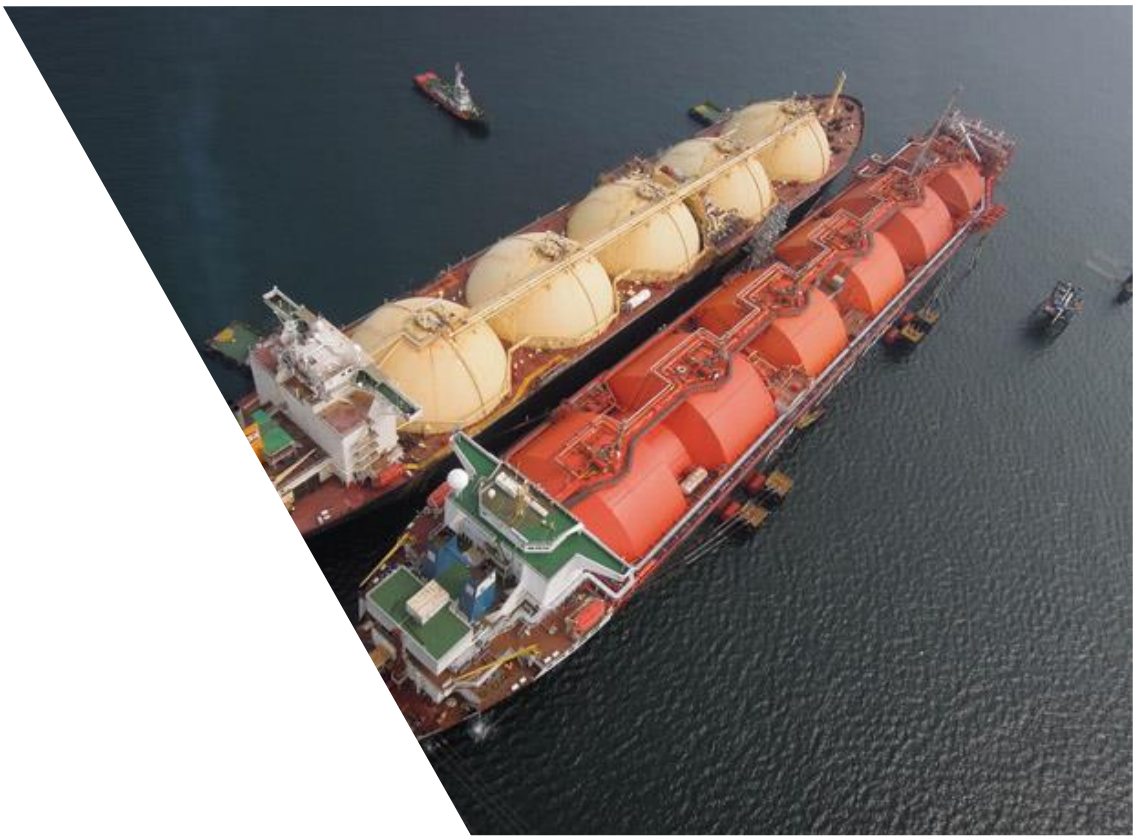
JEMENA

Port Kembla Lateral Looping NGP2 Pipeline FEED

Preliminary Hazard Analysis- NPG2 and Kembla Grange Tie-in Facility



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PROJECT 411010-00071 - SR-REP-0002 – Port Kembla Lateral Looping NGP2 Pipeline FEED

Rev	Description	Original	Review	WorleyParsons Approval	Date	Customer Approval	Date
A	Issued for Review	S. Babaei	T. Millen	F. Losty	14 Aug 2020		
B	Re-Issued for Review	S. Babaei	T. Millen	F. Losty	14 Aug 2020		
C	Re-Issued with Addendum	T. Millen	S. Babaei	F. Losty	06 Oct 2020		

Contents

1. Executive Summary

Jemena is currently planning to upgrade its existing Port Kembla Lateral (PKL) pipeline capabilities to strengthen the security of gas supply for the east coast gas market. The Port Kembla Lateral Looping (PKLL) Project involves the construction of a 5.7 kilometres long, buried gas transmission pipeline from the proposed Port Kembla Gas Terminal (PKGT) pipeline discharge point at Cringila station to the Eastern Gas Pipeline (EGP). This pipeline will supply gas into the EGP via a new End of Line (EoL) Tie-in facility in the vicinity of Jemena's existing Kembla Grange MLV/Lateral Offtake facility.

As part of the approvals process for the PKL pipeline, Jemena is required to complete a Level 2 (Semi Quantitative) Preliminary Hazard Analysis. The Department of Planning, Industry & Environment (DPIE) guideline "Multi-Level Risk Assessment" requires that incidents that have potential significant consequences beyond the site boundary must be quantified and demonstrated to be below the appropriate criteria.

A quantitative risk assessment has been undertaken for the new Port Kembla Lateral (PKL) pipeline, as well as the Kembla Grange tie-in facility. In conjunction with existing studies completed (namely HAZID, HAZOP and pipeline SMS review) this is intended to satisfy the requirements for a Level 2 Preliminary Hazard Analysis.

The results of the QRA modelling undertaken indicate that risk exposure associated with the PKL pipeline and the associated Kembla Grange tie-in facility will be below the fatality risk criteria specified in HIPAP-4.

1.1 Addendum to PHA Report

Subsequent to the issue of the QRA report, it was determined that the study basis was a lower operating pressure than a future proposed operating case (12 vs. 16.55MPa). An addendum was been generated to revise LSIR contours for the Kembla Grange Station, and associated lateral pipeline, and is attached to this study as Appendix B.

In addition to the pressure change, a number of other assumptions were reviewed and revised as part of the update. These related to pipeline hole size distribution (Table 6-3 of the main report), and the split between immediate and delayed ignition events (Table 7-1 of the main report).

Overall, the modifications showed a net reduction in the level of risk being demonstrated. As such there is no modification to the findings of the original QRA report with respect to the pipeline route.

2. Introduction

State Environmental Planning Policy No. 33 — Hazardous and Offensive Development (SEPP 33) was gazetted on 13 March 1992 and applies to any proposals which fall under the policy's definition of 'potentially hazardous industry' or 'potentially offensive industry'. Certain activities may involve handling, storing or processing a range of substances which in the absence of locational, technical or operational controls may create an off-site risk or offence to people, property or the environment. SEPP 33 ensures that only those proposals which are suitably located, and able to demonstrate that they can be built and operated with an adequate level of safety and pollution control, can proceed.

Jemena is currently planning to upgrade its existing Port Kembla Lateral (PKL) pipeline capabilities to strengthen the security of gas supply for the east coast gas market. The Port Kembla Lateral Looping (PKLL) Project involves the construction of a 5.7 kilometres long, buried gas transmission pipeline from the proposed Port Kembla Gas Terminal (PKGT) pipeline discharge point at Cringila station to the Eastern Gas Pipeline (EGP). This pipeline will supply gas into the EGP via a new End of Line (EoL) Tie-in facility in the vicinity of Jemena's existing Kembla Grange MLV/Lateral Offtake facility.

As part of the approvals process for the PKL pipeline, Jemena is required to complete a Level 2 (Semi Quantitative) Preliminary Hazard Analysis [3]. The Department of Planning, Industry & Environment (DPIE) guideline "Multi-Level Risk Assessment" requires that incidents that have potential significant consequences beyond the site boundary must be quantified and demonstrated to be below the appropriate criteria.

Figure 2-1 below illustrates the hazardous assessment process [3].

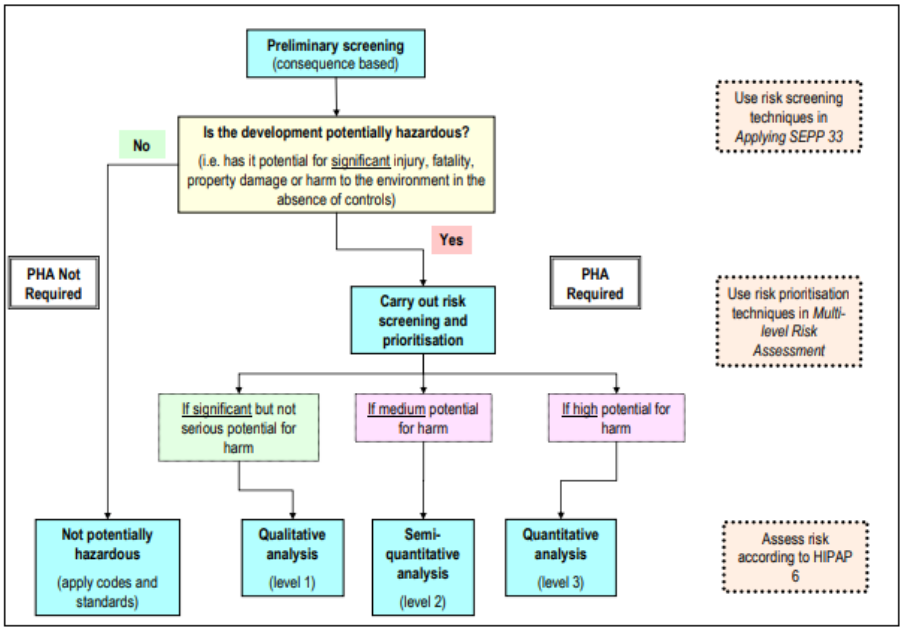

Figure 2-1 Hazardous Assessment Process

2.2 Objectives

The objective of this study is to undertake a Quantitative Risk Assessment (QRA), which in conjunction with existing studies completed (namely HAZID, HAZOP and pipeline SMS review) is intended to satisfy the requirements for a Level 2 Preliminary Hazard Analysis.

A Quantitative Risk Assessment (QRA) has been prepared consistent with the requirements of Hazardous Industry Planning Advisory (HIPAP) Paper No. 6 – Guidelines for Hazard Analysis (DPE, 2011) [2]. The key elements of this QRA are as follows:

- Identification of the nature and scale of all hazards at the facility, and the selection of representative incident scenarios;
- Analysis of the consequences of these incidents on people, property and the biophysical environment;
- Evaluation of the likelihood of such events occurring and the adequacy of safeguards;
- Calculation of the resulting risk levels of the facility; and
- Comparison of these risk levels with established risk criteria

2.3 Scope

The scope of this QRA includes:

- 5.7 km pipeline between Cringila station and Kembla Grange, described hereinafter as the PKL (Port Kembla Lateral).
- The Tie-in facility at Kembla Grange (covering two location options).

