PLANNING PROPOSAL 49-65 WENTWORTH AVENUE AND 80-120 PACIFIC HIGHWAY, DOYALSON

HAZARD ANALYSIS

DOYALSON WYEE RSL CLUB LIMITED

PREPARED FOR:	**Doyalson Wyee RSL**
DOCUMENT NO:	**21490-RP-001**
REVISION:	**2**
DATE:	**16-Jun-2021**

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DOCUMENT REVISION RECORD

Rev	Date	Description	Prepared	Checked	Approved	Method of issue
A	18-Dec-2020	Issued to Client for comments	P. Johnson V. Bhasin	J. Polich	S. Chia	Email PDF
0	22-Jan-2021	Final issue	V. Bhasin	J. Polich	S. Chia	Email PDF
1	07-Jun-2021	Updated to address DPIE comments	V. Bhasin	J. Polich	S. Chia	Email PDF
2	16-Jun-2021	Included Jemena correspondence reference	V. Bhasin	J. Polich	S. Chia	Email PDF

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ABBREVIATIONS

ALARP	As Low as Reasonably Practicable
APGA	Australian Pipelines and Gas Association
AS	Australian Standard
CFD	Computational fluid dynamics
DA	Development Application
DBYD	Dial Before You Dig
DG	Dangerous Goods
DPIE	Department of Planning, Industry and Environment
HAZID	Hazard and Identification study
HIPAP	Hazardous Industry Planning Advisory Paper
HSE	Health and Safety Executive
HSL	Health and Safety Laboratory
IGEM	Institute of Gas Engineers and Managers
IOGP	International Association of Oil and Gas Producers
LEP	Local Environment Plan
MAOP	Maximum Allowable Operating Pressure
MSB	Mine Subsidence Board
QRA	Quantitative Risk Assessment
SEPP	State Environmental Planning Policy
SMS	Safety Management Study (as per AS 2885)
TPA	Third Party Activity

1. SUMMARY

1.1. Overview

Urbis Pty Ltd (Urbis) is assisting Doyalson-Wyee RSL Club Ltd ('Club Ltd') with development of an urban structure plan which involves rezoning a site (45 ha) owned by Club Ltd located in Doyalson, NSW adjacent to the Pacific Highway. The overall site currently includes the RSL and various active outdoor recreational land uses.

The planning proposal for redevelopment of the site incorporates low density residential dwellings, seniors living housing, hotel accommodation, businesses such as childcare, medical centre and service station, recreational facilities and relocation of the RSL.

The site is crossed by a licensed high-pressure gas underground pipeline operated by Jemena under the requirements of the Australian Standard series AS/NZS 2885 *Pipelines - Gas and liquid petroleum* (AS 2285). In the event of a leak from the pipeline, there is a risk from fire and heat radiation or flame engulfment to any neighbouring populations.

1.2. Study requirement

The NSW *State Environmental Planning Policy (SEPP) (Infrastructure) 2007*, Ref [1], provides risk assessment requirements for development adjacent to pipeline corridors and the NSW Department of Planning, Industry and Environment (DPIE) requires a risk assessment as part of the planning proposal submission.

Urbis engaged Sherpa Consulting Pty Ltd (Sherpa) to undertake a risk assessment to assist Club Ltd to satisfy the Department of Planning, Industry and Environment (DPIE) requirements and to respond to the Gateway determination issued by DPIE on 12/10/2020.

1.3. Scope

The risk assessment was undertaken in consultation with Jemena using the methodology in DPIE's guideline *Hazardous Industry Planning Advisory Paper No 6 Hazard Analysis* (HIPAP 6, Ref [2]) to demonstrate compliance with the risk criteria in *Hazardous Industry Planning Advisory Paper No 10 Land Use Safety Planning* (HIPAP 10, Ref [3]).

The study scope included:

- Confirming pipeline design and operating parameters, and obtaining comments on proposed land uses with the pipeline operator, Jemena for input to the risk assessment.
- Identifying the potential gas leak scenarios and associated likelihood and consequence of ignited gas leaks.
- Quantitatively assessing the individual risk from the pipeline.

- Assessing the societal risk associated with the current and future populations for the development area.

Industry guidance available from the Institute of Gas Engineers and Managers (IGEM) and the UK Health and Safety Executive (UK HSE) for risk assessment of cross country pipelines was used to develop the technical assumptions for quantitative risk modelling (Refs [4] [5]).

1.4. Conclusions and recommendations

The pipeline risk assessment results demonstrate that:

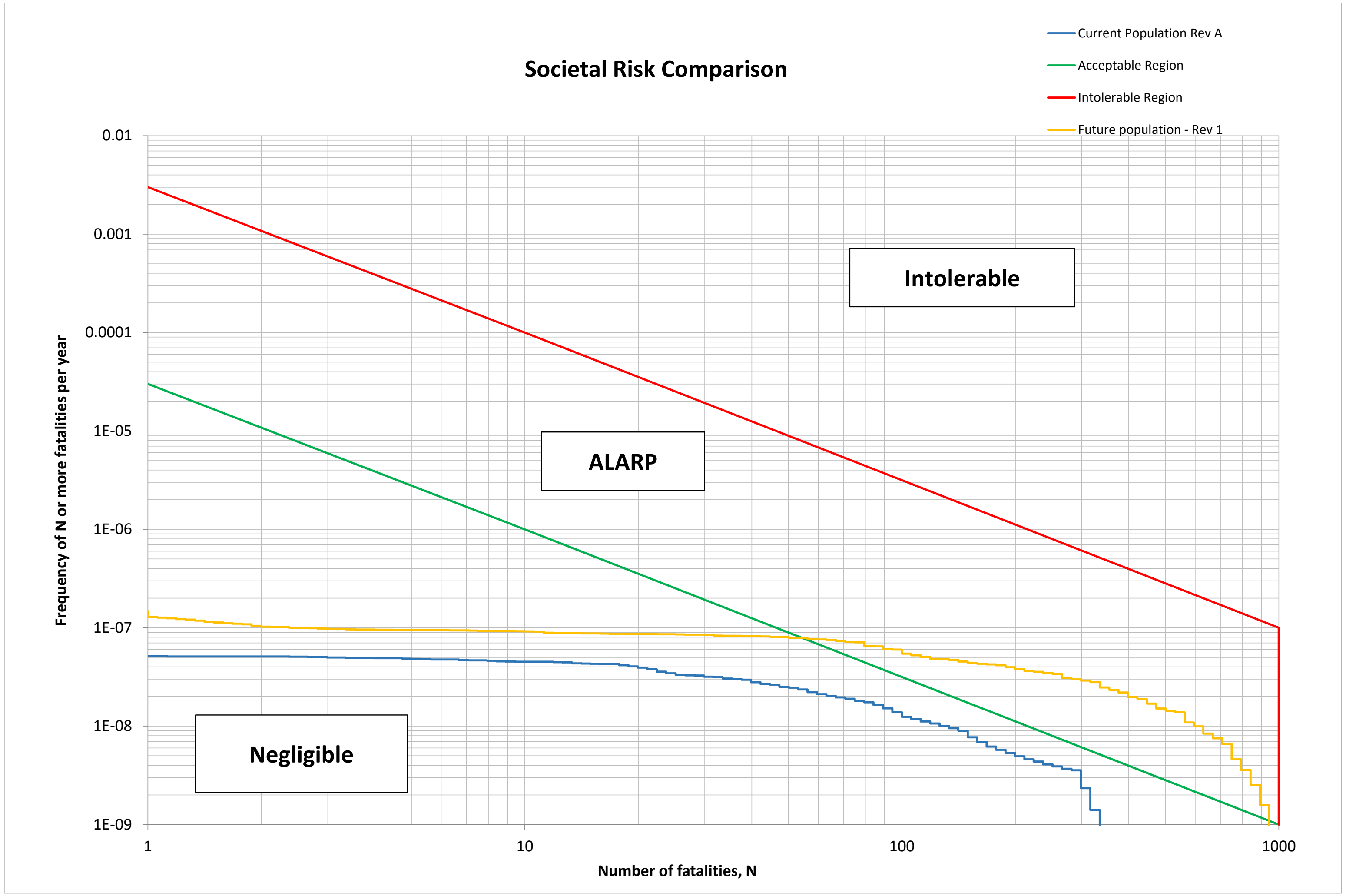
- The maximum calculated pipeline fatality risk is approximately 7.2 x 10^{-8} per year. This is below all risk criteria values for any defined land use in HIPAP10. Therefore all HIPAP 10 quantitative individual fatality and injury risk criteria are met for current land uses and future land use defined in the Planning Proposal.
- The societal risk FN curves are shown in Figure 1.1. These do not extend into the intolerable area for either current or future population cases. The future FN curve extends into the 'as low as reasonably practicable (ALARP)' region. It is within the negligible region for the current case. The maximum number of people (N) potentially affected is 945, below the maximum limiting criterion (1000) for N.

This project is at the planning proposal stage and is not a development application (DA) for specific buildings or other facilities. The risk results demonstrate that the planning proposal land uses are compatible with the pipeline risk levels. Jemena has also provided written advice that it has no objections to the proposed planning changes in proximity to its high pressure licenced pipeline including the senior living dwellings and other proposed sensitive land uses subject to the relevant updates to the AS 2885 Safety Management Studies (SMS) being carried out at the DA stage (Ref [6]).

Whilst the quantitative risk criteria are met, to satisfy the principal of reducing risk ALARP, potential mitigation options to further reduce societal risk should be considered as part of any specific design for development approval. Potential options for future consideration as to whether they are reasonably practicable include, but are not limited to:

- Selecting non-combustible building materials and fire rating of building walls and roofs nearest to the pipeline easement.
- Escape routes from buildings to direct people away from the pipeline.
- Setting a 'reasonably practicable' setback to occupied areas if risk cannot be demonstrated to be ALARP by adoption of other measures.

Figure 1.1: Societal risk comparison



2. INTRODUCTION

2.1. Background

Urbis Pty Ltd (Urbis) is assisting Doyalson-Wyee RSL Club Ltd ('Club Ltd') with development of an urban structure plan for a site owned by Club Ltd located in Doyalson adjacent to the Pacific Highway. The site is approximately 45 hectares and is part of a planning proposal process.

The planning proposal development area is crossed by a licensed high-pressure gas pipeline (between 100 and 110 Pacific Highway) operated by Jemena (refer to Figure 2.1).

Section 66C of the *State Environmental Planning Policy (SEPP) (Infrastructure) 2007*, Ref [1], provides context and specifies the notification and assessment requirements for development adjacent to a pipeline corridor as follows:

66C Determination of development applications

(1) Before determining a development application for development adjacent to land in a pipeline corridor, the consent authority must—

(a) be satisfied that the potential safety risks or risks to the integrity of the pipeline that are associated with the development to which the application relates have been identified, and

(b) take those risks into consideration, and

(c) give written notice of the application to the pipeline operator concerned within 7 days after the application is made, and

(d) take into consideration any response to the notice that is received from the pipeline operator within 21 days after the notice is given.

(2) Land is in a ***pipeline corridor*** for the purposes of this clause if the land is located—

(a) within the licence area of a pipeline for gas, or for petroleum or other liquid fuels, licensed under the *Pipelines Act 1967*, or

(b) within 20m of the centreline (measured radially) of a relevant pipeline, or

(c) within 20m of land the subject of an easement for a relevant pipeline.

(3) The following pipelines for gas, or for petroleum or other liquid fuels, are ***relevant pipelines*** for the purposes of this clause—

(a) the pipelines with licence numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 32, 33, 35 and 42 licensed under the *Pipelines Act 1967*,

(b) the Clyde to Gore Bay pipeline.

Further information is provided in the DPIE Planning Circular PS 18-010 *Development adjacent to high pressure pipelines transporting dangerous goods*), Ref [7].

Whilst this project is not yet at the devlopment application stage, consistent with Section of 66C of the SEPP, DPIE has included the following requirements in their gateway determination for the planning proposal:

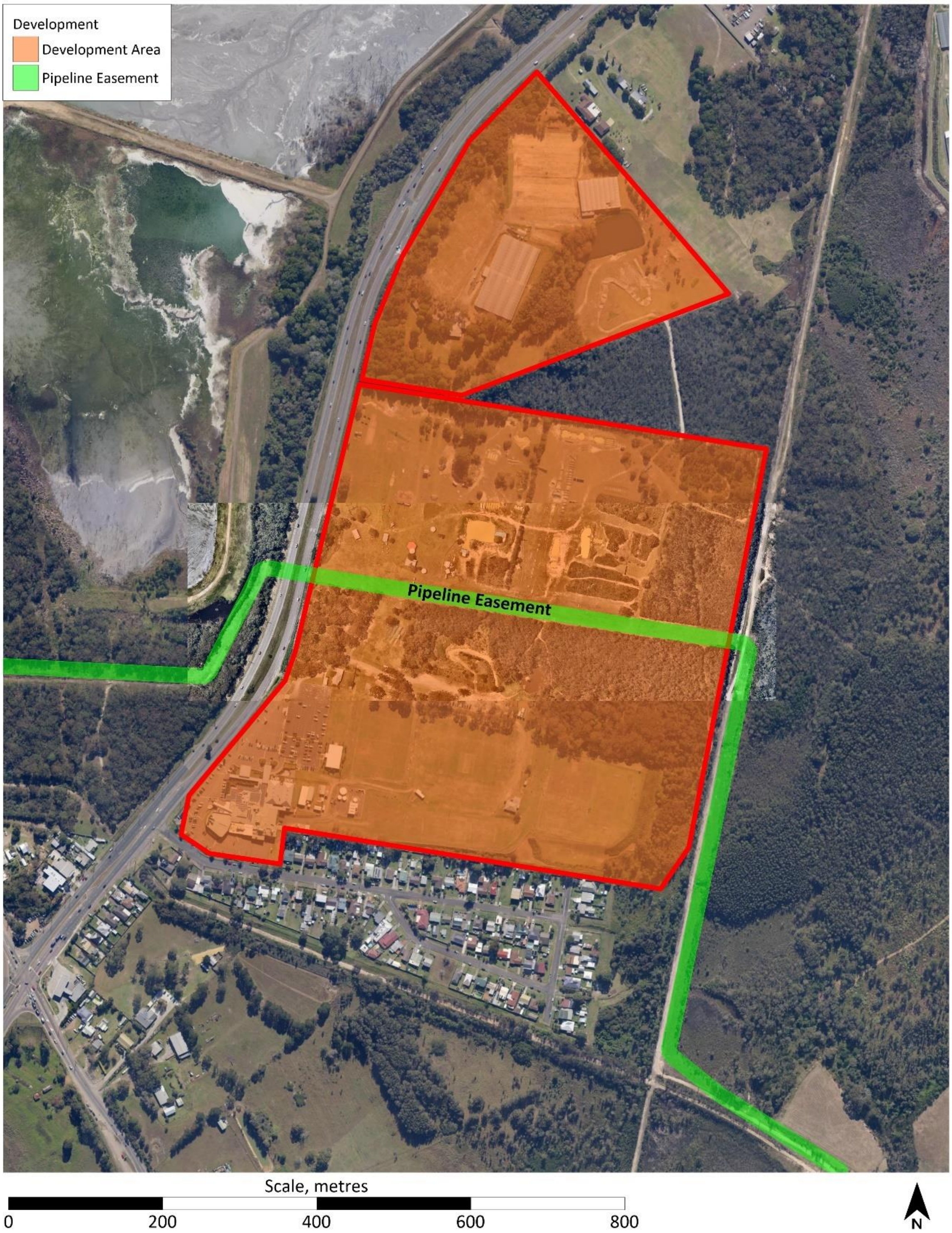
Extract from: Gateway Determination Planning proposal (Department Ref: PP_2020_CCOAS_005_00) 12 Oct 2020:

1. The resubmitted planning proposal should:
   (a) include a risk assessment in consultation with Jemena to demonstrate compliance with the risk criteria in Department's '*Hazardous Industry Planning Advisory Paper No. 10 'Land Use Safety Planning*' (HIPAP 10) guideline. The risk assessment is to be consistent with Department's '*Hazardous Industry Planning Advisory Paper No. 6 Hazard Analysis*' (HIPAP 6) guideline to assess the risk (individual and societal) from the pipeline to all the population introduced through the planning proposal;
   (b) ensure the existing high-pressure pipeline can continue to comply with AS 2885 requirements throughout the life of the proposed development by consulting with Jemena;

Urbis engaged Sherpa Consulting Pty Ltd (Sherpa) to undertake the risk assessment to assist Club Ltd to satisfy requirement 1(a), above.

