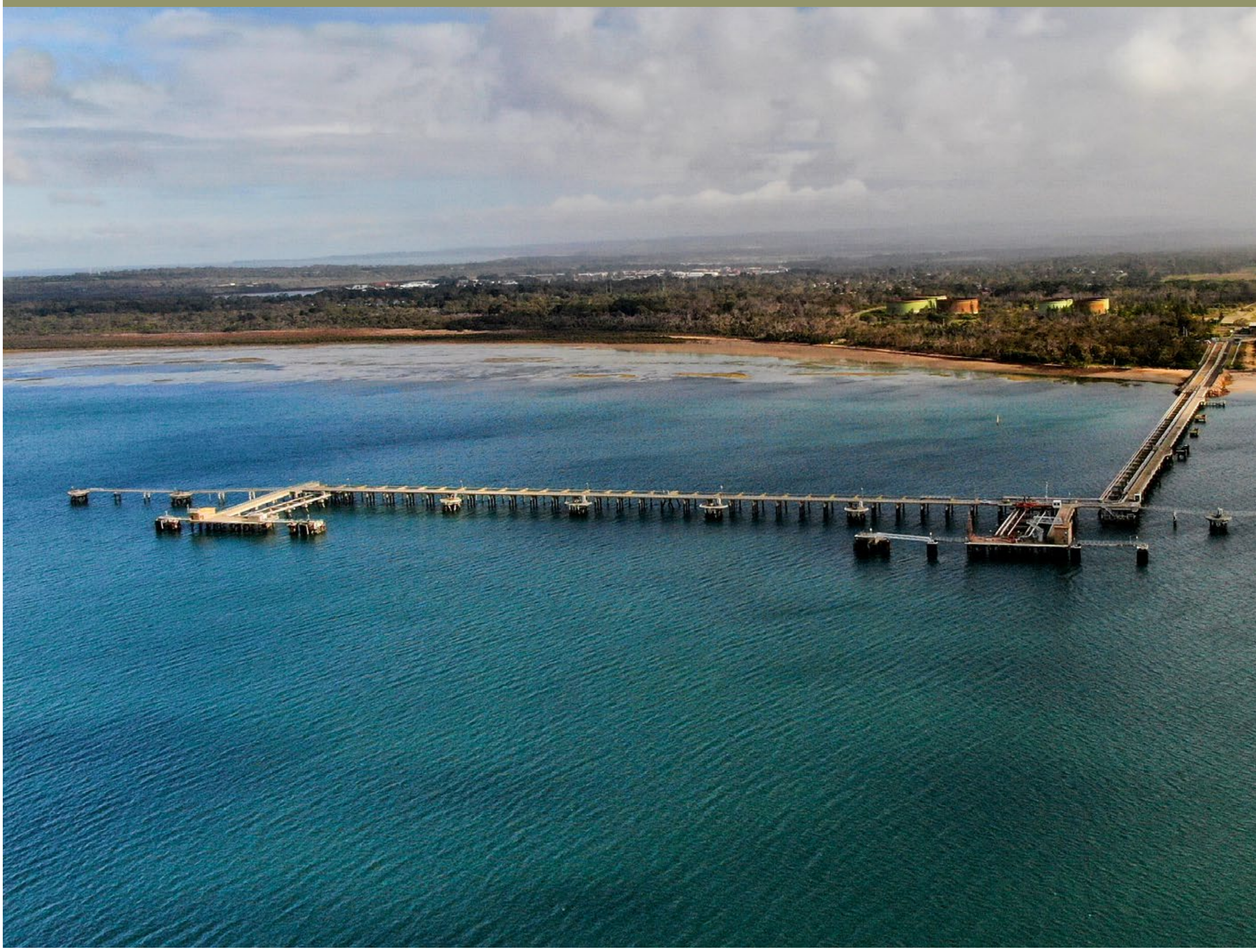
Gas Import Jetty
and Pipeline Project

Environment Effects Statement

July 2020



EES Technical Report K

Safety, hazard and risk assessments

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Gas Import Jetty and Pipeline Project
Environment Effects Statement

AGL Wholesale Gas Limited and APA Transmission Pty Limited

15-Jun-2020

Safety, hazard and risk assessments

Gas Import Jetty and Pipeline Project EES Technical Report K

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Client: AGL Wholesale Gas Limited and APA Transmission Pty Limited

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15-Jun-2020

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Executive summary

This report assesses the process safety, hazard and risk impacts associated with operation of the Gas Import Jetty and Pipeline Project (the Project). The environmental hazards identified for the Project are addressed in other technical reports prepared for the Gas Import Jetty and Pipeline Project Environment Effects Statement (EES).

The approach adopted for this report included a review of the existing design conditions, a review of the existing risk assessments and a review of the safety studies undertaken to date and the identification of potential impacts arising from a major incident during the operational phases.

The Project would establish a gas import jetty and pipeline in Victoria comprising:

- a floating storage and regasification unit (FSRU) at Crib Point Jetty – the Gas Import Jetty Works
- a gas pipeline between Crib Point and Pakenham to connect to the Victorian Transmission System (VTS) east of Pakenham – the Pipeline Works.

The Project would provide an additional supply of natural gas into the south-eastern Australian gas market for industrial, commercial and residential customers.

Potential supply gaps in Victoria's gas market are predicted from 2024. The Project would improve energy security for industrial, commercial and domestic customers and would increase competition in the market.

The Project has completed a suite of hazard identification studies, safety assessments and risk studies consistent with the requirements outlined in WorkSafe Victoria (WSV) Guidance note *Safety assessment for a major hazard facility: Advice for operators of major hazard facilities on conducting and documenting a safety assessment.* The safeguards and controls proposed in the basis of design are consistent with those adopted by hazardous industries and those accepted by regulators as providing sufficient protections and mitigations against major incidents. The design and the hazard, safety and risk studies will continue to be refined throughout the Project and presented to regulators as demonstration of compliance with the relevant legislation and recognised industry standards. The Project cannot proceed without all required regulatory approvals related to safety being obtained following the EES process.

A key element of the risk assessments has been the adoption of a risk tolerability criteria used in the quantitative risk assessments. It is also acknowledged that the suite of supportive EES technical assessments and reports adopt appropriate risk mitigation measures in relation to their technical area (i.e. traffic management, noise, visual impact, environment, land use etc.)

The level of incremental risk introduced by the Project has been demonstrated through preliminary quantitative risk assessments to be within the tolerable risk threshold adopted by the Project and suggested by the Hazardous Industry Planning Advisory Paper No.4 and the guidance provided by WSV in its publication titled *Major hazard facilities: Land use planning near a major hazard facility* and in its Guidance Note titled, *The Requirements for 'Demonstration' under the Occupational Health and Safety (Major Hazard Facility) Regulations.* The impacts considered incremental to the existing activities can be managed via the recommendations made in accompanying technical specialist reports.

The hazard, safety and risk impacts on the adjacent and nearby land users during gas operations are expected to be limited in nature and are not disproportionate to those already being experienced. The risk studies and the design of the Project will continue to be refined during the Project cycle. The design will be subject to review and presented to regulators to demonstrate compliance with the key legislation and nominated industry standards.

Land use context and existing conditions

The Project is located within the Western Port region between Crib Point Jetty and the proposed Pakenham Delivery Facility. The Project spans three local municipalities being Mornington Peninsula Shire, the City of Casey and Cardinia Shire. It traverses a mix of land use typologies, including existing port facilities at Crib Point, the township at Hastings, a range of agricultural and rural living land uses and the Pakenham East rail depot, before reaching the existing Longford – Dandenong Pipeline and Bunyip – Pakenham Pipeline also at East Pakenham (north of the Princes Highway).

Risk impacts on the adjacent and nearby land users during gas operations are expected to be limited in nature and are not disproportionate to those already being experienced. This is discussed in further detail in Section 9.2.

The Crib Point Jetty Berth 1 is currently being used for the discharge of gasoline and the introduction of the FSRU and the Crib Point Receiving Facility at Crib Point is not inconsistent with existing operations and port and industrial uses within the Port of Hastings.

Methodology

A systematic, risk-based approach has been applied to understanding the potential impacts of the Project and how to avoid, minimise or manage the risk of impact to the workforce, nearby operations and adjacent land users. The adoption of a risk-based approach and the assessment of hazards will be ongoing through the Project life cycle.

The adoption of an iterative risk-based approach ensures continuous improvement in risk mitigation and risk management as part of providing assurance that the Project risks are being appropriately considered and reduced so far as is reasonably practicable (SFAIRP).

The approach taken to the risk assessments has been, and will continue to be, consistent with Australian/New Zealand Standard AS/NZS ISO 31000:2018 Risk Management Process and follows the guidance notes for the management and control of risks published by WSV.

The preliminary hazard assessments have been made with regard to the land uses surrounding the Gas Import Jetty Works and Pipeline Works including the proposed operational workforce. These aspects are described in further detail in EES Technical Report L: *Land use impact assessment* and in EES Chapter 4 *Project description* respectively.

The assessment adopts the Measurement Length of the pipeline as the core study area and the immediate area around the Gas Import Jetty Works facilities (FSRU, Jetty Infrastructure and Crib Point Receiving Facility) and the Pakenham Delivery Facility. The Measurement Length has been calculated as 640 metres on either side of the pipeline and is used to classify existing and reasonably foreseeable land use adjacent to the pipeline and drives the safety design of the pipeline to mitigate threats to and from the pipeline.

The methodology for completing the hazard and risk analysis for the Project includes the following general steps:

- Identification of hazards – review of potential hazards and the associated impact that may occur based on previous data, experience or judgement.
- Consequence assessment – define the characteristic of identified potential hazards and the facility thresholds for each type of consequence (i.e. thermal radiation, flash fire, pool fire, vapour cloud explosion etc.)
- Likelihood analysis – define the probability of the identified potential consequence.
- Risk analysis –Compare the resultant risk against the Project risk criteria.
- Determine risk mitigation and manage options to ensure risk is reduced SFAIRP.

A number of different methodologies have been employed to assess hazardous consequence and risk, as applicable for the differing aspects of the Project, and the associated requirements for

demonstration of risk minimisation and compliance with the differing regulatory regimes. These differences are summarised in the report and further explained in Appendix A.

Construction safety hazards

During construction, the public and the workforce would be exposed to hazards routinely experienced in the construction of major infrastructure. While the Project is not introducing any new or unique construction hazards that are not already encountered on all major infrastructure projects, there are nonetheless a range of hazards that will require mitigation during construction.

Health, Safety and Environment (HSE) performance expectations shall be set with construction contractors, including requirements to undertake HSE Risk Workshops in accordance with AS/NZS ISO 31000:2018. Discussions of construction hazards relevant to public and worker safety would be considered as part of the studies during different phases of construction.

Risk assessment

A large uncontrolled release of liquefied natural gas (LNG) or natural gas leading to ignition has the potential for a major incident. This represents the highest consequence for a process safety incident. The consequence from these low likelihood, high consequence events will impact surrounding land users. The hazard, safety and risk impacts on the adjacent and nearby land users adjacent to and in the vicinity of Crib Point during gas operations are expected to be limited and not disproportionate to those already experienced by the current operations of unloading gasoline at Crib Point Berth 1.

The scenarios leading to a high consequence event have been identified in the hazard and risk studies. The potential effects from LNG incidents are discussed further in Section 5.0 and Appendix E. Safeguards and controls have been put in place as part of the design to mitigate these risks.

Quantitative Risk Assessments (QRA) have been adopted by the Project as the principal means by which the level of risk to adjacent and nearby land users has been estimated. The QRA is a tool used to compare options and ensure risks are mitigated SFAIRP. As noted in Worksafe Victoria Guidance Note for Requirements for Demonstration at MHFs, the results of the QRA may be used by comparison with pre-determined criteria or for comparing different options, as part of the overall demonstration of adequacy.

The results from the QRA are in Section 8.6, 9.0, Appendix C and Appendix D.

Mitigation measures

The following represent the key mitigation measures for managing the hazards and risks of the Project:

- All aspects of the Project are designed to the appropriate Australian or international standards.
- The FSRU proposed for Crib Point would be issued a Class notation (classification) by DNV GL.
- Classification attests to the vessel and process units being designed and operated in accordance with a prescribed set of DNV GL rules and engineering standards. Classification covers both the ship and the topside LNG regasification unit.
- The vessel will carry a Safety Management Certificate or interim safety management certificate – which certifies compliance with the International Safety Management (ISM)
- The vessel will carry an International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.
- The Jetty Infrastructure would include gas detection along the gas piping and be fitted with fire detection and fire water systems designed for six hours of continuous operation to prevent escalation of a fire event.
- The pipeline would be built to the requirements of Australian Standard (AS) 2885 *Pipelines - Gas and Liquid Petroleum* and subject to the requirements of the *Pipelines Act 2005* and the Pipelines Regulations 2017 that govern the management and regulation of pipelines in Victoria.
- The Safety Management Workshop identified all credible threats for the pipeline in accordance with the requirements of AS/NZS2885.6 and controls have been implemented in the design and

installation method of the pipeline, including increased depth of burial, increased protective slabbing; additional signage; the use of heavy duty pipe with increased wall thickness at critical locations and increased pipeline patrols.

- Each of the facilities at Crib Point and Pakenham would include automated instrumentation to detect abnormal conditions and enunciated alarms at a remote fully attended control room.
- Each of the pipeline facilities at Crib Point and Pakenham would be fitted with actuated isolation valves that can be closed by the shutdown system or manually locally or from a remote location in the event of an incident.
- Adequate safety interlocks including the ability to shut down the flow of gas from the FSRU, the jetty gas piping, the Crib Point and Pakenham facilities from a remote location.
- The gas production, gas export and gas transmission processes are fully instrumented and monitored. All abnormal conditions are alarmed to a permanently attended remote control room for action by operators. The safety systems between different project elements would be linked and an interface management plan in place for the effective management of the systems.
- The design of the automated safety shutdown systems includes the following key actions:
  - activation of emergency stop at the FSRU
  - activation of any emergency stop on the Jetty Infrastructure
  - activation of an emergency stop at Crib Point Receiving Facility
  - activation of any emergency stop between the FSRU and Crib Point will close all isolation valves and stop the transfer of gas from the FSRU to the jetty piping
  - the pipeline will include two mainline valves designed to limit the loss of gas in the unlikely event on an incident - MLV1 can be operated remotely.
- The pipeline would also be fitted with an in-line inspection facility to allow the internal inspection and condition of the pipeline to be made at periodic intervals.
- The pipeline would have a minimum of 1200 mm cover along the route with 2000 mm cover required at rail crossings as required by AS 2885.
- In the vicinity of the Pakenham East rail depot located in Pakenham, the pipeline would be protected by the provision of 20 metres x two concrete slabbing where the pipeline crosses minor access roads.
- To control the potential threat from installation of power poles over the pipeline, a standard design would include installation of protective slabbing over the pipeline for three metres either side in locations where the pipeline is within three metres of existing power poles and 10 metres of slabbing at road crossing locations in T1 (residential) areas.
- Additional marker posts would be installed within the right-of-way wherever the pipeline comes within 10 metres of existing power poles.

Abbreviations

Abbreviation	Definition
AECOM	AECOM Australia Pty Ltd
AGL	AGL Wholesale Gas Limited
ALARP	As Low As Reasonably Practicable
AMSA	Australian Maritime Safety Authority
APA	APA Transmission Pty Limited
API	American Petroleum Institute
ARO	Abrasive Resistance Overlay
BLEVE	Boiling Liquid Expanding Vapour Explosions
CP	Cathodic Protection
CPT	Crib Point Transmission (pipeline)
DELWP	Department of Environment, Land, Water and Planning
DFBE	Dual Layer of Fusion Bonded Epoxy
DCV	Domestic Commercial Vessel
DMA	Dynamic Mooring Analysis
DN	Nominal Diameter
EES	Environment Effects Statement
EMF	Environmental Management Framework
EMP	Environmental Management Plan
EOLSS	End of Line Scraper Station
ERP	Emergency Response Plan
ERW	Electric Resistance Welded
ESC	Essential Services Commission of Victoria
ESD	Emergency shutdown
ESV	Energy Safe Victoria
FSRU	Floating storage and regasification unit
GHS	Global Harmonized System
GJ/s	Gigajoule per second
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HCDG	High consequence dangerous goods
HDD	Horizontal directional drilling
HIPAP	Hazardous Industry Planning Advisory Paper
HIPPS	High Integrity Pressure Protection Systems
HMI	Human Machine Interface
HSE	Health, Safety and Environment

Abbreviation	Definition
IMO	International Maritime Organization
ISGOTT	International Guide for Oil Tankers and Terminals
ISM	International Safety Management
kscm	kilo standard cubic meters
kPa	Kilopascals
kPag	Kilopascal gauge
kW/m^2	Kilowatt per square metre
LFL	Lower Flammable Limit
LIN	Liquid nitrogen
LNG	Liquefied natural gas
LOPA	Layer of Protection Analysis
LSIR	Location Specific Individual Risk
MAOP	Maximum Allowable Operating Pressure
MHF	Major hazard facility
ML	Measurement Length
MLM	Mooring Load Management
MLV	Mainline valves
MoU	Memorandum of Understanding
MSV	Marine Safety Victoria
NG	Natural gas
NSW	New South Wales
OCIMF	Oil Companies International Marine Forum
OSV	Offload, storage and vaporisation
OTS	Office of Transport Security
PC	Principal Contractor
PoHDA	Port of Hastings Development Authority
PPE	Personal protective equipment
QRA	Quantitative Risk Assessment
RAV	Regulated Australian Vessel
ROW	Right of way
RPT	Rapid phase transition
SCADA	Supervisory Control and Data Acquisition System
SDS	Safety Data Sheets
SFAIRP	So Far As is Reasonably Practicable
SIF	Safety instrumented function
SIL	Safety Integrity Level
SIGTTO	Society of International Gas Tanker and Terminal Operators

Abbreviation	Definition
SMP	Safety Management Plan
SMS	Safety Management Study
SMYS	Specified Minimum Yield Strength
STS	Ship to ship
TSV	Transport Safety Victoria
UFL	Upper Flammable Limit
VCE	Vapour cloud explosion
VRCA	Victorian Regional Channels Authority
VTS	Victorian Transmission System
WSV	WorkSafe Victoria

1.0 Introduction

This report assesses the potential hazards, safety and risks associated with the construction and operation of the Gas Import Jetty and Pipeline Project (the Project).

The Project would provide an additional supply of natural gas into the south-eastern Australian gas market for industrial, commercial and residential customers.

The Australian Energy Market Operator has predicted potential supply gaps in Victoria's gas market from 2024 (AEMO, 2019). The Project would improve energy security for industrial, commercial and domestic customers and would increase competition in the market.

The joint proponents of the Project are AGL Wholesale Gas Limited (AGL) and APA Transmission Pty Limited (APA).

The Project would establish a gas import jetty and pipeline comprising:

- a floating storage and regasification unit (FSRU) at Crib Point Jetty – the Gas Import Jetty Works
- a gas pipeline between Crib Point and Pakenham to connect to the Victorian Transmission System (VTS) east of Pakenham – the Pipeline Works.

The Project was referred by AGL and APA to the Victorian Government under the *Environment Effects Act 1978* (Vic) on 13 September 2018 as two separate projects consisting of the Gas Import Jetty Works and Pipeline Works.

On 8 October 2018 the Minister for Planning issued a decision determining that an Environment Effects Statement (EES) was required for the Project due to the potential for a range of significant environmental effects.

The Gas Import Jetty Works and the Pipeline Works were also referred to the Commonwealth Government under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as separate projects.

Each project was designated as a controlled action requiring impact assessment under the EPBC Act. The EES process is the accredited environmental assessment for the controlled action decisions under the EPBC Act in accordance with the bilateral agreement between the Commonwealth and Victorian governments.

1.1 Purpose

The purpose of this report is to provide summary and explanation of the hazards, safety and risk assessments for the EES, excluding environment hazards, and to detail the mitigation measures currently in place to address the potential impacts. This will inform the development of an Environmental Management Framework (EMF) for the Project. The mitigation measures listed in the EMF will be implemented in the approvals and management plans for the Project. The environmental hazards are covered separately.

Why understanding risk is important

Understanding the safety, hazards and risks associated with the Project is critical as it enables the proponent to design systems and put in place procedures appropriate to the safeguarding of human life, assets and the environment.

To assess the safety, hazard and risks of the Gas Import Jetty Works and the Pipeline Works, both AGL and APA have undertaken, and plan to undertake, numerous formal safety studies and hazard assessments. These studies include both qualitative and quantitative methods.

The studies undertaken to date are consistent with those adopted by industries dealing with hazardous materials and are commensurate with the requirements and guidance from the nominated regulators identified in the report.

The principal studies undertaken include hazard identification workshops (HAZID), hazard and operability studies (HAZOP); pipeline Safety Management Studies (SMS) and Quantitative Risk Assessments (QRA).

The outcomes of the hazard assessments and risk studies will be incorporated into the design and the operating practices for the Project with the intent being to reduce the risk so far as is reasonably practicable (SFAIRP).

The safety, hazard and risk studies are an iterative process. They will be continually updated at different stages of the Project as the level of design detail and definition develops. This is a normal occurrence during the lifecycle of a Project.

The hazard assessments and risk studies, along with the resultant actions, provide a demonstration of adequacy that risks are being systematically identified, assessed and mitigated so far as is reasonably practicable to provide safe operations that meet community expectations.

1.2 Project description

The intent of the Project is to supply natural gas into the eastern Australian gas market for industrial, commercial and residential gas customers meeting a projected domestic gas shortfall and improving gas supply security.

The Project comprises two sets of works: the Gas Import Jetty Works and the Pipeline Works.

AGL would undertake the Gas Import Jetty Works. APA would undertake the Pipeline Works.

1.2.1 Gas Import Jetty Works

The Gas Import Jetty Works would consist of a liquefied natural gas (LNG) import facility comprising:

- continuous mooring of an FSRU at Berth 2 of the existing Crib Point Jetty to store LNG and regasify LNG into natural gas
- Jetty Infrastructure on the Crib Point Jetty including marine loading arms (MLAs) and gas piping to transfer the gas from the FSRU to the Crib Point Receiving Facility
- Crib Point Receiving Facility, including metering, odorant injection and nitrogen injection, which would be located on land adjacent to the Crib Point Jetty.

The FSRU vessel for the Project would be approximately 300 metres long and 50 metres wide. It would have capacity to store 170,000 cubic metres (m^3) of LNG. Visiting vessels carrying LNG (LNG carriers) would berth alongside the FSRU to transfer their LNG to the FSRU, which could take up to 36 hours.

The FSRU would store the LNG as a liquid and when required, return LNG back into a gaseous state by heating the LNG using either seawater or gas-fired boilers (a process known as regasification).

Following regasification, the natural gas would be transferred through gas piping along the jetty from the FSRU to the Crib Point Receiving Facility.

The Crib Point Receiving Facility would include treatment facilities to inject odorant and nitrogen (as required) into the natural gas to meet VTS gas quality specifications.

1.2.2 Pipeline Works

The Pipeline Works would comprise a bi-directional gas transmission pipeline to transport gas from the Crib Point Receiving Facility to the VTS east of Pakenham.

The pipeline would be approximately 57 kilometres long with a nominal diameter of 600 millimetres. The pipeline would be buried at a depth of generally 1.2 metres below ground (to the top of the pipe).

The Pipeline Works would also comprise the following facilities:

- the pigging facility at the Crib Point Receiving Facility to enable in-line inspections of the pipeline with a pipeline inspection gauge (pig)

- the above-ground Pakenham Delivery Facility situated adjacent to the Pakenham East rail depot to monitor and regulate the gas
- the below-ground End of Line Scraper Station (EOLSS) located at the connection point to the VTS, north of the Princes Highway in Pakenham
- two above-ground mainline valves (MLVs) located at different points along the pipeline alignment to enable isolation of the pipeline in an emergency.

1.2.3 Construction

The key construction activities for the Gas Import Jetty Works would include:

- establishment of construction sites including laydown areas
- installation of Jetty Infrastructure on the Crib Point Jetty, including MLAs, gas piping mounted to the jetty, electrical and instrumentation equipment and a firefighting system
- construction of the Crib Point Receiving Facility.

Construction for the Gas Import Jetty Works would take approximately 18 to 27 months, depending on weather conditions.

The key construction activities for the Pipeline Works would include:

- establishment of laydown areas
- construction of the pigging facility at Crib Point Receiving Facility, Pakenham Delivery Facility, two MLVs and the EOLSS
- pipeline construction using construction techniques such as trenching, horizontal directional drilling (HDD) or boring, typically within a 30-metre-wide pipeline construction right of way (ROW).

Construction for the Pipeline Works would take approximately 18 to 24 months, depending on weather conditions. Pipeline construction would progress in a linear manner.

Subject to the staging of the works outlined above, construction for the entire Project is expected to take approximately 18 to 27 months.

1.2.4 Operation and maintenance

When commissioned, the FSRU would be operated by an experienced third-party operator. The Crib Point Receiving Facility and associated Jetty Infrastructure would be owned and operated by AGL or an experienced third-party operator. The Pipeline Works would be owned and operated by APA.

The FSRU may leave Western Port during the Project lifetime for activities such as scheduled maintenance and extreme weather events.

The gas import jetty would initially receive approximately 12 LNG carriers per year with capacity to increase to approximately 40 LNG carriers per year. The number and frequency of LNG carriers arriving each year would depend on their storage capacity and gas demand.

The Crib Point Receiving Facility is designed to be automated and may be operated unmanned under normal operating conditions.

An operational easement of generally 15 metres wide would apply to the pipeline alignment. The pipeline easement would be routinely inspected for any operational or maintenance issues in accordance with APA procedures.

The pipeline would also be designed and constructed so that pigging could be undertaken to inspect the integrity of the pipeline as required. Pigging would be undertaken around 10 years after construction and then at a frequency determined by the first inspection.

The Pakenham Delivery Facility is also designed to be automated and operate unmanned under normal operating conditions.

The EOLSS would be buried with valves contained within concrete pits. The connection to the VTS would operate unmanned. Excavation of the site to access the EOLSS would be required for the pigging activities.

1.2.5 Decommissioning

The FSRU is proposed to operate for 20 years, although this may be shortened or extended to address security and stability of gas supply to south-eastern Australia. When the Project was no longer required, the FSRU would leave Western Port.

The Jetty Infrastructure installed on the Crib Point Jetty and the Crib Point Receiving Facility would be decommissioned and removed when no longer required. The Crib Point Jetty would remain as an operational jetty under the management of the Port of Hastings Development Authority (PoHDA).

The pipeline would have a design life of 60 years. If the Pipeline Works were no longer required, they would be decommissioned in accordance with Australian Standard AS2885 *Pipelines – gas and liquid petroleum* and relevant legislative and approval requirements at the time of decommissioning.

Key Project elements are shown in Figure 1-1.

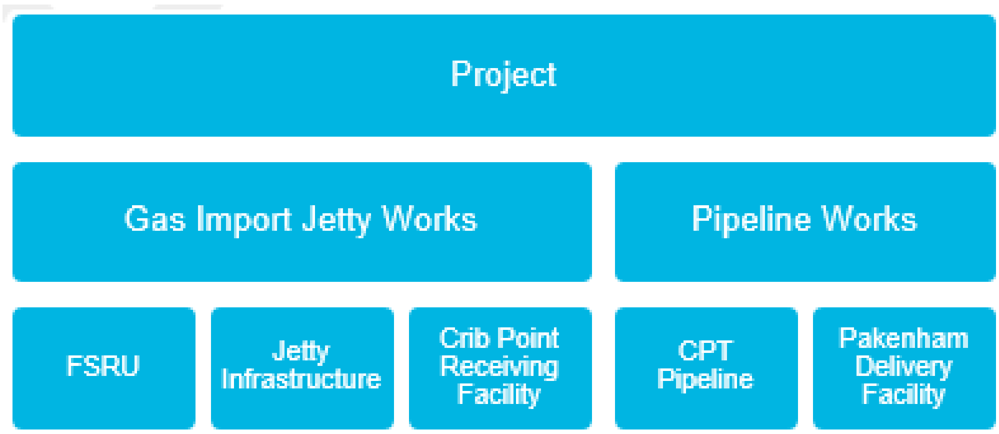


Figure 1-1 Project elements

1.3 Project Area

The Project Area is situated between Crib Point and Pakenham East in Victoria within the local government areas of Mornington Peninsula Shire, the City of Casey and Cardinia Shire.

The Project Area includes the construction and operation footprints for the Gas Import Jetty Works and the Pipeline Works.

The Project Area is detailed in EES Attachment VII *Map book*. An overview of the Project Area showing the proposed pipeline alignment and current options is shown in Figure 1-2.

The Gas Import Jetty Works would be located at the existing Crib Point Jetty (Berth 2) and on land immediately adjacent. The Crib Point Jetty is located within the Port of Hastings and within an area designated as a wetland of international significance under the Ramsar Convention on Wetlands of International Importance (the Western Port Ramsar site).

The Pipeline Works would be located on land between the Crib Point Receiving Facility and a connection point to the VTS east of Pakenham.

The pipeline alignment was selected to minimise impacts on sensitive land uses and where possible follows existing pipeline easements.

The pipeline would be located on land used for various purposes including rural residential living, road corridors, industry, conservation reserves, hobby farming, horse studs and agriculture. The pipeline would generally follow the Stony Point rail reserve through Hastings.

Towards Pakenham, the pipeline would cross the Gippsland rail line before reaching the proposed Pakenham Delivery Facility adjacent to the Pakenham East rail depot and connecting to the VTS north of the Princes Highway.

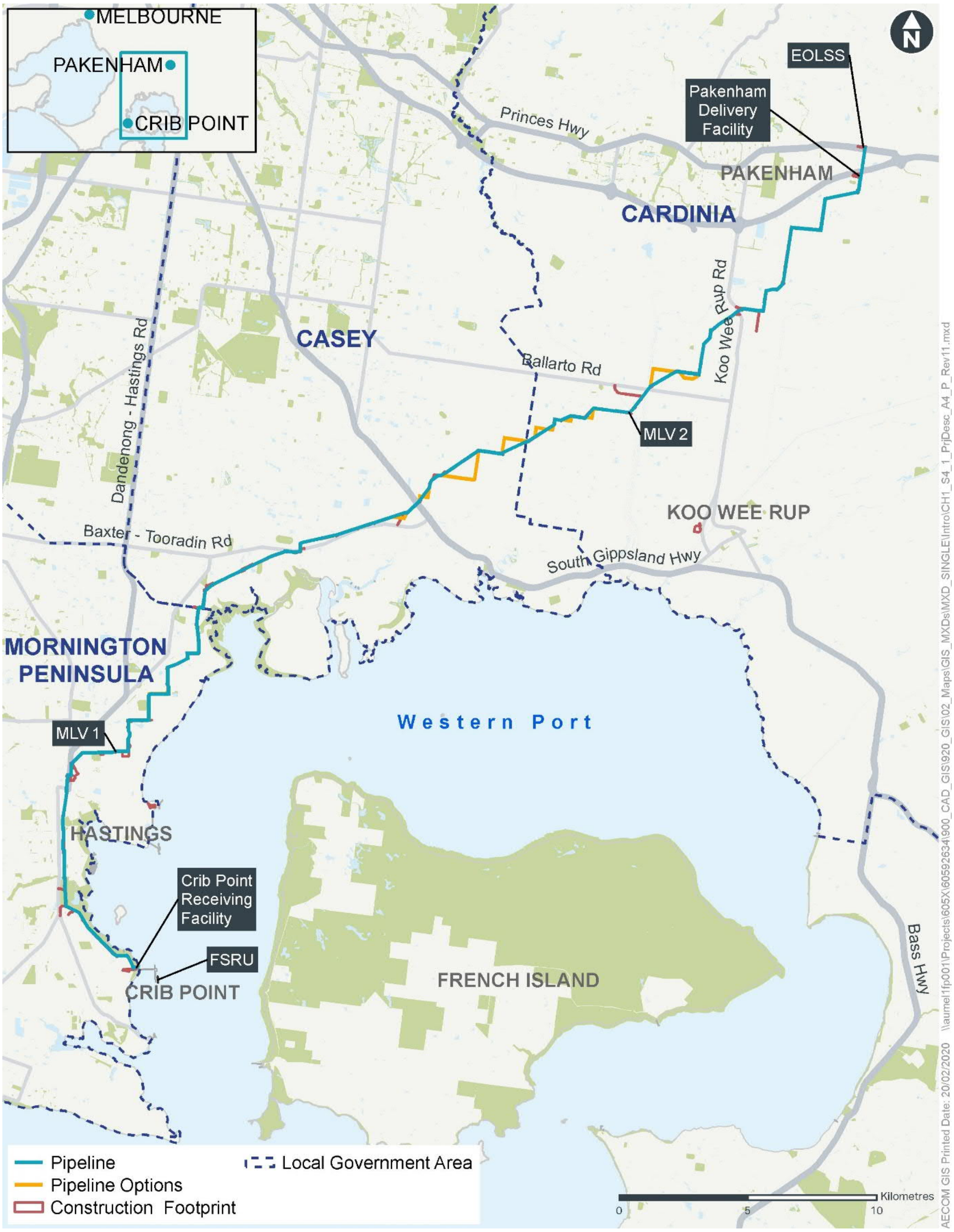


Figure 1-2 Project Area overview

1.4 Study area

The study area is shown in Figure 1-3.

For the gas pipeline, the study area encompasses the pipeline measurement length (ML), calculated at 640 metres on either side of the pipeline. The ML is used to classify existing and reasonably foreseeable land use adjacent to the pipeline and drives the safety design of the pipeline to mitigate threats to and from the pipeline.

The study area also includes the immediate area around the Gas Import Jetty Works facilities (FSRU, Jetty Infrastructure and Crib Point Receiving Facility) and the Pakenham Delivery Facility.

The outcome of the consequence assessments associated with the hazardous scenarios identified through QRA and other means, focus on specific areas of interest with respect to land use within and adjacent to the study area.

Risk contours illustrating the level of risk to people and property have been developed as part of the consequence assessment. These contours represent the risk to people and property arising from a major incident and have been geographically overlayed on a map of specific areas of interest within the study area.

Additionally, as part of the Safety Management Study (SMS) for the pipeline and consistent with AS/NZS2885 Part 6, an assessment of the predominant land use along the pipeline alignment has been used in support of developing location classes for the adjacent land use.

