APPENDIX 13

Preliminary Hazard Assessment

umwelt
Environmental & Social Consultants

apa

PRELIMINARY HAZARD ANALYSIS

KURRI KURRI LATERAL PIPELINE PROJECT

FINAL

March 2022

PRELIMINARY HAZARD ANALYSIS

KURRI KURRI LATERAL PIPELINE PROJECT

FINAL

Prepared by

Umwelt (Australia) Pty Limited

on behalf of

APA Group

Project Director:	Paul Douglass
Project Manager:	Marion O'Neil
Technical Director:	Tim Procter
Technical Manager:	Chris Bonomini
Report No.	21450/R09
Date:	March 2022

Environmental & Social Consultants

Acknowledgement of Country

Umwelt would like to acknowledge the traditional custodians of the country on which we work and pay respect to their cultural heritage, beliefs, and continuing relationship with the land. We pay our respect to the Elders – past, present, and future.

Document Status

Rev No.	Reviewer		Approved for Issue	
	Name	Date	Name	Date
FINAL	Tim Procter	7 March 2022	Paul Douglass	7 March 2022

Glossary

Abbreviation/Term	Definition
AS	Australian Standard
atm	atmospheres (1,013 millibars of pressure)
CCTV	Closed Circuit Television
CDL	Critical Defect Length
HDD	Horizontal Directional Drill
ICCP	Impressed Current Cathodic Protection
JGN	Jemena Gas Netork
K	Kelvin (-273 degs Celcius)
kg	kilogram
KP	Kilometer Point
kV	kilo Volt (1000 Volts)
Location Class	Classification of an area according to its predominant land use and density of human activity, reflecting both the THREATS to the PIPELINE SYSTEM from the land usage and the consequences for the population should the PIPELINE SYSTEM suffer a loss of containment
m	metre
m^3	metres cubed
MAOP	Maximum Allowable Operating Pressure
MJ	megajoule
mm	millimetres
mol%	molar percentage of gas
MPag	megapascal gauge
MW	megawatt
Rupture	Failure of the pipe such that the cylinder has opened to a size at least equivalent to the pipe diameter
Sm^3	Standard Cubic meters (at STP)
SMS	Safety Management Study (in accordance with AS 2885.6)
STP	Standard Temperature and Pressure conditions of 288.15 K (15 deg C) and 1 atm
SNP	Sydney Newcastle Pipeline
T	tonne
Threat	Any activity or condition that can adversely affect the pipeline system if not controlled
TJ	terajoule

Table of Contents

Figures

Tables

Appendices

1.0 Introduction

1.1 Project Overview

Snowy Hydro Limited is developing a gas-fired peaking power station, referred to as the Hunter Power Project (HPP), at the site of the former Hydro Australia Pty Ltd (Hydro) aluminium smelter at Kurri Kurri. The HPP aims to provide up to 750 megawatts (MW) of 'on-demand' electricity to supplement Snowy Hydro's generation portfolio with dispatchable capacity when the needs of electricity consumers are highest. The HPP was approved by the Secretary of the Department of Planning, Industry and Environment (DPIE) on 17 December 2021 and by the Commonwealth Minister for the Environment on 6th Feb 2022.

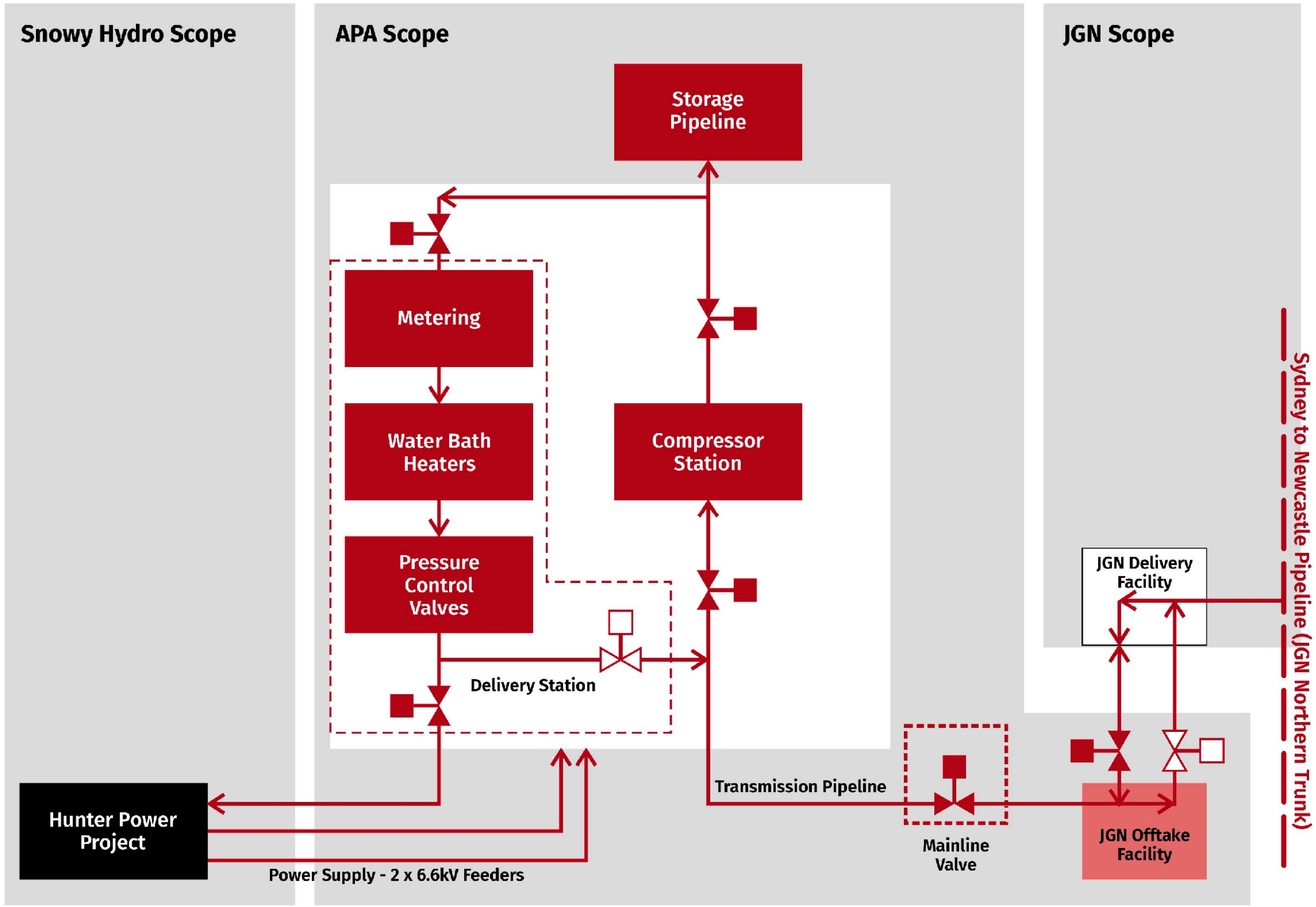
APA Group (APA) has been engaged by Snowy Hydro Limited to develop a gas supply solution for the HPP. APA has proposed the Kurri Kurri Lateral Pipeline (KKPL) Project (the Project) as the gas supply solution for the HPP.

The Project comprises the following primary components:

- A buried, steel, medium diameter (up to DN350), medium pressure (up to 6.9 megapascal (MPag)) transmission pipeline of approximately 20.1 km in length to provide a gas supply from the existing Sydney to Newcastle Pipeline (SNP), via receipt and delivery facilities, to the HPP site.
- A compressor station at the termination of the transmission pipeline to boost gas pressure prior to transfer to a storage pipeline.
- A buried, steel, medium diameter (up to DN350), high pressure (up to 15.3 MPag) interconnect pipeline of approximately 1.3 km in total length, providing an interface between the compressor station, storage pipeline and delivery station.
- A buried, steel, large diameter (up to DN1050), high pressure (up to 15.3 MPag) storage pipeline of approximately 24 km in total length downstream of the compressor station with approximately 70 terajoules (TJ) of useable gas storage ready to supply the HPP.
- A delivery station to receive gas from the storage pipeline and control temperature, pressure and flow rate prior to delivery of gas to the HPP.

The compressor station and delivery station are located within the HPP project site boundary.

The construction, operation, maintenance and decommissioning of these project components are evaluated in this Preliminary Hazard Assessment (PHA). A schematic outlining the relationship of these project components is provided in **Figure 1.1**.



Note: Not to Scale

FIGURE 1.1

Relationship of Project Components

A compressor station and storage pipeline are required as part of the Project as the SNP does not provide sufficient gas flow rates or pressure to meet the supply requirements of the HPP turbines. As such, a direct pipeline connection between the SNP and the HPP is not a viable solution for gas supply to the HPP.

The proposed alignment of the transmission pipeline would commence at the Project's proposed Jemena Gas Network (JGN) offtake facility near Black Hill, approximately 15 km northwest of Newcastle and terminate at the HPP, approximately 2 km north of Kurri Kurri, as shown on **Figure 1.2**.

Construction is planned to commence during Q4 2022 with a gas supply to the HPP provided during Q4 2023. The HPP is planned to be operational by the end of 2023.

The Project, including the surface facilities, would be designed, constructed, commissioned and operated in accordance with *Australian Standard 2885 Pipelines – Gas and Liquid Petroleum* (AS 2885 - a suite of standards outlining requirements for gas and petroleum pipelines which are designed, constructed and operated in Australia) and licenced under the *Pipelines Act 1967*.

This Preliminary Hazard Analysis (PHA) has been prepared by Umwelt (Australia) Pty Ltd (Umwelt) in accordance with the Secretary's Environmental Assessment Requirements (SEARs) issued by the Department of Planning, Industry and Environment (DPIE) on 23 July 2021. This report provides an assessment of the hazards and risks posed to public safety associated with the storage, handling and transport of hazardous materials and dangerous goods during Project construction and operation.

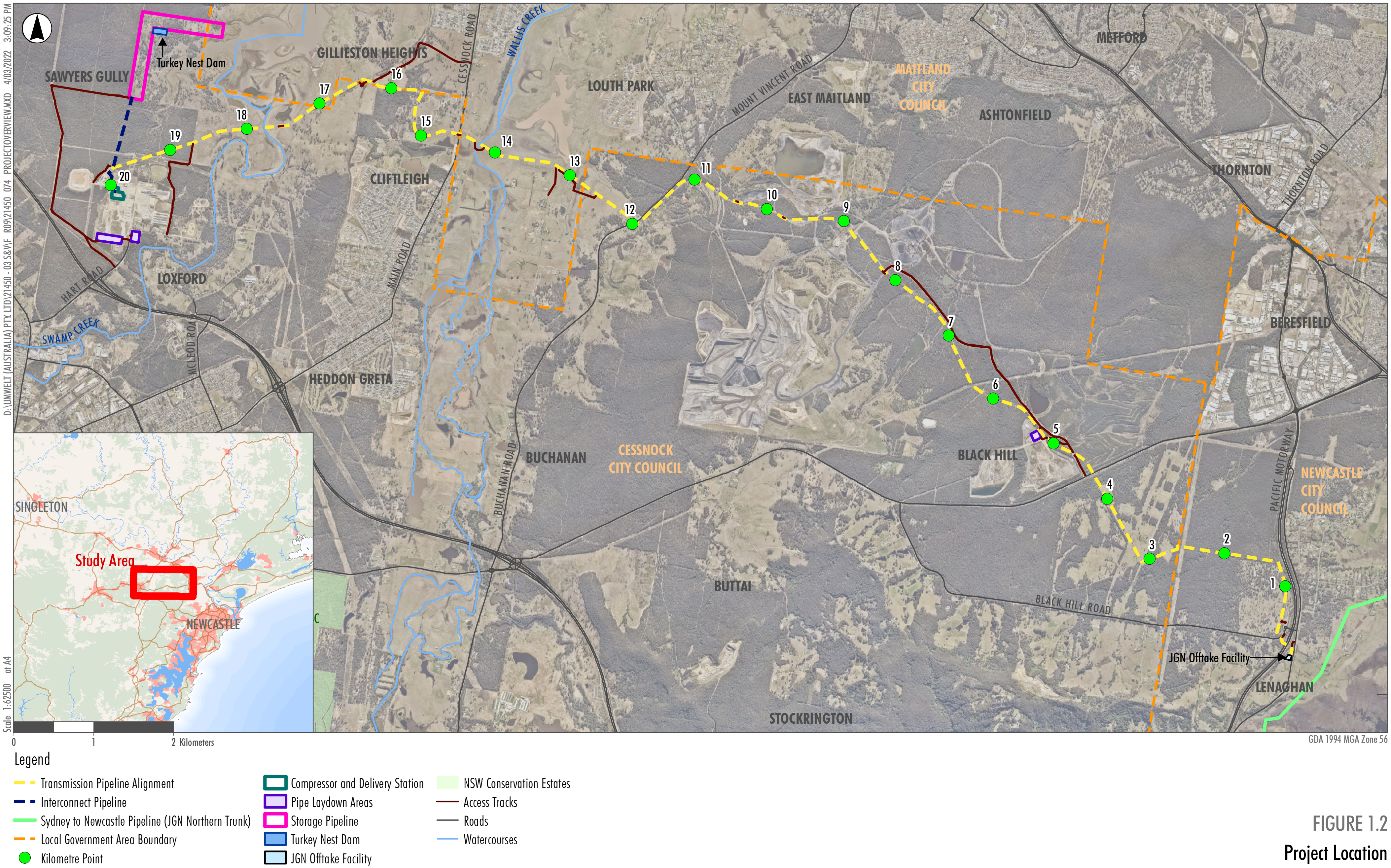


FIGURE 1.2

Project Location

Image Source: Neamap (August 2021) Data source: NSW LPI (2020;2021)

1.2 Assessment Requirements

The SEARs for the Project identify key issues and referenced guidelines that must be addressed in the Environmental Impact Statement. **Table 1.1** presents the assessment requirements relevant to the hazards and risks and where these have been addressed in this report.

Table 1.1 SEARS and Where Addressed

Requirement	Section where addressed
Hazards and Risks – including:	
• a Preliminary Hazard Analysis (PHA), covering an assessment of the hazards and risk impacts likely to be associated with the project, including gas leaks and transport, handling and management of dangerous goods. The assessment must be prepared consistent with Hazardous Industry Planning Advisory Paper No. 6 – Guidelines of Hazard Analysis (DPE, 2011) and Multi-level Risk Assessment. The PHA must:	This report
▪ be a quantitative risk assessment (QRA) to estimate the risks from the pipeline to the surrounding land uses, including ground movement or subsidence within or close to the Black Hill mine site, and with reference to applicable Australian Standards (including AS2885 Pipelines – Gas and Liquid Petroleum - Operation and Maintenance) and licensing requirements under the Pipelines Act 1967;	Refer to **Section 6.0**
▪ demonstrate that the pipeline corridors and designs to which approval is sought can comply with the Department's Hazardous Industry Planning Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning'; and	Refer to **Section 7.0**
▪ consider the PHA prepared for the proposed Hunter Power Project (Kurri Kurri Power Station (SSI-12590060), particularly in relation to safeguards against accident propagation or escalation between the two projects; and	Refer to **Section 7.3**
▪ on-going maintenance and safety management of the project, including potential impacts on and from bushfires and floods;	Refer to **Section 8.0**

This report has been prepared in accordance with the following guidelines and legislative requirements:

- *Applying SEPP 33: Hazardous and Offensive Development Application Guidelines, NSW Department of Planning, 2011*
- *Multi-level Risk Assessment, NSW Department of Planning, 2011*
- *Hazardous Industry Planning and Advisory Paper 4 – Risk Criteria for Land Use Safety Planning, NSW Department of Planning, 2011*
- *Hazardous Industry Planning and Advisory Paper 6 – Hazard Analysis, NSW Department of Planning, 2011*
- *Manual for classification of risks due to major accidents in process and related Industries, International Atomic Energy Agency, 1996*

1.3 Scope of Preliminary Hazard Analysis

The scope of the PHA includes an assessment of the risks associated with potential hazardous events:

- at the APA controlled offtake facility (the JGN offtake facility) including the potential for propagation of hazardous events between the JGN offtake facility and the adjacent Jemena controlled SNP delivery facility
- along the length of the transmission pipeline from the JGN offtake facility
- at the storage station (which incorporates the compressor station and delivery station) located the HPP site including the potential for propagation of hazardous events between the Project and the HPP
- along the length of the interconnect pipeline that transfers gas from the compressor station to the storage pipeline
- along the length of the storage pipeline.

2.0 Detailed Project Description

2.1 Project Components

The transmission pipeline and storage pipeline have varying characteristics required to fulfil separate functions, as described in the following sections. Both pipelines, however, will be designed and constructed in accordance with the *Australian Standard* (AS) *2885* (and in accordance with the *Australian Pipeline and Gas Association Code of Environmental Practice 2017*. The AS 2885 series includes the following:

- *AS/NZS 2885.0:2018 Part 0 – Pipelines, Gas and liquid petroleum, General requirements*
- *AS/NZS 2885.1:2018 Part 1 – Design and Construction (AS/NZS 2885.1)*
- *AS/NZS 2885.2:2018 Part 2 – Welding (AS/NZS 2885.2)*
- *AS/NZS 2885.3:2018 Part 3 – Operations and Maintenance (AS/NZS 2885.3)*
- *AS/NZS 2885.5:2018 Part 5 – Field Pressure Testing (AS/NZS 2885.5)*
- *AS/NZS 2885.6:2018 Part 6 – Safety Management Studies (AS/NZS 2885.6).*

The design of the storage pipeline will also incorporate requirements of *API 579-1:2016 Fitness-For-Service* and *BS 7910:2019 Guide to methods for assessing the acceptability of flaws in metallic structures* to address stress intensity factors for fatigue design.

In addition, the transmission pipeline will be designed, constructed and commissioned in accordance with the requirements of *ASME B31.12-ASME Design code for Hydrogen Piping and Pipelines* (ASME B31.12), in order to maintain readiness for the potential use of hydrogen in the east coast gas network. ASME B31.12 is the recommended hydrogen design standard to be used in conjunction with AS 2885 suite of design codes.

With regards to the gas storage pipeline, a significant increase in capital expenditure would be required to construct the storage pipeline for it to be capable of storing a hydrogen blended fuel. This is due to the design requirements of the gas storage pipeline, including the material selection and construction methods required to mitigate the increased embrittlement of pipeline material when storing a hydrogen blended fuel.

A summary of specifications for the transmission, storage and the interconnect pipelines between the compressor station and storage pipeline, is provided in **Table 2.1**. Further details regarding pipeline design are outlined in the following sections. All specifications and parameters are subject to refinement during detailed design.

The pipeline design and construction features described in the following sections all contribute to reducing the frequency of pipeline loss of containment events and the magnitude of a loss of containment event should one eventuate.

Table 2.1 Pipeline Specifications

	Transmission pipeline	Intercconnect pipeline (compressor station to storage pipeline)	Storage pipeline
Pipeline Length	Approximately 20.1 km	Approximately 1.3 km	Approximately 24 km
Nominal and outside diameter	DN350, 355.6 mm (14”)	DN350, 355.6 mm (14”)	DN1050, 1,067 mm (42”)
Material	High strength steel, Electric resistance welded (ERW)	High strength steel, Electric resistance welded (ERW)	High strength steel, submerged arc welded
Grade	Nominally API 5L PSL2 Grade X52	Nominally API 5L PSL2 Grade X52	Nominally API 5L Grade X60
External coating	Fusion bonded epoxy, with abrasion resistant coating on pipe segments for HDD	Fusion bonded epoxy, with abrasion resistant coating on pipe segments for HDD	Fusion bonded epoxy
Maximum Allowable Operating Pressure	6.9 MPag	15.3 MPag	15.3 MPag
Operational Capacity	Nominally up to 60 TJ per day	Included in 70 TJ storage pipeline capacity	Approximately 70 TJ of useable gas storage
Wall-thickness	Standard wall 8.6 mm	Standard wall 12.7 mm	Standard wall 28 mm Heavy wall 31 mm
Pipe segment lengths	12 or 18 m	12 or 18 m	12 m
Number of pipe segments	Around 1,150 triple random lengths (18 m) and 15 pipe segments of double random lengths (12 m) for bends	Around 78 triple random (18 m) pipe segments and 10 bend segments	Around 2,058 pipe segments and 50 bend segments
Typical construction footprint width	25 m	25 m	175 m Total width, distance between pipes will be approx. 8 m
Typical easement width	Nominally 20 m	Nominally 20 m	Nominally 120 to 140 m

2.1.1 Transmission pipeline

The transmission pipeline will be constructed of high strength steel lined pipe. The wall thickness of the pipe will be determined during detailed design and is anticipated to be 8.6 mm, as indicated in **Table 2.1**.

This pipe wall thickness is considered suitable for road and river crossings, as per the design calculation requirements specified in AS 2885.

The pipe wall thickness is considered to satisfy the “no rupture” requirement for the residential location class (T1) (as defined in AS/NZS 2885) for the pipeline. The “no rupture” requirement is usually satisfied by demonstrating that the critical defect length (CDL) of the pipeline must be larger than 150% of the maximum credible hole size that the pipeline could experience from an external interference threat (e.g. excavators bucket teeth). The CDL is the defect length at which the pipeline will fail to a full bore rupture when pressurised to the maximum allowable operating pressure (MAOP). It was assessed in the SMS for the transmission pipeline that there were no credible external interference threats (i.e. excavators above 35T under aggressive operation) that could create a penetration large enough to result in rupture of the pipeline.

2.1.1.1 Depth of Cover

The transmission pipeline will be buried for its entire length other than at surface facility locations. At locations where the pipelines are potentially exposed to increased erosional forces, such as watercourse crossings and floodplains, additional protection will be provided by increased depth of cover. The transmission pipeline would also be buried deeper beneath roads and watercourses. Larger watercourses that are highly likely to hold water during construction will be crossed using horizontal directional drilling (HDD).

Minimum depths of cover for the transmission pipeline, measured from top of pipe to natural ground level, are summarised in **Table 2.2**. These minimum depths are based on AS 2885 requirements, including location classification analysis.

Table 2.2 Minimum Depth of Cover – Transmission Pipeline

Location	Depth of Cover
Typical (per AS2885)	900 mm
Road crossings	1,200 mm
Watercourse crossings	1,500 mm
Rail crossings	2,000 mm

2.1.1.2 Scraper Stations

The routine operation of gas pipelines requires the periodic running of a pipeline inspection gauge (PIG) to clean and/or inspect the internal wall surface.

A scraper station with a PIG launcher/receiver will be located at the JGN offtake facility, with a PIG receiver to be located at the Compressor Station. Pipe work to enable the connection of a portable PIG launcher/receiver at the Compressor Station and/or the storage pipeline above ground connection header assembly will also be considered during detailed design.

2.1.1.3 Mainline Valve

A mainline valve (MLV) is an above ground facility comprised of an in-line buried block valve that can be closed to isolate sections of the transmission pipeline for maintenance or during emergency conditions. No venting apparatus is proposed for the MLV. MLVs may be designed for either manual or remote activation with the required functionality an outcome of the Safety Management Study (SMS) undertaken in accordance with AS/NZS 2885.6.

The Project may require one MLV, proposed to be located near Kilometre Point (KP) 12.1 contained in a secured compound within the pipeline easement. A photograph of a typical MLV is shown in **Photo 2.1**.

Photo 2.1 Typical Mainline Valve Compound

2.1.1.4 Corrosion Protection

The primary corrosion protection system for the transmission pipeline will be an external coating. Each pipe length will be coated with fusion bonded epoxy or similar for corrosion protection purposes except at each end to allow welding. Post welding, the uncoated weld margins will be cleaned and coated with spray applied epoxy.

One hundred per cent integrity testing will be undertaken on the coating in both the factory and just prior to being installed in the trench to ensure the integrity of the coating. In addition, a Direct Current Voltage Gradient (DCVG) survey will also be completed following completion of construction to further verify coating integrity.

As a secondary protection against corrosion, a sacrificial or impressed current cathodic protection system (ICCP system) may also be used, however, the requirement for this type of protection is subject to detailed design.

2.1.1.5 Marker Signs

Pipeline marker signs will be installed along the length of the transmission pipeline, to indicate the pipeline location in general accordance with AS/NZS 2885.1. The markers will be located in consultation with land holders and placed at a frequency to ensure continual line of sight along the alignment and will also be located at any bends, at property boundary fences and either side of crossings such as roads or watercourses.

Text on the signs will describe the presence of a high-pressure gas pipeline and provide the name and contact details of the operator.

2.1.1.6 Mine subsidence considerations

The transmission pipeline traverses three mine subsidence districts, as follows:

- Black Hill, between KP1.4 and KP4.6
- Louth Park, between KP10.9 and KP14.4
- Maitland West, between KP14.6 and KP15.9

In these areas the transmission pipeline will be designed, in consultation with Subsidence Advisory NSW, to ensure the pipeline is capable of withstanding subsidence, strains and tilts associated with nearby planned and/or previous underground mining activities.

2.1.1.7 Electricity transmission easements

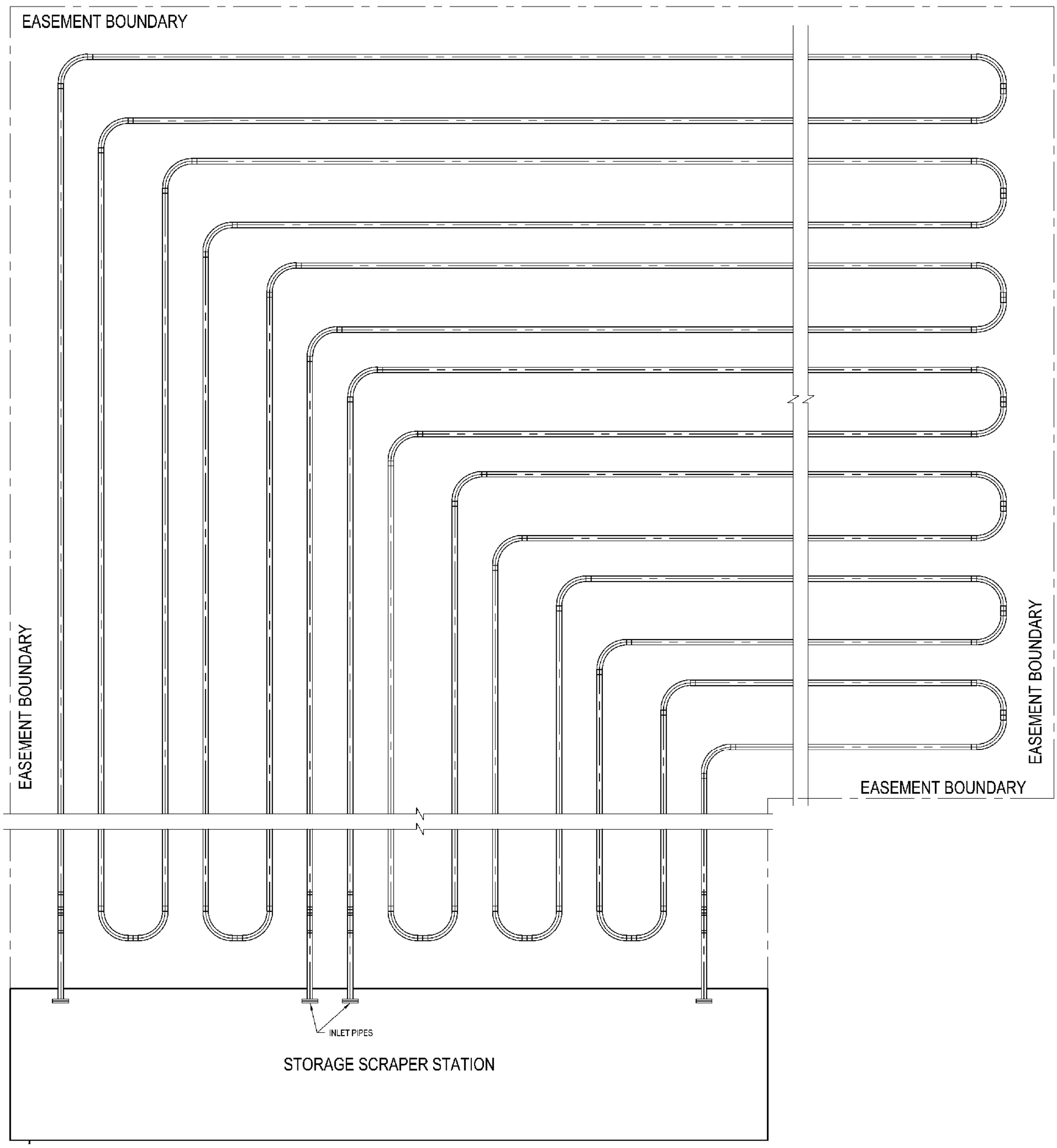
The transmission pipeline alignment crosses active high voltage electricity transmission easements in four locations. High voltage electrical transmission infrastructure has the potential to affect the safe construction, operation and maintenance of the transmission pipeline due to potential induction effects, and power line fault conditions. Appropriate pipeline cathodic protection and current mitigation measures will be provided as required to ensure the integrity of the pipeline and the safety of maintenance personnel. A detailed assessment will be conducted during the detailed design phase to ensure compliance with *AS 4853 Electrical Hazards on Metallic Pipelines*, and confirm whether the installation of discrete and/or continuous earthing points along the pipeline is necessary.

2.1.2 Storage Pipeline and Interconnect Pipeline

The storage pipeline will provide storage capacity for around 110.0 TJ (70 TJ of usable gas) based on a lean natural gas composition of 37.23 MJ/Sm^3 (but up to approximately 114.4 TJ for a rich natural gas with a Higher Heating Value (HHV) of 38.71 MJ/Sm^3), at operating pressures of between approximately 4,700 kPag and 15,320 kPag. This will provide sufficient gas supply (approximately 70 TJ) for the HPP to operate at full output for up to 10 hours. It is also proposed to configure the offtake facility and delivery station so that gas can flow from the storage pipeline back to the east coast gas network via the SNP.

The design concept being developed for the storage pipeline comprises two primary storage pipeline loops each comprised of a series of internal sub-loops, as shown in **Figure 2.1**. The total storage capacity of the storage pipeline will be shared between the two primary loops on an approximate 50% basis. The storage pipeline wall thickness will be 28 to 31 mm (refer to **Table 2.1**). It was assessed in the SMS for the storage pipeline that there were no credible external interference threats (i.e. excavators above 55 T under aggressive operation) that could cause a penetration large enough to result in rupture of the pipeline (penetration size less than the CDL as described for the transmission pipeline in **Section 2.1.1**).

The minimum separation distance between pipeline loops will be maintained to minimise the potential for propagation to an adjacent loop should a loss of containment event occur in one loop section. Although storage pipeline rupture is not considered a credible event, calaculations to determine the minimum separation distance have been based on a rupture scenario with consideration of cratering, direct contact and blast propagation scenarios.



Note: Not to Scale

FIGURE 2.1

Storage Pipeline Design

Image Source: APA (2021) Data source:

The interconnect pipeline wall thickness will be 12.7 mm (refer to **Table 2.1**) and it was assessed in the SMS for the storage pipeline that there were no credible external interference threats (i.e. excavators above 55T under aggressive operation) that could create a penetration large enough to result in rupture of the pipeline.

