated using the Shell FRED Ver. 4 modelling package (Ref. 9).

The release rates and resulting flame lengths are shown in Table 7.2. The release rates were calculated at the MAOP of the pipeline (15.3 MPa).

7.5. Heat Radiation Effects

The probabilities of fatalities corresponding to various heat radiation levels used for assessing heat radiation effects are shown in Table 7.1. These are conservatively based on exposure to an unprotected person with no means to escape (Ref.10).

TABLE 7.1: PROBABILITY OF FATALITY FROM EXPOSURE TO HEAT RADIATION

Fire Heat Radiation (kW/m^2)	Probability of Fatality
4.7	Very Low, mainly burn injury
6	10%
10	50%
14	100%

7.6. Jet Fire Heat Radiation Impact

The assessment of the heat radiation effects from an ignited pipeline release are summarised in Table 7.2.

TABLE 7.2: DISTANCES TO SPECIFIED HEAT RADIATION INTENSITIES

Incident No.	Description	Hole Size (mm)	Release Rate (kg/s)	Flame Length (m)	Distance to Heat Radiation Level (m)			
					4.7 kW/m^2	6 kW/m^2	10 kW/m^2	14 kW/m^2
Lateral Releases (45°)								
1.	Small Release	10	2.3	16.6	22.7	21	18.3	17
2.	Medium Releases	50	57.1	60	89	82	71	65
3.	Full Bore Rupture – Isolated	-	550	159	225	210	181	167
4.	Full Bore Rupture - Unisolated	508	5897	385	603	555	477	438
Vertical Releases (45°)								
1.	Small Release	10	2.3	15.5	16.6	15.3	12.1	10.2
2.	Medium Releases	50	57.1	55	66	59	47	40
3.	Full Bore Rupture – Isolated	-	550	139	169	151	122	107
4.	Full Bore Rupture - Unisolated	508	5897	359	447	408	325	282

8. FREQUENCY ASSESSMENT FOR QRA

8.1. Pipeline Incident Frequencies

The estimates of jet fire frequencies were derived from published historical records of pipeline incidents. The frequency of jet fires depends on:

- The initiating frequency of pipeline releases
- The probability of ignition of the jet release
- The probability of pipeline isolation (for full bore rupture only)
- The probability of jet release orientation

The assessment of the frequency of pipeline incidents took into account the proposed safety measures. The following safeguards were considered:

- Marker tape at high risk locations
- Depth of cover (750 mm for most of the pipeline)
- Wall thickness (12.7 mm minimum wall thickness)

The provision of these safeguards will result in a reduction in the likelihood of external interference leading to pipeline damage. Additional safeguards (additional depth of cover, concrete capping) were assessed to determine the minimum separation distance to land uses near the pipeline.

The base case (Sensitivity Case 1) for the sensitivity case represents the proposed minimum safeguards for cross country locations. At locations near land uses (residential, etc), additional safeguards may be required to ensure that the risk levels meet the Department of Planning Criteria.

Additional sensitivity cases were identified to assess the risk reduction achieved by additional marker tape, depth of cover and concrete capping. Table 8.1 summarises the sensitivity cases that were assessed.

TABLE 8.1: SUMMARY OF SENSITIVITY CASES

Sensitivity Case	Risk Reduction Measures
Case 1 (Base Case)	12.7mm wall thickness (WT) pipe, 750mm Depth of Cover (DOC)
Case 2	12.7mm WT pipe, 900mm DOC
Case 3	12.7mm WT, 1200mm DOC
Case 4	Marker Tape, 12.7mm wall thickness pipe, 750mm Depth of Cover
Case 5	Marker Tape, 12.7mm WT, 900mm DOC
Case 6	Marker Tape, 12.7mm WT, 1200mm DOC
Case 7	Marker Tape, 12.7mm WT, 1400mm DOC
Case 8	Marker Tape, 12.7mm WT, 900mm DOC, concrete capping
Case 9	Marker Tape, 12.7mm WT, 1200mm DOC, concrete capping
Case 10	Marker Tape, 12.7mm WT, 1400mm DOC, concrete capping

Details of the assessment of jet fire frequencies is given in Appendix 3. The total jet fire frequencies are summarised in Table 8.2 for the base case (i.e. 750mm DOC without marker tape).

TABLE 8.2: SUMMARY OF JET FIRE INCIDENT FREQUENCIES – BASE CASE

Case	**Jet Fire Frequency (per-km-yr)**			
	Pinhole (10mm hole size)	**Puncture (50mm hole size)**	**Rupture (Depressuring Release)**	**Rupture (Isolation Failure)**
Releases at 45° from Vertical				
Base Case	2.13E-03	2.32E-04	7.35E-04	5.24E-05
Vertical Releases				
Base Case	2.13E-03	1.86E-03	5.88E-03	4.2E-4

9. QUANTITATIVE RISK ASSESSMENT RESULTS

9.1. Results

The results of the quantitative risk assessment were presented as risk transects, showing the accumulated individual risk levels at any lateral distance from the centreline of the pipe. The graph shows the risk level that a receiver would be exposed to at any distance from the pipe. The graph can also be used to estimate the distance to the relevant risk criteria and to show whether there is adequate separation distance from the pipeline to adjacent land uses.

9.2. Individual Risk

The risk transect was developed for the base case (12.7 mm wall thickness pipe, buried at a depth of 750mm) which is representative of most of the pipeline. The risk transect for this case is shown in Figure 9.1. This shows that the risk resulting reaches an individual risk of 1 x 10^{-6} per year at about 105m from the centreline of the pipeline.

