Technical Report N

Safety, hazard and risk assessment

Viva Energy Gas Terminal Project

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Viva Energy Gas Terminal Project Environment Effects Statement

25-February-2022
Viva Energy Gas Terminal Project

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Contents

Executive Summary

This technical report provides a safety, hazard, and risk impact assessment as a supporting technical study for the Environment Effects Statement (EES) for the Viva Energy Gas Terminal Project (the project).

In December 2020, the Victorian Minister for Planning determined that the project requires assessment through an EES under the *Environment Effects Act 1978 (Vic)*. The reasons for the decision were primarily related to the potential for significant adverse effects on the marine environment of Corio Bay and the potential for contributing to greenhouse gas emissions. Secondarily, the EES was required to assess the effects of the project on air quality, noise, land use, Aboriginal and historic heritage, native vegetation, groundwater, traffic and transport as well as visual amenity.

In January 2021, the project was also determined to require assessment and approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* ('EPBC Act') due to the potential for the project to have a significant impact on wetlands of international importance, listed threatened species and communities, and listed migratory species. The EES process is the accredited environmental assessment process for the controlled action decision under the EPBC Act in accordance with the bilateral agreement between the Commonwealth and Victorian governments.

Overview

Viva Energy Gas Australia Pty Ltd (Viva Energy) is planning to develop a gas terminal using a ship known as a floating storage and regasification unit (FSRU), which would be continuously moored at Refinery Pier in Corio Bay, Geelong. The key objective of the project is to facilitate supply of a new source of gas for the south-east Australian gas market where there is a projected supply shortfall in coming years.

The FSRU would store liquefied natural gas (LNG) received from visiting LNG ships (that would moor directly adjacent to the FSRU), and regasify the LNG as required to meet industrial, commercial and residential customer demand. A 7-kilometre gas transmission pipeline would transfer the gas from the FSRU to the Victorian Transmission System (VTS) at Lara.

The gas terminal would be located adjacent to, and on, Viva Energy's Geelong Refinery in a heavily industrialised setting and would benefit from Viva Energy's experience and capability as an existing Major Hazard Facility (MHF) operator and potential synergies between the two facilities such as reuse of the FSRU seawater discharge within the refinery operations.

Methodology

A thorough and systematic examination of the potential impacts from the processes and systems for the planned supply of natural gas to the Victorian Transmission System (VTS) from the delivery of LNG by LNG carriers, the regasification of LNG to natural gas on board the FSRU berthed at the new Refinery Pier No. 5, the treatment of the natural gas to ensure it meets the required specification for supply within Victoria, and the transportation by pipeline from the FSRU to the VTS tie-in location at the Lara City Gate has been executed during the front end engineering design (FEED) stage.

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 WorkSafe Victoria (WSV).

The assessments have encompassed a number of risk and consequence modelling efforts, facility hazard and operability (HAZOP) studies, pipeline safety management study (SMS), and a quantitative risk assessment (QRA) with particular focus on the impact to the workforce, the general public and neighbouring land use.

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).

There is significant benefit in undertaking these assessments at an early stage within the project design, as that is where the major risk reduction benefits can be incorporated with the least impact on project milestones and commitments.

The methodology for completing the safety, 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 severity 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 could 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 have been identified, assessed and the associated mitigations will be implemented.

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

In assessing all risks, the worst-case scenario of a large uncontrolled release of LNG or natural gas leading to ignition has been considered. This represents the highest consequence for a process safety incident. The consequence from these low likelihood, high consequence events may impact surrounding land users. The hazard, safety, and risk impacts on the land users adjacent to and in the vicinity of Refinery Pier during project operations are expected to be limited and not disproportionate to those already experienced during the current operations of transferring flammable hydrocarbons at the other Refinery Pier berths.

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 A. 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 a principle 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 WSV 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.

All elements of the project meet the Hazardous Industry Planning Advisory Paper (HIPAP) No.4 tolerable individual fatality risk thresholds based on land use zoning, both on a project standalone basis, and when considered cumulatively with the existing refinery operation. The pipeline safety study identified all location classification based on current and future land use and completed assessment of all threats and has conservatively adopted the most sensitive classification for the design across the entire length. The results from the QRA are in Sections 6 to 9.