2.1.2.1 Depth of cover

The storage pipeline will be buried for its entire length, other than at the above ground connection header assembly. At locations where the pipelines are potentially exposed to increased erosional forces, such as watercourses and floodplains, additional protection will be provided by increased depth of cover.

Minimum depths of cover for the storage pipeline, measured from top of pipe to natural ground level and based on AS 2885/NZS requirements, are summarised in **Table 2.3**.

Table 2.3 Minimum Depth of Cover – Storage and HDD Pipelines

Location	Depth of Cover
Typical (per AS/NZS 2885)	900 mm
Watercourse crossings	1,500 mm

2.1.2.2 Cathodic protection

The storage pipeline will be protected from external corrosion by a sacrificial or ICCP system. The final selection of the CP system will occur during detailed design. The system will also mitigate stray currents from any parallel electricity transmission lines, in accordance with *AS 4853 Electrical hazards on metallic pipelines*. The above ground pipework will be isolated from the CP system using Monolithic Insulating Joints (MIJ). Any Cathodic Protection design is undertaken in accordance with *AS 2832 Guide to the Cathodic Protection of Metals Part 1, Pipes, Cables and Ducts*. Cathodic protection test points will be installed along the storage pipeline at selected intervals, subject to detailed design. Insulated joint test points will be installed at the pipeline insulating joints.

2.1.2.3 Integrity inspections

The routine cyclic operation of gas storage pipelines requires the periodic inspection to recertify that the pipeline is fit for service.

Integrity inspections during the operational life of the storage pipeline are proposed to be undertaken every 7-10 years by either inline ultrasonic inspection tools or specific hydrotesting methods. The storage pipeline design will be designed to allow for industry standard inline inspection tools and equipment by specifying bends and fittings to allow passage without hinderance. The minimum bend radius of the storage pipe will be five times the diameter of the pipe.

2.1.2.4 Fencing and marker signs

The operational easement for the storage pipeline will encompass an area of approximately 23 ha. The operational easement may be fenced with a typical 4 strand wire stock fence or similar, based on consultation with the landholder and the outcome of the SMS.

The above ground connection header assembly will be fenced with ring lock 1800 mm and 3 strands of barbed wire or similar security fencing.

Pipeline marker signs will also be installed in accordance with AS/NZS 2885.1.

2.1.3 Associated Surface Facilities

As noted in **Section 2.1**, the Project will require the construction of the following surface facilities to support the operation of gas transmission, interconnect and storage pipelines:

- JGN offtake facility — to control the flow of gas between the storage pipeline and the SNP via the delivery station and transmission pipeline.
- Compressor station – to increase gas pressure prior to delivery to the storage pipeline. Located at the termination of the transmission pipeline.
- Delivery station — to receive gas from the storage pipeline and control temperature, pressure and flow rate for delivery of gas to the HPP and gas flow back through the transmission pipeline to the SNP . Located adjacent to the HPP.

These facilities are further described in the sections below.

2.1.3.1 JGN Offtake Facility

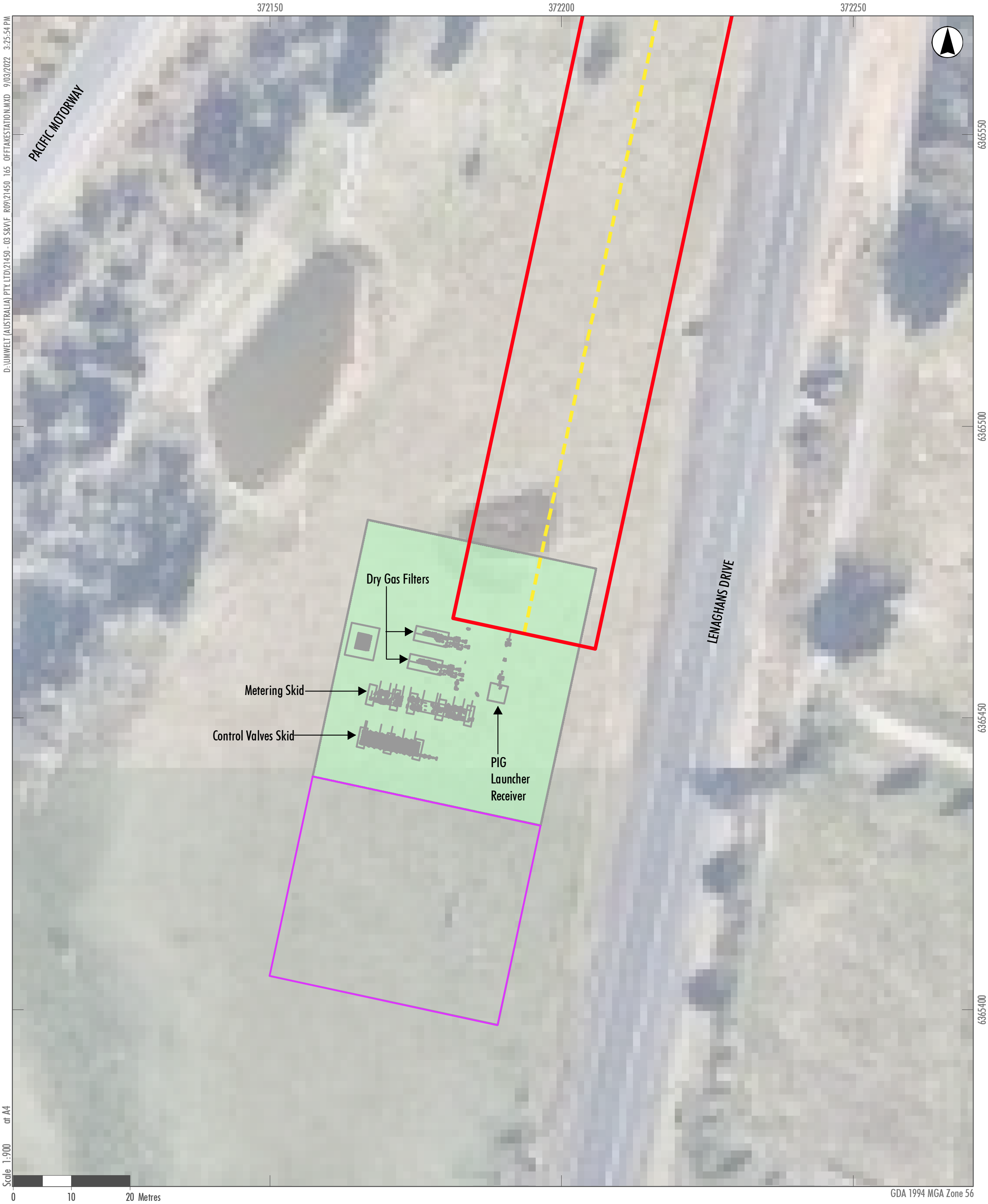
The JGN offtake facility is an above ground facility that will control the flow of gas from the Project back into the Sydney to Newcastle Pipeline. The JGN offtake facility will operate when gas is flowing from the storage pipeline back into the SNP via the transmission pipeline.

Infrastructure at the JGN offtake facility will include the following:

- PIG launcher/receiver
- Dry gas filters
- Gas chromatograph
- Flow metering
- Flow/pressure control and isolation valves
- Control hut, with Station Remote Terminal Unit (RTU) and associated communications.

The JGN offtake facility will require a maximum disturbance footprint of 0.4 ha, and an operational area of around 0.1 ha. A schematic depicting the typical layout of a JGN offtake facility is provided in **Figure 2.2**.

The total operational area required for the co-located APA and Jemena receipt and delivery facilities is estimated to be 0.2 ha.



Legend

- Transmission Pipeline Construciton Footprint
- Transmission Pipeline Alignment
- JGN Offtake Facility Boundary
- JGN Receipt Station

FIGURE 2.2

Schematic of a Typical Layout for the Offtake Station

Image Source: Nearmap (2021) Data source: APA (2021)

2.1.3.2 Compressor station

The compressor station is an above ground facility that will receive and compress gas from the transmission pipeline prior to transfer to the storage pipeline at a higher pressure. The compressor station will be located directly adjacent to the HPP.

The compressor station is proposed to consist of two electrically driven reciprocating compressors (which use pistons to compress the gas), operating on a 2 x 50% arrangement. The compressor station will receive gas from the transmission pipeline at pressures between 1.5 to 5.0 MPag and discharge gas to the storage pipeline at 15.3 MPag and enable the storage pipeline to be recharged at approximately 52.8 TJ of gas over a 24 hour period. Each compressor will be housed in a ventilated acoustic enclosure equipped with gas detection and associated alarms.

The compressor station will be electrically driven with a power demand of up to 7.5 MW. Electrically driven compressors are typically more efficient and reliable than gas driven compressors, as well as having significantly lower noise emissions and negligible air emissions.

The compressor station will require a high voltage power supply to provide the required power demand. This supply is proposed to be supplied by connection to the HPP switchboards at 6.6 kV by underground cable distribution feeders within the HPP building envelope. The high voltage supplies will be distributed internally within the compressor station by dedicated high voltage switchgear located within a high voltage substation building.

Low voltage equipment will be supplied by an internal distribution transformer, supplied from the high voltage switchgear. The low voltage switchgear and ancillaries will be located within switchrooms as required. An emergency low voltage supply will also be provided to the station for critical loads from the HPP essential services supply. This will be routed underground with the high voltage supply cabling.

The compressor station will be located within a site of approximately 100 m x 120 m. A compound of approximately 100 m x 100 m housing a cold vent stack will be located adjacent to the compressor station. The vent stack will be available for use during emergency situations and during occasional maintenance.

A layout plan of the storage station (includes the compressor station) is presented in **Figure 2.3**.

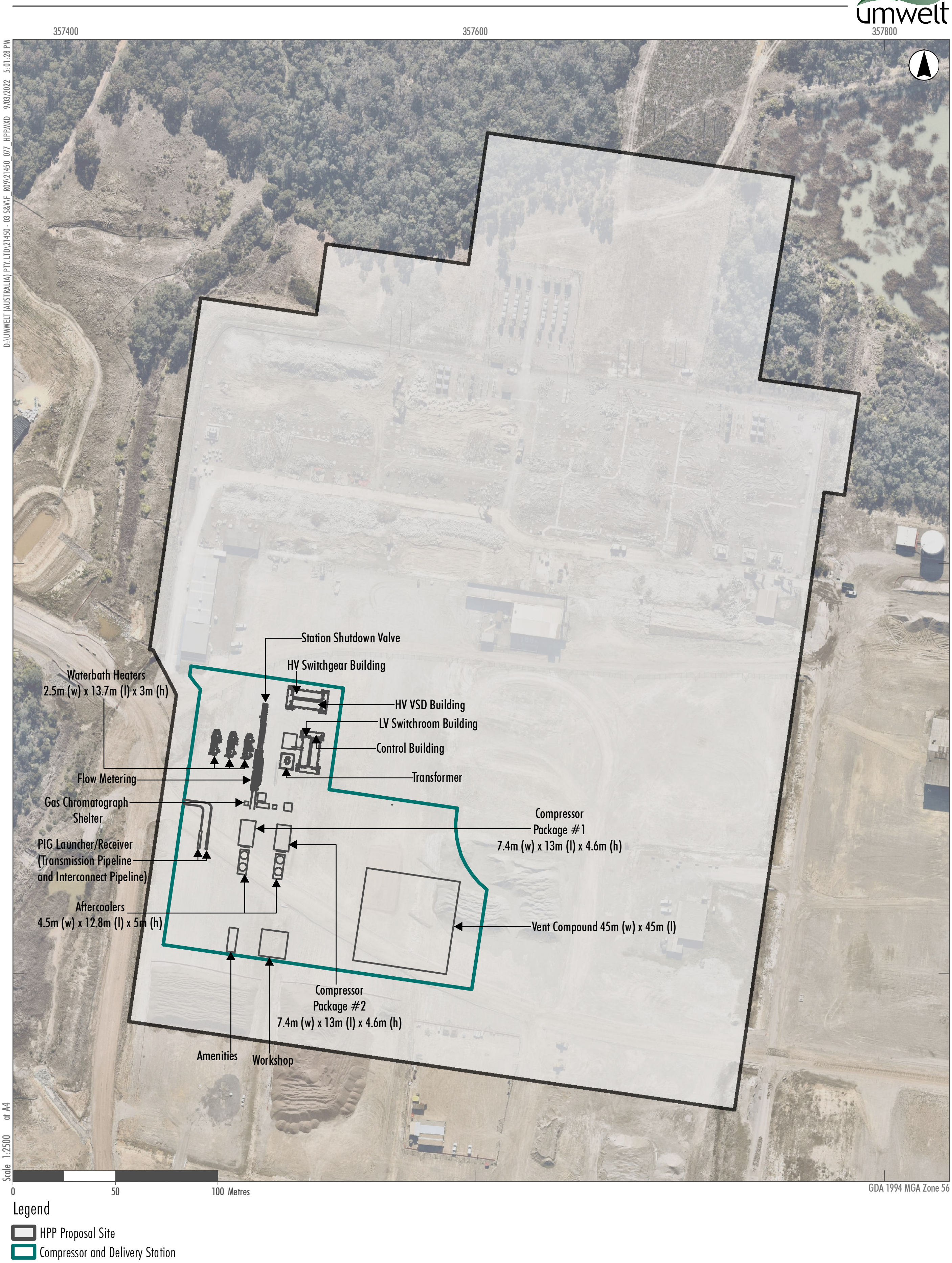


FIGURE 2.3

Layout of the Compressor Station and Delivery Station

Image Source: Nearmap (August 2021) Data source: APA (2021)

2.1.3.3 Delivery Station

The delivery station is an above ground facility to control the delivery of gas from the storage pipeline to the HPP. The delivery station monitors and regulates the temperature, pressure and flow rate of gas exiting the storage pipeline to meet the delivery specifications of the HPP. Note that the delivery station is referred to in the HPP EIS as the gas receiving station.

Gas temperature is proposed to be controlled using three water bath heaters, in a 3 x 50% configuration, on 2 duty/1 standby arrangement. Each water bath heater will be approximately 5 m high, excluding the vent outlets. The energy source for the water bath heaters is proposed to be gas sourced from the storage pipeline.

Multiple parallel control valves will control the pressure and flow rate of gas from the water bath heaters into the HPP. The control valves will reduce the pressure from the storage pipeline incoming pressure to the lower HPP supply pressure. In the event of an equipment failure, overpressure protection safeguards will be in place.

Custody transfer metering will be installed as part of the delivery station to measure the energy flow of gas being delivered to the HPP.

A vent stack for use during emergency situations and during occasional maintenance would be shared with the compressor station.

In addition to HPP supply, the delivery station will also connect to the transmission pipeline to enable flow of gas from the storage pipeline back into the SNP. Flow direction would be controlled by on/off valve switching. Currently, gas being supplied to the NSW load centres (spanning Newcastle to Wollongong) must be imported via the Eastern Pipeline or the Moomba to Sydney pipeline. During periods of tightness in the NSW gas market having a storage pipeline that can inject gas back into the network will help provide greater gas system security and will help with managing the peakiness in NSW gas customer loads.

Lighting would be provided for security and emergencies purposes at the facility as required.

The delivery station will be automated and designed so that it is capable of operating unmanned under normal operating conditions. It is likely that that the site will be monitored by two technicians on-site during daylight hours, and available for 24 hour call out to site as required.

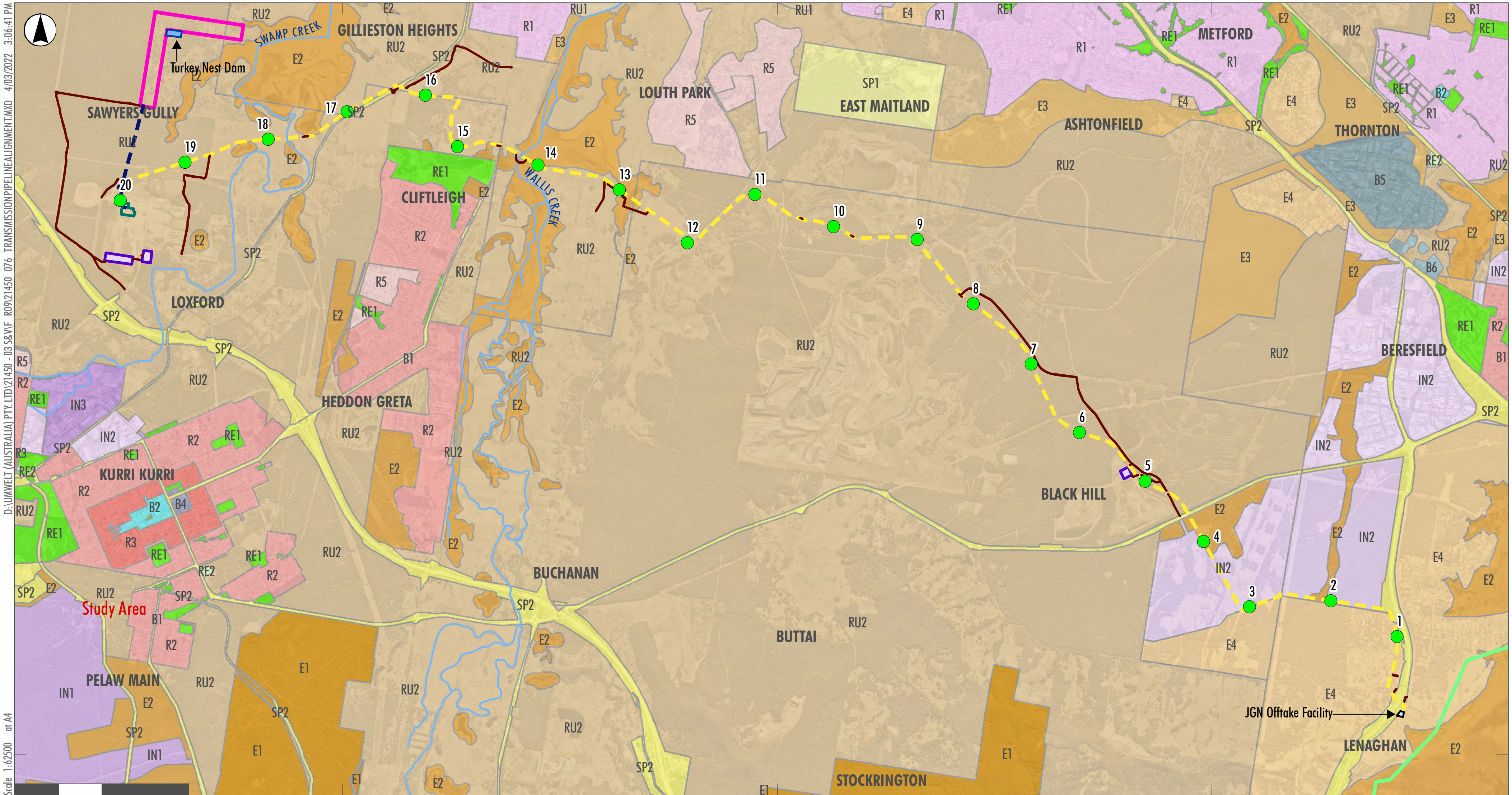
A layout plan of the storage station (includes the delivery station) is presented in **Figure 2.3**.

2.2 Pipeline Alignments and Surface Facility Locations

2.2.1 Transmission Pipeline Alignment

The alignment of the transmission pipeline is approximately 20.1 km in length, extending from the proposed JGN offtake facility to the approved HPP. The construction right of way (ROW) for the transmission pipeline would generally be 25 m wide, with additional work spaces required for truck turnarounds, vegetation storage, horizontal directional drilling (HDD) entry and exit locations, horizontal bore entry and exit locations, watercourse crossing workspaces and line pipe storage areas.

The local context of the transmission pipeline alignment is described in the following sections. **Figure 2.4** presents the transmission pipeline alignment and the existing, planned or potential future land uses along the alignment.



Scale 1:62500 at A4

D:\UMWELT (AUSTRALIA) PTY LTD\21450 - 03 S&VF R09\21450 076 TRANSMISSIONPIPELINEALIGNMENT.MXD 4/03/2022 3:06:41 PM

Legend

- Transmission Pipeline Alignment
- 14" Connecting Pipeline
- Sydney to Newcastle Pipeline (JGN Northern Trunk)
- Kilometre Point
- Compressor and Delivery Station
- Pipe Laydown Areas
- Storage Pipeline
- Turkey Nest Dam
- JGN Offtake Facility
- Access Tracks
- Watercourses

EPI Land Zoning

- B1 Neighbourhood Centre
- B2 Local Centre
- B4 Mixed Use
- B5 Business Development
- B6 Enterprise Corridor
- E1 National Parks and Nature Reserves
- E2 Environmental Conservation
- E3 Environmental Management
- E4 Environmental Living
- IN1 General Industrial
- IN2 Light Industrial
- IN3 Heavy Industrial
- R1 General Residential
- R2 Low Density Residential
- R3 Medium Density Residential
- R5 Large Lot Residential
- RE1 Public Recreation
- RE2 Private Recreation
- RU1 Primary Production
- RU2 Rural Landscape
- SP1 Special Activities
- SP2 Infrastructure

FIGURE 2.4

Existing Land Use

Image Source: Nearmap (August 2021) Data source: NSW LPI (2020;2021); NSW DPIE (2020)

2.2.1.1 KP0 to KP12

The transmission pipeline alignment starts at the APA controlled compound at the JGN offtake facility near Lenaghan, on the western side of Leneghans Drive KP0. The alignment initially traverses in northerly direction, on the western side of Lenaghan's Drive, to approximately KP0.1 where it turns west and crosses the Pacific Motorway. At around KP0.3 the alignment crosses Black Hill Road and traverses north within the lots to the west of Pacific Motorway road reserve to approximately KP1.3.

From KP1.3 the alignment then turns west to traverse the southern boundary of the approved but yet to be constructed Stevens Group Hunter Business Park industrial development, crossing Viney Creek and a Transgrid easement with a 330 kV overhead powerline, to approximately KP2.7. From here the alignment continues southwest following the southern boundary of the proposed Broaden Management industrial development and crossing an Ausgrid easement hosting a 66 kV overhead powerline to approximately KP3.1. The alignment then turns north-west and runs adjacent to a lot containing a Hunter Water Corporation reticulation main. John Renshaw Drive is crossed by a horizontal directional drill (HDD) between approximately KP4.1 and 4.5. This HDD will pass under the Hunter Water Corporation Chichester Trunk Gravity Main (CTGM), a critical public water supply pipeline from the Chichester Dam, supplying the Stony Pinch Reservoir and, in turn, the city of Newcastle. Between Viney Creek and John Renshaw Drive the alignment passes above previously mined sections of the Yancoal underground Abel Coal Mine, which is currently in care and maintenance.

From John Renshaw Drive until KP12.8 the alignment traverses land managed as rehabilitated or active coal mining operations by Donaldson Coal Pty Limited (a subsidiary company of Yancoal) and The Bloomfield Group. The alignment traverses this land in a north-westerly direction adjacent to a lot containing Hunter Water Corporation trunk mains with the alignment crossing the trunk mains that connect the CTGM to the Stony Pinch reservoir in this section, as well as an Ausgrid easement that accommodates a 132kV overhead powerline. The alignment reaches Buchanan Road near KP12.0.

2.2.1.2 KP12 to KP20.1

After crossing Buchanan Road, the alignment continues in a westerly direction crossing Buttai Creek by HDD at KP12.9, then enters the Wallis Creek floodplain and crossing Wallis Creek by HDD at KP14.2. Near KP14.4 the alignment exits the floodplain on the northern side of Testers Hollow, crossing Cessnock Road. From here the alignment curves to the north following the southern and western boundary of the proposed residential development on Lot 2 DP1249763 then turns west to follow the southern boundary of the Gillieston Heights South – Western Precinct residential development, prior to entering the buffer zone of the former Hydro aluminium smelter. The alignment crosses the South Maitland Railway at KP16.3 and then continues in a south-westerly direction adjacent to the South Maitland Railway prior to turning west and crossing Swamp Creek by HDD near KP17.8. HDD at KP18.7 will allow the alignment to pass under an Ausgrid easement containing high voltage overhead power lines at KP19.3 prior to reaching the compressor station at KP20.1.

2.2.2 Storage and Interconnect Pipeline Alignments

The storage pipeline will be approximately 24 km in length in a looped alignment and will be located to the north of the HPP within buffer zone land of the former Hydro aluminium smelter. The proposed location of the storage pipeline is west of Wentworth Swamp, on land that has predominantly been previously cleared.

The approximately 1.3 km interconnect pipeline will be located between the storage pipeline and the storage station and will transfer gas to/from the storage pipeline via an above ground header assembly comprising DN350 piping, individual loop isolation valves and associated loading and venting arrangements.

The storage pipeline alignment crosses the alignment of three unnamed minor watercourses but does not cross any roads or rail lines.

The DN350 interconnect pipeline crosses Black Waterholes Creek.

2.2.3 Associated surface facilitates

The proposed locations of associated surface facilities are as follows:

- The JGN offtake facility will be located on cleared grazing land at Lot 51 DP1158920, between Leneghans Drive and the M1 Pacific Motorway (refer to **Figure 2.2**).
- The compressor station and delivery station will be located on the existing hard stand of the former Hydro aluminium smelter directly adjacent to the HPP (refer to **Figure 2.3**).

3.0 Preliminary Hazard Analysis

Under *State Environment Planning Policy 33 – Hazardous and Offensive Development* (SEPP 33), a preliminary risk screening of a proposed development is required to determine the need for a PHA. The preliminary screening involves the identification and assessment of the storage of specific dangerous goods classes that have the potential for significant off-site effects. If, at the proposed location, and in the presence of controls, the risk level exceeds the acceptable criteria for impacts on the surrounding land use, the development is classified as 'hazardous' and may not be permissible within most land use zones in NSW. A 'hazardous industry' under SEPP 33 is one which, when all locational, technical, operational and organisational safeguards are employed continues to pose a significant risk.

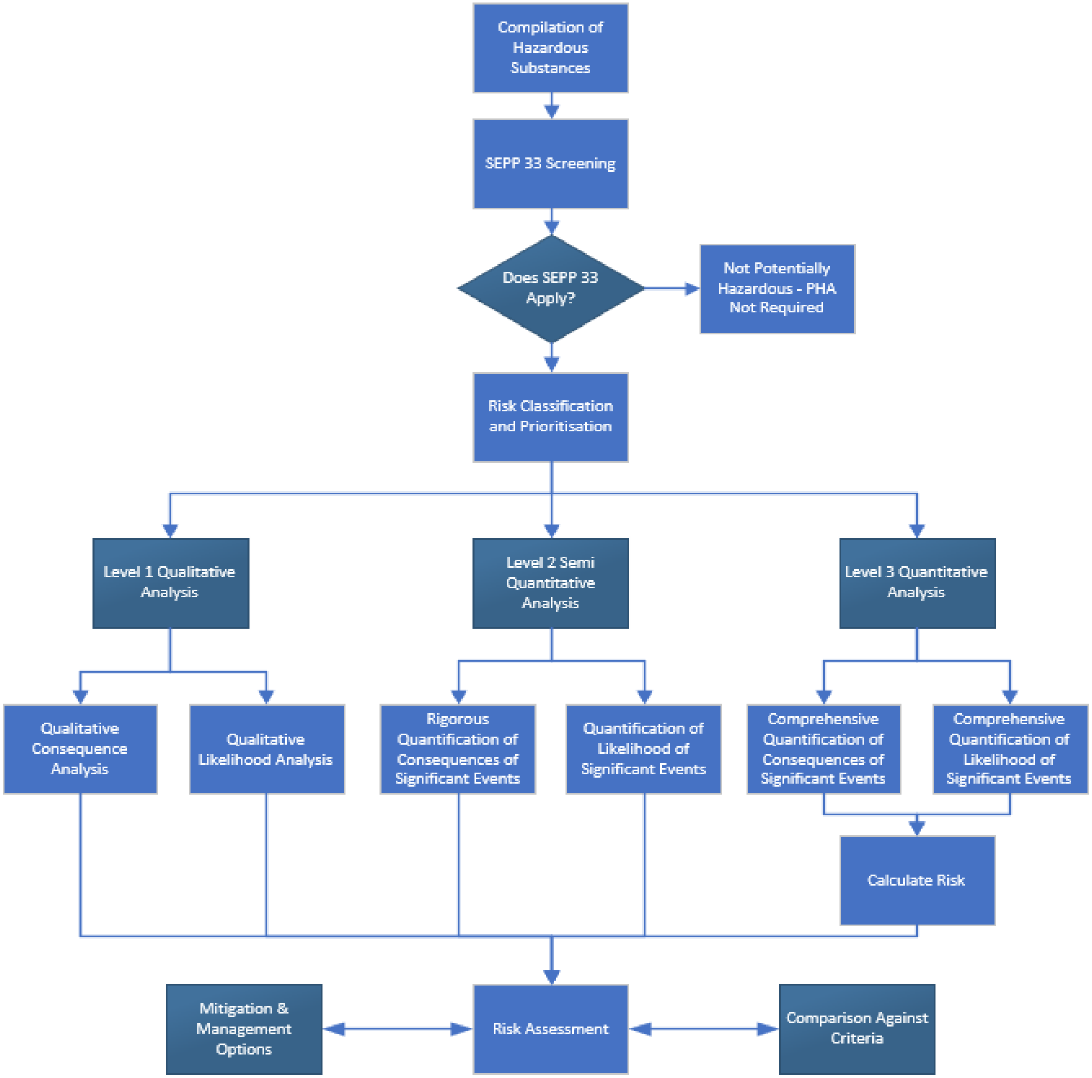
An 'offensive industry' is one which, even when controls are used, has emissions which result in a significant level of offence e.g. odour or noise emissions. Separate air quality and noise assessments have been completed for the Project to address potentially offensive impacts and are not discussed further within this report.

A proposal cannot be considered either hazardous or offensive until it is firstly identified as 'potentially hazardous' or 'potentially offensive' and subjected to the assessment requirements of SEPP 33. A PHA is required if a proposed development is 'potentially hazardous'.

A proposed development may also be 'potentially hazardous' if the number of traffic movements for the transport of hazardous materials exceeds the annual or weekly criteria outlined in Table 2 of Applying SEPP 33 (DoP 2011b). If these thresholds are exceeded a route evaluation study is likely to be required.

Hazardous Industry Planning Advisory Paper (HIPAP) *No. 6 – Guidelines for Hazard Analysis* (DoP 2011f) and *Multi-level Risk Assessment* (DoP 2011a) notes that a PHA should identify and assess all hazards that have the potential for off-site impact. The expectation is that the hazards would be analysed to determine the consequence to people, property and the environment and the potential for hazards to occur.

The methodology used to identify and assess the potential Project hazards and respective failure scenarios that have the potential for off-site impact is outlined in **Figure 3.1**. The details of how this methodology is implemented are discussed in the respective sections of this report.



Preliminary Screening
SEPP 33 Screening involves compiling information on the quantity of hazardous materials used, the mode of storage and location with respect to off-site land users and the number and size of annual and weekly road movements of the hazardous material.