Requirement 1(b), related to compliance with AS 2885 is not included in the scope of the risk assessment however Jemena has been involved in the consultation process as per Section 4.1.

Figure 2.1: Development area location



2.2. Objectives

The objectives of the study are as follows:

1. In consultation with the developer and Jemena, undertake a risk assessment consistent with HIPAP 6 to demonstrate compliance with the quantitative risk criteria in HIPAP 10.
2. Provide recommendations indicating, if the development can proceed as proposed, with amendments or with risk mitigating measures.

2.3. Scope

The study scope is limited to:

- the pipeline including the 500 m that traverses the development area, plus approximately 500 m to the west of the area and 800 m to the east and south of the area.
- population at the development area (current and future).
- population in the surrounding area up to approximately 300 m from the northern boundary and approximately 500 m in all other directions.

There were no other pipelines or facilities with significant inventory of hazardous materials identified around the vicinity of the Jemena pipeline traversing the study area.

2.4. Approach

The following activities were completed:

- Consultation with Jemena to establish the operational and physical equipment basis for the risk assessment and obtain any comments relating to proposed land uses.
- Consultation with the proponent to establish the location and proposed occupancy of buildings.
- Quantitative risk assessment to provide information on the risk posed by the pipeline to the proposed rezoned land uses and associated potential populations.
- Assessment of the current societal risk and change in societal risk associated with the potential new population.
- Comparison of the risk against the quantitative risk criteria specified in HIPAP No. 10 Land Use Safety Planning, Ref [3].
- Identification of risk treatment options if the criteria is not met.

2.5. Exclusions and limitations

The exclusions and limitations for this report are provided in Table 2.1.

Table 2.1: Exclusions and limitations

No	Exclusions and limitations	Remarks
1.	Pipeline information	The pipeline operator, Jemena, has provided the information for pipeline design and operating conditions. The assessment has been based upon the current operating conditions as advised by Jemena. No further verification by Sherpa was carried out.
2.	AS 2885 Safety Management System (SMS) updates	There is an existing pipeline AS 2885 SMS which is owned by the pipeline operator. Jemena has provided information to Sherpa extracted from the SMS to inform the risk assessment. The entire SMS is not contained in the risk assessment report. Any updates or addendums to the pipeline SMS are not within scope of this report. A Land Use Change SMS would need to be prepared by the pipeline operator should this proposal proceed to the development stage.
3.	Construction phase risk	Risks during the construction phase are excluded from this assessment. Risk issues related to construction phase will need to be addressed in accordance with AS 2885 via a construction SMS report.
4.	Escalation risk	As per the GHD Services Report and DBYD reports there are no other dangerous goods (DG) pipelines in the vicinity. Therefore, escalation risk is not relevant and is not assessed.
5.	Societal risk	The current and proposed population densities have been provided by the proponent. Any population surveys are outside the scope of the study. Any changes beyond the proposed population density (e.g. increase in area allocated to seniors living, alternative higher density land uses than assumed for low density housing) will require an update to this assessment.
6.	Qualitative risk criteria	HIPAP10 contains qualitative as well as quantitative risk criteria. The starting point of this assessment is the site layout and scale of development consistent with the proposed rezoning (i.e. limited to R2 low density residential and RE2 private recreation) developed as part of the Planning Proposal which accounts for other constraints (e.g. mine locations). Other potential layouts, lower density or less sensitive land uses are outside the scope of this study.

3. PLANNING PROPOSAL DESCRIPTION

3.1. Development description

The objective of the planning proposal is to rezone the development area and amend the planning controls to allow for:

- relocation and expansion of Doyalson-Wyee RSL Club
- redevelopment of the area to incorporate low density residential dwellings, 'seniors living' housing, medical facilities, childcare centre, service station, food outlets, hotel accommodation
- expand the recreation facilities to include an indoor sport facility, go kart track, paintball and expansion of the existing Raw Challenge course.

3.2. Zoning

The current and proposed future zoning for the development area is shown in Figure 3.1 (the development area boundary is the red line). Currently the site is zoned transition to the north and private recreation to the south.

The future zoning will be private recreation to the north and low density residential to the south.

3.3. Land use and populations

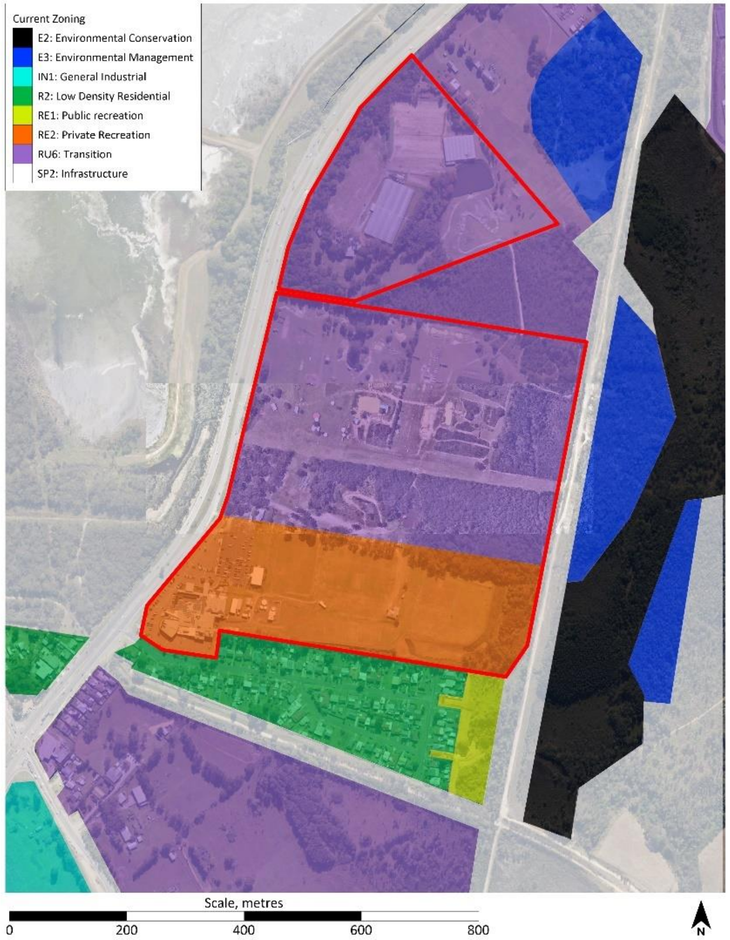
Refer to Figure 3.2 for the proposed current and future land uses for the development area (within red boundary) accounting for the rezoning.

Table 3.1 following Figure 3.2 provides a descriptive summary of changes in population in line with the planning proposal rezoning.

Additional information concerning changes in population can be found in APPENDIX A.

Figure 3.1: Current and future zoning

Current Zoning



Future Zoning

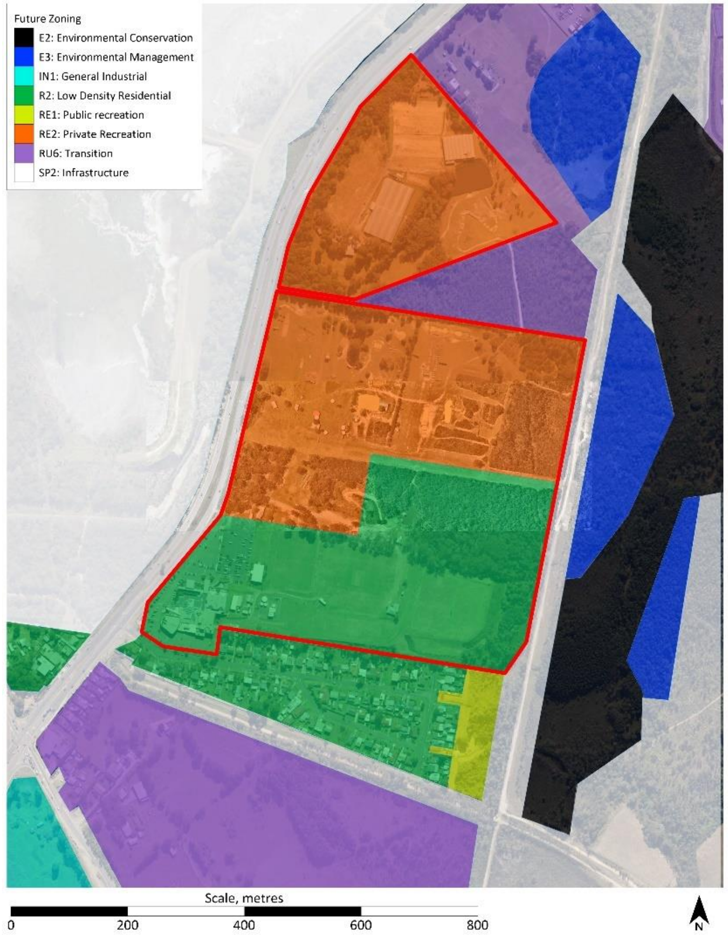


Figure 3.2: Development description and associated land use changes

Current

Future

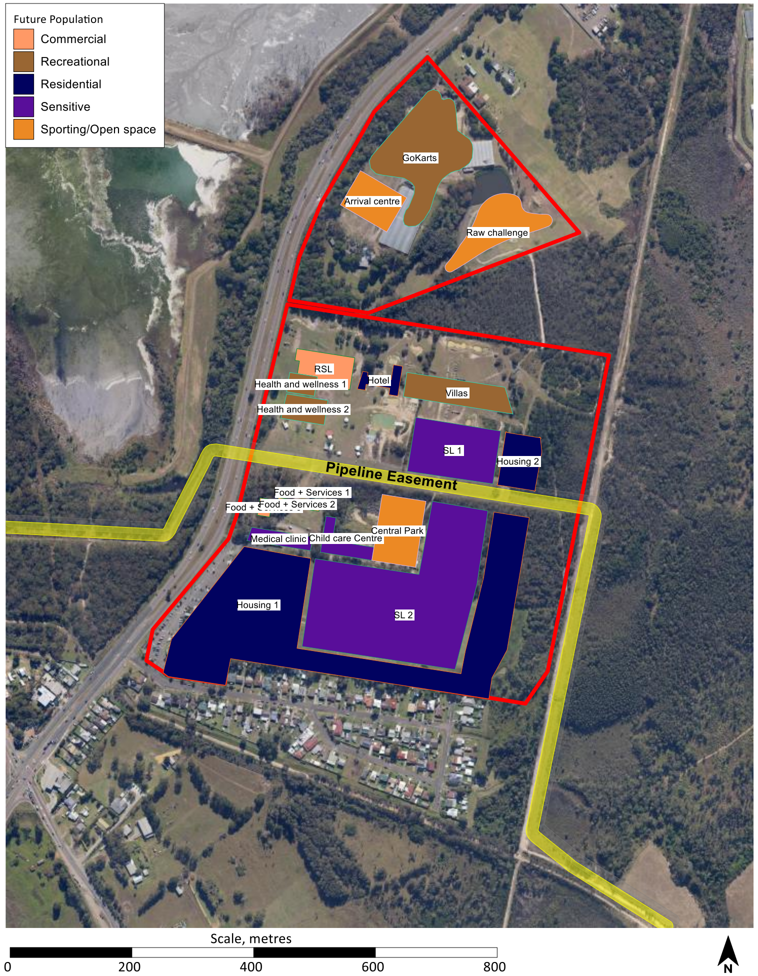


Table 3.1: Population comparison

	Colour	Current	Future
Residential housing		No population within the boundary. Nearest residential housing is approximately 330 m south of the pipeline.	Development includes: - 141 residential units - 220 seniors living units. Nearest residential housing is approximately 18 m north of the pipeline.
Commercial uses		RSL consists of approximately 300 patrons and staff, with periodic peak populations. It is approximately 120 m south from the pipeline.	Population numbers are not expected to significantly change. The RSL will move approximately 130 m north of the pipeline. New commercial areas have been included in the development proposal (e.g. medical centre, health wellness etc).
Recreational/open space uses		Oval is approximately 150 m from the pipeline, with periodic usage for events. Raw challenge area (active recreational usage) is used for challenges and approximately 20 m from the pipeline.	The oval will be replaced with residential development. Raw challenge area (active recreational usage) will transition to more commercial usage with smaller groups reducing the population and is moving approximately 350 m from the pipeline. Additional recreational areas have been included in the development proposal.

3.4. Pipeline details

The Colongra Gas Transmission and Storage Pipeline crosses the development site. The overall Colongra pipeline includes 3.5 kilometres of 10 inch (nominal diameter) feeder pipeline, a 42 inch (nominal diameter) storage pipeline, a compressor station that increases gas pressure from 3.4MPa to 13MPa and a let-down station. It is the largest onshore gas pipeline in Australia and is double looped to create nine kilometres of pipeline storage in a three kilometre stretch of land.