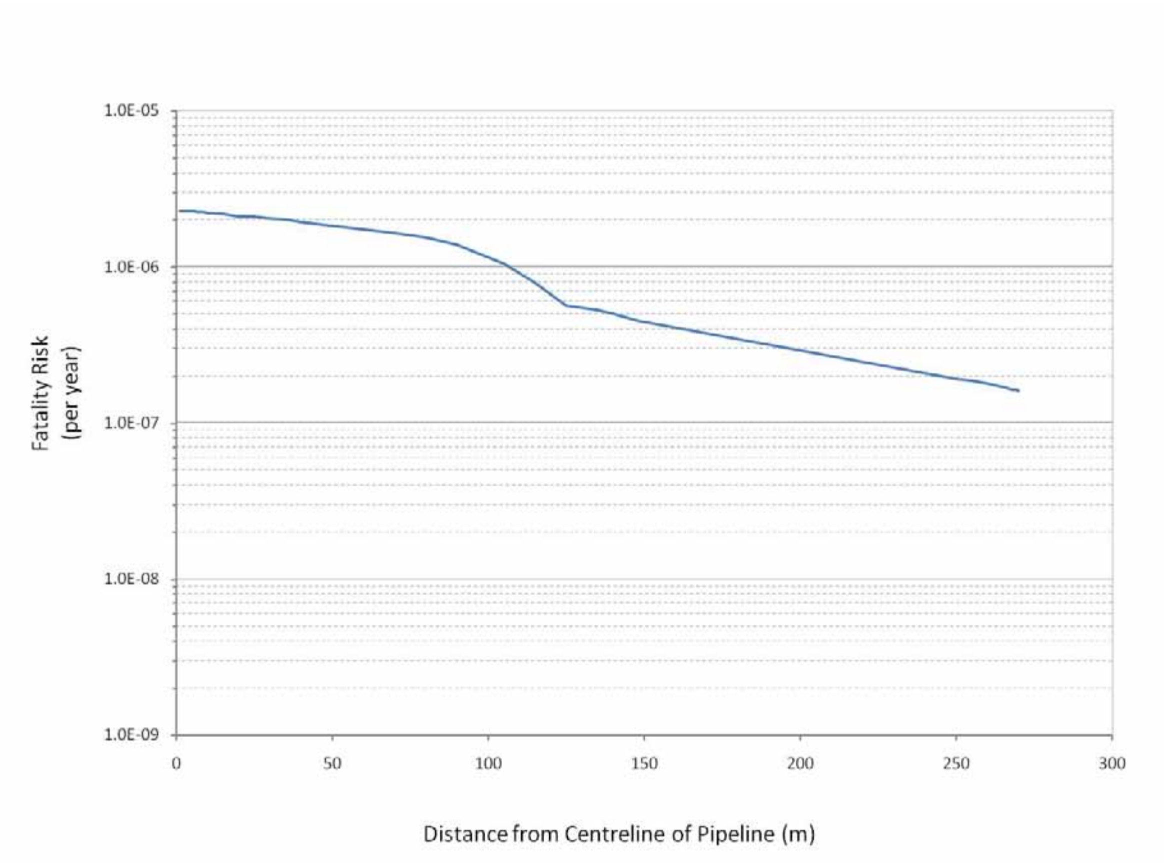

FIGURE 9.1: RISK TRANSECT FOR PIPELINE BASE CASE

The distances to the relevant risk criteria levels for each sensitivity case are summarised in Table 9.1.

TABLE 9.1: SUMMARY OF PIPELINE RISK ASSESSMENT RESULTS

Sensitivity Case	Distance to Individual Risk of Fatality (m)				
	0.5×10^{-6} per year (sensitive land use)	1×10^{-6} per year (residential)	5×10^{-6} per year (commercial)	10×10^{-6} per year (Active Open Space)	50×10^{-6} per year (Industrial)
Case 1 (Base Case, 750mm DOC)	140	105	Not Reached	Not Reached	Not Reached
Case 2 - 900mm DOC	132	103	Not Reached	Not Reached	Not Reached
Case 3 - 120mm DOC	121	92	Not Reached	Not Reached	Not Reached
Case 4 - marker tape, 750mm DOC	116	80	Not Reached	Not Reached	Not Reached
Case 5 - marker tape, 900mm DOC	112	60	Not Reached	Not Reached	Not Reached
Case 6 - marker tape, 1200mm DOC	106	35	Not Reached	Not Reached	Not Reached
Case 7 - marker tape, 1400mm DOC	104	17	Not Reached	Not Reached	Not Reached
Case 8 - marker tape, 900mm DOC, concrete capping	45	Not reached	Not Reached	Not Reached	Not Reached
Case 9 - marker tape, 1200mm DOC, concrete capping	35	Not reached	Not Reached	Not Reached	Not Reached
Case 10 - marker tape, 1400mm DOC, concrete capping	30	Not reached	Not Reached	Not Reached	Not Reached

9.3. Societal Risk

Societal risk is a measure of society's concerns for risks which result in multiple fatalities. For example, people may be concerned with the risks of aircraft crashes based on reporting of incidents with high casualty figures. By comparison, people may be less concerned with the risks of motor vehicle accidents which occur on a daily basis and do not receive the same level of public attention.

Societal risk is calculated by assessing the impact to the entire population around the facility and therefore depends on the population density in the area. Given the low population density in the area and the low individual risk, the societal risk level resulting from the pipeline operation will be negligible and has not been quantified.

9.4. Conclusions of QRA

The results of the risk assessment were compared with the relevant criteria for risk given in HIPAP No.4 by the NSW Department of Planning (Ref. 3). Preliminary details of land uses near the proposed pipeline route were reviewed. From Table 3.2 and

Table 3.3, the proposed pipeline route comes as close as about 2-3m from farm buildings, but it is not clear from the aerial photography whether these are sheds or farmhouses. Clearly identified farmhouses were identified as close as about 30m from the centreline of the pipeline. The results given in Table 9.1 can be used by the pipeline designer to provide an appropriate level of safeguards at any point on the pipeline to ensure that the risk levels meet the HIPAP No. 4 criteria.

The assessment considered the risk for a number of different cases with varying safeguards (additional depth of cover, concrete capping).

9.5. Recommendations Arising from QRA Results

The following recommendations are made as a result of the QRA:

1. The pipeline designers should use the distances summarised in Table 9.1 to determine an appropriate level of safeguards when finalising the pipeline route to ensure that the risk levels meets the HIPAP No. 4 risk criteria.
2. The QRA should be updated following the guidelines of HIPAP No.4 when details of the design and location of aboveground station are finalised.

10. AS2885 RISK ASSESSMENT RESULTS

10.1. AS2885 Risk Assessment Conclusions

A number of threats to the pipeline were identified during the hazard identification undertaken for the AS2885 risk assessment. Each threat was allocated a risk score. Details of the pipeline threats including the severity, frequency and risk scores are given in Table A2.1 in Appendix 2. In addition, proposed safeguards which may reduce the risk of each hazardous event have been identified.

10.2. AS2885 Risk Assessment Recommendations

Risk reduction measures should be put in place to reduce the risk of ‘intermediate’ risks to the ALARP level. The following recommendations have been made to ensure that the proposed design meets this requirement.

1. Scenarios assessed as being of an ‘intermediate’ risk in this preliminary assessment must be reviewed by the pipeline designer to establish what additional risk measures are suitable for these events. This review should consider the suggested risk reduction measures identified in the hazard identification table, in addition to other risk measures that may be identified during the detailed design stage.
2. The actions identified in Table A2.1 of Appendix 2 for ‘low’ risk events should be implemented in line with the ALARP principle to reduce the risk even further.
3. A detailed AS2885 risk assessment should be prepared during the detailed design, identifying location specific threats and proposed safeguards.
4. The proposed pipeline design should be assessed against the Pipeline Research Council International (PRCI) protocol for the assessment of likelihood of Stress Corrosion Cracking (Ref. 8).