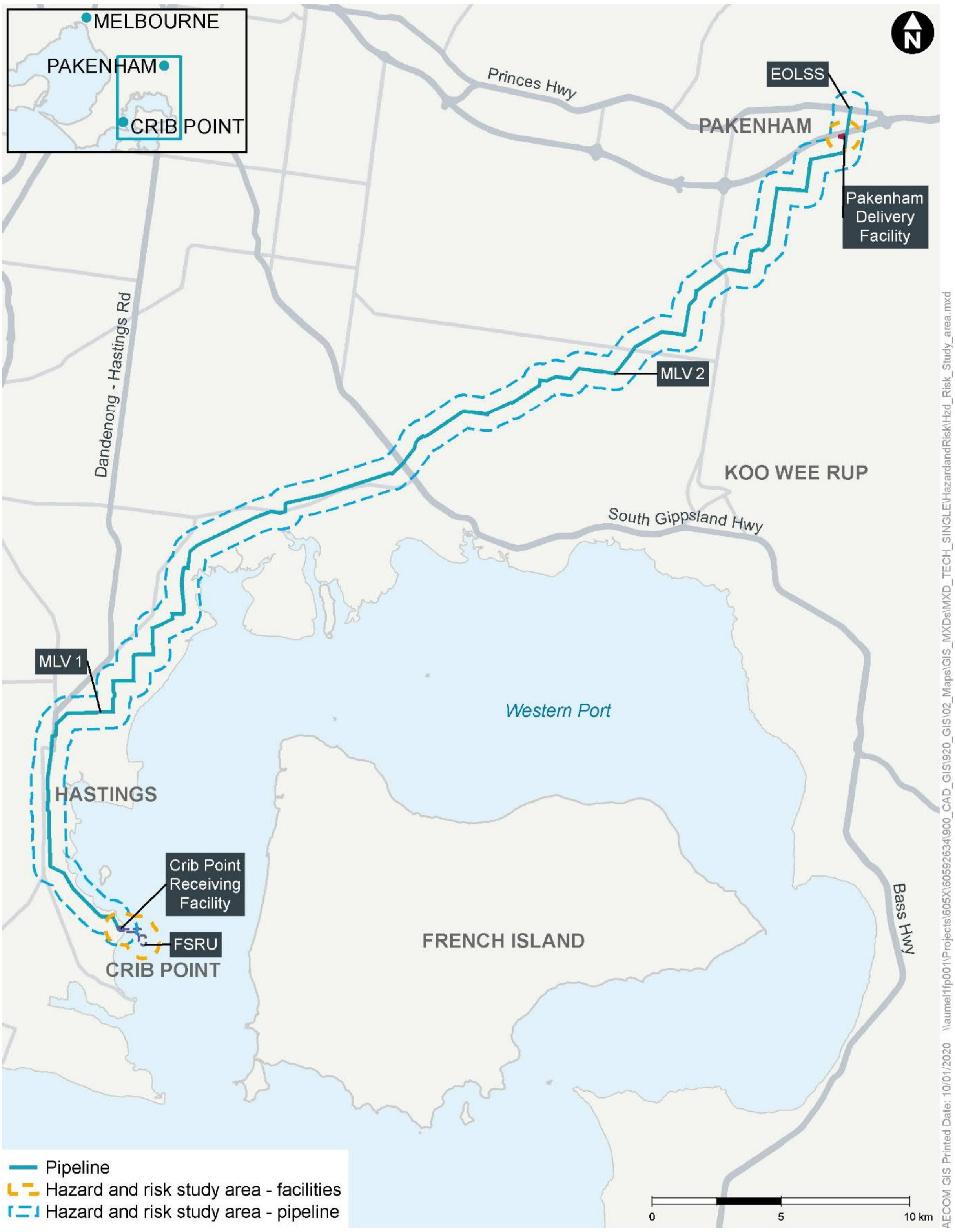


Figure 1-3 Study area

2.0 Scoping requirements

The EES scoping requirements for the Project were issued by the Victorian Minister for Planning in February 2019, and augment the key matters listed in the Minister's decision to require an EES.

The scoping requirements set out the specific matters to be investigated and documented in the EES in the context of the *Ministerial guidelines for assessment of environmental effects under the Environment Effects Act 1978*.

The EES is an accredited assessment process for the purposes of the assessment of the Project under the EPBC Act, and the EES scoping requirements also include matters to be assessed under the EPBC Act.

2.1 Evaluation objectives

The following draft evaluation objectives are relevant to safety, hazard and risk and identifies the desired outcomes in the context of potential Project effects.

The draft evaluation objectives, as set out in the final scoping requirements, provide a framework to guide integrated assessment of the environmental effects of the Project. These draft evaluation objectives are to be used in the context of the relevant legislative requirements set out in Section 0.

The draft evaluation objectives for safety, hazard and risk are:

Energy efficiency, security, affordability and safety – To provide for safe and cost-effective augmentation of Victoria's natural gas supply in the medium to longer term.
Social, economic, amenity and land use – To minimise potential adverse social, economic, amenity and land use effects at local and regional scales.

2.2 Assessment of specific safety, hazard and risk effects

The following extracts from the scoping requirements, issued by the Minister for Planning, are relevant to the draft evaluation objective listed above.

Table 2-1 Scoping requirements for safety, hazard and risk assessment

Aspect	Scoping requirement	Refer
Key issues	Workforce, nearby operations and public safety risks associated with the construction or operation of the project, including risks associated with or compounded by potential external threats (e.g. bushfire).	Section 5.0 Section 6.6 Section 7.6 Section 8.6 Section 9.0 Appendix C Appendix D
Priorities for characterising the existing environment	Characterise the human environment near the project relative to safety buffer standards for surrounding current land uses and reasonably foreseeable land uses.	Section 5.0 Section 6.6 Section 7.6 Section 8.6 Section 9.0 Appendix C Appendix D
Design and mitigation measures	Describe proposed measures to minimise risk and ensure safety for workforce, nearby operations and the public during construction and operation of the project.	Section 6.2 Section 7.2 Section 8.2 Section 9.0 Section 10.0

Aspect	Scoping requirement	Refer
		Section 11.0
Assessment of likely effects	Assess the level of residual risk relative to standards associated with the project, including the FSRU. Assess potential safety hazards to the public arising from project construction and operation.	Section 5.0 Section 9.1 Section 9.2 Appendix C Appendix D
Approach to manage performance	Describe the monitoring program to form part of the EMF to identify any potential hazards in time for corrective action to be taken. Describe the framework for emergency response, including contingency planning for foreseeable possible public safety or environmental emergencies.	Section 6.7 Section 7.6 Section 10.0 Section 11.0.

3.0 Legislation, policy and guidelines

Multiple regulatory agencies and organisations would be responsible for providing oversight across each of the different Project elements as part of project approvals, construction and operation. An overview of the relevant regulatory body or agency, along with the key legislative compliance requirements, is provided on Figure 3-1.

A summary of these requirements is discussed below with further detail provided under each of the respective sections relating to the individual Project elements.

- For the FSRU component of the Gas Import Jetty Works refer to Section 6.4.
- For the Jetty Infrastructure component of the Gas Import Jetty Works refer to Section 7.3.
- For the Pipeline Works refer to Section 8.3.

3.1 Gas Import Jetty Works

The Gas Import Jetty Works, comprising the continuously moored FSRU, the Jetty Infrastructure on Crib Point Jetty and the Crib Point Receiving Facility would require various maritime and land-based approvals.

The agencies responsible for providing regulatory approvals and oversight of the FSRU and the LNG carrier when it is inside the Port area include:

- Australian Maritime Safety Authority (AMSA)
- Aviation and Maritime Security (AMS)
- Port of Hastings Development Authority (PoHDA)
- Victorian Regional Channels Authority (VRCA).

The issuing of Project approvals would be subject to meeting the rigorous safety requirements outlined in existing legislation and the nominated standards for the Project.

The FSRU would hold the relevant certificates under applicable Australian maritime laws and international maritime conventions, including a safety management certificate or interim safety management certificate (SMC).

The safety and operational preparedness of the regasification and transfer process onboard the FSRU would be assessed in a manner that is consistent with the requirements for a major hazard facility (MHF) in Victoria. This in part would require the operator to submit a safety case (incorporating a safety management system and emergency plans) to WorkSafe Victoria (WSV) for approval prior to operations (refer to Section 6.7 and Figure 6-1 and Section 7.6 and Figure 7-1).

The agencies responsible for providing regulatory approvals and oversight for safe operation of the FSRU, Jetty Infrastructure and the Crib Point Receiving Facility include:

- Energy Safe Victoria (ESV)
- Worksafe Victoria (WSV)
- Port of Hastings Development Authority (PoHDA).

The jetty is located on Crown land and leased by PoHDA. The operator of the Crib Point Receiving Facility and the Jetty Infrastructure, including the MLAs and gas piping mounted to the jetty, will be required to submit a safety case to ESV for approval prior to operations.

As part of the safety case, the operator will be required to comply with a safety management system to eliminate or minimise hazards to people and property (refer to Section 7.3).

To provide clarity for the relevant operators and regulators and to ensure continuity of safe operations at each stage of the process, management plans will be used to integrate comprehensive safety management systems as required under the nominated key legislation.

3.2 Pipeline Works

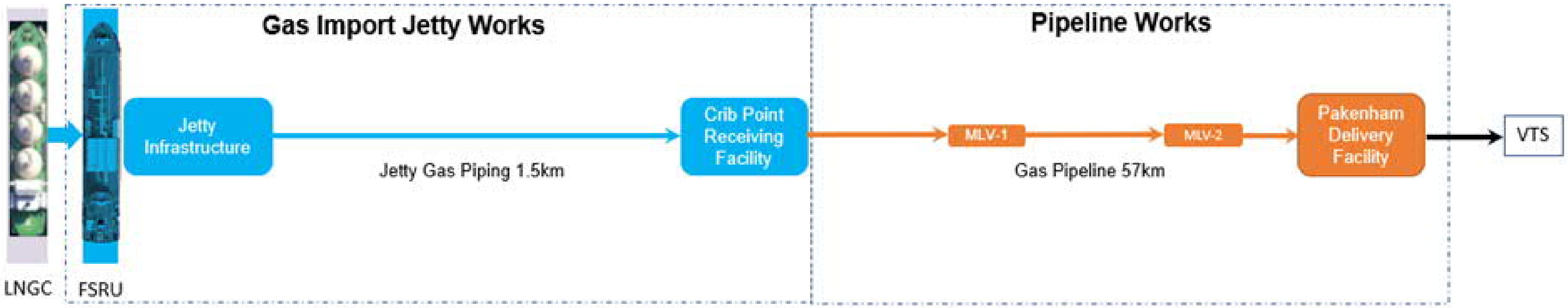
The agencies responsible for providing regulatory approvals and oversight of the Pipeline Works include:

- Energy Safe Victoria (ESV)
- Department of Environment, Land, Water and Planning (DELWP).

A Pipeline Licence will be required for the Pipeline Works under the *Pipelines Act 2005* (Vic) (Pipelines Act). Under the Pipelines Act, the following apply:

- The recipient of the Pipeline Licence has a duty to manage any pipeline operation to minimise, so far as is reasonably practicable, hazards and risks to the safety of the public arising from pipeline operation.
- A construction safety management plan must be prepared and accepted by ESV prior to any construction commencing
- An operational safety management plan must be prepared and accepted by ESV prior to any operation and maintenance commencing on the pipeline. The Pipeline Works will be operated in accordance with the approved safety management plans.

Further discussion on the regulatory framework for the Pipeline is provided in Section 8.3.



FSRU & LNGC in Port Area

Regulatory Body	Key Compliance Requirements
Australian Maritime Safety Authority (AMSA) Aviation and Maritime Security (AMS) PoHDA and Port of Hastings Harbour Master Victorian Regional Channels Authority (VRCA)	▪ Navigation Act 2012 ▪ Marine Orders 17, 32, 41 & 58 ▪ Marine Safety (DCV) National Law Act 2012 ▪ Marine Transport and Offshore Facilities Security Act 2003 ▪ Occupational Health and Safety (Maritime Industry) Act 1993 ▪ Maritime Transport and Offshore Facilities Security Act 2003 ▪ Port Management Act 1995 ▪ Marine Safety Act 2010 ▪ Harbour Master's Directions ▪ Port of Hastings Port Operating Handbook

Jetty Infrastructure & Crib Point Receiving Facility

Regulatory Body	Key Compliance Requirements
ESV WorkSafe Victoria PoHDA	▪ Gas Safety Act 1997 ▪ Gas Industry Act 2001 ▪ Gas Safety (Safety Case) Regulations 2018 ▪ SMS/Safety Case ▪ Occupational Health and Safety Act 2004 ▪ Occupational Health and Safety Regulations 2017 ▪ Port of Hastings Operating Handbook ▪ Port Management Act 1995

Gas Pipeline

Regulatory Body	Key Compliance Requirements
DELWP ESV	▪ Pipelines Act 2005 ▪ Pipelines Regulations 2017 ▪ ASNZS 2885 Pipelines – Gas and liquid petroleum ▪ Implement and maintain SMS - Licensee

Legend:

DELWP	Department of Environment, Land, Water and Planning
ESV	Energy Safe Victoria
FSRU	Floating Storage and Regasification Unit
LNGC	Liquified Natural Gas Carrier
MLV	Main Line Valve
PoHDA	Port of Hastings Development Authority
VTS	Victorian Transmission System

Figure 3-1 Summary of Regulators and Key Compliance Requirements

4.0 Methodology

A key objective of the Project is to minimise the risk to people that may arise from the construction or operation of the Project. To deliver against this objective requires a full understanding of the hazards and consequences that may occur during gas operation, including an understanding of the potential external threats.

A systematic, risk-based approach has been applied to understanding the potential impacts of the Project and how to avoid, minimise or manage the risk of impact to the workforce, nearby operations and the adjacent land users. The adoption of a risk-based approach and the assessment of hazards will be ongoing through the Project life cycle. Risk studies and hazard assessments will be ongoing. Studies already completed will be refined as the detailed design progresses.

The adoption of an iterative risk-based approach ensures continuous improvement in risk mitigation and risk management as part of providing assurance that the Project risks are being appropriately considered and reduced so far as is reasonably practicable (SFAIRP).

The approach taken to the risk assessments has been, and will continue to be, consistent with Australian/New Zealand Standard AS/NZS ISO 31000:2018 Risk Management Process and follows the guidance notes for the management and control and risks published by WSV.

The preliminary hazard assessments have been made with regard to the surrounding land use around the Gas Import Jetty Works and the Pipeline Works including the proposed operational workforce. These aspects are described in further detail in EES Technical Report L: *Land use impact assessment* and in EES Chapter 4 *Project description* respectively.

4.1 Overview

As part of the assessment of the process safety hazards and risks posed by the Gas Import Jetty Works and the Pipeline Works, AGL and APA have each undertaken a number of formal safety studies, hazard assessment workshops and risk assessments. The key findings from the principal risk reports and studies have been summarised in this report.

The safety, hazard and risk studies are ongoing. As areas of the design progress, these studies will be further refined as appropriate for the available design detail. This is the normal and accepted approach for projects of this nature.

The outcomes of these studies have been incorporated into the design elements for the Project and will form an integral part of developing safe operating practices for the Project to meet the objective of minimising risk SFAIRP by providing safe operations that meet community expectations.

The hazard and safety studies undertaken by the Project and the key outcomes of each are discussed under the respective Project elements. The risk assessment methodology adopted by the Project, including the use of a tolerable risk criteria is discussed further in the following sections.

4.2 Risk methodology

The EES scoping requirements for the Project require that a risk-based approach be adopted for assessment of the potential impacts of the Project. In accordance with this requirement, risk assessments have been carried out using an approach that is fully consistent with Australian/New Zealand Standard AS/NZS ISO 31000:2018 Risk Management Process.

The risk assessment process provides:

- a method for identifying key Project risks to inform where detailed investigations are required
- assurance that that the level of investigation is proportionate to the relative risk

- a means to access the effectiveness of proposed mitigation measures and whether additional measures may be required.

Risk is the product of the consequences arising from an event and the likelihood of the event occurring. The risk assessment process adopted for the Project involves the assignment of both consequence and likelihood ratings which when combined give an overall risk level for each identified hazard. The methodology for completing the hazard and risk analysis for the Project includes the following general steps:

- Identification of hazards – review of potential hazards and the associated impact that may occur based on previous data, experience or judgement.
- Consequence assessment – define the characteristic of identified potential hazards and the facility thresholds for each type of consequence (i.e. thermal radiation, flash fire, pool fire, vapour cloud explosion etc.)
- Likelihood analysis – define the probability of the identified potential consequence.
- Risk analysis –Compare the resultant risk against the Project risk criteria
- Determine risk mitigation and manage options to ensure risk is reduced SFAIRP.

Different methodologies have been employed to assess hazardous consequence and risk, as applicable for the differing aspects of the Project and the associated requirements for demonstration of risk minimisation, and compliance with the differing regulatory regimes. These differences are summarised below and explained in further detail in this section, and in Appendix A.

Quantitative Risk Assessment (QRA)

QRA is a technique used to systematically calculate the risks from hazardous events. It involves predicting the size of consequences associated with a hazard, and the frequency at which a release of the hazard may be expected to occur. These aspects are then combined in order to obtain numerical values for risk – usually risk of fatality. The technique is used to ensure that any hazards that may have far reaching effects pose minimal risk to the general public. Typically, these types of assessments are used in land use planning and provide numerical risk levels to relate the risks of an activity to other risks experienced in everyday life such as driving or air travel and have been assessed against the tolerable risk criterion for the Project. Quantitative Risk Assessments (QRAs) have been completed for the FSRU, the Jetty Infrastructure and the Crib Point Receiving Facility (the Gas Import Jetty Works) and the Pakenham Delivery Facility. These types of assessments are undertaken early in the design to determine whether the development can occur in the proposed location. Assessments are undertaken in accordance with the requirements of the NSW Government Hazardous Industry Planning Advisory Paper No. 6 Hazard Analysis (referred to as HIPAP 6).

Further discussion of the QRA process and methodology used to estimate the level of risk to adjacent land users is provided in Appendix A.

Safety Management Study (SMS)

This is a specific semi-quantitative assessment undertaken to consider the location specific threats to integrity of a buried pipeline and is used solely for the pipeline. It is used to ensure that the pipeline design is appropriate for the Project conditions, i.e. the terrain that the pipeline passes through and the fluids it contains. This study is in accordance with AS 2885 and the requirements of the Pipelines Regulations 2017. The SMS is described in more detail in Section 8.6.

Formal Safety Assessment (FSA)

This assessment is an identification of hazards having the potential to cause a gas incident (or major incident), a systematic assessment of risk including the likelihood and consequences of the incident; and an assessment of the adequacy of the technical and other measures undertaken, or to be undertaken, to minimise that risk SFAIRP. The FSA information can be drawn from other studies undertaken during the design development of the facilities. An assessment for gas incidents is a requirement of the Gas Safety (Safety Case) Regulations and as such will be undertaken for the jetty gas piping, the Crib Point Receiving Facility and the entire length of the gas pipeline including the

Pakenham Delivery Facility. In addition, a similar assessment of major incidents will be undertaken for the FSRU, as the inventory of LNG held on board would have triggered the Victorian Occupational Health and Safety Regulations 2017 if the inventory was located onshore.

Qualitative and semi-quantitative studies

These consist of a number of differing assessments to identify the aspects of risk to health and safety to demonstrate how those risks will be reduced SFAIRP. The safety assessment process also involves an investigation and analysis of gas or major incident hazards, the outcome of which provides a deeper understanding of the aspects of risk to health and safety associated with the Project. Completed studies include Hazard Identification (HAZID); and Hazard and Operability (HAZOP) studies on the preliminary design for the Gas Import Jetty Works and the Pipeline Works, along with a Fire Safety Study for the jetty gas piping and the Crib Point Receiving Facility. The timing and scope of these studies are dealt with in Sections 6.0, 7.0, and 8.0.

The risk studies and workshops have been formally facilitated by recognised technical specialists and consultants from industry and have included relevant Project stakeholders. The detailed methodology for the various safety assessments used during Project development are included as Appendix A.

4.3 Inherent safety in design

To ensure inherent safety and the SFAIRP principle is effectively implemented, a mechanism to ensure that all possible inherent safe design measures are introduced early into the Project (where possible) and are demonstrated to be SFAIRP has been developed.

As part of the process a basis of design has been prepared to ensure specified design requirements and safety performance standards are achieved. Traceable records of design validate conformance with regulatory requirements, industry standards and sound engineering practice.

The design of the FSRU is in accordance with the latest DNV GL[1] class, and flag state rules and AMSA requirements. Project procedures follow a systematic approach to planning, controlling and verifying the design, and ensuring adequate traceability. Design and construction activities that have been and will be undertaken in accordance with the requirements of this methodology to eliminate or reduce design, construction and commissioning risks have included:

- risk assessment workshops and QRA
- HAZOPs and Safety Integrity Level (SIL) assessments
- layout reviews
- Layers of Protection Analysis
- construction hazard identification workshops.

Other matters that have been addressed include:

- competency of design personnel
- exchange of information across technical and company interfaces
- ensuring risk reduction measures are incorporated at the design phase
- reviewing design changes as part of the overall risk management process.

[1] DNV GL is a pre-eminent global verification, inspection and risk management provider to the oil and gas industry. It has unrivalled technical experience in the global development of FSRUs and onshore terminals and has been involved in more than 40 FSRU projects globally.

4.4 Requirements for demonstration of so far as is reasonably practicable (SFAIRP)

Industrial activities can never be entirely free from risk and so many companies and regulators around the world require that safety risks are reduced to acceptable levels. The key question then is what level of risk is considered to be low enough.

The completion of formal safety studies is necessary as a demonstration of adequacy that risks have been identified, assessed and mitigated SFAIRP. This overarching requirement is outlined in WSV Guidance Note *Requirements for demonstration, April 2011* which provides advice to operators of major hazard facilities on how to demonstrate an ability to operate a facility safely.

Of key consideration is whether the risks introduced by the Project are *disproportionate* to the level of risk normally experienced. While the facilities may not constitute an MHF, the overarching principles relating to demonstrating that risks have been identified and mitigated SFAIRP nonetheless apply.

The SFAIRP process is required to assure the Project proponent that the level of risk has been reduced SFAIRP given the benefits of undertaking the activity. Risk can be considered in terms of people (safety), the environment, financial loss and/or company reputation. These may all have a bearing on determining whether a given risk is SFAIRP. This principle recognises that no industrial activity is entirely free from risk, and that there remains a level of risk where the cost (i.e. fiscal value, operability, etc.) of additional risk reduction measures is grossly disproportionate to the risk reduction achieved. This is reflected in the risk criteria adopted for the QRA that is defined in Section 4.5 below.

The SFAIRP principle considers:

- The nature and level of the risks assessed. The assessment of the risks needs to be based on the best available evidence and advice.
- That the residual risks are not unduly high.
- That the risks are periodically reviewed to ensure that they still meet the SFAIRP criteria, for example, by ascertaining whether further or new control measures need to be introduced to consider changes over time, such as new knowledge about the risk or the availability of new techniques for reducing or eliminating risks.

Demonstration of SFAIRP includes:

- systematically identifying and assessing all the hazards and potential major incidents associated with the facilities
- assessing the effectiveness of the controls in place and determine whether the controls are adequate and justify why any additional controls were not included
- identifying potential upgrades to existing controls or additional controls that could be implemented
- implementing risk reduction measures if it is reasonable and practicable to do so
- ensuring that design processes consider inherent safety and the hierarchy of controls
- identification of systems that are critical to the safety and development of their performance standards to ensure the effectiveness of controls to minimise the risk of a major incident
- The development and maintenance of safety management systems for the facilities that are linked to those controls and include:
    - ongoing monitoring of the facility integrity
    - contractor selection and management processes to manage interfaces with any third parties required to perform work at the facility
    - the development and testing of a comprehensive emergency response plan

  - operational controls, training and competency of operational staff
- that relevant regulations, codes, standards and industry guidelines have been identified and are being met
- that the Facility Operators' policies, procedures, guidelines and standards are being met and are reflective of current industry good practice
- that a consultation process has been followed and that risks associated with the operation of the facilities have been effectively communicated with stakeholders.

4.5 Use and Limitations of QRA

Quantitative approaches to assessing risk allow for a more precise and consistent approach to defining the likelihood, consequence and resultant severity of a major incident. It is recognised by regulators across jurisdictions that the results from a QRA may be used with a pre-determined criteria for comparing different options, as part of a demonstration of adequacy. These criteria may in principle be applied to any exposed population, on-site or off-site, although for a variety of reasons the actual levels of risk tolerability may vary between the different exposed groups.

Risk tolerability values for individuals exposed to major incident hazards should relate in a sensible manner to levels of risk from other industrial and non-industrial activities. Most established criteria relate specifically to fatality rates, but the regulations do not require any specific form of criteria

In the case of off-site risk to the general population, a set of 'interim' criteria have been used in a number of safety cases in Victoria, e.g. in relation to land use planning (Interim Victorian Risk Criteria – Risk Assessment Guidelines, prepared for the Altona Chemical Complex and the Victorian Government, by DNV Technica, October 1988). The criteria do not have legal status but provide guidance on values. WorkSafe Victoria (2011) references these criteria and states that they are a general guide to operators to evaluate their approach to risk reduction.

4.5.1 Limitations of QRA

The results from the QRA can vary significantly depending on the assumptions used in the risk calculations. These assumptions are particularly influential to the consequence analysis of loss of containment events including the calculation of the gas cloud size and the calculation of the thermal radiation that may be generated from an ignited release.

The assumptions used in the interim QRA for the Project have been fully documented in an assumptions register. The study boundaries and assumptions include assumptions in the following key areas:

- dispersion
- discharge rate
- jet fires
- pool fires
- fireballs and Boiling Liquid Expanding Vapour Explosions (BLEVEs)
- flammability
- explosions
- pool vaporisation
- toxicity
- weather
- event tree probabilities
- human vulnerability.

The assumptions are based on industry data and site-specific information and studies.

4.6 Establishing tolerable risk criteria

Risk criteria are standards used to translate numerical risk estimates, e.g. risk of fatality of 10^{-6} per year, as produced by a Quantitative Risk Assessment (QRA), into value judgements such as 'negligible risk' that can then be set against other value judgements in the decision-making process.

In the undertaking of the hazard identification, safety studies and risk assessments, the Project has considered both the qualitative and quantitative aspects of the risks.

The general principles adopted by the Project with respect to risk are:

- risk from a hazardous facility should be reduced wherever practicable, even where the risk of likelihood of exposure is low
- effects of significant events should, wherever be possible be contained within the site boundary.

Of specific consideration are the off-site risks and whether the risks to the surrounding land users, including the public, are disproportionate to the level of risk they would normally experience.

With respect to safety hazards, the principal risk criteria considered by the Project arising from a potential major incident are:

- risk of fatality to people
- risk of injury to people
- the risk of property damage.

To establish a threshold of tolerable risk, the Project has adopted the recommendations outlined in NSW Hazardous Industry Planning Advisory Paper No.4 (HIPAP 4). This publication provides suggested quantitative values of individual risk criteria for fatality, individual risk criteria for injury and criteria for property damage. The values presented in HIPAP 4 are implemented by jurisdictions in Australia, including Victoria, to assist in assessing if a risk is proportional and tolerable to that which would normally be experienced.

QRA studies have been used to estimate the risk to adjacent land users. The resultant outputs of the QRA studies have been compared against the set of generally accepted tolerability (or acceptance) criteria outlined in HIPAP 4. In the case of fatality risk, the HIPAP 4 criteria differentiate between the different types of land use, recognising the fundamental need to protect the more vulnerable members of the community from the consequences arising from potential major incidents.

Where the estimated quantitative risk has been assessed as being at or below the risk levels outlined in HIPAP 4 for a specific land use, it is generally considered that the hazard does not represent a disproportionate risk to adjacent and nearby land users.

The HIPAP 4 suggested values for risk tolerance are provided in Table 4-1.

Table 4-1 Location specific individual fatality risk tolerance criteria from HIPAP 4

Land Use	Risk of fatality (per million years) Tolerance Criteria	Risk of fatality (per annum) Tolerance Criteria
Hospitals, schools, child-care facilities, old age housing	0.5	5E-07
Residential, hotels, motels, tourist resorts	1	1E-06
Commercial developments, retail centres, offices, entertainment spaces	5	5E-06

Land Use	Risk of fatality (per million years) Tolerance Criteria	Risk of fatality (per annum) Tolerance Criteria
Sporting complexes and active open spaces	10	1E-05
Industrial	50	5E-05

4.7 Operational control

Safety Management Systems will be developed for each Project operator and used as the primary means of ensuring safety during the operational phase. The Safety Management Systems will comprise all policies, objectives, roles, responsibilities, accountabilities, codes, standards, communications, processes, procedures, tools, data and documents for managing safe operation of the facilities and adopted control measures. Elements of the Safety Management System control measures to ensure safe operation may include:

- safety policies and objectives
- resourcing, including roles and responsibilities
- process and procedures for operating and maintaining plant and equipment, including mechanical integrity of critical assets
- training requirement
- management of change
- performance standards
- design and construction standards and procedures
- process control and automation systems
- physical engineered devices which eliminate, reduce or mitigate major incidents
- operations/maintenance procedures needing to be performed to maintain safe operations
- monitoring, audits and reviews to ensure compliance with the Safety Management System

The Safety Management Systems will be developed from findings throughout the Project lifecycle including any actions and findings from safety studies.

The FSRU is required to have an integrated fleet Safety Management System in compliance with the International Safety Management (ISM) code by the International Maritime Organization (IMO). The Safety Management System would be developed for the FSRU such that it would meet the requirements of both international and Australian regulatory requirements.

5.0 Hazard Identification

This section includes a discussion on the hazards and potential impacts associated with the Project. Not all hazards identified below are applicable to all components of the Project. The relevant hazards to each element of the Project are identified further in Sections 6.0, 7.0 and 8.0.

5.1 Operational hazards and impacts

5.1.1 Hazardous materials and impacts

The Project will introduce the bulk storage and distribution of hazardous materials, of sufficient volume to have the potential for off-site consequences.

For the purpose of the hazard identification, safety studies and risk assessments the predominant hazardous materials of interest are liquified natural gas (LNG), natural gas (NG); odorant (stenching agent) and liquefied nitrogen (LIN). The dangerous good classification, hazard, location and estimated quantities of materials being introduced by the Project are listed in Table 5-1.

LNG and NG are flammable, and the predominant risk associated with the storage and distribution of flammable gases and liquids is the unplanned release with subsequent ignition leading to a fire or explosion. Fire and explosion risk represents the greatest potential for off-site impact.

The hazards associated with the storage and distribution of the flammable materials are discussed under each of the respective Project elements.

In addition to the flammability risks, the bulk storage of liquified gases presents both a cryogenic burn risk and an asphyxiation risk to people handling or working in the vicinity of where these are stored.

The *Dangerous Goods Act 1985* (the DG Act) allows for the licensing for the storage, handling and distribution of dangerous goods. A licence for applicable facilities would be issued by WSV. The DG Act applies to the onshore facilities only, and as such the FSRU itself would not be required to hold a DG licence under the DG Act.

Table 5-1 Dangerous Goods introduced by Project

Material	DG Class	HAZCHEM Code	Hazard	Location	Estimated Quantity
LNG (Liquified Nat. Gas.)	2.1	2WE	• Flammability • Cryogenic	FSRU storage	170,000 m^3
NG (Nat. Gas)	2.1	2SE	Flammability	• Jetty Infrastructure • Crib Point Receiving Facility • Pipeline • Pakenham Delivery Facility	1764 kilo standard cubic metres (kscm) in storage (in pipeline)
Odorant	3	3WE	Flammability	Crib Point Receiving Facility	40 m^3
LIN (Liquid Nitrogen)	2.2	2T	• Cryogenic • Asphyxiant	Crib Point Receiving Facility	3000 tonnes (3717 m^3)

The operational hazards and risks and the safe handling and storage practices associated with both liquified natural gas and natural gas are well established in Australia and internationally.

Leaks or a loss of containment may occur due to failures of pipe work, flanges, valves and failures of pressure vessels. Immediate or delayed ignition can occur from nearby work activity, naked flames, static electricity, hot surfaces or faulty electrical equipment.

A release of hydrocarbons can potentially lead to fire and explosion scenarios and constitute a major incident. The operational hazards resulting from a release of flammable gas with subsequent ignition leading to a fire or explosion represent the highest potential consequence.

The prevention of major incidents has been the primary focus of the hazard analysis, risk assessments and safety studies completed by the Project.

Fire and explosion risks represent the highest consequence impacts for the Project and in this context, the hazard analysis and risk studies have considered exposure to the following incident events each of which are discussed briefly in the following section:

- jet fires
- pool fires
- flash fires
- vapour cloud explosions
- rapid phase transition.

Within an FSRU the LNG is stored in bulk storage tanks, within the cargo holds of the vessel at close to its vaporisation temperature, being approximately -163°C. Any boil-off gas is collected and used by the vessel as fuel or as send out gas. Pressure relief valves are set to only allow a very low net positive pressure. Smaller releases of LNG discharged from height, due to boil-off, will vaporise before reaching the ground level (or sea surface), due to heat transfer with air and from the outer face of the containment vessel.

Additional risks introduced by the Project include cryogenic burn risk and asphyxiation risk associated with liquified gases and electrical risks from contact with exposed live conductors.

The potential effects from LNG releases are discussed further in Appendix E.

5.1.2 Fire and explosion risks

A release of liquified natural gas will form a vapour cloud that disperses in the atmosphere. A portion of the cloud would likely be flammable, giving rise to the possibility of ignition.

The ignition of a gas or liquid release can produce a jet or pool fire resulting in damage to unprotected equipment and present hazards to people from thermal radiation exposure. In addition to the flammability risks, LNG presents a cryogenic hazard potentially causing embrittlement of steel structures with the potential for frost burns to people through direct exposure.

Natural gas has a high energy content compared to other fuel sources making it ideal for a variety of domestic and commercial applications. Natural gas is odourless, non-toxic and non-corrosive. It has flammability range of 5 to 15 per cent by volume in air. It is important to minimise leaks and the control and management of ignition sources near to or in the presence of natural gas is an important safety aspect of the facility design.

The odorant used at Crib Point consists of >60% tetrahydrothiophene (CAS No. 110-01-0) and 20-40% tert-butyl mercaptan (CAS No. 75-66-1).

Jet and pool fires

For jet and pool fires, there is the potential for personnel injury (and potentially fatality) due to exposure to elevated levels of radiant heat. Where not directly exposed, radiant heat impinging on an egress route may prevent personnel from safely escaping a fire event.

The following heat flux impairment criteria, adopted from HIPAP 4 and AS/NZS2885.6, have been used in the fire safety studies; pipeline SMS and QRAs:

- 4.7 kilowatt per square metre (kW/m^2) for personnel impairment where exposure to this level of radiant heat will cause injury, at least second degree burns, after 30 seconds of exposure
- 12.6 kW/m^2 represents the threshold of fatality, for normally clothed people, resulting in third degree burns after 30 seconds of exposure
- 35 kW/m^2 has been used for structural impairment. Structural steel failure may occur at radiant heat levels above 35 kW/m^2.