Mitigation measures

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

- All aspects of the project are designed to the appropriate Australian or international standards.
- The FSRU proposed for the Gas Terminal Project would be issued a Class notation (classification) by DNV (or equivalent marine vessel Classification Society).
- Classification attests to the vessel and process units being designed and operated in accordance with a prescribed set of DNV (or equivalent Classification Society) 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) Code
- The vessel will carry an International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.
- The pier infrastructure would include gas detection in the locations near the Marine Loading Arms (MLA), fire water monitors connected to the refinery firewater system to prevent escalation of a fire event and possibly a boil-off gas (BOG) connection to the refinery fuel gas system, if required.
- 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 (Vic)* and the Pipelines Regulations 2017 that govern the management and regulation of pipelines in Victoria.
- The Safety Management Study 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.
- The facilities at the treatment facility would include automated instrumentation to detect abnormal conditions and enunciate alarms at a remote fully attended control room.
- The pipeline would be fitted with actuated isolation valves at either end of the pipeline that can be closed by the shutdown system or manually from either a local or remote location in the event of an incident.
- 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 an emergency stop on the pier head
    - activation of an emergency stop at Treatment Facility
- 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 underground pipeline section would have a minimum of 1200 mm cover along the route as required by AS 2885.
- The FSRU is located over 600 metres from the nearest process equipment at the Geelong Refinery to effectively eliminate (minimise the likelihood) of an incident at one location escalating to the other facility.
- The FSRU is located over 1.6km from both North Shore residents and Geelong Grammar School exceeding the impact distance for radiation from large scale pool fires.

Incorporating community raised safety, hazard and risk concerns

As part of the established project risk assessment processes highlighted above many of the specific concerns raised through the project stakeholder consultation and engagement program had already been identified, assessed and considered:

- General safety concerns associated with FSRU operation and LNG transportation
- Impact on maritime and port operations safety with increased ship visits
- The potential for a major incident from a transiting LNGC to impact on North Shore residents
- The potential for a major incident / explosion on the FSRU
- Concerns regarding potential vehicle incidents (e.g. heavy vehicles) impacting the gas pipeline
- Potential increase in security incidents (e.g. intentional damage to LNGC / FSRU)
  - more appropriately addressed by independent security threat analysis undertaken by the project

Appendix B provides a summary of project responses to stakeholder safety-related concerns.

Outcomes of the safety studies, including QRA results, were provided to attendees at the October 2021 Community Information Session which focused on safety, and through safety Fact Sheets and presentations available on the project website. At subsequent Community Information Sessions, knowledgeable technical specialists and project team representatives were available to discuss any safety-related matters raised by attendees.

Abbreviations

Abbreviation/Term	Definition
AECOM	AECOM Australia Pty Ltd
ALARP	As Low As Reasonably Practicable
AMSA	Australia Maritime Safety Authority
AS	Australian Standard
BLEVE	Boiling Liquid Expanding Vapour Explosion
BOG	Boil off Gas
BOM	Bureau of Meteorology
CMMS	Computerised Maintenance Management System
CP	Cathodic Protection
DELWP	Department of Environment, Land, Water, and Planning
DN	Nominal Diameter
DTS	Declared Transmission System
EES	Environment Effects Statement
EMF	Environmental Management Framework
EMP	Environmental Management Plan
ERP	Emergency Response Plan
ESD	Emergency Shut Down
ESV	Energy Safe Victoria
FEA	Fire and Explosion Analysis
FEED	Front End Engineering Design
FFT	Fire Fighting Tug
FSRU	Floating storage and regasification unit
HAZID	Hazard Identification
HAZOP	Hazard and Operability [Assessment / Study]
HCRD	Hydrocarbon Release Database
HDD	Horizontal directional drilling
HIPAP	Hazardous Industry Planning Advisory Paper
HIPPS	High Integrity Pressure Protective System
HSE	Health, Safety, and Environment
IMO	International Marine Organisation
IRPA	Individual Risk per annum
LFL	Lower Flammable Limit
LIN	Liquid Nitrogen