Note that for full context, elements of the Australian Industrial Energy (AIE) project scope (FSRU, pipeline to Cringila, and Cringila facility) are described within this report but are not the subject of the QRA.

2.4 Acronyms

Abbreviation	Definition
AIE	Australian Industrial Energy
AS	Australian Standard
DNVGL	Det Norske Veritas Germanischer Lloyd
DPIE	Department of Planning, Industry & Environment
EGP	Eastern Gas Pipeline
FEED	Front End Engineering Design
FSRU	Floating Storage and Regasification Unit
HAZID	Hazard Identification

Abbreviation	Definition
HAZOP	Hazard and Operability
HIPAP	Hazardous Industry Planning Advisory Paper
LNG	Liquefied Natural Gas
LNGC	Liquefied Natural Gas Carrier
LSIR	Location Specific Individual Risk
MAOP	Maximum Allowable Operating Pressure
NSW	New South Wales
OGP	International Association of Oil and Gas Producers
P&ID	Piping and Instrumentation Diagram
PHA	Preliminary Hazard Analysis
PKCT	Port Kembla Coal Terminal
PKGP	Port Kembla Gas Project
PKGT	Port Kembla Gas Terminal
PKL	Port Kembla Lateral
QRA	Quantitative Risk Assessment
SEPP	State Environmental Planning Policy
SMS	Safety Management Study
UKOOA	United Kingdom Offshore Operators Association
VCE	Vapour Cloud Explosion

3. System Description

3.1 LNG Terminal Overall Description

The PKGT is planned to be developed at Port Kembla and will include a Floating Storage and Regasification Unit moored to an existing berth in the inner harbour (see Figure 3-1). LNG carriers (LNGC) will moor in a side-by-side configuration to offload the LNG to the FSRU where it will be regasified and sent to shore via marine loading arms and aboveground station piping and connected to an onshore pipeline that will tie-in to the existing Eastern Gas Pipeline (EGP) at Kembla Grange.

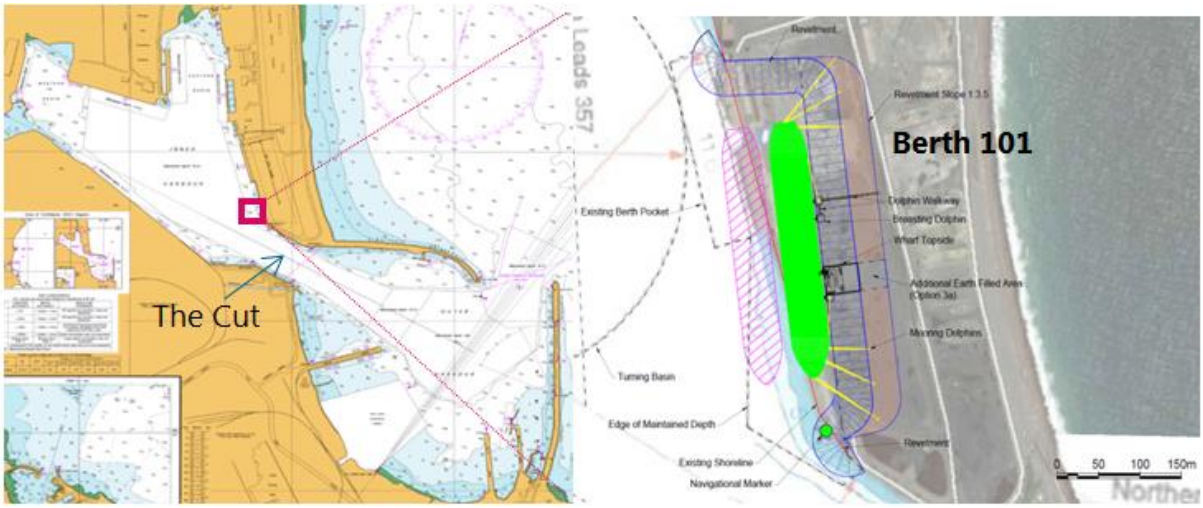

Figure 3-1 PKCT Berth 101 layout

3.2 Onshore Pipeline

An onshore gas pipeline connects the FSRU to the tie-in point at Cringila (NGP1 pipeline), which in turn is connected to the EGP via the PKL pipeline. The gas pipeline is a DN450 carbon steel pipeline and has a total length of 11,770m (6,100 m NGP1 and 5,670m PKL).

Licence 26 for the Eastern Gas Pipeline states a maximum allowable operating pressure (MAOP) of 14.895 MPa; with the exception for assembles (that can be later isolated and upgraded), the DN 450 mainline was constructed and tested to allow a future increase in operating pressure to 16.55 MPa (corresponding to 80% SMYS for the selected linepipe). Jemena intends to maintain this design basis for the Port Kembla Lateral Looping pipeline.

PKL commences downstream of the monolithic isolation joint at the discharge of the Cringilla facility, with approximately 4m of the pipeline section above ground (refer Figure 3-2).

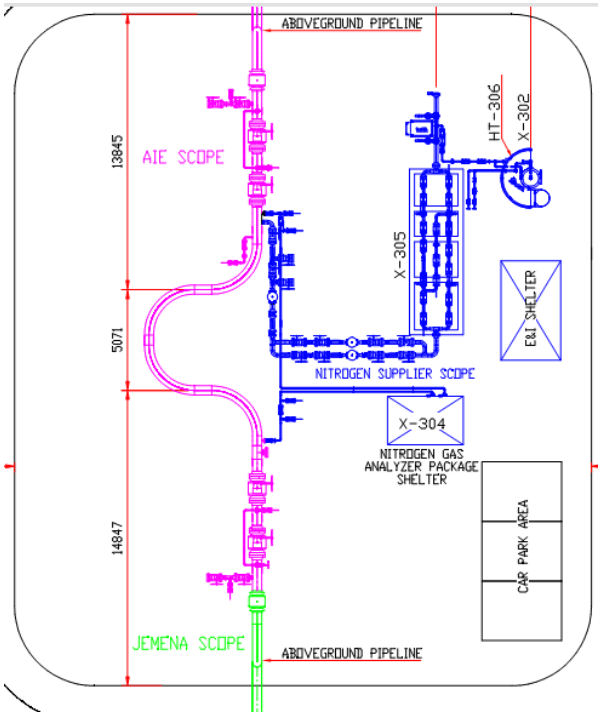

Figure 3-2- Cringilla Facility

Figure 3-3 and Figure 3-4 show the Pipeline routes for NGP1 and PKL respectively. PKL commences downstream of

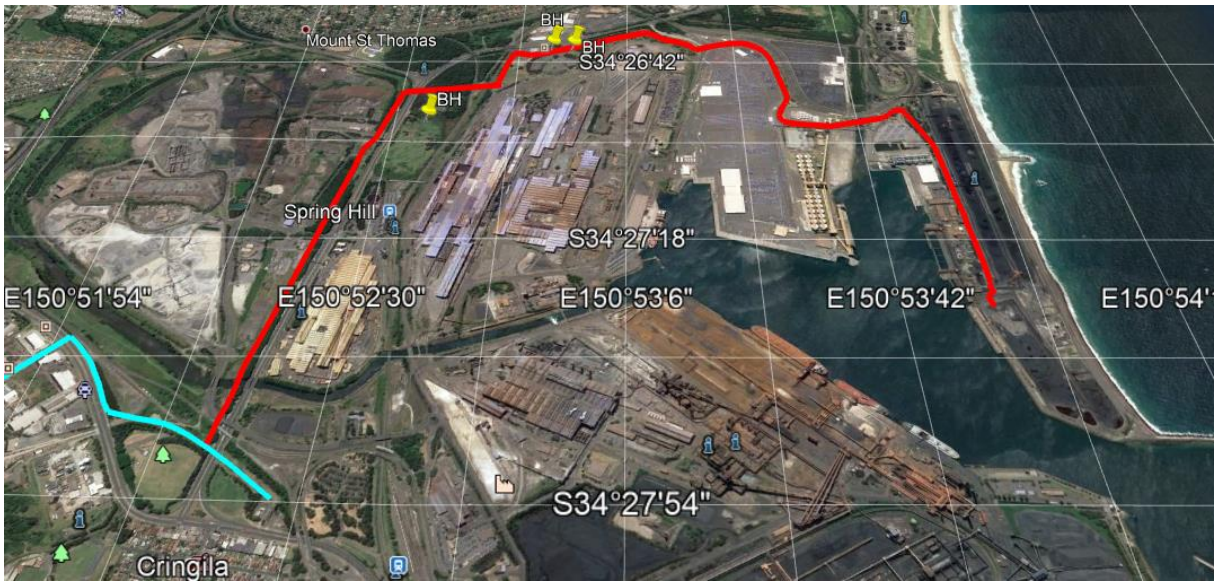

Figure 3-3- PKGT pipeline route - Berth 101 to Cringila (NGP1)

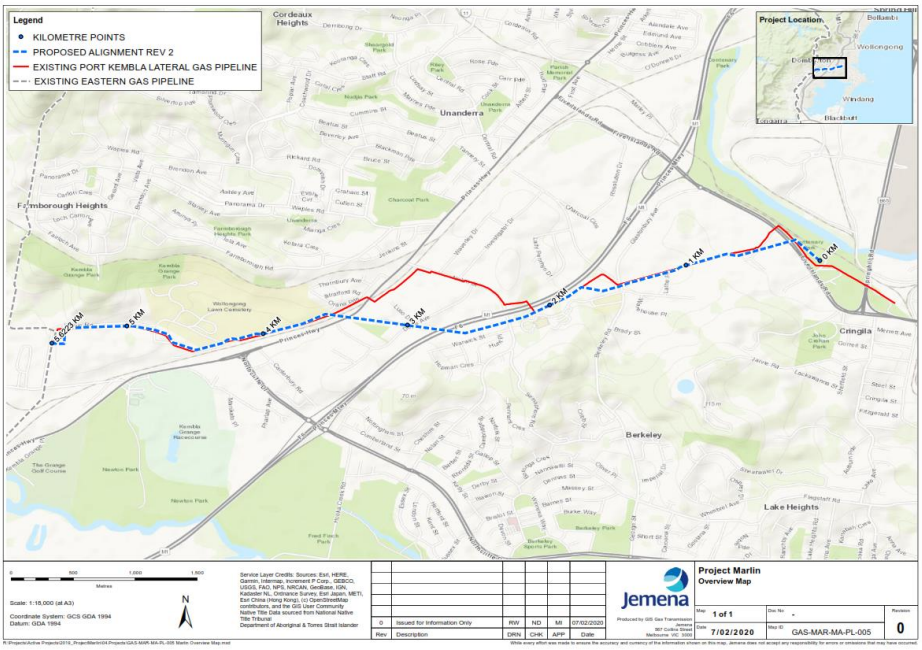

Figure 3-4- PKGT pipeline route – Cringila to Kembla Grange (PKL)

3.3 Kembla Grange Tie-in Facility

The PKL pipeline comes above ground near Jemena's existing Kembla Grange MLV/Lateral Offtake facility and tie-in to the EGP. The tie-in facility at Kembla Grange includes a gas custody transfer meter, pigging facility and two shutdown valves to segregate the PKGT from the EGP during an emergency. There are two potential locations for the tie-in facility, which are shown in Figure 3-5 as Options A and B.