Flash fires

Flash fires are assumed to pose risk to personnel; however, these burn for an insufficient duration to cause structural damage. The flash fire envelope is taken to be the distance to the Lower Flammable Limit (LFL) for any vapour cloud that may have formed from a release of hydrocarbon. The basis for impairment is the onset of fatality from exposure to radiant heat from contact with a flame front burning back to its source. Any contact with a moving flame front is assumed to generate sufficient radiant heat to ignite clothing resulting in the potential for a fatality.

Explosions

Vapour cloud explosions may occur as a result of delayed ignition of flammable material in a confined area. Overpressure modelling has been undertaken by the Project to determine the potential for injury and fatalities as a result of:

- direct exposure to overpressure
- building damage.

The following overpressure impairment criteria, adopted from HIPAP 4, have been used in the fire safety study; pipeline SMS and QRAs.

- 7.1 kilopascals (kPa) (outdoor exposure to overpressure) – ear drum loss
- 14kPa (indoors – side on overpressure for structural failure) – fatality risk from building collapse
- 35kPa (outdoors exposure to overpressure) – possible fatality.

Rapid Phase Transition

When the LNG pools on sea water, the heat input available from the water is such that the LNG can undergo and series of rapid vaporisations as physical explosions. These are known as rapid phase transitions or RPTs.

RPTs will result in surges in the rate of vaporisation from an LNG spill following each RPT. While an RPT is a physical explosion, the over-pressure resulting from these phenomena is not of the same magnitude as a chemical explosion (such as from ignited pressurised LPG or from construction explosives) and is unlikely to damage a ship's large structural elements.

5.1.3 Electrical hazards

The Project would not introduce any unique electrical hazards that are not already experienced as part of the proponent's normal operations. The electrical hazards associated with the Project arise from the accidental contact with live electrical conductors with the potential for injury and fatality.

Mitigations

- The risk from contact with live exposed electrical conductors during operation of the Jetty Infrastructure, pipeline and the pipeline facilities at Crib Point and Pakenham would be managed through compliance to the requirements from Energy Safe Victoria under the *Electrical Safety Act 1998*.
- The design and operation of the Jetty Infrastructure, pipeline and the pipeline facilities at Crib Point and Pakenham will be in accordance with *Electrical Safety Act 1998* and the Electrical Safety (General) Regulations 2019.
- The installation and operation of all electrical equipment associated with the Jetty Infrastructure, pipeline and the pipeline facilities at Crib Point and Pakenham will be accordance with AS/NZS3000 *Wiring rules*.
- The FSRU would not fall under the purview of the *Electrical Safety Act 1998* and the Electrical Safety (General) Regulations 2019. The vessel would be designed, operated and maintained to an international set of standards. The risk from contact with live exposed electrical conductors during operation and maintenance activities on board the FSRU would be managed through compliance to the Rules for Classification as described in Section 6.0.

5.1.4 Cryogenic liquid hazards

Cryogenic liquids are liquefied gases that are kept in their liquid state at very low temperatures. These liquids have boiling points below -150ºC and are gases at normal temperatures and pressures. Different cryogens become liquids under different conditions of temperature and pressure, but all have two common properties: they are extremely cold and small amounts of the liquid can expand into very large volumes of gas.

Liquified natural gas and liquid nitrogen are cryogens. The risk of cryogenic burns and asphyxiation from large releases has been assessed as part of the facility HAZID and control measures have been put in place to address the risk. These include containment; pressure relief and leak detection equipment. Personnel will be required to comply with all personal protective equipment (PPE) requirements.

The storage and handling of liquid nitrogen at the Crib Point Receiving Facility will be subject to regulatory approval from WSV under the *Dangerous Goods Act 1985* and Dangerous Goods (Storage and Handling) Regulations 2012. The key hazards associated with cryogens is listed below.

Extreme cold hazard

Cryogenic liquids and their associated cold vapours and gases can produce effects on the skin similar to a thermal burn. Brief exposures that would not affect skin on the face or hands can damage delicate tissues such as the eyes. Prolonged exposure of the skin or contact with cold surfaces can cause frostbite. Unprotected skin can stick to metal that is cooled by cryogenic liquids. The skin can then tear when pulled away. Even non-metallic materials are dangerous to touch at low temperatures. Prolonged breathing of extremely cold air may damage the lungs.

Asphyxiation hazards

When cryogenic liquids form a gas, the gas is very cold and usually heavier than air. This cold, heavy gas does not disperse very well and can accumulate near the floor. Even if the gas is non-toxic, it displaces air. When there is not enough air or oxygen, asphyxiation and death can occur. Oxygen deficiency is a serious hazard in enclosed or confined spaces.

Small amounts of liquid can evaporate into very large volumes of gas. For example, one litre of liquid nitrogen vaporizes to 695 litres of nitrogen gas when warmed to room temperature (21°C). LIN will be purchased from third parties and transported via road tanker to the Crib Point Receiving Facility. Further details on LIN facility at Crib Point are in Section 7.2.3.

LIN is inert, colourless, odourless, non-corrosive, non-flammable, and extremely cold. Liquid nitrogen has a boiling point of -195.8^{o} C. Vaporisation will occur in the event of a leak and a large leak will produce large amounts of gas.

Nitrogen comprises approximately 79 % of the air and is non-toxic and inert. However, it can act as an asphyxiant by displacing oxygen in air to levels below that required to support life. Inhalation of nitrogen in excessive amounts can cause dizziness, nausea, vomiting, loss of consciousness, and death. Death may result from errors in judgment, confusion, or loss of consciousness that prevents self-rescue. At low oxygen concentration, unconsciousness and death may occur in seconds and without warning.

Heat flux into the cryogen from the environment will vaporize the liquid and potentially cause pressure build-up in cryogenic containment vessels and transfer lines. Adequate pressure relief must be provided to all parts of a system to permit this routine out gassing and prevent explosion.

Mitigations

Personnel would be thoroughly familiar with the properties and safety considerations of liquid nitrogen before being allowed to handle liquid nitrogen and/or its associated equipment. Handling of liquid nitrogen would only be carried out by suitable competent personnel wearing appropriate PPE.

The recommended PPE when handling or using liquid nitrogen would be implemented including a full face shield over safety glasses/goggles; loose-fitting thermal insulated gloves; and long-sleeved shirts and pants without cuffs. In addition, safety shoes will be required for those involved with the handling of liquid nitrogen containers.

5.2 Construction hazards

AGL's commitment in their Health, Safety and Environment (HSE) Policy provides 'To conduct our business in a way that prevents harm to our people, our customers and the community, and minimises our impact on the environment'.

AGL's HSE governance processes includes a qualitive analysis of construction contractors' performance capabilities which includes evaluation of the contractor's safe systems of work to manage risk.

As part of AGL's contract requirements, HSE performance expectations are set with contractors, including requirements to undertake HSE Risk Workshops in accordance with AS/NZS ISO 31000:2018. Discussions of construction hazards relevant to public safety would be considered as part of the studies during different phases of construction.

The APA HSE Policy states that *all employees, including contractors, have an obligation to look after the safety of those who may be affected by their actions*. This obligation extends to the safety of the public.

The construction phase of the Pipeline Works will be managed under a Safety Management Plan (SMP) to ensure a structured safety management system is implemented to achieve a consistently high standard of safety performance. This SMP is a requirement of the *Pipelines Act 2005* and addresses APA's general duty, as pipeline licensee, to minimise the risks to public safety that arise from pipeline construction.

During construction, the public and the workforce would be exposed to hazards routinely experienced in the construction of major infrastructure. While the Project is not introducing any new or unique construction hazards that are not already encountered on all major infrastructure projects, there are nonetheless a range of hazards that will require mitigation during construction. These include, but are not be limited to, the following:

- Public safety:
  - controlling unauthorised access to construction sites
    - excavation hazards
    - moving plant and machinery
    - falling objects from elevated workers or crane assisted lifts
  - vehicle movements on public roads and at site access points
  - modified road access and crossings
  - noise and dust
- Workforce safety:
  - working in the vicinity of moving equipment and vehicles
  - working at heights
  - falling objects from elevated workers or crane assisted lifts
  - exposure to electrical hazards
  - excavation hazards
  - hazards associated with welding activities, such as fumes
  - noise and dust
  - confined spaces
  - working overwater during Jetty Infrastructure installation and construction.

Below is a summary of the hazards that have been identified during the construction stage and a high-level summary of the potential impacts on the workforce and the public.

- Construction of the Crib Point Receiving Facility and Jetty Infrastructure would include relocation of utility services and service connections. Scaffolding structures would be installed on the jetty to provide access to relevant work areas. These would present a risk of falling objects; collapse risk for scaffolding and introduce working at heights hazards for workers.
- Vehicles would facilitate delivery of materials during construction. Moving vehicles and an increase in traffic movement presents a risk to the workforce and the public.
- Major structural elements for the Jetty Infrastructure, including the MLAs, fire towers and fire pumps would be delivered to a local port and unloaded directly onto a material barge for transportation to the Jetty. These activities would introduce lifting hazards; falling object hazards and the hazard of collision between material barges and either the jetty or passing ships.
- Some sections of pipeline construction would be undertaken via trenchless HDD. Construction is likely to be conducted seven days per week, 24 hours per day from commencement of reaming in order to maintain HDD section stability.
- Additionally, some sections of pipeline construction would be via open trench cut and cover method. This would create the risk of trench collapse, entry to confined spaces; engulfment and the risk of injury from mechanical plant.

Mitigations

Measures to mitigate construction hazards to the public and project workforce would be outlined in the various management plans to be prepared by the selected contractors for the project. These would include plans such as a Construction Management Plan (CMP) or equivalent, Environmental Management Plan (EMP), Traffic Management Plan (TMP) and various Safety Management Plans (SMP).

The CMP and SMP would outline detailed measures for protection of the public and workforce from the type of hazards outlined above. Construction areas and laydown yards would be adequately segregated and secured, preventing access to the public. This may include, but is not limited to, fencing, barricading and barriers, and/or signage depending on the location.

The EMP would outline management and mitigation measures for other elements of potential construction risk. For example, the EMP would require implementation of the environmental risk management approaches to control dust (see EES Technical Report G: *Air quality impact assessment*) and noise (EES Technical Report H: *Noise and vibration impact assessment*). Construction equipment and workforce transport requirements would be subject to a Traffic Management Plan (TMP). This plan would set out the requirements for managing vehicle and equipment movements on public roads and at site access points. The TMP would also manage risk to the public where there are modified road access/conditions/crossings. Management measures may include signage, speed restrictions and traffic control depending on the location, the activity and the identified site-specific hazards.

The workforce would travel to site from pre-existing accommodation in Hastings and other nearby towns. They may travel independently, share vehicles or be transported via bus where possible.

The Pipeline Works would be staged and sequential, limiting the duration of local construction works and land use impacts across individual properties and minimising the footprint for construction risk exposure to the general community.

Piping required for the Pipeline Works would be stockpiled at nominated locations to be finalised as part of the Construction Management Plan. APA would enter into an agreement with landholders for the establishment of construction laydown areas. That property would be returned to the landholder after construction is complete.

The pipeline alignment travels through properties where an existing infrastructure corridor and easement is available to be leveraged. In cases where there is a lack of such corridors, the pipeline alignment generally travels around property boundaries.

The gas transmission pipeline and its construction would be subject to regulation by ESV. The FSRU and associated infrastructure (Gas Import Jetty Works) would be regulated by WSV.

Refer to EES Technical Report L: *Land use impact assessment* for further discussion on the impact that the construction of the Project elements would have on the surrounding land use and amenities.

6.0 Gas Import Jetty Works – FSRU

6.1 Overview

This section refers to the FSRU component of the works, with the Jetty Infrastructure and Crib Point Receiving Facility components discussed in Section 7.0. Salient points of the FSRU are:

- The FSRU is a registered sea-going vessel that includes cryogenic storage tanks and a topside regassification processing unit that is used for LNG vaporisation and gas export.
- The vessel will be assigned a class notation by DNV GL attesting to its compliance with an internationally recognised set of design; safety and operational standards.
- The FSRU would receive LNG from visiting LNG carriers that would pull alongside and be moored to the FSRU during the cargo transfer period. The transfer of LNG from the LNG carrier to the cryogenic storage tanks on the FSRU may take up to 36 hours depending on cargo size. The transfer would be carried out using purpose designed flexible cryogenic hoses. Once the transfer is complete the LNG carrier would leave port.
- The FSRU would store approximately 170,000 cubic metres (m^3) of LNG in a series of cryogenic storage tanks. The FSRU would convert LNG from a liquid state to a gaseous state by warming the LNG, a process known as regasification.
- Following regasification, the natural gas would be transferred from the FSRU to the Crib Point Receiving Facility via a ship manifold; MLAs and approximately 1500 metres of dedicated jetty piping.

FSRUs and LNG carriers operate around the world without significant incidents. LNG carriers also operate in Australia. It is reasonable to state that the selected FSRU arrangement would be safe to operate at Crib Point Jetty due to the following:

- The vessel would be designed and operated to recognised international standards (Refer Section 6.2)
- The vessel would carry:
  - a Safety Management Certificate or interim safety management certificate – which certifies compliance with the ISM (Refer Section 6.4.2)
  - an International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk (Refer Section 6.4.2)
  - Class Notation issued by a globally recognised classification society (Refer Section 6.2)
- A safety case would be developed consistent with the requirements of an MHF (Refer Section 6.4.1)
- Regulatory oversight would be provided by AMSA and WSV (Refer Section 6.4)
- Safety studies have been carried out relevant to the FSRU (Section 6.5 and Section 4.0 (Methodology)) and QRA (Refer Section 9.0 and Appendix A)
- The FSRU would be owned and operated by an experienced FSRU operating organisation.

6.2 Design and operation

The FSRU proposed for Crib Point would be issued a Class notation (classification) by DNV GL. The Classification system has gained worldwide recognition as a demonstration that an adequate level of safety and quality has been implemented in the design, construction, operation and maintenance of the vessel.

The vessel selected for the Project has been built and tested under the survey of DNV GL and would be routinely inspected by DNV GL while in operation in line with the requirements for the retention of its classification.

Classification attests to the vessel and process units being designed and operated in accordance with a prescribed set of DNV GL rules and engineering standards. Classification covers both the ship and the topside LNG regasification unit. Any modifications or changes to the vessel would require re-certification from DNV GL.

The Rules for Classification set out the technical and procedural requirements related to obtaining and retaining a Class Certificate throughout the lifetime of the vessel and stipulate the following requirements:

- design, construction, survey and testing of vessels
- design and testing of structures, materials, machinery, systems and equipment
- IMO conventions, standards and codes to be adopted.

In general, the rules and standards cover the requirements for:

- availability of Main Functions and the safety of installations supporting the Main Functions
- the structural strength and integrity of essential parts of the unit's hull and its appendages
- the safety of machinery, systems and equipment supporting non-Main Functions that constitute possible hazards to personnel and unit
- safety levels and availability beyond that of Main Class, including special equipment and systems such as Regasification units.

Rules for Classification of Ships, Part 6 Chapter 30 covers the Rules for Classification for Regasification. This came into effect in July 2013. Vessels built according to these rules will be assigned a class notation REGAS. The rules for REGAS class notation cover the following areas:

- Design Standards
- General Safety requirements
- Process Safety requirements
- Safety interlocks and safeguards
- LNG Loading operations
- Natural Gas Offloading operations
- Inspection and testing.

Class would be maintained during the operational life of the vessel conditional on all applicable requirements as part of the class notation being observed and regular surveys being carried out. Retention of Class is confirmed through annual endorsements and renewal of the Class Certificate at five-yearly intervals.

Initial Dynamic Mooring Analysis (DMA) and ship simulations have been completed in conjunction with VRCA and PoHDA. These will be finalised during detailed design to ensure efficient, sustainable and safe mooring operations of the FSRU and LNG carrier.

The ship to ship (STS) transfer of LNG from the LNG carrier to the FSRU is managed by the FSRU operator. The FSRU operator has comprehensive and detailed operational procedures in order to safely and efficiently conduct STS operations. These operational procedures are developed from the Society of International Gas Tanker and Terminal Operators (SIGTTO) and the Oil Companies International Marine Forum (OCIMF) guidelines, rules, regulations and industry best practice.

6.3 Industry safety record

Worldwide, LNG facilities have an excellent safety history. This includes the processing plants, marine terminals and LNG shipping. LNG has been produced and transported for over 50 years in increasing quantities. The excellent safety record is due mainly to competent, technically trained professionals, a thorough and detailed LNG design process, multiple risk studies for LNG plant design, controlled construction and operation and decommissioning, stringent regulatory bodies and regulations.

Over the last 50 years, LNG ships have covered more than 205 million kilometres without a major accident and with no collisions, fires, explosions or hull failures resulting in a loss of containment in ports or at sea. None of the spills resulted from a failure or breach of a containment system. LNG carrier spills have never resulted in loss of life (Centre for Energy Economics, 2012).

6.4 Regulatory Framework for FSRU

6.4.1 Overview

The safety requirements that apply to vessels that are part of the Gas Import Jetty Works would require a number of regulators to oversee those requirements. AMSA is the primary regulator for the FSRU, however it is envisaged that WSV would co-regulate the safe operations on the FSRU. AMSA would also be involved to some degree for certain operational activities, including the LNG carriers.

To ensure the safe operation of the FSRU whilst continuously moored, the health and safety of relevant personnel and public safety generally, it is proposed that:

- the existing Memorandum of Understanding (MoU) between WSV and Australian Maritime Safety Authority (AMSA) be varied to expressly contemplate regulation of the FSRU
- the FSRU will be assessed in a manner that is consistent with the requirements of an MHF under Chapter 5.2 of the existing OHS Regulations 2017 (Vic) (OHS Regulations) in recognition of the importance of ensuring the safety hazards and risks are appropriately assessed and managed
- management plans will be used to link safety management systems, plans or similar to interface between and assist the parties and various regulators.

To further ensure the highest safety standard are applied, DNV GL have conducted a preliminary QRA for hazards and risks associated with all modes of the FSRU including but not limited to:

- marine operations (approach and mooring) for the FSRU, LNG carrier and Petroleum tankers
- gas operations at Crib Point Jetty including gas send out from the FSRU, MLAs, STS transfer and interaction with United operations
- interactions (simultaneous operations) with external factors such as pipeline facilities and United Petroleum Pumping station.

6.4.2 Port maritime requirements

The FSRU would be a foreign flagged vessel, appropriately certified under international maritime law and subject to port state control inspection by AMSA under the *Navigation Act 2012* (Cth.) and Marine Orders issued under that Act.

A principal requirement of the Navigation Act and Marine Orders is that the FSRU must hold the applicable international maritime certificates, including:

- a Safety Management Certificate or interim safety management certificate – which certifies compliance with the ISM Code, a key requirement of which is that the FSRU implement and maintain a safety management system that ensures that the vessel and its operations are safe by identifying the hazards and risks in an operation; the procedures that the owner, the master and crew plan to implement to reduce those risks; the processes by which the owner, the master and

crew identify new risks, and the procedures the owner, the master and crew will follow if an incident occurs

- an International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

The VRCA and the Harbour Master would have a key role in regulating the safe movement of the FSRU, safety at berth for the FSRU, and for the arrival and departure of LNG carriers in Port and the transfer and delivery of LNG from and between these vessels. The FSRU's permanently moored operations, other operations at port and the arrival and departure of LNG carriers will be conducted within the safety legislation framework of the *Marine Safety Act 2010* (Vic). Relevant to the use of port waters shared with other users, that act imposes safety duties on participants in marine activities. The Port of Hastings Development Authority as port manager must have a safety and environment management plan with measures to be implemented to eliminate or reduce safety and environmental risks of the port, and compliance which is subject to regular audit. The FSRU's international certification (referred to above) is expected to be integral to the port manager's measures.

A maritime security plan must also be approved by the Office of Transport Security (Department of Home Affairs) under the *Maritime Transport and Offshore Facilities Security Act 2003* (Cth).

Emergency Management Planning and response plans will also be developed. Further details on this aspect are set out below.

6.4.3 Port Maritime Regulation

Multiple safety regulators would be involved in regulation of the FSRU, particularly while it is moored at Berth 2 at Crib Point and in gas producing operation.

PoHDA has primary responsibility for safety and hazard management within Western Port through the preparation of the Safety and Environment Management Plan and Health, Safety and Environment (HSE) system for "whole of port risks". The Safety and Environment Management Plan and HSE system will ultimately be revised to address the AGL Gas Import Jetty Works and in particular, the FSRU and the LNG carriers. The Port Operating Handbook (together with the Port of Hastings Harbour Master's Directions) provides a set of rules to govern port user activities including navigation of vessels in port, vessel management and cargo and berth management.

Other regulatory bodies and agencies likely to have roles in the regulation of the vessels in Port (depending on the particular activities) are listed below.

- Transport Safety Victoria (TSV)
- Marine Safety Victoria (MSV)
- Office of Transport Security (OTS)
- WorkSafe Victoria (WSV)
- Victorian Regional Channels Authority (VRCA)
- Australian Maritime Safety Authority (AMSA).

6.4.4 LNG storage, regasification and handling on the vessels

Currently the FSRU is not classified as an MHF under Part 5.2 of the OHS Regulations when in port as the LNG storage, regasification and handling on the vessels are being conducted in a Victorian port and not on land.

WSV’s advised policy position is that it will seek to modify the OHS Regulations by mid-2021 to include the FSRU as an MHF, however, at present it is not.

AGL will address the safety aspects of the FSRU in a manner that is consistent with the requirements of a major hazard facility under the Occupational Health and Safety Regulations 2017 by preparing a safety case, safety management system and emergency management plan.

Instead, the safety requirements for storing and handling LNG are currently regulated by WSV under the *Dangerous Goods Act 1985,* Dangerous Goods (Storage and Handling) Regulations 2000 and supplemented by the Victorian Code of Practice for the Storage and Handling of Dangerous Goods 2013. Further, the requirements and recommendations for the handling and transport of dangerous goods in port areas (including facilities, berths and operations) is covered by AS 3846-2005. In addition to the obligations under the Dangerous Goods legislation, this Standard applies specific safety requirements for the handling and transport of dangerous goods at port facilities on issues such as operating procedures, emergency planning and fire protection.

WorkSafe has foreshadowed that the relevant law will change to classify the FSRU as an MHF when in port. If the relevant MHF laws are changed, the operator will be required to submit a safety case to WSV before an MHF licence can be granted by the regulator under the OHS Regulations. The operator will also be required to review and revise the safety case as necessary including as part of any renewal process. Any safety case submitted to WSV must comply with regulation 385 and include the additional matters detailed in Schedule 17 of the OHS Regulations. Further, the operator must establish and implement a safety management system for the MHF in accordance with regulation 372, which provides a comprehensive and integrated management system for all risk measures adopted under Part 5.2.

Under regulation 375, an operator of an MHF must prepare an emergency plan for the MHF as an appropriate control of risk measures to demonstrate the facility can be operated safely. An emergency plan must:

- address the potential on-site and off-site consequences of a major incident occurring
- include all the matters specified in Schedule 16
- be prepared in conjunction with the local emergency services and municipal councils.

Whilst the MHF laws do not currently apply, AGL will continue to engage with WSV's Major Hazards Division who are primarily responsible for the licensing and safety oversight of all MHFs in Victoria.

This will ensure that best practice is followed and the highest levels of health and safety protection for personnel and the public will be provided so far as is reasonably practicable.

WSV and AMSA will co-regulate the safe operations on the FSRU. AMSA will also be involved to some degree for certain operational activities, including the LNG carriers.

In September 2018, WSV and AMSA entered into an MoU which seeks to delineate respective areas of regulation in relation to maritime and land-based workplaces. Under the MoU, AMSA has jurisdiction over Regulated Australian Vessels (RAVs), foreign flagged vessels and Domestic Commercial Vessels (DCVs). WSV has jurisdiction over the health safety and welfare of persons in Victorian workplaces including a ship or DCV personnel working on Victorian wharves. WSV's jurisdiction also extends to DCVs and may also include RAVs and foreign flagged vessels that are considered Victorian workplaces.

In respect to incident notification and response, the MoU also specifies which agency will respond in certain situations and details areas of overlap in Schedules 2 and 3. Presently, the MoU does not specifically contemplate the regulation of the FSRU (or any FSRUs).

To ensure that there is appropriate clarity on the responsibilities of each of the relevant regulators, AGL will engage and cooperate with WSV and AMSA to address the special nature of these activities and how they are to be regulated so that these arrangements are appropriately captured in the MoU. The MoU is also capable of being varied by written agreement between the parties and is subject to annual review.

AMSA will relevantly be involved in the marine systems including the Marine Orders extending to cargo handling equipment and gas carriers. The interface between ship and shore is addressed within the Classification system for example through DNV's barrier management standards option (which can be customised) and industry standards such as the International Code for Construction and Equipment

of Ships Carrying Liquefied Gases in Bulk (IGC Code). AMSA's work will be of great assistance to overlapping safety regulators.

6.4.5 Legislation applicable to maritime activities

The key legislation applicable to the maritime activities associated with the Project and relevant to this technical report are summarised in Table 6-1.

The balance of legislation applicable to marine traffic and operations at Hastings while the vessel is in port has been summarised in Table 6-2.

Table 6-1 Key legislation applicable to maritime activities

Legislation	Description	Implications for the Project	Regulator(s)
Navigation Act 2012 (Commonwealth)	Empowers AMSA to inspect vessels and to carry out and enforce national and international standards on the safety of life and navigation and on prevention of pollution of the marine environment. Enables more detailed regulation by Marine Orders.	AMSA is the responsible authority for verifying that the FSRU is safe. AMSA is the responsible authority in regard to international conventions giving responsibility to Australia to control ships in Australian waters so that they do not threaten safety or the environment.	AMSA
Marine Order 17 (Chemical tankers and gas carriers)	Sets the requirements for certification of vessels carrying liquefied gases in bulk, and safe operation of gas carriers.	The FSRU and LNG Carrier must have the required certificates and comply with international convention standards about construction and equipment.	AMSA
Marine Order 32 (Cargo Handling Equipment)	Prescribes matter for the equipment of a vessel that is used for loading and unloading cargo of the vessel.	AMSA may prohibit loading/unloading if it is likely to be unsafe and may impose conditions to ensure safety.	AMSA
Marine Order 41 (Carriage of dangerous goods)	Applies to the carriage of dangerous goods on a regulated Australian vessel and a foreign vessel.	These regulations deal with notifications and proper precautions and similarly with MO 32, give power to AMSA to intervene.	AMSA
Marine Order 58 (Safe management of vessels)	Implements the ISM Code.	Enables AMSA to not only confirm that required safety management system certificates are in place, but also that the system is applied in accordance with the ISM Code.	AMSA

Legislation	Description	Implications for the Project	Regulator(s)
Marine Safety (Domestic Commercial Vessel) National Law Act 2012 (Commonwealth)	Provides, as part of a cooperative scheme between the States and Commonwealth a single national framework for safe construction and operation of domestic commercial vessels	The Project is located in shared waters within which other vessels including Domestic Commercial Vessels will be operating. Larger vessels may be regulated as Registered Australian Vessels.	AMSA
Marine Safety Act 2010 (Vic)	This Act provides for safe marine operations in Victoria by imposing safety duties on a range of participants in marine activities, for navigation in State waters, mandating the office and functions of harbour masters and regulating pilotage.	The FSRU's permanently moored operations, other operations at port and the arrival and departure of LNG carriers will be conducted within the safety framework.	AMSA VRCA
Maritime Transport and Offshore Facilities Security Act 2003 (Commonwealth)	Safeguards against unlawful interference with maritime transport, ports and ships including by reducing the risk of terrorist or other unlawful activities.	Maritime industry participants are required to maintain and comply with maritime security plans.	AMSA AMS
Occupational Health and Safety (Maritime Industry) Act 1993 (Commonwealth)	Protection of maritime industry employees from risks to health and safety in their occupational environment.	This legislation may have a role depending on the crewing arrangements and nationality of crew and operator of any vessels.	AMSA
Protection of the Sea (Civil Liability for Bunker Oil Pollution Damage) Act 2008	Gives effect to the International Convention on Civil Liability for Bunker Oil Pollution Damage.	Any ship entering or leaving a port in Australia must carry an insurance certificate in a prescribed form relating to liability for pollution damage.	AMSA

Table 6-2 Legislation applicable to vessels in port

Legislation	Summary extract	Implications for the Project	Regulator(s)
Transport Integration Act 2010 (Victoria)	This Act provides a legislative framework for the provision of an integrated and sustainable transport system in Victoria consistent with the vision statement. The Act further sets out transport system objectives including environmental sustainability, integration of transport and safety, health and wellbeing. More specifically, the Act seeks to integrate land use and transport planning and decision-making by applying the framework to land use agencies whose decisions can significantly impact on transport. The Act requires agencies, including the Department of Transport and Planning Authorities, to consider the potential impact of land use planning proposals on transport.	Business owners and employees can reasonably expect to be considered and consulted during the EES. Interruption to movement during construction and in operation needs to be considered.	DoT
Port Management Act 1995 (Victoria)	The *Port Management Act 1995* sets out particular provisions for: the establishment, management and operation of commercial trading ports and local ports within Victoria; the economic regulation of certain port services; the imposition of certain port fees; the engagement of licensed harbour masters in certain circumstances; and the transfer of property, rights and liabilities and the management of Crown land and to make provision with respect to the rights of staff.	PoHDA's responsibility for safety and hazard management within the Port of Hastings under the Port Management Act requires the preparation of the Safety and Environment Management Plan and HSE system for "whole of port risks".	PoHDA
Westernport (Crib Point) Terminal Act 1963 (Victoria)	The aim of this Act is to assist in the development and operation of a terminal at Crib Point to receive, store and distribute petroleum, whether by pipeline or otherwise, as well as to provide for certain existing and new	None expected	PoHDA

Legislation	Summary extract	Implications for the Project	Regulator(s)
	easements for the construction and operation of certain pipelines.		
Western Port Development Act 1967 (Victoria)	The Act was developed in order to allow for the construction of additional port facilities in Western Port and the reclamation of certain land at old Tyabb. BlueScope Steel and Esso have significant existing uses in Western Port that are protected by this legislation.	None expected	PoHDA
Occupational Health and Safety Act 2004 (Victoria)	This Act is the main workplace health and safety law in Victoria. It aims to protect the health, safety and welfare of employees and others. This includes ensuring that the health and safety of the public is not at risk due to workplace activities.	The primary safety obligations of employers and other duty holders owing to employees and members of the public are contained in Part 3 of the Act.	WSV
Occupational Health and Safety Regulations 2017 (Victoria)	The objectives of these regulations are to promote occupational health and safety and to protect workers and other persons present at workplaces from work-related risks to their health, safety and well-being. The regulations support the objectives of the *Occupational Health and Safety Act 2004*.	The Occupational Health and Safety Regulations 2017 regulate the safety of major hazard facilities, including requirements for the preparation of a safety case, safety management system and emergency management plan. Currently the FSRU is not classified as a major hazard facility (MHF) under Part 5.2 of the OHS Regulations when in port as the LNG storage, regasification and handling on the vessels are being conducted in a Victorian port and not on land. WSV has advised that it will seek to modify the OHS Regulations by mid-2021 to include the FSRU as an MHF.	WSV
Dangerous Goods Act 1985	The main objects of this Act are— to promote the safety of persons and property in relation to the manufacture, storage, transport, transfer, sale and		WSV

Legislation	Summary extract	Implications for the Project	Regulator(s)
	use of dangerous goods and the import of explosives into Victoria; to ensure that adequate precautions are taken against certain fires, explosions, leakages and spillages of dangerous goods to allocate responsibilities to occupiers and owners of premises to ensure that the health and safety of workers and the general public is protected; to provide for licensing of persons required by the regulations to hold a licence in relation to dangerous goods.		
Dangerous Goods Act (Storage and Handling) Regulations 2012 (Victoria)	The aim of these regulations is to provide requirements for the safe storage and handling of dangerous goods. In particular, the regulations deal with the general duties of manufacturers and suppliers and the specific duties of occupiers in respect to consultation, information and training, hazard identification and risk control, preparedness for incidents, emergencies and incidents.		WSV

6.5 Studies completed

A suite of safety studies has been completed during the design of the FSRU, as required by the international standards and for the requirements on DNV GL Classification. The following key studies related to the safety, hazard and risk for the FSRU component of the Gas Import Jetty Works have been completed for the FSRU berthed at Crib Point. These studies consider location specific hazards and the interaction with the rest of the Project:

- Hazard Identification (HAZID)
- Hazard and Operability Study (HAZOP)
- Quantitative Risk Assessment (QRA).

6.6 Hazard and risks identified

6.6.1 Major risks

The specific operational hazards (Refer Section 5.0) associated with the FSRU and the storage of LNG and regasification to high pressure gas are the following:

- fire and explosion
- cryogenic exposure
- asphyxiation.

The consequence of a release of LNG is dependent upon process operating conditions, local weather conditions, the surrounding location of the LNG release, and whether ignition occurs or not. Appendix E provides a discussion of potential LNG release behaviours and associated risks.

The FSRU can operate in two modes known as open and closed loop which involve different regasification processes. These different operating modes generate different levels of risks onboard the vessel. Operation in closed loop has slightly higher risk because of the use of gas-fired boilers used to warm the LNG. The worst-case operations have been assessed and all major risks identified associated with the different operating modes.

6.6.2 Quantitative Risk Assessment

To ensure the highest safety standards are applied, DNV GL have conducted a preliminary QRA for hazards and risks associated with all modes of the FSRU operation including but not limited to:

- marine operations (approach and mooring) for the FSRU, LNG carrier and Petroleum tankers (at Berth 1)
- gas operations at Crib Point Jetty including gas send out from the FSRU, MLAs, ship to ship transfer and interaction with United operations
- interactions (simultaneous operations) with external factors such as Crib Point Receiving facilities and United Petroleum Pumping station facilities also included.

The results of the QRA are discussed further in Section 9.0 (Project Area interfaces). The Location Specific Individual Risk (LSIR) contours resulting from the QRA are illustrated in Appendix C.

6.7 Approval requirements for Licence to Operate

As a new facility which is designed but not constructed, the FSRU operator would apply to WSV for an MHF licence in accordance with Victorian OHS Regulations that would require it to develop a safety case to demonstrate it can safely and competently operate the MHF through well managed systems and effective safety governance.

As part of the safety case application, the operator must also establish and implement a safety management system for the MHF in accordance with regulation 372, which provides a comprehensive and integrated management system for all risk measures adopted under Part 5.2 of the OHS Regulations.