APPENDIX 1. AS2885 HAZARD IDENTIFICATION METHODOLOGY

A 1.1. Severity and Frequency Criteria

Tables A1.1 and A1.2 show the severity and frequency criteria from AS 2885.1-2007. Table A1.3 shows the risk matrix used for assessing the level of risk for the hazardous events, and criteria for high, intermediate, low and negligible risk. These tables are based on the criteria recommended in AS 2885.1-2007.

TABLE A1.1: SEVERITY CLASSES

Consequence Type	Severity Class				
	Catastrophic	**Major**	**Severe**	**Minor**	**Trivial**
People	Multiple fatalities result	Few fatalities; several people with life threatening injuries	Injury or illness requiring hospital treatment	Injuries requiring first aid treatment	Minimal impact on health and safety
Supply	Long-term interruption of supply	Prolonged interruption; long-term restriction of supply	Short-term interruption; prolonged restriction of supply	Short-term interruption; restriction of supply but shortfall met from other sources	No impact; no restriction of pipeline supply
Environment	Effects widespread; viability of ecosystems or species affected; permanent major changes	Major off-site impact; long-term severe effects; rectification difficult	Localized (<1 ha) and short-term (<2 y) effects, easily rectified	Effect very localized (<0.1 ha) and very short-term (weeks), minimal rectification	No effect; minor on-site effects rectified rapidly with negligible residual effect

TABLE A1.2: FREQUENCY CLASSES

Frequency Class	Frequency Description
Frequent	Expected to occur once per year or more
Occasional	May occur occasionally in the life of the pipeline
Unlikely	Unlikely to occur within the life of the pipeline, but possible
Remote	Not anticipated for this pipeline at this location
Hypothetical	Theoretically possible but has never occurred on a similar pipeline.

TABLE A1.3: RISK MATRIX

Frequency of Occurrence	Severity Class				
	Catastrophic	**Major**	**Severe**	**Minor**	**Trivial**
Frequent	Extreme	Extreme	High	Intermediate	Low
Occasional	Extreme	High	Intermediate	Low	Low
Unlikely	High	High	Intermediate	Low	Negligible
Remote	High	Intermediate	Low	Negligible	Negligible
Hypothetical	Intermediate	Low	Negligible	Negligible	Negligible

APPENDIX 2. AS2885 HAZARD IDENTIFICATION AND RISK ASSESSMENT

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
Design – General Locations									
1.1	Pipeline Design – general	Design process issues result in an inadequate design for pipeline and safeguards	No major impact identified	• Regulatory Approval Process • Design of pipe, equipment and process (e.g. cathodic protection) to be approved prior to construction • Manufacture of materials and components to be covered by quality assurance/inspection requirements of contracts and referenced standards • Design safeguards to be included • Final verification of system integrity (hydro-testing) • Fracture assessments/ Fracture control plan • Design to meet strict protocols of AS2885	Triv.	Hypo.	Negl.	Control plan to verify and approve design requirements	-
1.2	Pipeline Design – Route Selection	Route selection issues resulting in non-optimal selection of pipeline route	No major impact identified	• Landowner liaison • Environmental and safety assessment of route selected • Pipeline design and safeguards selected appropriate to local requirements • Design to meet strict protocols of AS2885	Min.	Rem.	Negl.		

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
1.3	Pipeline Design – general	Improper material specification	Potential for pipeline leaks	• Design review process • Design of pipe, equipment and process (e.g. cathodic protection) to be approved prior to construction • Manufacture of materials and components to be covered by quality assurance/inspection requirements of contracts and referenced standards • Final verification of system integrity (hydro-testing)	Min.	Rem.	Negl.		
Construction – General Locations									
2.1	Trench Digging	Trench collapse during construction activities	Potential fatality	• SMP to be implemented for project • Document and implement excavation risk assessment • Use shoring for all high risk locations • Safe Work Method Statements for relevant tasks • Minimal need for personnel in trench during construction	Maj.	Rem.	Interm.	• Review competency and certification of supervisors • Establish and implement competency for excavation inspector	-
2.2	Pipeline construction	Construction defects, e.g. weld defects, incorrect installation	Potential leaks	• Testing procedures • Radiography • Hydrostatic testing	Sev.	Rem.	Low		

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
2.3	Pipeline construction, 'unsafe work practices'	Unsafe work practice	Potential fatality	• Safety requirements as part of contractor selection process • Implementation of SMP for project including compliance with legislation • Audit of worksites and SMP • Only safe equipment to be allowed at work sites (inspection of contractors) • Competency system implemented for tasks • Safe Work Method Statements for relevant tasks	Maj.	Rem.	Interm.	• Regular SMP audit by independent party • Compile a risk register and implement a risk minimisation process as part of SMP	-
2.4	Pipeline construction, 'unsafe work practices'	Unsafe work practice	Multiple injuries	• Safety requirements as part of contractor selection process • Implementation of SMP for project including compliance with legislation • Audit of worksites and SMP • Only safe equipment to be allowed at work sites (inspection of contractors) • Competency system implemented for tasks • Safe Work Method Statements for relevant tasks	Sev.	Rem.	Low	• Regular SMP audit by independent party • Compile a risk register and implement a risk minimisation process as part of SMP	-

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
2.5	Pipeline construction, welding practices	Emission of ultraviolet radiation from welding onto public areas	Minor injury to public	• SMP to include controls for UV radiation from welding • Include all legislative and risk assessment controls • Screening of welding process	Sev.	Rem.	Low	Safety issue incorporated into SMP for project	-
2.6	Pipeline construction, radiographic testing of pipeline	Radiological emissions resulting in personnel exposure	Severe injury to public or construction worker	• SMP to include controls for radiography • Include all legislative and risk assessment controls • Screening of radiographic equipment	Sev.	Rem.	Low	Safety issue incorporated into SMP for project	-
2.7	Hydrostatic Testing	• Pipe burst • Hose burst • Equipment failures	• Mechanical impact to personnel • Severe injury	• Equipment testing to be included in SMP (for all critical equipment) • Compliance to OH&S legislation • Procedure for hydrostatic testing	Sev.	Rem.	Low	Compile a risk register and implement a risk minimisation process as part of SMP	-
2.8	Hydrostatic Testing	• Pipe burst • Hose burst • Equipment failures and release of water from pipe	Major erosion problem	• Procedure for hydrostatic testing • Environmental Management Plan • Erosion control equipment at site and installed • Contractors have attended environmental training	Sev.	Rem.	Low	Liaise with relevant authority for review of environmental controls	-