Figure 3-5 Potential locations for Tie-in facility at Kembla Grange

3.4 Location and Surrounding Land Use

Surrounding area of the proposed PKL pipeline route is a combination of industrial, residential and rural. A Safety Management Study (SMS) was carried out for the pipeline in line with the requirements of AS 2885.1 [4] and it was agreed in the workshop that based on the usage of land adjacent to the pipeline the overall location class along the pipeline length is Residential (T1), with secondary location class industrial (I) [11]

Figure 3-6 indicates the pipeline route and surrounding area within the measurement length of the pipeline, which is define as the radius of the 4.7 kW/m^2 radiation contour caused by a fire, resulting from a full-bore rupture of the pipeline, and extends 617.9m from the PKL.

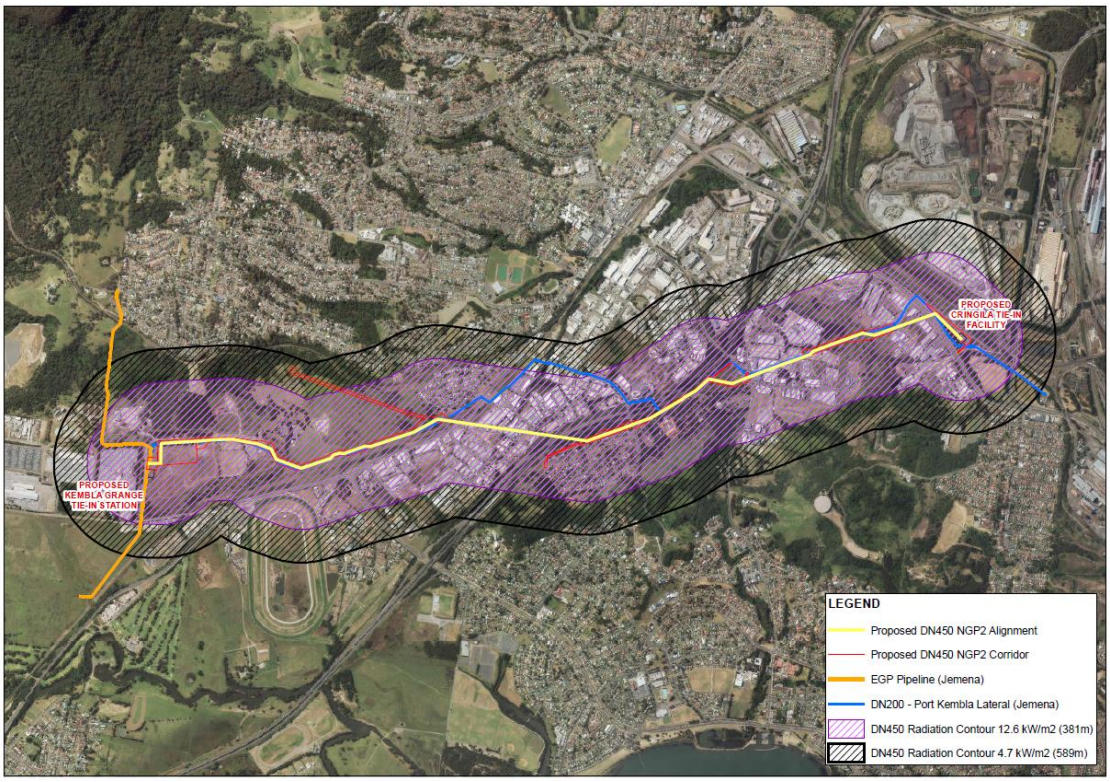

Figure 3-6 Surrounding area of the PKL pipeline within the Measurement Length

The Kembla Grange Tie-in facility at Kembla Grange as can be seen in Figure 3-6 is mainly surrounded by Rural area. There is industrial development to the west (predominantly a car yard), and public sporting facilities to the east (Sir Ian McLennan Oval).

4. Methodology

The QRA study has been carried out in accordance with the NSW HIPAP 6 guidelines for hazard and risk assessments [2]. The methodology is outlined in Figure 4-1 below.

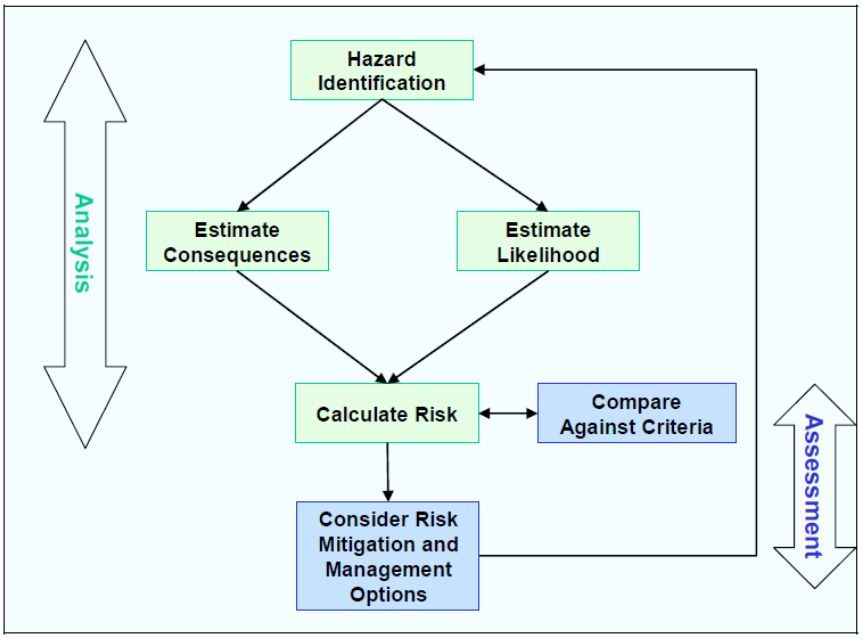

Figure 4-1: Hazard Analysis Methodology [2]

The methodology includes the following steps:

- Identification of Hazards (Section 5) – Review of possible accidents and the associated impacts that may occur based on previous accident experience or judgement where necessary.
- Consequences and Impact Analysis (Section 6) – Define the characteristic of the identified possible accidents.
- Frequency Analysis (Section 7) – Define the probability of the identified possible consequences.
- Risk Analysis (Section 8 and Section 9) – Define the acceptable risk levels and compare against the determined Location Specific Individual Risk contours.

5. Hazard Identification

A number of studies have been undertaken which have identified potential hazards associated with the new pipeline and tie-in facility, including:

- HAZID and HAZOP
- Pipeline Safety Management Study

The studies have identified a number of hazard causes which may lead to loss of containment events, including overpressurisation of the system, brittle failure, corrosion, and third-party impacts.

5.1 Loss of Containment Consequences

The only available hazardous material within the scope of this study is natural gas.

Natural gas is known to be a clean source of methane with very few contaminants. The natural gas composition used in this study is as presented in Table 5-1 and is calculated using composition of Rich LNG reported in Port Kembla BOD [10] adjusted with Nitrogen to achieve the AEMO Wobbe Index limitation of 51.9 MJ/Sm^3.

Table 5-1: Natural Gas Composition

Component	NG Composition [mol%]
Methane	79.83
Ethane	12.38
Propane	4.44
n-Butane	0.98
n-Pentane	0.02
Nitrogen	2.34

Natural gas will form a flammable mixture on release, with a lower flammable limit of approximately 4%. Should releases rapidly ignite, a jet fire will form, which is highly directional and will generate significant levels of radiant heat due to efficient burning.

Delayed ignition will result in a flash fire, and if sufficient congestion is present, a vapour cloud explosion (VCE). VCEs occur due to rapid combustion of flammable gas which generates pressure effects due to the acceleration of the flame front by congestion or confinement. As both pipeline and Kembla Grange tie-in facility are located in open areas and the degree of confinement and congestion is very low, explosion is not considered a credible scenario in this study.

The composition of the re-gasified LNG is such that toxic impacts are not considered to be credible.

5.2 Escalation Potential

A specific query was raised by DPIE relating to the separation distance between the looping pipeline and the existing pipeline, when they are in proximity in the same corridor.

Guidance with respect to spacing has been taken from “Underground parallel pipelines domino effect: An analysis based on pipeline crater models and historical accidents”, published in the Journal of Loss Prevention in the Process Industries [9]. The concept is that inter-pipeline escalation can occur when a crater forms, exposing the adjacent pipeline to direct flame impingement following a release event.

The potential crater dimensions are based on the pipeline pressure, diameter, and the soil type. For an 18” (DN450) pipeline in sandy soil, and operating at up to 150 barg, the total crater width (centred on the pipeline) is approximately 13m, and in clay soil the crater width is approximately half of this (refer to Figure 5-1). Based on this data, the current proposed minimum separation between the existing pipeline and the new looping pipeline is 7m in sandy soil and 3.5m in clay soil, and the risk of inter-pipeline escalation has been excluded from this analysis.