The specific requirements for the successful grant of an MHF licence involve a number of steps including notification, registration, safety case development and licensing which are captured in Figure 6-1.

When granting an MHF licence, WSV must be satisfied that:

- the intending licensee will be able to safely and competently operate the MHF
- the safety case complies with Division 8 of Part 5.2 of the OHS Regulations
- the applicant has complied with the operator's safety duties in Division 6 of Part 5.2 of the OHS Regulations
- the applicant has complied with its consulting, informing, instructing and training duties of Division 9 of Part 5.2 of the OHS Regulations
- the applicant has provided the necessary administrative information required for a licence application under regulation 449.

Compliance with the above requirements must be demonstrated across the entire facility.

Further, WSV may also impose terms and conditions on an MHF licence on a case by case basis relating to, for example, the licence term. WSV would provide ongoing regulatory oversight of the MHF and related safety case and any terms and conditions imposed on the licence will be re-examined during any licence renewal process.

The completion of the safety studies outlined in Section 4.0 and Appendix A would form part the safety case and application for an MHF Licence.

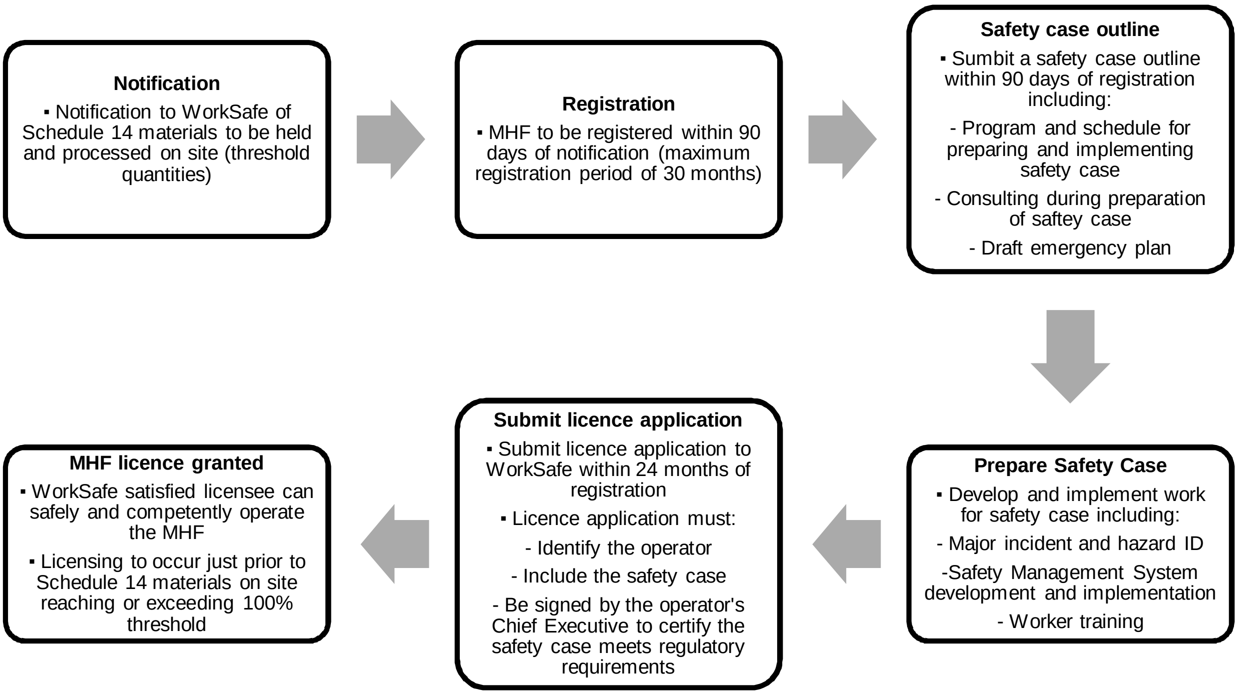


Figure 6-1 Steps to an MHF Licence

7.0 Gas Import Jetty Works – Jetty Infrastructure and Crib Point Receiving Facility

This section refers to the Jetty Infrastructure and Crib Point Receiving Facility component of the Gas Import Jetty Works.

7.1 Overview

The Crib Point Jetty is located on the western side of Western Port and is under the authority of PoHDA and VRCA. The jetty is located on Crown land and leased by the PoHDA.

The Jetty Infrastructure at Crib Point would include MLAs, new gas piping to shore (fully welded), a fire protection system and an electrical substation. Berth 2 is being enlarged and structurally refurbished to make it fit for use. Salient points to note are:

- MLAs would be used to connect the FSRU to the jetty gas piping. From the jetty gas piping the gas will be transported into the pipeline via a receiving station located onshore at Crib Point.
- The gas being transferred would vary from 2°C to 5°C and from 5,000 kilopascal gauge (kPag) to 10,000 kPag and provided at a peak rate of 750 million standard cubic feet per day.
- The gas piping on the jetty can be isolated at two locations: on the shore at an isolation valve in the receiving station, and emergency shutdown (ESD) valves located downstream of each MLA on Berth 2.
- The proposed Crib Point Receiving Facility is situated landside of the Crib Point Jetty and would receive the natural gas from the FSRU via the jetty gas piping. The main function of the facility is gas metering, odorant injection (a safety requirement which enables the normally odourless gas to be smelt), nitrogen injection (to treat rich gas when required) and measurement of gas composition.

The facilities are consistent with other gas facilities in Australia and there are no unique risks or hazards that are not encountered within other gas facilities. It is reasonable to state that the Jetty Infrastructure and Crib Point Receiving Facility will be safe to operate due to the following:

- All equipment would be designed and operated to Australian standards, and relevant International standards where applicable (Refer Section 7.2)
- Approvals for piping and facility would be issued by ESV and WSV under safety case style legislation. (Refer Section 7.3)
- Safety studies relevant to the Jetty Infrastructure and Crib Point Receiving Facility (Section 7.4 and Section 4.0 (Methodology)) and QRA (Refer Section 9.0 and Appendix A) have been carried out.

7.2 Design and operation

7.2.1 Marine loading arms

The MLAs would be 12” (300 mm) and each capable of transferring the full design flowrate of gas from the FSRU. Each of the MLAs is fitted with a quick connect/disconnect isolation and in the event the vessel moves out of range from the jetty, the MLA would vent, and the MLA would be safety disconnected from the vessel.

7.2.2 Gas piping

Downstream of each MLA an actuated shutdown valve would be provided, and a check valve, with a 12” x 24” reducer prior to connection into the 24” (600 mm) gas piping to shore which is fully welded and designed to B31.3.

An isolation valve is provided at the receiving facility tie-in point and can be operated locally or from a remote control room in an emergency thereby limiting the gas inventory that can be released in the event of a leak. This is part of the mitigation strategy to limit the volume of gas released in the unlikely event of an uncontrolled leak.

7.2.3 Crib Point Receiving Facility

Gas from the jetty gas piping will be sent to the Crib Point Receiving Facility. The receiving facility would consist of an actuated emergency isolation valves; pig launcher, odorant injection, nitrogen storage & injection, non-custody transfer metering, Gas Chromatographs and process automation and shutdown control system. The gas from the Crib Point Receiving Facility flows into the Pipeline Works (Pakenham Delivery Facility via a new 57-kilometre-long DN600 gas transmission pipeline).

Odorant Package

The Crib Point Receiving Facility includes an odorant system (aggregate capacity of approximately 40 m^3) that would be designed to inject mercaptan to the gas pipeline to assist in detection of natural gas in the event of a leak.

The odorant package would be provided as a turnkey piece of equipment consisting of two odorant storage tanks (~20m^3); injection package; transfer pump; activated carbon filter system and associated piping and instrumentation. Odorant would be delivered to the facility by road tanker and off-loaded to the storage tanks via flexible hoses. The odorant storage tanks as pressure vessels designed to pressure vessel standard AS1210.

The odorant package has been through a preliminary hazard and operability review and the resultant actions incorporated into the design. The odorant plant is a turn-key piece of equipment that is complete with standalone safety interlocks and emergency shutdowns. The final design for the odorant package is not yet finalised. The odorant package would follow a standard proven in use design consistent with other similar facilities.

Nitrogen Facility

The Crib Point Receiving Facility would include a nitrogen offload, storage and vaporisation (OSV) facility to ensure gas is delivered within specification. The plant would monitor and dilute rich gas such that gas provided by the facility into the gas network is within AS4564 specifications & AEMO Victoria guidelines. This is done by simply injecting the inert gas nitrogen into the mains gas supply and mixing to provide a homogeneous composition.

From a prepared state, the OSV would be capable of providing full 640 tonnes per day flow of nitrogen and would be capable of matching the FSRU production ramp rate of 125 MMSCFD/15 minutes. The system would be installed with sufficient cool down lines and control system to prepare site for flow.

Approximately 3000 net tonnes (~3717 m^3) of liquid nitrogen (LIN) is required to be stored onsite. This would be stored in a bulk storage tank. The final size and configuration will be determined in detailed design. LIN would be purchased from third parties and transported via road tanker to the OSV site. The site offloading station would comprise two gantries, capable of receiving numerous trucks per day of LIN consistent with transport studies. Offloading would be capable of servicing body trucks, semi-trailers and B-doubles. The gantries would accommodate B-double trailers.

7.3 Regulatory Framework

In the context of the following section, the Gas Import Jetty Works includes:

- the Jetty Infrastructure on the Crib Point Jetty including MLAs and gas piping to transfer the gas from the FSRU

- Crib Point Receiving Facility, which would be located on land adjacent to the Crib Point Jetty and would include treatment facilities to inject mercaptan (odorant) and nitrogen (as required) into the natural gas to meet VTS gas quality specifications.

The legislation identified as being applicable to safe operation of the Jetty Infrastructure and Crib Point Receiving Facility is summarised in Table 7-1:

Table 7-1 Legislation applicable to the Jetty Infrastructure and Crib Point Receiving Facility

Legislation	Description	Implications for the Project	Regulator
Gas Safety Act 1997 (Victoria)	The primary aim of this Act is to regulate the safety of gas supply and use in Victoria. The Act is administered by Energy Safe Victoria whose objectives are to facilitate the safe conveyance, sale, supply, measurement, control and use of gas.	The Crib Point Receiving Facility will be a facility capable of regulation by ESV under the Gas Safety Act 1997 (Vic), subject to the owner or operator being declared to be a "gas company" under the Gas Safety Act. Under the Gas Safety Act, gas companies must comply with general safety duties at each of their facilities. These duties include to minimise as far as practicable hazards and risks to the public and customers and their property from gas, interruptions to the conveyance or supply of gas and the reinstatement of an interrupted gas supply. A "gas company" must submit a safety case to ESV for a facility and may be required to undertake an independent validation of the safety case. The safety case will address the design, construction, commissioning and operation of the facility, and may be submitted in stages. The facility must be managed and operated in accordance with general duties to minimise hazards and risks to the safety of the public and property.	ESV
Gas Industry Act 2001 (Victoria)	This Act governs the Gas Industry and achieves its regulatory purpose through three fundamental pillars: (1) regulation of pricing; (2) licensing and; (3) attaching terms and conditions to	The gas piping can be characterised as a "distribution pipeline". A licence is required to provide services by means of a "distribution pipeline", unless an exemption is granted under section 24.	ESC

Legislation	Description	Implications for the Project	Regulator
	the sale and supply of gas. The Act requires that persons who distribute or sell gas are required to either, obtain a licence from Essential Services Commission (ESC) of Victoria or secure a licence exemption.		
Gas Safety (Safety Case) Regulations 2018	These Regulations make provision for safety cases in relation to gas facilities, provide for the reporting of gas incidents, and prescribe safety standards for the quality of gas and the testing of natural gas conveyed through a transmission pipeline.	The Regulations set out the safety case requirements for the Jetty Infrastructure and Crib Point Receiving Facility, including the content required for a safety management system. The Gas Safety Act and Safety Case Regulations require the Pipeline operator to identify, assess and mitigate all risks having the potential to cause a gas incident. The treatment of the risks identified, the assessment of risks so far as is reasonably practicable and safety management system will be described in the safety case. The safety case must be accepted by ESV prior to Commissioning and Operation and reviewed every five years in accordance with the Regulations.	ESV

While natural gas is a dangerous good within the meaning of the *Dangerous Goods Act 1985* (DG Act), the DG Act does not apply to the conveyance by gas by pipeline to which the *Gas Safety Act 1997* (Vic) (Gas Safety Act) applies.

7.3.1 Regulatory bodies

The key regulatory body for the Jetty Infrastructure and Crib Point Receiving Facility would be:

- ESV for the gas piping
- ESV or WSV for the other assets.

ESV is the technical and safety regulator responsible for the safe generation, supply and use of electricity, gas in appliances and gas installations, and control of the safety standards of gas work.

As the regulator for gas safety, ESV is responsible for ensuring that all new and existing gas facilities and installations are safe and meet legislative requirements. ESV is also responsible for the safety of gas infrastructure and licensed pipelines.

The Jetty Infrastructure and Crib Point Receiving Facility would be regulated by ESV under the Gas Safety Act, subject to the owner or operator being declared to be a gas company under that Act.

A gas company must submit a safety case to ESV for a facility and may be required to undertake an independent validation of the safety case. The safety case will address the design, construction, commissioning and operation of the facility, and may be submitted in stages. The facility must be managed and operated in accordance with general duties to eliminate or minimise hazards and risks to people and property under Division 1 of Part 3 of the Gas Safety Act. The gas company must also comply with gas quality requirements and reporting of gas incidents.

If the pipeline is declared a "transmission pipeline" by the Governor in Council and the Gas Industry Act applies to the gas company, it may be required to apply to the Essential Services Commission (ESC) for a licence to distribute gas unless it is exempted from obtaining a licence.

If there is a common operator of the FSRU and Crib Point Receiving Facility, and the OHS Regulations are changed in the manner contemplated by WSV in respect to the FSRU and as mentioned in Section 6.4.4 of the Report, then the MHF laws would apply to both the FSRU and the Crib Point Receiving Facility.

If this occurs then WSV will be the key regulatory body for both the FSRU and the Crib Point Receiving Facility.

7.3.2 Interaction between Pipelines Act 2005 and Port Management Act 1995

Section 10(1) of the Pipelines Act, together with Schedule 1 "Pipelines excluded from the Pipelines Act" provides that the Pipelines Act does not apply to a pipeline located entirely within a port (including any port within the meaning of the *Port Management Act 1995* (Vic)).

While the Pipelines Act does not apply to the Jetty Infrastructure and Gas Import Jetty Works, the operation, surveillance, inspection and maintenance will be carried out in a manner consistent with the intended outcomes of the Pipelines Act and managed under the safety and environmental regimen of the port in accordance with the *Port Management Act 1995* (Vic).

The land on which the Jetty Infrastructure and Crib Point Receiving Facility is located is declared Port of Hastings land, which is within the Port of Hastings. It is noted that planning approval under the *Planning and Environment Act 1987* (Vic) is required for the components of the works that are located within the declared land, namely the Jetty Infrastructure and Crib Point Receiving Facility (alongside the FSRU) as they are not exempted from planning approval which is the case where the Pipelines Act applies.

7.4 Studies

The following key studies have been completed related to the safety, hazard and risk for the Jetty Infrastructure and the Crib Point Receiving Facility components of the Project are:

- Crib Point Jetty Upgrade Project - Fire Safety Study
- Crib Point Receiving Facility - Fire Safety Study (Odorant)
- Preliminary Fire Safety Study for Crib Point Facility
- Project Spirit Crib Point - HAZID Workshop Report
- Crib Point Jetty Upgrade Project - Project HAZOP Study
- Crib Point Pakenham Pipeline - Odorant Package Vendor HAZOP Report
- Crib Point to Pakenham Pipeline Project - HAZOP Report
- Gas Import Jetty and Pipeline Project - QRA Report (including the FSRU)
- Crib Point Receiving Facility – QRA.

These studies and assessments form the basis upon which the process safety related hazards and risks have been assessed. Resultant safeguards and controls arising from these studies are discussed in the following sections.

7.5 Hazards identified

7.5.1 Major risks

The predominant risk associated with the Jetty Infrastructure and the Crib Point Receiving Facility is the loss of containment from the process and associated equipment/plant as potential sources of fire events. Risk associated with the storage of liquid nitrogen and odorant at the Crib Point Receiving Facility are discussed in Section 5.1. The following specific issues were raised for assessment.

Release of Gas – Gas piping

Crib Point gas will be predominantly methane. For the purposes of the risk studies, hazard assessments and fire safety study the gas has been assumed to be 2°C and 10,000 kPag which provides the greatest combination of gas release rate and density. On release and subsequent ignition, a jet fire may ensue and could be maintained if there is sufficient pressure at the release point.

Jet fires generate high levels of radiant heat associated with efficient combustion and may also generate significant damage through erosion and conductive heat transfer where flame impingement occurs. Should the release not immediately ignite, a flammable gas cloud will form, with delayed ignition leading to a flash fire or vapour cloud explosion if sufficient confinement is present. Delayed ignition events may also burn back to a sustained jet fire.

The catastrophic failure of an MLA could occur if the FSRU suddenly moved away from Berth 2; this is considered as a very short duration release due to the presence of quick disconnect closure systems on the MLA and therefore was not modelled as part of the fire safety studies or QRA.

Releases from the gas piping may be sustained for a sufficient duration to cause extensive damage and may prevent escape along the jetty. The releases from the gas piping generate the same heat flux contours at initial release conditions as the MLA though the contours would reduce with time as the pressure in the piping would fall if the piping is successfully isolated.

Approximately 140m of the gas piping would be within 270m of Mooring Dolphin 11, and hence has potential to make this location unsuitable for muster without shielding. The gas piping would be fully welded, and in clean service, making significant releases unlikely. Additionally, radiant heat from jet fires is highly directional, and therefore the probability of this location being impaired is expected to be low. The potential for impairment and requirement for any additional shielding will be determined in the QRA.

The Service Platform will house the electrical substation, air compressor and firewater pump skids and is potentially within a high radiant heat zone. Consideration should be given to providing heat shielding to the building and the firewater pump skids.

The gas piping would travel adjacent to the Service Platform so any piping fire between the Pierhead and main Trunk Way can expose the Service Platform to high radiant heat levels so protection to the firewater pump facilities and substation should be considered. Quantitative assessment will be necessary to determine if any additional shielding will be needed around the firewater pump skid in the event of a pipeline jet fire.

As for the Pierhead liquid hydrocarbon pool fire radiant heat impacts are significantly smaller than for hydrocarbon jet fires. Fires along the Trunk Way would be extinguished by emergency responders who would provide the required combatting facilities such as portable foam appliances.

Release of liquid hydrocarbon

Project-related

The following potential liquid hydrocarbon sources have been identified:

- diesel fuel associated with the firewater pumps
- gasoline or diesel associated with vehicles on the jetty
- hydraulic fluid associated with the operation of the MLAs.

Liquid hydrocarbon releases would result in a pool fire if ignition occurs. The Global Harmonized System of Classification and Labelling of Chemicals (GHS) defines flammable liquids into four categories up to a flashpoint of 93º C. GHS Category 4 liquids includes diesel fuel which is classified as a combustible liquid according to AS1940 and Australian WHS regulations.

Unlike petrol, which is highly flammable, diesel fuel is a *combustible* liquid with a flashpoint above 60º C. This relatively high flashpoint means that insufficient vapour is produced under ambient conditions and is therefore unlikely to ignite, other than as an escalation event. Likewise, hydraulic fluid is combustible, making ignition highly unlikely. For the purposes of hazardous area classification, storage requirements and fire protection the definition of a combustible product as taken from AS1940 has been adopted.

Diesel driven firewater pumps and their associated fuel storage tanks are provided with a skid pan for containment of small releases and it is assumed that a pool fire, if it occurred, would fill the contained area. The diesel storage tank would be double walled, reducing the potential for a significant release and removing the requirement for full bunding, as permitted by AS1940: *The storage and handling of flammable and combustible liquids*. Hydraulic oil would drain to a sump, which is assumed to define the maximum dimensions of the pool fire.

For uncontained vehicular pool fires, the flammable pool may spread to either a minimum film thickness, or until an equilibrium condition is reached where the burn rate is equal to the release rate. A 20 millimetre release has been assumed for vehicular fuel spills representing a situation where the fuel tank is accidentally punctured. For the purposes of the fire safety study, all liquid hydrocarbon fires have been modelled as nonane which best represents gasoline.

Co-Located Liquid Hydrocarbon Pipelines (United berth)

For the co-located United Petroleum pipeline and ship discharge operations, the following scenarios have been identified leading to the loss of gasoline or diesel fuel containment and have been modelled in the QRA.

- release from loading hoses at Jetty 1
- release from pipeline on Jetty from Jetty 1.

For each of these scenarios the consequences from heat radiation hazards arising from a jet fire and a pool fire for different release rates has been modelled. These are discussed in Section 5.1.2.

The risks associated with the United owned and operated liquid hydrocarbon pipelines currently exist at Crib Point. The cumulative impact of these risks has been included in the combined QRA.

The impact on the FSRU at berth arising from an incident during unloading operations at the United Petroleum will be considered in the Emergency Response Plan.

Bushfire risk

The Jetty Infrastructure and the Crib Point Receiving Facility works are located on cleared land, but some vegetation is present in surrounding areas. In particular, there are areas of Crown land managed by the State Government, which is responsible for its management, including managing bushfire risk. The safety case for the Jetty Infrastructure and the Crib Point Receiving Facility would include bushfire mitigation strategies.

7.5.2 Cryogenic hazards

The storage of liquid nitrogen at the Crib Point Receiving Facility introduce cryogenic hazards as described in Section 5.1.4. Ongoing, appropriate consideration of cryogenic hazards in the selection, construction, commissioning, operation and maintenance of cryogenic equipment would be managed and mitigated throughout the Project lifecycle.

7.5.3 Summary of hazard and risk studies

Quantitative Risk Assessment (QRA) – Jetty Infrastructure

A preliminary QRA for hazards and risks associated with the Jetty Infrastructure has been completed including but not limited to:

- marine operations (approach and mooring) for the FSRU, LNG carrier and United Petroleum tankers
- gas operations at Crib Point Jetty including gas send out from the FSRU, MLAs, ship to ship transfer and interaction with United Petroleum operations
- interactions (simultaneous operations) with external factors such as pipeline facilities and United Petroleum pumping station.

The results of the QRA are discussed further in Section 9.0 (Project Area interfaces). The LSIR contours resulting from the QRA are illustrated in Appendix C.

Releases from the gas piping on the jetty may be sustained for a sufficient duration to cause damage and may prevent escape along the jetty.

- The gas piping would travel adjacent to the Service Platform so any fire between the head of the pier and main approach way can potentially expose the Service Platform to high radiant heat levels. Quantitative assessments would be necessary to determine if any additional shielding will be needed around the firewater pump skid in the event of pipeline jet fire.
- Liquid hydrocarbon pool fire radiant heat impacts are significantly smaller than for hydrocarbon jet fires. Fires along the approach way would be extinguished by emergency responders who would provide the required combatting facilities such as portable foam appliances.
- The Service Platform which would house the electrical substation and firewater pump skids would potentially be exposed to radiant heat levels above 35kW/m^2. Both the substation and firewater pump skids are potentially within this radiant heat level and as such consideration should be given to providing some shielding to this building and the firewater pump skids.

7.5.4 Fire prevention and mitigation

The following fire prevention and mitigation strategies will be included in the design.

Minimisation of leak sources and inventory

The location with the highest leak potential is the MLAs, each of which is provided with an emergency isolation valve upstream of the gas piping. A significant release from this area would deplete within five minutes, significantly limiting fire damage potential.

The largest inventory is the gas piping system to shore which can be isolated at the head of the pier, and at the shore receiving facility. The consequence analysis has assumed that releases would be detected and isolated within 30 seconds and modelling results have shown reduction in consequence impacts after five minutes.

Control of ignition sources

Legislated hazardous area standards codes would be applied in detailed design and subsequently equipment would be appropriately certified for used in the hazardous zone. The substation would be

located at a distance outside the hazardous area and all ignition sources within the delineated hazardous area would be controlled. The hazardous zone represents the area where a potentially flammable atmosphere may exist and would be determined in detailed design through the application of Australian Standard AS/NZS 60079.10.1: *Explosive atmospheres*.

Fire protection and suppression

The FSRU and LNG carrier would have their own onboard fire protection and suppression systems.

Active fire protection and suppression would be provided for liquid fires and gas fires on the Jetty in compliance with relevant Australian Standards, including AS 3846 - 2005 *The handling and transport of dangerous cargoes in port areas.* and AS 2941: *Fire hydrant installation – System design, installation and commissioning*.

The primary firefighting strategy for gas fires is to cool adjacent equipment to prevent escalation events due to mechanical or structural failure and to enable personnel to evacuate the area safely.

Primary firefighting for liquid spill fires would be by portable foam carts and extinguishers. If a fire cannot be fought with portable foam carts or extinguishers, fire water can be supplied to provide cooling to equipment until the fire self-extinguishes.

The firewater demand has been determined based on the Basis of Design for this Project which is the protection of vulnerable facilities on the Jetty and the safe evacuation of personnel.

The design fire case for Berth 2 fire systems is a jet fire in the MLA area. The required firewater cooling rate is for the ship/shore manifold area, which is defined as the MLAs and associated piping and valves as well as for FSRU hull cooling.

Berth 2 would be provided with fire protection equipment that includes:

- Diesel fire pumps capable of combatting the largest design event and in accordance with Australian and International Standards. The diesel fuel supply would be designed for six hours of firewater per pump. The current design calls for two x 100% firewater pumps. The system would be designed as a dry pipe system (i.e.no requirement for a jockey pump to maintain pressure), and be designed for saltwater service, providing an indefinite supply of water.
- Fire water monitors on towers with sufficient range to reach the whole pierhead and the required area of the FSRU hull. This would consist of three oscillating monitors on individual towers, with one dedicated to the pierhead and the other two dedicated to the hull of the FSRU. Fire water monitors would be remotely actuated from a panel at the Service Platform and at the onshore security building.
- Portable foam carts (100-200L capacity), capable of extinguishing the largest identified hydrocarbon pool fires on Berth 2 – (location to be determined though would most likely be located next to either hydrant along with a hose box).
- Hydrants, fire extinguishers and minor fire protection equipment as required by Australian and International Standards. In accordance with AS 3846: *The handling and transport of dangerous cargoes in port areas* two hydrants would be provided at the pierhead. The hydrants would be able to reach the MLAs.
- Firewater remote start, and manual pump stop/start would also be provided at the firewater pump skid or if this is not a safe location somewhere on the jetty approach.

Fire water must be able to be provided for six hours. Due to the large volume of water for fire-fighting (estimated at 6.9 megalitres) it is intended that the sea water be used for firewater cooling as required by AS 3846.

Firewater would be provided by one of two 100% pumps which draw from Western Port and are compliant with AS 2941: *Fire hydrant installation – System design, installation and commissioning*.

Diesel fuel supply for six hours of operation is required. The Fire Safety Study concluded this is more than enough for the maximum duration of any credible fire from either an MLA or pipeline release.

Foam use on the jetty would be minimised as far as practicable in order to avoid environmental spill of firefighting foam. The fire safety study assumes that firefighting involving the use of foam would be done by trained personnel. All deck areas of Berth 2 have bunding/kerbing to contain spills and firefighting consumables to an extent that is practicable.

Portable foam type and dry chemical extinguishers should be provided for hydrocarbon liquid spot fires and general small fires respectively. These should only be used for fires in kerbed or bunded locations. The size and quantity of these extinguishers will be determined in Detailed Design.

7.6 Approval requirements for Licence to Operate

Under the Gas Safety Act, a gas company is not permitted to commence operation unless a safety case has been accepted or provisionally accepted by ESV.

A gas safety case for the transmission of natural gas and associated distribution infrastructure must comply with the requirements of Part 3 of the Gas Safety Act and Part 2 of the Gas Safety (Safety Case) Regulations 2018. Division 2 of Part 3 of the Act specifically deals with validation of a safety case for a facility which may include independent validation of all or a part of the safety case under section 38 of the Act.

ESV's two key expectations for safety case regimes are:

1. Safety is achieved though adequate risk controls of hazards and risks (by Licensed Network Owners/Operators meeting their general duties and demonstrating appropriate risk control measures to minimise risk as far as practicable); and
2. The whole of service life asset sustainability and integrity is a risk that is managed to ensure the facility remains safe throughout the life cycle of the facility.

A gas safety case must detail how a gas company will meet its general duties under the gas safety legislation and prescribed standards to achieve acceptable levels of safety and appropriate management of risk. It must also contain a formal safety assessment which establishes what practicable risk control measures should be adopted by the gas company to achieve these outcomes.

The safety case must also specify which safety management system will be implemented in relation to the facility, demonstrate technical and other measures outlined in the formal safety assessment and comply with the required information in Division 5 of Part 2 of the Gas Safety (Safety Case) Regulations 2018.

Accordingly, a facility's safety management system must include detail of:

- organisational structure and responsibilities
- published technical standards
- design, construction, installation, operations, maintenance and modification
- permit to work system
- emergency preparedness
- reporting of gas incidents
- internal monitoring, auditing and reviewing; gas incident recording, investigation and reviewing
- competence training.

Ultimately, a gas safety case must address all aspects of hazards and risks particular to the facility, detail the gas company's commitment to safety and offer a tailored approach to manage and control risks which is systems, performance and outcome focussed.

ESV will accept the safety case if satisfied it is appropriate for the relevant facility and it complies with all the requirements under gas safety laws. If the safety case is accepted, ESV will also monitor the gas company's safety performance to ensure acceptable levels of safety are achieved as against the safety case.

Gas companies must also review and resubmit their safety case to ESV every five years. This comprehensive process and extensive monitoring regime is detailed in the flow chart in Figure 7-1.

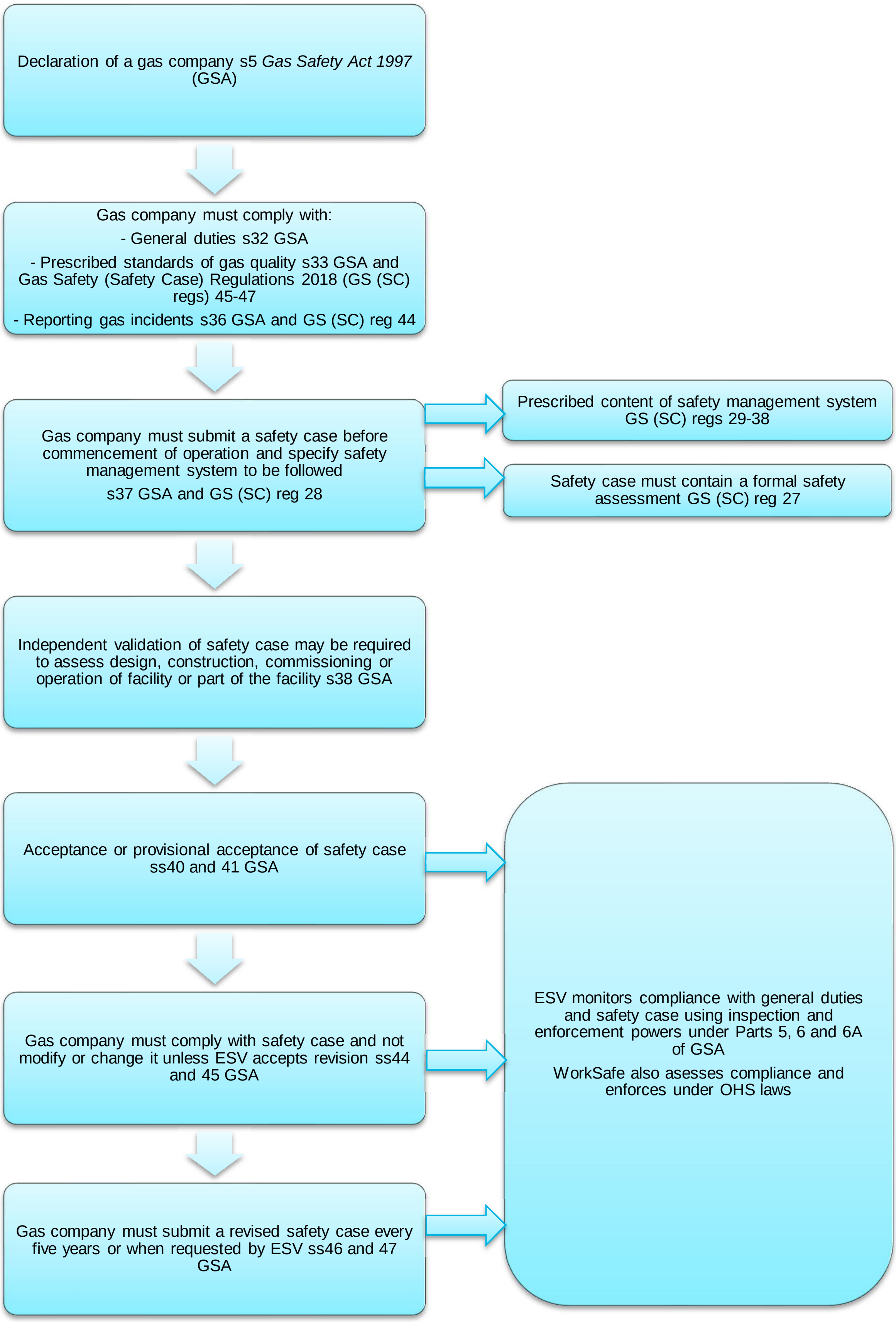


Figure 7-1 Process for Gas Safety Case

8.0 Pipeline Works

8.1 Overview

Natural gas would be delivered from the Crib Point Receiving Facility to the Pakenham Delivery Facility via a new gas transmission pipeline as shown in Figure 1-2. The pipeline would be approximately 57 kilometres long with a proposed nominal diameter of 600 millimetres (mm). The pipeline would be buried along its route with a minimum depth of cover of 1200 mm to the top of the pipe. Gas generated at Crib Point would be delivered into the Victorian Transmission System (VTS) via a pressure reduction facility at Pakenham.

The principal standards applicable to the pipeline design, operation and maintenance are covered in the AS2885 Series, Pipelines – Gas and liquid petroleum.

A Safety Management Study (SMS) has been completed for the proposed pipeline alignment in accordance with the requirements of the *Pipelines Act 2005* and the Pipeline Regulations 2017.