Abbreviation/Term	Definition
LNG	Liquefied natural gas
LOPA	Layers of Protection Analysis
LSIR	Location Specific Individual Risk
MAOP	Maximum Allowable Operating Pressure
MHF	Major Hazard Facility
ML	Measurement Length
MLA	Marine Loading Arm
MSV	Marine Safety Victoria
OGP	International Association of Oil and Gas Producers
OSHA	Occupational Safety and Health Administration
OTS	Office of Transport Safety
P&ID	Process and Instrumentation Drawing [/ Diagram]
PHA	Preliminary Hazard Analysis
PJ	Petajoule (1×10^{15} Joules)
PPE	Personal protective equipment
QRA	Quantitative Risk Assessment
ROW	Right of way
SDS	Safety Data Sheet
SFAIRP	So Far As Is Reasonably Practicable
SFARP	So Far As Reasonably Practicable
SIF	Safety Instrumented Function
SIGGTO	Society of International Gas Tanker and Terminal Operators
SIL	Safety Integrity Level
SMS	Safety Management System
SWP	South West Pipeline
UFL	Upper Flammable Limit
VCE	Vapour Cloud Explosion
VIC	Victoria
VTS	Victorian Transmission System
WSV	WorkSafe Victoria

Glossary of terms

Term	Definition
ALARP / ALAP / SFARP / SFAIRP	**As Low As Reasonably Practicable** As Low as Practicable So Far As Reasonably Practicable So Far As Is Reasonably Practicable 'Reasonably practicable' reflects that an assessment must be made by the risk owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting (or minimising) the risk (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the onus the onus on the risk owner to demonstrate ALARP.
BLEVE	**Boiling Liquid Expanding Vapour Explosion** occurs when a pressure vessel walls structurally weaken due to fire impingement resulting in failure and the remaining liquid under pressure suddenly boils (vapourises) ignites, and explodes
BOG	**Boil off Gas** is released from the LNG stored in the cargo tanks as heat from the surroundings is transferred slowly (due to thermal insulation) to the LNG
ERP	**Emergency Response Plan** is a document that has considered the potential major incidents and developed a response structure, process, and specific response guidance in conjunction with emergency response service providers and local council to enable timely and effective response in the unlikely event of a major incident occurring.
ESD	**Emergency Shut Down** is the operational response within the process where the safety system executes a series of actions in response to an emergency signal – this typically includes activating valves to close (to isolate materials that would escalate an event), removing motive energy from equipment to stop in operating, and other related actions.
FEA	**Fire and Explosion Analysis** is conducted to identify and assess the impact of accidental releases of flammable hazardous material with the potential to pose major accident risk if ignited at the site location.
HAZID	**Hazard Identification** is a qualitative technique for identification of hazards and threats and can be applied all stages of a project.
HAZOP	**Hazard and Operability [Assessment / Study]** is a structured assessment methodology where each section (node) of the process by considering a range of possible deviations from the normal operational modes to determine potential consequences, identify the risk controls already managing that

Term	Definition
	exposure, and considering whether additional risk control measures may be warranted.
IRPA	**Individual Risk per annum** is a measure of the risk to a specific individual based on the occupation as part of the facility workforce, or as a member of the public (see LSIR).
LFL	**Lower Flammable Limit** is the minimum fraction of the flammable material vapour required to be mixed with air in order for it to burn if ignited. A mixture below the lower flammable limit is considered to be "too lean" to burn suggesting there is not enough flammable material in the mixture
LOPA	**Layers of Protection Analysis** is a risk assessment methodology which uses simplified, conservative rules to define risk as a function of both frequency and potential consequence severity, and assists in assessing whether sufficient independent risk control measures have reduced risk so far as is reasonably practicable.
LSIR	**Location Specific Individual Risk** is a measure of the likelihood of a fatality assuming an individual is located at a specific location 100% of the time with no protection other than regular clothing. These points are joined to provide a risk contour at a specific LSIR probability.
ML	**Measurement Length** is a parameter used in AS2885 to determine the extent of land use considerations when determining pipeline classification. The measurement length assumes a full bore rupture of the pipeline and is the result of calculating the distance to 4.7kW/m^2 radiation contour.
QRA	**Quantitative Risk Assessment** is a formal and systematic approach to estimating the likelihood and consequences of hazardous events, and expressing the results quantitatively as risk to people, the environment or your business. It also assesses the robustness and validity of quantitative results, by identifying critical assumptions and risk driving elements.
SFAIRP	**So Far As Is Reasonably Practicable** See definition under ALARP
SFARP	**So Far As Reasonably Practicable** See definition under ALARP
SIF	**Safety Instrumented Function** is a specific safety related automated action triggered by a safety initiator (process outside of design envelope), or manual emergency shutdown initiation
SIL	**Safety Integrity Level** is a measurement of the risk reduction performance required for a safety instrumented function