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
2.9	Hydrostatic Testing	Usage and disposal of hydrostatic test water	Environmental impact of testing and disposal of potentially contaminated water	• Environmental Management Plan • Sourcing and disposal of test water to be included in EMP • Contractors have attended environmental training	Sev.	Rem.	Low	Liaise with relevant authority for review of environmental controls	-
Construction – Location Specific									
3.1	Pipeline construction at off-take to existing pipeline and local infrastructure	Interference with main trunk line at off-take	• Major leak • Fire if ignited and potential fatality	• Depth of cover • Pipeline wall thickness • Marker tape and pipeline markers • With main pipeline operator personnel, locate and mark pipe location prior to construction • Implement method for exclusion (e.g. fence off easement) reducing risk of impact on pipe • Ensure construction contractors are aware of location and provide supervision as required • Hand excavation/ potholing as required	Maj.	Hypo.	Low	• Provide main pipeline operator with design/ plan and construction procedures • Safety issue incorporated into SMP for project	-

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
3.2	Pipeline construction along roads, crossing roads	Traffic impact on members of public, construction worker or members of public	• Vehicle Impact • Potential fatality	• Prepare Traffic Management Plan (e.g. stop/go signs, barriers, lights after hours) • Barricades, signs • Provision of separation distance between construction area and roads • Awareness training	Maj.	Rem.	Interm.	• Liaison with local council to review traffic management plan • Review single lane operation and temporary road widening where appropriate • Establish if detour is appropriate	-
3.3	Pipeline construction along roads, crossing roads	Traffic impact on members of public, construction worker or members of public	• Local Traffic impact • Likely to be significant impact near built up areas	• Prepare Traffic Management Plan (e.g. stop/go signs, barriers, lights after hours) • Barricades, signs • Provision of separation distance between construction area and roads • Awareness training	Sev.	Occ.	Interm.	• Liaison with local council to review traffic management plan • Review single lane operation and temporary road widening where appropriate • Establish if detour is appropriate	-
3.4	Construction in forest, sensitive areas	Sparks from welding, grinders, other tools or vehicles starting a bushfire	Major bushfire causing major environmental impact and property damage	• Remove excess combustion material in vicinity where possible • Welding and power-tools (e.g. grinder) that can cause sparks shielded from fuel sources to avoid sparks acting as ignition source • Adequate control of vehicles (e.g. limited access by petrol vehicles with catalytic converter) • Fire fighting capabilities at site • Maintenance of vehicles and equipment	Maj.	Rem.	Interm.	• Comply with local bush fire requirements • Liaison with local fire fighting authority for review and approval of mitigation measures • No hot work during periods of high fire danger	-

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
3.5	Construction along powerline corridors	Mobile construction plant failing to maintain safe clearance distance from overhead HV conductors	Electrocution of person	• Mobile plant which cannot maintain safe clearances during construction are not to access the corridor. • TransGrid/ WorkCover Guidelines for equipment access and safe working distances • Training and accreditation of mobile plant operators for operations near power lines • Use of spotters when constructing works under/ near pipelines	Maj.	Rem.	Interm.	• Safety issue incorporated into SMP for project • Construction activities to comply with ESAA National Guidelines for Safe Approach Distances for Electrical Apparatus	-
3.6	Construction along powerline corridors	Induced voltage on pipeline and equipment during construction due to induced voltage/ capacitance effects	Shock hazard to construction worker	• Construction safety procedures • Grounding straps on equipment • Construction management procedures near powerlines	Maj.	Hypo.	Low	• Safety issue incorporated into SMP for project • Construction activities to comply with ESAA National Guidelines for Safe Approach Distances for Electrical Apparatus	-
3.7	Construction along powerline corridors	Construction of infrastructure (e.g. stations, facilities)	Impact on power line towers	• Required separation distances • Fenced off areas • Consultation with powerline authority	Sev.	Rem.	Low		

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
3.8	Construction of trench across 'minor' creeks	Sediment control fails	Soil erosion causing environmental impact	• Selection of appropriate crossing method depending on individual sites (e.g. coffer dam, redirection) • Environmental management plan • Adequate erosion control equipment at site and installed • Contractors to undergo appropriate environmental training	Sev.	Rem.	Low	• The environmental plan may need to address controls at each creek crossing as conditions vary • Liaise with relevant authority for review of environmental controls	-
3.9	Pipeline construction crossing or parallel to railway line	Impact on construction worker	• Person hit by train • Potential fatality	• Rail operator informed of work • Fencing off rail-track to avoid traffic across tracks • Safety management plan to include process and systems for managing work close to railway lines • Personnel working close to railway lines competent for these tasks	Maj.	Hypo.	Low	• Rail crossing procedures/plan to be reviewed/approved by rail authority • Safety issue incorporated into SMP for project	-
3.10	Directional drilling operations (e.g. roads, railways)	Leak of bentonite from drilling equipment	• Impact on flora • Visual impact from discolouring of soil	• Environmental Management Plan • Bentonite containment • Contractors have attended environmental training	Min.	Unlikely	Low	Liaise with relevant authority for review of environmental controls	-

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
3.11	Directional drilling across rivers and major creeks	Leak of bentonite from drilling equipment into creek	Severe discolouring of creek and impact on aquatic life	• Environmental Management Plan • Geological investigation • Depth of cover below creek bed • Bentonite containment • Contractors have attended environmental training	Sev.	Unlikely	Low	Liaise with relevant authority for review of environmental controls	-
3.12	Construction close to endangered or protected flora	Impact on endangered or protected flora	Removal of species from site	• Ecologist to identify such plants and location • Ecologist on site during construction • Personnel attended awareness training	Sev.	Unlikely	Low	• Re-seeding/ revegetation at exposed locations • Post-construction inspection • Ensure issues are included in EMP and pipeline operation manual • Include in induction and training of field personnel	-
3.13	Construction impact on native grasses	Impact on endangered or protected flora	Removal of species from site	• Ecologist to identify such plants and location • Ecologist on site during construction • Personnel attend awareness training	Sev.	Unlikely	Low	• Re-seeding/ revegetation at exposed locations • Post-construction inspection • Ensure issues are included in EMP and pipeline operation manual • Include in induction and training of field personnel	-