8.2 Design and operation

8.2.1 Crib Point to Pakenham Pipeline

The salient point with respect to the pipeline are:

- The Crib Point Pakenham Pipeline would be a privately-owned pipeline.
- The pipeline would be designed in accordance with AS/NZS 2885.1 and would be suitable for the transportation of natural gas meeting the process specification.
- The design would allow for reverse flow from the VTS to pressurise the pipeline for commissioning purposes and additionally to facilitate future customer connections to the pipeline.
- As part of the Project, APA would review the design of the cathodic protection in conjunction with the earthing design to ensure compliance with AS 4853: *Electrical hazards on metallic pipelines*.
- The buried pipeline would be protected against corrosion by an impressed current cathodic protection (CP) system designed and installed in accordance with AS/NZS 2885.1, AS 2832.1, APA specifications and Victorian Electrolysis Regulations. Additional protection would be provided to mitigate the effects of electrical interference from external sources including stray current from traction systems and interference from third party CP systems.
- APA would risk assess the exposure of the pipeline to lightning in accordance with the recommendations in AS1768: *Lightning protection*, with any mitigation measures implemented in the design. The design includes surge protection across all insulated flanges and monolithic isolation joints.
- The pipeline easement would be inspected for any operational or maintenance issues on a routine basis in accordance with APA procedures.
- The pipeline would also be designed and constructed so that in-line inspection equipment can be used to inspect the integrity of the pipeline.
- The inspection process, utilising intelligent in-line inspection, would be undertaken 10 years after the pipeline is put into initial service and then at a frequency determined by the results and findings of the first inspection.

The key pipeline design parameters are outlined in Table 8-1.

Table 8-1 Key pipeline parameters

Description / Parameter	Specification / Design
Nominal Diameter	DN600 (609.6mm)
Length	57 km
Minimum Depth of Cover (all location classes)	1200mm
Wall Thickness	10.41mm (standard) 12.70 mm (heavy wall)
Maximum Allowable Operating Pressure (MAOP)	10,210 kPag
Design Temperature range	-10C to +60C
Operating temperature range (deg. C)	-7 to +60C
Line Pipe Manufacturer Specification and Type	API 5L, PSL2 ERW
Pipeline material grade	Grade X60
External Coating	Dual Layer of Fusion Bonded Epoxy (DFBE)
Internal Coating	Epoxy
Cathodic Protection	Impressed Current

8.2.2 Pipeline alignment

The pipeline alignment would generally follow the Stony Point rail reserve through Hastings towards Pakenham and would cross the Gippsland rail line prior to reaching the proposed Pakenham Delivery Facility adjacent to the Pakenham East rail depot before connecting to the VTS north of the Princes Highway.

The alignment of the pipeline is shown on Figure 1-2 and covers 57 kilometres from coastal Crib Point/Hastings, north-eastwards to Packenham. The majority of pipe is buried using the cut and cover method, with the remaining alignment utilising the HDD or horizontal boring method for 39 crossings.

The pipeline alignment has been selected to minimise impacts on sensitive land uses and, where possible, it follows existing pipeline easements. The pipeline would be installed on land currently used for a variety of purposes, including rural residential living, road corridors, industrial, conservation reserves, hobby farms, horse studs and agriculture. An operational easement of generally 15 metres in width would apply along the pipeline alignment.

The pipeline would be buried with a minimum depth of cover of 1200 mm to the top of the pipe throughout its alignment for all location classes. The depth would be increased at specific areas as dictated by land use and identified threats noting that additional protective measures are required arising from the SMS.

8.2.3 Mainline valve stations

Two MLV stations would be installed at designated locations along the pipeline. Each station would be securely fenced and will operate as an unattended facility. The MLV stations provide isolatable sections of the pipeline that minimise gas volumes in the event of an incident leading to a loss of containment along the pipeline. The MLV stations would be designed to AS2885.1 and considered part of the pipeline system for regulatory; design, inspection and operational purposes.

Mainline valve station 1

Salient points with respect to MLV1 include:

- Mainline valve station 1 (MLV1) would be located in the southern portion of the pipeline alignment. It consists of a below ground actuated isolation valve; an integrated control panel including remote telemetry unit, backup power and communications systems; pipeline monitoring instrumentation and a cathodic protection system with test points.
- A functional description for the control of the Crib Point Pakenham Pipeline, including the Facilities, has been developed by APA. This includes the operational modes; alarms and safety interlocks providing operational safeguards for the pipeline.
- For MLV1, the remote manual opening and closing of the isolation valve is carried out through a remote SCADA System. The isolation valve can also be operated locally via a control panel within the fenced area of the MLV station.
- Pressure is monitored remotely via SCADA and pressure deviation alarms indicating abnormal conditions on the pipeline will be provided.
- A functional description for the control of the Crib Point Pakenham Pipeline, including the Facilities, has been developed by APA. This includes the operational modes; alarms and safety interlocks providing operational safeguards for the pipeline.

8.2.3.1 Mainline valve station 2

Salient points with respect to MLV2 include:

- Mainline valve station 2 (MLV2) would be located in the northern portion of the pipeline alignment. MLV2 is not automated and consists of a below ground isolation valve that can only be closed or opened manually at the valve station.
- Pressure gauges are provided at MLV2; however, these are not linked to a telemetry system and are intended for local use only.

8.2.4 Pakenham Delivery Facility

Salient point with respect to the Pakenham Delivery Facility include:

- The Pakenham Delivery Facility would be located approximately 1.4 kilometres south of the proposed VTS connection, adjacent to the Pakenham East rail depot. Gas flow into the VTS would be monitored and controlled at this location via the VTS connection.
- Key features of the Pakenham Delivery Facility include:
  - an actuated inlet isolation valve (downstream of pig launcher/receiver)
  - station inlet pig launcher/receiver, including pipeline isolation valve
  - dry gas filtration
  - custody transfer ultrasonic metering
  - gas composition measurement
  - water bath heating
  - fuel gas metering
  - flow control valves
  - one actuated station outlet isolation valve (upstream of pig launcher/receiver)
  - station outlet pig launcher/receiver, including pipeline isolation valve
  - Monolithic Isolating Joints for isolating pipeline from facility and also for insulating between above and below ground station piping.
  - instrument gas package

- station vent
- remote and automatic operation of isolation valves.

8.2.5 Victorian Transmission System Connection

The connection into the VTS includes the following key aspects:

- Two under-pressure tapping connections into the VTS
- One station isolation valve operated manually
- Provision to install a temporary pig launcher/receiver for pipeline internal inspections.

8.3 Regulatory Framework

8.3.1 Regulatory bodies

The Minister for Energy, Environment and Climate Change is the decision maker for pipeline licences in Victoria and has authority under the *Pipelines Act 2005* to issue and amend pipeline licences. The Minister is also empowered to accept an Environment Management Plan for any pipeline operations (which includes construction of a pipeline).

ESV is the independent agency responsible for regulating pipeline safety, both in construction and operation. ESV will review and provide acceptance of the Safety Management Plan and the Construction Safety Management Plan for any pipeline operations (which includes construction of a pipeline). ESV also accepts the safety case for a facility (including the pipeline and all assets associated with the pipeline's operation) under the *Gas Safety Act 1997*.

8.3.2 Approvals

The *Pipelines Act 2005* and the Pipelines Regulations 2017 govern the management and regulation of pipelines in Victoria. A Licence to Construct and Operate a Pipeline must be obtained by the proponent from the Minister for Energy, Environment and Climate Change.

8.3.2.1 Pipelines Act 2005

Pursuant to Section 14 & 15 of the *Pipelines Act 2005*, a person must not construct or operate a pipeline unless a licence to construct and operate that pipeline has been issued under the Pipelines Act. Regulation 8 of the Pipelines Regulations 2017 stipulates what must be included in any application for a licence. Key steps to acquiring a Pipeline Licence are outlined below.

Consultation Plan

An approved Consultation Plan is required prior to a proponent giving notice to each landowner and occupier of their intention to enter land or giving notice of a pipeline corridor.

The purpose of the plan is to set out the information that the proponent is to provide to owners and occupiers affected by the proposed pipeline.

Once the Consultation Plan is approved, APA will meet with landowners and occupiers throughout the life of the Project to:

- establish a line of communication and provide them with contact names and phone numbers
- explain the Project and the impact on their property, including easement acquisition, compensation, the regulatory process, their rights and obligations, etc.
- gather information on any future proposals for the land in an effort to minimise any impact on their businesses and lifestyle
- negotiate access to the land for pipeline alignment selection surveys and environmental studies.

In situations where access to land cannot be agreed with the landholder, APA may apply to the Minister for consent under the *Pipelines Act 2005* to enter the land.

Pipeline alignment selection

Pipeline alignment selection must include:

- Identification of the environmental, social and safety impacts arising from the proposed pipeline and pipeline operation, based on the surrounding current land uses and reasonably foreseeable future land uses, and measures undertaken to control, mitigate and manage the impacts from the proposed pipeline operation.

Details of alternative pipeline alignments considered by the application and reasons for selecting the proposed pipeline alignment and a comparison of the environmental, social and safety impacts arising from each of the alternative pipeline alignments and the proposed pipeline.

Section 100 of the *Pipelines Act 2005* requires that pipelines are required to be constructed in accordance with any prescribed standards, specifications and conditions. Australian Standard AS2885: *Pipelines – Gas and liquid petroleum* (AS2885) requires a central input into the design of the pipeline to be the consideration of the current and reasonably foreseeable land uses along the proposed pipeline corridor, for the design life of the pipeline.

Safety Management Plan

The *Pipelines Act 2005* Part 9 Division 2 Section 126 specifies that a licensee must prepare a Safety Management Plan (SMP), which needs to be submitted to and accepted by ESV prior to commencing any pipeline operations. The Pipeline Regulations 2017 outline the requirements of the SMP.

Environmental Management Plan

Part 9 Division 3 Section 133 of the *Pipelines Act 2005* specifies that a licensee must prepare an Environmental Management Plan (EMP) for approval by the Minister. A licensee cannot carry out a pipeline operation unless the Minister has accepted the EMP. The Pipeline Regulations 2017 outline the requirements of the EMP.

8.3.2.2 Pipelines Regulations 2017

Part 3 Regulation 8 of the Pipeline Regulations 2017 (the Regulations) sets out the information required to support a Pipeline Licence Application. An application must include (as relevant):

- (vii) identification of the environmental, social and safety impacts arising from the proposed pipeline and pipeline operation, based on the surrounding current land uses and reasonably foreseeable future land uses
- (viii) outline of the measures to be undertaken to control, mitigate and manage identified impacts arising from the proposed pipeline and pipeline operation

Safety Management Plan

Part 6 of the Regulations outlines the required content of a SMP.

The SMP must outline how the safety of employees, general public, the environment and the pipeline will be ensured by assessing all of the hazards and risks arising from the pipeline operation that have the potential to cause reportable or non-reportable safety incidents and describes the systems, practices and procedures undertaken, or proposed to be undertaken, to eliminate or minimise those risks so far as is reasonably practicable.

Licensees have an overarching SMP for “operations”, but in order to address Project specific requirements under the Pipelines Act for construction of new pipelines a separate construction SMP is typically prepared.

Environmental Management Plan

Part 7 of the Regulations outline the requirements of the EMP is required prior to construction of all pipelines. The Pipeline Regulations 2017 set out the matters to be included in an EMP.

EMPs describe how an action might impact on the natural environment in which it occurs and set out clear commitments from the licensee on how those impacts will be avoided, minimised and managed during design, construction and operation.

The EMP outlines measurement criteria for the mitigation measures proposed through the EES process and will be used to track the Project against the specific controls relevant to specific phases or activity associated with the Project.

8.3.2.3 Gas Safety Act 1997

ESV is the independent agency responsible for regulating pipeline safety, both in construction and operation. ESV administers the *Gas Safety Act 1997*, and associated regulations.

In 2018 the following gas safety regulations came into effect under the *Gas Safety Act 1997*:

- Gas Safety (Gas Installation) Regulations 2018
- Gas Safety (Safety Case) Regulations 2018.

The Regulations require compliance with a Safety Case, approved by ESV.

A safety case will be prepared for the facility which will stipulate safety management systems, standards of gas quality and requirements for testing of gas conveyed through pipelines, and requirements for reporting of gas incidents to ESV.

8.3.3 Interaction between Pipelines Act 2005 and Planning and Environment Act 1987

The *Pipelines Act 2005* provides for the licencing requirements of high-pressure gas transmission pipelines in Victoria. Pursuant to Section 85 of the *Pipelines Act 2005*, if a licence granted under this Act, no further approval is required for use or development of the pipeline pursuant to the *Planning and Environment Act 1987* unless the pipeline is exempted under the Act (as is the part of the pipeline that is located within the Port).

8.3.3.1 Standard AS/NZS2885

The pipeline will be designed in accordance with AS/NZS 2885.1:2018 Part 1 Pipelines – Gas and liquid petroleum, Part 1 Design and construct (AS/NZS 2885.1). The salient points relating to the design and construction of the pipeline are noted below:

- Section 4.7 of AS/NZS 2885.1 requires the route of a pipeline to be selected ‘having regard to public safety, pipeline integrity, environmental impact, and the consequences of escape of fluid’. This includes consideration of the land use existing at the time of design, and the future land use that can be reasonably determined by research of public records and consultation with land planning agencies in the jurisdiction through which the pipeline is proposed.
- An assessment of the predominant land use within the pipeline Measurement Length (ML) will enable a land use classification of the pipeline alignment, which in turn outlines the safety design requirements of the pipeline.
- The ML defines the area around the pipeline where location classes must be identified for the SMS regardless of whether pipeline rupture is a credible failure mode.
- AS/NZS 2885.6:2018: Pipelines – Gas and liquid petroleum, Part 6 Pipeline safety management (AS/NZS 2885.6) Section 2 Classification of locations states that ‘the primary location class shall reflect the population density’. The land use classifications include:
    - *R1 – Rural* Land that is unused, undeveloped or is used for rural activities such as grazing, agriculture and horticulture and includes infrastructure. Population is distributed in isolated dwellings.

  - *R2 – Rural Residential* As defined by the local planning scheme or occupied by single residence blocks typically in the range of one hectare to five hectares, also areas for which the number of dwellings with the Measurement Length radius from any point on the pipeline does not exceed approximately 50.
  - *T1 – Residential* Land that is developed for community living or is defined in a local planning instrument as residential or its equivalent. This location class applies where multiple dwellings exist in proximity to each other and dwellings are served by common public utilities.
  - *T2 – High Density* Land that is developed for high density community use or is defined in a local planning instrument as high density or its equivalent. High Density applies where multi-storey development predominates or where large numbers of people congregate in the normal use of the area. This location class contains more than approximately 50 dwellings per hectare.
- In addition to the land use classifications above, AS/NZS 2885.6 sets out secondary location class applicable to the Pipeline Works including:
  - *I – Industrial* Land used for manufacturing, processing, maintenance, storage or similar which pose a different range of potential threats. This secondary location class applies where development for factories, warehouse, retail sales of vehicles and plant predominates.
  - *S – Sensitive use* Land where the consequence of a failure event is increased because the land is used by sectors of the community who may be unable to protect themselves. Uses include schools, hospitals, aged care facilities and prisons.
  - C-*Crowd* The crowd Location class shall be applied to location where there may be crowds or congestion leading to concentration of population that are both intermittent and much higher than typical for the prevailing primary location class.
  - *HI- Heavy* Industrial sites developed or zoned for use by heavy industry or for toxic industrial use shall be classified as Heavy Industrial. They shall be assessed individually to assess whether the industry or the surroundings include features that-contain unusual threats to the pipelines systems.
  - *CIC Common Infrastructure Corridor* is land which, because of its function, results in multiple parallel infrastructure development within a common easement or reserve, or in easement which partially or fully overlay the pipeline easement.
  - *E - Environmental* The environmental location class identifies location of high environmental sensitivity to pipeline failure, including particularly areas where pipeline failure may impact on threatened ecological communities or species or where rectification of environmental damage may be difficult. Areas of high environmental sensitivity maybe identified by analysis of government environmental mapping within the pipeline measurement length and, where required, maybe validated by field surveys conducted by competent persons.

- The SMS for the Project has been undertaken in accordance with AS/NZS 2885.6 and has taken into consideration the design life of the pipeline.
- The SMS uses the land use classifications to inform both direct threats to the pipeline and the consequence of a pipeline failure to adjacent existing and future land uses.
- An outcome of this consideration of threat / consequence / likelihood is for the risk of a pipeline rupturing to be designed out to as low as reasonably practicable.
- The majority of the proposed pipeline adopts the design criteria consistent with a T1 environment, regardless of the actual land use classification. The physical protective measures of wall thickness and depth of cover have been designed conservatively and exceed the requirements of AS/NZS 2885.1 for the known threats within the ML.

8.3.4 Pipeline Licence approval process

The approval process must be completed prior to any construction. To commence this process an approved Consultation Plan is required. The purpose of the plan is to set out the information that the proponent is to provide to owner and occupiers affected by the proposed pipeline.

Once the Consultation Plan is approved APA will meet with landowners and occupiers to:

- Establish a line of communication and provide them with contact names and phone numbers.
- Explain the Project and the impact on their property, including easement acquisition, compensation, the regulatory process, their rights and obligations, etc.
- Gather information on any future proposals for the land in an effort to minimize any impact on their businesses and lifestyle.
- Negotiate access to the land for pipeline route selection surveys and environmental studies This includes the proponent giving formal notice to each landowner and occupier of intention to enter land.
- Negotiate agreements for the pipeline easement and access to the land for pipeline construction. This includes giving formal notice of the pipeline corridor.

In situations where access to land cannot be negotiated with the landholder, APA can apply to the Minister for Energy, Environment and Climate Change for consent under the *Pipelines Act 2005* to enter the land.

Once environmental studies and land surveys of the pipeline are completed and the pipeline alignment defined, a Pipeline Licence Application is made to the Minister for Energy. The Pipeline Licence Application will be supported by the following information:

- Consultation Plan
- Safety Management Plan
- Environmental Management Plan.

The notice and public exhibition of the Pipeline Licence Application may be combined with those of the EES. In deciding whether to grant a Pipeline Licence to the applicant, the Minister for Energy will consider the Minister for Planning's assessment of environmental effects, prepared at the conclusion of the EES process.

8.3.5 Licence to Construct and Operate a Pipeline

In Victoria, transmission pipelines require approval in the form of Licence to Construct and Operate a Pipeline, pursuant to the *Pipelines Act 2005*. A Licence to Construct is required before pipeline construction can commence.

An SMP is required prior to construction of the pipeline. The SMP will be prepared by APA. The consent application may be staged, whereby sections of the pipeline alignment or stages of construction are targeted. This enables work to commence while some preliminary work may still be unfinished.

The SMP will be prepared for the pipeline construction (based on similar documents used in recent APA projects). The SMP will form part of the tender documents for prospective tenderers to provide Safety Management Systems that comply with the requirements of the SMP. A staged submission for welding, hydrostatic testing [2], commissioning manuals and procedures will be undertaken prior to the work occurring for approval by ESV in its role as responsible Regulator.

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[2] Hydrostatic testing is a way of checking the integrity of the pipeline by subjecting it to pressure and monitoring for leaks. This test ensures the pressure tightness and strength of the pipeline meets the specified design codes.

An EMP will be prepared for the pipeline construction (based on similar documents used in recent APA projects). The EMP will form part of the tender documents for prospective tenderers. The selected Contractor must comply with the requirements of the EMP.

For Operation in accordance with Part 8 of the *Pipelines Act 2005*, APA will prepare a Safety and Operating Plan in order to obtain the Licence to Operate.

8.4 Studies completed

The following safety, hazard and risk studies have been completed as part of the Pipeline Works:

- Detailed Design Safety Management Study for the pipeline (SMS)
- Pipeline Heat Radiation Release Calculation
- Pipeline Penetration Resistance Calculation
- Hazard and Operability Study (HAZOP) for the pipeline and facilities
- Functional Safety SIL Assignment Report for the facilities
- Quantitative Risk Assessment (QRA) on the pipeline facilities

8.5 Studies to be completed

An SMP for the pipeline will be completed in accordance with the *Pipelines Act 2005* and Regulations.

The SMP is in progress, however all the components required to complete this (e.g. facility description, safety management system and facility safety assessments) have been completed. Any additional inputs to the SMP can be readily derived from existing information already produced by the Project.

The Project supports planning for bushfire resilience by locating in areas which are generally cleared of hazardous vegetation. The pipeline's location underground minimises impacts and risks associated with bushfires during operation. The Safety Case will include bushfire risk mitigation plans.

8.6 Risk study results

8.6.1 Major risks

The principal safety, hazard and risk studies completed by the Pipeline Works in the context of safety, hazard and risk were:

- SMS for the pipeline
- Quantitative Risk Assessment for the facilities.

These studies have examined the consequences and likelihood associated with fire and explosion risks as a result of an incident on the pipeline. The consequences were assessed against a recognised framework outlined in HIPAP 4.

The primary risk associated with the gas transmission pipeline is a loss of containment (via a leak or rupture) of high-pressure flammable gas, with subsequent ignition leading to fire and potentially explosion.

The hazards associated with a release of gas and ignition arise from the thermal radiation for jet, pool or flash fires and the overpressure effects from a potential explosion of a gas cloud, as follows:

- Jet fires, resulting from the ignition of a continuous release gas producing a long, stable, high-temperature flame. In case of a low-pressure, low-velocity or intermittent release, the resulting fire may be much shorter and less stable than in the case of a jet fire and generally would not result in equipment damage or injury.

- Flash fires, occurring when a cloud of gas is ignited, resulting in a flame travelling through the cloud.
- Vapour cloud explosion, occurring when a large cloud of gas is ignited. Vapour cloud explosions associated with lighter-than-air gases (such as natural gas) generally require confinement (such as in a building or enclosure) for the cloud to accumulate. Because of the requirement for gas to be confined, vapour cloud explosions are not considered credible for a pipeline release.

The risk of fatality or injury from exposure to a jet or pool fire comes via the level of heat radiation (kW/m^2) and the duration of exposure. The risk of fatality or injury from exposure to a flash fire assumes a fatality of 100% of persons located within a flame envelope where the flame envelope is the area within which the flammable gas is physically combusted.

A risk assessment study in the form of an SMS has been conducted in accordance with the requirements AS/NZS 2885. The study has been completed along the pipeline route and has identified *location classifications* through which the pipelines will pass based on land use and has assessed the types of threats to and from the pipelines at these locations.

8.6.2 QRA Results

A QRA for hazards and risks associated with all modes of operation for the Pakenham Delivery Facility was carried out including but not limited to gas receipt, gas treatment and transmission to the VTS.

The areas of interest with respect to off-site risk in the vicinity of the Pakenham Delivery Facility and the respective level of risk relative to the tolerable risk criteria outlined in HIPAP 4 are shown in Table 8-2.

Table 8-2 Calculated risk vs HIPAP 4 Criteria – Pakenham Delivery Facility

Location of Interest	Land Use (HIPAP 4)	Calculated Risk (per annum)	HIPAP 4 Criteria (per annum)	HIPAP 4 Criteria Met
Residential Area to North East	Residential	3.39E-07	1.0E-06	Yes
Residential Area to East	Residential	9.20E-07	1.0E-06	Yes
Rail Yard	Open Space	7.28E-06	1.0E-05	Yes
Freeway	Open Space	8.43E-06	1.0E-05	Yes

8.6.3 QRA Conclusions – Pakenham Delivery Facility

- The LSIR of fatality contours for the Pakenham Delivery Facility are also presented graphically in Appendix D.
- The LSIR contours indicate that the risk levels are below 50 in a million per annum which is the criterion for industrial land use, and often taken as the limitation of risk at the site boundary.
- Risk levels of 5 in a million per annum do not impact on areas classified as active open space and residences are situated outside the 1 in a million risk contour adopted by the Project as the tolerable risk criteria in accordance with HIPAP 4.
- The delivery facility itself sits within the APA property boundary and risk acceptability will be assessed against APA internal criteria considering the frequency of occupancy on site.
- It may be concluded that the proposed facilities meet the risk criteria as stipulated in the Land Use Planning guidelines (HIPAP 4) produced by the NSW Department of Planning that are being used for the Project.
- The risk for incidents for the whole site meets HIPAP4 risk criteria and satisfies the SFAIRP criteria.

8.6.4 Safety Management Study (SMS)

In accordance with AS/NZS2885.6, an SMS was completed for the pipeline including the valve stations and control systems.

In accordance with AS/NZS2885.6, the SMS was validated in a formal workshop involving a team that was collectively competent in the subject area; had detailed field based knowledge of the pipeline alignment and its surroundings; and had the authority to make decisions regarding the pipeline design.

The SMS identified potential threats to the integrity of the pipeline along the proposed corridor and multiple independent controls have been assessed and applied to each *credible* identified threat. Any threat that was not considered to be *controlled* has been risk assessed and the residual risk shown to be As Low As Reasonably Practicable (ALARP) consistent with the requirements of AS/NZS2885.6.

A description of the general SMS process and intended outcomes can be found in Appendix A.4.

Measurement length determination

The *measurement length* is the radial distance of a 4.7kW/m^2 heat contour for an ignited full bore rupture calculated in accordance with the method outlined in Appendix B of AS/NZS 2885.6.

Measurement length is used in the determination of location class (land use adjacent to the pipeline) and the respective protective requirements irrespective of whether pipeline rupture is a credible failure mode. The 4.7kW/m^2 level represents the heat exposure where second degree burns, and injury may occur after 30 seconds.

The measurement length for a full bore rupture of the proposed DN600 gas pipeline operating at a pressure of 10.2M pa, for the purposes of the determining the land use adjacent to the pipeline, has been calculated at **640 metres**.

The predominant land use within this measurement length has been used in the location analysis as the basis for assessing threats and mitigations both to, and from, the pipeline.

Location analysis

As part of the SMS, the pipeline alignment was sectioned according to the predominant land use. For each section a threat analysis was completed, looking at the potential threats to pipeline system integrity and risks to people, property and the environment. During the threat assessment process, the pipeline was divided into 10 sections along the entire 57-kilometre alignment.

For each of these sections, a *primary location class* based population density and land use within the measurement length (640 m) was assigned. Where appropriate, one or more *secondary location class* reflecting special land use were allocated to locations along the proposed alignment. The location classifications were based on the requirements of AS/NZS2885.6:2018.

The location class analysis was based on the land use permitted in the legislation, regulations and planning scheme applicable to the land along the proposed alignment. A detailed investigation was undertaken as part of the SMS to identify all reasonably anticipated changes in land use along the route over the design life of the pipeline. Where the extent of the anticipated land use change can reasonably be determined, the pipeline location class has been based on the most demanding of the current and anticipated land uses.

Location classifications for the respective sections of the pipeline are summarised in Table 8-2.

Pipeline design

The aspects of the pipeline design and in-service requirements driven by the location classification are summarised below.

Each of these has been considered in the design and will be considered for the in-service operation of the pipeline.

- wall thickness
- penetration resistance requirements
- spacing of mainline valves
- fracture arrest length
- minimum depth of cover
- high consequence areas (no rupture)
- if shallow cover is permitted
- as-built survey accuracy
- isolation plan requirements for loss of containment
- energy release rate (< 1 gigajoule per second (GJ/s) in T2 or S locations; 10 GJ/s in T1 and I locations)
- signage spacing (100 m for T1; 50 m for T2)
- external interference protection.

Location classes

- A summary of the location classification for the sectioned pipeline alignment taken from the SMS is provided in below.

Table 8-3 Location classification along pipeline alignment

Section	Start (km)	End (km)	Length (km)	Location Class	
				Primary	Secondary
1. The Esplanade to Woolleys Rd, Crib Point	0	0.9	0.87	T1	S, I
2. Woolleys Rd, Crib Point to Warringine Park, Bittern	0.9	4.4	3.5	T1	
3. Warringine Park, Bittern to Hastings township	4.4	5.5	1.11	T1	I
4. Hastings township to Denham Rd, Hastings	5.5	11.4	5.93	T1	S, I
5. Denham Rd, Hastings to South East Boundary Rd, Pearcedale	11.4	19.8	8.35	R1	I
6. South East Boundary Rd, Pearcedale to Rutherford Creek, Devon Meadows	19.8	29.4	9.65	R1	
7. Rutherford Creek, Devon Meadows to South	29.4	30.7	1.24	R1	S

Section	Start (km)	End (km)	Length (km)	Location Class	
				Primary	Secondary
Gippsland Hwy, Devon Meadows					
8. South Gippsland Hwy, Devon Meadows to Bald Hill Rd, Pakenham	30.7	53.1	22.47	R1	
9. Bald Hill Rd, Pakenham to Pakenham East rail depot, Nar Nar Goon	53.1	54.7	1.58	T1	I
10. Pakenham East rail depot, Nar Nar Goon to Princes Hwy, Nar Nar Goon North	54.7	56.5	1.79	T1	S, I

Where;

- Rural (R1): a primary location class that denotes land that is unused, undeveloped or used for rural activities such as grazing or agriculture.
- Residential (T1): a primary location class that denotes land that is developed, supports community living, suburban with multiple dwellings.
- Sensitive (S): a secondary location class that denotes land used by sectors of the community who may be unable to escape or protect themselves.
- Industrial (I): a secondary location class that demotes land used for manufacturing, processing, maintenance, storage, factories, warehousing etc.

Pipeline Heat Radiation and Energy Release

AS 2885.6:2018 requires a determination be made with respect to the distances that the thermal radiation from an ignited release of gas having intensities of 4.7 kW/m^2 and 12.6 kW/m^2 will extend.

The thermal radiation contour and energy release rate are dependent on pipeline parameters, including the size of any potential leak point, operating pressure and calorific value of the gas.

The respective radiation contours and energy release rates for potential hole sizes are illustrated in the Fire Safety Study and tabulated below in Table 8-4. The methodology used to determine the radiation contours and energy release rates is consistent with the guidance provided in AS/NZS 2885.6:2018 Appendix B.

Heat radiation contours

A thermal radiation level of 4.7 kW/m^2 will cause injury, at least second degree burns, after 30 seconds of exposure.

A thermal radiation level of 12.6 kW/m^2 represents the threshold of fatality for normally clothed people resulting in third degree burns after 30 seconds of exposure.

The distance from the pipeline at which these thresholds will be reached are dependent on hole size, release pressure and properties of the gas.

The following table shows the calculated radiation contours and energy released for various hole sizes on the proposed DN600 gas pipeline operating at 10.2 MPa.

Table 8-4 Heat Radiation Contours

Potential Hole Size	Radiation Contour (4.7 kW/m^2)	Radiation Contour (12.6 kW/m^2)	Energy Release Rate (GJ/s)
36mm	65m	40m	1.00
25mm	45m	28m	0.48
12mm	22m	13m	0.11
3mm	5m	3m	0.01

Energy release rates and location classification

AS/NZS 2885.1-2018 Clause 4.9.3 and AS/NZS 2885.6-2018 Clause 2.4 combine to provide limits on the energy release rates relative to the respective location classification. With respect to the pipeline the following apply:

- Residential (T1) / Industrial (I)
  - Where there are residential areas (i.e. community living) within the measurement length, the energy release rate shall not be greater than 10 GJ/s. The same requirements have been applied to Industrial locations (I).
- Sensitive location (S)
  - Where there is a sensitive development (i.e. schools, hospital, aged care facility, prison) within the measurement length, the energy release rate shall not be greater than 1 GJ/s.

The SMS concluded that due to the soft ground conditions, large and forceful HDD drilling which is required where ground conditions are hard is not considered a credible threat along the pipeline alignment in Sensitive (S) location classes, and as such, a hole greater than 36 mm due to HDD drill impact on the pipeline, and that required for a greater than 1 GJ/s energy release rate, is not credible.

Threats

Threat identification was undertaken across the full length of the pipeline including all facilities. The threat categories covered by the SMS included threats from:

- external interference
- corrosion
- natural events
- faults in design
- faults in construction
- intentional and wilful damage.

Threat analysis

A full list of the identified threats, pipeline protection measures, hazard prevention, failure analysis and risk evaluation for credible threats is provided in the Safety Management System workshop report.

Summary of threats

The threat identification process carried out as part of the Safety Management Study yielded the following outputs:

- A total of 212 potential threats to the pipeline and facilities were identified.
- 114 of the 212 potential threats were considered non-credible. Non-credible threats do not require controls.

- 98 of the 212 potential threats have been considered credible. Identified credible threats require further risk evaluation to arrive at a 'risk ranking'.
- 21 of the 98 credible threats required no further risk evaluation.
- 76 of the 98 credible threats have been evaluated as presenting a *low* or *negligible* risk. These low and negligible risks are considered to be ALARP.
- Of the 98 credible threats one has been evaluated as presenting an *intermediate* risk. This threat was defined as 'Vertical auger boring to install new power poles'. This required a formal ALARP assessment that included the application of additional control measures.
- There were no high or extreme risks identified.

Non-credible vs controlled threats

The accepted definitions outlined in AS2885.0 for *non-credible* and *controlled* threats were used during the SMS when evaluating threats to the pipeline. For the purposes of the threat assessment and risk evaluation, the following general definitions have been used in the SMS:

- A *non-credible* threat is where the likelihood of occurrence is so low that is does not exist for any practical purpose at the nominated location. The credibility or otherwise of a threat is characteristic of the threat itself and is assessed independently of any protective or mitigation measures that may be applied.
- A *controlled* threat is a threat where sufficient protective measures have been applied so that the possibility of a failure event due to the identified threat has been removed for all practical purposes.

Location specific vs non-location specific threats

Location is an essential element of threat identification when assessing the risk to pipeline. Threats may exist:

- at a specific location (e.g. excavation threat at a particular road crossing)
- throughout specific sections of a pipeline (e.g. farming; forestry; land instability)
- over the entire length of the pipeline (e.g. corrosion).

Threats that occur over the entire length of the pipeline are also referred to as non-location-specific. They are often described differently to location-specific threats (e.g. corrosion versus external interference threats at a road crossing or within a farming area).

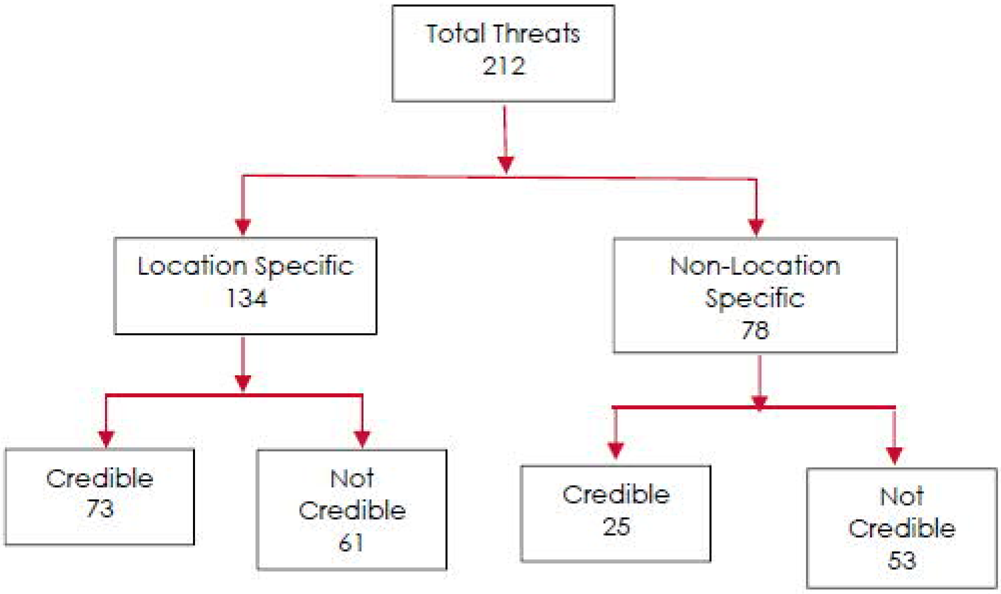

Figure 8-1 Total number of identified threats

Risk rating of threats

Only credible threats were subjected to further risk evaluation.