Term	Definition
UFL	**Upper Flammable Limit** is the maximum fraction of the flammable material vapour required to be mixed with air in order for it to burn if ignited. A mixture above the upper flammable limit is considered to be “too rich” to burn suggesting there is too much flammable material (or insufficient air/oxygen) in the mixture.
VCE	**Vapour Cloud Explosion** occurs when a large flammable mass of hydrocarbon vapour is ignited in a confined or partially confined space. The combustion of the flammable vapour in air typically result in an 8 times volume increase of hot combustion products compared to ambient reactants causing an explosion.

1. Introduction

This technical report provides a summary of safety, hazard and risk assessments conducted to support the Environment Effects Statement (EES) for the Viva Energy Gas Terminal Project (the project).

Viva Energy Gas Australia Pty Ltd (Viva Energy) is planning to develop a gas terminal using a ship known as a floating storage and regasification unit (FSRU), which would be continuously moored at Refinery Pier in Corio Bay, Geelong. The key objective of the project is to facilitate supply of a new source of gas for the south-east Australian gas market where there is a projected supply shortfall in coming years.

The FSRU would store liquefied natural gas (LNG) received from visiting LNG carriers (that would moor directly adjacent to the FSRU) and would convert LNG back into a gaseous state by heating the LNG using seawater (a process known as regasification) as required to meet industrial, commercial, and residential customer demand. A 7-kilometre gas transmission pipeline would transfer the gas from the FSRU to the Victorian Transmission System (VTS) at Lara.

The project would be situated adjacent to, and on, Viva Energy's Geelong Refinery, within a heavily developed port and industrial area on the western shores of Corio Bay between the Geelong suburbs of Corio and North Shore. Co-locating the project with the existing Geelong Refinery and within the Port of Geelong offers significant opportunity to minimise potential environmental effects and utilise a number of attributes that come with the port and industrial setting.

In December 2020, the Victorian Minister for Planning determined that the project requires assessment through an EES under the *Environment Effects Act 1978* (Vic). The reasons for the decision were primarily related to the potential for significant adverse effects on the marine environment of Corio Bay and the potential for contributing to greenhouse gas emissions. Secondarily, the EES was required to assess the effects of the project on air quality, noise, land use, Aboriginal and historic heritage, native vegetation, groundwater, traffic and transport as well as visual amenity.

In January 2021 the project was also determined to require assessment and approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* ('EPBC Act') due to the potential for the project to have a significant impact on wetlands of international importance, listed threatened species and communities, and listed migratory species. The EES process is the accredited environmental assessment process for the controlled action decision 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 a summary, and explanation, of the safety, hazard and risk assessments for the EES, excluding environmental hazards, and to detail the mitigation measures 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 would be implemented in the approvals and management plans for the project.

1.2. Why understanding safety, hazard and risk is important

The project would introduce the bulk storage and distribution of hazardous materials, of sufficient volume to have the potential for off-site consequences. Both the project and the associated marine transportation of LNG represent a safe and efficient method to provide and transport natural gas to the Victorian market. Under normal cryogenic storage temperature (~162°C) at, or just above, ambient pressure (1.013 bar), LNG is non-flammable due to the presence of a 100% natural gas vapour phase in storage. Both the FSRU and LNG carriers are able to maintain these conditions under normal operation by allowing the boil-off gas to be used as it is generated from the cryogenic tanks. Any boil-off gas is collected and used by the vessel as fuel or exported to Geelong Refinery's fuel gas system. Excess boil-off gas from the FSRU sent to the refinery displaces current supplies of natural gas from the VTS.