A proposed development should be considered potentially hazardous if the storage or transport of hazardous substances exceeds the respective screening thresholds and further risk assessment is required. If the storage and transport of hazardous materials does not exceed thresholds then no further analysis is necessary and the safety management regime should rely on observance of the requirements of engineering codes and standards.

Risk Classification and Prioritisation
Risk classification and prioritisation involves ranking of the facility using techniques to make broad estimates of the consequence and likelihood of accidents. The output may be expressed in terms of individual and societal risk and is compared against respective criteria for determining the appropriate level of analysis for further risk assessment.

Level 1 Analysis – Significant but not serious potential for harm
A Level 1 analysis is a qualitative assessment based on detailed hazard identification. The objective is to demonstrate that the activity does not pose a significant risk. Where the qualitative analysis cannot satisfactorily demonstrate there will be no significant risk, further analysis is required.

Level 2 Analysis – Medium potential for harm
A Level 2 analysis supplements the Level 1 analysis by quantifying the main risk contributors to show that their consequences are acceptable.

Level 3 – High potential for harm
A Level 3 quantitative analysis is required when the screening and hazard identification process and/or risk classification and prioritisation process has identified risk contributors with consequences beyond the site boundaries. The analysis requires a comprehensive quantification of significant consequences and their likelihood.

Risk Assessment
The Risk Assessment compares the results of the risk analysis with the respective risk criteria. Where the level of risk is not acceptable, risk minimisation, mitigation and management options need to be investigated.

Figure 3.1 Overview of PHA Methodology

3.1 Preliminary Risk Screening

Preliminary risk screening is undertaken to determine the requirement for a PHA. SEPP 33 contains a number of assessment criteria for the storage quantities as well as transports quantities and frequencies of hazardous material that have the potential to create off-site impacts.

3.1.1 Storage Quantity Screening

Permanent stores of hazardous materials, other than the natural gas within the storage pipeline, will be limited to combustible liquids at the compressor station and delivery station located adjacent to the HPP and the Storage Pipeline during operation of the Project.

Table 3.1 contains an inventory of hazardous materials to be stored during the operational phase of the Project and relevant SEPP 33 screening criteria. The storage quantity of natural gas, a Class 2.1 flammable gas exceeds the SEPP 33 screening threshold and therefore confirms that a PHA is required for the Project.

During construction, APA will utilise an 60 kL self bunded diesel storage tank for refuelling of vehicles and mobile plant. SEPP 33 does not define screening thresholds for combustible liquids such as diesel (Class C1). All combustible liquids will be stored in accordance with *AS 1940 – 2017 The storage and handling of flammable and combustible liquids* (AS 1940) with adequate separation distances from any minor quantities of Class 3 flammable liquids. As such the diesel may be assessed as a Class C1 combustible liquid and is therefore not subject to SEPP 33 screening. Only minor quantities of hazardous materials with SEPP 33 screening thresholds will be stored on the construction sites and these materials will be managed in accordance with a Construction Environment Management Plan (CEMP) developed specifically for the Project.

3.1.2 Transport Screening

The transport quantities and frequencies of hazardous materials to the compressor station stores for the operational phase of the Project will be limited to combustible liquids which are not subject to SEPP 33 screening thesholds. During construction, only minor quantities of hazardous materials (i.e. at quantities below SEPP 33 screening thresholds) will be transported to the construction sites.

Table 3.1 Operational Project Phase Hazardous Materials Inventory

Material	Storage Location	Storage Type	ADG Code Class/Division (PG)	Proposed Maximum Inventory	SEPP 33 Screening Threshold	Trigger SEPP 33
Natural Gas	Storage Pipeline	Bulk	2.1	1,660 T	0.1 T	Yes
Diesel Fuel	Compressor Station	Bulk	C1	5,000 L	-	No
Lubrication Oil	Compressor Station	Packages (Drums)	C2	5,000 L	-	No

4.0 Risk Classification and Prioritisation

Multi-level Risk Assessment (MLRA) (DoP, 2011) suggests the use of a preliminary analysis of the risks related to a proposed development to enable the selection of the most appropriate level of risk analysis in the PHA. This preliminary analysis includes risk classification and prioritisation using a technique adapted from the *Manual for classification of risks due to major accidents in process and related Industries* (International Atomic Energy Agency (IAEA), 1996). A complete description of the technique is presented in the MLRA (DoP, 2011a). The technique is based on a general assessment of the consequences and likelihoods of accidents and their risks to individuals and society, and the comparison of these risks to relevant criteria to determine the level of assessment required, be it qualitative or quantitative.

4.1 Methodology

The objective of the risk classification and prioritisation process is to identify whether the risks identified as part of the SEPP 33 preliminary screening process pose acceptable risks or whether further assessment is required. The assessment involves the following steps:

- classification of the type of activities and materials inventories
- estimation of consequences
- estimation of probabilities of major accidents for fixed installations
- estimation of societal risk
- evaluation of alternatives
- assessment using criteria to determine the required level of risk assessment.

For each potentially hazardous activity information is required regarding the location, type, production and storage condition of the activity, as well as name, physical state and amount of hazardous substances involved. Table II of the *Manual for classification and prioritization of risks due to major accidents in process and related industries* (IAEA, 1996) provides a guideline of required information.

If a facility has effective physical isolation and separation between the storage vessels with the same dangerous goods classification, then the content of the largest storage vessel would typically be used to estimate the effect of an incident.

When selecting the activities likely to have the potential to cause risk/damage, the following should be considered:

- if more than one substance in the same activity can cause damage independently from the other substances, analyse them separately
- if a group of substances may act together, consider them as a single (equivalent) substance
- if a flammable substance is also toxic, both effects have to be accounted for. After following the methodology within MLRA (DoP, 2011) it will be clear whether flammable properties are important or not, compared with toxic properties.

4.1.1 Estimation of Consequences

Consequences of an accident depend on the type of substance, activity and the quantity involved, as well as the population exposed to its effect.

The external consequences ($C_{a,s}$) of major accidents to humans are calculated using equation (1) of *Manual for classification and prioritization of risks due to major accidents in process and related industries* (IAEA, 1996):

$$C_{a,s} = A \times d \times f_a \times f_m$$

where:

- $C_{a,s}$ external consequences (fatalities per accident) where the subscript 'a' represents an activity and subscript 's' represents a hazardous substance
- A affected area (hectares; 1 ha = 10,000 m^2)
- d population density in defined populated areas (persons/ha)
- f_a correction factor for populated area
- f_m correction factor for mitigation effects.

Alternatively, if the population (N) within the affected area is known, the consequence can be estimated as follows:

$$C_{a,s} = N \times f_m$$

In accordance with the *Manual for classification and prioritization of risks due to major accidents in process and related industries* (IAEA, 1996) this calculation was undertaken for all relevant hazardous substances and activities, i.e. the storage of natural gas in the Storage Pipeline and the transport of natural gas in the Lateral Pipeline.

4.1.2 Estimation of Probabilities of Major Accidents for Fixed Installations and Transport

The probability number ($N_{i,s}$) of major accidents to humans is calculated using equations (2) and (3) of *Manual for classification and prioritization of risks due to major accidents in process and related industries* (IAEA, 1996):

Fixed Installations

$$N_{i,s} = N^*_{i,s} + n_l + n_f + n_0 + n_p$$

Transport (including pipelines)

$$N_{i,s} = N^*_{i,s} + n_c + n_{td} + n_p$$

where:

- $N^*_{i,s}$ the average probability number for the installation and the substance
- n_l probability number correction parameter for the frequency of loading/unloading operations
- n_f probability number correction parameter for the safety systems associated with flammable substances
- n_0 probability number correction parameter for the organisational and management safety
- n_p probability number correction parameter for wind direction towards the populated area
- n_c probability number correction parameter for the safety conditions of the transport system
- n_{td} probability number correction parameter for the traffic density (not applicable for pipelines).

In accordance with the *Manual for Classification of Risk and prioritization of risks due to major accidents in process and related industries* (IAEA, 1996) this calculation was undertaken for all relevant hazardous substances and activities, the results of these calculations are provided in **Section 4.3**.

This probability number was then converted into a probability $P_{i,s}$ by means using the relationship between N and P which is defined as:

$$N = log10 (P)$$

$P_{i,s}$ defines the frequency (number of accidents per year) of accidents involving a hazardous substance (subscript 's') for each hazardous fixed installation (subscript 'i'), which causes the consequences that have been estimated previously.

4.2 Criteria for Multi-level Risk Assessment

The method of determining the assessment criteria recommended by DPE is outlined in Figure A1.3 of the MLRA (DoP, 2011a). This figure shows the three criteria regions. Below the lower criterion line the risk would be considered negligible. Above the upper criterion line the risk would be considered intolerable. The region between the two criteria lines is considered to be tolerable depending on the results of an evaluation of other risk criteria.

These criteria are used to determine the level of assessment required by the PHA as follows:

- Level 1 assessment – can be justified if the analysis of the facility demonstrates the societal risk is negligible and there are no potential accidents with significant off-site consequences.
- Level 2 assessment – can be justified if the societal risk estimates fall within the middle region i.e. between the upper and lower criteria lines and the frequency of risk contributors having off-site consequences is relatively low. The assessment must demonstrate that the facility will comply, at least in principle, with the DPE risk criteria, based on broad quantification of the risk.
- Level 3 assessment – is required if the societal risk estimates are in the intolerable zone, or where there are significant off-site risk contributors and a level 2 assessment fails to demonstrate that risk criteria will be met.

According to Section 3.1 of MLRA (DoP, 2011a), quantification of the risk must be undertaken on any component identified in the risk classification and prioritisation process which has off-site consequences extending significantly beyond the site boundary at a frequency greater than 1×10^{-7} per year. **Section 4.4** presents the ranking and prioritisation results and the required level of risk assessment for the Project.

4.3 Estimation of Societal Risk

The risk to the public from each potentially hazardous activity is estimated by combining the estimated consequences to humans and the probabilities of major accidents.

Using the results of the assessments undertaken in **Sections 4.1.1** and **4.1.2**, the activities are classified and grouped according to *Manual for classification and prioritization of risks due to major accidents in process and related industries* (IAEA, 1996). Details of the scenarios modelled and the consequence and probability number estimates are outlined in **Table 4.1**. Only two scenarios were assessed as there are only two activities associated with the Project involving significant quantities of hazardous materials, i.e. the storage of natural gas in the storage pipeline and the transport of natural gas in the transmission pipeline. **Appendix A** contains the consequence and probability number estimate calculations.

Table 4.1 Dangerous Goods Scenarios Modelled for Societal Risk

Descriptor	Substance	ADG/Division Class	Activity	Hazardous Event	Consequence Number ($C_{a,s}$)	Probability Number ($N_{i,s}$)
S1	Natural Gas (15.2 MPa)	2.1	Storage	Fire/Explosion	157.1	3.2×10^{-7}
T1	Natural Gas (6.9 MPa)	2.1	Transport	Fire/Explosion	1.0	1.0×10^{-7}

4.4 Rank and Prioritise the Results

The cumulative risk of the modelled scenarios listed in Table 4.1 is presented in **Chart 4.1** as a F-N curve.

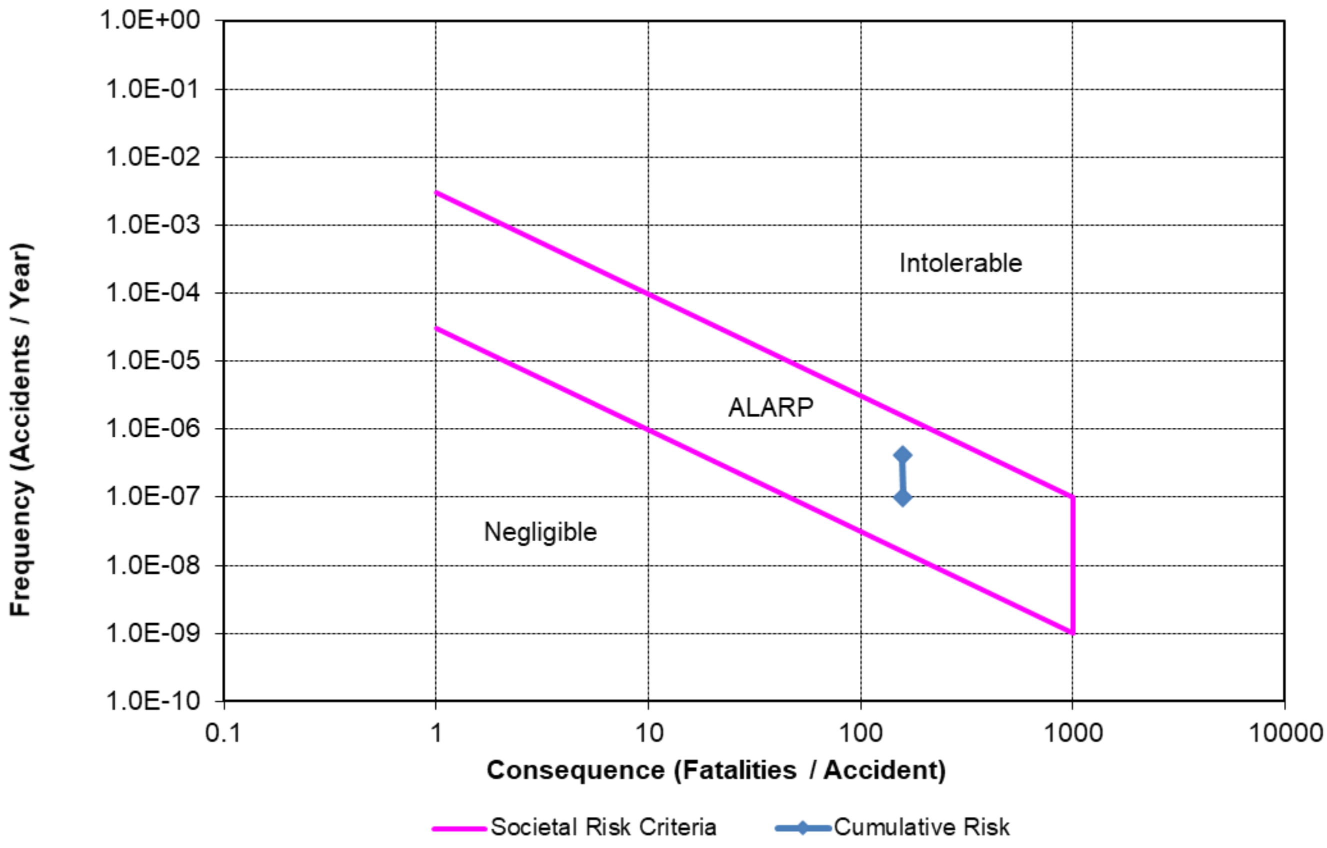


Chart 4.1 Societal Risk Plot

A cumulative risk plotted in the Intolerable region is considered undesirable regardless of whether individual risk criteria are met. Cumulative risk plotted in the Negligible region is not considered significant while the focus for cumulative risk plotted within the As Low As Reasonably Possible (ALARP) region is on reducing risks as far as possible. Cumulative risk within the ALARP region is considered tolerable provided other quantitative and qualitative criteria of *HIPAP No.4 Risk Criteria for Land Use Safety Planning* (HIPAP 4) are met. The end point of the cumulative risk curve for the Project hazards (refer to **Chart 4.1**) is within the ALARP region which indicates that a Level 2 semi quantitative risk assessment is required to demonstrate that HIPAP 4 criteria can be met for the Project.

5.0 Level 1 Qualitative Risk Assessment

It was determined using the MLRA (DoP, 2011) risk classification and prioritisation process (refer to **Section 4.0**) that a Level 2 Semi-quantitative risk assessment would be required to demonstrate that the Project can comply with relevant criteria in *HIPAP No. 4 Risk Criteria for Land Use Safety Planning* (DoP, 2011e). As indicated in Table 5 of MLRA (DoP, 2011), a Level 2 assessment requires the elements of a Level 1 assessment.

5.1 Methodology

A Level 1 assessment requires (as a minimum):

- hazard identification using word diagrams, simplified fault/event trees and checklists
- identification of key scenarios and qualitative assessment of risks
- evaluation of the risks against the following qualitative criteria from HIPAP No. 4 Risk Criteria for Land Use Safety Planning (DoP 2011e):

  a. *All 'avoidable' risks should be avoided. This necessitates the investigation of alternative locations and alternative technologies, wherever applicable, to ensure that risks are not introduced in an area where feasible alternatives are possible and justified.*

  b. *The risk from a major hazard should be reduced wherever practicable, irrespective of the numerical value of the cumulative risk level from the whole installation. In all cases, if the consequences (effects) of an identified hazardous incident are significant to people and the environment, then all feasible measures (including alternative locations) should be adopted so that the likelihood of such an incident occurring is made very low. This necessitates the identification of all contributors to the resultant risk and the consequences of each potentially hazardous incident. The assessment process should address the adequacy and relevancy of safeguards (both technical and locational) as they relate to each risk contributor.*

  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.*

  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.*

- demonstration of adequacy of the proposed technical and management controls to ensure ongoing safety of the proposed development
- should include all facilities which reported exceedances of initial screening thresholds.

5.2 Level 1 Risk Criteria

The risk criteria from AS 2885.6 was used for this Level 1 assessment. The risk criteria for consequence severity, frequency estimation and risk matrix are provided in **Appendix B**.

5.3 Hazard Identification

5.3.1 Hazardous Materials

Compressed Natural Gas

Natural gas is a flammable hydrocarbon gas mixture that consists primarily of methane with varying quantities of heavier hydrocarbons (ethane, propane, butane) and other gases in minor quantities such as carbon dioxide. Odorant gases such as mercaptans are also present in natural gas and are added prior to piping to customers to give odourless natural gas a smell for the purpose of leak detection. **Table 5.1**presents the physical properties of natural gas relevant to this PHA.

Table 5.1 Natural Gas Physical Properties

Property	Value
Density at Atmospheric Pressure and 20°C[1]	0.5613 (lean) to 0.6126 (rich) kg/Sm^3
Autoignition Temperature[2]	540°C
Lower Explosive Limit (LEL)[2]	5%
Upper Explosive Limit (UEL)[2]	15%

Sources:
[1] Kurri Kurri Lateral Pipeline Project Customer Design Requirements (APA, 2021)
[2] AGL Natural Gas Chemwatch Material Safety Data Sheet, 2013

Diesel

During construction, APA will store up to 60 kL of diesel fuel (a Class C1 combustible liquid) in a self bunded storage tank. Being a combustible liquid (i.e. has a flash point >60.5°C), diesel presents a relatively low fire risk compared to natural gas. In the event of loss of containment and ignition, a diesel pool fire can pose a thermal radiation threat to people and property in relatively close proximity to the fire. A loss of containment of diesel is likely to result in soil contamination and may contaminate surface waters and groundwaters depending on the location and quantity of the spill.

5.4 Hazard Study

A hazard identification workshop was undertaken using guidewords as prompts to assist workshop attendees identify potential hazardous events and scenarios that could have off-site impacts. Credible hazardous events and scenarios were recorded and risk scoring was applied by the workshop attendees for each hazardous event and scenario. The guidewords used and the minutes from the hazard identification workshop are attached in **Appendix B**.

The hazard study identified the following hazardous event scenarios with the potential for off-site consequences as being credible and requiring further assessment (i.e. semi-quantitative assessment):

JGN Offtake Station

- DN350 mm flange leak @ 6.9 MPa, leak size based on gasket failure between bolts holes, immediate ignition (jet fire)
- DN350 mm flange leak @ 6.9 MPa, leak size based on gasket failure between bolts holes (flash fire).

Loss of containment events in excess of the flange leak described above were not considered credible for the following reasons:

- Impacts from vehicles and mobile equipment in compound insufficient to break pipe and fittings
- Pipe and fittings designed and constructed in accordance with relevant standards including ASME B31.12 and the AS 2885 series
- APA's routine maintenance and inspection regime will ensure pipe and fitting integrity is maintained
- Secured SNP delivery facility compound is secured and includes CCTV surveillance.

Transmission Pipeline

- Excavator tooth penetrates pipeline resulting in 50 mm diameter hole, immediate ignition (jet fire)
- Excavator tooth penetrates pipeline resulting in 50 mm diameter hole, delayed ignition (flash fire).

As indicated in **Section 2.1.1** the transmission pipeline will be designed and constructed not to rupture (i.e. maximum credible penetration < 150% x critical defect length). Under normal operating conditions (Excavator Bucket Force Multiplier, B=0.75) the pipe can only be penetrated by a 55T excavator fitted with penetration teeth or tiger teeth. Under aggressive operating conditions (Excavator Bucket Force Multiplier, B=1.3), 15T and above excavators fitted with penetration teeth or tiger teeth can penetrate the pipeline with the failure mode being a leak in all cases. Operation of excavators in excess of 35T above the lateral pipeline is not considered credible.

Ground movement (e.g. due to inherent geotechnical instability of the land or instability associated with current or historical mining impacts) has not been considered as a credible failure mode that could lead to rupture of the storage and interconnect pipelines as the pipeline design and construction will accommodate the potential for ground movement. The mitigation measures to address potential mine subsidence impacts on the transmission pipeline will be agreed with Subsidence Advisory NSW who are responsible for the regulation of development in mine subsidence districts.

Compressor and Delivery Station

- DN400 mm flange leak @ 15.32 MPa, leak size based on gasket failure between bolts holes, immediate ignition (jet fire)
- DN400 mm flange leak @ 15.32 MPa, leak size based on gasket failure between bolts holes, delayed ignition (flash fire)
- Compressor heat exchanger tube rupture (heat exchangers comprise DN20, DN25 and DN32 tubes) @ 4.14 MPa (DN32), 8.08 MPa (DN25) and 15.32 MPa (DN20), immediate ignition (jet fire)
- Compressor heat exchanger tube rupture (heat exchangers comprise DN20, DN25 and DN32 tubes) @ 4.14 MPa (DN32), 8.08 MPa (DN25) and 15.32 MPa (DN20), delayed ignition (flash fire)
- Vapour cloud explosion within compressor acoustic enclosure, base modelling on volume of enclosure and gas concentration at the UEL, i.e. maximum fuel load of explosive atmosphere.

Loss of containment events in excess of the flange leak described above were not considered credible for the following reasons:

- Impacts from vehicles and mobile equipment in compound insufficient to break pipe and fittings
- Pipe, fittings and vessels designed and constructed in accordance with relevant standards including AS 2885 series, ASME B31.12, *ASME B31.3 Process Piping*, *ASME Boiler and Pressure Vessel Code 2021* and *AS 1210-2010 Pressure Vessels*.
- APA's routine maintenance and inspection regime will ensure pipe, fittings and vessel integrity is maintained
- Secured SNP delivery facility compound is secured and includes surveillance.

Storage and Interconnect Pipelines

- DN350 mm flange leak on above ground storage pipeline header arrangement @ 15.3 MPa, leak size based on gasket failure between bolts holes, immediate ignition (jet fire)
- DN350 mm flange leak on above ground storage pipeline header arrangement @ 15.3 MPa, leak size based on gasket failure between bolts holes, delayed ignition (flash fire)
- Excavator tooth penetrates pipeline resulting in 50 mm diameter hole, immediate ignition (jet fire)
- Excavator tooth penetrates pipeline resulting in 50 mm diameter hole, delayed ignition (flash fire).

As indicated in **Section 2.1.2** the storage pipeline will be designed and constructed not to rupture (i.e. maximum credible penetration < 150% x critical defect length) and cannot be penetrated by impact from a 55T excavator for all tooth types under normal operating conditions (Excavator Bucket Force Muliplier, B=0.75). Under aggressive operating conditions (Excavator Bucket Force Multiplier, B=1.3) excavators 30T and above fitted with penetration teeth or tiger teeth can penetrate the pipeline causing a leak and a 55T excavator fitted with penetration teeth can rupture the pipeline. However, operation of excavators in excess of 35T above the storage pipelines is not considered credible.

As indicated in **Section 2.1.2** the interconnect pipeline will be designed and constructed not to rupture (i.e. maximum credible penetration < 150% x critical defect length) and cannot be penetrated by impact from a 55T excavator for all tooth types under normal operating conditions (Excavator Bucket Force Muliplier, B=0.75). Under aggressive operating conditions (Excavator Bucket Force Multiplier, B=1.3) excavators 30T and above fitted with penetration teeth can penetrate the pipeline causing a leak and a 55T excavator fitted with penetration teeth can rupture the pipeline. However, operation of excavators in excess of 30T above the storage pipelines is not considered credible.

Ground movement (e.g. due to inherent geotechnical instability of the land or instability associated with current or historical mining impacts) has not been considered as a credible failure mode that could lead to rupture of the storage and connection pipelines as the pipeline design and construction will accommodate the potential for ground movement. As such, ground movement along with other failure modes (e.g. external interference, corrosion) are considered to only result in leaks less than 50 mm in equivalent diameter.

6.0 Level 2 Semi Quantitative Risk Assessment

6.1 Risk Criteria

HIPAP No 4 – Risk Criteria for Land Use Safety Planning (HIPAP 4) (NSW, 2011) provides individual risk criteria for fatality, injury, and property damage/accident propagation as described in the following sections.

6.1.1 Individual Fatality Risk

Individual fatality risk is estimated assuming that an individual is at the point of risk exposure (i.e. with exposure to a potentially fatal consequence, such as 23 kW/m^2 of thermal radiation, that is estimated to occur at a particular frequency) 24 hours per day, 365 days per year. The different individual fatality risk criteria applied by HIPAP 4 to various types of land use are presented in **Table 6.1**.

Table 6.1 Individual Fatality Risk Criteria

Land Use	Risk Criteria (fatalities/million/year)
Hospitals, schools, child-care facilities, old age housing	0.5
Residential, hotels, motels, tourist resorts	1
Commercial developments including retail centres, offices and entertainment	5
Sporting complexes and active open space	10
Industrial	50

Source: *HIPAP No 4 – Risk Criteria for Land Use Safety Planning (NSW, 2011)*

6.1.2 Individual Injury Risk

Individual injury risk is estimated assuming that an individual is at the point of risk exposure (i.e. with exposure to a potentially injurious consequence, such as 4.7 kW/m^2 of thermal radiation, that is estimated to occur at a particular frequency) 24 hours per day, 365 days per year. The Project relevant HIPAP 4 injury risk criteria for different hazardous event consequences apply to residential and sensitive receivers and are presented in **Table 6.2**.

Table 6.2 Individual Injury Risk Criteria

Impact	Risk Criteria (injuries/million/year)
Thermal Radiation of 4.7 kW/m^2	50
Explosion Overpressure of 7 kPa	50

Source: *HIPAP No 4 – Risk Criteria for Land Use Safety Planning (NSW, 2011)*

6.1.3 Property Damage and Accident Propagation Criteria

Hazardous events may also result in damage to nearby structures as well as initiate further hazardous events such as fires and explosions at adjoining industrial developments. **Table 6.3** presents the HIPAP 4 criteria for exposure to thermal radiation and explosion overpressure consequences at neighbouring potentially hazardous installations or at land zoned to accommodate such installations.

Table 6.3 Property Damage and Accident Propagation Risk Criteria

Impact	Risk Criteria (exposures/million/year)
Thermal Radiation of 23 kW/m^2	50
Explosion Overpressure of 14 kPa	50

Source: *HIPAP No 4 – Risk Criteria for Land Use Safety Planning (NSW, 2011)*

6.2 Consequence Analysis

The potential off-site impacts of the hazardous events identified for quantitative assessment of consequences (refer to **Section 5.4**) are exposure to damaging, injurious and fatal levels of thermal radiation and explosion overpressure. **Table 6.4** and **Table 6.5** present the likely effects of various levels of thermal radiation and explosion overpressure respectively.

Table 6.4 Consequences of Thermal Radiation

Thermal Radiation (kW/m^2)	Effect
1.2	• Received from the sun at noon in summer
2.1	• Minimum to cause pain after 1 minute
4.7	• Will cause pain in 1 5-20 seconds and injury after 30 seconds' exposure (at least second degree burns will occur)
12.6	• Significant chance of fatality for extended exposure • High chance of injury • Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure • Thin steel with insulation on the side away from the fire may reach a thermal level high enough to cause structural failure
23	• Likely fatality for extended exposure and chance of fatality for instantaneous exposure • Spontaneous ignition of wood after long exposure • Unprotected steel will reach thermal stress temperatures which can cause failure • Pressure vessel needs to be relieved or failure would occur
35	• Cellulosic material will pilot ignite within one minute's exposure • Significant chance of fatality for people exposed instantaneously

Source: HIPAP No 4 – Risk Criteria for Land Use Safety Planning (NSW, 2011)

Table 6.5 Consequences of Explosion Overpressure

Explosion Overpressure (kPa)	Effect
3.5	• 90% glass breakage • No fatality and very low probability of injury
7	• Damage to internal partitions and joinery but can be repaired • Probability of injury is 10%. No fatality
14	• House uninhabitable and badly cracked
21	• Reinforced structures distort • Storage tanks fail • 20% chance of fatality to a person in a building

Explosion Overpressure (kPa)	Effect
35	• House uninhabitable • Wagons and plants items overturned • Threshold of eardrum damage • 50% chance of fatality for a person in a building and 1 5% chance of fatality for a person in the open
70	• Threshold of lung damage • 100% chance of fatality for a person in a building or in the open • Complete demolition of houses

Source: HIPAP No 4 – Risk Criteria for Land Use Safety Planning (NSW, 2011)

6.2.1 Consequence Modelling Methodology

Thermal radiation impacts for the hazardous events involving above ground pipework were modelled using the Breeze Incident Analyst (Breeze®) software package. Breeze® incorporates a suite of consequence models including a jet fire model, various gas dispersion models and various explosion models as well as an extensive chemical database containing relevant chemical properties for modelling purposes. All Breeze® model output files are included in **Appendix C**.

6.2.1.1 Jet Fire Modelling

The jet fire model predicts thermal radiation at a user nominated height above ground level at varying horizontal distances from the flammable material release point. Breeze® allows modelling of jet fires at various angles from the horizontal, unlike the jet fire model in ALOHA (the United States Environment Protection Agency consequence modelling software package) which only allows modelling of vertical jet fires. Jet fire modelling undertaken for the hazardous events involving above ground pipework was undertaken assuming a horizontal jet at the MAOP of the pipe system being analysed which ensures the estimated thermal radiation impacts are conservative. The natural gas release was modelled with the properties of methane.

The equivalent hole size for the flange leaks were estimated using the following equation:

$$d_e = \frac{1.30(ab)^{0.625}}{(a+b)^{0.25}}$$

where

d_e is the equivalent diameter (mm)

a is the length of leak arc (mm)

b is the width of flange leak (mm)

The flange leak width was assumed to be 4.45 mm (the thickness of the sealing element on a spiral wound gasket) and the length of the leak was based on arc length between bolt holes for ASME Class 600 (for leaks at 6.9 MPa) and ASME Class 900 flanges (for leaks at 15.32 MPa).