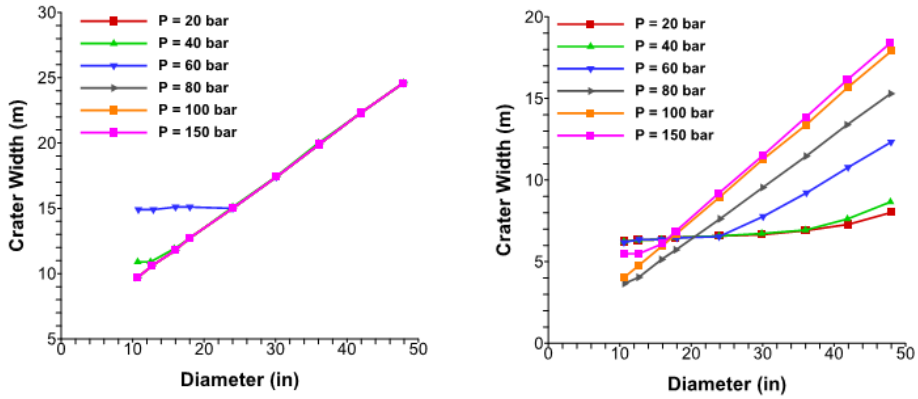

Figure 5-1 Pipeline Crater Width

6. Consequence Modelling Assumptions and Inputs

DNV GL PHAST Risk (also known as SAFETI) version 6.7 was used to model the possible identified consequences from releases of hazardous inventories and resulting risk contours.

The following section describes the assumptions, inputs and scenario development for the modelling undertaken.

6.1 Release Scenarios

The release cases modelled in this study are summarised in Table 6-1 below. All releases have been modelled at a pressure of 12,000kPag, and temperature of 10˚C.

Table 6-1: Hazardous Inventories

Scenario ID	Scenario
1	Natural Gas pipeline from Cringila to Kembla Grange facility- PKL
2	PKL Inlet pipeline at Kembla Grange- (Above ground pipeline to the isolation valve, SDV-5001)
3	Metering and associated pipework
4	Pig Receiver
5	Tie-in to EGP (from SDV-5008 to the point pipe goes underground)

All releases have been modelled at initial process conditions until depleted, with the exception of full-bore pipe ruptures which are modelled based on the release rate at 30 seconds after release. Whilst isolation capability exists at both Kembla Grange and the Cringila Station, this has conservatively been ignored in the modelling.

6.2 Hole Size Distribution

The hole size distributions used in this study are consistent with the PHA for Port Kembla Gas Project (PKGP) [12] and as follows:

Table 6-2: Leak Size at Kembla Grange Facility

Leak Description	Leak Diameter (mm)
Small	10
Medium	25
Medium – Large	50
Large	100
Catastrophic (Full Bore)	Rupture

Table 6-3: Leak Size – Pipeline

Leak Description	Leak Diameter (mm)
Small	20
Medium	50
Large	100
Full Rupture	Full Bore Rupture

6.3 Leak Direction and Elevation

Three different release orientations were modelled. Directional probabilities are as follows:

- 50% for horizontal;
- 25% for vertical (up); and
- 25% for vertical (down).

A leak from the pipeline is assumed to have following orientation probabilities:

- 20% for vertical (up); and
- 80% for vertical (45° diagonal).

Releases from the Kembla Grange tie-in facility were modelled at an elevation of 1m, and releases from the buried NPG1 pipeline at an elevation of 0m. All risk impacts have been measured at a height of 1.65m above ground level.

6.4 Environmental Conditions

Environmental conditions and wind direction probabilities used in the consequence modelling are taken from the PKGP PHA [12] and summarised in Table 6-4 and Table 6-5 as follows.

Table 6-4: Weather Parameters

Weather ID	Wind Speed (m/s)	Pasquil Stability	Air Temperature (°C)	Relative Humidity (%)	Ground Temperature (°C)
Calm	1	F	5	68	17
Average	5	D	25	68	21
Windy	10	D	40	68	25

Table 6-5: Weather Probability Distribution

Weather ID	N	NE	E	SE	S	SW	W	NW	Occurrence
Calm – 1F	2.59%	5.80%	2.86%	3.49%	2.77%	3.83%	2.41%	1.55%	25.28%
Average – 5D	5.24%	12.64%	3.52%	5.86%	10.68%	7.53%	6.22%	2.47%	54.15%
Windy – 10D	0.78%	4.20%	0.72%	1.30%	5.49%	2.54%	4.64%	0.90%	20.57%

7. Frequency Analysis

7.1 Release Frequency

Release frequency has been estimated based on a parts count using issued P&IDs, and application of failure rates premised on historical data.

A parts count was undertaken using the Revision E of Piping and Instrumentation Diagrams (P&IDs) for Kembla Grange Tie-in facility [14], with the following assumptions applied:

- An additional 15% contingency was applied to all parts count in the frequency assessment to account for future minor changes to the P&IDs and design modifications.
- Pig receiver VSR-501 and associated piping are only in use during pigging operation which is assumed to be an 8-hour operation twice per year.
- Per DNV guidance, the failure frequency for the above ground sections of the pipeline within the boundary of the Kembla Grange is estimated to be 25% of the total failure frequency of the facility [8].

Release frequencies for each release scenario are summarised in Appendix A.

Consistent with NPG1 pipeline [12], the OGP [7] data has been used for the release frequency calculation of NPG2 pipeline within this QRA, which correlates release frequency based on pipeline wall thickness. For a wall thickness of 10-15mm, a release frequency of 0.081 per 1000km per year is recommended.

7.1 Ignition Probability

Given a release, the probability of ignition is dependent on a range of factors including:

- Release rate;
- Material state (liquid or gas);
- Material physical properties (flash point, density, flammability limits); and
- Ignition sources present (hot work, uncertified / old equipment, energy sources).

There are a range of correlations available for applying an ignition probability to a release, and most are based on the release rate and state. The ignition probabilities utilised in this QRA are based on the United Kingdom Offshore Operators Association (UKOOA) ignition correlations [5] which take into account the factors above as well as the nature of the surrounding area with respect to potential ignition sources.

The ignition probabilities in this QRA were determined using the UKOOA ignition correlation no. 4 (Pipe Gas LPG Rural) for the releases at Kembla Grange facility and correlation no. 3 (Pipe Gas LPG Industrial) for release from buried PKL. The split between immediate and delayed ignition is based on Cox, Lees and Ang [6] as per Table 7-1.

Table 7-1: Probability of Immediate versus Delayed Ignition

Release Size	Rate (kg/s)	Fraction of Ignition Probability Attributed to Immediate Ignition	Fraction of Ignition Probability Attributed to Delayed Ignition
Minor	< 1	0.96	0.04
Major	1 – 50	0.88	0.12
Massive	> 50	0.70	0.30

The consequences of hydrocarbon fire events are as follows:

- Immediately ignited gas releases result in jet fires.
- Delayed ignition gas releases are modelled as flash fires.

Ignition probabilities for each release scenario are summarised in Appendix A.

7.2 Fatality Probability

For jet fires, it is assumed that fatality occurs as a result of exposure to a radiant heat. Table 7-2 provides typical effects of radiant heat exposure, as source from HIPAP 4 [1].

Table 7-2: Radiant Heat Consequences [1]

Radiation (kW/m²)	Effect – People
2.1	■ Minimum level to cause pain after 1 minute
4.7	■ Pain in 15-20 seconds ■ Injury after 30 seconds exposure (second degree burns minimum)
12.6	■ Significant chance of fatality with extended exposure ■ High chance of injury
23	■ Likely fatality with extended exposure ■ Chance of fatality with instantaneous exposure
35	■ Significant chance of fatality

Within the QRA, fatality due to exposure to radiant heat is premised on the following Probit equation for personnel located outdoors:

Probit = $-36.38 + 2.56 \ln (t.q^{4/3})$, where

- t = exposure time, in seconds
- q = radiant heat load, in W/m^2

OGP recommends a 30% chance of fatality for personnel exposed to 12.5 kW/m^2 radiant heat onshore, which corresponds to an exposure time of 30 seconds. As such, this value is used as the basis for the maximum exposure time within the QRA. Exposure is assumed to commence from the time of ignition (at time = 0 for early ignition events), which may be conservative when considering the delayed ignition of pool fire events, and the rapid depressurisation of large bore releases.

For flash fires, fatality is assumed to occur when persons are engulfed within the fire event, which is defined by the extent of the flammable cloud.

8. Risk Criteria

Risk has been measured in terms of Location Specific Individual Risk (LSIR), which is the level of risk that would be experienced by a person in a particular location for a full calendar year. LSIR criteria has been sourced from the NSW Department of Urban Affairs and Planning Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 (Risk Criteria for Land Use Safety Planning), as presented in Table 8-1 below.

Table 8-1: Fatality Risk Criteria

Risk (pa)	Land Use
5E-07	Sensitive land use; e.g. hospitals, schools, child-care facilities, old age housing
1E-06	Residential area; including hotels, motels, tourist resorts
5E-06	Commercial development; including retails centres, offices and entertainment centres
1E-05	Active open space; including sporting complexes
5E-05	Industrial

Societal risk differs from individual risk by taking into account society's aversion to accidents which have the potential to result in multiple fatalities. A wide range of factors need to be taken into consideration when calculating societal risk including details of the population density and movement in public areas.

Societal risk will only be considered within this study if LSIR contours indicate areas of elevated risk (approaching LSIR criteria) on areas with potential for high occupancy.

9. RISK RESULTS

Risk Results are presented separately for PKL pipeline and the Kembla Grange tie-in facility as per following sections:

9.1 Risk Results for PKL Pipeline

Figure 9-1 to Figure 9-6 below show individual fatality risk contours for the PKL pipeline. They are presented in six sections to provide more details of the impact level on surrounding area.

Of the HIPAP-4 criteria listed in Section 8, risk at a level of 1E-06 per annum or above was not recorded at any location along the pipeline, and only the lowest risk criterion of 5E-07 per annum, corresponding to the exposure limit for sensitive land use, was recorded. It is not considered that any sensitive locations along the pipeline route are impacted at, or above this level. As the risk exposure along the pipeline is well below tolerable limits for LSIR exposure and does not impact on particular locations of high occupancy, no societal risk assessment has been undertaken.