Outside normal operations, and in the event of a loss of containment to atmosphere, the LNG will rapidly vaporise, becoming a natural gas release, expanding to occupy ~600 times the volume of the released LNG. The natural gas vapour may then mix with air to potentially form a flammable mixture, capable of both ignition and explosion given suitable conditions.

In addition to LNG and natural gas, the project will also introduce bulk storage of liquid nitrogen (LIN) and an odorant (anticipated to be Spotleak 1005) to ensure gas meets the AEMO Declared Transmission System (DTS) gas quality specifications.

It is therefore important to understand the physical and chemical properties that define the hazards associated with LNG, liquid nitrogen (LIN) and odorant, how they impact on the risk, and finally how to ensure the health, safety, and environmental consequences are eliminated or minimized so far as is reasonably practicable.

The physical presence of a new facility, its location, and support activities pose ongoing hazards, as well as hazards associated with the construction of the new facilities. As with the understanding of the dangerous goods introduced, all hazards associated with these other aspects of the project, throughout all phases of the project need to be identified, considered, and appropriately managed to eliminate or minimize the risk associated with them so far as is reasonably practicable.

Understanding the safety, hazards and risks associated with the project is critical as it enables the proponent to design systems and put in place appropriate measures to safeguard human life, assets and the environment.

To assess the safety, hazard and risks of the project Viva Energy has undertaken, and plans 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 during front end engineering design (FEED) include hazard identification workshops (HAZID), hazard and operability studies (HAZOP); pipeline Safety Management Studies (SMS) Quantitative Risk Assessments (QRA) and Safety Integrity Level (SIL) study.

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 updated as project develops and the details are further defined. This is a normal occurrence during the lifecycle of any project or facility.

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.

1.3. Project area

The project would be located at, and adjacent to, the Geelong Refinery and Refinery Pier in the City of Greater Geelong, 75 kilometres (km) south-west of Melbourne. The project area is within a heavily developed port and industrial area on the western shores of Corio Bay between the Geelong suburbs of Corio and North Shore. The Geelong central business district is located approximately 7 km south of the project.

Corio Bay is the largest internal bay in the south-west corner of Port Phillip Bay and is a sheltered, shallow basin at the western end of the Geelong Arm, with an area of 43 square kilometres (km^2). The Point Wilson/Limeburners Bay section of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site is located along the northern shoreline of Corio Bay, approximately one kilometre to the north-east of the project.

The Port of Geelong has been in operation for over 150 years and is the largest industrial bulk cargo port in Victoria, attracting over 600 ship visits and handling more than 14 million tonnes of product annually. Geelong's shipping channels extend 18 nautical miles through Corio Bay from Point Richards through to Refinery Pier. Ports Victoria manages commercial navigation in the port waters in and around Geelong and is responsible for the safe and efficient movement of shipping, and for maintaining shipping channels and navigation aids. The channels are man-made having been deepened and widened through periodic dredging to support port trade development.

Refinery Pier is the primary location within the Port of Geelong for movement of bulk liquids. Vessels up to 265 metres in length currently utilise the four berths at Refinery Pier which service Viva Energy refinery operations. The majority of ship visits to the port are to Refinery Pier, with Viva Energy accounting for over half of the trade through the Port of Geelong.

The Geelong Refinery has been operating since 1954 with both the refinery and the co-located LyondellBasell plant being licensed Major Hazard Facilities (MHFs). A range of industrial activities are situated in the Port environs including wood fibre processing and chemical, fertiliser and cement manufacturing.

To the north of the Geelong Refinery, along the proposed underground pipeline corridor, the area is predominantly rural. There are several other existing Viva Energy-owned underground pipelines running between the refinery and the connection point to the South West Pipeline (SWP) at Lara. The proposed pipeline route follows already disturbed pipeline corridors, where possible, through a mix of land uses.

The project area is shown in Figure 1-1.