The pipeline location has been identified via Dial Before You Dig (DBYD), consultation with Jemena, and a survey as per the Services Report prepared by GHD (Ref [8]). The development area and the location of the pipeline easement are shown in Figure 2.1. The development area is crossed by the 42 inch storage pipeline. The approximate route of the pipeline and where it crosses the development is shown in Figure 3.3.

Sherpa obtained pipeline details including operating conditions as shown in Table 3.2 by consultation / confirmation with Jemena as summarised in Table 4.1.

Table 3.2: Pipeline details

Parameter	Unit	Jemena response
Affected kp	-	kp10.3 to kp11.3 [(a)]
Material transported	-	Natural gas [(a)]
Size of easement	-	20 m [(a)] in total with pipeline in the centre of the easement
Operating pressure	kPa(g)	3,400 to 13,000 [(a)]
Max Allowable Operating Pressure (MAOP)	kPa(g)	13,000 [(a)]
Pressure used in the risk assessment quantification	kPa(g)	13,000 [(a)] (i.e. equal to MAOP)
Usage time – by product type	%	Assumed 100%[(a)]
Burial depth underground (depth of cover)	m	Greater than 1.2 [(a)]
Diameter	mm	1050 [(a)]
Wall thickness	mm	24 [(a)] Wall thickness of approximately 14mm required for pressure containment. Additional wall thickness provided to meet AS2885 no rupture requirements.
Critical defect length	mm	334 [(a)]
AS 2885 'no rupture' pipeline	-	Yes [(a)] The pipeline is designed in accordance with the requirements in AS2885.1 clause 4.9.2 for high consequence areas (which covers residential / sensitive land uses), i.e. it is a 'no rupture' pipeline.
Flow rate (maximum, any limitations)	m^3/hour	Not available [(a)]

Parameter	Unit	Jemena response
Any other equipment in area of pipeline adjacent/crossing site (e.g. valve stations, recompression, other possible leak points etc.)	-	None [(a)]
Known defects in the area or other relevant information to pipeline integrity	-	None [(a)] (Hydrotesting to 1.25 of MAOP confirms all defects in the steel and welding have been tested. Periodic pigging for inspection purposes)
Additional mitigation in segment if relevant, e.g. concrete covers, additional depth of cover, additional wall thickness	-	No covers [(a)] Isolation valves many kilometres from the development site. Isolatable segment of the storage pipeline from compressor station is approximately 9 km long in total including loops. Additional wall thickness as per comments above. Pipeline is coated and has cathodic protection.
Pipeline route	-	Obtained from Jemena [(b)]
Notes: (a) Various emails from Dario Stella (Dario.Stella@jemena.com.au) to Jenny Polich (Sherpa), November 2020 – January 2021, May 2021. (b) Email from Robert Campbell (Robert.Campbell@jemena.com.au) to Phil Johnson (Sherpa), 20 November 2020		

Figure 3.3: Pipeline route

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4. METHODOLOGY

4.1. Consultation with pipeline operator

With the agreement of Urbis, Sherpa co-ordinated contact with Jemena (the pipeline operator). Consultation was carried out by emails and telephone to confirm initial pipeline details obtained from a dial before you dig (DBYD) request. Consultation was limited to establishing the basis for modelling the pipeline and understanding Jemena's requirements for rezoning and development adjacent to the pipeline corridor.

At the request of DPIE in comments on the initial submission of the hazard study in January 2021 (as per email from Nicholas Hon, DPIE 19 April 2021 and subsequent discussions), additional consultation with Jemena was undertaken by Sherpa over April to May 2021 to obtain further input in relation to the inclusion of potentially sensitive land uses in the planning proposal R2 and RE2 areas close to the pipeline.

This consultation did not result in any revision to the planning proposal layout / land uses as shown in Figure 3.2. However Urbis has advised that a special provision clause could be proposed under the Local Environment Plan (LEP) to restrict sensitive land uses (as defined under the HIPAP) within close proximity of the pipeline should this be needed to resolve any future Jemena feedback. Jemena subsequently advised by letter it has no objection to the proposal (June 2020 Ref [6]).

The consultation history is summarised in Table 4.1.

Table 4.1: Consultation with Jemena

No	Reference	With	Interaction
1	17 November 2020 (email)	Danny Guerrera Lands Management	Initial acknowledgment of enquiry.
2	20 November 2020 (email)	Jemena (Dario Stella and Robert Campbell), Engineering	Provision of pipeline details, see Table 3.2 including confirmation of no rupture design as per AS2885. Provision of pipeline shape file for use in the risk model.
3	24 November 2020 (telecon)	Jemena (Dario Stella), Engineering	Discussion on key issues/concerns related to the pipeline. In summary, Jemena's main concern related to the construction phase, which would be assessed separately as per AS 2885.
4	14 December 2020 (email)	Jemena (Dario Stella), Engineering	Additional design details re ground movement from AS 2885 study provided.
5	18 December 2020 (email)	Jemena (Dario Stella and Robert Campbell), Engineering	Draft hazard analysis report provided to Jemena for comment.
6	April, May 2021 (email)	Jemena (Dario Stella), Engineering	Additional design details supplied demonstrating compliance with AS2885 no rupture design.

No	Reference	With	Interaction
7	Various dates May 2021 (phone and email)	Luke Duncan Lands Management	Discussion to re-confirm if Jemena had further comments on potentially sensitive land uses included in the planning proposal close the pipeline. Verbal advice from Jemena to Sherpa was that Jemena's preference was to avoid aged care and childcare centres and other less mobile populations close to pipeline. Seniors living in itself was not a concern unless this lead to future assisted living / aged care facilities. No advice or preferences for specific distances / separation distances was provided by Jemena. DPIE advised they had confirmed this position with Jemena (email DPIE to Sherpa, dated 2 June 2021). NOTE: Urbis (planning consultant) has advised that a special provision clause could be proposed under the Local Environment Plan (LEP) to restrict sensitive land uses (as defined under the HIPAP) within close proximity of the pipeline should this be required to address future Jemena feedback.
8	7 June 2021 Letter (Ref [6])	Luke Duncan Lands Management	Jemena provided written advice to DPIE that it has no objection to the proposed planning changes in proximity to its high pressure licenced pipeline including the Senior Living dwellings and other proposed sensitive land uses subject to the relevant updates to the AS 2885 Safety Management Studies (SMS) being carried out at the DA stage.

4.2. Hazard analysis

The overall approach to the hazard analysis followed the guidance provided in HIPAP No. 6 *Hazard Analysis*, Ref [2], and risk management process outlined in AS ISO 31000:2018 *Risk management – Principles and guidelines,* Ref [9].

Industry technical guidance for risk assessment of cross country pipelines was used to develop the technical assumptions used in the modelling (Refs [4] [5]).

The main steps were:

1. Establish context, scope and criteria

   This activity includes identification of the pipeline details, land rezoning proposal and risk criteria appropriate for assessment.

To commence the study, Sherpa contacted the hazards branch at DPIE to agree on the context and scope of the hazard analysis and consulted with the pipeline operator Jemena.

2. Risk identification

   This activity identifies events that may lead to loss of containment event from the pipeline, based on existing hazard identification information and informed by consultation with the pipeline operator.

3. Risk analysis

   Risk analysis combines the consequence and frequency information to determine the risk posed by the pipeline. The pipeline risk was assessed in the form of a quantitative risk assessment (QRA) as follows:

   - Consequence analysis: to determine the consequence impact following a loss of containment event from the pipeline and undertaken using commercial software models Gexcon Effects and DNVGL PHAST.
   - Frequency analysis: to determine the failure frequency of the pipeline based on gas pipeline specific data sources and input from the pipeline operator.

   Individual and societal risk posed by the pipeline was quantified using Gexcon Riskcurves software.

   Estimated population data (current and proposed) was used to quantify the change in societal risk posed by the pipeline to the proposed development.

4. Risk evaluation

   Risk evaluation includes assessment of risk against the HIPAP No. 10 land use planning criteria for individual risk and societal risk, Ref [3].

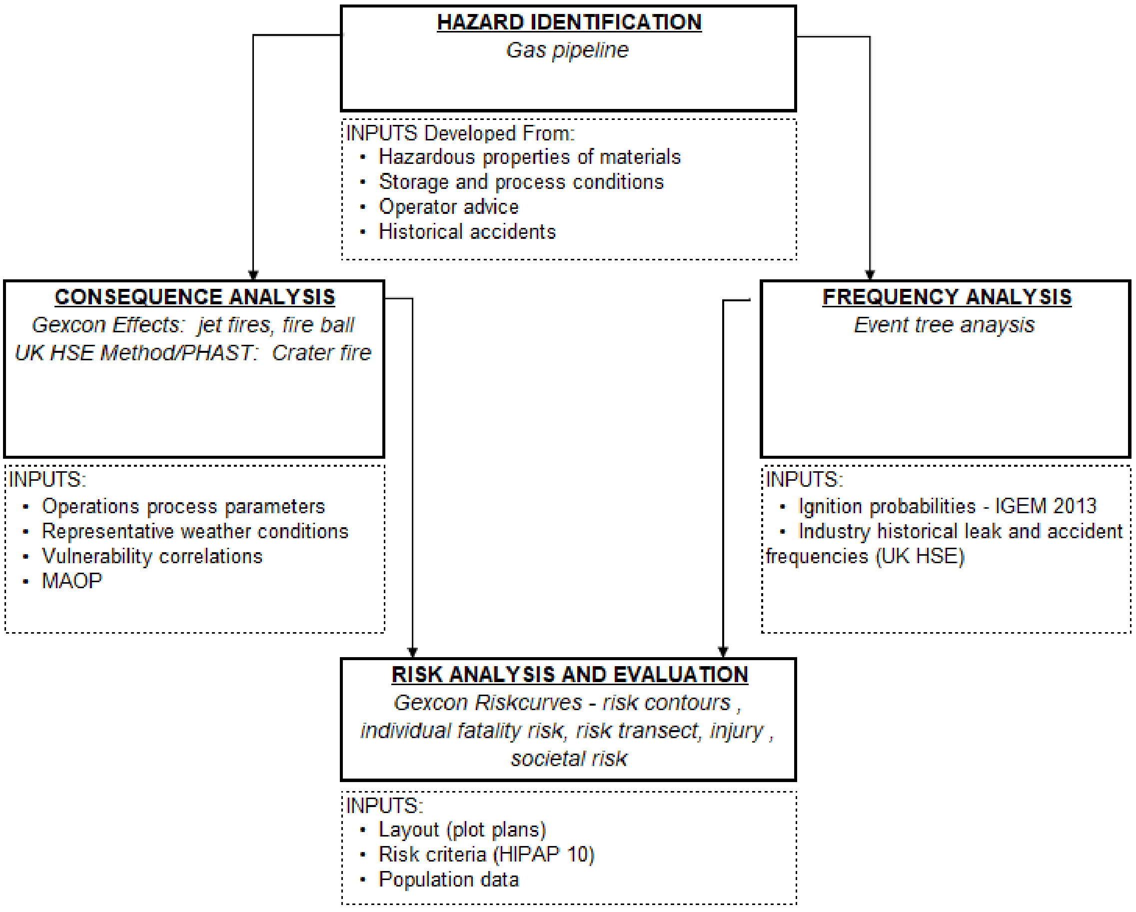
   Existing and proposed land zoning were both compared against criteria to determine the impact of proposed rezoning.

5. Risk treatment

   This activity (if required) included determination of potential risk treatment options where the risks do not comply with the land use planning criteria.

Refer to Figure 4.1 for the hazard analysis methodology.

Figure 4.1: Hazard analysis methodology



4.3. Quantitative risk criteria

4.3.1. Individual risk

For this study, risks were assessed using the risk criteria provided in the NSW DPIE publication HIPAP No. 10, *Risk Criteria for Land Use Safety Planning* (Ref. [3]), which are reproduced in Table 4.2.

Table 4.2: HIPAP No. 10 land use planning criteria

Description and land use	Criteria (per year)
Individual fatality risk	
Hospitals, child-care facilities and old age housing (sensitive land uses). ***No intensification of sensitive use development should take place***	5×10^{-7}
Residential developments and places of continuous occupancy such as hotels and tourist resorts (residential land use). ***No intensification of residential use development should take place[(a)]***	1×10^{-6}
Commercial developments, including offices, retail centres and entertainment centres (commercial land use).	5×10^{-6}
Sporting complexes and active open space areas.	1×10^{-5}
Target for lease/facility boundary.	5×10^{-5}
Injury risk – heat radiation not exceeding 4.7 kW/m^2	
Residential and sensitive use.	5×10^{-5}
Injury risk – explosion overpressure not exceeding 7 kPa	
Residential and sensitive use.	5×10^{-5}
Injury risk – toxic exposure[(b)]	
Residential and sensitive use areas. Seriously injurious to sensitive members of the community following a relatively short period of exposure.	1×10^{-5}
Residential and sensitive use areas. Irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community.	5×10^{-5}
Notes: (a) Residential intensification may be appropriate for a 'pre-mitigation risk' of less than 1×10^{-5} per year and a mitigated risk of less than 1×10^{-6} per year. (b) Toxic injury risk criteria is not relevant as natural gas has no acute toxicity properties.	

The individual fatality risk criteria for land use safety planning are the peak individual risk, which is a conservative measure as it is based on 24 hour-per-day exposure with no allowance for the protection buildings may offer or for the potential to move away and escape from a developing incident.

These risk tolerability criteria have been chosen by the NSW DPIE so as not to impose a risk that is significant when compared to the background risk to which people are normally exposed.