Thermal radiation impacts associated with subsurface pipe jet fire (i.e. 50 mm holes as a result of excavators penetrating the transmission, interconnect or storage pipelines) were modelled separately by GHD (*Technical Memorandum, KKSP Rupture Radiation and Hole Sizes, 2021* and *Kurri Kurri lateral Pipeline Fracture Control Plan KUR.2373-PL-L-0001, 2021*) as part of the preliminary design process and SMS. Full bore pipe rupture scenarios were also modelled as part of the preliminary design process and SMS and are included in **Appendix D** with the 50 mm hole size calculations.

6.2.1.2 Flash Fire Modelling

Flash fires occur when the natural gas does not ignite immediately upon release. For a high pressure natural gas release the turbulent jet will induce air and form a flammable natural gas – air envelope that if ignited will rapidly burn back to the release point and most likely transition to a jet fire if the release of natural gas is ongoing. Given the short duration of a flash fire, the extent of significant thermal radiation impacts is limited to the extent of the flammable natural gas – air envelope.

Estimation of the extent of impacts associated with flash fire events was undertaken by using the dispersion modelling features in Breeze®. Breeze® includes a source term model that estimates the gas state of a release entering the atmosphere and determine the most appropriate non source term model (i.e. the dispersion model) for modelling of the release. The source term model requires the user to input a range of source parameters including pipe diameter, release hole size, release height above ground, pipe pressure and temperature, discharge coefficient and whether the leak is connected to a continuous or limited supply of gas. The results of the source term model (e.g. release rate and temperature) are then used directly in the non-source term model that was determined as being most appropriate for modelling of the release. Breeze® determines a recommended non source term model to use based on the release characteristics (e.g. continuous or finite) and the calculated Richardson number. The Richardson number is used to determine whether a release should be treated as a dense or neutrally-buoyant gas. While methane (the chemical used in the modelling to represent natural gas) is a lighter than air gas, the Richardson number determined by the source term model indicated that the release should be modelled as a dense gas and recommended the use of the SLAB dense gas dispersion model.

The SLAB dispersion model was run to predict the maximum extent of the flammable gas plume, i.e. the extent at which the gas plume concentration drops below 5% by volume methane under stable and more dispersive meteorological conditions, i.e. under stability class F and 1.5 m/s wind speed and stability class D and 10 m/s wind speed respectively. Hole sizes for flange leaks were as used for the jet fire modelling (refer to **Section 6.2.1.1**).

6.2.1.3 Vapour Cloud Explosion Modelling

The vapour cloud explosion (VCE) scenario was based on a natural gas-air mixture at the UEL for natural gas (15% by volume) occupying the free volume within a compressor acoustic enclosure (assuming 20% of enclosure volume is occupied by equipment). A compressor enclosure is approximately 440 m^3 and is estimated to have a free volume of 352 m^3. The volume of natural gas in the enclosure at UEL (15% by volume) is estimated to be 52.8 m^3 which equates to approximately 32.35 kg at standard conditions (288.15 K and 1 atm).

Breeze® allows for calculation of explosion overpressures using either the TNT Equivalence model, the TNO Multi-Energy model or the Baker-Strehlow-Tang model. The TNO Multi-Energy model has been applied for the compressor enclosure VCE as it is a broadly accepted model for estimation of VCE overpressures. A conservative initial blast strength of 10 (the maximum possible) was applied during modelling.

6.2.2 Consequence Modelling Results

6.2.2.1 Jet Fires

Table 6.6 presents the predicted thermal radiation contours associated with the jet fire events identified as credible in the hazard study (refer to **Section 5.4**).

Table 6.6 Jet Fire Thermal Radiation Contours

Location	Scenario	Hole Size / Equivalent Hole Size (mm)	Operating Pressure (MPa)	Impact Extent for 4.7 kW/m^2 (m)	Impact Extent for 12.6 kW/m^2 (m)	Impact Extent for 23 kW/m^2 (m)
JGN Offtake Facility	DN350 flange leak, gasket failure between bolt holes	13.42	6.90	31	28	26
Compressor and Delivery Station	DN400 flange leak, gasket failure between bolt holes	14.28	15.32	47	41	39
Compressor and Delivery Station	Compressor Heat Exchanger DN20 Tube Rupture	20.96	15.32	64	56	52
	Compressor Heat Exchanger DN25 Tube Rupture	26.64	8.08	60	53	49
	Compressor Heat Exchanger DN32 Tube Rupture	35.08	4.14	57	50	47
Storage Pipeline Header	DN350 flange leak, gasket failure between bolt holes	13.63	15.32	45	40	37
Transmission Pipeline[1]	Excavator tooth penetration	50.0	6.90	61	37	-[2]
Storage or Interconnecting Pipeline[1]	Excavator tooth penetration	50.0	15.32	92	56	-[2]

Note: [1] Modelling undertaken by GHD (refer to **Appendix D**)

[2] Calculation of 23 kW/m^2 contour not undertaken

6.2.2.2 Flash Fires

Table 6.7 presents the predicted flash fire impact extents (horizontally from the release point) associated with the flash fire events identified as credible in the hazard study (refer to **Section 5.4**).

Table 6.7 Flash Fire Impact Extent

Location	Scenario	Stability Class - Wind Speed (m/s)	Hole Size/ Equivalent Hole Size (mm)	Operating Pressure (MPa)	Impact Extent (m)
JGN Offtake Facility	DN350 flange leak, gasket failure between bolt holes	F-1.5	13.42	6.90	6
Compressor and Delivery Station	DN400 flange leak, gasket failure between bolt holes	F-1.5	14.28	15.32	15
Compressor and Delivery Station	Compressor Heat Exchanger DN20 Tube Rupture	F-1.5	20.96	15.32	23
	Compressor Heat Exchanger DN25 Tube Rupture	F-1.5	26.64	8.08	21
	Compressor Heat Exchanger DN32 Tube Rupture	F-1.5	35.08	4.14	20
Storage Pipeline Header	DN350 flange leak, gasket failure between bolt holes	F-1.5	13.63	15.32	14
Transmission Pipeline[1]	Excavator tooth penetration	F-1.5	50.0	6.90	44
Storage or Interconnecting Pipeline[1]	Excavator tooth penetration	F-1.5	50.0	15.32	74
JGN Offtake Facility	DN350 flange leak, gasket failure between bolt holes	D-10	13.42	6.90	6
Compressor and Delivery Station	DN400 flange leak, gasket failure between bolt holes	D-10	14.28	15.32	14
Compressor and Delivery Station	Compressor Heat Exchanger DN20 Tube Rupture	D-10	20.96	15.32	24
	Compressor Heat Exchanger DN25 Tube Rupture	D-10	26.64	8.08	21
	Compressor Heat Exchanger DN32 Tube Rupture	D-10	35.08	4.14	20
Storage Pipeline Header	DN350 flange leak, gasket failure between bolt holes	D-10	13.63	15.32	13
Transmission Pipeline[1]	Excavator tooth penetration	D-10	50.0	6.90	45
Storage or Interconnecting Pipeline[1]	Excavator tooth penetration	D-10	50.0	15.32	72

6.2.2.3 Vapour Cloud Explosion

Table 6.8 presents the predicted overpressure contours for a VCE within a compressor enclosure at the storage station.

Table 6.8 Compressor Enclosure VCE Overpressure Contours

Overpressure	Impact extent for 7 kPa (injury) (m)	Impact extent for 14 kPa (propagation) (m)	Impact extent for 21 kPa (20% fatality) (m)
Distance to Overpressure Contour	97	59	47

6.3 Frequency Analysis

6.3.1 Underground Pipeline Loss of Containment

A range of frequency data associated with gas pipeline loss of containment (LOC) events is available from across the world, and particularly from Europe. However, the Australian experience strongly indicates that that the frequency of failures and hazardous events is significantly lower than the broader global experience. The Australian pipeline industry has been capturing data on incidents in which pipelines have been damaged or threatened since the 1965 (Standards Australia, 2018). To date, no fatalities have occurred as a result of a gas pipeline incident in Australia. **Table 6.9** presents LOC data for Australian gas pipelines collected presented in *Experience with the Australian / New Zealand Pipeline Incident* Database (Australian Pipeline and Gas Association (APGA), 2018) for the period January 2001 to April 2018. LOC frequencies derived from the data are also presented in **Table 6.9**.

Table 6.9 Australian Gas Pipeline Loss of Containment Event Summary (Jan 2001 - Apr 2018)

Description	Number of Events	Frequency (events/1,000 km/year)[1]
Total LOC Events	17	3.27×10^{-5}
LOC Events by Type		
Leak	15	2.89×10^{-5}
Rupture	2	3.85×10^{-6}
LOC Events by Cause		
Material Defect	2	3.85×10^{-6}
Lightning	5	9.62×10^{-6}
External Interference	3	5.77×10^{-6}
Erosion/Earth Movement	3	5.77×10^{-6}
Corrosion	3	5.77×10^{-6}
Construction Defect	1	1.92×10^{-6}

Note: [1] Estimated based on a total average pipeline length of 30,000 km for the period January 2001 to April 2018 which was based on the total pipeline lengths in 2000 and 2018 presented Experience with the Australian/New Zealand Pipeline Incident Database (APGA, 2018)

AS/NZS 2885.6 notes that while overseas failure rate data, including European Gas Pipeline Incident Group (EGIG) data, might have some uses, it has been shown that the average failure rates of Australian pipelines are much lower than in other regions and that it is not appropriate to use overseas data to estimate Australian pipeline failure rates. **Table 6.10** presents EGIG primary failure rates resulting in LOC for the period 2000 to 2019 for failure modes comparable to those presented in **Table 6.9**. Comparison of the Australian pipeline LOC rates (refer to **Table 6.9**) with the EGIG LOC rates (refer to **Table 6.10**) demonstrates the significantly lower frequency of LOC events for Australian pipelines.

Further to the data presented in **Table 6.10**, the five year moving average gas pipeline rupture frequency for European gas pipelines for the period 2015 to 2019 was 0.013 ruptures/1,000 km/year (EGIG, 2020) which is several orders of magnitude greater than the frequency of ruptures experienced in Australia from January 2001 to April 2018 (refer to **Table 6.9**).

Table 6.10 EGIG Gas Pipeline Loss of Containment Rates (2000 – 2019)

Cause	Frequency (events/1,000 km/year)
External Interference	0.054
Corrosion	0.033
Material Failure/Construction Defect	0.020
Ground Movement	0.020

Source: Gas Pipeline Incidents, 11th Report of the European Gas Pipeline Incident Data Group (EGIG, 2020)

Appendix F of AS/NZS 2885.6 provides a guide for semi-quantitative estimation of event frequencies as presented in **Table 6.11**. Comparison of the numerical frequencies presented in **Table 6.11** with the Australian pipeline LOC rates (refer to **Table 6.9**) suggests:

- that rupture events are "Hypothetical", i.e. have a frequency $<10^{-5}$ noting that the data presented in **Table 6.9** indicates a rupture frequency of 3.85×10^{-6}
- that leak events are "Remote", i.e. have a frequency of 10^{-3} and 10^{-5} noting that the data presented in **Table 6.9** indicates a leak frequency of 2.89×10^{-5}.

Table 6.11 AS/NZS 2885.6 Frequency Classes

Class	Description	Numerical Guidelines (events/1,000 km/year
Frequent	Expected to occur once per year or more	≥1
Occasional	May occur occasionally in the life of the pipeline	1 to 0.1
Unlikely	Unlikely to occur within the life of the pipeline, but possible	0.1 to 0.001 (10^{-1} to 10^{-3})
Remote	Not anticipated for this pipeline at this location	0.001 to 0.00001 (10^{-3} to 10^{-5})
Hypothetical	Theoretically possible but would only occur under extraordinary circumstances	<0.00001 ($<10^{-5}$)

The United Kingdom Health and Safety Executive (UK HSE) rupture rates for underground natural gas pipelines in the UK presented in *Update of pipeline failure rates for land use planning assessments* (UK - Health and Safety Laboratory, 2016) gives an overall rupture frequency (for all failure modes) of 2.64×10^{-3} ruptures/1,000 km/year which is also greater than the Australian rupture frequency by several orders of magnitude.

However, in a meeting with the NSW DPIE Hazard team on 28 October 2021 to discuss the PHA for the Project, it was indicated that DPIE Hazard has not formally accepted APGA failure frequency data and advised that the PHA should adopt UK HSE failure frequency data. **Table 6.12** presents natural gas pipeline failure rates sourced from *Update of pipeline failure rates for land use planning assessments* (UK - Health and Safety Laboratory, 2016) which have been adopted for the PHA.

Table 6.12 UK HSE Natural Gas Pipeline Failure Frequencies (events/1,000 km/year)

Failure Mode	Pinhole (≤ 25mm)	Small Hole (≤ 25 to ≤75 mm)	Large Hole (≤ 75 to ≤ 110 mm)	Rupture (> 110 mm)
Mechanical (<115 mm Ø)	4.5×10^{-1}	1×10^{-5}	1×10^{-5}	1×10^{-5}
Mechanical (127 to 273 mm Ø)	1.5×10^{-1}	1×10^{-5}	1×10^{-5}	1×10^{-5}
Mechanical (≥ 305 mm)	8.7×10^{-3}	1×10^{-5}	1×10^{-5}	1×10^{-5}
Corrosion (5 to <10 mm wall thickness)	3.3×10^{-2}	1×10^{-5}	1×10^{-5}	1×10^{-5}
Corrosion (≥10 mm wall thickness)	1×10^{-4}	1×10^{-5}	1×10^{-5}	1×10^{-5}
Ground Movement/Other	1.2×10^{-2}	2.5×10^{-3}	1.5×10^{-4}	2.5×10^{-3}
Third Party Activity	2.2×10^{2}	2.4×10^{-3}	1×10^{-4}	1×10^{-4}

6.3.1.1 Transmission Pipeline

At any point along the transmission pipeline alignment, frequency of a fatal jet fire impact is dependent on:

- the frequency of the loss of containment event (refer to **Table 6.12**)
- the probablitity of ignition of the gas release (refer to **Table 6.14**) and
- the length of pipeline that is within the 12.6 kW/m2 thermal radiation impact distance (for the credible loss of containment scenario) from a particular point.

For a point on the alignment on a straight section of pipeline and immediately above the pipeline, the length of transmission pipeline that exposes that point to a potential fatality impact is twice the 12.6 kW/m^2 thermal radiation impact distance. For a point on the pipeline alignment located within the acute angle of a bend, the length of pipeline that exposes that point to a potential fatality impact could be greater than twice the 12.6 kW/m^2 thermal radiation impact distance but is dependent on the 12.6 kW/m^2 thermal radiation impact distance and acuteness of the pipeline bend. That is, the greater the 12.6 kW/m^2 thermal radiation impact distance and the more acute the pipeline bend, the greater the length of pipeline that exposes a point within the bend to a potential fatality risk.

The most acute pipeline bend along the transmission pipeline alignment is located at KP15.6 and the length of pipeline that is within the 12.6 kW/m^2 thermal radiation impact distance of 37 m (refer to **Table 6.4**) resulting from ignition of a gas release due to a 50 mm excavator tooth penetration is approximately 110 m, or approximately three times the fatality impact distance. Applying a pipeline length of 111 m (three times the 12.6 kW/m^2 thermal radiation impact distance of 37 m) results in a fatality impact frequency of 2.66×10^{-8} per year for a jet fire event resulting from ignition of a gas release due to a 50 mm excavator tooth penetration.

As previously discussed in **Section 6.3** failure rate data collected by APGA indicates that the frequency of failure rates for gas pipelines in Australia is significantly lower than European failure rates. For the period January 2001 to April 2018, the estimated frequency of loss of containment associated with external interference was 5.77×10^{-6} events/1,000 km/year (refer to **Table 6.9**) which is greater than two orders of magnitude below the UK HSE frequency of 2.40×10^{-3} events/1,000 km/year for small hole loss of containment events due to third party activity (refer to **Table 6.12**). The loss of containment frequency associated with external interference of 5.77×10^{-6} events/1,000 km/year is comparable with the AS/NZS 2885.6 lower frequency of 0.00001 (refer to **Table 6.11**), or 10×10^{-6}, for an event considered to have a remote likelihood of occurring. While the UK HSE frequency of 2.40×10^{-3} events/1,000 km/year is comparable with the AS/NZS 2885.6 upper frequency of 0.001 (refer to **Table 6.11**), or 1×10^{-3}, for an event considered to have a remote likelihood of occurring.

Applying the AS/NZS 2885.6 lower frequency for events considered to have a remote likelihood of occurring to a loss of containment event caused by a 50 mm excavator tooth penetration resulting in a jet fire or flash along the sections of pipeline where there is either current, planned or potential residential development, results in a fatality impact frequency of 1.11 x 10^{-11} per year.

6.3.1.2 Storage Pipeline

Given the looped arrangement of the storage pipeline, the length of pipeline that poses a potential fatality impact to any point along the pipeline alignment will be greater than that for the transmission pipeline. The point along the storage pipeline alignment that is exposed to a potential fatality impact from the maximum pipeline length is located within the ninety degree bend formed by the north – south and east – west pipeline loop sections. For a loss of containment and ignition event associated with a 50 mm excavator tooth penetration, the estimated maximum length of pipeline posing a fatality risk impact (impact distance of 57 m) to a point within the storage pipeline bend is 1,200 m. Applying a pipeline length of 1,200 m results in a fatality impact frequency of 2.88 x 10^{-78} per year for a fire event resulting from ignition of a gas release due to a 50 mm excavator tooth penetration on the storage pipeline.

6.3.1.3 Interconnect Pipeline

A pipeline length equivalent to three times the 12.6 kW/m^2 thermal radition impact distance (impact distance of 57 m, pipeline length of 171 m) for a 50 mm excavator tooth penetration of the interconnect pipeline and ignition of the interconnect pipeline has been applied to estimate the frequency of fatality impacts at a point along the interconnect pipeline alignment. Applying a pipeline length of 171 m results in a fatality impact frequency of 4.1 x 10^{-8} per year for a fire event resulting from ignition of a gas release due to a 50 mm excavator tooth penetration on the interconnect pipeline.

6.3.2 Flanges

Failure Rate and Event Data for use within Risk Assessments (UK HSE, 2017) recommends a failure rate of 1 x 10^{-7} events/flange/year for a spiral wound gasket failure between flange bolt holes. The frequency of flange leaks at each surface facility was determined by multiplying the gasket failure frequency by the following the number of flanged connections (as estimated by APA):

- 50 flanged connections at the JGN offtake station
- 250 flanged connections at the compressor station and delivery station
- 150 flanged connections at the storage pipeline header

6.3.3 Compressor Heat Exchanger Tube Rupture

The compressor intercoolers and aftercoolers are air cooled heat exchangers comprising DN20, DN25 (intercoolers) and DN32 (aftercoolers) pipework. *Failure Rate and Event Data for use within Risk Assessments* (UK HSE, 2017) provides failure rates for above ground pipelines in a gas installation. The rupture rate for pipes > 110 mm is 6.5 x 10^{-9}/m/year. While the heat exchange tubes are smaller diameter, it is considered that the design rigour applied to a gas compressor heat exchanger would provide for a comparably low rupture frequency and the rupture rate of 6.5 x 10^{-9}/m/year has been adopted for use in the frequency analysis compressor heat exchanger jet fire and flash fire events.

6.3.4 Compressor Enclosure Flammable Atmosphere Frequency

The frequency of a flammable atmosphere developing in a compressor acoustic enclosure is dependent on:

- the number of compressors (three)
- the frequency of compressor leaks
- the size of the leak
- the frequency of acoustic enclosure ventilation system failures
- the frequency of acoustic enclosure gas detection system failures
- the frequency that the automatic shut off system fails when gas is detected.

The frequencies of a flammable atmosphere forming in a compressor acoustic enclosure has been estimated based on the frequency data presented in **Table 6.13** and the event tree in **Figure 6.1** which proposes various scenarios that could result in the formation of a flammable atmosphere. Note that it was assumed that a flammable atmosphere could not be formed for a Pin Hole leak with the ventilation system operating and holes larger than a Small Hole (>75 mm) would result in an atmosphere exceeding the UEL. The cumulative frequency (Pin Hole + Small Hole) for formation of a flammable atmosphere in a compressor acoustic enclosure was estimated to be 8.51 x 10^{-7} and this value has been adopted for use in estimating the frequency of a VCE event in a compressor acoustic enclosure.

Table 6.13 Compressor Enclosure Flammable Atmosphere Frequency Input Data

Item	Failure Frequency	Source
Pin Hole (≤ 25 mm)	8.60 x 10^{-2} failures/m/year	Failure Rate and Event Data for use within Risk Assessments (UK HSE, 2017)
Small Hole (25 to ≤ 75 mm)	3.30 x 10^{-3} failures/m/year	Failure Rate and Event Data for use within Risk Assessments (UK HSE, 2017)
Gas Detection and Shut Off System Failure	1 x 10^{-9} failures/demand	Control Systems (https://www.hse.gov.uk/comah/sragtech/techmeascontsyst.htm) (for high integrity protective system)
Ventilation System Failure	6 x 10^{-5} failures/hour	Hazard and Barrier Analysis Guidance Document (USA Department of Energy, Office of Operating Experience Analysis and Feedback, 1996) (pumps/circulators failure frequency)

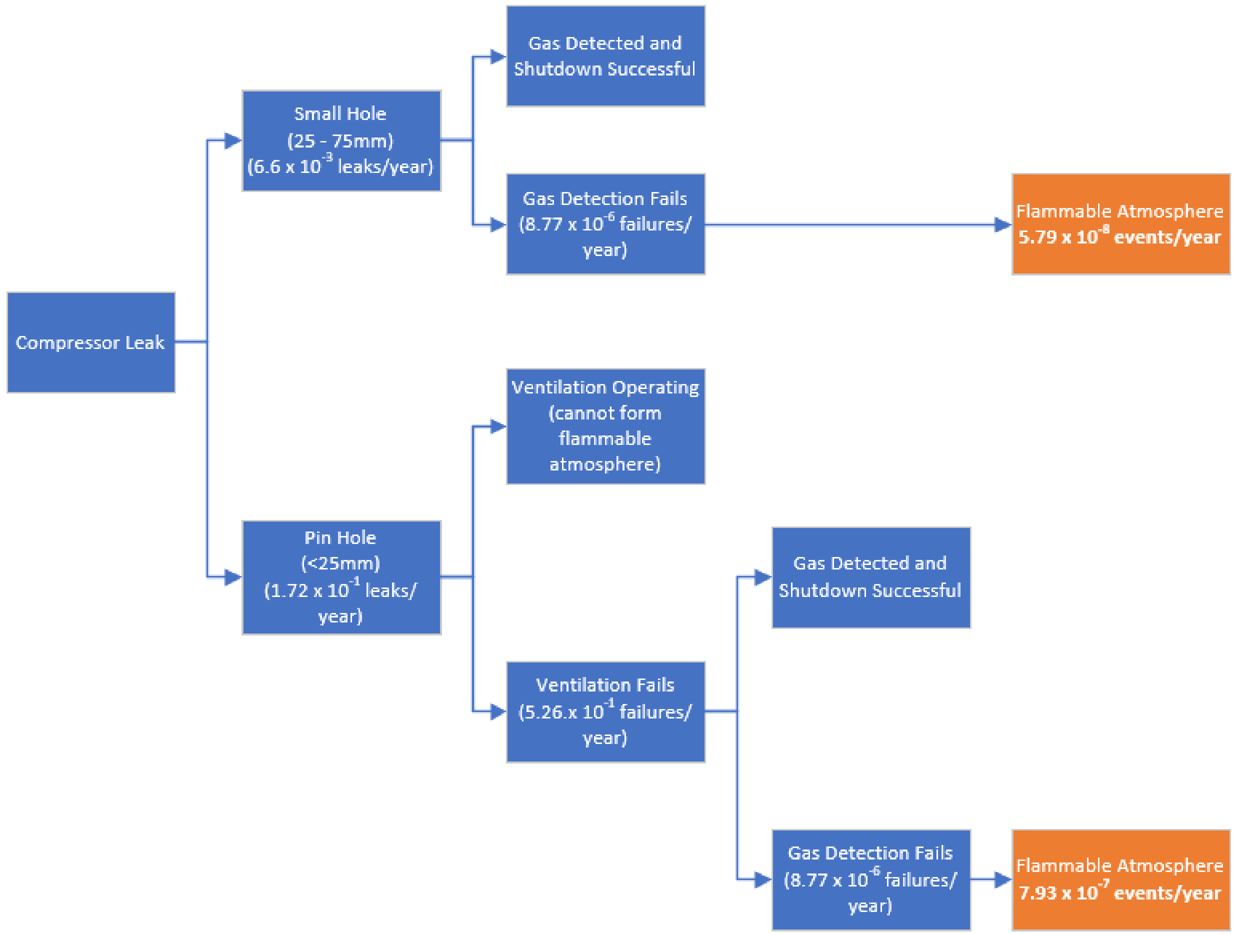


Figure 6.1 Compressor Acoustic Enclosure Flammable Atmosphere Event Tree

6.3.5 Ignition Probability

Not all gas releases following pipeline LOC are ignited resulting in a fire or explosion event. Appendix F of AS/NZS 2885.6 provides ignition probabilities for gas releases based on a general interpretation of data presented in *Gas Pipeline Incidents, 9th Report of the European Gas Pipeline Incident Data Group (period 1970 – 2013)* (EGIG, 2015). **Table 6.14** presents the ignition probabilities suggested in AS/NZS 2885.6 which have been adopted for the PHA.

Table 6.14 Ignition Probabilities for Gas Pipeline Failures

Size of Leak	Ignition Probability
Small leak (pinhole or crack)	2% to 5%
Large Leak (between pinhole and rupture)	5% to 10%
Rupture, pipe ≤ DN 400 mm	10%
Rupture, pipe > DN 400 mm	30%

6.3.6 Land Use and Risk Criteria

Table 6.15 presents the land use types distributed along the transmission pipeline and the HIPAP 4 individual fatality and injury risk criteria for the most sensitive land use along the nominated pipe section. The UK HSE pipeline failure frequency data (refer to **Table 6.12**), the probability of gas release ignition (refer to **Table 6.14**) and the length of pipeline that could expose a point along the pipeline alignment to a jet fire 12.6 kW/m^2 thermal radiation impact distance (has a greater extent than a flash fire) have been used to estimate the frequency of fatality for comparison with the criteria presented in **Table 6.15**. The same approach (i.e. three times that 12.6 kW/m^2 thermal radiation impact distance) has been applied for estimation of the interconnect pipeline fatality impact frequencies, while the lengths storage pipeline that pose a fatality impact have been estimated based on spatial analysis to ensure the pipeline loops are accounted for. Land uses and associated HIPAP 4 risk criteria for the SNP delivery facility, storage station, interconnect pipeline and storage pipeline are presented in **Table 6.16**.

Table 6.15 Transmission Pipeline Land Use Types, Length of Exposure and Risk Criteria

KP Start	KP End	Land Use	HIPAP 4 Individual Fatality Risk Criteria (fatalities/year)	HIPAP 4 Individual Injury Risk Criteria (fatalities/year)
0	2.0	Some rural residential dwellings within 12.6 kW/m^2 radiation contour for rupture. Treat all as residential.	1 x 10^{-6}	50 x 10^{-6}
2.0	4.4	Currently active open space but confirmed for industrial development. Treat as active open space as it has more conservative criteria than industrial.	10 x 10^{-6}	-
4.4	8.5	Mine site, industrial	50 x 10^{-6}	-
8.5	14.3	**Current** Currently mine site within the 12.6 kW/m^2 radiation contour for rupture and some rural residential dwellings within the 4.7 kW/m^2 radiation contour for rupture. Possible future residential. Treat as residential.	1 x 10^{-6}	50 x 10^{-6}
14.3	18.0	Likely future residential.	1 x 10^{-6}	50 x 10^{-6}
18.0	18.7	Rural, no dwellings. Treat as active open space.	10 x 10^{-6}	-
18.7	20.1	Industrial	50 x 10^{-6}	-

Table 6.16 Other Facilities Land Use Types and Risk Criteria

Facility	Land Use	HIPAP 4 Individual Fatality Risk Criteria (fatalities/year)	HIPAP 4 Individual Injury Risk Criteria (fatalities/year)
JGN Offtake Facility	Rural residential with no dwellings. Treat as active open space.	10×10^{-6}	-
Compressor and Delivery Station	Industrial	50×10^{-6}	-
Storage and Interonnecting Pipeline	The 12.6 kW/m^2 radiation contour for rupture primarily encompasses land zoned as industrial with only a small area to the north east being rural. Treat as industrial.	50×10^{-6}	-

6.3.7 Frequency of Hazardous Events

Table 6.17 presents the estimated frequency of hazardous events associated with the Project based on the frequency, probability and land use data presented in **Sections 6.3.1** to **6.3.6**. Frequency calculations are included in **Appendix E**.

Table 6.17 Frequency of Hazardous Events

Locations	Hazardous Event Scenario	Frequency (events/year)
Transmission Pipeline (fatality impacts)	Excavator tooth penetration (50 mm hole) and jet fire or flash fire	2.66×10^{-8}
Transmission Pipeline (injury impacts)	Excavator tooth penetration (50 mm hole) and jet fire or flash fire	4.10×10^{-8}
Storage Pipeline	Excavator tooth penetration (50 mm hole) and jet fire or flash fire	2.88×10^{-7}
Interconnect Pipeline	Excavator tooth penetration (50 mm hole) and jet fire or flash fire	4.10×10^{-8}
JGN Offtake Facility	Flange leak and jet fire or flash fire	7.50×10^{-5}
Compressor Station and Delivery Station	Flange leak and jet fire or flash fire	1.25×10^{-6}
Storage Pipe Header	Flange leak and jet fire or flash fire	2.50×10^{-7}
Compressor Station	Compressor heat exchanger full bore pipe rupture and jet fire or flash fire	4.66×10^{-6}
Compressor Station	Compressor acoustic enclosure VCE	8.51×10^{-8}

7.0 Risk Assessment

The following risk assessment is based on a comparison of the results of the semi-quantitative risk analysis presented in **Sections 6.2** and **6.3** with HIPAP 4 (DoP, 2011) risk criteria (refer to **Section 6.1**).

7.1 Individual Fatality Risk

7.1.1 Transmission Pipeline

All credible hazardous events associated with the transmission pipeline will have possible off-site fatality impacts. The credible hazardous event associated with the transmission pipeline with the most significant impact is a jet fire resulting from ignition of a gas release due to a 50 mm excavator tooth penetration and results in fatality impacts (12.6 kW/m^2 thermal radiation contour, refer to **Table 6.4**) extending up to 37 m from the point of release. The frequency of a jet fire with fatality impacts resulting from ignition of a gas release due to a 50 mm excavator tooth penetration is 2.66 x 10^{-8} per year which is below the HIPAP 4 individual risk criteria of 1 x 10^{-6} fatalities/year (refer to **Table 6.1**).

Further, the cumulative frequency of fatality impacts at any point along the transmission pipeline alignment for all failure modes and hole sizes ranging from small to rupture (as per **Table 6.12**) was undertaken by applying:

- a pipeline length equivalent to three times the 12.6 kW/m^2 thermal radiation impact distance for a 50 mm hole size to small leak failure mode frequencies

- a pipeline length equivalent to three times the 12.6 kW/m^2 thermal radiation impact distance for pipeline rupture and large leak failure mode frequencies

The estimated cumulative frequency of fatality impacts for all failure modes and leak sizes ranging form small to rupture is 2.39 x 10^{-7} which is also below the HPAP 4 criteria. However, it is noted that hazardous events for failures exceeding a small hole are not considered to be credible (refer to **Section 5.4**).