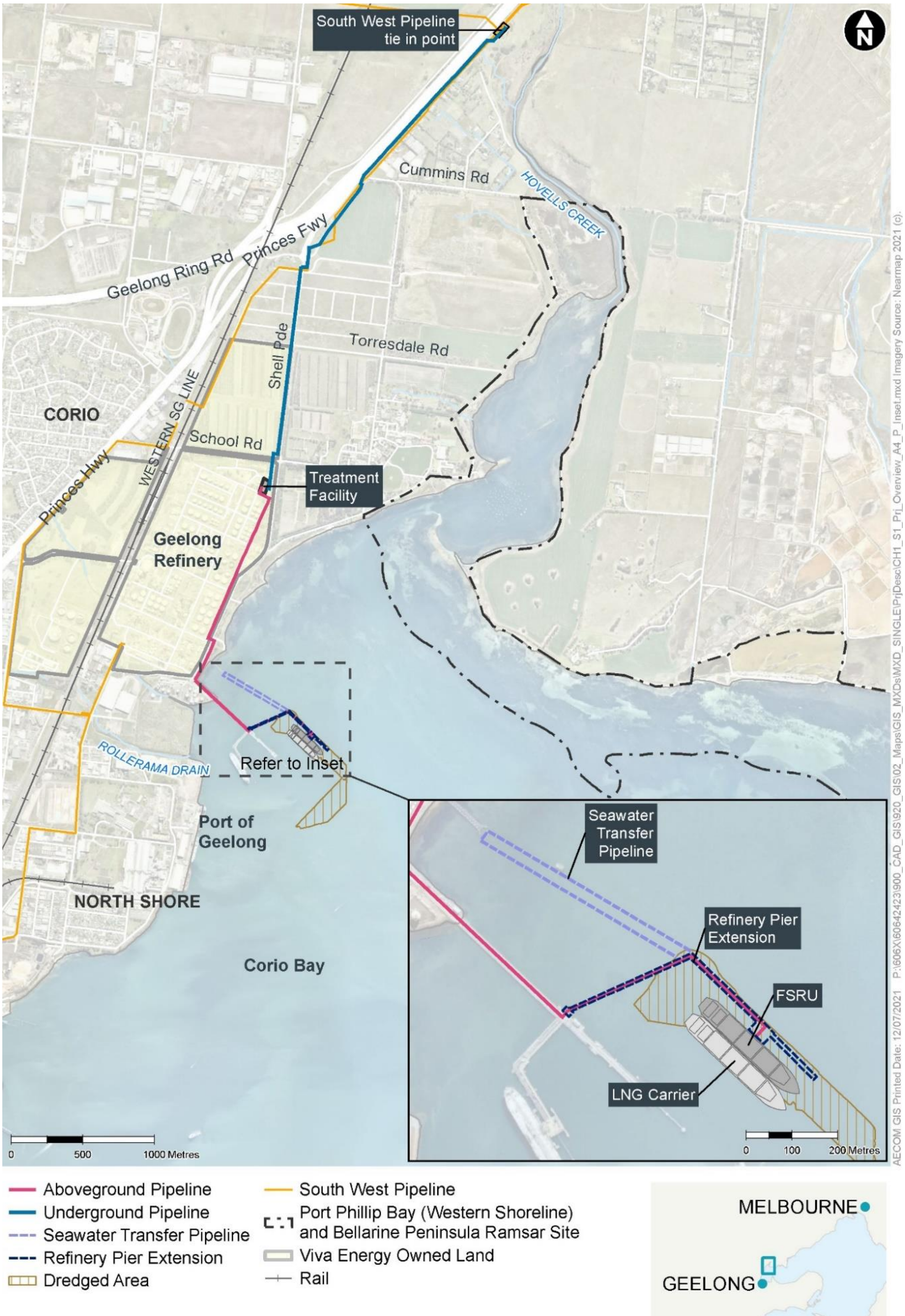


Figure 1-1: Project overview

1.4. Project description

This section summarises the project as described in Chapter 4: *Project description*. Key components of the project include:

- extension of the existing Refinery Pier with an approximately 570 metre (m) long angled pier arm, new berth and ancillary pier infrastructure including high pressure gas marine loading arms (MLAs) and a transfer line connecting the seawater discharge points on the FSRU to the refinery seawater intake
- continuous mooring of an FSRU at the new Refinery Pier berth to store and convert LNG into natural gas. LNG carriers would moor alongside the FSRU and unload the LNG
- construction and operation of approximately 3km of aboveground gas pipeline on the pier and within the refinery site connecting the FSRU to the new treatment facility
- construction and operation of a treatment facility on refinery premises including injection of nitrogen and odorant (if required)
- construction and operation of an underground gas transmission pipeline, approximately 4 km in length, connecting to the SWP at Lara.