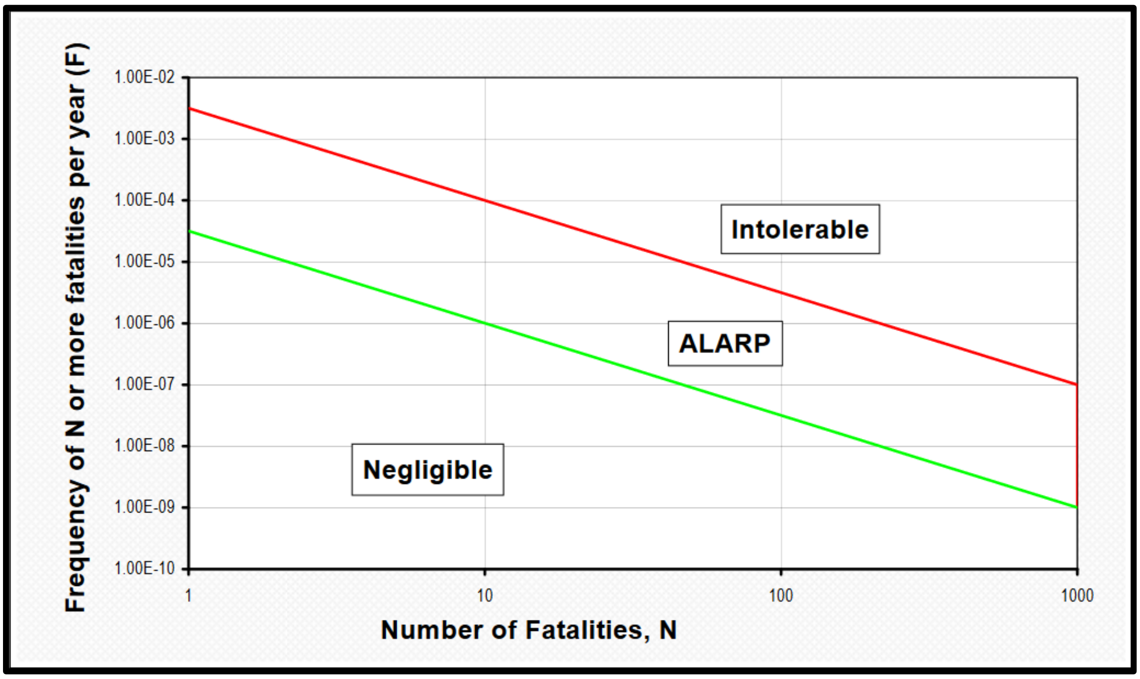
4.3.2. Societal risk

Societal risk criteria cover multiple fatality situations. Where a development proposal involves a significant intensification of population in the vicinity of a potentially hazardous facility, the change in societal risk needs to be considered, even if individual risk criteria are met.

The incremental societal risk should be compared against the indicative criteria of Figure 4.2. This includes an upper limit of affected population (i.e. N<1000) as shown by the vertical red line on the right side of the graph.

Provided the incremental societal risk lies within the negligible region, development should not be precluded. If incremental risks lie within the ALARP region, options should be considered to relocate people away from the affected areas. If, after taking this step, there is still a significant portion of the societal risk plot within the ALARP region, the proposed development should only be approved if benefits clearly outweigh the risks.

Figure 4.2: Indicative societal risk criteria



4.4. Qualitative risk criteria

HIPAP10 also states that irrespective of the numerical value of any risk criteria level for risk assessment purposes, it is essential that certain qualitative principles be adopted concerning the land use safety acceptability of development.

The starting point for this hazard analysis is that rezoning with a layout developed to suit other site constraints is proposed in the vicinity of an existing high pressure gas pipeline. In this context the broad assessment of the planning proposal against the qualitative criteria is provided in Table 4.3.

DPIE has advised that their consultation will continue with Jemena in relation to the planning proposal to ensure that any further inputs relating to qualitatively reducing the risk are assessed and addressed if found to be 'reasonably practicable'.

Table 4.3: HIPAP10 qualitative risk criteria

HIPAP 10 qualitative principle	Planning proposal context
(a) All 'avoidable' risks should be avoided.	The pipeline is existing and cannot be relocated, decommissioned or operating parameters modified to reduce the hazard in any significant way.
(b) The risk from a major hazard should be reduced wherever practicable.	The pipeline is already designed as a no-rupture pipeline as per AS2885 and must operate at the stated pressures and flow to supply the power station. Therefore additional risk reduction at source is not likely to practicable. The pipeline is also managed in accordance with the statutory requirements of AS2885 to ensure integrity is maintained.
(c) The consequences (effects) of the more likely hazardous events (i.e. those of high probability of occurrence) should, wherever possible, be contained within the boundaries of the installation.	The boundary of the pipeline 'site' is the easement boundary. It is not possible to contain the effects of events within this. However as per the consequence modelling (APPENDIX C) impacts from more likely events (25mm or smaller leaks resulting in vertical jet fires) would remain within the easement.
(d) Where there is an existing high risk from a hazardous installation, additional hazardous developments should not be allowed if they add significantly to that existing risk.	In the context of this study, a 'high' risk is interpreted as a risk where HIPAP 10 quantitative risk criteria are not met. The purpose of the hazard analysis is to demonstrate the quantitative risk criteria can be met by the planning proposal. Therefore if the hazard study results show the risk is 'high' (i.e. does not meet quantitative criteria) the planning proposal cannot proceed in the proposed form without modification. (Refer to Section 8 for risk results which demonstrate compliance with quantitative risk criteria, i.e. risk is not 'high').

5. HAZARD IDENTIFICATION

5.1. Overview

Hazard identification (HAZID) comprised the following steps:

- Review of past incidents involving natural gas pipelines.
- Review of external natural hazards or environmental conditions and their potential impact on the pipeline.
- Identification of hazardous incident scenarios (including external natural hazards), which have been recorded in a hazard identification word diagram (APPENDIX B).
- Development of scenarios to carry forward for assessment.

5.2. Natural gas

A representative composition of natural gas is shown in Table 5.1. Natural gas contains mainly methane, which is flammable between 5–15 vol% and is a simple asphyxiant. On release, the gas tends to rise as it has a lower density than air at ambient conditions.

Table 5.1: Natural gas composition

Component	Composition (%)
Methane	97.1 – 97.5
Ethane	0 – 0.1
Butane	<0.001
Pentane	<0.001
Carbon dioxide	0.1
Nitrogen	2.3 – 2.6
Hydrogen sulphide	0

5.3. Incident review

A high level review of available literature was undertaken to identify whether there had been reported incidents involving loss of containment of natural gas from pipelines and aboveground facilities. A number of incident databases were consulted, in particular the *eMars database* (EU) and the *Australian pipeline incident database.* The Australian Pipelines and Gas Association (APGA) has developed an Australian specific incident database that covers the period between 1965 and 2010. This includes statistics relating to damage incidents, which covers loss of containment incidents, damage to the coating or pipe caused by mechanical equipment and other defects that require either reduction in the maximum operating pressure or pipe repair.

Based on the incidents reviewed, the following observations were made:

- A number of incidents involving natural gas releases from pipelines have been recorded.

- The majority of the leaks were not ignited and therefore did not result in fatality/injury.
- There has never been a death or injury recorded in connection with damage to a pipeline in Australia.

5.4. Hazard identification table

Hazards to people and property that were identified include the following:

- Release of natural gas from the transmission pipeline due to:
  - Corrosion (internal or external)
  - Mechanical failure (e.g. due to vehicle impact and material defects)
  - External events (e.g. third party damage, ground movement).

Potential causes and consequences including external hazards are identified in the hazard identification word diagram in APPENDIX A.

Safeguards to mitigate the risks associated with the identified hazards are also summarised in APPENDIX A.

5.5. Scenarios assessed

The potential consequences of natural gas releases from the pipeline have been developed from the guidance in the Institute of Gas Engineers and Managers *Assessing the risks from high pressure Natural Gas pipelines* (IGEM, Ref. [5]). These include:

- **Jet fire**: immediate ignition of a natural gas leak (i.e. non-rupture leak) from a pressurised inventory. The fire size is a function of the rate of flammable material released, which is in turn a function of pressure and release hole size.
- In the event of immediate ignition following a pipeline rupture, a **fireball** may occur.
- In the event of delayed ignition, a **crater fire** would occur. In the event that the natural gas release is not ignited immediately, the flammable vapour jet impacts the ground and is released from the whole cross section of the pipeline crater.

The UK Health and Safety Executive (UK HSE, Ref [10]) guidance indicates that as natural gas is lighter than air, a flammable mixture at ground level with a potential flash fire is very unlikely, and historical incidents do not result in large flammable gas clouds. Computational fluid dynamics (CFD) calculations and experimental work carried out at Loughborough University indicate that ground-level flash fires are unlikely for high pressure pipeline releases of methane. Buoyant behaviour becomes apparent so ignition by remote ignition sources at ground level is not possible and it is the UK HSE's policy not to model flash fires for pipelines conveying natural gas. (Ref [11].

Therefore flash fires / vapour cloud explosions were not quantitatively assessed in this study.

5.6. Escalation

There were no escalation scenarios identified as follows:

- There are no other hazardous material pipelines in the gas pipeline easement so escalation between pipelines is not applicable.
- There are no escalation targets in the proposed development facilities (such as significant sized LPG vessels or toxic inventories) whose failure would result in escalation of the initial event.

6. CONSEQUENCE ANALYSIS

6.1. Overview

Consequence analysis was undertaken for the scenarios identified in Section 5.5.

The consequences of the hazardous scenarios were modelled using the following:

- Jet fire – Gexcon Effects v11.2.1
- Fireball – TNO Yellow book methodology (Ref [12])
- Crater fire – PHAST v8.23. UK HSE HSL (Ref. [4]) and Journal of Loss Prevention (Ref [13]) methodology was used as a basis for estimating the crater diameter for crater fire calculations.

Inputs for consequence analysis are summarised in Section 6.2. The consequence analysis results are reported in terms of distances to specified levels of harm. These levels correspond to the land use planning criteria for fatality and injury (Section 6.3).

A summary of the consequence results for each of the hazardous scenarios assessed is shown in Section 6.3 and detailed results are provided in APPENDIX C.

6.2. Modelling inputs

6.2.1. Process conditions

Table 6.1 summarises the process conditions used to model the scenarios identified in Section 5.5 as provided by Jemena.

Table 6.1: Process conditions selected for consequence analysis

ID	Hazardous scenario	Pressure (barg)	Temperature (°C)	Pipeline diameter (mm)	Wall thickness (mm)
PIP-01	Release of natural gas from high pressure gas transmission pipeline (underground steel)	130	25	1050	24

6.2.2. Representative hole sizes

Loss of containment was modelled by selecting a representative hole size in each of the hole size ranges from the leak frequency data discussed in Section 7.2. Leak frequency data typically indicates that smaller hole sizes within a range dominate (IOGP, Ref. [14]). In this case the upper end of the hole size range has been selected as basis for modelling as summarised in Table 6.2.

Table 6.2: Release scenarios and hole sizes

Release scenario	Representative hole size
Pinhole release, due to corrosion or defects (d≤ 25mm)	25 mm diameter
Small hole release (25<d≤75mm)	75 mm diameter
Large hole release (75<d≤110mm)	110 mm diameter
Maximum hole size (d>110mm)	Pipeline diameter (double sided pipeline release)
Notes: - Critical defect length confirmed by Jemena as 334mm - Equivalent diameter to critical defect length is 114mm using UK HSE correlation as per APPENDIX C, failures larger than this hole size will propagate to rupture. Therefore 110mm as per UK HSE data is an appropriate upper limit hole size. Modelling of larger hole sizes not required.	

6.2.3. Release rates

Releases were modelled as follows:

- Jet fires - Releases from all hole sizes (not ruptures) were modelled as initial maximum release rate at the pipeline pressure (i.e. no allowance for depressuring of the pipeline).
- For pipeline rupture, the following approach was used:
  - Fireball – the amount of fuel for the fireball was estimated by using UK HSE (Ref. [10]) mass/duration correlation. Maximum mass of 300 tonnes and maximum duration of 30 seconds.
  - Crater fire - it is assumed, the flammable vapour cloud would take time to reach its full extent and as it develops, the release rate will decrease due to pressure drop along the pipeline. For the pipeline rupture scenario, the pipeline blowdown rate 30 seconds after rupture was used. This is consistent with the approach in Appendix Y of AS 2885.1 for its radiation contour calculation.

6.2.4. Release orientation

Releases from the buried transmission pipeline were modelled as horizontal and vertical releases.

6.2.5. Meteorological data

Historical meteorological weather data for the area for input to risk modelling was obtained from the Bureau of Meteorology (BoM). The data set was obtained from the Newcastle weather station, Ref [15] and the consolidated data used for this analysis is in APPENDIX E.

6.3. Assessment criteria

To determine the impact of fires on people and property, it is necessary to relate their physical effects (e.g. heat radiation) to different levels of harm (i.e. probability of fatality). The consequence criteria (i.e. levels of harm) used in this study are shown in Table 6.3.

These criteria are based on the levels given in HIPAP 4.

Table 6.3: Consequence criteria for people

Event	Level	Probability of fatality assumed in QRA (1)	Other effects
Jet fire/crater fire (Heat radiation)	4.7 kW/m2	-	Injury only as per HIPAP 4
	12.6 kW/m2	33%	-
	23 kW/m2	95%	-
	35 kW/m2	100%	Often this will be within the flame envelope
	Within flame envelope	100%	-
Fireball	Diameter of fireball	100% fatality within the diameter of the fireball projected onto the ground. Heat radiation outside the diameter of the fireball is calculated as per the probit equation for fires, but using the estimated fireball duration	-

NOTES:

1) TNO Green Book probit used to convert heat radiation/thermal dose to probability of fatality

$Pr = -36.38 + 2.56 \ln (tQ^{1.33})$

Assumed 30 sec exposure

Pr	probit corresponding to probability of death	(-)
Q	heat radiation level	(W/m2)
T	exposure time	(s)

6.4. Results

Table 6.4 summarises the consequence distances for the scenarios. Detailed results are contained in APPENDIX C.

Modelling results for heat radiation are based on receptors located at 1.5 m above ground level. The results show:

- Using the UK HSE correlation (Ref [10]) the fireball mass is 300 tonnes and impact area extends up to 554 m for a full bore rupture for 1% fatality. This affects the development proposal area.
- Fatality effects from a crater fire from a full bore rupture extend up to approximately 700m which affects the development proposal area.
- For jet fires, consequences from the most likely scenario (a vertical jet from a leak of up to 25mm) would be contained within the easement area. Larger holer sizes have fatality effects extending up to approximately 175 m (horizontal jets) which affect the development proposal area.
- The crater diameter is 13.8 m. This diameter is contained within the pipeline easement area.

Table 6.4: Consequence results summary

Stream tag	ID	Consequence	Hole size (mm)	Maximum distance to (m)[(a)]						
				1% Fatality	4.7 kW/m²		12.6kW/m²		23 kW/m²	
					Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal
Transmission pipeline	PIP_01	Jet fires	005	N/A	7	14	5	12	3	10
			043	N/A	55	103	32	88	18	82
			091	N/A	103	205	59	174	28	161
		Fireball[(b)]	RUP	554	N/A	N/A	N/A	N/A	N/A	N/A
		Crater fire	RUP	N/A	1047	N/A	702	N/A	528	N/A

Note:
(a) N/A indicates that a particular consequence is not relevant (e.g. fireballs only occur in the event of immediate ignition following a pipeline rupture)
(b) Fireball mass as 300 tonnes

7. ESTIMATION OF FREQUENCY OF HAZARDOUS EVENTS

7.1. Overview

The likelihood or frequency of an event is the number of occurrences of the event over a specified time period, generally taken as one year. The likelihood of each scenario was estimated using event tree analysis (refer to APPENDIX D), taking into account the following factors:

- Leak frequencies from pipelines (including reduction factors relevant to the specific pipeline design and location)
- Ignition probability
- Release orientation.