There is also a small area of industrial land between the storage pipeline and compressor station where potential fatality impacts from the storage pipeline, interconnect pipeline and transmission pipeline could occur. The estimated cumulative fatality impact frequency for the storage pipeline (refer to **Section 7.1.2**), interconnect pipeline (refer to **Section 7.1.3**) and transmission pipeline for all failure modes and hole sizes ranging from small to rupture is 2.09 x 10^{-5} which is below the HIPAP 4 criteria of 50 x 10^{-6} for Industrial land use.

7.1.2 Storage Pipeline

All credible hazardous events associated with the storage pipelines will have possible off-site fatality impacts. The credible hazardous event associated with the storage pipeline with the most significant impact is a jet fire resulting from ignition of a gas release due to a 50 mm excavator tooth penetration and results in fatality impacts (12.6 kW/m^2 thermal radiation contour, refer to **Table 6.2**) extending up to 57 m from the point of release.

The frequency of jet fire event with fatality impacts resulting from ignition of a gas release due to a 50 mm excavator tooth penetration for the storage pipeline is 2.88 x 10^{-7} per year (based on a length of pipeline that poses fatality impacts to a point on the pipeline alignment of 1,200 m). The primary land use zone along the storage pipeline alignment is industrial (refer to **Table 6.16**) with a HIPAP 4 individual fatality risk criteria of 50 x 10^{-6} fatalities/year. As such, the storage pipeline is considered to meet the HIPAP 4 individual fatality risk criteria.

Further, the cumulative frequency of fatality impacts at any point along the storage pipeline alignment for all failure modes and hole sizes ranging from small to rupture (as per **Table 6.12**) was undertaken by applying:

- a pipeline length of 1,200 m a 50 mm hole size to small leak failure mode frequencies
- the entire storage pipeline length to rupture and large leak failure mode frequencies

The estimated cumulative frequency of fatality impacts for all failure modes and leak sizes ranging from small to rupture is 1.98 x 10^{-5} which is also below the HPAP 4 criteria. However, it is noted that hazardous events for failures exceeding a small hole are not considered to be credible (refer to **Section 5.4**).

There is also a small area of industrial land between the storage pipeline and compressor station where potential fatality impacts from the storage pipeline, interconnect pipeline and transmission pipeline could occur. As indicated in **Section 7.1.1**, the estimated cumulative fatality impact frequency for all failure modes and hole sizes ranging from small to rupture in this area is estimated to be 2.09 x 10^{-5} which is below HIPAP 4 criteria of 50 x 10^{-6} (or 5 x 10^{-5}).

While there is a small area of land to the north east of the storage pipeline where the active open space where the active open space HIPAP 4 risk criteria of and 10 x 10^{-6} fatalities/year is considered to apply (refer to **Table 6.16**), the length of pipeline that poses a fatality risk to this area as a result of rupture is conservatively estimated to be 7,250 m. The frequency of fatality impacts for this area is estimated to be 6.48 x 10^{-6} which is below HIPAP 4 criteria 10 x 10^{-6}.

7.1.3 Interconnect Pipeline

All credible hazardous events associated with the interconnect pipeline will have possible off-site fatality impacts. The credible hazardous event associated with the interconnect pipeline with the most significant impact is a jet fire resulting from ignition of a gas release due to a 50 mm excavator tooth penetration and results in fatality impacts (12.6 kW/m^2 thermal radiation contour, refer to **Table 6.2**) extending up to 57 m from the point of release.

The frequency of a jet fire event with fatality impacts resulting from ignition of a gas release due to a 50 mm excavator tooth penetration for the storage and interconnect pipeline is 4.10 x 10^{-8} per year. The land use zone along the interconnect pipeline alignment that could be exposed to a fatality risk is industrial (refer to **Table 6.16**) with a HIPAP 4 individual fatality risk criteria of 50 x 10^{-6} fatalities/year. As such, the interconnect pipeline is considered to meet the HIPAP 4 individual fatality risk criteria.

Further, the cumulative frequency of fatality impacts at any point along the interconnect pipeline alignment for all failure modes and hole sizes ranging from small to rupture (as per **Table 6.12**) was undertaken by applying:

- a pipeline length equivalent to three times the 12.6 kW/m^2 thermal radiation impact distance for a 50 mm hole size to small leak failure mode frequencies

- a pipeline length equivalent to three times the 12.6 kW/m^2 thermal radiation impact distance for pipeline rupture and large leak failure mode frequencies

The estimated cumulative frequency of fatality impacts for all failure modes and leak ranging from small to rupture is 8.74 x 10^{-7} which is also below the HPAP 4 criteria. However, it is noted that hazardous events for failures exceeding a small hole are not considered to be credible (refer to **Section 5.4**).

There is also a small area of industrial land between the storage pipeline and compressor station where potential fatality impacts from the storage pipeline, interconnect pipeline and transmission pipeline could occur. As indicated in **Section 7.1.1**, the estimated cumulative fatality impact frequency for all failure modes and hole sizes ranging from small to rupture in this area is estimated to be 2.09 x 10^{-5} which is below HIPAP 4 criteria of 50 x 10^{-6} (or 5 x 10^{-5}).

7.1.4 JGN Offtake Facility

The maximum modelled distance of a credible hazardous event with a fatality impact at the SNP delivery is associated with thermal radiation from a DN350 flange jet fire. The fatality thermal radiation contour (12.6 kW/m^2, refer to **Table 6.4**) extends 28 m from the point of release and could impact off-site receivers (i.e. an individual) in very close proximity to the compound.

A DN350 mm flange jet fire is estimated to have a frequency of occurrence of 7.5 x 10^{-7} per year. There will also be a small area off site that could have potential fatality impacts associated with JGN offtake facility jet fires as well as transmission pipeline fires. The cumulative frequency of fire events with off site impacts associated with the transmission pipeline for all failure modes and hole sizes ranging from small to rupture (refer to **Section 7.1.1**) and the JGN offtake facility is 9.89 x 10^{-7}.

The land use immediately surrounding the SNP delivery facility is considered to be active open space with a HIPAP 4 individual fatality risk criteria of 10 x 10^{-6} fatalities/year (refer to **Table 6.1**). The cumulative frequency of off-site fatality impacts associated with JGN offtake station and transmission pipeline fire of 9.89 x 10^{-7} fatalities/year is below HIPAP 4 individual fatality risk criteria 10 x 10^{-6} (or 100 x 10^{-7}).

7.1.5 Compressor Station and Delivery Station

The maximum modelled distance of a credible hazardous event with a fatality impact at the compressor station and delivery station is associated with thermal radiation from a jet fire resulting from ignition of a compressor heat exchanger tube rupture. The fatality thermal radiation contour (12.6 kW/m^2, refer to **Table 6.4**) extends 56 m from the point of release. Based on the proposed location of the compressor heat exchangers, potential fatality impacts associated with a jet fire will not extend off site. The jet fire event is estimated to have a frequency of occurrence of 4.66 x 10^{-6} per year, however, as the potential fatality impacts do not extend off site, the VCE frequency will not contribute to off site fatality risk.

The maximum modelled distance to possible fatality impacts (the 21 kPa overpressure contour, refer to **Table 6.5**) associated with a VCE in a compressor acoustic enclosure was 47 m. Based on the proposed location of the compressor enclosures, potential fatality impacts associated with a VCE will not extend off site. The VCE event is estimated to have a frequency of occurrence of 8.51 x 10^{-8}, however, as the potential fatality impacts do not extend off site, the VCE frequency will not contribute to off site fatality risk.

Ignition of a DN400 mm flange leak between bolt holes is estimated to have a maximum possible fatality impact distance of 46 m (associated with a jet fire) and could extend off site. A DN400 mm flange jet fire event is estimated to have a frequency of 1.25 x 10^{-6} per year.

There will also be a small area off site that could have potential fatality impacts associated with compressor and delivery station jet fires as well as transmission pipeline and interconnect pipeline fires. The cumulative frequency of fire events with off site impacts associated with the transmission pipeline (refer to **Section 7.1.1**), the interconnect pipeline (refer to **Section 7.1.3**) for all failure modes and hole sizes ranging from small to rupture and compressor station and delivery station is 2.86 x 10^{-6}.

The land use immediately surrounding the compressor station and delivery station is industrial with a HIPAP 4 individual fatality risk criteria of 50 x 10^{-6} fatalities/year (refer to **Table 6.1**). The cumulative frequency of off-site fatality impacts associated with a transmission pipeline, the interconnect pipeline and compressor and storage station of 2.86 x 10^{-6} fatalities/year is below the HIPAP 4 individual fatality risk criteria of 50 x 10^{-6}.

7.2 Injury Risk

All credible hazardous events associated with the transmission pipeline will have possible off-site fatality impacts. The credible hazardous event associated with the transmission pipeline with the most significant impacts is a jet fire resulting from ignition of a gas release due to a 50 mm excavator tooth penetration and results in injurious impacts (4.7 kW/m^2 thermal radiation contour, refer to **Table 6.4**) extending up to 57 m from the point of release. The frequency of a jet fire with injurious impacts resulting from ignition of a gas release due to a 50 mm excavator tooth penetration is 4.10 x 10^{-8} per year which is below the HIPAP 4 individual risk criteria of 1 x 10^{-6} fatalities/year (refer to **Table 6.1**).

Further, the cumulative frequency fires with injurious impacts resulting from small hole, large hole and ruptures for all failure modes was estimated to be 3.87 x 10^{-7} which is also below the relevant HIPAP 4 injury risk criteria. However, it is noted that hazardous events for failures exceeding a small hole are not considered to be credible (refer to **Section 5.4**).

Fire events resulting from pinhole failures (< 25 mm) are considered very unlikely to transition to hazardous events that would impact residential or sensitive receivers if they occur while the pipeline is buried (e.g. due to ground movement). If escalation to a hazardous event occurs when the pipeline is exposed, it will be during a controlled activity where access to the immediate area is restricted and the extent of any impacts would be extremely unlikely to impact a residential or sensitive receiver.

As such, the Project is considered to meet the HIPAP 4 individual injury risk criteria.

7.3 Propagation Risk

A DN400 mm flange fire (jet fire or flash fire, depending on proximity of flanged connection to site boundary) at the compressor station and delivery station has the potential for off site propagation impacts on neighbouring industrial zoned land including the HPP. HIPAP 4 requires that the frequency of thermal radiation impacts at adjacent industrial facilities does not 50 x 10^{-6} per year (refer to **Table 6.1**). As the estimated frequency of propagation impacts associated with a DN400 mm flange fire (i.e. approximately 1.25 x 10^{-6}) is less than 50 x 10^{-6} fatalities/year, the compressor station and delivery station are considered to meet the HIPAP 4 propagation risk criteria.

It should be noted that no hazardous events associated with the HPP were identified in *Hunter Power Project Hazard and Risk Assessment* (Jacobs, 2021) with impacts that could result in propagation to the compressor station and delivery station (referred to as the Gas Receiving Station in the Jacobs report (2021)) at a frequency exceeding HIPAP 4 criteria.

A DN350 mm flange fire (jet fire or flash fire, depending on proximity of flanged connection to site boundary) at the JGN offtake facility has the potential for off site propagation to the JGN delivery facility. As the estimated frequency of propagation impacts associated with a DN350 mm flange fire (i.e. approximately 7.50 x 10^{-7}) is less than 50 x 10^{-6} fatalities/year, the compressor station and delivery station are considered to meet the HIPAP 4 propagation risk criteria.

There are also areas along the transmission pipeline alignment that have current industrial land use or are proposed for future industrial development. Given the frequencies of hazardous events along the transmission pipeline that could have off-site injury impacts are below the HIPAP 4 criteria of 50 x 10^{-6} events/year (refer to **Section 7.2**), the frequency of propagation impacts will therefore comply with the HIPAP 4 propagation criteria of 50 x 10^{-5} events/year.g

8.0 Risk Management

The control of risks is a continuous process where strategies are put into place to eliminate risks wherever possible, mitigate the residual risks identified using appropriate control measures, safeguards and procedures, and, lastly, accept the residual risk and manage the impacts should the hazardous event occur. The risk control strategies and their effectiveness are broadly described as:

- engineering control to either completely eliminate the risk (100 per cent effectiveness) or to implement physical controls and safeguards (minimum 90% effectiveness)
- administrative control based around procedures (maximum 50% effectiveness)
- personnel control using training and the control of work methods (maximum 30% effectiveness).

The qualitative risk assessment identified a range of technical control measures and non-technical safeguards and procedures that will be put in place to eliminate or mitigate the level of risk associated with the operation of the facility.

Technical safeguards are those controls that are incorporated into the process or control system hardware, software or firmware. Non-technical controls are management and operational controls, such as security policies, operational procedures, maintenance procedures and training. Technical and non-technical safeguards can also be divided into preventive controls which inhibit or prevent hazardous events from occurring and detective controls such as control system alarms that warn of unacceptable process deviations, or security monitoring systems that initiate an alarm in the event of violations of security protocols.

8.1 Technical Control Measures

The technical control measures identified in **Appendix B** and described in detail in **Section 2.0** that will be implemented as part of the Project include:

- All underground pipelines and stations will be designed and constructed in accordance with relevant standards including the AS/NZS 2885 series and ASME B31.12 (for pipelines and stations that are to be 10 mol% hydrogen ready)
- All fittings and equipment installed at the Project will be Australian Gas Association (AGA) certified and suitably rated for the hazardous area in which it is installed.
- The transmission, interconnect and storage pipelines will be designed and constructed not to rupture when subject to the identified credible threats (including ground movement and buoyancy, external interference, flooding, lightning, corrosion, fatigue) along the pipeline alignment. These threats will be mitigated through:
  - minimum pipeline wall thickness
  - appropriate depth of cover
  - unconsolidated backfill for pipeline sections with greater potential for ground movement (areas with potential for mine subsidence)
  - corrosion protection coatings (fusion bonded epoxy) and cathodic protection systems
  - lightning protection
  - selection of pipeline alignment to as far as practicable avoid residential land use and areas of geotechnical instability.

- Pipeline systems will have appropriate controls and interlocks to detect significant loss of containment events and automatically shut down gas supply. This will limit the potential for ignition of a gas release by limiting the duration of the release as well as limiting the duration of a jet fire event should the release be ignited.

8.2 Non-technical Control Measures

The non-technical safeguards and procedures identified in **Appendix B** include:

- Surface facilities will be located in secure compounds
- Asset protection zones around the compounds will be maintained free of combustible material
- Hazardous area classification will be undertaken for all installations and a hazardous area dossier prepared for the Project
- Weekly site checks of surface facilities by operators which will include audible and visual leak inspections
- Atmosphere testing (e.g. Oxygen, LEL) as required (depending on activities) for personnel entry to surface facility compounds and mandatory testing for vehicle entry (as a vehicle is an ignition source)
- Surface facility fencing ensures off-site ignition sources (e.g. smokers) are excluded from the defined hazardous envelope
- Bollards and concrete edging/kerbing (generally at edge of hazardous area) to protect pipe and fittings from vehicle/mobile plant impacts
- Compressor acoustic enclosures will be ventilated and have gas detection systems that initiate shut down
- Commissioning activities will be strictly controlled to ensure no ignition sources near vented gas
- A maintenance system will be implemented that includes routine inspection and maintenance plans in accordance with AS/NZS 2885.3
- A work permit system and job safety analyses for maintenance activities
- Hot work procedures and permits
- Pipeline markers and signage. The markers will be located in consultation with land holders and placed at a frequency to ensure continual line of sight along the alignment and will also be located at any bends, at property boundary fences and either side of crossings such as roads or watercourses
- Pipeline marker tape will be buried above the along entire length of all underground pipelines to indicate the presence of the pipeline to anyone undertaking an excavation above the pipeline
- The location of all underground pipelines will be registered with Dial Before You Dig
- Emergency management plans consistent with *HIPAP No. 1 Emergency Planning* (DoP, 2011) and *Planning for Bushfire Protection 2019* (NSW Rural Fire Service, 2019) will be prepared for the construction and operation phases of the Project.

9.0 Conclusions

The PHA prepared for the Project identified a number of hazardous events associated with natural gas and the potential for harmful off-site impacts. Consequence modelling was undertaken to determine the maximum extent for the range of credible hazardous events (refer to **Section 6.2**) identified during a hazard study workshop undertaken with APA (refer to **Section 5.4**). The frequency of these credible hazardous events was estimated using published failure frequency data (refer to **Section 6.3**) and used with the consequence analysis results to assess the Project risks with respect to HIPAP 4 risk criteria (refer to **Section 7.0**.

All Project components were assessed as meeting the HIPAP 4 individual fatality risk criteria (refer to **Section 7.1**) using UK HSE frequency data for leaks ranging from small holes to pipeline ruptures for a range of failure modes (refer to **Table 6.15**). The UK HSE frequency data was adopted for the frequency analysis based on the advice of the NSW DPIE Hazard team and it is acknowledged that the UK HSE data provides conservative failure mode frequencies. It is noted that AS/NZS 2885.6 indicates that average failure rates of Australian pipelines are much lower than in Europe.

Applying pipeline failure mode frequencies derived from APGA data for Australian pipelines, the estimated individual fatality risks associated with pipeline fire events for the Project would be lower than those presented in **Section 7.1**, and further below HIPAP 4 criteria.

The frequencies of the modelled credible hazardous events for all Project components with potential injurious impacts to residential and sensitive receivers were estimated to be below the HIPAP 4 criteria of 50×10^{-6} events/year (refer to **Section 7.2**).

The frequency of hazardous events with potential propagation impacts for all Project components were estimated to be below the HIPAP 4 criteria of 50×10^{-6} events/year (refer to **Section 7.3**).

It is therefore considered that if the risk management measures outlined in **Section 8.0** are implemented, the Project will meet HIPAP 4 risk criteria for individual fatality, injury and propagation.

10.0 References

Applying SEPP 33: Hazardous and Offensive Development Application Guidelines, NSW Department of Planning, 2011

Multi Level Risk Assessment, NSW Department of Planning, 2011

Hazardous Industry Planning and Advisory Paper 4 – Risk Criteria for Land Use Safety Planning, NSW Department of Planning, 2011

Hazardous Industry Planning and Advisory Paper 6 – Hazard Analysis, NSW Department of Planning, 2011

Manual for classification of risks due to major accidents in process and related Industries, International Atomic Energy Agency, 1996

AS/NZS 2885.6:2018 Pipelines – Gas and liquid petroleum, Part 6: Pipeline safety management, Standards Australia, 2018

Experience with the Australian / New Zealand Pipeline Incident Database, Australian Pipeline and Gas Association, 2018

Gas Pipeline Incidents, 11th Report of the European Gas Pipeline Incident Data Group, European Gas Pipeline Industry Group, 2020

Update of pipeline failure rates for land use planning assessments, UK Health and Safety Laboratory for the Health and Safety Executive, 2015)

Failure Rate and Event Data for use within Risk Assessments, UK Health and Safety Executive, 2017

Control Systems, https://www.hse.gov.uk/comah/sragtech/techmeascontsyst.htm, UK Health and Safety Executive, 2021

Hazard and Barrier Analysis Guidance Document, USA Department of Energy, Office of Operating Experience Analysis and Feedback, 1996

Wentworth Storage Bottle (WEN) Preliminary SMS Workshop Repport, GPA Engineering Pty Ltd, 2021

Kurri Kurri Lateral Pipeline (KKLP) Preliminasry FEED SMS Workshop Report, GPA Engineering Pty Ltd, 2021

APPENDIX A

IAEA Calculations

IAEA Risk Classification and Prioritisation

Estimation of External Consequences

Hazardous Material: Storage Pipeline - Natural Gas Fire/Explosion

Select the appropriate effect category from Table II

IAEA Table II(a): Classification of Substances by Effect Categories

Ref. No.	Type of substance	Description of substance	Activity	Quantity (t) 0.2-1	1-5	5-10	10-50	50-200	200-1000	1000-5000	5000-10000	>10000
1	Flammable liquid	Vapour pressure <0.3 bar at 20°C	Storage with tank pit	-	-	-	-		AI	BI	BI	CI
2			Pipeline	-	_	-	-	-	-	-	-	-
3			Other	-	-	-	AI	BI	CI	DII	X	X
4		Vapour Pressure 0.3 bar at 20°C	Storage with tank pit	-	-	-	-	-	BI	CII	CII	DII
6			Other	-	-	-	BII	CII	DII	E II	X	X
7	Flammable gas	Liquefied by pressure	Rail, road, overground storage	-	AI	BI	C I	D I	E I	X	X	X
9			Other	-	BII	CIII	CIII	DIII	E III	X	X	X
10		Liquefied by cooling	Storage with tank pit	-	-	-	-	-	BI	CII	CII	DII
11			Other		-	-	BII	CII	DII	E II	X	X
13		Under pressure > 25 bar: high toxicity	Storage of cylinders (25-100kg)	-	-	CIII	CII	CI	CI	X	X	X
14	Explosive	In bulk (causing single explosion)		AI	BI	BI	CI	CI	DI	X	X	X
15		In packages (e.g. shells)		BIII	BIII	CIII	CI	CI	DI	X	X	X
16	Toxic liquid	Low toxicity	Storage with tank pit	-	-	-	-		A II	A II	B II	C III
17			Other	-	-	-	A III	A II	B II	C II	C II	C II
18		Medium toxicity	Storage with tank pit	-	-	-	A III	B III	D III	E III	F III	F III
21			Other	-	BII	C III	D III	E III	F III	F III	X	X
22		High toxicity	Storage with tank pit	-	-	A II	B III	C III	E III	F III	G III	G III
25			Other	BII	CII	D III	E III	F III	F III	G III	X	X
26		Very high toxicity	Storage with tank pit	AII	BII	C III	E III	F III	G III	G III	H III	H III
29			Other	CIII	DIII	E III	F III	G III	H III	H III	X	X
30	Toxic gas	Liquefied by pressure: low toxicity		AII	BII	B II	CIII	C II	DIII	D III	D III	E III
31		medium toxicity		BII	CII	C II	DIII	E III	F III	F III	G III	H III
32		high toxicity		CII	DIII	E III	E III	F III	G III	G III	X	X
33		very high toxicity		DIII	EIII	F III	G III	G III	H III	-	X	X
34		extreme toxicity		EIII	FIII	G III	H III	H III	X	X	X	X
35		Liquefied by cooling: low toxicity	In the case of activities on water use 30-34 instead of 35-39	-	-	-	A II	A II	B II	B II	C II	DIII
36		medium toxicity		-	AII	B II	C II	D III	D III	E III	F III	G III
37		high toxicity		BII	CII	D III	E III	E III	F III	F III	G III	H III
38		very high toxicity		DIII	EIII	F III	F III	G III	G III	X	X	X
39		extreme toxicity		EIII	FIII	G III	H III	H III	X	X	X	X

***Note**: For flammable liquids in underground tanks, the quantity should be divided by 5 and the substance treated as 'other' i.e. Refs 3 or 6.*

***Symbols**: 'X' means the combination of that substance and that amount does not usually exist in practice. It is suggested that a full QRA should be carried out in any such case. '-' means that the effects are small enough to be ignored.*

Effect Category: EII

Comments regarding selection

1,660 tonnes of natural gas stored in pipeline based on ~110 TJ of natural gas, a rich natural gas heating value of 37.23 MJ/Sm3 with density of 0.5613 kg/Sm3. While gas is not stored in cylinders, this is the most applicable selection given the natural gas is not liquefied and is in storage at a pressure exceeding 25 bar. Result indicates that storage of this quantity of flammable gas in cylinders does not usually exist and that a quantitative risk assessment should be undertaken. For the purpose of this assessment an effect category of EII has been applied which corresponds to flammable gas liquified by cooling stored with tank pit.

Based on the selected effect category, identify maximum effect distance and/or area from Table III.

IAEA Table III: Effect Categories: Maximum Distance and Area of Effect (*A*)

Effect distance (m)		Effect area category (ha)		
Category	Max. Distance (m)	I	II	III
A	0-25	0.2	0.1	0.02
B	25-50	0.8	0.4	0.1
C	50-100	3	1.5	0.3
D	100-200	12	6	1
E	200-500	80	40	8
F	500-1000	-	-	30
G	1000-3000	-	-	300
H	3000-10 000	-	-	1000

Comments

Maximum Effect Distance (m): 500

Effect Area (ha): 79

If known enter population density of surrounding land or use Table IV as an estimate.

IAEA Table IV: Population Density (*d*)

Description of the area	Density (persons/ha)
Farmland, scattered houses	5
Individual dwellings	10
Village, quiet residential area	20
Residential area	40
Busy residential area	80
Urban area, shopping centres, centre of city	160

Comments

Surrounding land use includes rural (north and east), bushland (west), the former industrial Hydro aluminium smelter site (south) and the Kurri Kurri Speedway (south east). The Hydro site will accommodate the Hunter Power Project gas fired ppower station.
The typical population densities are likely to be much less then 5 persons/ha, use 2 persons/ha.

Population Density (persons/ha): 2

Select population correction factor from Table V.

IAEA Table V: Population Correction Factor (f_A)

Effect area Category	Populated fraction (%) of circular area				
	100%	50%	20%	10%	5%
I	1	0.6	0.2	0.1	0.05
II	1	1	0.4	0.2	0.1
III	1	1	1	1	1

Comments

This selection assumes that the populated fraction of the effect area is to the south of the storage pipeline (i.e. the Hunter Power Project site)

Population Correction Factor, f_A: 1

Select mitigation correction factor from Table VI.

IAEA Table VI: Correction Factor for Mitigation (f_m)

Substances (reference numbers)	Factor
Flammables (1-12)	1
Flammables (13)	0.1
Explosives (14, 15)	1
Toxic liquid (16-29, 43-46)	0.05
Toxic gas (30-34, 37-39, 40-42)	0.1
Toxic gas (35-36)	0.05

Comments

Conervatively assume no mitigation

Mitigation Correction Factor, f_m: 1

ESTIMATE OF EXTERNAL CONSEQUENCES

$C_{a,s} = A \times d \times f_A \times f_m$

$C_{a,s} = 157.1$

Estimation of Probability and Frequency

Select the average probability number from Table VI or Table XV

IAEA Table VII: Average Probability Number ($N^*_{i,s}$)

Substances	Activity	
(reference numbers)	Storage	Plant
Flammable liquid (1-3)	8	7
Flammable liquid (4-6)	7	6
Flammable gas (7)	6	5
Flammable gas (9)	7	6
Flammable gas (10,11)	6	-
Flammable gas (13)	4	-
Explosive (14,15)	7	6
Toxic liquid (16-29)	5	4
Toxic gas (30-34)	6	5
Toxic gas (35-39)	6	-
Toxic gas (42)	5	4
Combustion products (43-46)	3	-

TABLE XV. AVERAGE PROBABILITY NUMBER ($N^*_{i,s}$) FOR TRANSPORT ACCIDENTS[a]

Substances (reference numbers)		Transport			
		Road	Rail	Water[b]	Pipeline
Flammable liquid	(2)				6
Flammable liquid	(5)				5
Flammable liquid	(3, 6)	8.5	9.5	7.5 9[c]	3
Flammable gas	(7)	9.5	10.5		
Flammable gas	(8)				6
Flammable gas	(9)			10	
Flammable gas	(11)			9	
Flammable gas	(12)				6
Explosive	(14)	9	10	8	
Toxic liquid	(19, 23, 27)	7.5	8.5		
Toxic liquid	(20, 24, 28)			6.5 8[c]	
Toxic gas	(31, 32)	9.5	10.5	9	
Toxic gas	(36, 37)			8	6
Toxic gas	(40, 41, 42)				5[d]

[a] The table shows only the values that are necessary in the framework of the Manual.
[b] Inland waterways.
[c] Double hull.
[d] For substances that are very corrosive in contact with water.

Average Probability Number, $N^*_{i,s}$: 6

Comments

Although we are treating S1 as storage, use average probablity number for pipelines as the storage probability number is based storage in cylinders and the S1 storage system is a pipeline.

Select probability number correction parameter for frequency of loading/unloading operations from Table VIII

IAEA Table VIII: Probability Number Correction Parameter (n_l) For Loading/Unloading Operations Frequency

Frequency of loading/ unloading (per year)	Parameter
1-10	+0.5
10-50	0
50-200	-1
200-500	-1.5
500-2000	-2

***Note** that this does not apply to cylinders (Ref No 13)*

Comments

The Storage Pipeline is supplied by the Compression Plant from the Lateral Pipeline. If it is taken that loading/unloading is characterised by a signficant increase/decrease in Storage Pipeline operating pressure (e.g. for maintenance or inspection purposes) then this is only likely to occur 1 - 10 times per year.

Loading/Unloading Correction Parameter, n_l 0.5

If the hazardous material is flammable select appropriate correction parameters from Table IX

IAEA Table IX: Probability Number Correction Parameter (n_f) for Flammables

Substance	Safety measures	Factor
Flammable gas (7, 13)	Sprinkler system	+0.5
Flammable gas (10)	Double containment	+1
Flammable gas (13)	Fire wall	+1
	Sprinkler system	+0.5
	5-50 stored cylinders	+1
	50-500 stored cylinders	0
	>500 stored cylinders	-1

Comments

Flammables correction Parameter, nf 0

No correction factor applied as none of the safety measures refelect the Storage Pipeline scenario.

Select organisational safety probability correction parameter from Table X.

IAEA Table X: Probability Number Correction Parameter (n_o) for Organisational Safety

Above average industry practice	+0.5
Average industry practice	0
Below average industry practice	-0.5
Poor industry practice	-1
Non-existent safety practices	-1.5

Note: *Several factors are included: safety management, age of the plant, maintenance, documentation and procedures, safety culture, training, emergency planning etc.*

Comments

Organisational Safety Correction Parameter, no: 0

Assume APA Group safety systems are typical of industry practice in Australia.

Select wind direction correction parameter from Table XI.

IAEA Table XI: Probability Number Correction Parameter (n_p) for Wind Direction Towards Populated Area(s) in the Affected Zone

Effect area category	Part of the area (%) where people are living				
	100%	50%	20%	10%	5%
I	0	0	0	0	0
II	0	0.5	0.5	0.5	0.5
III	0	0.5	0.5	1	1.5

Comments

No correction applied as wind direction would not significantly mitigate a jet fire.

Wind Direction Correction Parameter, n_p: 0

ESTIMATE OF PROBABILITY NUMBER AND FREQUENCY

$$N_{i,s} = N^*_{i,s} + n_l + n_f + n_o + n_p$$

$$N_{i,s} = 6.5$$

$$P = 3.16E\text{-}07$$

Estimation of External Consequences

Hazardous Material: Lateral Pipeline - Natural Gas Fire/Explosion

Select the appropriate effect category from Table IV

TABLE IV(b). CLASSIFICATION BY EFFECT CATEGORIES OF SUBSTANCES FLOWING IN UNDERGROUND PIPELINES OUTSIDE PLANTS

Ref. No.	Type of substance	Description of substance	Diameter[a] (m)	Category
2	Flammable liquid	Vapour pressure at 20°C <0.3 bar	>0.2	A I
5		Vapour pressure at 20°C ≥0.3 bar	0.2–0.4 >0.4	A I B II
8	Flammable gas	Liquified by pressure	<0.1 0.1–0.2 >0.2	C I D I E I
12		Under pressure	0.2–1 >1	A I B I
40	Toxic gas	Medium toxicity	<0.1 0.1–0.2	E III F III
41		High toxicity	<0.1 0.1–0.2	F III G III
42		Pressure >25 bar, high toxicity	<0.02 0.02–0.04 0.04–0.1	D III E III F III

[a] Diameter of the largest pipe.