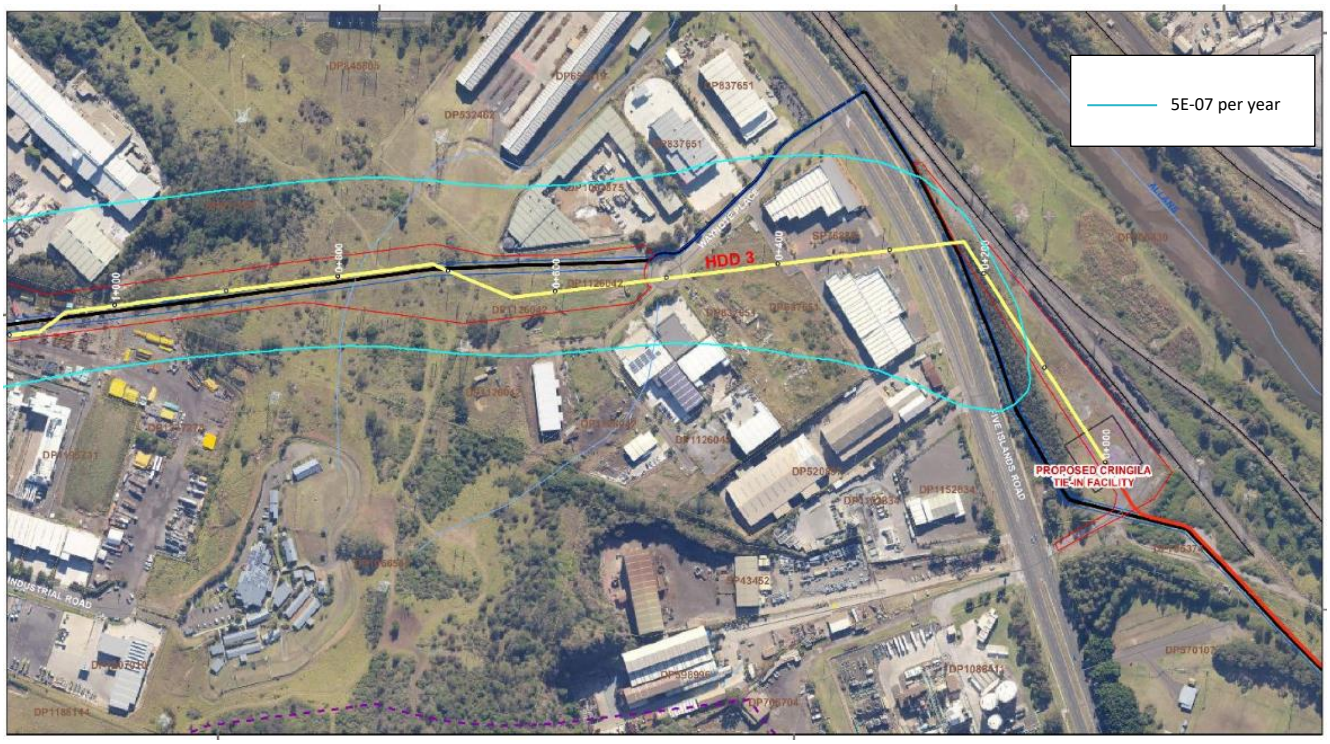

Figure 9-1 Risk Contour PKL Pipeline- section1

Figure 9-2 Risk Contour PKL Pipeline- section2

Figure 9-3 Risk Contour PKL Pipeline- section3

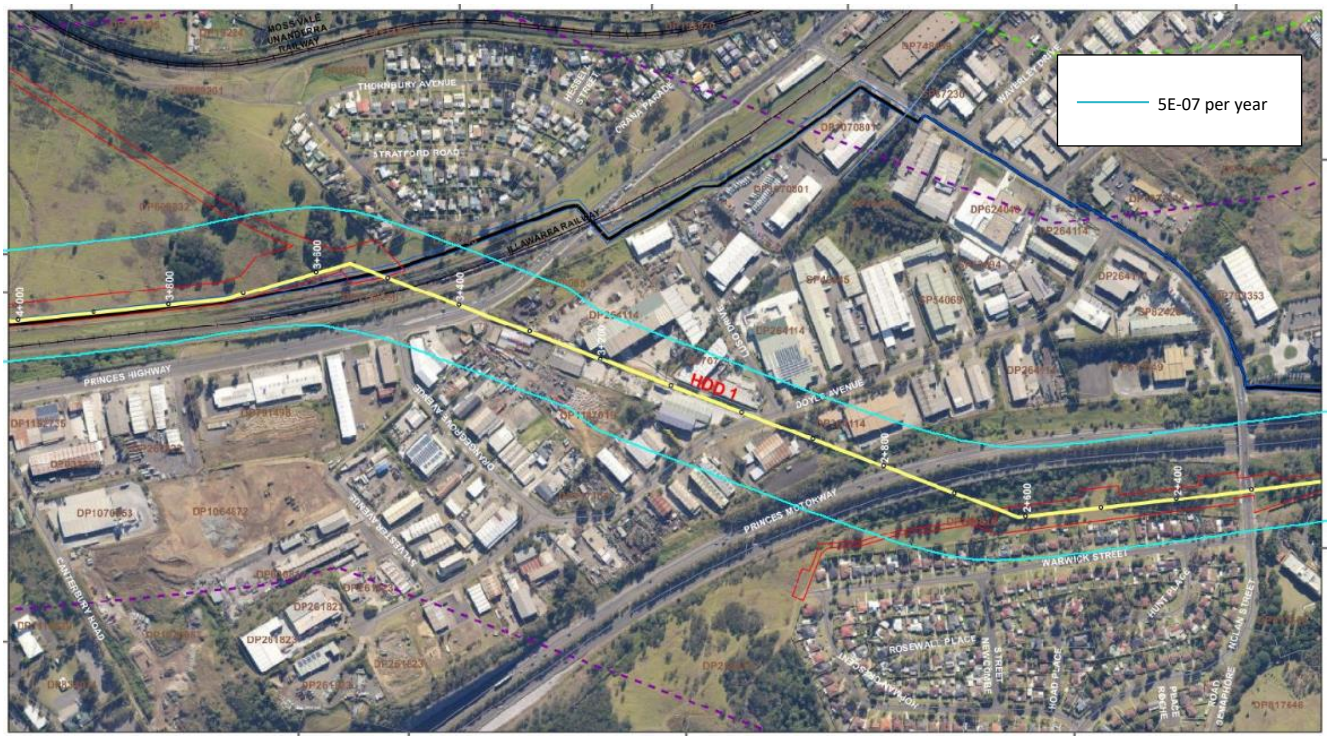

Figure 9-4 Risk Contour PKL Pipeline- section 4

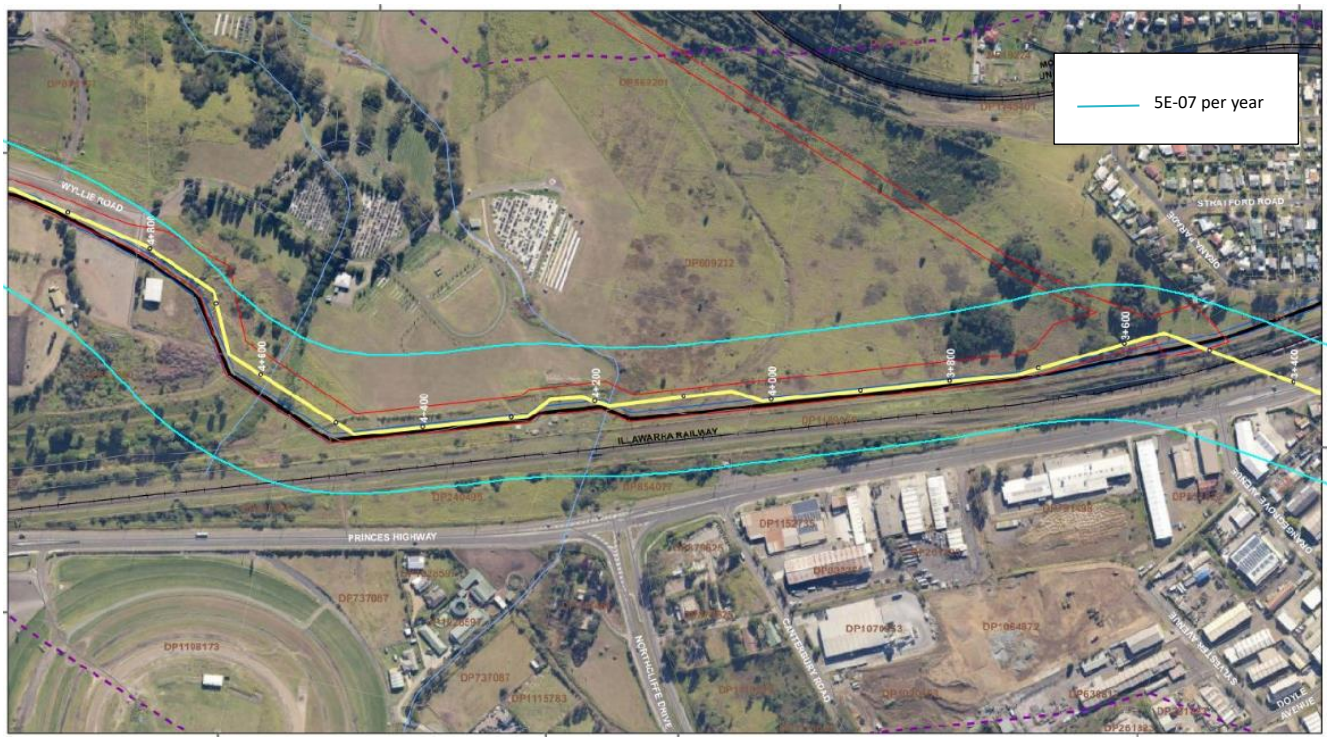

Figure 9-5 Risk Contour PKL Pipeline- section 5

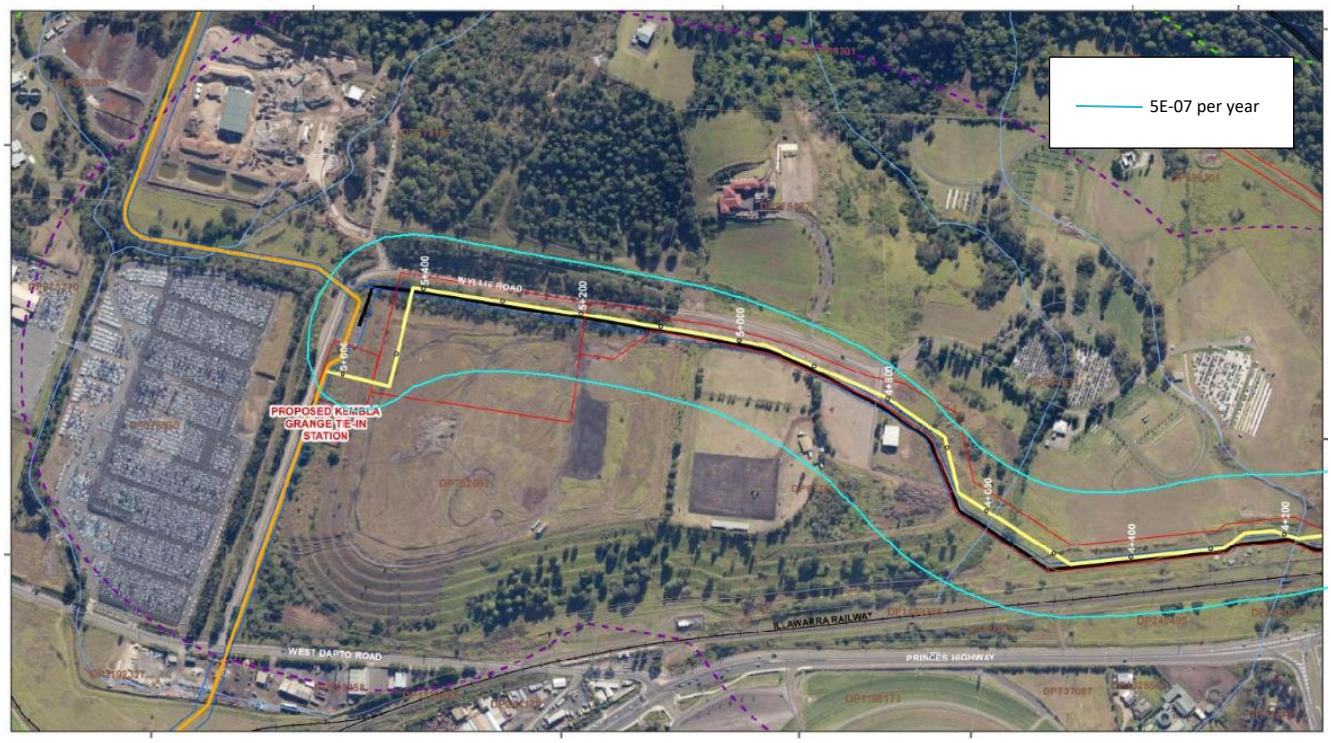

Figure 9-6 Risk Contour PKL Pipeline- section 6

9.2 Individual fatality risk contours for Kembla Grange Tie-in Facility

Figure 9-7 and Figure 9-8 show the individual fatality risk contours generated from the modelling conducted at the Kembla Grange Tie-in facility. When assessed against the HIPAP No 4 criteria, the following conclusions can be made:

- The highest HIPAP risk category produced from modelling is 1.0E-5 per annum, corresponding to the criterion for sporting complexes and active open space.
- The 1E-05 risk contour for active open space covers part of Wyllie road to the north and west of the site and covers some part of the car parking to the west in option B and does not reach it in option A; there is no active open space such as a sports complex within this risk contour.