APPENDIX D shows the event tree following a failure of pipeline and leak of natural gas. The event tree was developed based on IGEM methodology (Ref [5]).

7.2. Leak frequencies

The leak frequencies for buried steel pipelines used in this study are from UK HSE HSL database (Table 72, Ref. [4]), as summarised in Table 7.1. These are broadly consistent with Australian data sources.

Table 7.1: Base leak frequencies for buried steel pipelines

Modes of failure	Definition	Leak failure rates by hole size (per km-yr)			
		Pinhole (d≤ 25mm)	Small hole (25<d≤75mm)	Large hole (75<d≤110mm)	Rupture (d>110mm)
Mechanical failure (d≥305mm)	Mechanical and construction faults	8.70E-06	1.00E-08	1.00E-08	1.00E-08
Corrosion (t≥10mm)	Internal and external corrosion	1.00E-07	1.00E-08	1.00E-08	1.00E-08
Ground movement and other	Land movements due to earthquakes, heavy rains/floods, general subsidence of the surrounding earth, as well as operator error	1.20E-05	2.50E-06	1.50E-07	2.50E-06
Third Party Activity (TPA)	Damage from agricultural machinery, damage from heavy plant, damage from drills/boring machines and hot tapping	2.20E-05	2.40E-06	1.00E-07	1.00E-07

7.3. Reduction Factors

7.3.1. Third party activity

The likelihood of Third Party Activity (TPA)/external interference such as excavation damaging a pipeline is affected by the pipeline design.

As per Table 3.2 this pipeline is designed under AS 2885 as a 'no rupture' pipeline. This means that 'credible threats' from third party impact by machinery (e.g. excavators/augers) that may penetrate the pipeline cannot propagate to rupture based on the mechanical design of the pipeline. A TPA 'credible threat' is defined in terms of the machinery weight and tooth type that have been identified in the AS 2885 SMS as potentially in use for activities in the vicinity of the pipeline.

Conservatively, the risk assessment allows for rupture due to excavation by machinery with a penetration capability exceeding the 'credible threat' considered in the AS 2885 'no rupture' design case. The statistical leak frequencies of rupture due to TPA has been reduced using risk reduction factors relating to the pipeline mechanical design and other mitigation factors as per the guidance in IGEM (Ref. [5]) as shown in APPENDIX D. The factors applicable to this pipeline are summarised in Table 7.2.

Table 7.2: Reduction factors for external interference

Factors	Value	Reason
Design factor (Rdf)	1	Not known – no reduction factor assumed. (For factor to be added design factor must be <0.72. This has not been accounted).
Wall thickness (Rwt)	0.1	24mm - outside the upper limit of IGEM Figure 9, i,e. the reduction factor approaching zero (i.e. not a credible event) as shown in the correlation reproduced in APPENDIX D. Assumed to be 0.1 for this assessment (conservative).
Depth of cover (Rdc)	1	1.2m - no reduction factor. The minimum depth of cover has been used based on Jemena information.
Surveillance frequency (Rs)	1	Not included.
Installation of concrete (or equivalent) slab protection (Rp)	1	None.
Overall factor for TPA	**0.1**	

7.3.2. Ground movement

The dominant contribution identified in the statistical leak data for ground movement is landslips. There is no specific risk of landslip identified, however the pipeline is in a mine subsidence area. As advised by Jemena the pipeline has been designed to withstand subsidence (see APPENDIX B for details).

Earthquakes can also cause damage but primarily around an active fault line or an area where soil liquefaction is a risk. Modern, welded ductile steel pipelines, with adequate corrosion protection, (such as the Colangra pipeline) have a good performance record (Ref [16]). The earthquake maps from Geoscience Australia show a low earthquake risk at the site location and there are no active fault lines. Industry data (EGIG 2020) notes there have been no gas pipeline failures due to earthquake in since 1970 and the majority of the pipeline damage events are due to landslide. Earthquake damage is not regarded as a dominant risk in this location for the pipeline as seismic activity is low and this is a modern pipeline with high quality welds and a very high wall thickness. Therefore no adjustment to base frequency data has been made to additionally account for earthquakes.

Conservatively, ground movement was retained as a potential cause of pipeline failure and included in the quantified risk assessment. The total rupture failure frequency due to ground movement (all causes) was calculated based on IGEM guidance (Ref [5]), to account for the pipeline being present in a mine subsidence area. IGEM methodology uses the landslide incident rate per km and survival value (which is based on pipeline wall thickness and diameter) to calculate a rupture failure frequency as per the correlation in APPENDIX D.

This pipeline is very thick walled hence has a high survival value. Refer to Table 7.3 for the parameters used to calculate the rupture frequency due to ground movement.

Table 7.3: Ground movement parameters

Parameter	Value	Comment
Landslide incident rate	2×10^{-5}	IGEM (Ref [5]) Appendix 4 – Weighted average land slide potential.
Survival value	2×10^{-3}	IGEM (Ref [5]) Appendix 4, Figure 15 as reproduced in APPENDIX D. Best estimate survival value is 1×10^{-4} based on the pipeline description 'High quality girth welds with 24 mm wall thickness'. However DPIE advised Sherpa that a conservative approach should be adopted as the survival value assuming poor quality welds (for 24mm wall thickness this is 2×10^{-3}) should be adopted for the assessment.
Overall rupture	4×10^{-8}	Per year.

7.3.3. Frequency used

Taking into account the applicable frequency reduction factors, Table 7.4 shows the overall failure frequencies used in the risk assessment.

Table 7.4: Final failure frequency

Modes of failure	Leak failure rates by hole size (per km-yr)			
	Pinhole (d≤ 25mm)	**Small hole (25<d≤75mm)**	**Large hole (75<d≤110mm)**	**Rupture (d>110mm)**
Mechanical failure (d≥305mm)	8.70E-06	1.00E-08	1.00E-08	1.00E-08
Corrosion (t≥10mm)	1.00E-07	1.00E-08	1.00E-08	1.00E-08
Ground movement and other (includes effect of reduction factors as per Table 7.3)	1.20E-05	2.50E-06	1.50E-07	4.00E-08
Third Party Activity (TPA) (includes effect of reduction factors as per Table 7.2)	2.20E-06	2.40E-07	1.00E-08	1.00E-08
TOTAL	**2.30E-05**	**2.76E-06**	**1.80E-07**	**7.00E-08**
Key:				
(shaded)	Frequencies adjusted by mitigation factors			
(unshaded)	Frequencies as per base steel pipeline statistical data			

7.4. Ignition probability

The probability of ignition following loss of containment from a pipeline is based on data in the IGEM (Ref. [5]) methodology. The following relationship was used to determine ignition probability:

$$P_{ign} = 0.0555 + 0.0137\ pd^2;\ 0 \le pd^2 \le 57$$

and

$$P_{ign} = 0.81;\ pd^2 > 57$$

P_{ign} = probability of ignition
p = pipeline operating pressure (bar)
d = pipeline diameter (m)

Note the following:

- For a rupture case the total probability of ignition is apportioned 0.5 for immediate ignition and 0.5 for delayed ignition.
- For a puncture/small leak case, the same methodology is used, however the hole diameter is applied instead of the pipeline diameter and there is no distinction between immediate and delayed ignition.

A summary of the ignition probabilities used is shown in Table 7.5.

Table 7.5: Probability of ignition for pipelines

Size of Leak	Ignition probability
Pinhole-crack (5 mm)	0.056
Small puncture (43 mm)	0.059
Large puncture (91 mm)	0.070
Rupture Overall Immediate Delayed	 0.81 0.41 0.41

7.5. Release orientation

Releases from the buried transmission pipeline were modelled as horizontal and vertical releases, as follows:

- For pipelines, the main cause of small and large holes is external interference, with damage to the top of the pipeline or a crater with gas ejected vertically. Therefore, it was assumed that 80% of small and large holes and rupture events are in the vertical direction, and 20% in a lateral direction
- Since pinhole releases are typically due to corrosion, which could occur at any point on the pipeline, it has been assumed that 50% of pinhole releases are in a vertical direction and 50% in a lateral direction.

A horizontal orientation was chosen for the 'lateral releases' as a worst case.

7.6. Results

The resulting ignited event likelihoods estimated for the transmission pipeline are shown in Table 7.6.

Table 7.6: Leak and outcome frequencies

TOTAL leak frequency	25mm hole	75mm hole	110mm hole	Rupture
	2.30E-05	**2.76E-06**	**1.80E-07**	**7.00E-08**
Total Fire Frequency (per km.yr)	1.28E-06	1.62E-07	1.27E-08	5.67E-08
Jet fire horizontal fire (per km.yr)	6.39E-07	3.25E-08	2.53E-09	
Jet fire vertical fire (per km.yr)	6.39E-07	1.30E-07	1.01E-08	
Crater Fire (per km.yr)	n/a	n/a	n/a	2.84E-08
Fireball (per km.yr)	n/a	n/a	n/a	2.84E-08
Notes: n/a this frequency has not been assessed as it is not relevant (e.g. fireballs only occur in the event of immediate ignition following a pipeline rupture).				

8. RISK ASSESSMENT

8.1. Overview

Risk assessment involves combining the off-site scenario consequences and their associated likelihoods and comparing against criteria. For the pipeline in this study the individual fatality and injury risk and societal risk were calculated for following two cases:

- Current case – pipeline with current land use zoning
- Future case – pipeline with future land use zoning.

The assessed risks were evaluated against the risk criteria used in the study, as detailed in Section 4.3.

8.2. Individual fatality and injury risk results

Individual fatality risks from the pipeline are presented as risk transects, which show the risk as a function of the perpendicular distance from the pipeline.

Figure 8.1 shows the individual fatality risk transect for both the current case and the future case. The risk transect does not change between these two cases as the pipeline is not changing and remains at the stated operating conditions.

The transect shows the maximum fatality risk is approximately 7 x 10^{-8} per year immediately next to the pipeline and remains in the order of magnitude 10^{-8} up to 550 m from the pipeline.

A comparison against the risk criteria is presented in Table 8.1. As the maximum frequency of 7.2 x10^{-8} per year is below all risk criteria for all land uses, HIPAP individual risk criteria are fully met for both existing and proposed land uses.

Figure 8.1: Individual fatality risk transect

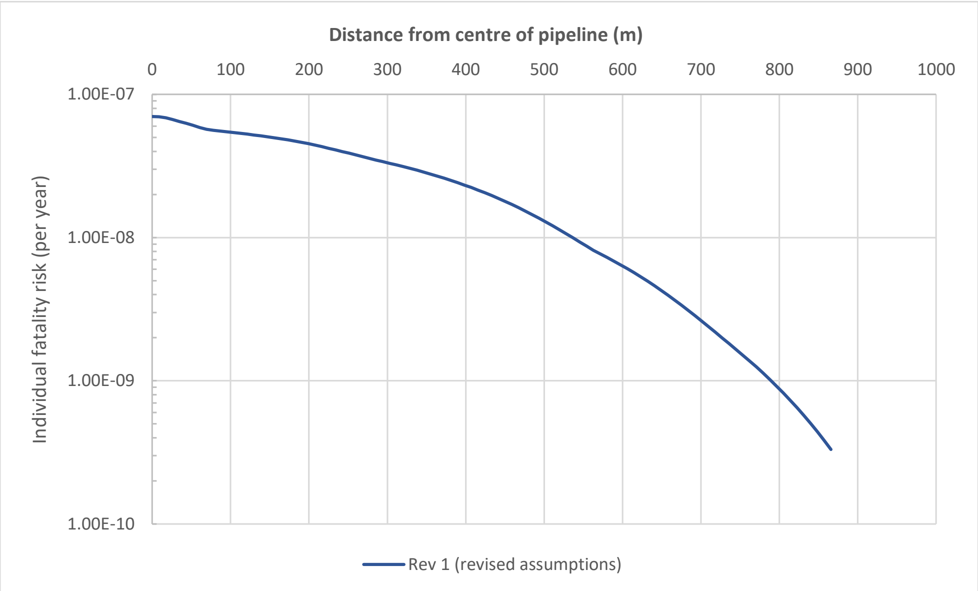


Table 8.1: Individual and injury risk compared with criteria

Description and land use	Criteria (per year)	Discussion
Individual fatality risk		
Hospitals, child-care facilities and old age housing (sensitive land uses). ***No intensification of sensitive use development should take place***	5×10^{-7}	Complies – maximum risk level is below all safety planning risk criteria for all land uses (current and future).
Residential developments and places of continuous occupancy such as hotels and tourist resorts (residential land use). ***No intensification of residential use development should take place***[(a)]	1×10^{-6}	
Commercial developments, including offices, retail centres and entertainment centres (commercial land use).	5×10^{-6}	
Sporting complexes and active open space areas.	1×10^{-5}	
Target for lease/facility boundary.	5×10^{-5}	
Injury risk – heat radiation not exceeding 4.7 kW/m²		
Residential and sensitive use.	5×10^{-5}	Complies – maximum risk level is below injury risk criteria.
Injury risk – explosion overpressure not exceeding 7 kPa		
Residential and sensitive use.	5×10^{-5}	N/A - no explosion overpressure (as per Section 5.5).
Notes: (a) Residential intensification may be appropriate for a ‘pre-mitigation risk’ of less than 1×10^{-5} per year and a mitigated risk of less than 1×10^{-6} per year.		

8.3. Societal risk results

Societal risk provides a method to account for the number of people exposed to a risk as well as the magnitude of the individual risk to each of those people. It is used to ensure that the risk impact on the community as a whole is not excessive.

Surrounding land use population densities assumed for the study are summarised in APPENDIX A.

Unlike individual fatality risk, societal risk allows for mitigation factors such as protection from building, resulting in a reduced thermal radiation indoors, and probability of presence to be included. These have been factored into the calculation as summarised in APPENDIX A.

Calculated societal risk FN curves are shown in Figure 8.2 and Figure 8.3 for the current case and future case respectively.