Comments regarding selection

Effect Category: A1

Underground pipeline transport of under pressure flammable gas in 14" (DN 350 mm).

Based on the selected effect category, identify maximum effect distance and/or area from Table III.

IAEA Table III: Effect Categories: Maximum Distance and Area of Effect (*A*)

Effect distance (m)		Effect area category (ha)		
Category	Max. Distance (m)	I	II	III
A	0-25	0.2	0.1	0.02
B	25-50	0.8	0:4	0.1
C	50-100	3	1.5	0.3
D	100-200	12	6	1
E	200-500	80	40	8
F	500-1000	-	-	30
G	1000-3000	-	-	300
H	3000-10 000	-	-	1000

Comments

Maximum Effect Distance (m): 25

Effect Area (ha): 0.2

If known enter population density of surrounding land or use Table IV as an estimate.

IAEA Table IV: Population Density (*d*)

Description of the area	Density (persons/ha)
Farmland, scattered houses	5
Individual dwellings	10
Village, quiet residential area	20
Residential area	40
Busy residential area	80
Urban area, shopping centres, centre of city	160

Comments

Population Density (persons/ha): 5

Surrounding land is rural with scaterred houses, public space (including main roads), mining/industrial and the Kurri Kurri Speedway.
The typical population densities are likely to be less then 5 persons/ha, however this number has been selected as a conservative estimate.

Select population correction factor from Table V.

IAEA Table V: Population Correction Factor (f_A)

Effect area Category	Populated fraction (%) of circular area				
	100%	50%	20%	10%	5%
I	1	0.6	0.2	0.1	0.05
II	1	1	0.4	0.2	0.1
III	1	1	1	1	1

Comments

Assumes that at particular points along pipeline route 100% of the surrounding land use may be populated.

Population Correction Factor, f_A: 1

Select mitigation correction factor from Table VI.

IAEA Table VI: Correction Factor for Mitigation (f_m)

Substances (reference numbers)	Factor
Flammables (1-12)	1
Flammables (13)	0.1
Explosives (14, 15)	1
Toxic liquid (16-29, 43-46)	0.05
Toxic gas (30-34, 37-39, 40-42)	0.1
Toxic gas (35-36)	0.05

Comments

Mitigation Correction Factor, f_m: 1

ESTIMATE OF EXTERNAL CONSEQUENCES

$C_{a,s}$ = **A x d x f_A x f_m**

$C_{a,s}$ = **1.0**

Estimation of Probability and Frequency

Select the average probability number from Table XV

TABLE XV. AVERAGE PROBABILITY NUMBER ($N^*_{i,s}$) FOR TRANSPORT ACCIDENTS[a]

Substances (reference numbers)		Transport			
		Road	Rail	Water[b]	Pipeline
Flammable liquid	(2)				6
Flammable liquid	(5)				5
Flammable liquid	(3, 6)	8.5	9.5	7.5 9[c]	3
Flammable gas	(7)	9.5	10.5		
Flammable gas	(8)				6
Flammable gas	(9)			10	
Flammable gas	(11)			9	
Flammable gas	(12)				6
Explosive	(14)	9	10	8	
Toxic liquid	(19, 23, 27)	7.5	8.5		
Toxic liquid	(20, 24, 28)			6.5 8[c]	
Toxic gas	(31, 32)	9.5	10.5	9	
Toxic gas	(36, 37)			8	6
Toxic gas	(40, 41, 42)				5[d]

[a] The table shows only the values that are necessary in the framework of the Manual.
[b] Inland waterways.
[c] Double hull.
[d] For substances that are very corrosive in contact with water.

Comments

Average Probability Number, $N^*_{i,s}$: 6 — Flammable gas pipeline transport - as per Table XV

Select probability number correction parameter for frequency of loading/unloading operations from Table VIII

IAEA Table VIII: Probability Number Correction Parameter (n_l) For Loading/Unloading Operations Frequency

Frequency of loading/ unloading (per year)	Parameter
1-10	+0.5
10-50	0
50-200	-1
200-500	-1.5
500-2000	-2

***Note** that this does not apply to cylinders (Ref No 13)*

Comments

Loading/Unloading Correction Parameter, n_l 0 — No adjustment. Not applicable for supply pipeline.

If the hazardous material is flammable select appropriate correction parameters from Table IX

IAEA Table IX: Probability Number Correction Parameter (n_f) for Flammables

Substance	Safety measures	Factor
Flammable gas (7, 13)	Sprinkler system	+0.5
Flammable gas (10)	Double containment	+1
Flammable gas (13)	Fire wall	+1
	Sprinkler system	+0.5
	5-50 stored cylinders	+1
	50-500 stored cylinders	0
	>500 stored cylinders	-1

Comments

Flammables correction Parameter, n_f 0 — No adjustment. Not applicable for supply pipeline.

Select correction parameter for the safety conditions of transport from Table XVII.

TABLE XVII. PROBABILITY NUMBER CORRECTION PARAMETER (n_c) FOR THE SAFETY CONDITIONS OF TRANSPORT SYSTEMS

(a) Road, ship and pipeline transport

	Road	Ship	Pipeline
Safe[a]	+1	+0.5	+1
Average[b]	–	–	–
Unsafe[c]	-1	-0.5	-1

[a] Examples:
- Routes without crossings; routes with low or no traffic.
- Roads with separate cart-roads.
- Waterways: wide, straight.
- Pipelines made with updated regulation and with specific measures.

[b] Values to be used if it is not possible to categorize the route under the other two categories.

[c] Examples:
- Routes known to be frequently place of incidents.
- Roads with a junction with high traffic; with a fork sharp bend; with no traffic lights; with slippery pave.
- Waterways: with bends; with crossings; with traffic of ferries; with moorings for transshipment; with obstacles like bridges and locks.
- Pipelines: if old; if made with out of date regulation; if their location is not known or if they are not indicated.

In reality the real figures for 'safe' and 'unsafe' can have even a larger deviation from the average than the figures given in the table.

Comments

Transport Safety Conditions
Correction Parameter, nc: 1

Select wind direction correction parameter from Table XI.

IAEA Table XI: Probability Number Correction Parameter (n_p) for Wind Direction Towards Populated Area(s) in the Affected Zone

Effect area category	Part of the area (%) where people are living				
	100%	50%	20%	10%	5%
I	0	0	0	0	0
II	0	0.5	0.5	0.5	0.5
III	0	0.5	0.5	1	1.5

Comments

Wind Direction Correction Parameter, n_p: 0

ESTIMATE OF PROBABILITY NUMBER AND FREQUENCY

$N_{i,s} = N^*_{i,s} + n_l + n_f + n_c + n_p$

$N_{i,s} = 7$

P = 1.00E-07

APPENDIX B

Hazard Identification Workshop Minutes

Risk Assessment Workshop

Date of Workshop: 4/08/2021 & 8/11/2021

Location: Online

Job Title: Kurri Kurri Lateral Pipeline

Job Number: 21450

Job Description:	Snowy Hydro Limited is proposing to develop a gas-fired peaking power station, referred to as the Hunter Power Project (HPP), at the site of the former Hydro Australia Pty Ltd (Hydro) aluminium smelter at Kurri Kurri. The HPP is proposed to provide up to 750 megawatts (MW) of 'on-demand' electricity to supplement Snowy Hydro's generation portfolio with dispatchable capacity when the needs of electricity consumers are highest. The HPP is currently undergoing separate assessment under both NSW and Commonwealth planning and environmental assessment frameworks. APA Group (APA) has been engaged by Snowy Hydro Limited to develop a gas supply solution for the HPP. APA has proposed the Kurri Kurri Lateral Pipeline Project (the Project) as the gas supply solution for the HPP.
Purpose, Scope and Context:	The purpose of this risk assessment workshop is to identify hazards that may have off-site impacts associated with the Project. NSW Department of Planning Secretary's Environmental Assessment Requirements (SEARs) have identified hazard and risk as an area to be addressed in the EIS. Risk screening and prioritisation has shown that a Level 2 Semi Quantitative risk assesment is required and as such all aspects of a Level 1 Qualititative risk assessment are required. The risk assessment will focus on health and safety risks posed to the surrounding off-site land users and the risks posed to the surrounding biophysical environment. i.e. the risk rankings are relevant to off-site land users not on-site personnel.

Workshop Attendees

Name	Company	Position/Role	Part Day
Chris Bonomini	Umwelt	Principal Engineer/ Facilitator	
Tom Hatfield	APA	Environmentak Assessment Manager	x (4/11)
Wayne Bailey	APA	Projects Engineer Lead	
George Tsiros	APA	Project Mechanical Lead	x (4/11)

AS 2885 Risk Scoring System

Scoring Matrix

Likelihood		1	2	3	4	5
Level		**Trivial**	**Minor**	**Severe**	**Major**	**Catastrophic**
A	Frequent	11	16	20	23	25
B	Occassional	7	12	17	21	24
C	Unlikely	4	8	13	18	22
D	Remote	2	5	9	14	19
E	Hypothetical	1	3	6	10	15

Legend

23 to 25:	EXTREME RISK; immediate action required;
18 to 22:	HIGH RISK; senior management attention needed;
13 to 17:	INTERMEDIATE RISK; management responsibility must be specified; and
7 to 12:	LOW RISK; managed by routine procedures.
1 to 6:	NEGLIGIBLE

Qualitative Measures of Likelihood

	Level	Description
A	Frequent	Expected to occur once per year or more
B	Occassional	May occur occassionally in the life of the pipeline
C	Unlikely	Unlikely to occur within the life of the pipeline, but possible
D	Remote	Not anticipated for this pipeline at this location
E	Hypothetical	Theoretically possible but would only occur under extraordinary circumstances

Qualitative Measures of Consequence or Impact or Severity

	Level	People Losses	Supply	Environmental Harm
1	Trivial	Minimal impact on health and safety	No loss or restriction of pipeline supply	No effect; or minor impact rectified rapidlay (days) with negligible residual effect
2	Minor	Injuries requiring first aid treatment	Interruption or restriction of supply but shortfall met from other sources	Impact very localised and very short term (weeks), minimal rectification
3	Severe	Injury or illness requiring hospital treatment	Localised societal impact or short term loss of supply interruption (hours)	Localised impact, substantially rectified within a year or so
4	Major	One or two fatalities; or several people with life threatening injuries	Widespread societal impact such as loss of supply to a major city for a short time (hours to days) or to a localised area for a longer time	Major impact well outside pipeline corridor or site, or long term severe effects; or rectification difficult
5	Catastrophic	Multiple fatalities result	Widespread or significant societal impact, such as comlpete loss of supply to a major city for an extended time (more than a few days)	Impact widespread; viability of ecosystems or species affected; or permanent major changes

Hazard Identification

Date 4/08/2021 & 8/11/2021 **Job:** Kurri Kurri Laterial Pipeline **Job #:** 21450

Section/Area: SNP Delivery Facility

Ref	Asset	Guideword	Hazard Event Description	Threats (causes of hazard event)	Consequence	Current Barriers	C	L	R	Action
1	Pipe and Fittings	Fire and Explosion	Loss of containment and ignition of natural gas	Physical damage (e.g. during maintenance activities) Corrosion Fatigue & Erosion Equipment Failure Incorrect Equipment Sizing Malicious damage Natural hazards - lightning strike Bushfire/grass fire Venting during commissioning	One or two fatalities and/or serious injuries	Pipe designed not to rupture (i.e. maximum credible penetration < 150% x critical defect length) Pipe design in accordance with ASME B31.12 - 2019 Hydrogen Piping and Pipelines (as facility is to cater for natural gas with up to 10 mol% hydrogen) Controls and remote monitoring to detect major leaks and shut down supply Weekly site checks by operators including audible and visual leak inspection Atmosphere testing (e.g. Oxygen, LEL) as required (depending on activities) for personnel entry to compound and mandatory testing for vehicle entry (as vehicle is an ignition source) Secured compound APA maintenance system which includes routine inspection and maintenance plans in accordance with AS/NZS 2885: 2018 Pipelines – Gas and liquid petroleum Part 3 Operation and maintenance Asset protection zones around compound will be maintained free of combustible material Hazardous area classification and equipment selection/installation in accordance with AS60079/NZS Explosive atmospheres series Fencing maintains distance outside hazardous envelope to potential off-site ignition sources (e.g. smokers) Work permit system and job safety analyses for maintenance activities Hot work procedures Commissioning activities strictly controlled to ensure no ignition sources near vented gas	4	E	10	Undertake quantititave analysis of credible loss of containment and ignition events. Credible events: -DN350 mm flange leak @6.9 MPa, gasket leak between bolt holes, immediate ignition (jet fire) -DN350 mm flange leak @6.9 MPa, gasket leak between bolt holes, delayed ignition (flash fire) Complete a hazardous area classification for the SNP delivery facility

Umwelt Environmental Consultants

Hazard Identification

Date 4/08/2021 & 8/11/2021 **Job:** Kurri Kurri Laterial Pipeline **Job #:** 21450

Section/Area: Transmission Pipeline

Ref	Asset	Guideword	Hazard Event Description	Threat (cause of hazard event)	Consequence	Current Barriers	C	L	R	Action
1	Pipeline	Fire and Explosion	Loss of containment and ignition of natural gas	Mine subsidence Blasting at operational mine Physical damage to pipe (e.g. third party construction activities, farming activities)) Corrosion and possible acid sulphate soils Fatigue Flooding Earthquakes Lightning Potential future freight rail line Earth movement and buoyancy (groundwater) Upslope dam wall failure (Lake Kennerson, 200 ML)	Multiple fatalities	Consideration of land use (e.g. residential, agriculture, rail line, mine haul roads), geotechnical stability (e.g. underground mine voids, mine spoil dumps) soil properties and natural hazards (e.g. earthquake, floods) when specifying depth of cover and design standards (note that the entire length of pipeline is designed for location class T1 Residential) Pipe to be designed and constructed not to rupture (i.e. maximum credible penetration < 150% x critical defect length). Under normal operating conditions (Bucket Force Multiplier, B=0.75) the pipe can only be penetrated by a 55 t excavator fitted with penetration teeth or tiger teeth. Under aggressive operating conditions (Bucket Force Multiplier, B=1.3), excavators 15 t and above fitted with penetration teeth or tiger teeth can penetrate the pipeline, the failure mode being a leak in all cases. Operation of excavators in excess of 35T above the lateral pipeline is not considered credible. Pipe to be designed, constructed, operated and maintained in accordance with the AS/NZS 2885: 2018 Pipelines – Gas and liquid petroleum series with reference to ASME B31.12 design standard to cater for natural gas with up to 10 mol% hydrogen Internal and external coatings applied to pipeline to prevent corrosion as well as cathodic protection APA maintenance system which includes routine inspection and maintenance plans in accordance with AS/NZS 2885: 2018 Pipelines – Gas and liquid petroleum Part 3 Operation and maintenance Controls and remote monitoring to detect major leaks and shut down supply Lightning protection Work permit system and job safety analyses for maintenance activities Hot work procedures Signage Pipeline marker tape along entire length Stakeholder engagement Dial before you dig	5	E	15	Quantitatively analyse loss of containment and ignition event. Credible event: -Excavator tooth - 50 mm hole, immediate ignition (jet fire) -Excavator tooth - 50 mm hole, delayed ignition (flash fire). Jet fire from a 50 mm hole results in a 4.7 kW/m^2 radiation contour of 57 m and a 12.6 kW/m^2 radiation contour of 37 m.
2	Diesel Tank and Refuelling Equipment	Fire	Diesel loss of containment and ignition	Physical damage caused by vehicles or mobile plant Operator error (e.g. overfill) Equipment failure (e.g. valve of fuel hose leak) Grass fire due to construction activities (e.g. welding, grinding, vehicles and equipment)	One or two fatalities	Hot work procedures Combustible material exclusion zone to be maintained around diesel tank in accordance with AS1940 Self bunded diesel storage tank to be used Spill kits to be maintained on site Competency requirements for personnel using refuelling equipment All drivers/operators of mobile plant to be suitably licenced	4	E	10	Prepare an emergency response plan for the construction phase of the project in consultation with the RFS, FRNSW and the LEMC

Umwelt Environmental Consultants

3	Diesel Tank and Refuelling Equipment	Toxicity	Major diesel release to land and water	Physical damage caused by vehicles or mobile plant Operator error (e.g. overfill) Equipment failure (e.g. valve of fuel hose leak)	Contamination of soil and water resource Harm to aquatic species Contamination of farmland	Self bunded diesel storage tank to be used Diesel tank will be located in earthen bund and at least 50 m from drainage lines and water bodies Spill kits to be maintained on site Competency requirements for personnel using refuelling equipment All drivers/operators of mobile plant to be suitably licenced	4	E	10	Prepare an emergency response plan for the construction phase of the project in consultation with the RFS, FRNSW and the LEMC
4	All	Fire	Grass or bushfire	Construction activities (e.g. welding, grinding, vehicles and equipment)	Multiple fatalities	Construction corridor will be cleared of vegetation Hot work procedures First attack fire fighting equipment will be maintained on site Consultation with emergency services prior to undertaking high fire risk activities during periods of extreme and catastrophic fire rating	5	E	15	Prepare an emergency response plan for the construction phase of the project in consultation with the RFS, FRNSW and the LEMC

Umwelt Environmental Consultants

Hazard Identification

Date 4/08/2021 & 8/11/2021 **Job:** Kurri Kurri Laterial Pipeline **Job #:** 21450

Section/Area: Storage Station

Ref	Asset	Guideword	Hazard Event Description	Threats (causes of hazard event)	Consequence	Current Barriers	C	L	R	Action
1	Delivery Station Pipe and Fittings	Fire and Explosion	Loss of containment and ignition of natural gas	Physical damage (e.g. during maintenance activities, vehicle movements) Corrosion Fatigue & Erosion Equipment Failure Incorrect Equipment Sizing Malicious damage Natural hazards - lightning strike Bushfire/grass fire Venting during commissioning Hunter Power Plant explosion or fire event Shrapnel from Hunter Power Plant mechanical failure event	One or two fatalities Propagation to HPP	Pipe designed not to rupture (i.e. maximum credible penetration < 150% x critical defect length) Pipe design in accordance with ASME B31.12 - 2019 Hydrogen Piping and Pipelines (as facility is to cater for natural gas with up to 10 mol% hydrogen) Controls and remote monitoring to detect major leaks and shut down supply Weekly site checks by operators including audible and visual leak inspection Atmosphere testing (e.g. Oxygen, LEL) as required (depending on activities) for personnel entry to compound and mandatory testing for vehicle entry (as vehicle is an ignition source) Secured compound APA maintenance system which includes routine inspection and maintenance plans in accordance with AS/NZS 2885: 2018 Pipelines – Gas and liquid petroleum Part 3 Operation and maintenance Asset protection zones around compound will be maintained free of combustible material Hazardous area classification and equipment selection/installation in accordance with AS/NZS 60079 Explosive atmospheres series Fencing maintains distance outside hazardous envelope to potential off-site ignition sources (e.g. smokers) Work permit system and job safety analyses for maintenance activities Lightning protection Gas detection and ventilation of acoustic enclosures around equipment. Hot work procedures Commissioning activities strictly controlled to ensure no ignition sources near vented gas Bollards and concrete edging/kerbing (generallly at edge of hazardous area) to protect pipe and fittings	4	E	10	Undertake quantititave analysis of credible loss of containment and ignition events. Credible events: -DN400 mm flange leak @15.32 MPa, gasket leak between bolt holes, immediate ignition (jet fire) -DN400 mm flange leak @15.32 MPa, gasket leak between bolt holes, delayed ignition (flash fire) Complete a hazardous area classification for the delivery station

Umwelt Environmental Consultants

2	Compressor Station Pipe and Fittings	Fire and Explosion	Loss of containment and ignition of natural gas	Physical damage (e.g. during maintenance activities) Corrosion Fatigue & Erosion Equipment Failure Incorrect Equipment Sizing Malicious damage Natural hazards - lightning strike Bushfire/grass fire Venting during commissioning Hunter Power Plant explosion or fire event Shrapnel from Hunter Power Plant mechanical failure event	One or two fatalities Propagation to HPP	Pipe designed not to rupture (i.e. maximum credible penetration < 150% x critical defect length) Pipe to be designed, constructed, operated and maintained in accordance with the AS/NZS 2885: 2018 Pipelines – Gas and liquid petroleum series Controls and remote monitoring to detect major leaks and shut down supply Weekly site checks by operators including audible and visual leak inspection Atmosphere testing (e.g. Oxygen, LEL) as required (depending on activities) for personnel entry to compound and mandatory testing for vehicle entry (as vehicle is an ignition source) Secured compound APA maintenance system which includes routine inspection and maintenance plans in accordance with AS/NZS 2885: 2018 Pipelines – Gas and liquid petroleum Part 3 Operation and maintenance Asset protection zones around compound will be maintained free of combustible material Hazardous area classification and equipment selection/installation in accordance with AS60079/NZS Explosive atmospheres series Fencing maintains distance outside hazardous envelope to potential off-site ignition sources (e.g. smokers) Work permit system and job safety analyses for maintenance activities Gas detection and ventilation on enclosures. Hot work procedures Commissioning activities strictly controlled to ensure no ignition sources near vented gas	4	E	10	Undertake quantititave analysis of credible loss of containment and ignition events. Credible events: -compressor heat exchanger tube rupture, immediate ignition (jet fire) -compressor heat exchanger tube rupture, delayed ignition (flash fire) -Vapour cloud explosion within compressor acoustic enclosure, base on volume of enclosure and gas concentration at UEL (maximum fuel load of explosive atmosphere) Complete a hazardous area classification for the SNP compressor station

Hazard Identification

Date 4/08/2021 & 8/11/2021 **Job:** Kurri Kurri Laterial Pipeline **Job #:** 21450

Section/Area: Storage Pipeline and Connection Pipeline

Ref	Asset	Guideword	Hazard Event Description	Threats (causes of hazard event)	Consequence	Current Barriers	C	L	R	Action
1	Storage Pipeline	Fire and Explosion	Loss of containment and ignition of natural gas -underground pipeline loops -header arrangement	Physical damage to pipe (e.g. third party construction activities, farming activities)) Corrosion and possible acid sulphate soils Fatigue Earthquakes Lightning Earth movement and buoyancy (groundwater)	Multiple fatalities	Consideration of land use (e.g. agriculture, industrial), geotechnical stability, soil properties and natural hazards (e.g. earthquake, floods) when specifying depth of cover and design standards (note that the entire length of pipeline is designed for location class T1 Residential) Pipe to be designed and constructed not to rupture (i.e. maximum credible penetration < 150% x critical defect length) and cannot be penetrated by impact from a 55T excavator for all tooth types under normal operating conditions (Bucket Force Muliplier, B=0.75). Under aggressive operating conditions (Bucket Force Multiplier, B=1.3) excavators 30T and above fitted with penetration teeth or tiger teeth can penetrate the pipeline causing a leak and a 55T excavator fitted with a penetration teeth can rupture the pipeline. However, operation of excavators in excess of 35T above the pipeline is not considered credible. Pipe to be designed, constructed, operated and maintained in accordance with the AS/NZS 2885: 2018 Pipelines – Gas and liquid petroleum series Internal and external coatings applied to pipeline to prevent corrosion as well as cathodic protection APA maintenance system which includes routine inspection and maintenance plans in accordance with AS/NZS 2885: 2018 Pipelines – Gas and liquid petroleum Part 3 Operation and maintenance Controls and remote monitoring to detect major leaks and shut down supply Lightning protection Work permit system and job safety analyses for maintenance activities Hot work procedures Signage Pipeline marker tape along entire length Stakeholder engagement Dial before you dig	5	E	15	Quantitatively analyse loss of containment and ignition event. Credible event: Header Arrangement -DN300 mm flange leak @15.3 MPa, gasket leak between bolt holes, immediate ignition (jet fire) -DN300 mm flange leak @15.3 MPa, gasket leak between bolt holes, delayed ignition (flash fire) Underground Pipeline Loops -Excavator tooth - 50 mm hole, immediate ignition (jet fire) -Excavator tooth - 50 mm hole, delayed ignition (flash fire). Jet fire from a 50 mm hole results in a 4.7 kW/m2 radiation contour of 92 m and a 12.6 kW/m2 radiation contour of 56 m. Complete a hazardous area classification for the storage pipeline header

Umwelt Environmental Consultants

2	Interconnevcting Pipeline	Fire and Explosion	Loss of containment and ignition of natural gas	Physical damage to pipe (e.g. third party construction activities, farming activities)) Corrosion and possible acid sulphate soils Fatigue Earthquakes Lightning Earth movement and buoyancy (groundwater)	Multiple fatalities	Consideration of land use (e.g. agriculture, industrial), geotechnical stability, soil properties and natural hazards (e.g. earthquake, floods) when specifying depth of cover and design standards (note that the entire length of pipeline is designed for location class T1 Residential) Pipe to be designed and constructed not to rupture (i.e. maximum credible penetration < 150% x critical defect length) and cannot be penetrated by impact from a 55T excavator for all tooth types under normal operating conditions (Bucket Force Muliplier, B=0.75). Under aggressive operating conditions (Bucket Force Multiplier, B=1.3) excavators 55T and above fitted with penetration teeth or tiger teeth can penetrate the pipeline. Operation of excavators in excess of 55T above the pipeline is not considered credible. Pipe to be designed, constructed, operated and maintained in accordance with the AS/NZS 2885: 2018 Pipelines – Gas and liquid petroleum series Internal and external coatings applied to pipeline to prevent corrosion as well as cathodic protection APA maintenance system which includes routine inspection and maintenance plans in accordance with AS/NZS 2885: 2018 Pipelines – Gas and liquid petroleum Part 3 Operation and maintenance Controls and remote monitoring to detect major leaks and shut down supply Lightning protection Work permit system and job safety analyses for maintenance activities Hot work procedures Signage Pipeline marker tape along entire length Stakeholder engagement Dial before you dig	5	E	15	Quantitatively analyse loss of containment and ignition event. Credible event: -Excavator tooth - 50 mm hole, immediate ignition (jet fire) -Excavator tooth - 50 mm hole, delayed ignition (flash fire). Jet fire from a 50 mm hole results in a 4.7 kW/m^2 radiation contour of 92 m and a 12.6 kW/m^2 radiation contour of 56 m. PHA will discuss full bore rupture scenarios in relation to measurement length and frequency of events that could cause this to occur, e.g. major ground movement event.
3	All	Fire	Grass or bushfire	Construction activities (e.g. welding, grinding, vehicles and equipment)	Multiple fatalities	Construction cooridor will be cleared of vegetation Hot work procedures First attack fire fighting equipment will be maintained on site Consultation with emergency services prior to undertaking high fire risk activities during periods of extreme and catastrophic fire rating	5	E	15	Prepare an emergency response plan for the construction phase of the project in consultation with the RFS, FRNSW and the LEMC

APPENDIX C

Breeze Incident Analyst Model Outputs

Jet Fire Model Outputs

DN350 Flange @ 6.9 MPa

JET FIRE MODEL	
Physical state	Vapor phase only
INPUT DATA	
FUEL	
Chemical Name	METHANE
Molecular weight (g/g-mole)	16.04
Boiling point (C)	-161.55
Heat of combustion(KJ/kg)	50029
STORAGE CONDITION	
Storage temperature(C)	20
Storage pressure(absolute)(bar)	69
Pipe diameter(meters)	0.338
RELEASE CONDITION	
Jet Angle from horizontal(degree)	0
Mass flow rate(g/s)	1800.987
Jet Velocity(m/s)	921.819
Release Density(kg/m**3)	1.757
Equivalent Diameter(cm)	4.549
Release height(meters)	1
LOCAL AMBIENT CONDITIONS	
Air temperature(C)	20
Ambient pressure(mmHg)	760
Wind speed(m/s)	1.5
Wind Speed at release height(m/s)	0.838
Relative humidity (%)	50
Air density(kg/m**3)	1.191
Results data	
Visible flame length(meters)	17.803
Flame lift-off(meters)	4.359
Width of Flame Base(meters)	0.278
Width of Flame Tip(meters)	5.867
Angle between the axis of the hole and the flame(degree)	0.376
Fraction of Heat Radiation from Flame Surface	0.121
Flame Surface Emissive power(Kw/m2)	54.092
Height for Radiation Calculations(meters)	1.5

Radiation results at specified distances at height 1.5meters

Horizontal downwind distance meters	Effective View Factor	Radiation kW/m**2
1.0	0.017	0.907
2.0	0.022	1.198
3.0	0.038	2.067
4.0	0.135	7.278
5.0	0.495	26.791
6.0	0.632	34.209

7.0	1.0	54.092
10.0	1.0	54.092
25.0	0.475	25.695
50.0	0.008	0.446

Maximum Horizontal Distance for Specified Radiation at Height of1.5meters

Radiation kW/m**2	Horizontal distance meters
4.7	30.881
12.6	27.094
23	25.308

DN350 Flange Leak @ 15.32 MPa

JET FIRE MODEL

Physical state	Vapor phase only

INPUT DATA

FUEL

Chemical Name	METHANE
Molecular weight (g/g-mole)	16.04
Boiling point (C)	-161.55
Heat of combustion(KJ/kg)	50029

STORAGE CONDITION

Storage temperature(C)	20
Storage pressure(absolute)(bar)	153.2
Pipe diameter(meters)	0.33

RELEASE CONDITION

Jet Angle from horizontal(degree)	0
Mass flow rate(g/s)	4311.96
Jet Velocity(m/s)	1067.482
Release Density(kg/m**3)	1.757
Equivalent Diameter(cm)	6.541
Release height(meters)	1

LOCAL AMBIENT CONDITIONS

Air temperature(C)	20
Ambient pressure(mmHg)	760
Wind speed(m/s)	1.5
Wind Speed at release height(m/s)	0.838
Relative humidity (%)	50
Air density(kg/m**3)	1.191

Results data

Visible flame length(meters)	25.416
Flame lift-off(meters)	6.24
Width of Flame Base(meters)	0.37
Width of Flame Tip(meters)	8.359
Angle between the axis of the hole and the flame(degree)	0.287
Fraction of Heat Radiation from Flame Surface	0.117
Flame Surface Emissive power(Kw/m2)	61.727
Height for Radiation Calculations(meters)	1.5

Radiation results at specified distances at height 1.5meters

Horizontal downwind distance meters	Effective View Factor	Radiation kW/m**2
1.0	0.015	0.923
2.0	0.016	1.007
3.0	0.019	1.186
4.0	0.027	1.643
5.0	0.049	3.039
6.0	0.201	12.393
7.0	0.551	34.022
10.0	1.0	61.727