Risk evaluation and rating was carried out using the risk matrix of Table 3.3 of AS/NZS2885.6 3. The combination of consequence analysis and frequency analysis was used to risk rate the credible threats.

A summary of the credible threat analysis and the risk evaluation is provided below.

Table 8-5 Summary of Credible Threat Analysis and Risk Rating

Threats (specific)	Total	Risk Rating					
		Extreme	High	Intermediate	Low	Negligible	Not Assessed
Location	73	-	-	1	33	25	14 (further risk evaluation not required)
Non-Location	25	-	-	-	7	11	7 (further risk evaluation not required)
Total	98	-	-	1	40	36	21

Demonstration of ALARP

AS/NZS2885.6 requires that risks be reduced As Low As Reasonably Practicable (ALARP).

For the purposes of the AS/NZS2885.6 clause 4.1 states that risks associated with a threat to or from the pipeline are deemed ALARP if:

- the threat is controlled
- the residual risk is assessed to be low or negligible
- the residual risk is formally demonstrated to be ALARP.

Negligible risks

Risks evaluated as being negligible during the SMS of the pipeline alignment and validated at the SMS workshop are deemed ALARP and no further action is considered necessary.

Low risks

Risks evaluated as being low during the SMS of the pipeline alignment and validated at the SMS workshop are deemed ALARP. Additional measures have been taken to ensure that these risks are being managed to prevent any further rise in risk. These measures are included under the discussion of threat control measures and in the pipeline design and parameters.

Intermediate risks

One of the threats has been evaluated as presenting an intermediate risk. This threat was defined as "Vertical auger boring to install new power poles". This required a formal ALARP assessment that included the application of additional control measures.

The ALARP assessment found that the threat could only be completely mitigated by lowering the pipeline well below the likely depth that an auger might need to go however the cost of having to do this for the entire length of T1 location class, approximately 15 m of the pipeline, would make the cost grossly disproportional to the benefit achieved considering the difficulty an auger would have to rupture the pipeline.

There were however two additional mitigations considered as being to be appropriate to mitigating this threat to ALARP:

- Add additional marker posts to the pipeline ROW in areas of high potential risk may occur and also where power poles (and possible replacement of such) are located within 10m of the pipeline. This will facilitate increased liaison activities targeting, include telecommunication, large developers and excavation companies.
- The installation of additional protective slabbing, greater than normal APA standards. This includes an additional 10 metres of slabbing at every road crossing (in T1) and slabbing whenever the pipeline is laid within three metres of an existing power pole. With the exception of occasions when the pipeline will be buried directly under existing asphalt. In addition, the length of pipeline between the Pakenham PRS and end of line will be protective slabbed, unless the pipeline is deeper than three metres.

Threat review and controls summary

The following threat controls have been proposed for the pipeline design and operation:

- The pipeline will be designed in accordance with AS/NZS 2885.1: 2018.
- A conservative pipeline design has been adopted. The physical protections provided by wall thickness and depth of cover exceeds requirements for the location class of R1. If there is change in population density in the future, more procedural measures may be required, but the physical

protections - which are hard to change once in operation – have been designed conservatively and beyond the requirements dictated by the location classification.

- Pressure testing plan is allowing for reaching 100% Specified Minimum Yield Strength (SMYS) (14.16MPa). Specified Minimum Yield Strength is the minimum stress a pipe may experience that will cause plastic (permanent) deformation. The test pressure is required to determine the Maximum Allowable Operating Pressure (MAOP) of a pipeline.
- The regular operational patrol regime, as implemented in urban areas across APA's existing pipeline network, will be adopted for the Hastings area to monitor whether there are activities occurring which could represent a threat to the pipeline.
- Managing latent dents or defects will be via inline inspection. In-line inspection (internal) of the pipeline will be carried out 10 years post construction and then on a frequency determined by the results of the previous inspection. A geometry pigging run will be completed before commissioning to establish baseline data for ongoing evaluation of the pipeline health.
- Access to the right-of-way easement will be maintained across length of pipeline alignment. Pipeline markers will be installed along the route and additional marker posts installed in higher risk areas to alert parties conducting works to the pipeline location.
- Soil conditions do not indicate surface rock. It was the conclusion of the SMS workshop that a penetration tooth attached to an excavator operated by a third party in the future is not a credible scenario. No heavy-duty drilling is anticipated by third parties due to soft ground at surface depths along the pipeline alignment.
- To control the potential threat from external interference related to road crossings (drain clearing, installation of services etc.) by method of open cut, the standard design for this pipeline will have protective slabbing as per APA standard designs.
- In several crossings and other specific land use areas, the pipeline construction technique will be installation via the HDD technique. Coating damage during HDD is a threat to pipeline integrity. The SMS workshop concluded that this threat is controlled through improved coatings; an Abrasive Resistance Overlay (ARO); and the requirement to replace the section if flaws are detected. A trenchless crossing construction management plan is a mandatory document to be approved in accordance with AS/NZS 2885.1-2018.
- Installation via open cut of the pipeline in the rail corridor from Kilometre Point KP5 to KP10 in the Hastings vicinity (refer to EES Attachment VII *Map book*) would have a minimum of 1200 mm cover along the route with 2000 mm cover required at rail crossings.
- In the vicinity of the Pakenham East rail depot located in Pakenham (KP53 to KP56) the pipeline will be protected by the provision of 20m x 2 concrete slabbing where the pipeline crosses minor access roads.
- To control for the threat from installation of power poles over the pipeline, a standard design will include installation of protective slabbing over the pipeline for three metres either side in locations where the pipeline is within three metres of existing power poles and 10 metres of slabbing at road crossing locations in T1 areas. Additional marker posts will be installed within the right-of-way wherever the pipeline comes within 10 metres of existing power poles.
- Creating a hole by HDD leading to an energy release rate greater than 1 GJ/s in the pipeline in a sensitive location is not a credible scenario due to soft soil conditions.
- The pipeline meets the 'no rupture' requirements against a threat from a 25T excavator with tiger tooth (worst case assumption for penetration test). Use of larger than 25T excavators is not considered credible for the pipeline route. The use of penetration teeth in excavators is not considered credible; the credible tooth type is considered to be general purpose.
- At MLV1, the risk from vehicle impact is not credible given the station is located above the elevation of the road. The valve is equipped with remote actuation for remote shut-off if required.
- At MLV2 flooding is a credible threat. This has been catered for in the design. The valve at MLV2 is manually operated and provision for actuation has been provided for future development.

- Theft and vandalism are credible threats at the Crib Point Receiving Facility and the Pakenham pressure reductions station. The sites will be fenced and routinely patrolled by security contractors. Remote intrusion monitoring will be considered in detailed design as a control.

Ongoing review of SMS assumptions

The assumptions used in the risk evaluation process and the conclusions of the SMS will be reviewed on an ongoing basis during pipeline operation.

In particular, the assumptions that the credible equipment size along the pipeline alignment is limited to 25T with general purpose teeth and that there is no credible likelihood of forceful drilling along the pipeline alignment will be continuously reviewed for validity during routine pipeline patrols and during the periodic operational SMS (at least every five years).

9.0 Project Areas interfaces

9.1 Overview

A QRA was conducted to systematically address the likelihood and consequence of all potential hydrocarbon related risks for the Project in order to determine if such risks are tolerable in accordance with the established risk criteria.

Preliminary QRAs have been completed for the FSRU, Jetty Infrastructure and Crib Point Receiving Facility. The results from the QRAs including the impact from the United Petroleum operated Berth 1 have been combined to provide the cumulative effects across the area adjacent to the Crib Point project area. These estimated risks have been compared against the risk criteria for the Project (HIPAP 4) to establish if the risk is within the tolerable risk criteria.

The QRA for the Gas Import Works, identified 42 potential failure cases leading to an incident. The following specific scenarios with potential to lead to a major incident were raised for assessment within the QRA:

- release from the FSRU LNG transfer system
- release from the FSRU Process facilities
- release from marine loading arms at Berth 2 (AGL)
- release from gas piping on Crib Point Jetty (AGL)
- release from fuel unloading hoses at Berth 1 (United)
- release from fuel pipeline on Crib Point Jetty (United).

Each of these scenarios can potentially lead to the uncontrolled release of hydrocarbons with the risk of subsequent ignition leading to a pool fire; jet fire or explosion.

The consequence of each of these initiating incidents were modelled with the resultant risk of fatality and risk of injury plotted on a series of risk contours. The results are discussed below and illustrated in Appendix C.

9.2 QRA – Gas Import Jetty Works

A QRA study was conducted to evaluate the risk imposed by the unloading of LNG from LNG carrier to FSRU, transfer of gas from the Crib Point Jetty to the Crib Point Receiving Facility and the risks imposed by the diesel and octane tankers at United Berth 1.

DNV GL conducted a preliminary QRA for hazards and risks associated with Project works at Crib Point including but not limited to:

- all modes of the FSRU operation
- marine operations (approach and mooring) for the FSRU, LNG carrier and Petroleum tankers
- gas operations on the Crib Point Jetty including gas send out from the FSRU, MLAs, STS transfer
- Crib Point Receiving Facilities operations
- interactions (simultaneous operations) with external factors such United Petroleum unloading activities and operations of the pumping station.

The QRA will require refinement as the design progresses, however it is reasonable to expect that the findings of the QRA will not significantly change as:

- FSRU component of the QRA is based on other operating FSRU for the worst case configuration.

- Jetty piping design is at 90% complete and no significant change in design or location is expected.
- Crib Point component of the QRA will require some minor movement of equipment but the QRA has been completed on a conservative basis and no significant change in volumes or operating conditions is anticipated.

The LSIR contours for fatality risk are provided in Appendix C and the results relative to the HIPAP 4 criteria summarised below in Table 9-1.

The propagation damage and injury risk likelihoods are provided in Appendix C and the results of relative to the HIPAP 4 criteria are summarised below in Table 9-2.

Table 9-1 Summary of Gas Import Jetty Works QRA results vs HIPAP 4

HIPAP 4 Criteria (per annum)	Land Use	HIPAP 4 Criteria Met
5E-07	Sensitive land use; e.g. Hospitals, schools, child-care facilities, old age housing	Yes
1E-06	Residential, hotels, motels, tourist resorts	Yes
5E-06	Commercial developments, retail centres, offices, entertainment spaces	Yes
1E-05	Active open spaces – including sporting complexes	Yes
5E-05	Industrial	Yes

Table 9-2 Summary of propagation and injury risk – Gas Import Jetty Works

Criteria (per annum)	HIPAP 4 Criteria	HIPAP 4 Criteria Met
5E-05	Property damage from Thermal Radiation - 23kW/m^2	Yes
5E-05	Overpressure damage and Propagation – 14 kPa	Yes
5E-05	Injury from Thermal Radiation - 4.7 kW/m^2	Yes
5E-05	Injury from Overpressure – 7 kPa	Yes

Specific areas of interest

The three areas of interest with respect to off-site risk selected for further evaluation are the Victorian Maritime Centre; Picnic Point; and the closest point at which the public can get near to the LNG import facilities, denoted as Public Access. The estimated risk at these locations assessed against the HIPAP4 criteria is summarised in Table 9-3.

Table 9-3 Calculated risk vs HIPAP4 criteria – Gas Import Works areas of interest

Location of Interest	**Land Use (HIPAP 4)**	**Calculate Risk (per annum)**	**HIPAP 4 Criteria (per annum)**	**HIPAP 4 Criteria Met**
Victorian Maritime Centre	Commercial development	2.67E-06	5.0E-06	Yes
Picnic Point	Active open space	1.26E-06	1.0E-05	Yes
Public Access	Active open space	6.12E-06	1.0E-05	Yes

9.2.1 QRA Conclusions – Gas Import Jetty Works

The following findings are made from the preliminary QRA study conducted for the Gas Import Jetty Works.

- Picnic Point
  - At the risk ranking point placed at "Picnic Point" at Woolleys Beach Reserve, the LSIR is approximately $1.3x10^{-6}$/year.
  - The risk contributors are:
    - 94% of the risk at that point is contributed by a full-bore rupture of the liquid phase of the Suction Drum in the FSRU system. The hazard types contributing to this risk impact arise from flash fire with explosion and pool fire.
    - 5% of the risk is from leaks from Crib Point Facility, leading to jet fire and flash fire.
- Public Access
  - At the "Public Access" risk ranking point (placed at the location where the public could have the closest access to the FSRU), the LSIR is approximately $6.1x10^{-6}$/year.
  - The risk contributors are:
    - 53% of the risk is from leaks from Crib Point Receiving Facility, leading to jet fire and flash fire
    - 23% of the risk is existing risk from Berth 1 United Petroleum operations when unloading octane or diesel, leading to impacts from flash fire, explosion and pool fire
    - 17% of the risk is due to a full-bore rupture of the liquid phase of the suction drum in the FSRU system, leading to impact from flash fire with explosion and pool fire
    - 6% of the risk is from the gas piping on the Crib Point Jetty, leading to jet fire, flash fire and explosion.
- Victorian Maritime Centre
  - At the risk ranking point placed at the "Victorian Maritime Centre", the LSIR is approximately 3×10^{-6}/year.
  - The risk contributors are:
    - 95% of the risk is from leaks from the Crib Point Receiving Facility, leading to jet fire and flash fire
    - 5% of the risk is from a full-bore rupture of the liquid phase of the suction drum in the FSRU system, due to impact from flash fire with explosion and pool fire.

Conclusions

The 1 $x10^{-6}$/year risk contour does not reach any residential areas.

The contours corresponding to 50 chances in a million years radiation heat flux of $4.7kW/m^2$ or overpressure of 7 kPa (representing the threshold for any injury) do not reach any residential areas or specified receptors.

The Picnic Point and Public Access recreational area are designated as open spaces, this meets the risk criteria of not exceeding. $1x10^{-5}$ per year.

As the Victorian Maritime Centre is designated as a commercial development, it meets the risk criteria of not exceeding 5 $x10^{-6}$ /year.

The proposed facilities meet the risk criteria as stipulated in the Land Use Planning guidelines (HIPAP 4) produced by the NSW Department of Planning that are being used for the Project.

The HAZID conducted for the Gas Import Jetty has derived a list of action items which are to be considered for implementation to further mitigate or reduce the risk.

9.3 Safety system and control interfaces

9.3.1 Emergency shutdown safeguards

The Project would include numerous safety systems each responsible for the monitoring, control and shutdown of the gas export process in the vent on an emergency. Due to the interconnectivity of the respective facilities each operator would have the ability to close shutdown valves within other operator facilities.

The salient features and intent of each of the shutdown systems is discussed below.

Emergency shutdown philosophy

The design of the safety shutdown systems includes:

- Automatic activation of emergency stops at the FSRU
- Automatic activation of any emergency stop at the Jetty
- Automatic activation of an emergency stop at Crib Point Receiving Facility
- Jetty gas piping low-low pressure reading on the gas piping (from a pressure transmitter), which will indicate a potential leak and as result initiates a closure of the emergency shutdown valves
- ESD on power failure (note that emergency systems are backed up by an uninterruptible power supply)
- Isolation of gas flow at the Jetty Infrastructure, Crib Point and Pakenham via remote operation of actuated emergency isolation valves.

Activation of any emergency stop between the FSRU and Crib Point will close all isolation valves and stop the transfer of gas from the FSRU to the jetty gas piping. Activation of the emergency stop on the mainline valves (MLV1 and MLV2) on the gas pipeline line between Crib Point and Pakenham will send a signal to Crib Point Receiving Facility and the FSRU that initiates a gas export stop.

There are also safety shutdown systems on the FSRU that would protect the gas pipeline, including:

- high-high pressure reading in the gas export header on the FSRU
- low-low pressure reading in the gas export header on the FSRU
- low-low temperature reading in the gas export header on the FSRU.

The FSRU is equipped with several other safety shutdown functions not directly related to pipeline segments downstream of the FSRU.

The systems also include the provision of:

- manual activation of emergency stops at the FSRU
- manual activation of any emergency stop at the Jetty
- manual activation of an emergency stop at Crib Point Receiving Facility.

9.3.2 Summary of shared interface signals

The following is a preliminary outline of the interfaces signals that will be shared between the respective elements of the Project. These interfaces have been agreed to by the proponents of the Project and will be refined as detailed design for each project element is finalised.

APA to AEMO

The Crib Point Receiving Facility would provide AEMO with a series of process measurements and alarms as summarised below:

- From Crib Point:
    - gas flowrate, pressure & temperature measured at the flowmeter

  - gas quality measurements and calculations
  - status of Crib Point Receiving Facility ESD (SESD-1001).
- From Pakenham:
  - gas flowrate, pressure & temperature measured at the custody transfer flowmeter
  - gas quality measurements and calculations
  - position of outlet facility isolation valve (ESDV-5040)
  - status of Pakenham Delivery Facility ESD (SESD-5001).

From Crib Point Receiving Facility to FSRU

The following signals will be sent from the Crib Point Receiving Facility to the FSRU:

- gas flowrate, pressure & temperature measured at the flowmeter
- gas quality measurements and calculations
- position of inlet facility isolation valve (ESDV-1001)
- status of Crib Point Receiving Facility ESD system
- pressure of gas at receiving point to Crib Point.

From FSRU to Crib Point Receiving Facility

The following signals will be sent from the FSRU to the Crib Point Facility:

- operating status of the FSRU, i.e., filling LNG from tanker to FSRU, gas export etc
- continuous feed of gas quality data from the on board gas chromatographs
- continuous feed of gas flowrate data from the on board custody transfer meter
- status of FSRU ESD.

Shutdown interfaces

The design of the safety shutdown systems includes the following key actions:

- activation of emergency stop at the FSRU
- activation of any emergency stop on the Jetty Infrastructure
- activation of an emergency stop at Crib Point Receiving Facility.

Activation of any emergency stop between the FSRU and Crib Point will close all isolation valves and stop the transfer of gas from the FSRU to the jetty pipeline.

Activation of the emergency stop on the mainline valves on the gas pipeline line between Crib Point and Pakenham would send a signal to Crib Point Receiving Facility to initiate a gas export stop.

- The position of the Crib Point Facility isolation valve ESDV-1001 would be sent to the FSRU.
- The status of the ESD system at Crib Point Receiving Facility and the Pakenham Delivery Facility will be sent to the FSRU.
- The status of the ESD system on the FSRU will be sent APA SCADA.

A detailed Cause & Effects matrix has been developed showing the resultant actions based on process inputs and activation of emergency systems. This will be refined as the detailed design is completed.

All interfaces between the respective systems have been communicated on a detailed Functional Description and Operating Philosophy document. This document will be updated and refined as the Project develops.

10.0 Emergency management and response

10.1 Development of emergency response plans

The approach to emergency management and response for the Project will be aligned with the Emergency Management Victoria framework to ensure planning, preparedness, operational coordination and community participation are fundamentals when implementing the following objectives from the *Emergency Management Act 1986,* Section 4A by addressing:

- prevention—the elimination or reduction of the incidence or severity of emergencies and the mitigation of their effects
- response—the combating of emergencies and the provision of rescue and immediate relief services
- recovery—the assisting of persons and communities affected by emergencies to achieve a proper and effective level of functioning.

Emergency management and response will be a component of the emergency management structure implemented at Crib Point under the umbrella of the PoHDA Emergency Management Plan.

The PoHDA Emergency Management Plan identifies the requirement that the Facility Operators, shall develop an emergency plan that is consistent with the PoHDA Emergency Management Plan.

There will be a requirement for extensive consultation during the planning phase leading up to the construction phase, in preparation for the operations phase and as an ongoing commitment during the operations phase. This will include:

- Preparation of Emergency Response Plans (ERPs) undertaken in consultation with PoHDA, WSV, Victoria Police, the Country Fire Authority and Metropolitan Fire Board.
- Consultation on and coordination with United Petroleum on the Crib Point Jetty emergency response.
- Consultation with Mornington Peninsula Shire Council, and Regional and State Emergency Management Committees.
- Emergency Response Planning involving the movement of vessels prepared in consultation with and to meet the reasonable requirements of the VRCA Harbour Master and PoHDA.
- Consultation with relevant neighbouring facilities and the community.

The number of stakeholders present at Crib Point changes regularly dependent upon operations and construction activity. This will influence the primary party/parties responding to an emergency and how the response can impact others onsite and offsite. Accordingly, an emergency may involve one operating stakeholder or multiple stakeholders working in areas adjacent to each other.

To ensure the response to an emergency is effective and timely the approach to emergency management would provide a framework for multiple agencies to activate in an emergency situation and would be the basis for incorporating external emergency support to the Gas Import Jetty.

10.2 ERP structure and content

The ERP will be developed specifically for use at the Crib Point Gas Import Jetty Works, and be based on the design, equipment, operations and environment in which the import operation would be undertaken.

The ERP will be risk based with the ERP structure and content based on a series of parameters including identification of the following:

- what defines an emergency

- the hazards related to constructing and operating the Gas Import Jetty
- the potential for emergencies occurring
- the characteristics of emergencies that can occur
- an estimation of the potential consequences of hazards on people, the environment and property
- what is required to activate the ERP and de-activate the ERP.

Accordingly, the ERP will also set out requirements for:

- Emergency detection and shutdown systems, practices and procedures - Including, for example, FSRU emergency and ship to shore systems; quick release hooks; jetty flowline and ESD valves; shutdowns; gas and fire detection and alarms; fire detection and protection systems and fire mitigation.
- Contingency planning for responses to foreseeable incidents based on risk assessment processes and associated emergency procedures for responding to these contingencies - Including, for example, oil spill response in the Port of Hastings; identification of levels of emergencies; emergency functions and organisation structure; emergency resources; reporting and notification associated with an emergency; and termination of an emergency response.
- An implementation strategy for managing the ERP including training, reviews, continuous improvements; safety management system; and critical control performance standards.
- Development and maintenance of procedures to align with the requirements of AS3745: 2010 *Planning for Emergencies in Facilities*.

10.3 Construction phase emergency response

The emergency response during the construction phase will be based on the capabilities planned and implemented by the construction Principal Contractor (PC). The PC Emergency Response Plan will be aligned with the requirements of POH-HSE-PLN-001 the Port of Hastings Development Authority (PoHDA) Emergency Management Plan.

As the Crib Point Jetty is an operating site for other organisations, the PC ERP would be developed in consultation with:

- AGL
- PoHDA
- United Petroleum
- APA
- the Pipeline construction PC
- the site security contractor.

The aim of the consultation would be to ensure the planning, preparation, response and recovery is integrated and complimentary. This approach will ensure that an event occurring in an area under the management and control of another stakeholder can be effectively responded to by other stakeholders. The lead ERP will be that belonging to the stakeholder where the emergency has been initiated.

The construction ERP will sit within the PoHDA emergency management framework for the Port of Hastings. This framework is supported by the VRCA Emergency Management Plan.

All works on water or when a vessel is at Berth 1 will be subject to the directions of the Port of Hastings Harbour Master or their delegate acting in the role of incident controller in accordance with the PoHDA Emergency Management Plan.

During the construction phase there will be up to three ERPs at Crib Point subject to the two emergency management plans for the Port of Hastings. These plans sit within the Victorian Emergency Management framework for support and offsite emergency impact management. This framework is represented in Figure 10-1.

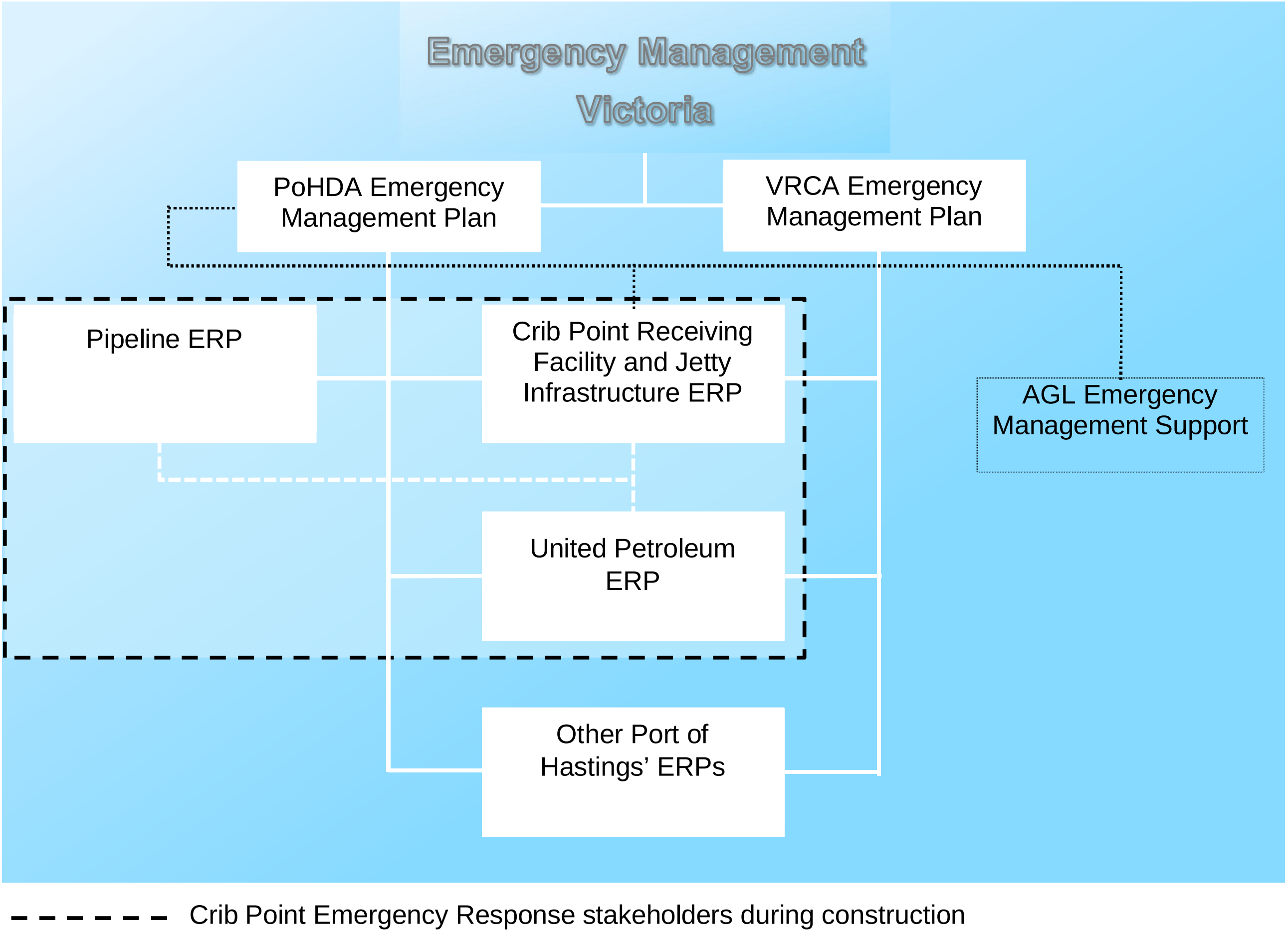

Figure 10-1: Crib Point Construction Phase Emergency Management Framework

10.4 Operations phase emergency response

Towards the end of the construction phase preparations would be made for the arrival of the FSRU. The operations phase structure would be in place for the arrival of the FSRU and tested inclusive of the FSRU once berthed at Crib Point.

At a designated time/date agreed between relevant parties, a handover of operational management and control will be undertaken between the construction PC and the Operator of the Gas Import operation. The changeover would include a change of emergency response plan and responsibilities of the personnel responding to emergency incidents.

The Gas Import Operation emergency response stakeholders include:

- Gas Import Operator: Operator of the Crib Point Receiving Facility and Jetty Infrastructure
- Operator of the FSRU
- APA: pipeline operator
- various LNG carriers: the operators of the LNG carriers transporting LNG to Crib Point and involved in the STS transfer of LNG to the FSRU.

During a potential or actual emergency, the lead emergency response would be the stakeholder where the emergency event occurred or could occur. The incident site commander would initiate the response within the PoHDA Emergency Management Framework. All other stakeholders would activate their emergency response based on supporting the stakeholder responding to the emergency or to undertake an evacuation.

If an emergency occurs whilst a ship is transiting into/out of Port waters, the vessel ERP will be initiated within the framework of the VRCA EMP, supported by the PoHDA EMP. The Incident Controller for both plans is fulfilled by the Harbour Master or their delegate. The emergency response capability for the LNG carriers will be integrated in the early stages of an LNG carrier arriving at Crib Point. This process will occur each time an LNG carrier arrives at Crib Point and prior to STS.

The impact on the FSRU at berth arising from an incident during unloading operations at the United Petroleum will be considered in the ERP.

Emergency support to an LNG carrier in the Port of Hastings prior to mooring at Crib Point is managed by the Harbour Master and VRCA Emergency Management Plan. The Operations phase emergency structure for the Gas Import Operations is identified in Figure 10-2.

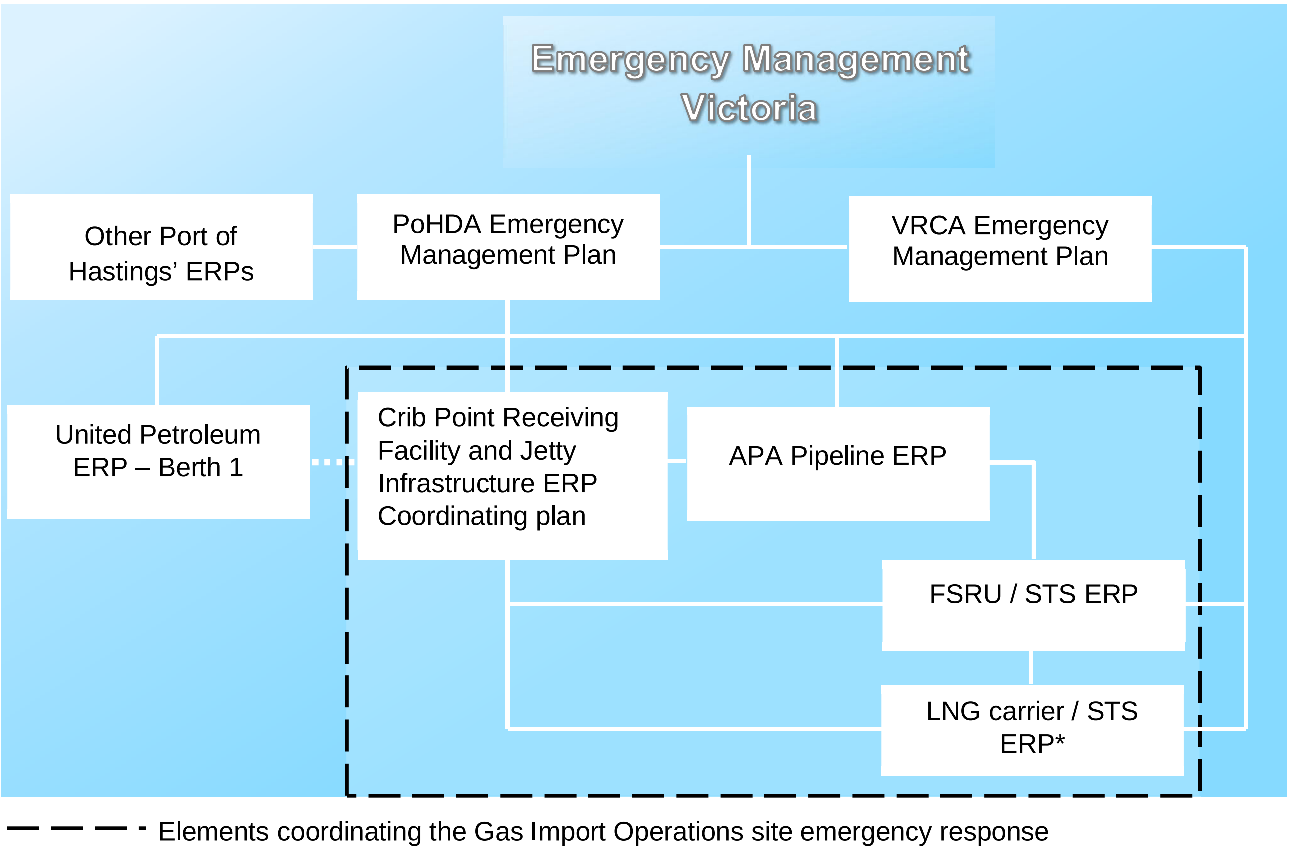

Figure 10-2: Crib Point Operations Phase Emergency Management Framework

11.0 Recommended mitigation measures

This section outlines the recommended mitigation measures for safety, hazard and risk identified as a result of the assessment.

In the course of finalising this report, consultation was undertaken with AGL and APA and other designers, contractors and specialists to ensure that the recommended mitigation measures would be achievable and compatible with those proposed by other specialists.

These recommended mitigation measures have been refined as a result of these discussions and should be incorporated into the EMF, which will be implemented through the Project approvals as described in Chapter 25 *Environmental Management Framework* to effectively manage the environmental performance of the Project.