Figure 8.2: Societal risk curve – current case

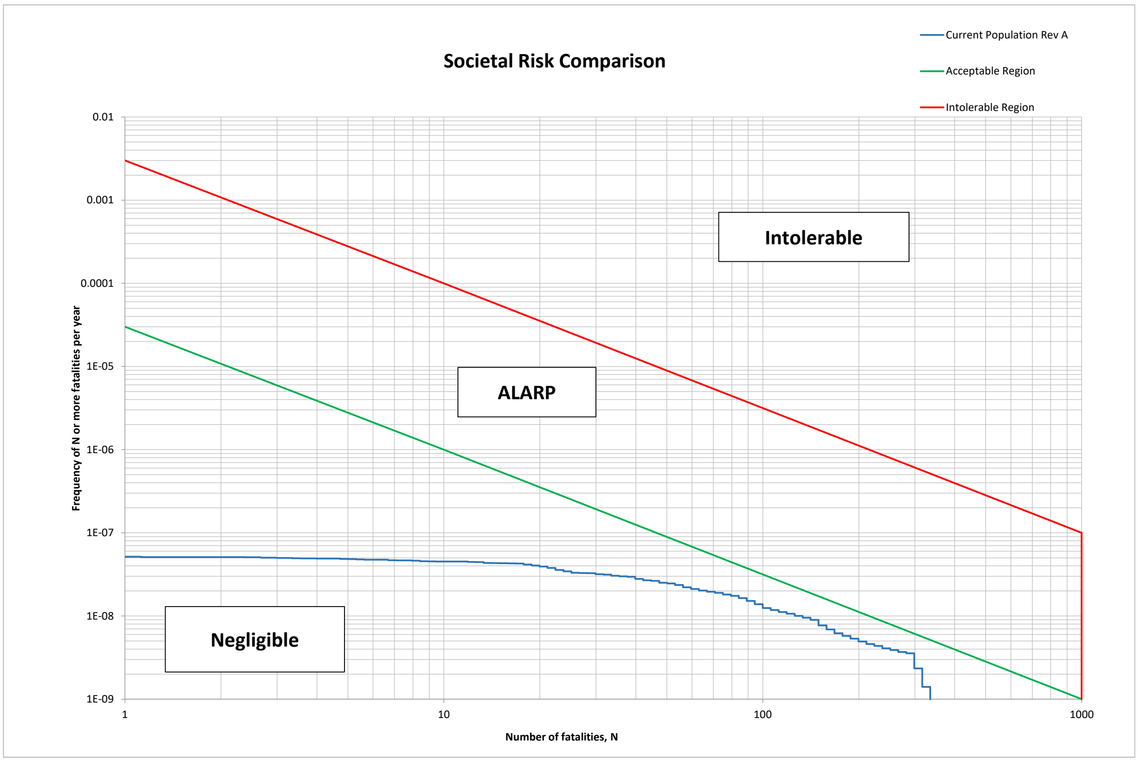
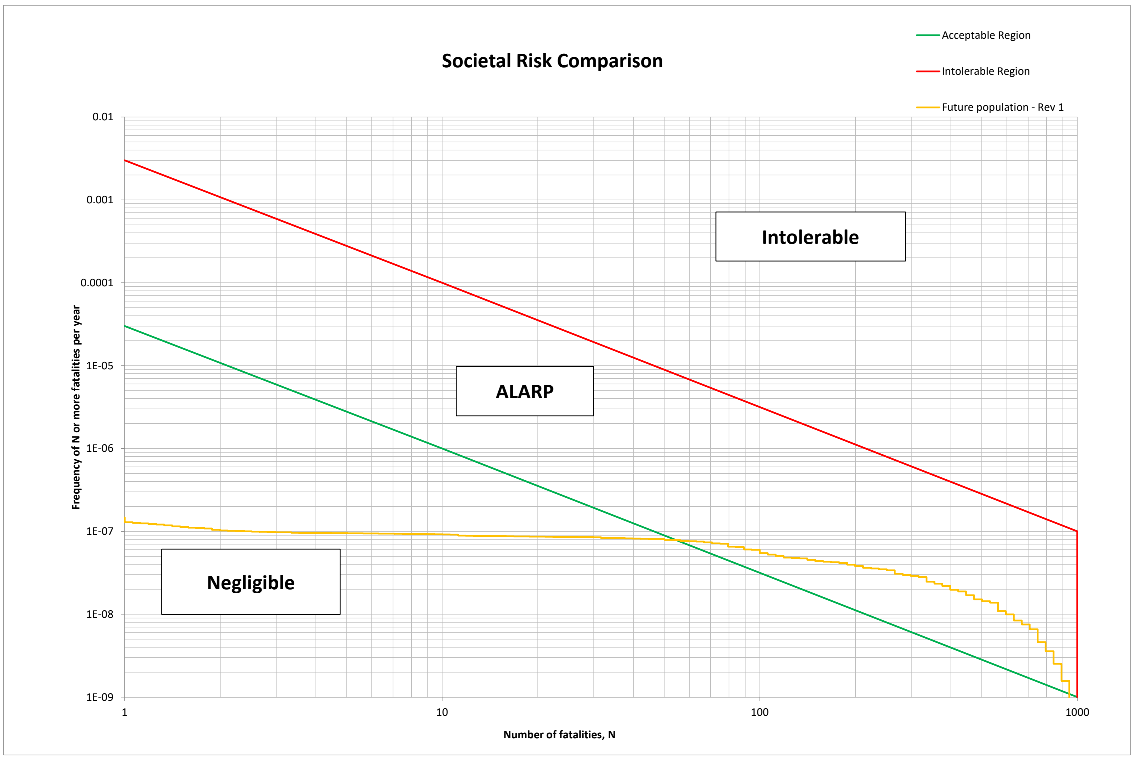


Figure 8.3: Societal risk curve – future case



The current case FN curve is fully within the negligible region, therefore the societal risk is negligible and meets the societal risk criteria.

The future case FN curve moves into the ALARP region in the area on N> 100. Maximum N is 945 and does not exceed the limiting criterion that N does not exceed 1000.

9. CONCLUSION

9.1. Results

An assessment of a planning proposal to rezone the RSL site at 80-120 Pacific Highway, Doyalson which is crossed by a gas pipeline was conducted following DPIE guidance HIPAP 6.

The pipeline risk assessment results demonstrate that:

- The maximum calculated pipeline fatality risk is approximately 7.2 x 10^{-8} per year. This is below all individual risk criteria values for any land use. Therefore HIPAP 10 individual fatality and injury risk criteria are fully met for the current land uses and the future land uses defined in the planning proposal.
- The societal risk FN curves are shown in Figure 1.1. These do not extend into the intolerable area for either current or future population cases. The future FN curve extends into the ALARP region. It is within the negligible region for the current case.

9.2. Recommendations

This project is at the planning proposal stage and is not a development application for specific buildings or other facilities. The risk results demonstrate that the planning proposal land uses are compatible with the pipeline risk levels. Whilst the quantitative risk criteria are met, to satisfy the principal of reducing risk ALARP, potential mitigation options to further reduce societal risk should be considered as part of the detailed design (i.e. at the development application stage).

At a future date any specific design for development approval needs to consider whether anything else in the way of risk reduction is ‘reasonably practicable’ and then implement those ‘reasonably practicable’ design mitigations (cost is an allowable consideration).

Potential options for future consideration include, but are not limited to:

- Selecting non-combustible building materials and fire rating of building walls and roofs nearest to the pipeline easement.
- Escape routes from buildings to direct people away from the pipeline.
- Setting a ‘reasonably practicable’ setback to occupied areas if risk cannot be demonstrated to be ALARP by adoption of other measures.

APPENDIX A. POPULATION FOR SOCIETAL RISK

A1. Overview

The difference in cumulative societal risk has been assessed for this study.

HIPAP 10 societal risk criteria for land use change or population intensification in the vicinity of a hazardous facility are expressed in sense of assessing incremental societal risk (i.e. to new population only). However, for this study the changes involve relocation of existing populations within the effect area of the pipeline ignited leaks, and also new populations. The population set changes due to relocation and different land usage between the cases, therefore the cumulative societal risk has been assessed which accounts for the total population in the redevelopment area currently and the future case.

In discussions with DPIE, Sherpa was advised to also account for population in areas outside the redevelopment area that were affected by the pipeline segment included in the risk assessment. This has been included as per this appendix, Section A3.

A2. Development proposal population

The current onsite population is shown in Figure A.1 and Table A.1. These are modelled as temporary populations as they are not present continuously throughout the year with a fixed number of people.

The proposed future onsite population is shown in Figure A.2 and Table A.2. Residential uses are modelled as fixed populations, as the average day/night populations will be present throughout the year.

Table A.3 shows the RSL population. This population is applicable to both the current and future case. Populations are split between a continuous day/night occupancy and temporary populations to account for the variance (i.e. peak populations) in number of people present throughout the day/week in the RSL.

Figure A.1: Current population area

Table A.1: Current population

Location	People	Fraction		Fraction inside		Fraction of year		Comments
		Day	Night	Day	Night	Day	Night	
Ovals 1	300	1	0	0	0	0.003	0	400 at any one time - (Peak Monday 5pm - 7pm during touch football) 3 months per year, assumed 2 hours per day
Ovals 2	100	1	0	0	0	0.25	0	100 at any time per day, assumed 4 hours per day
Raw challenge	400	1	0	0	0	0.01	0	400 At any one time (Peak 11 am on Saturday). Operates 4 days per year over 2 weekends
RSL	As per Table A.3							

Figure A.2: Future population

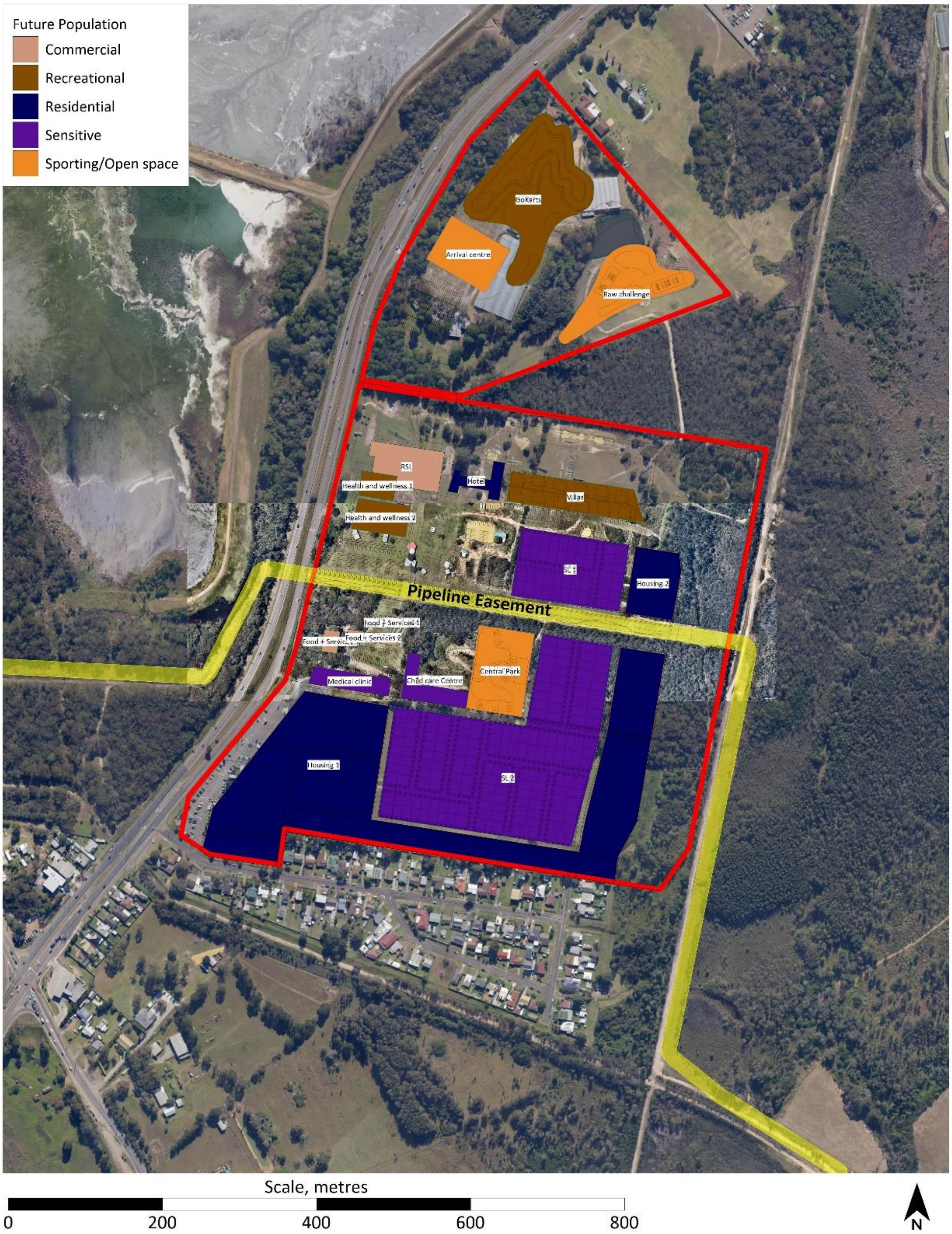


Table A.2: Future onsite population

	Fraction inside		Population	
Location	**Day**	**Night**	**Day**	**Night**
Arrival centre	0.93	0.99	26	0
Central Park	0.93	0.99	17	0
Child care Centre	0.93	0.99	170	0
Food + Services 1	0.93	0.99	17	17
Food + Services 2	0.93	0.99	51	51
Food + Services 3	0.93	0.99	37	37
GoKarts	0.93	0.99	17	0
Health and wellness 1	0.93	0.99	35	0
Health and wellness 2	0.93	0.99	67	0
Hotel	0.93	0.99	75	107
Housing 1	0.93	0.99	227	324
Housing 2	0.93	0.99	20	29
Medical clinic	0.93	0.99	60	0
Raw challenge	0.93	0.99	34	0
SL 1	0.93	0.99	40	58
SL 2	0.93	0.99	160	228
Villas	0.93	0.99	56	81
RSL	As per Table A.3			

Table A.3: RSL population

	People night	**People day**	**Pop. type**	**Day**	**Night**	**Units**
Base RSL (7 days)	287	137	Fixed	-	-	
RSL (Fri/Sat) peak (additional to base)	107	35	Temp.	4.00	4.00	hours/week
RSL peak (additional to base)	205	42	Temp.	2.00	2.00	hours/day

A3. Population outside development area

The surrounding offsite population was estimated based on the TNO Green Book (Ref [17]) data for land use zoning. Refer to Table A.4 for information and Figure A.4 for population.

The population area was taken based on the pipeline consequence which would affect the population beyond the development boundary.

Figure A.3: Surrounding population

Table A.4: Surrounding population

Type of land uses	Total Population	Day population (person/ha)	Night population (person/ha)	Comments
E2: Environmental Conservation	0	0	0	
E3: Environmental Management	5	3.5	5	Central coast council allows certain development with consent in E3 area. As an estimate scattered housing was used.
IN1: General Industrial	40	40	8	
R2: Low Density Residential	25	17.5	25	
RE1: Public recreation	36	36	0	This is not a camping ground so 'little use recreation' was used as best estimate.
RU6: Transition	25	25	5	No information is provided as to what this zone is. On the map there are potentially warehouses, or facilities so therefore quiet residential area was used.