25.0	1.0	61.727
50.0	0.039	2.383

Maximum Horizontal Distance for Specified Radiation at Height of1.5meters

Radiation kW/m**2	Horizontal distance meters
4.7	44.745
12.6	39.221
23	36.612

DN400 Flange Leak @ 15.32 MPa

JET FIRE MODEL

Physical state	Vapor phase only

INPUT DATA

FUEL

Chemical Name	METHANE
Molecular weight (g/g-mole)	16.04
Boiling point (C)	-161.55
Heat of combustion(KJ/kg)	50029

STORAGE CONDITION

Storage temperature(C)	20
Storage pressure(absolute)(bar)	153.2
Pipe diameter(meters)	0.381

RELEASE CONDITION

Jet Angle from horizontal(degree)	0
Mass flow rate(g/s)	4733.031
Jet Velocity(m/s)	1067.482
Release Density(kg/m**3)	1.757
Equivalent Diameter(cm)	6.853
Release height(meters)	1

LOCAL AMBIENT CONDITIONS

Air temperature(C)	20
Ambient pressure(mmHg)	760
Wind speed(m/s)	1.5
Wind Speed at release height(m/s)	0.838
Relative humidity (%)	50
Air density(kg/m**3)	1.191

Results data

Visible flame length(meters)	26.51
Flame lift-off(meters)	6.509
Width of Flame Base(meters)	0.392
Width of Flame Tip(meters)	8.719
Angle between the axis of the hole and the flame(degree)	0.264
Fraction of Heat Radiation from Flame Surface	0.117
Flame Surface Emissive power(Kw/m2)	62.243
Height for Radiation Calculations(meters)	1.5

Radiation results at specified distances at height 1.5meters

Horizontal downwind distance meters	Effective View Factor	Radiation kW/m**2
1.0	0.015	0.925
2.0	0.016	0.999
3.0	0.019	1.157
4.0	0.025	1.526
5.0	0.041	2.561
6.0	0.13	8.118
7.0	0.633	39.4
10.0	1.0	62.243

25.0	1.0	62.243
50.0	0.049	3.06

Maximum Horizontal Distance for Specified Radiation at Height of1.5meters

Radiation kW/m**2	Horizontal distance meters
4.7	46.707
12.6	40.942
23	38.214

DN20 Heat Exchanger Tube Rupture

JET FIRE MODEL

Physical state	Vapor phase only

INPUT DATA

FUEL

Chemical Name	METHANE
Molecular weight (g/g-mole)	16.04
Boiling point (C)	-161.55
Heat of combustion(KJ/kg)	50029

STORAGE CONDITION

Storage temperature(C)	50
Storage pressure(absolute)(bar)	150.32
Pipe diameter(meters)	0.021

RELEASE CONDITION

Jet Angle from horizontal(degree)	0
Mass flow rate(g/s)	9144.154
Jet Velocity(m/s)	1056.817
Release Density(kg/m**3)	1.757
Equivalent Diameter(cm)	9.574
Release height(meters)	1

LOCAL AMBIENT CONDITIONS

Air temperature(C)	20
Ambient pressure(mmHg)	760
Wind speed(m/s)	1.5
Wind Speed at release height(m/s)	0.838
Relative humidity (%)	50
Air density(kg/m**3)	1.191

Results data

Visible flame length(meters)	35.774
Flame lift-off(meters)	8.781
Width of Flame Base(meters)	0.597
Width of Flame Tip(meters)	11.767
Angle between the axis of the hole and the flame(degree)	0.101
Fraction of Heat Radiation from Flame Surface	0.117
Flame Surface Emissive power(Kw/m2)	65.848
Height for Radiation Calculations(meters)	1.5

Radiation results at specified distances at height 1.5meters

Horizontal downwind distance meters	Effective View Factor	Radiation kW/m**2
1.0	0.014	0.94
2.0	0.015	0.994
3.0	0.016	1.055
4.0	0.017	1.145
5.0	0.02	1.332
6.0	0.027	1.783
7.0	0.045	2.946

10.0	1.0	65.848
25.0	1.0	65.848
50.0	0.481	31.674

Maximum Horizontal Distance for Specified Radiation at Height of1.5meters

Radiation kW/m**2	Horizontal distance meters
4.7	63.322
12.6	55.467
23	51.803

DN25 Heat Exchanger Tube Rupture

JET FIRE MODEL

Physical state	Vapor phase only

INPUT DATA

FUEL

Chemical Name	METHANE
Molecular weight (g/g-mole)	16.04
Boiling point (C)	-161.55
Heat of combustion(KJ/kg)	50029

STORAGE CONDITION

Storage temperature(C)	55
Storage pressure(absolute)(bar)	80.8
Pipe diameter(meters)	0.027

RELEASE CONDITION

Jet Angle from horizontal(degree)	0
Mass flow rate(g/s)	7687.207
Jet Velocity(m/s)	971.63
Release Density(kg/m**3)	1.662
Equivalent Diameter(cm)	9.155
Release height(meters)	1

LOCAL AMBIENT CONDITIONS

Air temperature(C)	20
Ambient pressure(mmHg)	760
Wind speed(m/s)	1.5
Wind Speed at release height(m/s)	0.838
Relative humidity (%)	50
Air density(kg/m**3)	1.191

Results data

Visible flame length(meters)	33.797
Flame lift-off(meters)	8.283
Width of Flame Base(meters)	0.619
Width of Flame Tip(meters)	11.13
Angle between the axis of the hole and the flame(degree)	0.053
Fraction of Heat Radiation from Flame Surface	0.119
Flame Surface Emissive power(Kw/m2)	62.851
Height for Radiation Calculations(meters)	1.5

Radiation results at specified distances at height 1.5meters

Horizontal downwind distance meters	Effective View Factor	Radiation kW/m**2
1.0	0.014	0.908
2.0	0.015	0.965
3.0	0.016	1.028
4.0	0.019	1.165
5.0	0.023	1.46
6.0	0.034	2.131
7.0	0.071	4.489

10.0	1.0	62.851
25.0	1.0	62.851
50.0	0.289	18.156

Maximum Horizontal Distance for Specified Radiation at Height of1.5meters

Radiation kW/m**2	Horizontal distance meters
4.7	59.446
12.6	52.143
23	48.697

DN32 Heat Exchanger Tube Rupture

JET FIRE MODEL

Physical state	Vapor phase only

INPUT DATA

FUEL

Chemical Name	METHANE
Molecular weight (g/g-mole)	16.04
Boiling point (C)	-161.55
Heat of combustion(KJ/kg)	50029

STORAGE CONDITION

Storage temperature(C)	55
Storage pressure(absolute)(bar)	41.4
Pipe diameter(meters)	0.035

RELEASE CONDITION

Jet Angle from horizontal(degree)	0
Mass flow rate(g/s)	6675.364
Jet Velocity(m/s)	923.228
Release Density(kg/m**3)	1.417
Equivalent Diameter(cm)	8.752
Release height(meters)	1

LOCAL AMBIENT CONDITIONS

Air temperature(C)	20
Ambient pressure(mmHg)	760
Wind speed(m/s)	1.5
Wind Speed at release height(m/s)	0.838
Relative humidity (%)	50
Air density(kg/m**3)	1.191

Results data

Visible flame length(meters)	32.129
Flame lift-off(meters)	7.866
Width of Flame Base(meters)	0.621
Width of Flame Tip(meters)	10.588
Angle between the axis of the hole and the flame(degree)	0.029
Fraction of Heat Radiation from Flame Surface	0.121
Flame Surface Emissive power(Kw/m2)	60.972
Height for Radiation Calculations(meters)	1.5

Radiation results at specified distances at height 1.5meters

Horizontal downwind distance meters	Effective View Factor	Radiation kW/m**2
1.0	0.015	0.89
2.0	0.016	0.949
3.0	0.017	1.035
4.0	0.02	1.208
5.0	0.026	1.616
6.0	0.043	2.638
7.0	0.118	7.188

10.0	1.0	60.972
25.0	1.0	60.972
50.0	0.187	11.412

Maximum Horizontal Distance for Specified Radiation at Height of1.5meters

Radiation kW/m**2	Horizontal distance meters
4.7	56.293
12.6	49.414
23	46.149

Dispersion Model Outputs (for Flash Fire Impacts)

DN350 Flange Leak @ 6.9 MPa, F1.5

BREEZE Incident Analyst (version 4.0.0.45)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	5	
Ambient pressure(mmHg)	760	
Relative humidity (%)	50	
Wind direction (degrees)	270	
Wind speed(m/s)	1.5	
Anemometer height(meters)	10	
Surface roughness(meters)	0.03	
Stability option	Stability class	
Stability class(1=A - 6=F)	F (6)	
Computed Monin-Obukhov length(meters)		14.264
Inversion layer height(meters)	None	

Chemical data:

Name	Methane	
Molecular weight (g/g-mole)	16.04	
Vapor heat capacity at constant pressure (J/kg-K)		2240
Boiling point (C)	-161.55	
Heat of vaporization (J/kg)	509880	
Liquid heat capacity (J/kg-K)	3349	
Liquid density(kg/m**3)	424.1	
Saturation pressure constant SPB	597.84	
Saturation pressure constant SPC	-7.16	

Release data:

Source type	Horizontal
Emission rate(g/s)	1670.68
Source area(m**2)	0.002
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-161.55

Output data:

Concentration level 1(%(vol))	5	
Concentration level 2(%(vol))	15	
Concentration averaging time(seconds)		10
Height of interest(meters)	1.5	
Maximum downwind distance(meters)		0

Results data:

MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	5.959
15	0

DN350 Flange Leak @ 6.9 MPa, D10

BREEZE Incident Analyst (version 4.0.0.45)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	20
Ambient pressure(mmHg)	760
Relative humidity (%)	50
Wind direction (degrees)	270
Wind speed(m/s)	10
Anemometer height(meters)	10
Surface roughness(meters)	0.03
Stability option	Stability class
Stability class(1=A - 6=F)	D (4)
Computed Monin-Obukhov length(meters)	999999986991104
Inversion layer height(meters)	None

Chemical data:

Name	Methane
Molecular weight (g/g-mole)	16.04
Vapor heat capacity at constant pressure (J/kg-K)	2240
Boiling point (C)	-161.55
Heat of vaporization (J/kg)	509880
Liquid heat capacity (J/kg-K)	3349
Liquid density(kg/m**3)	424.1
Saturation pressure constant SPB	597.84
Saturation pressure constant SPC	-7.16

Release data:

Source type	Horizontal
Emission rate(g/s)	1670.68
Source area(m**2)	0.002
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-161.55

Output data:

Concentration level 1(%(vol))	5
Concentration level 2(%(vol))	15
Concentration averaging time(seconds)	10
Height of interest(meters)	1.5
Maximum downwind distance(meters)	0

Results data:
MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	5.857
15	0

DN350 Flange Leak @ 15.32 MPa, F1.5

BREEZE Incident Analyst (version 4.0.0.45)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	5
Ambient pressure(mmHg)	760
Relative humidity (%)	50
Wind direction (degrees)	270
Wind speed(m/s)	1.5
Anemometer height(meters)	10
Surface roughness(meters)	0.03
Stability option	Stability class
Stability class(1=A - 6=F)	F (6)
Computed Monin-Obukhov length(meters)	14.264
Inversion layer height(meters)	None

Chemical data:

Name	Methane
Molecular weight (g/g-mole)	16.04
Vapor heat capacity at constant pressure (J/kg-K)	2240
Boiling point (C)	-161.55
Heat of vaporization (J/kg)	509880
Liquid heat capacity (J/kg-K)	3349
Liquid density(kg/m**3)	424.1
Saturation pressure constant SPB	597.84
Saturation pressure constant SPC	-7.16

Release data:

Source type	Horizontal
Emission rate(g/s)	3826.39
Source area(m**2)	0.005
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-161.55

Output data:

Concentration level 1(%(vol))	5
Concentration level 2(%(vol))	15
Concentration averaging time(seconds)	10
Height of interest(meters)	1.5
Maximum downwind distance(meters)	0

Results data:

MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	13.778
15	0

DN350 Flange Leak @ 15.32 MPa, D10

BREEZE Incident Analyst (version 4.0.0.45)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	20	
Ambient pressure(mmHg)	760	
Relative humidity (%)	50	
Wind direction (degrees)	270	
Wind speed(m/s)	10	
Anemometer height(meters)	10	
Surface roughness(meters)	0.03	
Stability option	Stability class	
Stability class(1=A - 6=F)	D (4)	
Computed Monin-Obukhov length(meters)		999999986991104
Inversion layer height(meters)	None	

Chemical data:

Name	Methane	
Molecular weight (g/g-mole)	16.04	
Vapor heat capacity at constant pressure (J/kg-K)		2240
Boiling point (C)	-161.55	
Heat of vaporization (J/kg)	509880	
Liquid heat capacity (J/kg-K)	3349	
Liquid density(kg/m**3)	424.1	
Saturation pressure constant SPB	597.84	
Saturation pressure constant SPC	-7.16	

Release data:

Source type	Horizontal
Emission rate(g/s)	3826.39
Source area(m**2)	0.005
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-161.55

Output data:

Concentration level 1(%(vol))	5	
Concentration level 2(%(vol))	15	
Concentration averaging time(seconds)		10
Height of interest(meters)	1.5	
Maximum downwind distance(meters)		0

Results data:

MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	12.67
15	0

DN400 Flange Leak @ 15.32 MPa, F1.5

BREEZE Incident Analyst (version 4.0.0.45)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	5
Ambient pressure(mmHg)	760
Relative humidity (%)	50
Wind direction (degrees)	270
Wind speed(m/s)	1.5
Anemometer height(meters)	10
Surface roughness(meters)	0.03
Stability option	Stability class
Stability class(1=A - 6=F)	F (6)
Computed Monin-Obukhov length(meters)	14.264
Inversion layer height(meters)	None

Chemical data:

Name	Methane
Molecular weight (g/g-mole)	16.04
Vapor heat capacity at constant pressure (J/kg-K)	2240
Boiling point (C)	-161.55
Heat of vaporization (J/kg)	509880
Liquid heat capacity (J/kg-K)	3349
Liquid density(kg/m**3)	424.1
Saturation pressure constant SPB	597.84
Saturation pressure constant SPC	-7.16

Release data:

Source type	Horizontal
Emission rate(g/s)	4200.04
Source area(m**2)	0.006
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-161.55

Output data:

Concentration level 1(%(vol))	5
Concentration level 2(%(vol))	15
Concentration averaging time(seconds)	10
Height of interest(meters)	1.5
Maximum downwind distance(meters)	0

Results data:

MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	14.793
15	0

DN400 Flange Leak @ 15.32 MPa, D10

BREEZE Incident Analyst (version 4.0.0.45)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	5
Ambient pressure(mmHg)	760
Relative humidity (%)	50
Wind direction (degrees)	270
Wind speed(m/s)	10
Anemometer height(meters)	10
Surface roughness(meters)	0.03
Stability option	Stability class
Stability class(1=A - 6=F)	D (4)
Computed Monin-Obukhov length(meters)	999999986991104
Inversion layer height(meters)	None

Chemical data:

Name	Methane
Molecular weight (g/g-mole)	16.04
Vapor heat capacity at constant pressure (J/kg-K)	2240
Boiling point (C)	-161.55
Heat of vaporization (J/kg)	509880
Liquid heat capacity (J/kg-K)	3349
Liquid density(kg/m**3)	424.1
Saturation pressure constant SPB	597.84
Saturation pressure constant SPC	-7.16

Release data:

Source type	Horizontal
Emission rate(g/s)	4200.04
Source area(m**2)	0.006
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-161.55

Output data:

Concentration level 1(%(vol))	5
Concentration level 2(%(vol))	15
Concentration averaging time(seconds)	10
Height of interest(meters)	1.5
Maximum downwind distance(meters)	0

Results data:

MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	13.257
15	0

DN20 Heat Exchanger Tube Rupture, F1.5

BREEZE Incident Analyst (version 4.0.0.28)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	5
Ambient pressure(mmHg)	760
Relative humidity (%)	50
Wind direction (degrees)	270
Wind speed(m/s)	1.5
Anemometer height(meters)	10
Surface roughness(meters)	0.03
Stability option	Stability class
Stability class(1=A - 6=F)	F (6)
Computed Monin-Obukhov length(meters)	14.264
Inversion layer height(meters)	None

Chemical data:

Name	Methane
Molecular weight (g/g-mole)	16.04
Vapor heat capacity at constant pressure (J/kg-K)	2240
Boiling point (C)	-161.55
Heat of vaporization (J/kg)	509880
Liquid heat capacity (J/kg-K)	3349
Liquid density(kg/m**3)	424.1
Saturation pressure constant SPB	597.84
Saturation pressure constant SPC	-7.16

Release data:

Source type	Horizontal
Emission rate(g/s)	8618.33
Source area(m**2)	0.011
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-161.55

Output data:

Concentration level 1(%(vol))	5
Concentration level 2(%(vol))	15
Concentration averaging time(seconds)	10
Height of interest(meters)	1.5
Maximum downwind distance(meters)	0

Results data:
MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	23.453
15	3.216

DN20 Heat Exchanger Tube Rupture, D10

BREEZE Incident Analyst (version 4.0.0.28)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	20
Ambient pressure(mmHg)	760
Relative humidity (%)	50
Wind direction (degrees)	270
Wind speed(m/s)	10
Anemometer height(meters)	10
Surface roughness(meters)	0.03
Stability option	Stability class
Stability class(1=A - 6=F)	D (4)
Computed Monin-Obukhov length(meters)	999999986991104
Inversion layer height(meters)	None

Chemical data:

Name	Methane
Molecular weight (g/g-mole)	16.04
Vapor heat capacity at constant pressure (J/kg-K)	2240
Boiling point (C)	-161.55
Heat of vaporization (J/kg)	509880
Liquid heat capacity (J/kg-K)	3349
Liquid density(kg/m**3)	424.1
Saturation pressure constant SPB	597.84
Saturation pressure constant SPC	-7.16

Release data:

Source type	Horizontal
Emission rate(g/s)	8618.33
Source area(m**2)	0.011
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-161.55

Output data:

Concentration level 1(%(vol))	5
Concentration level 2(%(vol))	15
Concentration averaging time(seconds)	10
Height of interest(meters)	1.5
Maximum downwind distance(meters)	0

Results data:

MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	23.767
15	0

DN25 Heat Exchanger Tube Rupture, F1.5

BREEZE Incident Analyst (version 4.0.0.28)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	5
Ambient pressure(mmHg)	760
Relative humidity (%)	50
Wind direction (degrees)	270
Wind speed(m/s)	1.5
Anemometer height(meters)	10
Surface roughness(meters)	0.03
Stability option	Stability class
Stability class(1=A - 6=F)	F (6)
Computed Monin-Obukhov length(meters)	14.264
Inversion layer height(meters)	None

Chemical data:

Name	Methane
Molecular weight (g/g-mole)	16.04
Vapor heat capacity at constant pressure (J/kg-K)	2240
Boiling point (C)	-161.55
Heat of vaporization (J/kg)	509880
Liquid heat capacity (J/kg-K)	3349
Liquid density(kg/m**3)	424.1
Saturation pressure constant SPB	597.84
Saturation pressure constant SPC	-7.16

Release data:

Source type	Horizontal
Emission rate(g/s)	7286.64
Source area(m**2)	0.01
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-153.691

Output data:

Concentration level 1(%(vol))	5
Concentration level 2(%(vol))	15
Concentration averaging time(seconds)	10
Height of interest(meters)	1.5
Maximum downwind distance(meters)	0

Results data:

MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	20.786
15	0

DN25 Heat Exchanger Tube Rupture, D10

BREEZE Incident Analyst (version 4.0.0.28)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	20
Ambient pressure(mmHg)	760
Relative humidity (%)	50
Wind direction (degrees)	270
Wind speed(m/s)	10
Anemometer height(meters)	10
Surface roughness(meters)	0.03
Stability option	Stability class
Stability class(1=A - 6=F)	D (4)
Computed Monin-Obukhov length(meters)	999999986991104
Inversion layer height(meters)	None

Chemical data:

Name	Methane
Molecular weight (g/g-mole)	16.04
Vapor heat capacity at constant pressure (J/kg-K)	2240
Boiling point (C)	-161.55
Heat of vaporization (J/kg)	509880
Liquid heat capacity (J/kg-K)	3349
Liquid density(kg/m**3)	424.1
Saturation pressure constant SPB	597.84
Saturation pressure constant SPC	-7.16

Release data:

Source type	Horizontal
Emission rate(g/s)	7286.64
Source area(m**2)	0.01
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-153.691

Output data:

Concentration level 1(%(vol))	5
Concentration level 2(%(vol))	15
Concentration averaging time(seconds)	10
Height of interest(meters)	1.5
Maximum downwind distance(meters)	0

Results data:
MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	20.946
15	0

DN32 Heat Exchanger Tube Rupture, F1.5

BREEZE Incident Analyst (version 4.0.0.28)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	5
Ambient pressure(mmHg)	760
Relative humidity (%)	50
Wind direction (degrees)	270
Wind speed(m/s)	1.5
Anemometer height(meters)	10
Surface roughness(meters)	0.03
Stability option	Stability class
Stability class(1=A - 6=F)	F (6)
Computed Monin-Obukhov length(meters)	14.264
Inversion layer height(meters)	None

Chemical data:

Name	Methane
Molecular weight (g/g-mole)	16.04
Vapor heat capacity at constant pressure (J/kg-K)	2240
Boiling point (C)	-161.55
Heat of vaporization (J/kg)	509880
Liquid heat capacity (J/kg-K)	3349
Liquid density(kg/m**3)	424.1
Saturation pressure constant SPB	597.84
Saturation pressure constant SPC	-7.16

Release data:

Source type	Horizontal
Emission rate(g/s)	6473.91
Source area(m**2)	0.011
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-133.758

Output data:

Concentration level 1(%(vol))	5
Concentration level 2(%(vol))	15
Concentration averaging time(seconds)	10
Height of interest(meters)	1.5
Maximum downwind distance(meters)	0

Results data:

MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	19.03
15	0

DN32 Heat Exchanger Tube Rupture, D10

BREEZE Incident Analyst (version 4.0.0.28)
SLAB Summary Output File

Meteorological data:

Ambient temperature(C)	20
Ambient pressure(mmHg)	760
Relative humidity (%)	50
Wind direction (degrees)	270
Wind speed(m/s)	10
Anemometer height(meters)	10
Surface roughness(meters)	0.03
Stability option	Stability class
Stability class(1=A - 6=F)	D (4)
Computed Monin-Obukhov length(meters)	999999986991104
Inversion layer height(meters)	None

Chemical data:

Name	Methane
Molecular weight (g/g-mole)	16.04
Vapor heat capacity at constant pressure (J/kg-K)	2240
Boiling point (C)	-161.55
Heat of vaporization (J/kg)	509880
Liquid heat capacity (J/kg-K)	3349
Liquid density(kg/m**3)	424.1
Saturation pressure constant SPB	597.84
Saturation pressure constant SPC	-7.16

Release data:

Source type	Horizontal
Emission rate(g/s)	6473.91
Source area(m**2)	0.011
Release duration(seconds)	600
Release height(meters)	1
Initial liquid mass fraction	0
Release temperature(C)	-133.758

Output data:

Concentration level 1(%(vol))	5
Concentration level 2(%(vol))	15
Concentration averaging time(seconds)	10
Height of interest(meters)	1.5
Maximum downwind distance(meters)	0

Results data:

MAXIMUM DISTANCE TO LEVELS OF CONCERN (LOC)

Concentration (%(vol))	Maximum Distance (meters)
5	19.068
15	0

Compressor Enclosure Vapour Cloud Explosion

MULTI-ENERGY EXPLOSION MODEL

INPUT DATA

Modeled Chemical	Methane
Heat Combustion	50029

Results data

Subcloud1:

Absolute Coordinates(meters)	0 0
Explosive Mass(kilograms)	32.35
Charge Strength	10
Energy(Btu)	1533983.172

CALCULATED DISTANCES AT SPECIFIED OVERPRESSURES

Overpressure bar(g)	Distance meters
0.070	96.926
0.140	58.453
0.210	46.529

APPENDIX D

GHD Radiation Calculations

Heat Radiation Release Calculation

PIPELINE

Kurri Kurri Lateral Pipeline Project

21159

Document No		KUR.2373-CAL-L-0005					
Rev	**Date**	**Status**	**Originated**	**Checked**	**Approved**	**Client Approval**	**Date**
1	5/10/2021	Issued for Use	N.Menon	E.Sabeti	M.Walton		
			Pipeline Engineer	Pipeline Engineer	Engineering Manager		

Template Rev. 01_18.06.2021

apa		DOCUMENT No:	KUR.2373-CAL-L-0005
		Rev	1
Project Title:	Kurri Kurri Lateral Pipeline Project	Project No:	21159
Prepared by:	N.Menon — Date 5/10/2021	Sheet	1 of 5
Checked by:	E.Sabeti — Date 5/10/2021		
Approved by:	M.Walton — Date 5/10/2021		

Legend:	Input for each case
Locked	Sourced from code
Locked	Output Calculations

Heat release calculation for Full Bore Rupture

Scope

To determine the energy release rate and radiation contour for pipeline 30 seconds after rupture or a leak

Input

Pipe Nominal Diameter	*D*	DN350	mm
Pipe Outside Diameter	*OD*	355.6	mm
Pipe Thickness	*tw*	8.6	mm
Pipeline MAOP	*P*	6.9	MPa
Gas Temperature	*T*	0	°C
Gas Composition File	Kurri_Rich.mix		

Results

Full Bore Rupture			
12.6kW/m² Radiation Contour Radius	$D_{12.6}$	216	m
4.7kW/m² Radiation Contour Radius	$D_{4.7}$	354	m
Enenergy Release Rate	*Q*	30	GJ/s

Leak from a hole			
Hole Diameter	Dh	50	mm
12.6kW/m² Radiation Contour Radius	$D_{12.6}$	37	m
4.7kW/m² Radiation Contour Radius	$D_{4.7}$	61	m
Enenergy Release Rate	*Q*	0.871	GJ/s

Push the calculate botton to update the cells below

Leak from a hole to create 1GJ/s			
Hole Diameter	Dh	54	mm
12.6kW/m² Radiation Contour Radius	$D_{12.6}$	40	m
4.7kW/m² Radiation Contour Radius	$D_{4.7}$	65	m
Enenergy Release Rate	*Q*	1.00	GJ/s

Leak from a hole to create 10GJ/s			
Hole Diameter	Dh	169	mm
12.6kW/m² Radiation Contour Radius	$D_{12.6}$	126	m
4.7kW/m² Radiation Contour Radius	$D_{4.7}$	206	m
Enenergy Release Rate	*Q*	10.00	GJ/s

apa				DOCUMENT No:	KUR.2373-CAL-L-0005
				Rev	1
Project Title:	*Kurri Kurri Lateral Pipeline Project*			Project No:	21159
Prepared by:	*N.Menon*	Date	5/10/2021	Sheet	2 of 5
Checked by:	*E.Sabeti*	Date	5/10/2021		
Approved by:	*M.Walton*	Date	5/10/2021		

Legend:	Input for each case
Locked	Sourced from code
Locked	**Output Calculations**

Heat release rate and radiation contour radius calculations

Gas Composition File *Kurri_Rich.mix*

Scope:

To determine the energy release rate and radiation contour for pipeline 30 seconds after rupture

All gas properties calculated using REFPROP

INPUTS:

Pipeline data			
Outside Diameter of Pipe	*D*	355.6	mm
Wall Thickness	t_w	8.6	mm
Inside Diameter of Pipe	*Di*	338.40	
Pipeline MAOP (kPa)	*P*	6,900	kPa

Calculations			
Lower Heating Value	H_C	34.923	MJ/sm^3
Density at Standard condition	ρ_{atmos}	0.7521	kg/m^3
Pipeline Operating Temperature	$T_{°C}$	0	°C
Fraction of Heat Radiated	*Fh*	0.25	
Gas constant	*R*	8314	J/(kg*mol)/K
Fraction of Heat Intensity Transmitted	τ	1	
Pipeline Operating Temperature (Absolute)	*T*	273.15	K
Specific Heat at constant Pressure	*Cp*	2.8668	kJ/kg*K
Specific Heat at constant Volume	*Cv*	1.6760	kJ/kg*K
Ratio of Specific Heats	*k*	1.7105	
Critical/Sonic Velocity	v_s	381.5	m/s
Flow Factor	*Phi*	0.9579	
Coefficient of critical discharge	C_d	0.620	
Release rate decay factor	*Lambda*	0.33000	
Initial release	*Q in*	966.09	kg/s
Effective release	*Q eff*	637.62	kg/s
Energy release	*Q*	29.61	GJ/s
First Contour (12.6 kw/m2)	*KI*	12.60	kW/m^2
Second Contour (4.7 kw/m2)	*KII*	4.70	kW/m^2
Radiation Contour: 12.6kW/m^2	$D_{12.6}$	216	**m**
Radiation Contour: 4.7kW/m^2	$D_{4.7}$	354	**m**

Note:

Ref.: GRI-00/0189 and AS 2885.6-2018

apa		DOCUMENT No:	KUR.2373-CAL-L-0005
		Rev	1
Project Title:	*Kurri Kurri Lateral Pipeline Project*	Project No:	21159
Prepared by:	*N.Menon* Date 5/10/2021	Sheet	3 of 5
Checked by:	*E.Sabeti* Date 5/10/2021		
Approved by:	*M.Walton* Date 5/10/2021		

Legend:	Input for each case
Locked	Sourced from code
Locked	**Output Calculations**

Heat release rate and radiation contour radius calculations

Gas Composition File *Kurri_Rich.mix*

Scope:

To determine the energy release rate and radiation contour for pipeline 30 seconds after a leak

All gas properties calculated using REFPROP

INPUTS:

Pipeline data			
Outside Diameter of Pipe	*D*	355.6	mm
Wall Thickness	t_w	8.6	mm
Inside Diameter of Pipe	*Di*	338.40	
Pipeline MAOP (kPa)	*P*	6,900	kPa

Hole size			
Hole Diameter	*Dh*	53.59066285	mm

Calculations			
Lower Heating Value	H_C	34.923	MJ/sm^3
Density at Standard condition	ρ_{atmos}	0.7521	kg/m^3
Pipeline Operating Temperature	$T_{°C}$	0	°C
Fraction of Heat Radiated	*Fh*	0.25	
Gas constant	*R*	8314	J/(kg*mol)/K
Fraction of Heat Intensity Transmitted	τ	1	
Pipeline Operating Temperature (Absolute)	*T*	273.15	K
Specific Heat at constant Pressure	*Cp*	2.8668	kJ/kg*K
Specific Heat at constant Volume	*Cv*	1.6760	kJ/kg*K
Ratio of Specific Heats	*k*	1.7105	
Critical/Sonic Velocity	v_s	381.5	m/s
Flow Factor	*Phi*	0.9579	
Coefficient of critical discharge	C_d	0.835	
Release rate decay factor	*Lambda*	0.33000	
Initial release	*Q in*	32.63	kg/s
Effective release	*Q eff*	21.54	kg/s
Energy release	*Q*	1.00	GJ/s
First Contour (12.6 kw/m2)	*KI*	12.60	kW/m^2
Second Contour (4.7 kw/m2)	*KII*	4.70	kW/m^2
Radiation Contour: 12.6kW/m^2	$D_{12.6}$	40	**m**
Radiation Contour: 4.7kW/m^2	$D_{4.7}$	65	**m**