Table 11-1 Recommended mitigation measures - safety, hazard and risk

ID	Mitigation measure	Works area	Project phase
MM-HR01	**Gas Import Jetty Works safety standards** The Gas Import Jetty Works will be designed, constructed and operated to meet relevant safety standards. The FSRU will be designed, operated and maintained under the purview of DNV GL. It should comply with the Rules for Classification as required to retain its Class Notation. This should include requirements for inspection, maintenance and functionality of all on-board safety systems. Refer Section 6.2.	Gas Import Jetty Works	Design, construction and operation
MM-HR02	**Pipeline Works safety standards** The Pipeline Works will be designed, constructed and operated in accordance with AS2885. This should include completion of a Safety Management Study with the identification of threats and appropriate mitigation measures including increased depth of burial, heavier duty piping and protective slabs. Refer Section 8.6.4 for threats and control measures.	Pipeline Works	Design, construction and operation
MM-HR03	**Process control system and automated emergency shutdown systems** The operation of the Gas Import Works and Pipeline Works will be monitored using high integrity process automation and shutdown systems. Abnormal conditions will be alarms locally and remotely to fully attended control rooms. Out of normal conditions will result in an automatic shutdown of gas operations via closing of emergency shutdown valves. The control, monitoring and shutdown systems will be fail-safe and be designed to best industry practices with redundancy. Refer to Section 9.3. The pipeline is also fitted with two mainline valves along its route to limit loss of gas in the event of a leak. MLV1 can be closed remotely. Refer to Section 8.2.3.	Gas Import Jetty Works and Pipeline Works	Design, construction and operation

ID	Mitigation measure	Works area	Project phase
MM-HR04	**Fire Protection** Refer to Section 7.5.3. The FSRU or LNG carrier will be provided with their own onboard fire protection and suppression systems. This is a requirement of the DNVB GL class notation. Active fire protection and suppression will be provided for liquid fires and gas fires on the Jetty in compliance with Australian Standards. The design fire case for Berth 2 fire systems is a jet fire in the MLA area. The required firewater cooling rate is for the ship/shore manifold area, which is defined as the MLAs and associated piping and valves as well as for FSRU hull cooling. The diesel fuel supply will be designed for six hours of firewater per pump. The current design calls for two x 100% firewater pumps. The system will be designed as a dry pipe system (i.e.no requirement for a jockey pump to maintain pressure), and be designed for saltwater service, providing an indefinite supply of water. Fire and gas detection will be provided along the gas piping on the jetty.	Gas Import Jetty Works and Pipeline Works	Design and operation
MM-HR05	**Dangerous Goods (DG)** Dangerous goods, as defined by the Australian Dangerous Goods Code, and flammable and combustible liquids will be stored and handled in accordance with the *Dangerous Goods Act 1985,* Dangerous Goods (Storage and Handling) Regulations 2012, EPA Victoria Publication 1698 – *Liquid Storage and Handling Guidelines* and all relevant Australian Standards – including but not limited to the requirements of: • AS1940 – *The storage and handling of flammable and combustible liquids* • AS1210 – *Pressure vessels* • AS4343 – *Pressure equipment – hazard levels* • AS3846 – *The handling and transport of dangerous cargoes in port areas* • AS2941 – *Fixed fire protection installations – pumpset systems* • AS/NZS60079 – *Explosive atmospheres*.	Gas Import Jetty Works and Pipeline Works	Construction and operation
MM-HR06	**Monitoring of chemical and fuel storage facilities** Routine visual monitoring and recording of chemicals and fuel storage facilities will occur as part of routine operational practices.	Gas Import Jetty Works and Pipeline Works	Construction and operation

ID	Mitigation measure	Works area	Project phase
MM-HR07	**Emergency response plans** Emergency response plans, such as for spills, should be developed and implemented for both the construction and operations phases of the Project. Refer to Section 10.0.	Gas Import Jetty Works and Pipeline Works	Construction and operation
MM-HR08	**Site Safety Advisor** A suitably competent person should be appointed as Site Safety Advisor during construction and will have on-site a set of the relevant safety data sheets (SDS) for hazardous and dangerous materials.	Gas Import Jetty Works and Pipeline Works	Construction

12.0 Conclusion

The safety and hazard impacts associated with operation of the Project have been assessed. The approach adopted for the assessment included a review of the existing conditions, a review of the existing risk assessment and safety studies undertaken to date and the identification of potential impacts arising from a major incident during the operational phases.

The Gas Safety Act and Safety Case Regulations require the Pipeline operator to identify, assess and mitigate all risks having the potential to cause a gas incident. The treatment of the risks identified, the assessment of risks so far as is reasonably practicable and safety management system will be described in the safety case. The safety case must be prepared and accepted by ESV prior to Commissioning and Operation and reviewed every five years in accordance with the Regulations.

The operator of the Crib Point Receiving Facility and the Jetty Infrastructure on the Crib Point Jetty, including the MLAs and gas piping mounted to the jetty, would also be required to submit a safety case to ESV for approval prior to operations. The operator of the FSRU will submit a safety case (incorporating a safety management system and emergency plans) to WSV for approval prior to operations in a manner that is consistent with the requirements for an MHF in Victoria.

The Project cannot proceed without all required regulatory approvals related to safety being obtained following the EES process.

The safety, hazard and risk assessments comprised a review of the following:

- the planning and regulatory framework applicable to the Project
- current regulatory requirements and the likely future requirements being considered by the nominated regulatory agencies, including WSV
- hazard and safety studies and risk assessments completed by the Project
- safety and risk workshop outputs including HAZID, HAZOP, Fire Safety, SMS and QRA studies
- the design basis for the Project elements
- the design safeguards and controls required as part of the DNV GL classification for the FSRU
- the design basis for the pipeline including the design parameters and the functional description for the Crib Point and Pakenham facilities
- the emergency shutdown system design basis; operation philosophy and function description for the pipeline and facilities
- the Piping and Instrument Diagrams; Cause and Effect Matrix; SIL verification studies and Operating Philosophy pipeline and facilities
- Location Specific Individual Risk contours arising from the QRA
- threats identified and controls for the pipeline
- location classifications for the pipeline arising from the safety management workshop
- affected land identification and information.

A key element of the risk assessments has been the adoption of risk tolerability criteria used in QRAs. It is also acknowledged that the suite of supportive EES technical assessments and reports adopt appropriate environmental risk mitigation measures in relation to their technical area (i.e. traffic management, noise, visual impact, environment, land use etc.).

The level of incremental risk introduced by the Project has been demonstrated through preliminary QRAs to be within the tolerable risk threshold adopted by the Project and suggested by the Hazardous Industry Planning Advisory Paper No.4. Additionally, the level of risk meets the guidance provided by WSV in its publication titled *Major hazard facilities: Land use planning near a major hazard facility* and in its Guidance Note titled, *Requirements for 'Demonstration' under the Occupational Health and Safety (Major Hazard Facility) Regulations.*

The Project has completed a suite of hazard identification studies, safety assessments and risk studies consistent with the requirements outlined in WSV Guidance note *Safety assessment for a major hazard facility Advice for operators of major hazard facilities on conducting and documenting a safety assessment.*

The studies and reviews undertaken have identified all incidents leading to a potential major incident. The safeguards and controls proposed in the basis of design are consistent with those adopted by hazardous industries and those accepted by the nominated regulators as providing sufficient protections and mitigations against major incidents. These studies and the design will continue to be refined during the natural project cycle and presented to regulators as a demonstration of compliance, during the approvals process, to the key legislation and nominated industry standards.

The hazard, safety and risk impacts on the adjacent and nearby land users during Gas Import Jetty Works operations are expected to be limited and not disproportionate to those already experienced by the current operations of unloading gasoline at Crib Point Berth 1.

The results from the Gas Import Jetty Works QRA and the Pipeline Works QRA show that the level of risk at the Crib Point Jetty and nearby public land use resulting from a major incident is within the suggested acceptable thresholds as defined by HIPAP 4. Further work will be completed to ensure that these risks are reduced so far as is reasonably practicable throughout the design, construction and operational phases of the Project.

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Appendix A

Safety Study Methodologies

Appendix A Safety Studies: Methodology and Purpose

A.0 Introduction

This appendix describes the methodology and purpose of each of the respective safety studies, hazard and risk assessments that have either been completed or are planned to be completed for the Project. This appendix is provided in the context of providing the reader of the report with a basic understanding of what is undertaken and what the intended outcome is for each study and assessment.

A.1 HAZID

A Hazard Identification (HAZID) study is a qualitative technique for identification of hazards and threats and can be applied all stages of a Project. Early identification and assessment of hazards during concept development provides essential input to project development decisions at a time when a change of design has a minimal cost penalty. A HAZID study is carried out by an experienced multi-discipline team using a structured approach based on a checklist of potential hazards. Potential problems are highlighted for action outside the meeting. The analysis serves the operator as proof that the installations can be designed, constructed and operated such that hazards for employees, third parties, the environment and the surroundings are largely minimised.

Objectives

The objectives of the a HAZID are generally to:

- identify all potential hazards and hazardous events that have the potential to result in a major incident
- identify credible MIs through a process of qualitative or semi-qualitative risk assessment
- evaluate potential consequences should the hazards be realised
- identify the prevention, control and mitigation measures provided
- identify areas where further understanding of safeguard effectiveness is needed
- make recommendations to reduce the likelihood of hazard occurrence or mitigate the potential consequences
- identify actions and responsible parties for completion of the actions
- provide input to and interface with other safety studies such as a QRA, fire safety studies, etc.

Design HAZID studies

The scope of the HAZID studies completed thus far included:

- FSRU and ship-to-ship equipment
- MLAs, emergency shutdown devices and jetty piping
- United Petroleum Berth including off-loading hose and jetty piping
- Crib Point Receiving Facility
- Pakenham Delivery Facility
- End of Line Scrapper Station (EOLSS)
- Main Line Valve 1 (MLV1)
- Main Line Valve 2 (MLV2)
- Nitrogen storage

Hazards identified in the HAZID studies were carried forward into the QRA and fire safety studies. Only those major accident events and scenarios considered to be credible have been brought forward for quantitative risk assessment.

During Design development, any additional HAZIDs will be undertaken as necessary to ensure all risks are identified.

Construction HAZIDs

If the project is approved, Construction Contractors will be appointed to install various components of the works (i.e the Crib Point to Pakenham pipeline, including the MLV's HAZIDs will be undertaken by the appointed Construction Contractors to identify safety and environment issues and risks specifically related to the delivery of their construction work scope. The Contractors will close out associated actions from that workshop to ensure all risks are appropriately treated prior to commencement of any works onsite.

A.2 Fire safety study

The fire safety study is a critical element in the safety assurance process. The objective of the fire safety study is to ensure that the fire protection systems in place and available at a facility are suitable to meet the risks presented by the potential fire scenarios.

This is achieved by modelling the likely impacts of a fire and then determining the fire protection resources needed to protect against those events. This ensures that the fire system is suitable to properly manage the fire risk and not just meet minimum requirements, as set out in codes and standards.

The requirements of a fire protection system are initially established via consequence modelling of the fire events and then the performance of the fire protection system can be determined via hydraulic modelling of the fire protection systems including fire pumps, monitors and deluge systems. NSW Hazardous Industry Planning Advisory Paper No. 2 provides guidance on fire safety studies and this has been adopted for the FSRU and the jetty piping.

A preliminary fire safety study has been completed for the jetty topsides and the Crib Point Receiving Facility. The fire safety study will be updated as the Project design develops and in consultation with the Country Fire Authority.

A.3 Safety Integrity Level (SIL) Assessment

The main objective of a SIL assessment is to assess the integrity level for all instrumented protection functions (known as safety instrumented functions or SIFs) that have been provided to reduce the likelihood and consequences of major incidents to personnel. Therefore, the SIFs need to be reviewed through a systematic assessment process to determine any requirement for increased reliability and/ or higher integrity to reduce risks. This is achieved through a SIL Assessment Workshop, in accordance with the standard IEC 61511.

Assignment of SIL is an exercise in risk analysis where the risk associated with a specific hazard, that is intended to be protected against by a SIF, is calculated without the beneficial risk reduction effect of the SIF. The unmitigated risk is then compared against a tolerable risk target. The difference between the unmitigated risk and the tolerable risk, if the unmitigated risk is higher than tolerable, must be addressed through risk reduction of the SIF. This amount of required risk reduction is correlated with the SIL target. The order of magnitude of risk reduction that is required correlates with a required SIL level. For example, if one order of magnitude is required this relates to a SIL 1 device requirement. This means that the device needs to be designed, operated and maintained to ensure that if functions with a reliability of at least 90%.

There are several methods used to assign a SIL. These are normally used in combination, and may include: Risk matrices, risk graphs, Layers of protection analysis. During detailed design development SIL verification calculations are required to ensure that the equipment design meets the required integrity levels.

The FSRU design development has included SIL assessment and verification to assure the required integrity of the instrumented protection systems on board the vessel. In addition, SIL Assignment workshops were undertaken to assess the requirements for instrumented protective functions for the operation of the Jetty Infrastructure, Crib Point Receiving Facility and Pakenham Delivery Station

The outcomes from the SIL assessment will be included in the design of the protective functions for the pipeline. The SIL assessment will be updated as the design develops, and other protective measures are implemented in the design.

A.4 Pipeline Safety Management Study

The purpose of a pipeline Safety Management System (SMS) is to assign location classes along the route of the pipeline to;

- identify and validate threats to the pipeline;
- provide assurance that the threats to the pipeline and associated risks are identified and understood by those who are responsible for addressing them; and
- develop appropriate controls, plans and action items to manage the risks.

The Crib Point to Pakenham Preliminary Pipeline SMS Workshop was conducted using the methodology as defined in the standards AS 2885.1 and AS 2885.6. The conduct of Safety Management Study workshops are defined in the standards AS 2885.1 and AS 2885.6.

A.5 HAZOP

A Hazard and Operability (HAZOP) study is a design review technique used for hazard identification, and for the identification of design deficiencies which may give rise to hazards or operability problems. HAZOP is most commonly applied to systems which transfer or process hazardous substances or activities where the operations involved can be hazardous and the consequences of failure to control hazards may be significant in terms of damage to life, the environment or property. A HAZOP study is carried out using a 'bottom-up' structured approach by an experienced multi-discipline team, facilitated by a HAZOP leader.

The objectives of the HAZOP are to:

- identify hazards and operability issues associated with the design
- identify deviations from design intent, deviation causes, consequences, and safeguards
- provide an action list with due dates
- identify appropriate person/discipline to progress the action to close out.

HAZOP studies are conducted in a workshop format in accordance with AS IEC 61882, bringing together a multi-disciplined team of operations personnel and experienced design engineers. The workshop utilises a clearly defined step-by-step methodology and considers standardised deviations from normal process operations.

HAZOPs have been conducted for all areas of the project, including a HAZOP that looked specifically at the interfaces between the project areas that have different Operating organisations. HAZOPs will be held at any stage in the project if there is a material change to the design post the original HAZOP.

A.6 Quantitative Risk Assessment (QRA)

The basis for adopting a tolerable risk criterion is that, generally, various levels of risk are tolerated on a daily basis both to individuals and a society as a whole. Where risk is taken with free and full knowledge it is considered a voluntary risk and these usually include a variety of everyday tasks. In reality, most types of risk have a degree of voluntary and involuntary natures to them. The risk from a hazardous industrial facility is perceived as an involuntary risk.

When a risk is imposed on an individual or group of people, such as the development proposed by the Project, the concept of acceptability or tolerability of that risk in the decision making process is that any increase in risk should not be disproportionate to the local level of risk normally experienced.

Wherever a facility produces, stores or handles significant quantities of flammable or toxic materials a QRA is the principal means widely recognised by which the on-site and off-site risks are determined.

The objective of the QRA is to systematically address the likelihood and consequence of all potential hydrocarbon related risks for the Project in order to determine if such risks are tolerable in accordance with the established risk criteria. Recommendations can then be made for risk reduction measures if the resulting risk levels exceed the tolerable risk criteria.

The QRA process focuses on the effects of a potential MI and those atypical events with the potential to have impacts outside the boundaries of the Project. The QRA does not cover long term or chronic impacts or continuous small emissions. These are addressed via other mechanisms including environmental protection licences, site remediation action plans and occupational health and safety management studies.

The output from the QRA is a set of risk numbers that estimate the risk at each specific location. The risk from each individual event is combined to form contours of cumulative risk resulting from all modelled events. The LSIR is presented as isopleths similar to elevation contours on a map. The inner contours represent the highest risk and contours are plotted in declining order of magnitude.

These risk numbers do not imply that an event will not occur for the specified time period. These risk levels are statistical representations of risk. They provide a likelihood estimation that an incident leading to a specific outcome might occur within this average timeframe.

The QRA is applied to all credible risks identified of the Project leading to major incidents, as far as they are of relevance. A number of QRA studies have been completed for the Gas Jetty Import Works and the Facilities. The methodology used for these is consistent with recognised industry practices. The QRA draws on the available design information and the results from other risk studies prepared for the Project.

Preliminary QRAs have been completed for the FSRU, Jetty Infrastructure, Crib Point Receiving Facility and the Pakenham Delivery Facility. The results from the preliminary QRAs covering the FSRU, Jetty Infrastructure, Crib Point Facility and The United Petroleum operated Berth 1 have been combined to provide the cumulative effects from facilities at the Crib Point project area against the QRA risk criteria for the Project, i.e. the recommendations and guidance within HIPAP 4.

Major incident events-

The MIs identified and included in the QRA studies include:

- release from the FSRU LNG Transfer System
- release from the FSRU Process facilities, including regassification trains
- release from marine loading arms at Berth 2 (AGL)
- release from Pipeline on Jetty at Berth 2 (AGL)
- release from loading hoses at Berth 1 (United Petroleum)
- release from pipeline on jetty at Berth 1 (United Petroleum).

Inputs

The meteorological data, ignition data and population data entered into the model are critical to the risk results.

Inputs to the model included:

- release conditions (e.g. temperature, pressure, hole size and duration)
- release source characteristics (e.g. elevation, orientation)

- physical properties of the released material (e.g. heat of vaporisation)
- atmospheric conditions (e.g. wind speed, atmospheric stability).

Consequence assessment

Risk modelling software, DNV GL PHAST Risk (also known as SAFETI) version 6.7 was used to model the potential consequences from a hydrocarbon-related failure, that is a release and ignition of LNG and natural gas.

The software uses the discharge, dispersion, and impact models to estimate effect zones of flammable dispersion, heat radiation, and explosion overpressures. The hazard consequences listed below were identified during the HAZID process.

The consequences for the following scenarios have been modelled:

- heat radiation from jet fires
- heat radiation from pool fires
- heat radiation from flash fires
- overpressures from vapour cloud explosions.

The consequence modelling estimated the area impacted by each event and the associated impact distance caused by that event. The following consequence distance to thermal radiation, lower flammability limits and overpressure were produced for the QRA study:

- Flash fire envelope: : 50% & 100% Lower Flammable Limit (LFL)
- Thermal radiation: : 35, 12.6, 4.7 kW/m^2
- Overpressure: : 35, 14, 7 kPa (Gas Import Jetty Works only)

Likelihood assessment

The likelihood (or frequency) of an event, or in this case an incident, is the number of occurrences of the event in a specified time period, usually expressed by a per annum number. The estimation of the event likelihood relies upon historical equipment failure data and the use of event trees to define a pathway to the event consequence or outcome.

The event tree framework used in the QRA for modelling a flammable release is shown below.

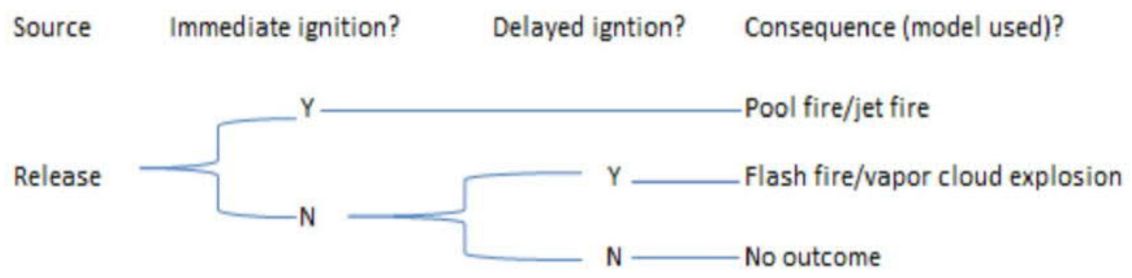

Figure 13-1 Event Tree structure used for QRA

There are a range of correlations available for applying ignition probability data to a release. These are based in the release rate and the state, i.e. gas or liquid. The consequences of hydrocarbon fire events have been modelled as follows:

- Immediate ignition of a gas release is modelled as a jet fire.
- Delayed ignition gas releases are modelled as flash fires or explosions (depending on the level of confinement and congestion surrounding the release).

Input parameters

For hydrocarbon process equipment a set of standardised industry failure frequency data has been used in the development risk models. The discharge rate, release duration, ignition probability of the leak frequencies of the failure cases identified as part of the hazard identification process for the following areas:

- FSRU
- Berth 2 and jetty gas piping
- Berth 1 and jetty liquid fuel piping (United Petroleum)
- Crib Point Receiving Facility
- Pakenham Delivery Facility

Risk analysis

The risk analysis brings together calculations from the frequency assessment and consequence modelling so that both can be presented together. The QRA modelling combines the consequences for each failure case in each wind direction, the wind probability data, the frequency of the event, and the vulnerability data to arrive at risk numbers at the different locations.

The risk estimate is calculated for each frequency-consequence pair and is summed at each specific location to provide the total cumulative risk from all sources impacting the area.

Risk analysis results are typically presented in several different ways to provide a complete picture. For the QRA study, the risk metric used was LSIR.

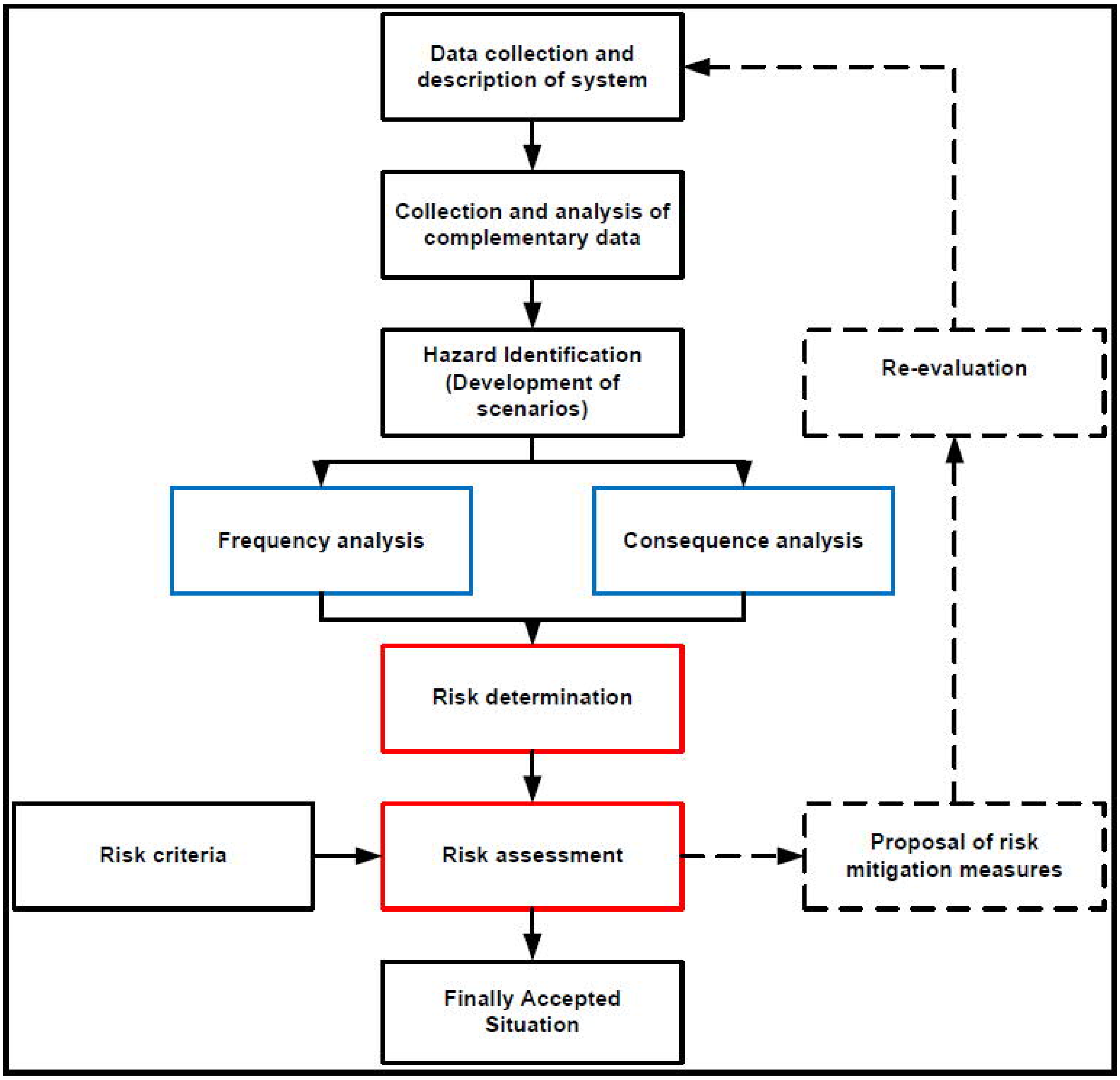

Figure 13-2 Illustration of QRA Process

A.7 Formal Safety Assessment

Overview

A Formal Safety Assessment is a requirement of both the Gas Safety (Safety Case) Regulations that apply to the Jetty piping and Crib Point Receiving Facility, and the Occupation Health & Safety (MHF) Regulations which AGL are using as a basis for their assessment of the FSRU. The objectives of an FSA are to demonstrate that:

- a comprehensive and robust approach to hazard identification and risk assessment is carried out
- the hazard identification process considers both personnel safety, facility integrity and property damage
- the process of hazard identification ensures that all hazards with the potential to result in a major incident (as defined in the OH&S(MHF) Regulations) are identified
- the control measures identified for MIs enable the risk from those events to be managed to a level that is reduced So Far As Is Reasonably Practicable (SFAIRP)

The overall FSA approach is summarised as follows:

- identify all facility specific hazards and all credible hazardous events associated with those hazards (Appendices A1 & A5 describe two typical hazard identification type methodologies)
- identify the controls in place to reduce the likelihood or consequence of the hazardous events
- screen the hazardous events to identify MIs for further analysis
- assess the characteristics and potential consequences associated with those MIs
- perform a Layers of Protection Analysis (LOPA) on the significant contributors to a MI to determine whether the control measures in place are adequate
- conduct assessment of the risk with risk levels assessed against the risk acceptance criteria as necessary
- identify potential upgrades to existing controls or additional controls for eliminating or reducing risk levels to SFAIRP and assess whether the upgrades are practicable.

The facility hazard and risk register contains details of all the identified facility/operation specific hazards and hazardous events. This hazard register is continually updated throughout the FSA process and the life of the facilities.

The FSA must be undertaken with adequate consultation with members of the workforce and other stakeholders.

Control Measure Identification

A control measure is defined as any system, procedure, process, device or other means of eliminating, preventing, reducing or mitigating the risk of hazardous events. Controls can be physical equipment, process controls systems, management processes and plans, operating or maintenance procedures, emergency response plans and key personnel and their actions.

For the purposes of the FSA, the control measures are defined in terms of:

- preventative measures, for example
  - hazard management in accordance with the safety management system
  - basic process control systems including operator actions/procedures and critical alarms
  - safety devices – emergency shutdown (ESD)/safety instrumented functions (SIF)
- mitigative measures, for example
- firefighting systems
- post release physical protection

- emergency response plans (ERP) and procedures.

In documenting controls, the emphasis is on identifying independent protective layers - a device, system or action which can prevent a scenario from proceeding to its undesired consequence and is independent of the initiating event or the action of any other layers of protection associated with the scenario.

The preventative control measures reduce the likelihood of the hazardous event occurring. The mitigative control measures reduce the magnitude of the consequences of the hazardous event.

This process allows the Facility Operator to:

- gain sufficient knowledge, awareness and understanding of the control measures for MIs
- identify all existing and potential control measures
- provides a basis for identifying, evaluating, defining and justifying the selection (or rejection) of control measures for eliminating or reducing risk and lay the foundations for demonstrating the adequacy of the controls necessary to assure the safety of the facility
- shows clear links between control measures and the potential MIs
- assists in demonstrating that risk is reduced SFAIRP.

For each of the hazards that may result in a MI, a control effectiveness assessment is required. Each of the controls identified for each cause are qualitatively assessed for order of magnitude reliability.

Hazardous Event Screening

The identified hazardous events are then screened to determine which events could result in a MI, as these events are examined in further depth. An MI is defined in the Victorian Occupational Health and Safety Regulations 2017 as:

an uncontrolled incident, including an emission, loss of containment, escape, fire, explosion or release of energy, that—

(a) involves Schedule 14 materials; and

(b) poses a serious and immediate risk to health or safety

Consequence Assessment

MIs are assessed in further detail to gain a full understanding of the potential consequences of a hydrocarbon-related failure or an asphyxiant release of nitrogen. Consequence assessment is described in further detail in A6, QRA, and consequence criteria are covered in Appendix B.

Layers of Protection Assessment (LOPA)

For events that are defined as MIs a risk assessment using a LOPA approach is undertaken. LOPA is a systematic way of reviewing the events leading to a potential MI and the control measures that exist to prevent or mitigate the escalation potential of the MI. There may be several controls in place and these are referred to as “layers of protection”.

The key objectives of the LOPA are to:

- demonstrate that risks are reduced SFAIRP
- demonstrate the proportionality of controls are consistent and appropriate for the level of risk.
- consider the independence of controls
- identify or recommend any additional risk reduction measures that:
  - eliminate or reduce the likelihood of the MI; or
  - reduce the consequence severity of the MI.

The Figure below shows an overview of the LOPA methodology. The LOPA is a semi-quantitative approach that utilises the Facility Operator’s risk matrix to confirm that the breadth and depth of

controls are such that the risk level is reduced by sufficient orders of magnitude to demonstrate that the residual risk is reduced SFAIRP.

SFAIRP Workshop

To ensure inherent safety and the SFAIRP principle is effectively implemented, a mechanism to ensure that all possible inherent safe design measures are introduced early into the project (where possible) and are demonstrated to be SFAIRP is required. All the assessments carried out to date, and future assessments feed into the demonstration of SFAIRP.

A specific SFAIRP workshop will be held in the next stage of design to determine whether the current design is SFAIRP, or whether more can be done to reduce risk. This workshop takes the format of questioning the design and each potential MI event and brainstorming if further controls can be identified.

Control hierarchy

When considering controls (or layers of protection) for identified risks, consideration is given to the application of a hierarchy of controls that identify the most effective to the least effective control options, as shown below

- **Elimination -** Removing the hazard completely – the most effective approach by removing the risk entirely
- **Substitution** – Replacing a higher risk option with a lower one. Care needs to be taken to ensure additional new hazards are not introduced.
- **Engineering** – Making change to the process, plant or equipment to reduce the hazard
- **Administrative** – Establishing policies, processes and procedures to minimise risk
- **Personal Protective Equipment** – Provide a barrier between the wearer and the hazard

Any additional risk reduction measures identified are subject to the following considerations:

- Control hierarchy position.
- does the control provide a clear or measurable reduction in risk?
- is it technically feasible and can it be implemented?
- will it be supported and utilised by site personnel?
- is it consistent with national and/or industry standards and practices?
- does it introduce additional risk in other operational areas?
- is the cost disproportionate to the risk reduction achieved?

If the first five of these considerations are satisfied, and the cost of the additional risk reduction measures are not grossly disproportionate to the risk reduction achieved then they should be implemented.

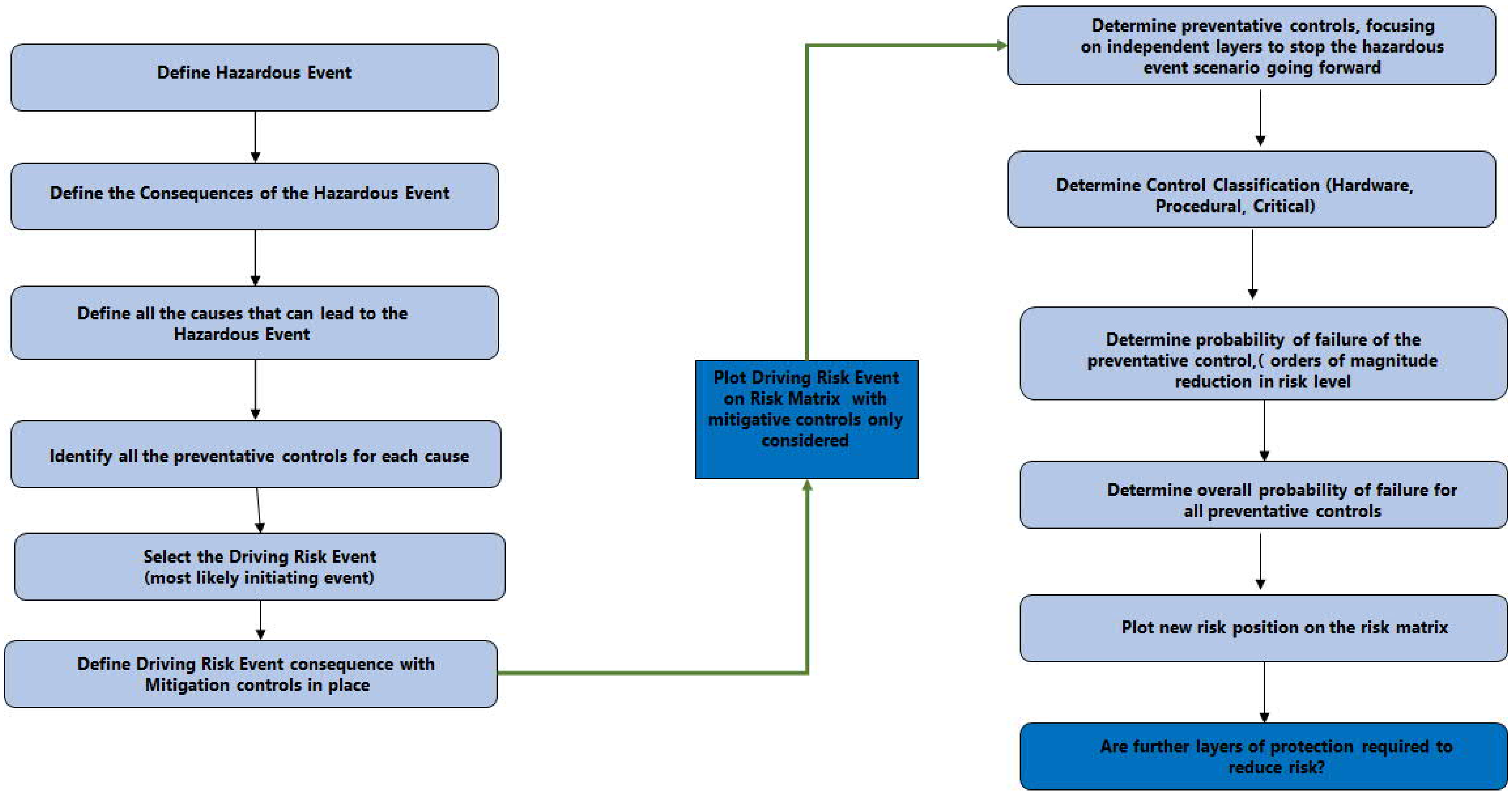

Figure 13-3 LOPA Process

Appendix B

Consequence & Risk Criteria Used in QRA

Appendix B Risk Criteria Used in QRA

The risk criteria adopted by the Project for use in the Quantitative Risk Assessments assumes has been adopted from HIPAP 4. The criterion uses a representative member of the public in the open at a specific point continuously, i.e. 24 hours per day, 365 days per year without the ability to escape. The units of measure used in determining the risk criteria are 'probability of fatality per annum'.