A4. Mitigation factors

Mitigation factors are applied to the vulnerability of people in the societal risk calculations as per Table A.5 for different types of effect.

Table A.5: Mitigation factors

Effect	Comments	Factor Outdoor Population	Factor Indoor Population
Jet fire - heat radiation	No effect indoors as walls provide adequate shielding. As per TNO Purple Book QRA guidance effect of clothing accounted for outdoor population.	0.14	0
Jet fire – within flame zone and to 35 kW/m^2	Engulfment with sustained fuel supply. No additional factors applied.	1	1
Fireball - heat radiation	Short duration event. Indoor populations shielded from effect.	1	0

APPENDIX B. HAZARD IDENTIFICATION WORD DIAGRAM

The hazard identification word diagram is given in this Appendix and shows the leak scenarios identified the pipeline.

Hazard	Cause	Preventative safeguards	Consequence	Mitigative Safeguards	Quantification comments?
Release of natural gas from transmission line (underground steel)	Third party damage / excavation	Pipeline depth of cover, markers and signage. Wall thickness in excess of mechanical design requirement Designed as 'no rupture' pipeline as per AS 2885 clause 4.9.2 as required to meet requirements for high consequence areas within pipeline measurement length.	If ignited, a jet fire, fireball or crater fire would occur, resulting in pipeline damage and potentially: • injury/fatality of personnel (if present) NOTE: A large flammable cloud / explosion was not quantified as natural gas is lighter than air, a flammable mixture at ground level with a potential flash fire is very unlikely.	• Remote monitoring of pressure and flow • Emergency shutdown system • Emergency response procedures	TPA frequency adjusted to account for pipeline design additional wall thickness (refer to Section 7.3).
	Mechanical failure - defects	Inspection and preventative maintenance program. Wall thickness in excess of mechanical design requirement for pressure (actual thickness 24mm compared to approximately 14mm required for pressure containment). Hydrotested to 1.25 x MAOP i.e. defects in the material and welding have been tested			Leak frequency accounts for mechanical failure all causes (refer to Section 7.2) Due to the design, the pipeline is not subject to fatigue failure and there is no case to increase statistical failure frequencies to account for fatigue.
	Mechanical failure - fatigue	The pipeline is designed for full pressure cycles ie 0 to MAOP as per relevant engineering standards. (Normal operating pressure cycles as the pipeline functions as a buffer storage however the operating pressure range is well below a full pressure cycle)			
	Corrosion	Gas is dry / meets moisture specification (to prevent internal corrosion) Cathodic protection and coating of pipeline (to prevent external corrosion) Inspection and preventative maintenance program.			Leak frequency accounts for corrosion (Section 7.2).
	Landslide /subsidence	Site identified as a mine subsidence area (https://www.planningportal.nsw.gov.au/spatialviewer/#/find-a-property/address). This has been accounted for in the pipeline design as per the guidelines provided by the Mine Subsidence Board (MSB)[(a)] which require design for 250 mm subsidence, 2 mm/m strain and 3 mm/m tilt. Jemena conservatively designed the pipeline for 500 mm subsidence.			Frequency adjusted to account for pipeline design and ground movement (refer to Section 7.3).
	Earthquake	Design standards appropriate for potential earthquake loads. According to the earthquake maps the area is classified as a low earthquake hazard [(b)]			No adjustment made – covered by total frequency for ground movement.
	Bushfire	Pipeline is underground therefore cause is not relevant.			N/A

(a) Email [DBYD JOB:20586330 SEQ:103742940 - Wentworth Ave Doyalson NSW 2262 - request for Jemena input to Hazard Analysis, question re subsidence] from Dario Stella (Dario.Stella@jemena.com.au) to Jenny Polich (Sherpa), 14 December 2020, 11:53am

(b) See www.geoscience.ga.gov.au.

APPENDIX C. CONSEQUENCE ANALYSIS METHODOLOGY AND RESULTS

C1. Overview

This appendix documents the consequence analysis methodology and results for the pipeline. In particular, further details are provided on the following:

- Equivalent diameter for critical defect length
- Crater calculation
- Fireball mass correlation

C2. Maximum leak diameter

The most common form of 3rd party damage is a gouge, which is assumed to act as a crack-like defect. Depending upon the depth and the pressure, the gouge will fail as a through wall defect, resulting in a leak. If the length of the gouge is greater than a critical length (which is dependent upon the pipe properties and pressure), the defect will be unstable and fast propagation driven by the energy of the pressurised gas will occur. This will result in a rupture.

As per IGEM guidance (Section A4.2, Ref [5]) the maximum area through which gas escapes at the critical length is usually determined as an equivalent hole size. The formula below has been used in published literature to convert the pipeline critical defect length to an equivalent diameter (Ref [18]).

$$L = (Dt)^{1/2}\left(\frac{A}{7.548 \times 10^{-4}}\right)^{\frac{1}{3.706}}$$

Where:

A is the normalised hole area (i.e. hole area/pipeline internal cross-sectional area)

Pipe diameter:	D (mm)	1050
Crack length:	L (mm)	334
Wall thickness:	t (mm)	24

Resulting in an equivalent diameter: 114 mm.

Note that the calculated equivalent hole diameters are much smaller than the critical defect lengths. This is because the opening crack-like defect through which gas is escaping is long and very narrow, typically with an aspect ratio (width:length) of <0.1.

C3. Inventory in pipeline and flowrates for consequence modelling

The estimated gas inventory in the 1050mm nominal diameter 9km pipeline segment from the compressor station at a pressure if 13,000kPag is approximately 1150 tonnes. If the compressor station is shutdown this is the limiting inventory.

Assuming that this shutdown does not occur (and also assuming the next upstream segment of the pipeline is at 13,000kPag) the total inventory is 2560 tonnes which in PHAST corresponds to an approximately 26km segment of 1050mm pipeline (including the 9km storage pipeline).

Both cases have been assessed to determine the effect of inventory on the release rate at 30 secs (as per AS2885) for modelling impacts from the rupture case. Conservatively the unisolated / larger inventory case has been used in the risk model for ruptures.

For leaks (i.e. hole sizes) inventory is not relevant as the maximum release rate (i.e at zero seconds not allowing for any depressurisation reducing leak rates) has been used to model consequences.

Table C.1 summarises the release rates used in the consequence assessment included in the risk model.

Table C.1: Effect of inventory on release rates

Scenario	Time after release	Flowrate kg/sec	Comments
9km pipeline peak flowrate	0 sec (rupture)	30,575	Double sided flow Not used
26km pipeline peak flowrate	0 sec (rupture)	30,575	Double sided flow Not used
9km pipeline 30 seconds flowrate (i.e. isolated at compressor station)	30 sec (rupture)	5,614	Double sided flow Not used
26 km pipeline 30 seconds flowrate	30 sec (rupture)	10,335	Double sided flow Used for crater fire / rupture scenario Conservative as does not account for isolation / more rapid depressurisation. In any case the compressor would not be able to sustain these rates
25 mm leak	0 sec	12.4	-
75 mm leak	0 sec	111.9	-
110 mm leak	0 sec	240.6	-

C4. Crater

The Journal of Loss Prevention (Ref [13]) provides the following formula to calculate a crater size formed when a pressurised underground gas pipeline ruptures.

Based model can be expressed as

$$CW = 40.795 + 0.382D_p - 0.068P + 4.844D_c - 10.069\gamma - 0.020\rho_{soil}, \quad (15)$$

Table C.2 describes the parameters used to calculate the crater width for this pipeline upon loss of containment.

Table C.2: Parameters for pipeline

	Description	Value	Unit	Ref
D_p	Pipeline diameter	1.05	m	Jemena
		41.3	in	
D_c	Depth of cover	1.2	m	Jemena
P	Pipeline operating pressure	130	bar	Jemena
γ	Specific heat ratio of gas	1.27	-	Table 4 (Ref [13])
ρ_{soil}	Density of soil	1350	kg/m3	Table 4 (assumed silt clay loam, Ref [13])
CW	**Crater width**	**13.8**	**m**	

C5. Fireball mass

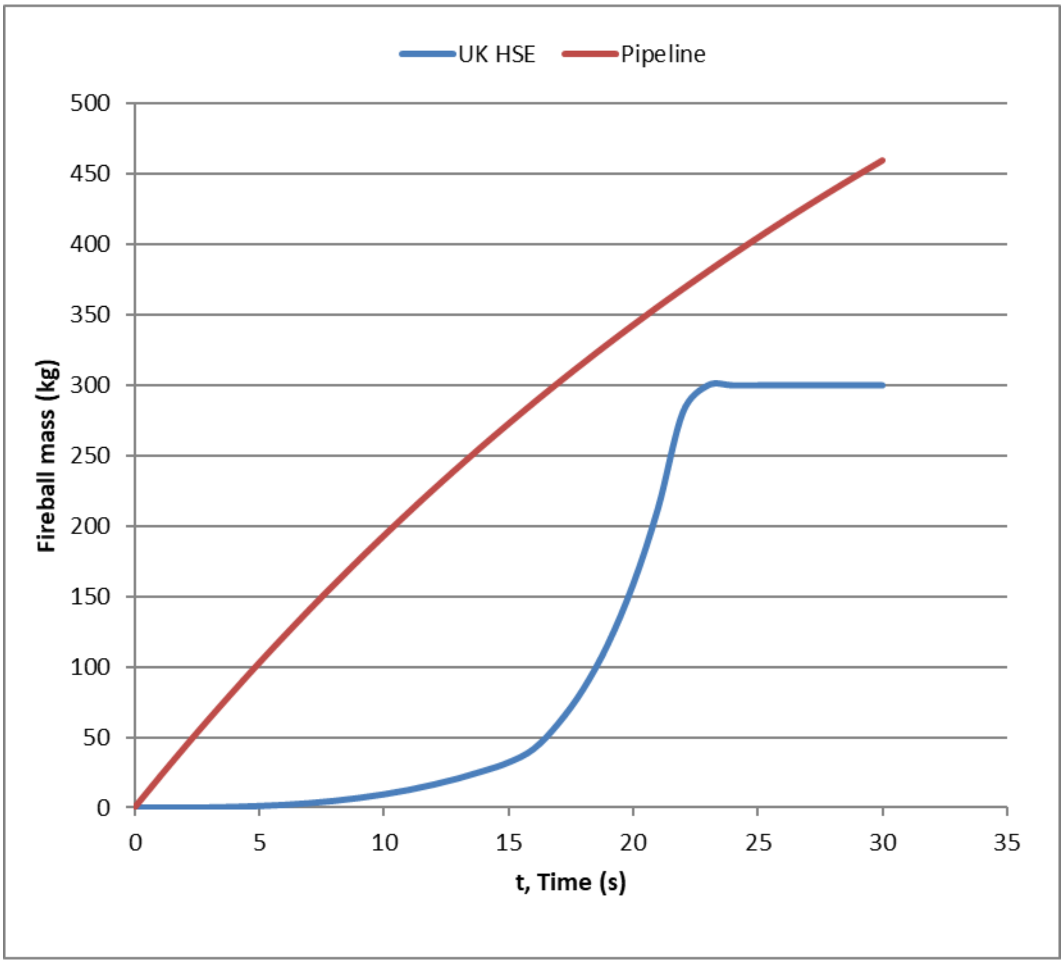
UK HSE (Ref. [10]) uses the following mass/duration correlation to determine the fireball mass.

$$M = Max\ [\ (29t / 4.5A)^3, (29t / 8.2A)^6\ ]$$

Where M is mass in tonnes, t the duration in seconds and A substance specific factor (30.4 for natural gas).

The mass vs time was calculated for the pipeline using Gexcon Effects long pipeline rupture model. This was plotted against the UK HSE correlation described above as shown in Figure C.1. The pipeline is above the correlation and therefore 300 tonnes is used as this is the limit in UK HSE.

Figure C.1: Mass vs time fireball correlation



C6. Results

The consequences of the hazardous events assessed in this study include the following:

- Fireball, in the event of immediate ignition following a pipeline rupture
- Jet fire, if a continuous natural gas release is ignited immediately
- Crater fire, in the event of delayed ignition of a natural gas release

The results of the analysis are shown in Table C.3 to Table C.5.

Table C.3: Consequence analysis results for fireballs

Stream tag	Size (t)	Mass fuel (kg)	Fireball diameter (m)	Duration (s)	Distance (m) to heat radiation			
					Injury	1% Fatality	50% Fatality	100% Fatality
PIP_Fireball	300	300,000	390.5	22.62	1077	554	282	Within Fireball

Table C.4: Consequence analysis results for jet fires

Stream tag	Release				Maximum distance to heat radiation @D8 (m)					
	Pressure (barg)	Temp (ºC)	Orientation	Hole size (mm)	Release rate (kg/s)	Flame length (m)	Flame width (m)	4.7 kW/m²	12.6kW/m²	23 kW/m²
PIP_JF	130	25	Vertical	025	12.4	9	6	34	20	11
				075	111.9	23	17	88	50	23
				110	240.6	32	24	121	69	31
			Horizontal	025	12.4	40	11	63	54	50
				075	111.9	107	30	173	147	135
				110	240.6	150	41	207	175	162