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
3.14	Construction in Travelling Stock Route	Impact on flora, fauna, TSR operations	Removal of species from site	• Route Selection to avoid sensitive locations • Ecologist to identify such plants and location • Ecologist on site during construction • Personnel attend awareness training • Liaison with local rural lands protection boards	Sev.	Unlikely	Low	• Re-seeding/ revegetation at exposed locations • Post-construction inspection • Ensure issues are included in SMP and pipeline operation manual • Include in induction and training of field personnel	-
3.15	Construction near sporting and recreational areas	Construction site not adequately fenced off	Person falls into trench or injured by construction equipment	• Implementation of SMP for project • Safety audit of work practices as part of SMP • Construction areas and equipment fenced off • Trench not left open	Maj.	Hypo	Low		-

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
3.16	Pipeline construction close to other natural gas pipelines	Interference with mains	• Major leak • Fire if ignited and potential fatality	• Depth of cover • Pipeline wall thickness • Marker tape and pipeline markers • With owner/operator of main pipeline, locate and mark pipe location prior to construction • Implement method for exclusion (e.g. fence off easement) reducing risk of impact on pipe • Ensure construction contractors are aware of location and provide supervision as required • Hand excavation/ potholing as required	Maj.	Hypo	Low	• Provide owner/operator of main pipeline with design/plan and construction procedures • Safety issue incorporated into SMP for project	-
3.17	Pipeline construction close to other utilities and easements (power, water, telecoms)	Interference with other utility/ services	Interruption to service	• Through 'dial before dig' system, ensure services are located and marked on work site • Ensure construction contractors are aware of location and provide supervision as required • Hand excavation/ potholing as required	Sev.	Unlikely	Low	Safety issue incorporated into SMP for project	-
3.18	Pipeline construction	Construction in acid sulphate soil	Generation of concentrated acid, environmental impact	• Minimal trench exposed at acid sulphate prone areas to minimise acid generation • Lime treatment • HDD	Min.	Rem.	Negl.		

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
Commissioning									
4.1	Pipeline Commissioning	• Loss of gas due to external interference • Equipment failure / leaks	Gas leak with potential ignition	• Commissioning procedures • Gas monitoring during commissioning • Security measures	Min.	Unlikely	Low		-
Operational – General Locations									
5.1	Pipeline, general	• Pinhole leaks • External corrosion • Stress corrosion cracking • Weld defects	Gas leak	• Cathodic protection / monitoring • Anti-corrosion pipe coating • Hydrotesting • Induction control along powerlines • 'Holiday' testing of pipe coating • Welding procedures • Radiography • Intelligent pigging	Min.	Rem.	Negl.	Include in operational procedures and plans	-
5.2	Pipeline, general	Third party interference	Major leak, potential for ignition therefore potentially leading to fatality	• Depth of cover • Wall thickness • Marker tape in trench in high risk areas • Pipeline markers • Pipeline surveillance • Liaison process with all landowners and users • Emergency Response Plan with regular drills	Maj.	Rem.	Interm.	• Isolation and venting valves • Include in operational procedures and plans • Member of dial before dig 'club'	-

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
5.3	Pipeline, general	Seismic activity	Major leak	• Depth of cover • Wall thickness • Emergency Response Plan with regular drills • Structural integrity of pipelines	Maj.	Rem.	Interm.	• Isolation and venting valves • Include in operational procedures and plans • Review seismic loading requirements of pipeline design	-
5.4	Pipeline, general	Vehicle loading at road crossings, powerline easements, stock routes	Pipeline damage due to excess loading	• Pipeline designed to typical road vehicle loading • Depth of cover • Wall thickness • Pipeline markers • Liaison with powerline operator, councils, etc • Limited traffic along corridor • Pipeline surveillance	Min.	Unlikely	Low		-
5.5	Pipeline, general	Stress corrosion cracking	• Potential for leak, rupture in worst case, fire if ignited • Short term loss of supply	• Conditions not conducive to SCC (e.g. no significant pressure cycling, compressor after-cooler minimise potential for high temperatures • Cathodic protection • Pipeline coating	Sev.	Rem.	Low		
5.6	Pipeline, general	Fatigue	• Potential for leak, rupture in worst case, fire if ignited • Short term loss of supply	• Unlikely to have significant pressure fluctuations • Pipeline design to incorporate potential fatigue impacts	Sev.	Rem.	Low		

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
5.7	Pipeline, general	Coating damage, e.g. construction fault	Potential corrosion, leak	• Cathodic protection • 'Holiday' testing of coating integrity • Intelligent pigging • Inspection and maintenance	Min.	Unlikely	Low		
5.8	Pipeline, general	Overpressure	• Pipeline stress • Potential for leak, rupture in worst case, fire if ignited • Short term loss of supply	• Pipeline designed to full MAOP (15.3Mpa) • Remote monitoring of system pressures • Pipeline isolation	Sev.	Rem.	Low		
5.9	Pipeline, general	Overtemperature	Pipeline equipment damage	• Pipeline designed to full MAOP (15.3Mpa) • Remote monitoring of system pressures • Pipeline isolation	Min.	Rem.	Negl.		
5.10	Pipeline, general	Pipeline in acid sulphate or contaminated soils	Corrosion, leak	• Cathodic protection • Pipeline coating	Min.	Rem.	Negl.		

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
Operational – Location Specific									
6.1	Pipeline in powerline easement	Induced voltage from nearby powerline on pipeline and equipment (including CP test points) from normal and fault current in powerlines	Potential shock hazard if personnel working on pipeline facilities at the time of the fault	• Pipeline design to minimise impact of induced voltage (e.g. zinc-ribbon earthing) • Facilities and test points lockable to prevent public access. • Personnel have to be in contact with pipeline equipment at time of fault current to be at risk	Maj.	Hypo.	Low		-
6.2	Pipeline in powerline easement	Induced voltage from nearby powerline on pipeline coating	Corrosion	• Pipeline design to minimise impact of induced voltage (e.g. zinc-ribbon earthing) • Intelligent pigging	Min.	Unlikely	Low		-
6.3	Pipeline near mining leases	• Ground subsidence resulting in excessive stress on pipeline • Seismic impact from blasting	Major leak, causing major supply interruptions	• Route selection to avoid locations • Pipeline wall thickness • Structural integrity of pipeline • Ongoing liaison with mining company / Mine Subsidence Board • Pipeline surveillance • Emergency Response Plan with regular drills	Maj.	Remote	Interm.	• Pipeline route selected to avoid mining leases • Establish with mining companies whether they will mine under easement and what method to be used • If undermined, implement ground monitoring process	-