- The 5E-06 risk contour in both location options only covers part of the car park site to the west and does not include any commercial developments.
- The 1E-06 risk contour for residential areas includes mainly open areas and few adjacent industrial sites; no residential land is within the extent of this risk contour for neither of location options.
- The 5E-07 risk contours and for both locations A and B remain in open area and industrial lands and do not include any sensitive location such as aged care facilities, child care centres, etc.

As for the pipeline assessment, LSIR is well below the target criteria, and there are no locations of elevated occupancy near the Kembla Grange tie-in facility. As such, societal risk has not been assessed for this location.

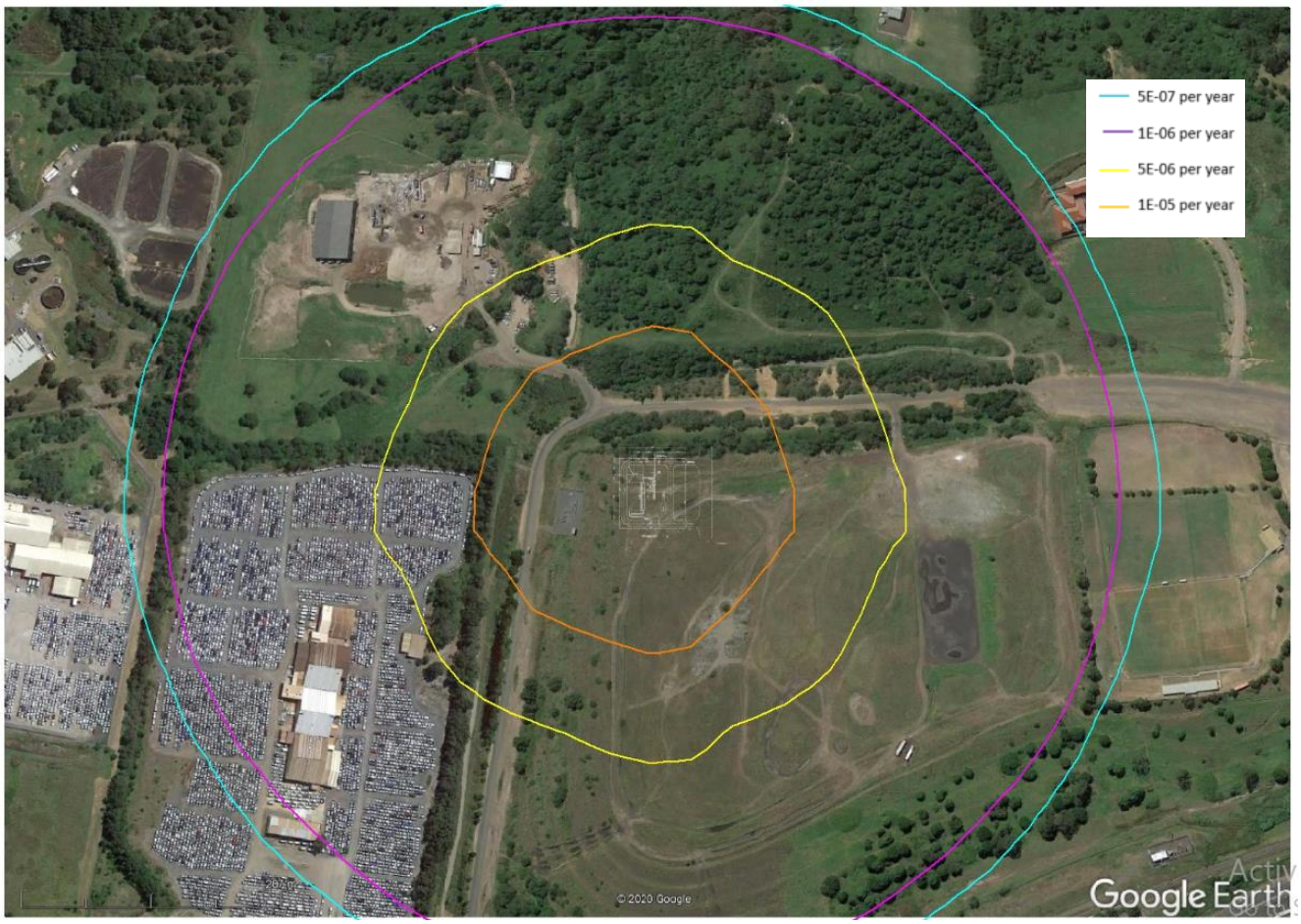

Figure 9-7 Risk Contours for Kembla Grange- Location A

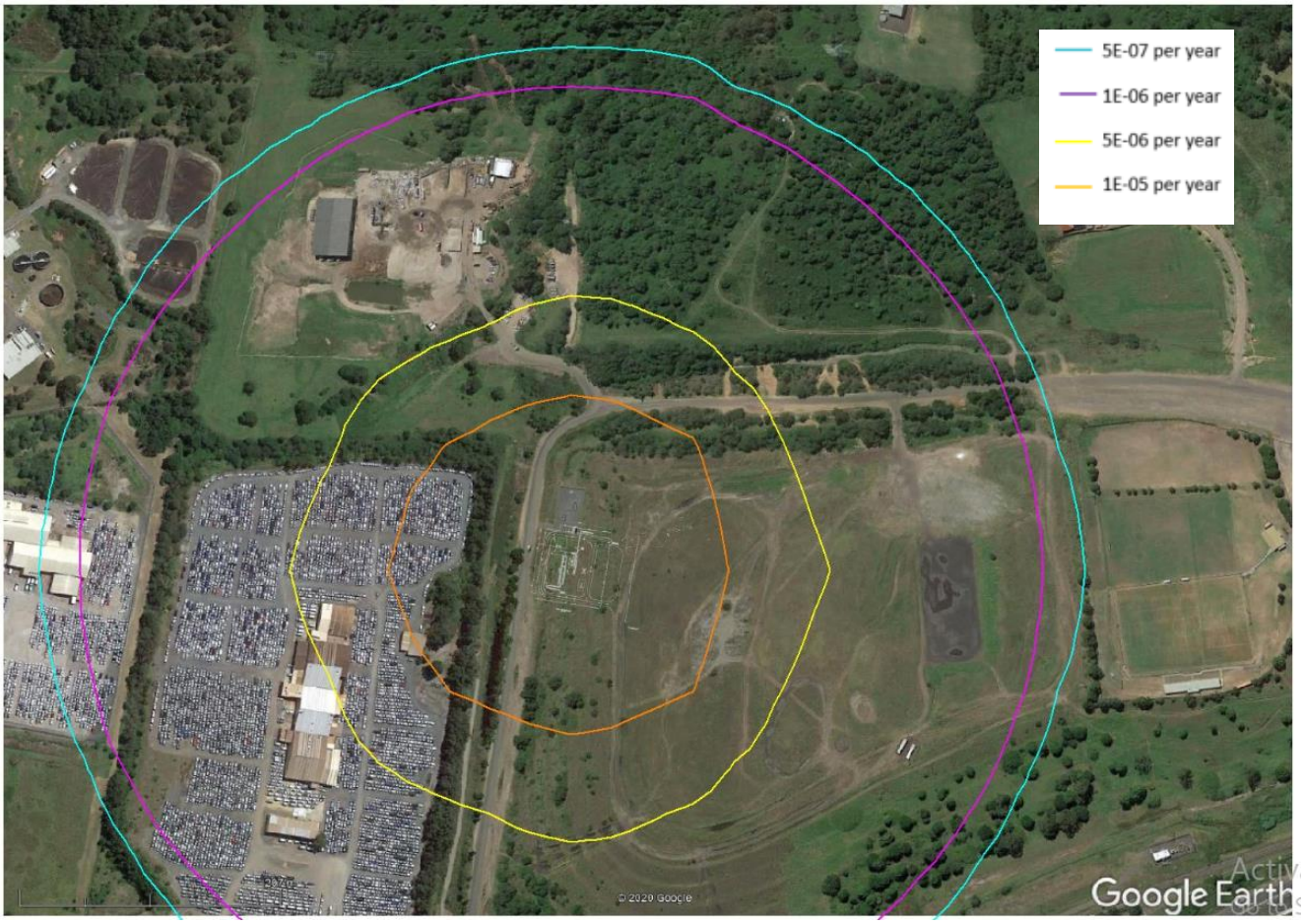

Figure 9-8 Risk Contours for Kembla Grange- Location B

10. CONCLUSION

The results of the QRA modelling undertaken indicate that risk exposure associated with the PKL pipeline and the associated Kembla Grange tie-in facility will be below the fatality risk criteria specified in HIPAP-4.