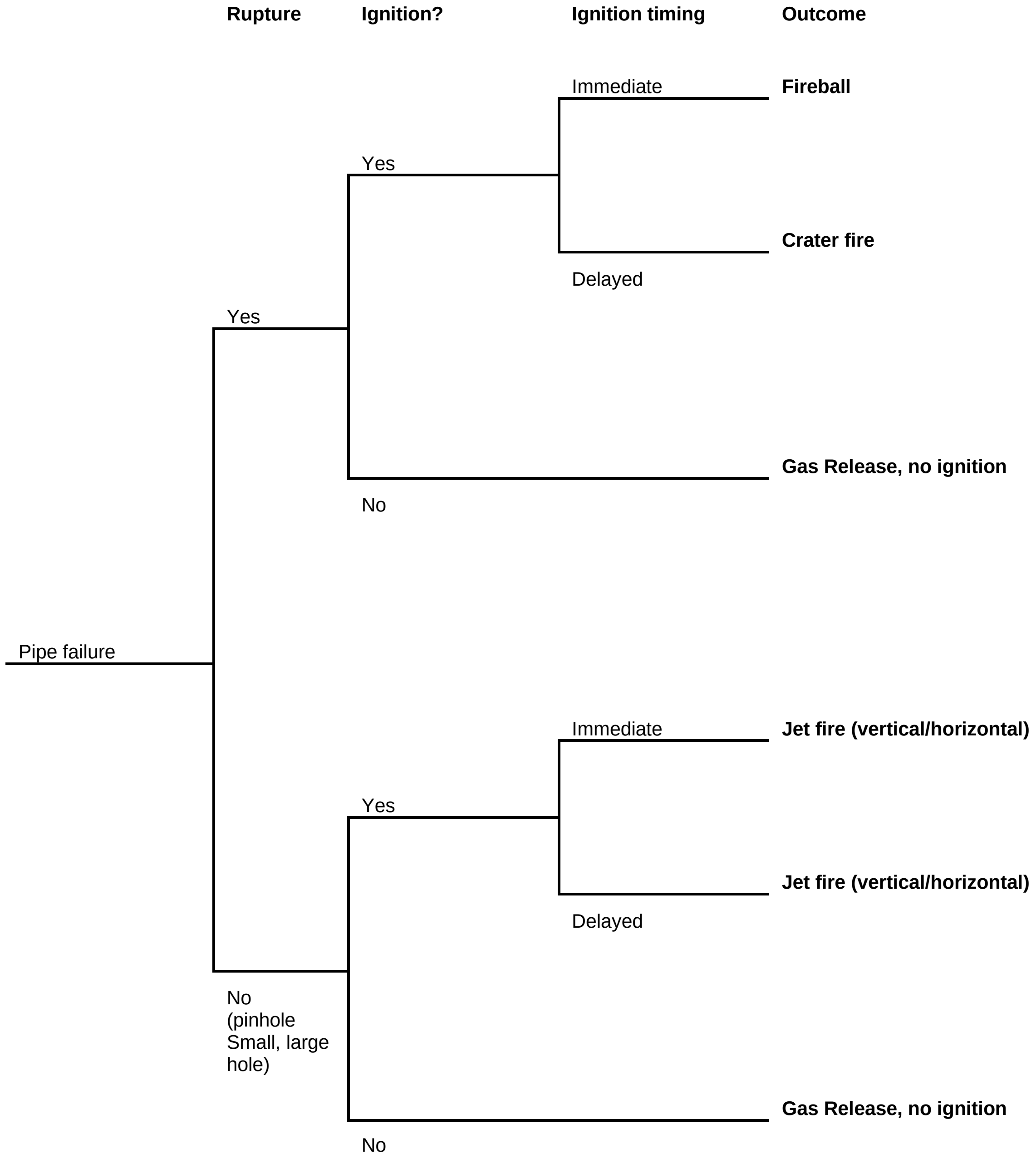
Table C.5: Consequence analysis results for crater fire

Stream tag	Release				Maximum distance to heat radiation @D8 (m)						
	Pressure (barg)	Temp (ºC)	Orientation	Hole size (mm)	Release rate at 30 seconds (kg/s)	Crater size (expanded jet diameter) (m)	Flame length (m)	Flame width (m)	4.7 kW/m²	12.6 kW/m²	23 kW/m²
PIP_CF	130	25	Vertical	RUP	10,333	13.8	52	104	1047	702	528

APPENDIX D. LIKELIHOOD ANALYSIS METHODOLOGY AND RESULTS

D1. Event tree

The following shows the event tree used for this study, it was developed based on IGEM, Ref [5].



D2. Reduction factors

Third party activity / external interference:

The graph shows a factor approaching zero for a 24mm pipeline.

For this study 0.1 conservatively selected.

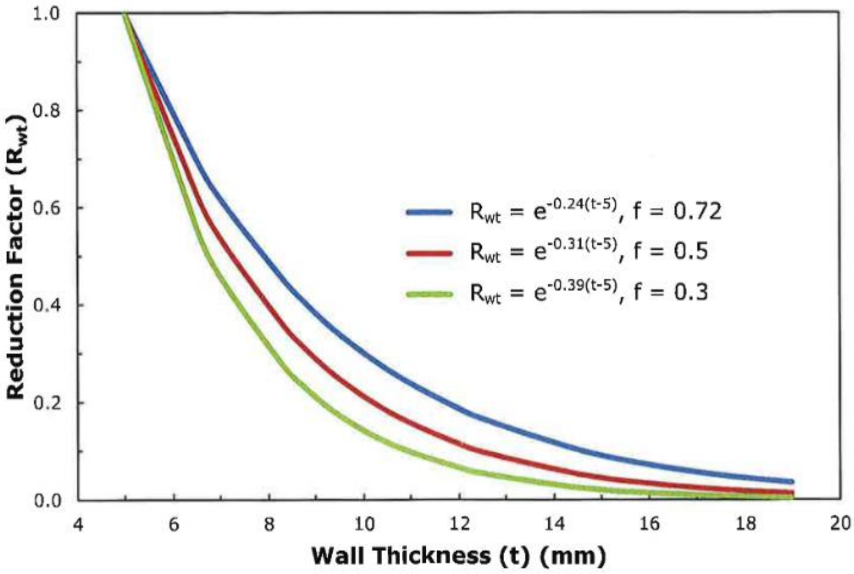


FIGURE 9 - REDUCTION IN EXTERNAL INTERFERENCE TOTAL FAILURE FREQUENCY DUE TO WALL THICKNESS

Ground movement

Survival values for pipelines due to landslip can be estimated from the IGEM correlation following.

The 'best estimate survival value is 1 x 10^{-4} based on the pipeline description 'High quality girth welds with 24 mm wall thickness' such as this pipeline.

However DPIE advised Sherpa in technical response comments that a conservative approach should be adopted as the survival value assuming poor quality welds (for 24mm wall thickness this is 2 x 10^{-3}) should be adopted for the assessment.

The IGEM guidance indicates that a survival value of approximately 0.03 would apply to all leaks due to ground movement. As required by DPIE in technical response comments, the UK HSE leak frequency is used as is, i.e. the leak frequency has not been adjusted for pinhole, small and large hole leaks.

The survival values for rupture are presented in Figure 15.

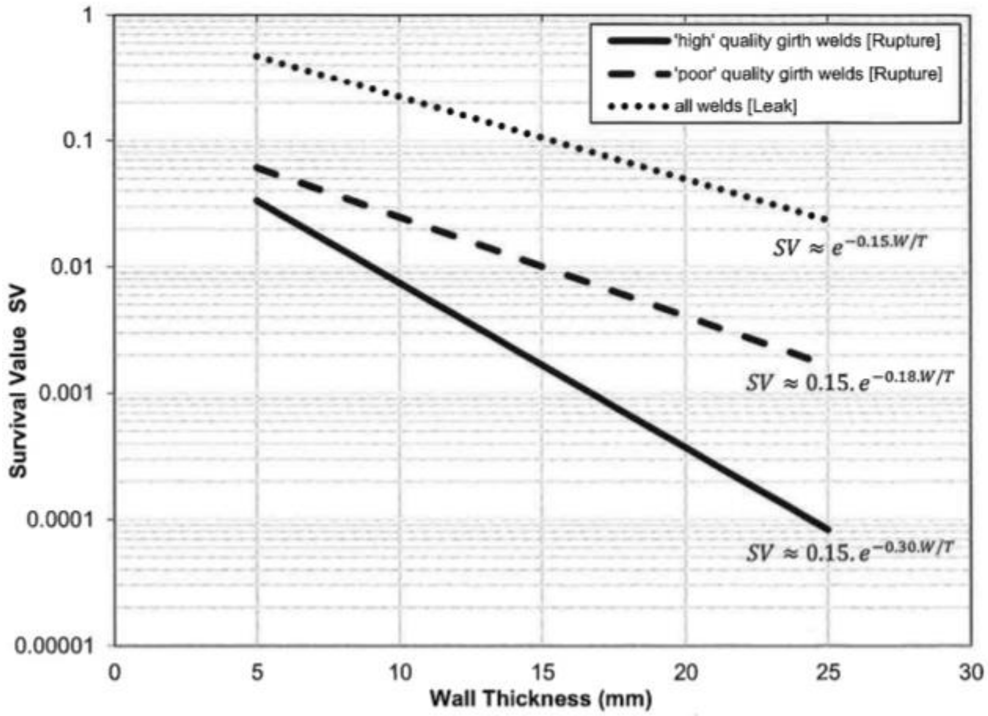


FIGURE 15 - SURVIVAL VALUE TREND LINES FOR RUPTURE DUE TO NATURAL LAND SLIDING

D3. Event tree frequencies

The resulting frequencies used in the QRA model are summarised below.

	25mm hole	**75mm hole**	**110mm hole**	**RUPTURE**
TOTAL leak frequency	**2.30E-05**	**2.76E-06**	**1.80E-07**	**7.00E-08**
Ignition Probability (Igem 2013)	0.056	0.059	0.070	0.81
Fire Frequency (per km.yr)	1.28E-06	1.62E-07	1.27E-08	5.67E-08
Orientation Probability (for JF)				
Horizontal	50%	20%	20%	-
Vertical	50%	80%	80%	-
Frequencies for Riskcurves				
JF horizontal fire (per km.yr)	6.39E-07	3.25E-08	2.53E-09	
JF vertical fire (per km.yr)	6.39E-07	1.30E-07	1.01E-08	
Crater Fire (per km.yr)	-	-	-	2.84E-08
Fireball (per km.yr)	-	-	-	2.84E-08

APPENDIX E. METEOROLOGICAL DATA

E1. Meteorological data

The meteorological weather data was obtained from the BoM, Ref [15]. The data was obtained from the nearest weather station with adequate data for use in the study, Newcastle Station.

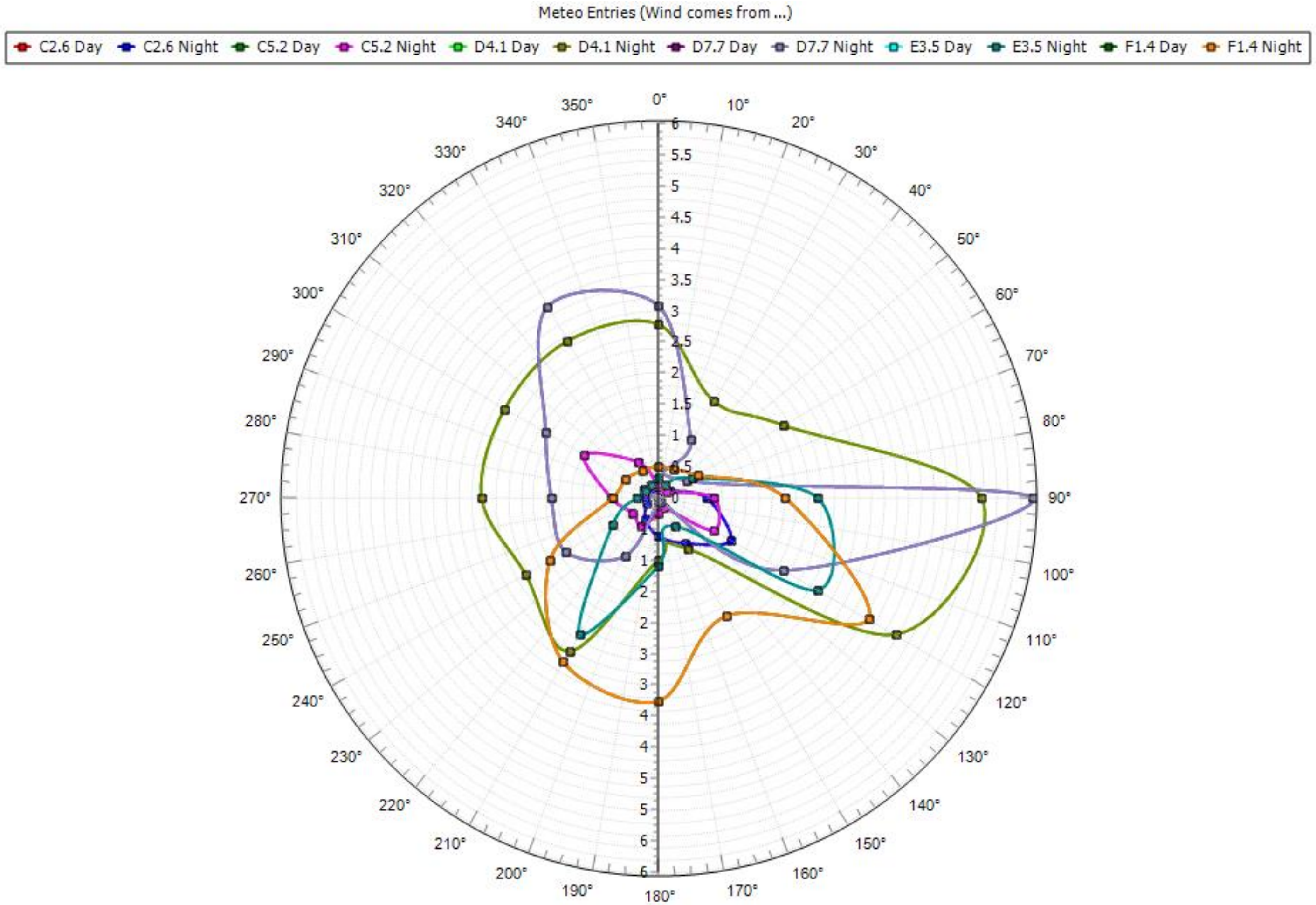
Analysis of the data was completed to consolidate the data into six representative Pasquill stability classes. Using this approach wind speed, solar radiation and cloud data are taken into account to determine atmospheric stability, Ref [19].

Refer to Table E.1 for the dataset and Figure E.1 for the wind rose.

Table E.1: Meteorological weather data (wind direction from)

Class	Day	Night	000 - 030	030 - 060	060 - 090	090 - 120	120 - 150	150 - 180	180 - 210	210 - 240	240 - 270	270 - 300	300 - 330	330 - 360
2.6 C	2.7%	2.7%	0.1	0.2	0.2	0.8	1.4	0.8	0.6	0.4	0.2	0.2	0.3	0.2
5.2 C	3.3%	3.3%	0.2	0.1	0.2	0.9	1.0	0.2	0.3	0.5	0.5	0.8	1.4	0.7
4.1 D	16.1%	16.1%	2.8	1.8	2.3	5.2	4.5	0.9	1.0	2.8	2.5	2.8	2.8	2.9
7.7 D	11.6%	11.6%	3.1	1.1	0.5	6.0	2.3	0.1	0.1	1.1	1.7	1.7	2.1	3.5
3.5 E	6.3%	6.3%	0.3	0.2	0.6	2.6	3.0	0.5	1.1	2.5	0.9	0.4	0.2	0.3
1.4 F	10.0%	10.0%	0.5	0.5	0.7	2.0	3.9	2.2	3.3	3.0	2.0	0.7	0.6	0.5

Figure E.1 Wind Rose



APPENDIX F. REFERENCES

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