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
6.4	Pipeline near residences, industrial areas, buildings	Third party interference	• Pipeline damage • Leak, fire if ignited • Potential fatality	• Depth of cover • Marker tape • Pipeline markers • Pipeline patrols • Liaison with landowners	Maj.	Hypo.	Low	• Member of dial before dig 'club' • Liaison with commercial and industrial sites to ensure their emergency plan include relevant issues • Additional safeguards (Depth of cover, wall thickness, concrete slabs) as required	-
6.5	Pipeline near boundary fences	Interference due to fence maintenance activity, post-hole digging	• Pipeline damage • Leak, fire if ignited • Potential fatality	• Depth of cover • Marker tape • Pipeline markers • Pipeline patrols • Liaison with landowners	Maj.	Rem.	Interm.	• Member of dial before dig 'club' • Additional safeguards (Depth of cover, wall thickness, concrete slabs) as required	-
6.6	Pipeline	Pipeline 'floats' in 'black soil' country	• Pipeline exposed • Potential third party impact • Pipeline stress	• Weighting of pipeline • Pipeline patrols • Route surveys	Min.	Remote	Negl.	• Likely locations to be identified as part of route selection process	-
6.7	Pipeline in built-up areas	Additional load on pipeline at roads, driveways	Major leak	• Depth of cover • Wall thickness • Concrete slab where required • Pipeline markers • Pipeline surveillance • Emergency Response Plan with regular drills • Liaison with property owners	Major	Hypo.	Low	• Isolation valves • Member of dial before dig 'club'	-

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
6.8	Pipeline at river/ creek crossings	• Scouring/ erosion of pipeline • Flood events	• Pipeline exposed • Additional pipe stress	• Route selection of crossing point • Depth of cover • Directional drill below creek bed at major creek crossings • Wall thickness • Pipeline surveillance	Min.	Rem.	Negl.		
6.9	Maintenance of aboveground stations	• Leak in station • Venting operations	• Gas leak • Fire if ignited	• Gas detection • Monitoring • Operating/ maintenance procedures	Min.	Remote	Negl.	Include in operating procedures	-
6.10	Operational impact on flora and fauna	Vehicles for patrol, inspection and maintenance impact on flora and fauna (native grasses, forest, TSR)	Environmental Impact	• Training of personnel on environmental management • Location of sensitive areas in EMP	Min.	Rem.	Negl.		
6.11	Impact from External event (Bush fire).	Thermal radiation from a fire may impact the pipeline, if exposed.	Pipeline is buried, and so no impact envisaged.		Triv..	Occ	Low		

TABLE A2.1: PRELIMINARY HAZARD IDENTIFICATION AND AS2885.1-2007 RISK ASSESSMENT

Item No.	Description	Threat	Consequence/ Effects	Safeguards	Risk Assessment			Additional Risk Reduction Measures	Comments / Actions
					Sev	Freq	Risk		
6.12	Impact from External event (Bushfire)	Thermal radiation from a fire may impact above-ground stations	• Damage to surface facilities • Possible escalation to leak and ignition to jet fire	• Vegetation well cleared around above-ground facilities • Security fence placed around the station outside the hazardous area classified by AS 2430 • Gravel or hardstand area inside the fenced site around gas filled equipment. • Equipment materials and low thermal radiation impact will limit the damage. It is unlikely that loss of containment would result.	Sev.	Rem.	Low		
6.13	Impact from External event (inclement weather, flooding).	High winds, flooding may result in station equipment damage	• Damage to surface facilities • Possible escalation to leak	• Remote monitoring • Station location to be selected to be away from flood prone areas	Sev.	Rem.	Low		

APPENDIX 3. FREQUENCY ASSESSMENT

A 3.1. PIPELINE RELEASE FREQUENCIES

A 3.1.1. Generic Pipeline Failure Data

The failure rate data used for the assessment of the frequency of pipeline releases was derived from the **E**uropean **G**as Pipeline **I**ncident Data **G**roup (EGIG, Ref. 11). The European data are useful because of the significant exposure in terms of kilometre years experienced (approximately 2.4 million kilometre-years from 1970-2004). The large exposure provides a statistically significant basis, particularly when estimating the frequency of different causes of failure. The data also includes factors such as wall thickness, depth of cover, probability of ignition, etc.

The EGIG data, however, are considered conservative when applied to pipelines in Australia. This is because there is a higher density of pipelines and higher population densities along pipeline routes in Europe than in Australia. This will tend to result in higher failure rates for European pipelines compared with the experience of pipelines in Australia, particularly for incidents caused by external interference.

The EGIG database is continually updated and summary data are periodically reported. The data show that the failure rates for pipeline failures are gradually reducing over time, reflecting the improvements in pipeline technology and safeguards. The overall failure frequency reported for the period 1970-2004 was 0.41 incidents per 1000 km-yr compared with a failure frequency of 0.17 incidents per 1000 km-yr for the years 2000-2004.

While the EGIG data are expected to be quite conservative for the QHGPL which is generally located in remote regions, the data are useful to estimate the frequency of different causes of failures such as corrosion, external interference, material defects, etc.

A 3.1.2. Base Failure Frequencies

Table A3.1 summarises the data derived from the EGIG report (Figure 18, Ref. 11) for the period 1970-2004. The data are categorised by the identified cause of the incident and show the relative frequency of each cause. The most frequent cause of pipeline failures is due to external interference (52%) with the next most likely causes being construction/ material defects (18%) and corrosion (17%).

The incidence of hot-tap errors (taken as the likelihood of tapping into the wrong pipeline or inadvertently impacting an adjacent pipeline) will be insignificant as there will only be one offtake in the vicinity on the existing main gas pipeline. Therefore the frequency for hot-tap errors has been set to zero. Little seismic activity has been reported for locations along the pipeline route. There is a potential for pipeline damage from ground movement at locations near mining leases due to subsidence or seismic impact from blasting, however pipeline rupture is less likely to occur from this activity.

TABLE A3.1: BASE FREQUENCY OF PIPELINE FAILURES

Cause	Pipeline Base Frequency by Cause and Hole Size (per 1000 km-yr)		
	Pinhole-Crack (d<10mm)	Hole (10mm < d<50mm)	Rupture (d>100mm)
External Interference	0.055	0.118	0.041
Construction/Material	0.046	0.018	0.005
Corrosion	0.064	0.004	0
Ground Movement	0.008	0.008	0.001
Hot tap error	0	0	0
Other/Unknown	0.027	0.004	0
Total	**0.188**	**0.155**	**0.036**

A 3.1.3. Additional Safeguards

The base frequencies given in Table A3.1 were then adjusted to take account of the proposed design for the QHGPL. The safeguards proposed include:

- Marker tape at high risk locations
- Depth of cover (750mm minimum depth of cover)
- Wall thickness (12.7 mm minimum wall thickness)

The provision of these safeguards will result in a reduction in the likelihood of external interference leading to pipeline damage. A number of sensitivity cases were assessed, taking into account different levels of additional safeguards. These cases are summarised below.