11. REFERENCES

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11. Port Kembla Lateral Looping PKL Pipeline FEED, Pipeline Safety Management Study Workshop, 401010-00071-SR-REP-0001, Rev 0
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13. Port Kembla Gas Terminal HAZID and HAZOP Studies Report, 401010-01496-SR-RPT-0003 Rev 0
14. EGP Pipeline Tie-in Facility P&ID, 401010-01496-PR-PID-5001&2, Rev E

Appendix A. Summary of Release Scenarios

Scenario	Hole Size (mm)	Release Rate (kg/s)	Release Frequency (p.a.)	Ignition Probability	Immediate Ignition Probability	Delayed Ignition Probability
PKL Inlet pipeline at Kembla Grange- (Above ground pipeline to the isolation valve, SDV-5001)	10	2.11	1.20E-03	1.63E-03	1.44E-03	1.96E-04
	25	13.19	1.30E-04	2.50E-03	2.20E-03	3.00E-04
	50	52.75	1.63E-05	7.58E-03	5.30E-03	2.27E-03
	100	211.00	7.21E-07	2.30E-02	1.61E-02	6.90E-03
	Rupture	889.00	1.74E-05	7.28E-02	5.10E-02	2.18E-02
Metering and associated pipework	10	2.11	2.23E-02	1.63E-03	1.44E-03	1.96E-04
	25	13.19	1.70E-03	2.50E-03	2.20E-03	3.00E-04
	50	52.75	9.32E-04	7.58E-03	5.30E-03	2.27E-03
	100	211.00	9.43E-06	2.30E-02	1.61E-02	6.90E-03
	Rupture	889.00	3.80E-04	7.28E-02	5.10E-02	2.18E-02
Pig Receiver	10	2.11	1.14E-02	1.63E-03	1.44E-03	1.96E-04
	25	13.19	1.18E-03	2.50E-03	2.20E-03	3.00E-04
	50	52.75	1.44E-04	7.58E-03	5.30E-03	2.27E-03
	100	211.00	3.54E-06	2.30E-02	1.61E-02	6.90E-03
	Rupture	889.00	6.60E-04	7.28E-02	5.10E-02	2.18E-02
Tie-in to EGP (from SDV-5008 to the point pipe goes underground)	10	2.11	3.67E-03	1.63E-03	1.44E-03	1.96E-04
	25	13.19	1.85E-04	2.50E-03	2.20E-03	3.00E-04
	50	52.75	1.43E-04	7.58E-03	5.30E-03	2.27E-03
	100	211.00	0.00E+00	2.30E-02	1.61E-02	6.90E-03
	Rupture	889.00	6.41E-05	7.28E-02	5.10E-02	2.18E-02

Appendix B. QRA Report Addendum

1. PKLL QRA Addendum

Worley completed a Quantitative Risk Assessment (QRA) for the Jemena Port Kembla Lateral Looping (PKLL) project in August 2020. The scope of analysis included a 5.7km long buried gas transmission pipeline from the discharge of the Cringila station to the Eastern Gas Pipeline (EGP), and a new end of line (EoL) tie-in facility in the vicinity of Jemena's existing Kembla Grange MLV/Lateral Offtake facility.

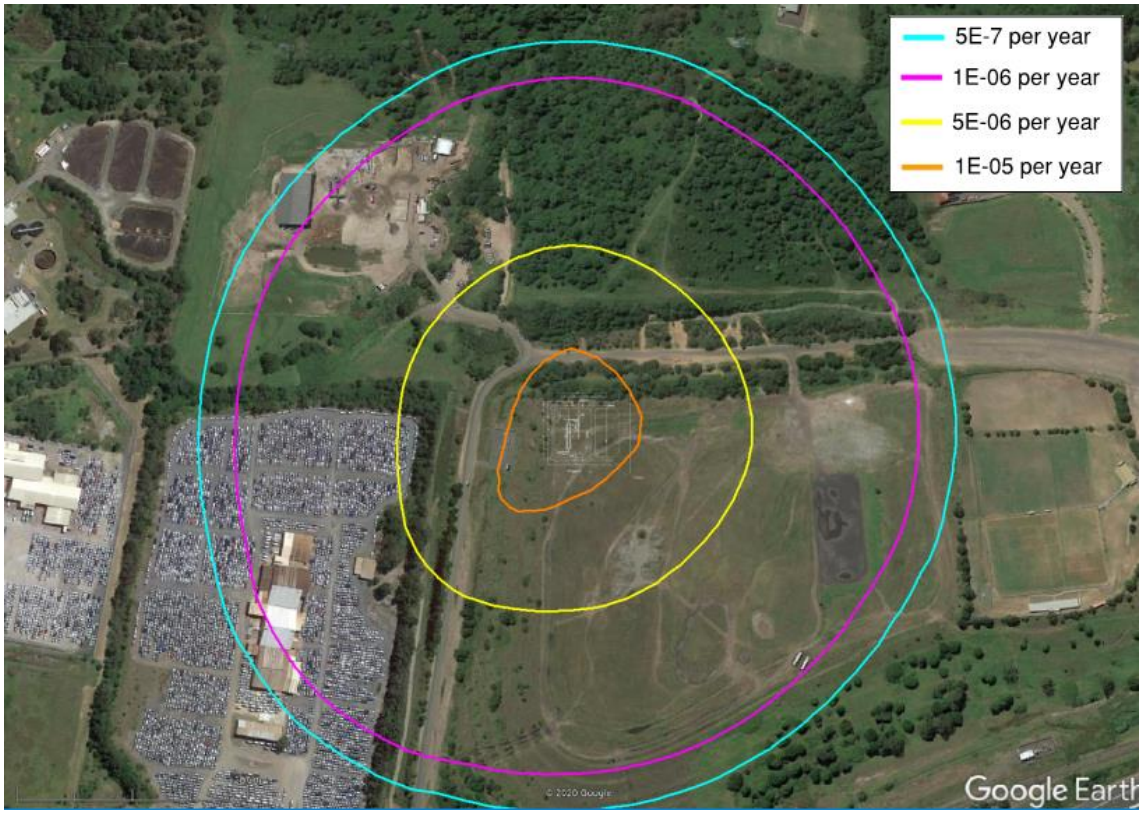
It has been determined that the study basis was a lower operating pressure than a future proposed operating case (12 vs. 16.55MPa). This addendum has been generated to revise LSIR contours for the Kembla Grange Station, and associated lateral pipeline.

In addition to the pressure change, a number of other assumptions were reviewed and revised as part of the update. These related to pipeline hole size distribution, and the split between immediate and delayed ignition events.

Figure 1-1 shows the LSIR contours for a section of the pipeline, and Figure 1-2 for Kembla Grange Location A. Overall, the modifications showed a net reduction in the level of risk being demonstrated. As such there is no modification to the findings of the original QRA report with respect to the pipeline route.

Figure 1-1: LSIR Contour - Pipeline Section 3

Figure 1-2: LSIR Contour – Kembla Grange Location A



2. Summary of Changes

2.1 Operating Pressure

The original analysis was undertaken to align to the extent practicable with that undertaken for the connecting AIE NGP1 pipeline, which runs from the Floating Storage and Regassification Unit (FSRU) at Port Kembla, to the Cringila station.

The PKLL QRA was based on an operating pressure of 12Mpa, which is consistent with the NGP1 study, however the Eastern Gas Pipeline constructed and tested to allow a future increase in operating pressure to 16.55 MPa (corresponding to 80% SMYS for the selected linepipe), and therefore it is credible that in the future, the PKLL may be operated at up to this MAOP.

This addendum has revised the QRA results premised on the MAOP, which has a twofold effect on risk results. Firstly, the higher pressure increases the consequence distances associated with jet and flash fire events. Secondly, as QRA ignition probabilities are correlated to release rate, the change in pressure results in a small increase to overall ignition probability. Table 2-1 shows the impact of pressure increase (and release rate) on ignition probability.

Table 2-1: Impact of Operating Pressure on Ignition Probability

Hole Size (mm)	Original Study (12MPa)		Revised Study (16.55MPa)	
	Release Rate (kg/s)	Ignition Probability	Release Rate (kg/s)	Ignition Probability
10	2.11	1.63E-03	2.86	1.70E-03
25	13.19	2.50E-03	17.92	3.19E-03
50	52.75	7.58E-03	71.67	9.69E-03
100	211	2.30E-02	286.67	2.94E-02
Rupture	889	7.28E-02	1175.39	9.11E-02

In undertaking this assessment however, a more comprehensive review of NGP1 assumptions was undertaken, and have been modified as follows:

2.2 Pipeline Failure Rate and Hole Size Frequency

The NGP1 pipeline assessment was premised on OGP report 434-04 (Riser & Pipeline Release Frequencies), issued in March 2010. This has subsequently been superseded by a September 2019 revision of the document.