It is recognised that relying entirely upon fatality risk criteria may not account for community concern related to risk of injury as well as risk of fatality; and fatality risk levels may not entirely reflect people's individual vulnerability to risk. Therefore, in addition to a fatality risk, HIPAP 4 also suggests risk criteria in terms of injury and property damage.

B.1 Individual fatality risk

'Individual fatality risk' is the risk of fatality to a person at a specifically defined location. In the context of the Project the risk of fatality arises from the fire and explosion events associated with the ignition of LNG, natural gas or flammable odorant release.

As an output of the QRA process, a set of Location Specific Individual Risk of fatality contours (LSIR) have been developed for the operation of the LNG import facility, the Crib Point Receiving Facility and the Pakenham Delivery facility.

LSIR is the risk for an individual who is present at a particular location, continuously all year (i.e., 24 hours a day seven days a week) without wearing personal protective equipment. It is the frequency at which an individual may be expected to sustain a given level of harm from the realisation of specific hazards. LSIR is often interpreted as the likelihood of an incident occurring over a specified interval. The LSIR fatality risk contours represent the distances from the facility corresponding to a particular fatality risk level (i.e. likelihood) that individuals are exposed to.

A key focus of the LSIR fatality risk contours is the potential risk of fatality to off-site populations, which should be taken to mean the general public. As part of the risk assessment the land use within the risk contours is compared against the tolerable risk criteria adopted by the Project. From this an assessment is made as to the level of risk being tolerable.

In this context risk is measured as the likelihood (or frequency) of an individual suffering a fatality. This risk is based on a person being exposed at that location 24 hours per day, 365 days per year. The likelihood units are per annum; however, as the risk of fatality is extremely low, the data is typically expressed as per million years (or number of fatalities x 10^{-6} per year). For example, with reference to the table below, a per annum tolerable risk criterion for residential areas of '1E-06' can be interpreted as meaning that a fatality likelihood (risk) of '1 in one million years of operation' is considered tolerable so far as is reasonably practicable.

The tolerable risk criteria, used to assess the location specific individual risk of fatality, has been taken from HIPAP4, which is generally accepted as the basis for determining acceptable risk criteria for Victorian hazardous facilities. The HIPAP 4 tolerable risk criteria adopted by The Project in the QRA studies is provided below for reference.

Table 13-1 Fatality risk tolerability criteria adopted for the Project

Land Use	Risk of fatality (per million years)	Risk of fatality (per annum)
Hospitals, schools, child-care facilities, old age housing	0.5	5E-07
Residential, hotels, motels, tourist resorts	1	1E-06
Commercial developments, retail centres, offices, entertainment spaces	5	5E-06
Sporting complexes and active open spaces	10	1E-05
Industrial	50	5E-05

B.2 Injury risk

The primary concern with respect to an injury arises from effects of thermal radiation, i.e. heat as a result of a fire incident and from the effects of overpressure resulting from an explosion scenario. Overpressure, also called a blast wave, refers to the sudden onset of a pressure wave after an explosion. This pressure wave is caused by the energy released in the initial explosion—the bigger the initial explosion, the more damaging the pressure wave. Overpressure presents a risk to both people and buildings.

The scenarios leading to either a fire or an explosion event have been identified as part of the hazard identification process. Those hazards identified as being ‘high’ or ‘moderate’ in accordance with an agreed risk matrix were brought forward to the QRA for further analysis.

It should be noted that there are no Victorian criteria specified for location-specific risk of injury. As such the risk criteria used by the Project to assess the risk of injury have been taken directly from the suggested criterion used in NSW Hazardous Industry Planning Advisory Paper No. 4 (HIPAP 4).

The HIPAP4 criterion and guidance is accepted by WSV and referenced widely in its requirements as a demonstration of adequacy that risks have been reduced so far as is reasonably practicable.

The risk criteria adopted for injury resulting from heat radiation and overpressure effects are discussed in the following sections. It should be noted that ‘injury risk’ was not assessed as part of the Pakenham QRA.

B.2.1 Heat radiation risk criteria

The effects of heat flux (radiation) because of a fire are listed below. The ultimate effect depends on the duration of people’s exposure to the resultant heat. For the purpose of injury, a lower heat radiation level compared to that which may cause a fatality is appropriate and has been adopted by the Project as part of its risk assessment.

The heat flux exposure tolerance for the assessment of risk of injury adopted from HIPAP 4 for the Project are as follows:

- Incident heat flux radiation at residential and sensitive use areas are not to exceed a risk level of 50 per million per year for a heat flux level of 4.7 kilowatts per square metre (kW/m^2).

Table 13-2 Effects of heat radiation

Heat Radiation (kW/m^2)	Effect
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute of exposure
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least second degree burns will result). This flux level not to be exceeded at adjacent residential areas more than 50 x 10-6 per year.
12.6	Significant chance of fatality for extended exposure. High chance of injury. After long exposure, the temperature of wood rises to a point where it can be readily ignited by a naked flame. Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure.
23	Likely fatality for extended exposure and chance for fatality for instantaneous exposure. Spontaneous ignition of wood after long exposure. Unprotected steel will reach thermal stress temperatures which can cause failures Pressure vessel needs to be relieved or failure will occur. This flux level not to be exceeded at adjacent industrial areas more than 50 x 10-6 per year.
35	Cellulous material will pilot ignite within one minute of exposure. Significant chance of fatality of people exposed instantaneously.

B.2.2 Overpressure risk criteria

The effects of overpressure resulting from various levels of explosion are listed below. For the purpose of injury, a lower overpressure threshold compared to that which may cause a fatality is appropriate and has been adopted by the Project. For the purpose of establishing a risk criterion for the Project relating to overpressure effects, a 7kPa threshold has been adopted.

The overpressure exposure tolerance for the assessment of risk of injury adopted from HIPAP 4 by the Project as follows:

- Incident explosion overpressure at residential and sensitive use areas should not exceed a risk of 50 per million per year for an explosion overpressure level of 7 kPa.

This is consistent with the suggested thresholds in HIPAP 4.

Table 13-3 Effects of explosion overpressure

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
35	House uninhabitable Threshold of eardrum damage 50% chance of fatality for a person in a building and 15% change 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 destruction of houses

B.3 Risk of property damage and propagation

The risk criteria used by the Project to assess the risk of property damage have been obtained from HIPAP4. There are currently no Victorian criteria specified for property damage risk. HIPAP4 criteria have been adopted by the Project as they are widely used and accepted across Australia. The effects from heat flux and overpressure are detailed in Table 13-2 and Table 13-3.

The heat flux and overpressure criteria for the assessment of property damage used by the Project are as follows:

- Incident heat flux radiation at neighbouring potentially hazardous installations or at land zoned to accommodate such installations should not exceed a risk of 50 per million per year for a heat flux level of 23 kW/m^2.
- Incident explosion overpressure at neighbouring potentially hazardous installations, at land zoned to accommodate such installations or at the nearest public buildings should not exceed a risk of 50 per million per year for an explosion overpressure level of 14 kPa.

The limits recommended in HIPAP 4 with respect to property damage from heat radiation and overpressure are consistent with risk criteria used internationally, notably those defined in NFPA 59A.

B.4 WSV Guidance Note Recommendations for Demonstrations (Worksafe, April 2011)

In the case of off-site risk to the general population, a set of 'interim' criteria has been used in a number of cases in Victoria, e.g. in relation to land use planning (Interim Victorian Risk Criteria – Risk Assessment Guidelines, prepared for the Altona Chemical Complex and the Victorian Government, by DNV Technica, October 1988). WorkSafe Victoria (2011) references these criteria and states that they are a general guide to operators to evaluate their approach to risk reduction. The criteria do not have legal status but provide guidance on values. These values are:

- risk of fatality must not exceed 10 per million per year at the boundary of any new facility
- if risk exceeds 10 per million per year at the boundary of an existing facility, risk reduction measures must be taken

- if risk off-site is between 0.1 and 10 per million per year, all practicable risk reduction measures are to be taken, and residential developments are to be restricted
- risk levels below 0.1 per million per year are broadly tolerable
- a plot of cumulative number of fatalities, from all potential incidents, against frequency remains in the low or medium region.

Appendix C

QRA Results – Gas Import Jetty Works

Appendix C Preliminary QRA Results – GIJ Works

C.1 Individual Fatality Risk

- The individual fatality or injury risk measures represent the likelihood of a specified level of harm at a specified location.
- No account is taken of whether anyone is actually present at that location. It includes the likelihood of fatality or injury occurring within a specified time frame and the type of injury that is likely to occur.

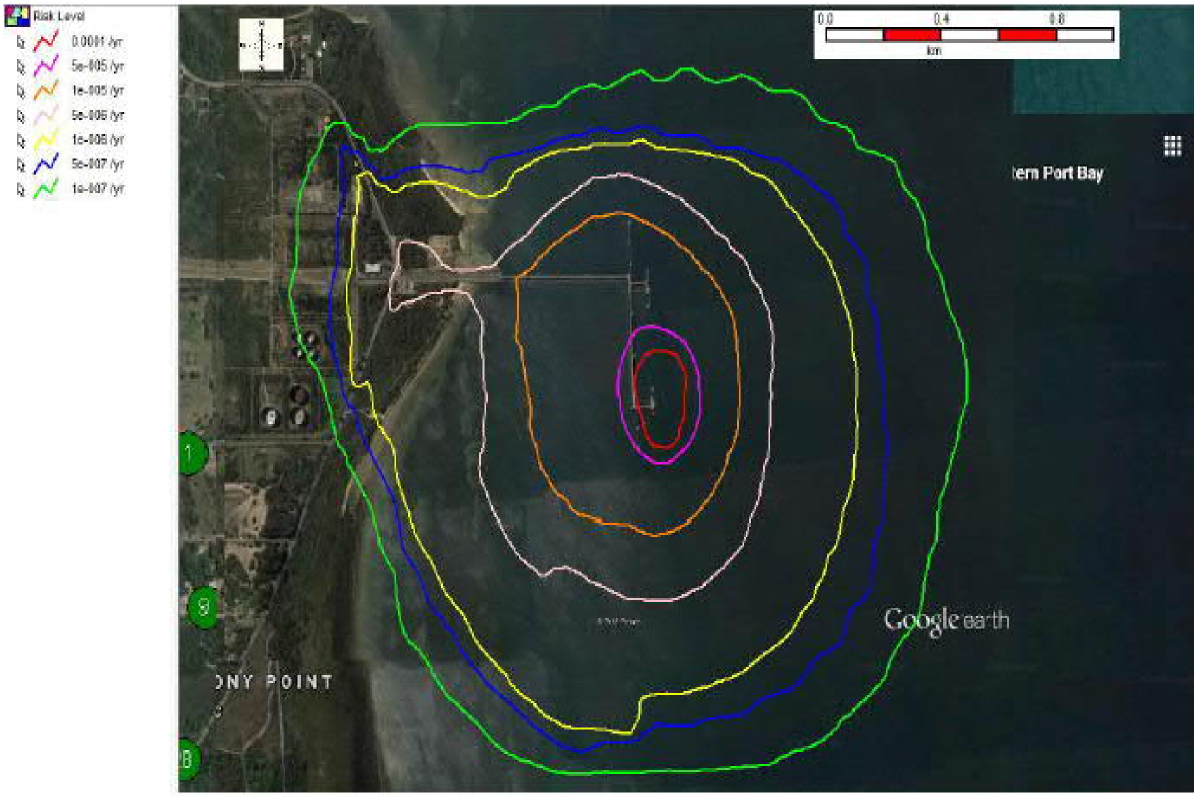

Figure 13-4 LSIR Contours Gas Import Jetty Works - FSRU

Results

The individual fatality risk contours for the Gas Import Jetty Works and the Crib Point Receiving Facility are represented in Figure 13-4.

Based on the results of the QRA modelling, the following observations are made:

- The '50 in a million likelihood of fatality' represented by the 5.0E-05 risk contour, considered tolerable for industrial land use, is restricted to the immediate area around the FSRU and Berth 2. This contour is limited to close in areas around the FSRU coming close to jetty Berth 1 and does cut across the approach to jetty Berth 2.
- The '10 in a million likelihood of fatality', represented by the1.0E-05 risk contour, tolerable for active open spaces extends across the jetty approach but does not extend to the shoreline. The area inside this risk contour is a controlled area and is not expected to be a highly trafficable area in terms of people or vehicle movements. With the exception of tankers berthing at jetty Berth 1 and Port of Hastings tugboats, there are not expected to be any ship or boat movements in this area.

- The ‘5 in a million likelihood of fatality’, represented by the 5.0E-06 risk contour, considered tolerable for commercial developments extends to the shoreline and encroaches upon a public access recreational area which has been identified as the closest point at which the public can get near to the FSRU. Refer to Fig. 12-9. This area has been assessed as an open space, and as such, the 6.12E-06 per year fatality risk likelihood at this location meets the criteria of not exceeding 1.0E-05 per year likelihood as defined in HIPAP 4. The Crib Point Receiving Facility is located within this risk contour which is acceptable for an industrial facility of this type.
- The ‘1 in a million likelihood of fatality’, represented by the 1.0E-06 risk contour, considered tolerable for residential areas extends to the western side of the Crib Point Receiving Facility and crosses over a number of roadways. The land use within this contour is predominantly a mix of industrial land and open space with some commercial development. The Maritime Museum and Picnic Point fall within this contour. The Maritime Museum has been assessed as a commercial development, and as such, the 2.67E-06 per year fatality risk likelihood estimated at this location, meets the risk criteria of not exceeding 5.0E-06 per year likelihood as defined by HIPAP 4. Picnic Point has been assessed in the context of being an open space with respect to HIPAP 4. As such, the 1.26E-06 per year fatality risk likelihood estimated at this point meets the risk criteria of not exceeding 1E-05 per year likelihood as defined in HIPAP 4.
- The ‘5 in 10 million likelihood of fatality’, represented by the 5.0E-07 risk contour, considered tolerable for sensitive land use remains on industrial; commercial and open space areas around the berth and the receiving facility. There are no hospitals, schools or other sensitive receptors impacted by this contour.
- The 1.0E-07 risk contour is provided for illustrative purposes and does not extend to residential areas.

C2. Specific Areas of Interest

- The three areas of interest with respect to off-site risk selected for further evaluation are the Victorian Maritime Centre; Picnic Point; and the closest point at which the public can get near to the LNG import facilities, denoted as Public Access.
- The calculated risk at these locations assessed against the HIPAP4 criteria is provided below.

Table 13-4 Calculated risk vs HIPAP4 criteria

Location of Interest	Land Use (HIPAP 4)	Calculate Risk (per annum)	HIPAP 4 Criteria (per annum)	HIPAP 4 Criteria Met
Victorian Maritime Centre	Commercial development	2.67E-06	5.0E-06	Yes
Picnic Point	Active open space	1.26E-06	1.0E-05	Yes
Public Access	Active open space	6.12E-06	1.0E-05	Yes

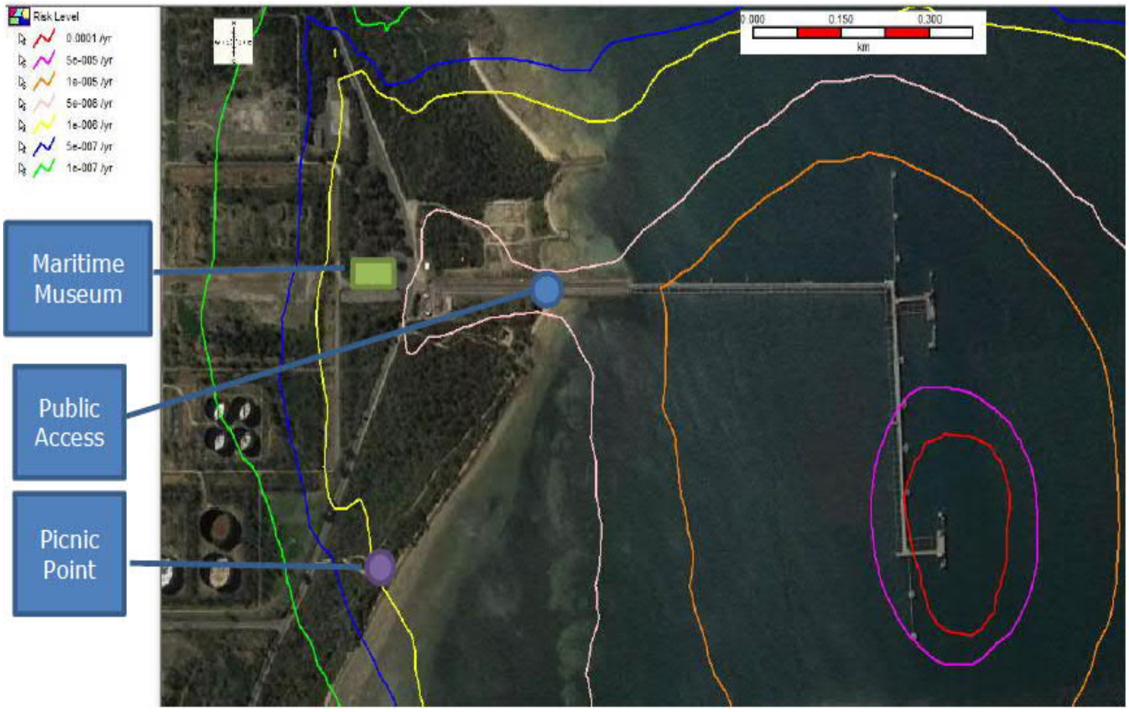

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Figure 13-5 LSIR Contours for Gas Import Works (areas of interest)

C2. Propagation damage and injury risk

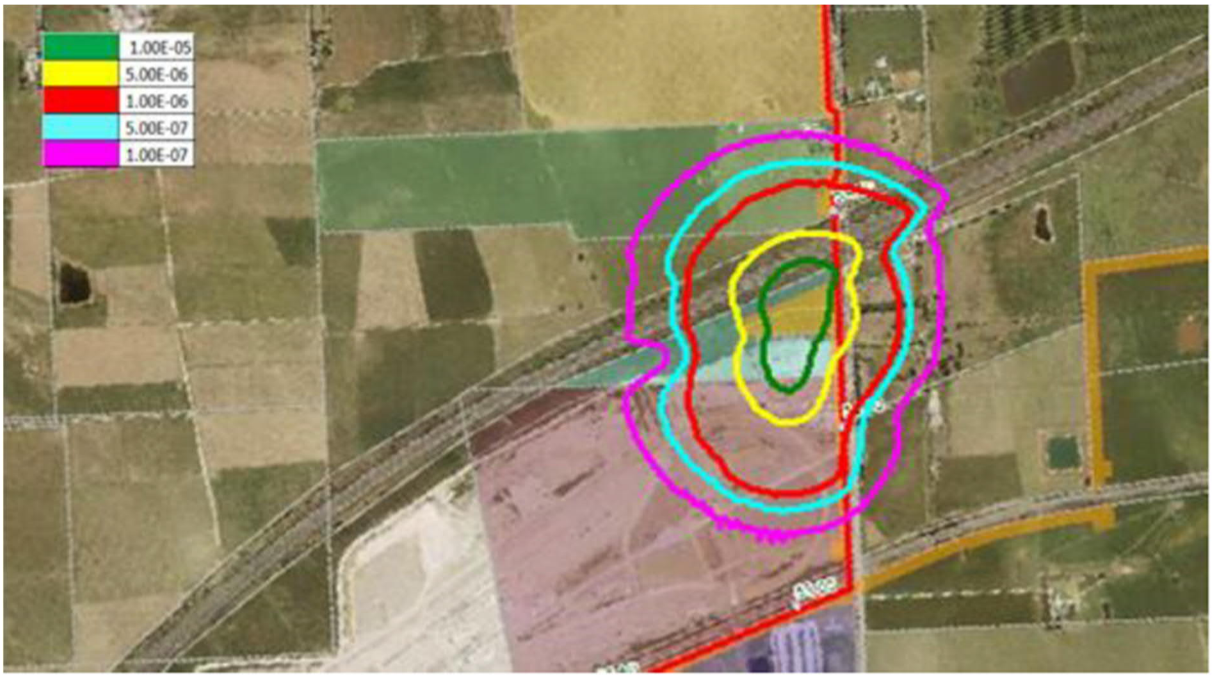
- Injury risk to people from heat radiation levels in excess of 4.7 kW/m^2 and explosion overpressure levels greater that seven kPa due to the FSRU alone were assessed as part of the QRA.
- Additionally, damage and propagation risk due to heat radiation in excess of 23 kW/m^2 and explosion overpressure levels greater that 14 kPa due to the FSRU only were assessed to determine whether there is a potential for the FSRU itself to present a risk of escalation at nearby facilities.

Appendix D

QRA Results - Pakenham Delivery Facility

Appendix D QRA Results - Pakenham Delivery Facility

- The LSIR contours indicate that the risk levels are below 50 in a million per annum which is the criterion for industrial land use, and often taken as the limitation of risk at the site boundary.
- Risk levels of five in a million per annum do not impact on areas classified as active open space and residences are outside the one in a million risk contour adopted by the Project as the tolerable risk criteria in accordance with HIPAP 4.



Location of Interest	Land Use (HIPAP 4)	Calculated Risk (per annum)	HIPAP4 Criteria (per annum)	HIPAP 4 Criteria Met
Residential Area to North East	Residential	3.39E-07	1.0E-06	Yes
Residential Area to East	Residential	9.20E-07	1.0E-06	Yes
Rail Yard	Open Space	7.28E-06	10.0E-06	Yes
Freeway	Open Space	8.43E-06	10.0E-06	Yes

Appendix E

Potential Effects of LNG Hazards

Appendix E Potential Effects of LNG Hazards

This appendix summarise the key risks associated with a release and subsequent ignition of large quantities of LNG.

A. Release of LNG

At atmospheric pressure, LNG will boil off at approximately -163°C, presenting a cryogenic hazard causing embrittlement of carbon steel structures and potential frost burns to exposed personnel. Evaporated natural gas will be cold and heavier than air and will thus be spread by gravity.

LNG is neither carcinogenic nor toxic. It is, however, an asphyxiant which dilutes or displaces the oxygen containing atmosphere, leading to death by asphyxiation if exposure is long enough. Since natural gas in its pure form is colourless and odourless, confined spaces are subject to special attention. With large uncontrolled release quantities, personnel in direct surroundings may be exposed to low oxygen concentrations (<6-15 V%), which should be counteracted by technical and procedural solutions.

When the natural gas is mixed with air, it will gradually become flammable. Natural gas is only flammable within a narrow range of concentrations in the air (typically between 5% and 15% for pure methane). Less air does not contain enough oxygen to sustain a flame, while more air dilutes the gas too much for it to ignite. In the event of a spill, LNG vapours will disperse with the prevailing wind. Cold LNG vapour will appear as a white cloud.

The cryogenic nature of LNG facilities represents a risk of the personnel, structural steel, equipment, instrumentation or control and power cabling being exposed to potentially injurious low temperatures.

The cryogenic exposure of personnel causes frost burns. The cryogenic exposure of carbon steel causes embrittlement, possibly resulting in structural failure. Consequently, protection from cryogenic exposure, as well as from fire exposure, is needed.

Since hazardous concentration levels of methane, resulting in asphyxiation, are much higher than the combustible range, this additional hazard is usually not considered in a QRA.

In small spills of LNG discharged from height, most of the LNG will vaporize before reaching the ground level (or sea surface), due to heat transfer with air and from the outer face of the containment vessel.

For very large spills, air cannot transfer enough heat to vaporize all the LNG before reaching ground level (or sea surface), so the spill forms a pool.

Spilled LNG will simultaneously undergo several physical processes. These include pool formation, spread and boil-off. Pool formation for cryogenic boiling liquids is a dynamic process balancing the LNG input rate, gravitational spread, surface tension effects, heat transfer and gas boil-off. When the LNG pools on sea water the heat input available from the water is such that the LNG can undergo and series of rapid vaporisations as physical explosions.

B. Pressurised LNG Release

E1. Flash Fire

Dispersing clouds of methane (and any other hydrocarbons present) can be ignited anywhere where the concentration of gas in the air is above the Lower Flammable Limit (LFL) and below the Upper Flammable Limit (UFL) for the given temperature and pressure.

The majority of clouds which are ignited do so at their edge as they disperse and meet a strong ignition source (e.g. open flame, internal combustion engine, sparks). An ignited cloud will “flash back” across all its flammable mass (i.e. that part within the flammable range – between the UFL and LFL). It will then burn at the UFL boundary until the entire hydrocarbon is consumed. This will almost always flash back to the source and ignite the pool.

Flash fire zones move at different speeds through flammable clouds. Factors affecting this include the material flame speed, the concentration (maximum speed at stoichiometric concentrations, lower

speeds at LFL and UFL), the temperature, the condensed moisture, the degree of turbulence and the presence of congestion or objects that enhance turbulence.

If a flash fire reaches the evaporating spill of LNG, it will cause this to ignite and burn as a pool fire.

E2. Pool Fire

If LNG spills near an ignition source, the evaporating gas in a combustible gas-air concentration will burn above the LNG pool. A pool fire may result after a flash fire. An LNG pool fire generates significant thermal radiation. Large LNG fires tend to be smoky and this smoke absorbs a substantial fraction of the thermal radiation. An additional factor is that the spreading LNG spill pool can become fairly thin. Once combustion is added to evaporation, the pool will shrink significantly in size – to a sustainable pool fire diameter.

E3. Vapour Cloud Explosion

A vapour cloud explosion (VCE) can occur when a large flammable mass of hydrocarbon vapour is ignited in a confined or partially confined space. The thermodynamics of the combustion of a stoichiometric mixture of hydrocarbon in air will result in an 8 times volume increase of hot combustion products compared to ambient reactants. This is mainly due to the high temperature of the combustion gases and partly due to an increase in the number of moles of gas. In a confined space (e.g. an enclosed box), the final pressure will be a maximum of 8 bar (about 120 psi). In an open space, an outdoors situation, there is no confinement and the experimental evidence is that methane gas will burn relatively slowly (in the order of 10 m/s) with all the expansion resulting in a vertical rise of gas. Ignition trails on dispersed unconfined LNG vapour clouds have confirmed that no significant overpressures are developed (<1 mbar).

Within methane (natural gas) clouds, flame propagation is slow, and the flame may be extinguished prematurely and not be sustained throughout the cloud. Sufficient flame velocity (i.e. >100 m/s) to create significant explosion overpressures will not occur over water if there is no congestion or confinement.

It is, however, prudent to examine the facility's design to identify areas where vapour cloud explosions (VCE) may cause damage, particularly if the damage may extend off site. An area of potential interest for VCE is the jetty structure, between the jetty and the vessel, while LNG is being bunkered. While there is some degree of congestion between the jetty/associated equipment and vessel the area is not considered sufficiently congested to confine any vapour cloud. DNV GL has conducted leading experimental research into this topic at its Spadeadam Research and Testing facility in the UK. This work demonstrated that damaging pressure is only generated by combustion of a vapour cloud in two special sets of circumstances. The first mechanism for generating pressure involves confinement of the vapour cloud. Combustion raises the temperature of the gases in the cloud, but the confinement prevents expansion. As a consequence, the pressure will rise until the confining structure fails. In the case of a marine LNG tanker, there is no significant confinement available and certainly none that could contain the full vapour cloud. This pressure generation mechanism can therefore be excluded. The other way pressure can be generated is by the vapour cloud engulfing significant areas of congestion (most likely process pipe work). In this case, expansion of the combustion products is possible as there is no confinement. The expansion generates flow that interacts with the congestion in a way that enhances the rate of combustion. This mechanism leads to flame acceleration to high speeds and it is the speed of the flame that generates the damaging pressures. Typically, flame speeds well in excess of 100 m/s are required.

For marine LNG Carriers, there is no significant congestion in the local vicinity and therefore any application of the generic vapour cloud explosion calculation methods is not valid. Refer to DNV-GL TECHNICAL MEMO Review of Vapour Cloud Explosion and BLEVE Risk, Memo No: 119XBY25-2/ NPO Revision No: Rev 1 Date of issue: 2018-06-19.

E4. Jet Fire due to delayed ignition

Dispersing clouds of hydrocarbons can be ignited anywhere where the concentration is above the LFL and below the UFL. The majority of clouds which are ignited do so at their edge as they disperse and meet a strong ignition source (e.g. open flame, internal combustion engine, sparks). An ignited cloud will “flash back” across all its flammable mass (i.e. that part within the flammable range – between the UFL and LFL).

It will then burn at the UFL boundary until all the hydrocarbon is consumed. This will almost always flash back to the source and lead to a residual jet fire. Factors affecting this include the material flame speed, the concentration (maximum speed at stoichiometric concentrations, lower speeds at LFL and UFL), the temperature, condensed moisture, the degree of turbulence and the presence of congestion or objects that enhance turbulence.

Note that jet fire can also occur with immediate ignition of the release of flammable gas.

E5. BLEVE

A description of a Boiling Liquid Expanding Vapour Explosion (BLEVE) is given in Lees (Mannan, 2005) explains the mechanism:

> *“When a vessel containing liquid under pressure is exposed to fire, the liquid heats up and the vapor pressure rises, increasing the pressure in the vessel. When this pressure reaches the set pressure of the relief valve, the valve operates. The liquid level falls as the vapor is released to the atmosphere. The liquid is effective in cooling that part of the vessel wall, which is in contact with it, but the vapor is not. The temperature in the proportion of the vessel wall which has the benefit of liquid cooling falls as the liquid vaporizes. After a time, metal which is not cooled by liquid becomes exposed to the fire; the metal becomes hot and weakens and may then rupture. This can happen even if the relief valve is operating correctly. A pressure vessel is designed to withstand the relief valve set pressure, but only at the design temperature conditions. If the metal has its temperature raised, it may lose it strength sufficiently to rupture.”*

Fire impingement on a pressurised liquefied gas tank can result in a BLEVE. BLEVE incidents occur primarily in the LPG industry as explosion events for static LPG tanks or explosion events for mobile storage tanks. The biggest risk of LPG tank BLEVE is in the event of a road accident where a fire occurs that then impinges on the LPG storage tank. In recent years, a number of BLEVE incidents for occurred for LNG tanks used for road transport (Catalonia, Spain, in June 22, 2002 – 1 fatality and 2 injured, China October 6, 2012 5 killed including 3 firefighters). While natural gas explosion events have less power than LPG events these incidents have still involved fatalities. It is important to note that LNG road tankers will have tanks that can contain the LNG at pressure, with the LNG being well above its ambient boiling point. <u>This is a very different situation to marine LNG tanks.</u>

LNG BLEVE incidents have occurred globally but only in road traffic accidents and have occurred in the same manner as LPG tanks subject to fire. These road tankers are pressurised LNG. Marine LNG tanks are insulated from the outside environment (to prevent excessive vaporisation of product) and operated at cryogenic temperatures but at pressures only slightly above ambient. The pressure relief systems fitted to the cargo tanks are rated for the scenario of fire impingement to the insulated tank, and 100% redundant. The absence of fire loading to directly impinge on a tank and the inability to develop any significant pressure means <u>a BLEVE cannot occur</u>.

Refer to DNV-GL TECHNICAL MEMO Review of Vapour Cloud Explosion and BLEVE Risk, Memo No: 119XBY25-2/ NPO Revision No: Rev 1 Date of issue: 2018-06-19.

E6. Rapid Phase Transition

Spilled LNG will undergo several physical processes. These include pool formation, spread and boil-off. Pool formation for cryogenic boiling liquids is a dynamic process balancing the LNG input rate, gravitational spread, surface tension effects, heat transfer and gas boil-off. When the LNG pools on

sea water the heat input available from the water is such that the LNG can undergo and series of rapid vaporisations as physical explosions. These are known as rapid phase transitions or RPTs.

RPTs will result in surges in the rate of vaporisation from an LNG spill following each RPT. While an RPT is a physical explosion the over-pressure resulting from these phenomena is not of the same magnitude as a chemical explosion (such as from ignited pressurised LPG or from construction explosives) and is unlikely to damage a ship's large structural elements.

E7. Risks of Uncontrolled venting due to Rollover

“Rollover” refers to the rapid release of LNG vapour that can occur as a result of the spontaneous mixing of layers of different densities of LNG in a storage or cargo tank.

A pre-condition for rollover is that stratification has occurred, i.e. the existence in the tank of two separate layers of LNG of different density. Rollover can only occur if stratification has taken place in the LNG. Stratification of LNG can occur when an LNG tank is filled with LNG of different densities. Stratification will occur readily if the LNG being introduced into the tank is either denser than that of the “heel” remaining in the tank and filling is at the bottom, or if the LNG introduced is lighter than the heel and filling is into the top of the tank. The possibility of a sudden release of large amounts of vapour and the potential over-pressurisation of the tank resulting in possible damage or failure is recognised by the major design codes and these codes require this phenomenon to be taken into consideration when sizing relief devices.

Whilst the relief valves may prevent damage to the tank, LNG vapour is not only flammable and heavier than air on release, but a valuable commodity and a potent greenhouse gas and therefore venting is to be avoided whenever possible.

Whilst rollover in receiving terminals has been well studied, the risk of rollover in LNG ships has always been considered low. This is attributed to the trading pattern which has involved dedicated trade routes with vessels trading from a single loading port.

LNG ships do not normally have either the instrumentation to detect stratification or the means to force mix the tank contents, and as such the normal mitigation method is to avoid the circumstances arising in the first place. For the floating storage facilities, particularly if none of the methods to detect and mitigate the effects of stratification are installed, if a risk of stratification is identified as part of the loading procedures prior to loading, the cargo is not off loaded from the carrier to the FSRU.

Refer to SIGTTO publication Guidance for the Prevention of Rollover in LNG Ships, ISBN 978-1-85609-558-7.

C. Non-Pressurised LNG Releases

E8. Boil-off gas

Within an FSRU the LNG is stored in bulk storage tanks, within the cargo holds of the vessel at its atmospheric boiling point (approximately -163°C). Any boil-off gas is collected and used by the vessel as fuel or as send out gas. Pressure relief valves are set to only allow a very low net positive pressure.

Most spill scenarios for the storage tank occur at atmospheric pressure plus any liquid head of LNG (i.e. the static liquid column above the point of release). The significance of this is that there is no pressure flashing of LNG to methane and the phase change from liquid to gas occurs due to heat transfer and boil-off.

In small spills of LNG discharged from height, most of the LNG will vaporize before reaching the ground level (or sea surface), due to heat transfer with air and from the outer face of the containment vessel.

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