Sensitivity Case 1 - (Base Case)

- 12.7mm wall thickness pipe, 750mm Depth of Cover

This represents the base case, i.e. the minimum level of safeguards proposed for the majority of the pipeline route in cross-country areas.

Where necessary, additional safeguards may be required to meet the NSW Department of Planning risk criteria. Additional sensitivity cases were identified to assess the risk reduction achieved by marker tape, additional depth of cover and concrete capping:

- Sensitivity Case 2 - 12.7mm WT, 900mm DOC
- Sensitivity Case 3 - 12.7mm WT, 1200mm DOC
- Sensitivity Case 4 - Marker Tape, 12.7mm WT, 900mm DOC
- Sensitivity Case 5 - Marker Tape, 12.7mm WT, 900mm DOC
- Sensitivity Case 6 - Marker Tape, 12.7mm WT, 1200mm DOC
- Sensitivity Case 7 - Marker Tape, 12.7mm WT, 1400mm DOC
- Sensitivity Case 8 - Marker Tape, 12.7mm WT, 900mm DOC, concrete capping
- Sensitivity Case 9 - Marker Tape, 12.7mm WT, 1200mm DOC, concrete capping

- Sensitivity Case 10 - Marker Tape, 12.7mm WT, 1400mm DOC, concrete capping

The additional pipewall thickness will also reduce the likelihood of releases resulting from corrosion. The following sections discuss the reduction factors that were used to account of the additional safeguards.

A 3.1.4. Marker Tape

Corder (Ref. 12) has reported that a damage reduction factor of 1.67 was achieved when marker tape is provided above pipelines based on experimental data derived from testing undertaken by British Gas. This factor was used to reduce the frequency of impacts resulting from external interference.

A 3.1.5. Additional Depth of Cover

Table A3.2 summarises the risk reduction factors from the testing reported by Corder (Ref. 12). Note that a reduction factor of 1.0 resulted for depths of cover of 1.1m and that lower depths of cover result in a reduction factor greater than 1, i.e. there is an increase of the relative frequency of external impact. The base case depth of cover for the QHGPL pipeline project is 750mm and therefore an increase in the relative frequency of external interference by a factor of 1.35 was used for the base case.

TABLE A3.2: REDUCTION FACTORS FOR ADDITIONAL DEPTH OF COVER

Depth of Cover (m)	Reduction Factor
0.75	1.35
0.9	1.21
1	1.11
1.1	1.02
1.2	0.92
1.4	0.73

A 3.1.6. Pipewall Thickness

Table A3.3 summarises the frequency multiplying factor for a range of pipewall thicknesses derived from the EGIG data. The minimum wall thickness for the QHGPL pipeline is 12.7mm. Additional wall thickness will reduce the likelihood of external interference. Additional wall thickness will also reduce the likelihood of corrosion (pinhole leaks only).

TABLE A3.3: FREQUENCY MULTIPLYING FACTOR FOR PIPEWALL THICKNESS

Pipeline Wall Thickness (mm)	Reduction Factor By Pipewall Thickness and Size of Hole		
	Pinhole-Crack (d<10mm)	Hole (10mm < d<50mm)	Rupture (d>100mm)
2.5 (0-5mm)	4.0	2.4	5.8
7.5 (5-10mm)	1.0	1.0	1.0
12.5 (10-15mm)	0.5	0.5	0.5
Multiplying factors used for the QHGPL pipeline			
12.7	0.5	0.5	0.5

A 3.1.7. Final Pipeline Failure Frequencies

The revised failure frequencies incorporating risk reduction factors for the frequency assessment are summarised in Table A3.4.

TABLE A3.4: SUMMARY OF FINAL PIPELINE FAILURE FREQUENCIES (INCLUDING REDUCTION FROM ADDITIONAL SAFEGUARDS- BASE CASE)

Cause	Pipeline Base Frequency by Cause and Hole Size (per 1000 km-yr)		
	Pinhole-Crack (d<10mm)	**Hole (10mm < d<50mm)**	**Rupture (d>100mm)**
External Interference	0.020	0.049	0.012
Construction/Material	0.045	0.020	0.005
Corrosion	0.030	0.004	0.000
Ground Movement	0.008	0.008	0.001
Hot tap error	0.000	0.000	0.000
Other/Unknown	0.025	0.003	0.000
Total	**0.128**	**0.084**	**0.018**

A 3.1.8. Ignition Probabilities

The probability of ignition used in the frequency assessment was based on the EGIG 2005 Report (Ref. 11).

TABLE A3.5: PROBABILITY OF IGNITION FOLLOWING GAS RELEASE

Hole Size	Ignition Probability
Pinhole (10mm)	3.0%
Hole (50mm)	2.0%
Rupture (508mm)	30%

A 3.1.9. Probability of Leak Detection

The pipeline will be provided with mainline valves located at a spacing as required by AS2885.1-2007, as follows for gas pipelines:

- Rural (R1) – as required
- Rural residential (R2) – 30km
- Residential (T1) and High Density (T2) – 15km

A general spacing of 50km spacing for mainline valves has been adopted for rural (R1) areas. The stations will be provided with telemetry which will allow remote monitoring of the pipeline operating conditions. A pipeline rupture would be readily detected by a sudden drop in pipeline pressure which would initiate closure of the valves.

It is unlikely that pinholes and punctures would be readily detected by remote monitoring and may depend on the operating conditions at the time of the leak. Small releases in remote locations may not be readily detected until a routine patrol of the pipeline occurs. Therefore it was assumed that pinhole and puncture releases would not be detected for some time and the release rate was modelled as a steady-state release at the maximum allowable operating pressure (MAOP).

In the event of a rupture, and following successful isolation of the pipeline, the pipeline would depressurise rapidly. If however, the pipeline shutdown failed (due to hardware failures, valve failure or operator error), then the release would continue at the full operating pressure for an extended period. Two separate cases were assessed for the frequency assessment:

- Full-bore rupture followed by pipeline isolation with a release rate determined by the depressuring curve
- Full-bore rupture and failure of pipeline isolation with a steady state release at full operating pressure.

Fault Tree Analysis was undertaken to estimate the probability of pipeline isolation failure as shown in Figure A3.1. The reliability data used for the assessment is given in Table A3.6.

Published failure rates are generally quoted as the number of failures over a specified time period as per Items 1 and 2 in Table A3.6. To convert failure rates to a probability of failure, the 'Fractional Dead Time' (FDT) is calculated using the following formula:

$FDT = ½ \times \lambda \times T$

where λ = the failure rate (per time period)

T = the testing period (in units consistent with the failure rate)

In other cases, failure probability is quoted as a straight failure probability as per Items 3 and 4 in Table A3.6.