Note:

Ref.: GRI-00/0189 and AS 2885.6-2018

apa			DOCUMENT No:	KUR.2373-CAL-L-0005
			Rev	1
Project Title:	*Kurri Kurri Lateral Pipeline Project*		Project No:	21159
Prepared by:	*N.Menon*	Date 5/10/2021	Sheet	4 of 5
Checked by:	*E.Sabeti*	Date 5/10/2021		
Approved by:	*M.Walton*	Date 5/10/2021		

Legend:	Input for each case
Locked	Sourced from code
Locked	**Output Calculations**

Heat release rate and radiation contour radius calculations

Gas Composition File *Kurri_Rich.mix*

Scope:

To determine the energy release rate and radiation contour for pipeline 30 seconds after a leak

All gas properties calculated using REFPROP

INPUTS:

Pipeline data			
Outside Diameter of Pipe	*D*	355.6	mm
Wall Thickness	t_w	8.6	mm
Inside Diameter of Pipe	*Di*	338.40	
Pipeline MAOP (kPa)	*P*	6,900	kPa

Hole size			
Hole Diameter	*Dh*	169.4685559	mm

Calculations			
Lower Heating Value	H_C	34.923	MJ/sm^3
Density at Standard condition	ρ_{atmos}	0.7521	kg/m^3
Pipeline Operating Temperature	$T_{°C}$	0	°C
Fraction of Heat Radiated	*Fh*	0.25	
Gas constant	*R*	8314	J/(kg*mol)/K
Fraction of Heat Intensity Transmitted	τ	1	
Pipeline Operating Temperature (Absolute)	*T*	273.15	K
Specific Heat at constant Pressure	*Cp*	2.8668	kJ/kg*K
Specific Heat at constant Volume	*Cv*	1.6760	kJ/kg*K
Ratio of Specific Heats	*k*	1.7105	
Critical/Sonic Velocity	v_s	381.5	m/s
Flow Factor	*Phi*	0.9579	
Coefficient of critical discharge	C_d	0.835	
Release rate decay factor	*Lambda*	0.33000	
Initial release	*Q in*	326.31	kg/s
Effective release	*Q eff*	215.37	kg/s
Energy release	*Q*	10.00	GJ/s
First Contour (12.6 kw/m2)	*KI*	12.60	kW/m^2
Second Contour (4.7 kw/m2)	*KII*	4.70	kW/m^2
Radiation Contour: 12.6kW/m^2	$D_{12.6}$	126	**m**
Radiation Contour: 4.7kW/m^2	$D_{4.7}$	206	**m**

Note:

Ref.: GRI-00/0189 and AS 2885.6-2018

apa

				DOCUMENT No:	KUR.2373-CAL-L-0005
				Rev	1
Project Title:	*Kurri Kurri Lateral Pipeline Project*			Project No:	21159
Prepared by:	*N.Menon*	Date	5/10/2021	Sheet	5 of 5
Checked by:	*E.Sabeti*	Date	5/10/2021		
Approved by:	*M.Walton*	Date	5/10/2021		

Heat release rate and radiation contour radius calculations

Legend:	Input for each case
Locked	Sourced from code
Locked	**Output Calculations**

Gas Composition File *Kurri_Rich.mix*

Scope:

To determine the energy release rate and radiation contour for pipeline 30 seconds after a leak

All gas properties calculated using REFPROP

INPUTS:

Pipeline data			
Outside Diameter of Pipe	*D*	355.6	mm
Wall Thickness	t_w	8.6	mm
Inside Diameter of Pipe	*Di*	338.40	
Pipeline MAOP (kPa)	*P*	6,900	kPa

Hole size			
Hole Diameter	*Dh*	50	mm

Calculations			
Lower Heating Value	H_C	34.923	MJ/sm^3
Density at Standard condition	ρ_{atmos}	0.7521	kg/m^3
Pipeline Operating Temperature	$T_{°C}$	0	°C
Fraction of Heat Radiated	*Fh*	0.25	
Gas constant	*R*	8314	J/(kg*mol)/K
Fraction of Heat Intensity Transmitted	τ	1	
Pipeline Operating Temperature (Absolute)	*T*	273.15	K
Specific Heat at constant Pressure	*Cp*	2.8668	kJ/kg*K
Specific Heat at constant Volume	*Cv*	1.6760	kJ/kg*K
Ratio of Specific Heats	*k*	1.7105	
Critical/Sonic Velocity	v_s	381.5	m/s
Flow Factor	*Phi*	0.9579	
Coefficient of critical discharge	C_d	0.835	
Release rate decay factor	*Lambda*	0.33000	
Initial release	*Q in*	28.40	kg/s
Effective release	*Q eff*	18.75	kg/s
Energy release	*Q*	0.87	GJ/s
First Contour (12.6 kw/m2)	*KI*	12.60	kW/m^2
Second Contour (4.7 kw/m2)	*KII*	4.70	kW/m^2
Radiation Contour: 12.6kW/m^2	$D_{12.6}$	37	**m**
Radiation Contour: 4.7kW/m^2	$D_{4.7}$	61	**m**

Note:

Ref.: GRI-00/0189 and AS 2885.6-2018

Heat Radiation Release Calculation

PIPELINE

Wentworth Storage Bottle Project (Interconnect Pipeline)

21159

Document No		WEN.3367-CAL-L-0005					
Rev	**Date**	**Status**	**Originated**	**Checked**	**Approved**	**Client Approval**	**Date**
1	14/10/2021	Issued for Use	E.Sabeti	N.Menon	M.Walton		
			Pipeline Engineer	Pipeline Engineer	Engineering Manager		

Template Rev. 01_18.06.2021

apa		DOCUMENT No:	WEN.3367-CAL-L-0005
		Rev	1
Project Title:	Wentworth Storage Bottle Project (Interconnect Pipeline)	Project No:	21159
Prepared by:	E.Sabeti Date 14/10/2021	Sheet	1 of 5
Checked by:	N.Menon Date 14/10/2021		
Approved by:	M.Walton Date 14/10/2021		

Legend:	Input for each case
Locked	Sourced from code
Locked	Output Calculations

Heat release calculation for Full Bore Rupture

Scope

To determine the energy release rate and radiation contour for pipeline 30 seconds after rupture or a leak

Input

Pipe Nominal Diameter	*D*	DN350	mm
Pipe Outside Diameter	*OD*	355.6	mm
Pipe Thickness	*tw*	12.7	mm
Pipeline MAOP	*P*	15.32	MPa
Gas Temperature	*T*	0	°C
Gas Composition File	Kurri_Rich.mix		

Results

Full Bore Rupture			
12.6kW/m² Radiation Contour Radius	$D_{12.6}$	324	m
4.7kW/m² Radiation Contour Radius	$D_{4.7}$	530	m
Eneregy Release Rate	*Q*	66	GJ/s

Leak from a hole			
Hole Diameter	Dh	50	mm
12.6kW/m² Radiation Contour Radius	$D_{12.6}$	57	m
4.7kW/m² Radiation Contour Radius	$D_{4.7}$	93	m
Eneregy Release Rate	*Q*	2.053	GJ/s

Push the calculate botton to update the cells below

Leak from a hole to create 1GJ/s			
Hole Diameter	Dh	35	mm
12.6kW/m² Radiation Contour Radius	$D_{12.6}$	40	m
4.7kW/m² Radiation Contour Radius	$D_{4.7}$	65	m
Eneregy Release Rate	*Q*	1.00	GJ/s

Leak from a hole to create 10GJ/s			
Hole Diameter	Dh	110	mm
12.6kW/m² Radiation Contour Radius	$D_{12.6}$	126	m
4.7kW/m² Radiation Contour Radius	$D_{4.7}$	206	m
Eneregy Release Rate	*Q*	10.00	GJ/s

apa				DOCUMENT No:	WEN.3367-CAL-L-0005
				Rev	1
Project Title:	*Wentworth Storage Bottle Project (Interconnect Pipeline)*			Project No:	21159
Prepared by:	*E.Sabeti*	Date	14/10/2021	Sheet	2 of 5
Checked by:	*N.Menon*	Date	14/10/2021		
Approved by:	*M.Walton*	Date	14/10/2021		

Legend:	
	Input for each case
Locked	Sourced from code
Locked	**Output Calculations**

Heat release rate and radiation contour radius calculations

Gas Composition File *Kurri_Rich.mix*

Scope:

To determine the energy release rate and radiation contour for pipeline 30 seconds after rupture

All gas properties calculated using REFPROP

INPUTS:

Pipeline data			
Outside Diameter of Pipe	*D*	355.6	mm
Wall Thickness	t_w	12.7	mm
Inside Diameter of Pipe	*Di*	330.20	
Pipeline MAOP (kPa)	*P*	15,320	kPa

Calculations			
Lower Heating Value	H_C	34.923	MJ/sm^3
Density at Standard condition	ρ_{atmos}	0.7521	kg/m^3
Pipeline Operating Temperature	$T_{°C}$	0	°C
Fraction of Heat Radiated	*Fh*	0.25	
Gas constant	*R*	8314	J/(kg*mol)/K
Fraction of Heat Intensity Transmitted	τ	1	
Pipeline Operating Temperature (Absolute)	*T*	273.15	K
Specific Heat at constant Pressure	*Cp*	3.9318	kJ/kg*K
Specific Heat at constant Volume	*Cv*	1.7561	kJ/kg*K
Ratio of Specific Heats	*k*	2.2389	
Critical/Sonic Velocity	v_s	447.0	m/s
Flow Factor	*Phi*	1.1922	
Coefficient of critical discharge	C_d	0.620	
Release rate decay factor	*Lambda*	0.33000	
Initial release	*Q in*	2169.28	kg/s
Effective release	*Q eff*	1431.73	kg/s
Energy release	*Q*	66.48	GJ/s
First Contour (12.6 kw/m2)	*KI*	12.60	kW/m^2
Second Contour (4.7 kw/m2)	*KII*	4.70	kW/m^2
Radiation Contour: 12.6kW/m^2	$D_{12.6}$	324	**m**
Radiation Contour: 4.7kW/m^2	$D_{4.7}$	530	**m**

Note:

Ref.: GRI-00/0189 and AS 2885.6-2018

apa

DOCUMENT No:	WEN.3367-CAL-L-0005
Rev	1

Project Title:	*Wentworth Storage Bottle Project (Interconnect Pipeline)*			Project No:	21159
Prepared by:	*E.Sabeti*	Date	14/10/2021	Sheet	3 of 5
Checked by:	*N.Menon*	Date	14/10/2021		
Approved by:	*M.Walton*	Date	14/10/2021		

Legend:

	Input for each case
Locked	Sourced from code
Locked	**Output Calculations**

Heat release rate and radiation contour radius calculations

Gas Composition File *Kurri_Rich.mix*

Scope:

To determine the energy release rate and radiation contour for pipeline 30 seconds after a leak

All gas properties calculated using REFPROP

INPUTS:

Pipeline data			
Outside Diameter of Pipe	*D*	355.6	mm
Wall Thickness	t_w	12.7	mm
Inside Diameter of Pipe	*Di*	330.20	
Pipeline MAOP (kPa)	*P*	15,320	kPa

Hole size			
Hole Diameter	*Dh*	34.90672223	mm

Calculations			
Lower Heating Value	H_C	34.923	MJ/sm^3
Density at Standard condition	ρ_{atmos}	0.7521	kg/m^3
Pipeline Operating Temperature	$T_{°C}$	0	°C
Fraction of Heat Radiated	*Fh*	0.25	
Gas constant	*R*	8314	J/(kg*mol)/K
Fraction of Heat Intensity Transmitted	τ	1	
Pipeline Operating Temperature (Absolute)	*T*	273.15	K
Specific Heat at constant Pressure	*Cp*	3.9318	kJ/kg*K
Specific Heat at constant Volume	*Cv*	1.7561	kJ/kg*K
Ratio of Specific Heats	*k*	2.2389	
Critical/Sonic Velocity	v_s	447.0	m/s
Flow Factor	*Phi*	1.1922	
Coefficient of critical discharge	C_d	0.835	
Release rate decay factor	*Lambda*	0.33000	
Initial release	*Q in*	32.65	kg/s
Effective release	*Q eff*	21.55	kg/s
Energy release	*Q*	1.00	GJ/s
First Contour (12.6 kw/m2)	*KI*	12.60	kW/m^2
Second Contour (4.7 kw/m2)	*KII*	4.70	kW/m^2
Radiation Contour: 12.6kW/m^2	$D_{12.6}$	40	**m**
Radiation Contour: 4.7kW/m^2	$D_{4.7}$	65	**m**

Note:

Ref.: GRI-00/0189 and AS 2885.6-2018

apa		DOCUMENT No:	WEN.3367-CAL-L-0005
		Rev	1
Project Title:	*Wentworth Storage Bottle Project (Interconnect Pipeline)*	Project No:	21159
Prepared by:	*E.Sabeti* Date 14/10/2021	Sheet	4 of 5
Checked by:	*N.Menon* Date 14/10/2021		
Approved by:	*M.Walton* Date 14/10/2021		

Legend:
- Input for each case
- Locked — Sourced from code
- Locked — **Output Calculations**

Heat release rate and radiation contour radius calculations

Gas Composition File *Kurri_Rich.mix*

Scope:

To determine the energy release rate and radiation contour for pipeline 30 seconds after a leak

All gas properties calculated using REFPROP

INPUTS:

Pipeline data			
Outside Diameter of Pipe	*D*	355.6	mm
Wall Thickness	t_w	12.7	mm
Inside Diameter of Pipe	*Di*	330.20	
Pipeline MAOP (kPa)	*P*	15,320	kPa

Hole size			
Hole Diameter	*Dh*	110.3498936	mm

Calculations			
Lower Heating Value	H_C	34.923	MJ/sm^3
Density at Standard condition	ρ_{atmos}	0.7521	kg/m^3
Pipeline Operating Temperature	$T_{°C}$	0	°C
Fraction of Heat Radiated	*Fh*	0.25	
Gas constant	*R*	8314	J/(kg*mol)/K
Fraction of Heat Intensity Transmitted	τ	1	
Pipeline Operating Temperature (Absolute)	*T*	273.15	K
Specific Heat at constant Pressure	*Cp*	3.9318	kJ/kg*K
Specific Heat at constant Volume	*Cv*	1.7561	kJ/kg*K
Ratio of Specific Heats	*k*	2.2389	
Critical/Sonic Velocity	v_s	447.0	m/s
Flow Factor	*Phi*	1.1922	
Coefficient of critical discharge	C_d	0.835	
Release rate decay factor	*Lambda*	0.33000	
Initial release	*Q in*	326.29	kg/s
Effective release	*Q eff*	215.35	kg/s
Energy release	*Q*	10.00	GJ/s
First Contour (12.6 kw/m2)	*KI*	12.60	kW/m^2
Second Contour (4.7 kw/m2)	*KII*	4.70	kW/m^2
Radiation Contour: 12.6kW/m^2	$D_{12.6}$	126	**m**
Radiation Contour: 4.7kW/m^2	$D_{4.7}$	206	**m**

Note:

Ref.: GRI-00/0189 and AS 2885.6-2018

apa

		DOCUMENT No:	WEN.3367-CAL-L-0005
		Rev	1
Project Title:	*Wentworth Storage Bottle Project (Interconnect Pipeline)*	Project No:	21159
Prepared by:	*E.Sabeti* Date 14/10/2021	Sheet	5 of 5
Checked by:	*N.Menon* Date 14/10/2021		
Approved by:	*M.Walton* Date 14/10/2021		

Legend:	
	Input for each case
Locked	Sourced from code
Locked	**Output Calculations**

Heat release rate and radiation contour radius calculations

Gas Composition File *Kurri_Rich.mix*

Scope:

To determine the energy release rate and radiation contour for pipeline 30 seconds after a leak

All gas properties calculated using REFPROP

INPUTS:

Pipeline data			
Outside Diameter of Pipe	*D*	355.6	mm
Wall Thickness	t_w	12.7	mm
Inside Diameter of Pipe	*Di*	330.20	
Pipeline MAOP (kPa)	*P*	15,320	kPa

Hole size			
Hole Diameter	*Dh*	50	mm

Calculations			
Lower Heating Value	H_C	34.923	MJ/sm^3
Density at Standard condition	ρ_{atmos}	0.7521	kg/m^3
Pipeline Operating Temperature	$T_{°C}$	0	°C
Fraction of Heat Radiated	*Fh*	0.25	
Gas constant	*R*	8314	J/(kg*mol)/K
Fraction of Heat Intensity Transmitted	τ	1	
Pipeline Operating Temperature (Absolute)	*T*	273.15	K
Specific Heat at constant Pressure	*Cp*	3.9318	kJ/kg*K
Specific Heat at constant Volume	*Cv*	1.7561	kJ/kg*K
Ratio of Specific Heats	*k*	2.2389	
Critical/Sonic Velocity	v_s	447.0	m/s
Flow Factor	*Phi*	1.1922	
Coefficient of critical discharge	C_d	0.835	
Release rate decay factor	*Lambda*	0.33000	
Initial release	*Q in*	66.99	kg/s
Effective release	*Q eff*	44.21	kg/s
Energy release	*Q*	2.05	GJ/s
First Contour (12.6 kw/m2)	*KI*	12.60	kW/m^2
Second Contour (4.7 kw/m2)	*KII*	4.70	kW/m^2
Radiation Contour: 12.6kW/m²	$D_{12.6}$	57	**m**
Radiation Contour: 4.7kW/m²	$D_{4.7}$	93	**m**

Note:

Ref.: GRI-00/0189 and AS 2885.6-2018

APPENDIX E

Frequency Calculations

Transmission Pipeline 50 mm Penetration and Ignition

Input Data

Parameter	Value	Source
Frequency of Loss of Containment due to Third Party Activity / External Interference, F_L	2.40 x 10^{-3} events/1,000 km/year	Table 72 Proposed natural gas failure rates, Update of pipeline failure rates for land use planning assessments (UK Health and Safety Executive, Health and Laboratory, 2015)
Probability of Ignition of Release, P_i	10%	Table F2, AS/NZS 2885.6:2018 Pipelines – Gas and liquid petroleum, Part 6: Pipeline safety management (Standards Australia, 2018)
Pipeline Length, L (the length of pipeline that has the potential to expose a point on the pipeline alignment to a fatality impact)	0.111 km (3 x 37 m where 37 m is the 12.6 kW/m^2 contour radius)	APA ArcGIS Webapp for Project which includes the following layers: - transmission pipeline alignment - transmission pipeline measurement lengths (i.e. 4.7 kW/m^2 and 12.6 kW/m^2 radiation contours for full bore pipe rupture)

Frequency of transmission pipeline fires:

$$F = \frac{F_L \; events}{1{,}000 \; km.year} \times P_i \times L \; km$$

$$F = (2.4 \times 10^{-3}) \times 10\% \times 0.111$$

$$\boldsymbol{F = 2.66 \times 10^{-8} \; events/year}$$

Storage Pipeline 50 mm Excavator Tooth Penetration and Ignition

Input Data

Parameter	Value	Source
Frequency of Loss of Containment due to Third Party Activity / External Interference, F_L	2.40 x 10^{-3} events/1,000 km/year	Table 72 Proposed natural gas failure rates, Update of pipeline failure rates for land use planning assessments (UK Health and Safety Executive, Health and Laboratory, 2015)
Probability of Ignition of Release, P_i	10%	Table F2, AS/NZS 2885.6:2018 Pipelines – Gas and liquid petroleum, Part 6: Pipeline safety management (Standards Australia, 2018)
Pipeline Length, L (the length of pipeline that has the potential to expose a point on the pipeline alignment to a fatality impact)	1.2 km	APA ArcGIS Webapp for Project which includes the following layers: - storage pipeline alignment - storage pipeline measurement lengths (i.e. 4.7 kW/m^2 and 12.6 kW/m^2 radiation contours for full bore pipe rupture)

Frequency of storage pipeline fires:

$$F = \frac{F_L\ events}{1{,}000\ km.year} \times P_i \times L\ km$$

$$F = (2.4 \times 10^{-3}) \times 10\% \times 1.2$$

$$\boldsymbol{F = 2.88 \times 10^{-7}\ {}^{events}/_{year}}$$

Flange Leak and Ignition at Compressor and Delivery Station

Input Data

Parameter	Value	Source
Frequency of failure of gasket segment equivalent to 20% of pipe diameter, F_L	5.00 x 10^{-6} events/flange/year	Table FR 1.2.5 Flanges and Gaskets, Failure Rate and Event Data for use within Risk Assessments (UK Health and Safety Executive, 2017)
Probability of Ignition of Release, P_i	10%	Table F2, AS/NZS 2885.6:2018 Pipelines – Gas and liquid petroleum, Part 6: Pipeline safety management (Standards Australia, 2018)
Number of flanges, N	250	Provided by APA

Frequency of fires from flange leaks:

$$F = \frac{F_L \; events}{flange.year} \times P_i \times N \; flange$$

$$F = (5.00 \times 10^{-6}) \times 10\% \times X$$

$$\boldsymbol{F = 1.25 \times 10^{-6} \; {events}/{year}}$$

Compressor Heat Exchanger Tube Rupture and Ignition

Input Data

Parameter	Value	Source
Frequency of Heat Exchanger Tube Rupture, F_R	6.50×10^{-9} events/m/year	Table FR 3.1.2 Above Ground Pipelines in Gas Installation, Failure Rate and Event Data for use within Risk Assessments (UK Health and Safety Executive, 2017)
Probability of Ignition of Release, P_i	10%	Table F2, AS/NZS 2885.6:2018 Pipelines – Gas and liquid petroleum, Part 6: Pipeline safety management (Standards Australia, 2018)
Length of DN20 Heat Exchanger Tube (aftercooler), L_{DN20}	1732.4 m	Project heat exchanger thermal and mechanical design data sheet (AXH air-coolers, 2021)
Length of DN25 Heat Exchanger Tube (intercooler 2), L_{DN25}	1000.4 m	
Length of DN32 Heat Exchanger Tube (intercooler 1), L_{DN32}	854.0 m	
Number of Heat Exchangers, N	2	Storage station design drawing

Frequency of fires from DN20 tube sections leaks per heat exchanger:

$$F_{DN20} = \frac{F_R\ events}{m.year} \times P_i \times L_{DN20}\ m$$

$$F_{DN20} = (6.50 \times 10^{-9}) \times 10\% \times 1732.4$$

$$F_{DN20} = 3.38 \times 10^{-6}\ {}^{events}/_{year}$$

Frequency of fires from DN25 tube sections leaks per heat exchanger:

$$F_{DN25} = \frac{F_R\ events}{m.year} \times P_i \times L_{DN25}\ m$$

$$F_{DN25} = (6.50 \times 10^{-9}) \times 10\% \times 1000.4$$

$$F_{DN25} = 1.95 \times 10^{-6}\ {}^{events}/_{year}$$

Frequency of fires from DN32 tube sections leaks per heat exchanger:

$$F_{DN32} = \frac{F_R\ events}{m.year} \times P_i \times L_{DN32}\ m$$

$$F_{DN32} = (6.50 \times 10^{-9}) \times 10\% \times 854.0$$

$$F_{DN32} = 1.67 \times 10^{-6}\ {}^{events}/_{year}$$

Frequency of heat exchanger fires:

$$F = N(F_{DN20} + F_{DN25} + F_{DN32})$$

$$F = 2(3.38x10^{-6} + 1.95 \times 10^{-6} + 1.67 \times 10^{-6})$$

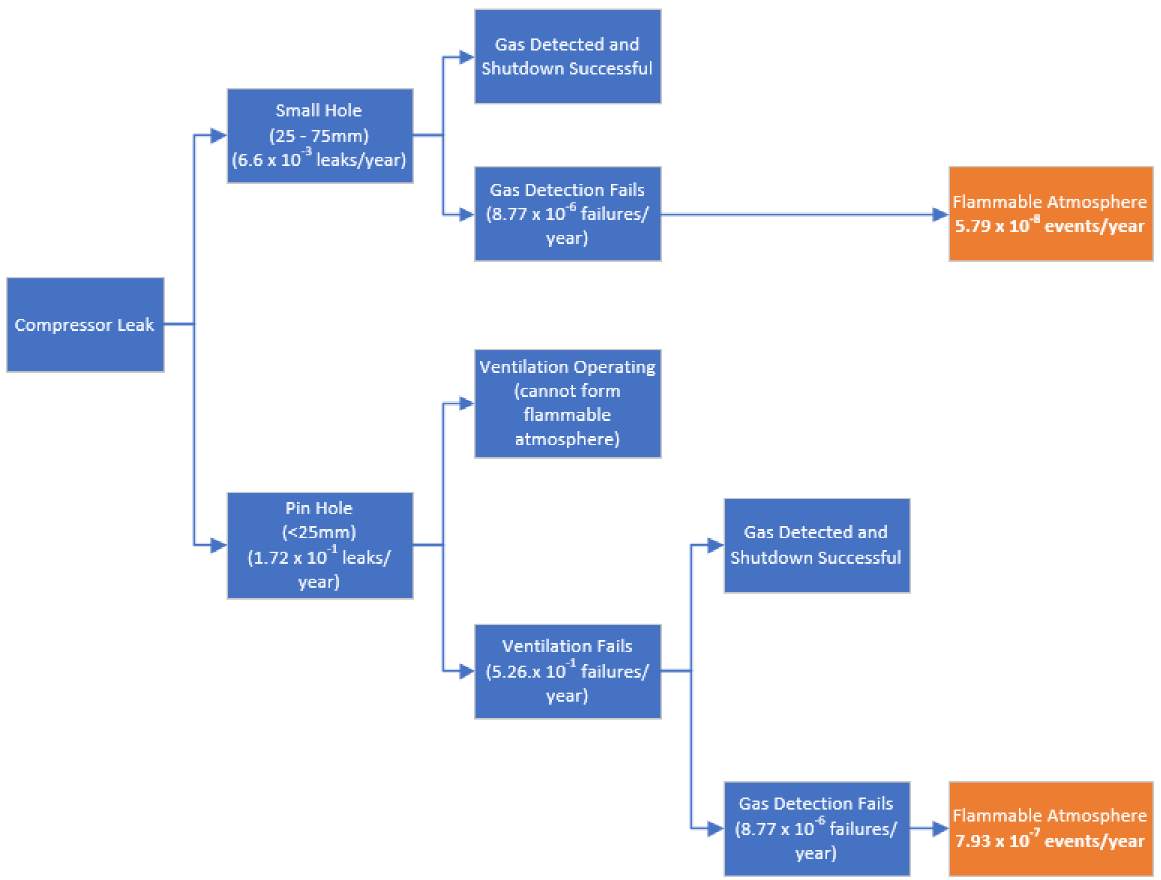
$$\boldsymbol{F = 4.66 \times 10^{-6}} \, {}^{events}/_{year}$$

Compressor Acoustic Enclosure Vapour Cloud Explosion

Input Data

Parameter	Value	Source
Frequency of Compressor Pin Hole Loss of Containment (<25 mm), F_{PH}	8.60 x 10^{-2} events/compressor/year	Table FR 3.1.4 Compressors, Failure Rate and Event Data for use within Risk Assessments (UK Health and Safety Executive, 2017)
Frequency of Compressor Small Hole Loss of Containment (>25 mm to ≤75 mm), F_{SH}	3.30 x 10^{-3} events/compressor/year	
Frequency of Gas Detection and Shutdown Control System Failure, F_C	1.00 x 10^{-9} events/h (8.77 x 10^{-6} events/year)	Control Systems (https://www.hse.gov.uk/comah/sragtech/techmeascontsyst.htm) (high integrity protective system)
Frequency of Enclosure Ventilation System Failure, F_v	6.00 x 10^{-5} events/h (5.26 x 10^{-1} events/year)	Hazard and Barrier Analysis Guidance Document (USA Department of Energy, Office of Operating Experience Analysis and Feedback, 1996) (pumps/circulators failure frequency)
Probability of Ignition of Release, P_i	10%	Table F2, AS/NZS 2885.6:2018 Pipelines – Gas and liquid petroleum, Part 6: Pipeline safety management (Standards Australia, 2018)
Number of Compressors, N	2	Storage station design drawing

Flammable Atmosphere Formation Event Tree



Frequency of VCE from pin hole loss of containment:

$$F_{PH-f} = \frac{F_{PH}\ events}{compressor.year} \times \frac{F_v \text{ events}}{year} \times \frac{F_c \text{ events}}{year} \times P_i \times N\ compressor$$

$$F_{PH-f} = (8.60 \times 10^{-2}) \times (5.26 \times 10^{-1}) \times (8.77 \times 10^{-6}) \times 10\% \times 2$$

$$F_{PH-f} = 7.93 \times 10^{-8}\ {}^{events}\!/_{year}$$

Frequency of VCE from small hole loss of containment:

$$F_{SH-f} = \frac{F_{SH}\ events}{compressor.year} \times \frac{F_c \text{ events}}{year} \times P_i \times N\ compressor$$

$$F_{SH-f} = (3.30 \times 10^{-3}) \times (5.26 \times 10^{-1}) \times (8.77 \times 10^{-6}) \times 10\% \times 2$$

$$F_{SH-f} = 5.79 \times 10^{-9}\ {}^{events}\!/_{year}$$

Cumulative compressor enclosure VCE frequency

$$F = F_{PH-f} + F_{SH-f}$$

$$F = 7.93 \times 10^{-8} + 5.79 \times 10^{-9}$$

$$\boldsymbol{F = 8.51 \times 10^{-8}}\ {}^{events}\!/_{year}$$

Australian Pipeline Loss of Containment Frequency Derivation Based on APGA Data

Reference:

> *Pipeline Loss of Containment Events 1/1/2001 to 30/4/2018 (Experience with the Australian/New Zealand Pipeline Incident Database*, Colin Symonds, APGA, 2018)

Input Data

Parameter	**Value**	**Source – Reference Section**
Data Period, t	1/1/2018 – 30/4/2018 (17.33 years)	Figure 10d
Approximate Average Australian Pipeline Length Over Data Period, L	30,000 km	Figure 4a
# Loss of Containment Events Over Data Period – All Causes, N_T	17	Figure 10d
# Loss of Containment Events Over Data Period – External Interference, N_E	3	

Frequency of loss of containment events for all causes

$$F_T = \frac{N_T}{L\ km \times t\ years}$$

$$F_T = \frac{17}{30{,}000 \times 17.33}$$

$$\boldsymbol{F_T = 3.27x10^{-5}\ events/year}$$

Frequency of loss of containment events for external interference

$$F_E = \frac{N_E}{L\ km \times t\ years}$$

$$F_T = \frac{317}{30{,}000 \times 17.33}$$

$$\boldsymbol{F_T = 5.77x10^{-6}\ events/year}$$

Environmental & Social Consultants

Umwelt (Australia) Pty Limited

T| 1300 793 267 E| info@umwelt.com.au www.umwelt.com.au