This revision has implications on both the failure rate and the recommended distribution of hole sizes.

The 2010 report provided a failure rate of 0.081 per 1000km, premised on the pipeline diameter and wall thickness. Within the 2019 report, this value has increased to 0.091 per 1000km for pipelines between 17 and 23 inches in diameter, with no consideration of wall thickness.

The 2019 study also proposes a revised hole size distribution, which for onshore gas pipelines is more heavily skewed towards small and medium leaks (refer Table 2-2). The studies have been updated to reflect the most recent published failure rate, and hole size distribution.

Table 2-2: OGP 434-04 Hole Size Distribution (2010 vs. 2019)

Leak Description	Diameter (mm)	Hole Size Distribution (%)	
		2010	2019
Small	<20	50	70
Medium	20-80	18	15
Large	>80	18	5
Catastrophic (Full Bore)	Rupture	14	10

2.3 Immediate vs. Delayed Ignition Probability

The NGP1 study applied a split between immediate and delayed probability based on release rate, and sourced from Cox, Lees and Ang "Classification of Hazardous Locations".

The data used was Table 16.3, which provides the estimated probability of explosion given ignition for releases of natural gas, with the explosion probability used to define the delayed ignition probability. The split between immediate and delayed ignition probability per NGP1 QRA is shown in Table 2-3.

Table 2-3: Immediate vs. Delayed Ignition Probability (NGP1, per Cox, Lees & Ang)

Release Size	Rate (kg/s)	Fraction of Ignition Probability Attributed to Immediate Ignition	Fraction of Ignition Probability Attributed to Delayed Ignition
Minor	< 1	0.96	0.04
Major	1 – 50	0.88	0.12
Massive	> 50	0.7	0.3

It is noted however that not all delayed ignition events will lead to an explosion, and as such this approach under estimates the proportion of delayed ignition events, and thus over-estimates immediate ignition.

A more recent and applicable reference is IP Research Report "Ignition Probability Review, Model Development and Look-Up Correlations".

Table 2.13 (OIR 12 data ignition outcome distribution by media) suggests that 29% of ignited gas releases will result in a jet fire (immediate ignition event), with the remaining 61% flash fires and explosions. This is backed up by Table 2.15 (Plant ignition timings distribution) which suggests that 36% of ignition events occur within 30 seconds of release (media independent).

Therefore, a 30% to 70% split between immediate and delayed ignition is considered more appropriate, and has been applied to the PKLL QRA studies.

3. Results

The following section outlines changes in LSIR contours along the pipeline route, and at Kembla Grange.

3.1 Pipeline

The previous study showed risk contours of 5E-07 per annum (criterion for sensitive land use), with no risk recorded at the 1E-06 (criterion for residential development) level.

As the gas is buoyant, and all releases are modelled as vertical or angled 45˚ from horizontal, the risk profile is dominated by jet fires. Whilst the pressure change has increased release rate and ignition probability, the revised hole size distribution, and in particular the revised split between immediate and delayed ignition has resulted in an overall risk reduction, such that there is no risk recorded at the 5E-07 level. Risk contours have been produced for the 3E-07 risk level, and are located broadly consistently with the previous 5E-07 contour.

Revised LSIR contours for the pipeline are shown in Figure 3-1 to Figure 3-6. As the study modifications have resulted in a net lower risk than previous being demonstrated, there is no modification to the findings of the original QRA report with respect to the pipeline route.

Figure 3-1: LSIR Contour - Pipeline Section 1

Figure 3-2: LSIR Contour - Pipeline Section 2

Figure 3-3: LSIR Contour - Pipeline Section 3

Figure 3-4: LSIR Contour - Pipeline Section 4

Figure 3-5: LSIR Contour - Pipeline Section 5

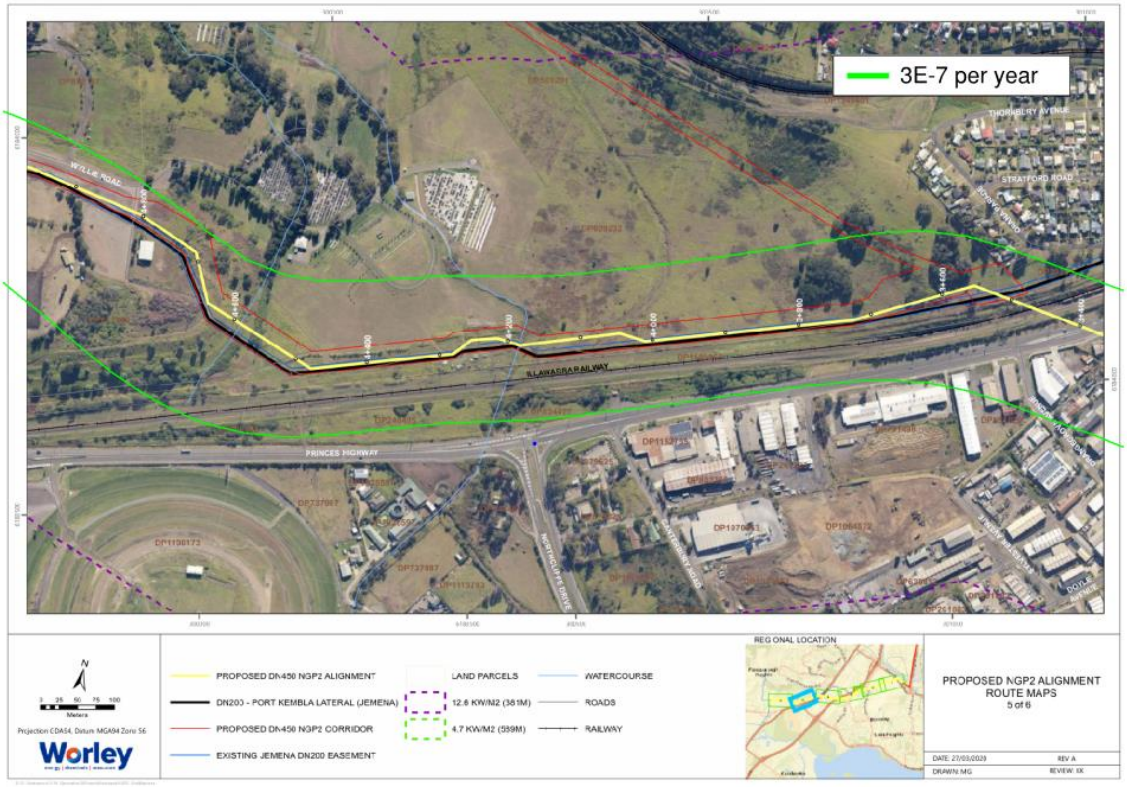


Figure 3-6: LSIR Contour - Pipeline Section 6

3.2 Kembla Grange

Previous analysis concluded that LSIR was well below the target criteria, and there are no locations of elevated occupancy near the Kembla Grange tie-in facility.

The reduction in immediate ignition probability has resulted in a contraction in LSIR contours at all levels.

Revised LSIR contours for the Kembla Grange facility are shown in Figure 3-7 and Figure 3-8. As the study modifications have resulted in a net lower risk than previous being demonstrated, there is no modification to the findings of the original QRA report with respect to the Kembla Grange facility.

Figure 3-7: LSIR Contour – Kembla Grange Location A

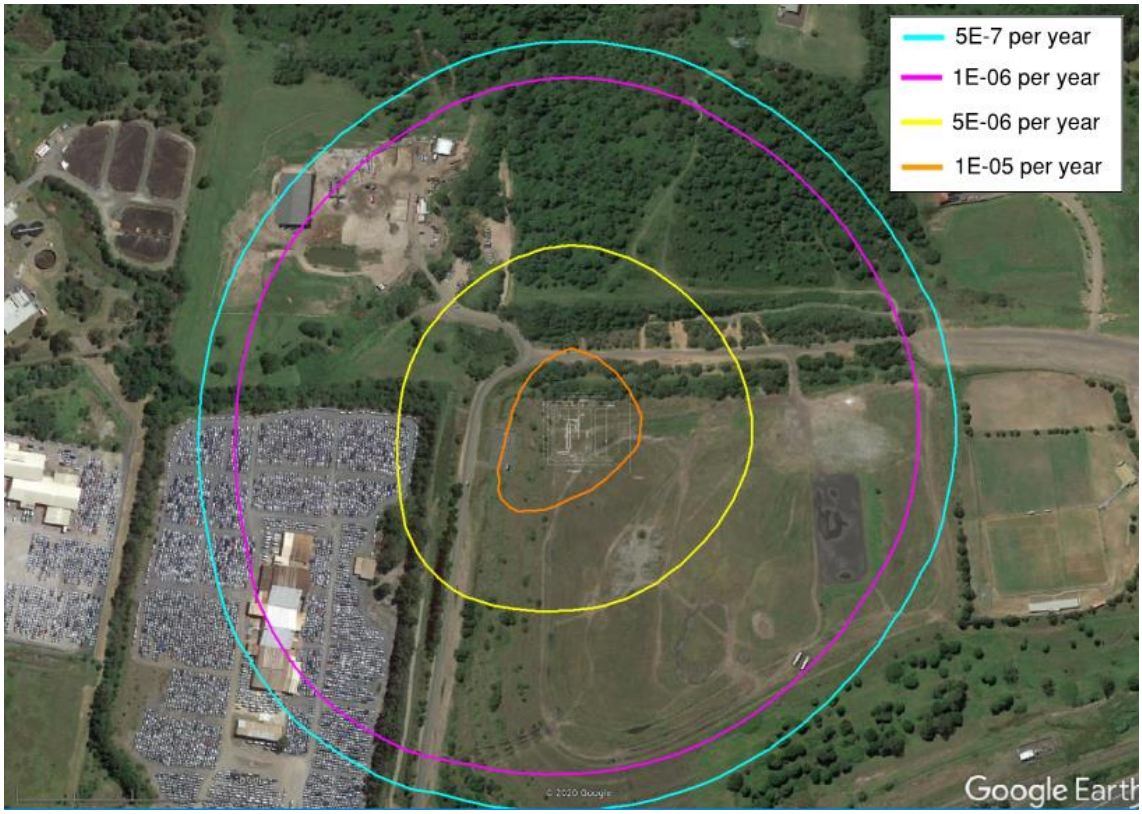


Figure 3-8: LSIR Contour – Kembla Grange Location B