The fault tree analysis showed that the probability of pipeline shutdown failure is 0.066.

TABLE A3.6: PROBABILITY OF IGNITION FOLLOWING GAS RELEASE

Item	Failure Description	Source Reference	Failure Rate (Failures per million hours)	Testing Frequency	Failure Probability
1.	Pressure switch fails to operate on pressure drop	CCPS 2.1.4.1.3 (Ref. 13)	0.4	Annual	1.8×10^{-3}
2.	Failure of SCADA System to send signal	OREDA (Ref. 14)	1.05	Monthly	0.044
3.	Isolation valve fails to close	CCPS 3.5.3.3 (Ref. 13)	-	-	2.2×10^{-3}
4.	Human Error – Operator fails to Initiate Shutdown	HEART - Type E (Ref. 15)	-	-	0.02

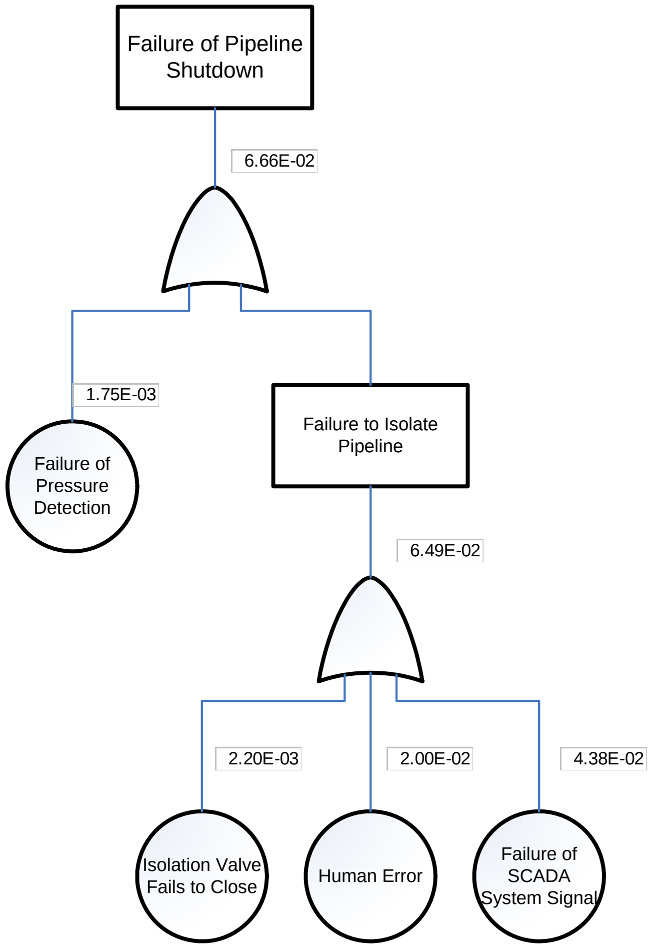

FIGURE A3.1 PROBABILITY OF FAILURE TO SHUTDOWN ON DEMAND

A 3.1.10. Orientation of Release

The direction of the release will affect the radiation impact in the event of an ignition of a gas release. There are no data readily available for the probability of flame direction; however consideration of the failure mechanisms gives some insight into the direction of jet releases.

Depending on the cause of the release, pinholes due to corrosion and holes due to mechanical defects can occur at any location around the pipe circumference. This could result in a jet release in any direction.

Releases from the top of the pipeline will create a hole to the surface and release to atmosphere. Releases at the bottom of the pipeline will create a crater and, depending on the size of the release, the jet flame will tend to be obscured by the edges of the crater, limiting the effects adjacent to the pipeline. Lateral releases will scour the ground adjacent to the pipeline creating a crater which will tend to deflect the jet in an upward direction (nominally 45°).

A pipeline rupture will result in a catastrophic release, creating a massive crater and could potentially result in fragments of pipeline being ejected from the crater. The direction of the resulting jet flame release has been reported to occur longitudinally in some cases, i.e. the release occurs in the direction of the open end of the pipeline. However, depending on the extent of pipeline bending and damage that has occurred, the direction of release could be to the side or upwards. No statistical data on the direction of rupture releases was found.

The most likely cause of pipeline releases is external interference which will generally be from above and to a lesser extent from the side. The potential for jet fires in a downward direction was included in the directional probability for vertical releases. Based on this it was assumed that 80% of the jet fires (50mm releases and ruptures) would be in a vertical direction and 20% in a horizontal direction as shown in Figure A3.2. For pinhole leaks, it was assumed that the likelihood of release would 50% in the horizontal direction and 50% in the vertical direction.

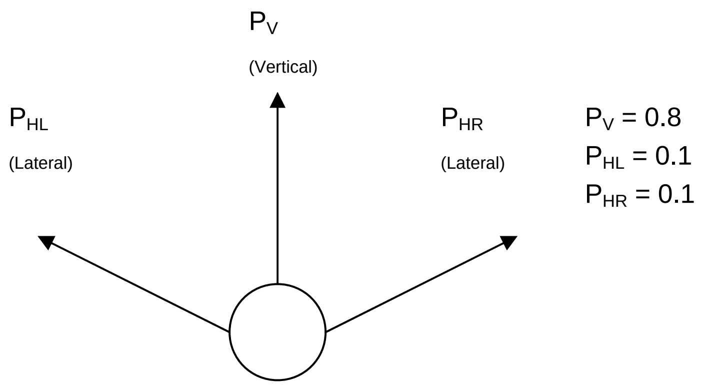

FIGURE A3.2 PROBABILITY OF JET FLAME DIRECTION

A 3.1.11. Jet Fire Frequencies

The resulting frequencies of jet fires shown in Table A3.7 were calculated using the following:

- The frequency of pipeline release, incorporating the risk reduction of safeguards (from Table A3.4)
- The probability of ignition (Table A3.5)
- The probability of isolation of pipeline ruptures (from Section A 3.1.9)
- The probability of jet release orientation (from Section A 3.1.10)

TABLE A3.7: SUMMARY OF JET FIRE INCIDENT FREQUENCIES (BASE CASE)

Case	**Jet Fire Frequency (per-1000km-yr)**			
	Pinhole (10mm hole size)	**Puncture (50mm hole size)**	**Rupture (Depressuring Release)**	**Rupture (Isolation Failure)**
Releases at 45° from Vertical				
Base Case	1.92E-03	1.67E-04	5.08E-04	3.62E-05
Vertical Releases				
Base Case	1.92E-03	1.34E-03	4.06E-03	2.90E-04

APPENDIX 4. REFERENCES

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