The Refinery Pier extension would be located to the north-east of Refinery Pier No. 1. The new pier arm would be positioned to allow for sufficient clearance between an LNG carrier berthed alongside the FSRU and a vessel berthed at the existing Refinery Pier berth No. 1. Dredging of approximately 490,000 cubic metres of seabed sediment would be required to allow for the new berth pocket and swing basin.

The FSRU vessel would be up to 300m in length and 50m in breadth, with the capacity to store approximately 170,000 cubic metres (m^3) of LNG. The FSRU would receive LNG from visiting LNG carriers and store it onboard in cryogenic storage tanks at about -160°C.

The FSRU would initially receive up to 160 PJ per annum (approximately 45 LNG carriers) depending on demand. The number of LNG carriers would also depend on their storage capacity, which could vary from 140,000 to 170,000 m^3.

When gas is needed, the FSRU would convert the LNG back into a gaseous state by heating the LNG using seawater (a process known as regasification). The natural gas would then be transferred through the aboveground pipeline from the FSRU to the treatment facility where odorant and nitrogen would be added, where required, to meet VTS gas quality specifications. Nitrogen injection would occur when any given gas cargo needs to be adjusted (diluted) to meet local specifications. Odorant is added as a safety requirement so that the normally odourless gas can be smelt when in use. From the treatment facility, the underground section of the pipeline would transfer the natural gas to the tie-in point to the SWP at Lara.

The operation of the FSRU and regasification process would be undertaken by a dedicated FSRU crew, with the primary process controls, safety systems and control room located on the FSRU. There would be communication linkages to the refinery control room to provide secondary capability to execute shutdown functions if required. The other project facilities (pipeline, treatment facility) would be operated from the refinery control room. During detailed design, the need for secondary capability for limited safety shutdown action to be triggered from the FSRU will be determined.

1.4.1. Key construction activities

Construction of the project would occur over a period of up to 18 months. The key construction activities relate to:

- localised dredging of seabed sediments to enable the FSRU and LNG carriers to berth at Refinery Pier and excavation of a shallow trench for the seawater transfer pipe
- construction of a temporary loadout facility at Lascelles Wharf
- construction of the new pier arm and berthing infrastructure, and aboveground pipeline along Refinery Pier and through the refinery

- construction of the treatment facility on a laydown area at the northern boundary of the refinery site
- construction of the buried pipeline
- construction at the tie-in point to the SWP at Lara

There are no construction activities required for the FSRU component of the project. The vessel would be built, commissioned and all production and safety systems verified prior to being brought to site.

An estimated 490,000 cubic metres (m^3) of dredging would be required, over an area of approximately 12 hectares (ha), adjacent to the existing shipping channel to provide sufficient water depth at the new berth and within the swing basin for visiting LNG carriers to turn. Dredging within the new berth would be undertaken to a depth of 13.1 metres and the swing basin would be dredged to a depth of 12.7 metres. The dredging footprint is shown in Figure 1-1. It is planned to deposit the dredged material within the existing dredged material ground (DMG) in Port Phillip Bay to the east of Point Wilson, approximately 26 km from Refinery Pier.

The temporary loadout facility at Lascelles Wharf would be the first construction activity to take place in order to facilitate the Refinery Pier extension. This would involve the installation of 10 piles using hydraulic hammers.

Construction of the pier arm would be carried out once dredging was complete, primarily from the water using barge-mounted cranes. Steel piles would be driven into the seabed by cranes mounted on floating barges and pre-cast concrete and pre-fabricated steel components would be transported to site by barge and lifted into position. The installation of pier infrastructure such as the marine loading arms (MLAs), piping from the FSRU to the existing refinery seawater intake (SWI) and aboveground pipeline would also be undertaken from the water using barge-mounted cranes and construction support boats.

Installation of the 3km above ground pipeline along the pier and through the refinery is anticipated to take 3.5 months to complete. The above ground pipeline would run along the pier to the existing pipe track east of Shell Parade within the pier foreshore compound. It would then pass through a road under-crossing to the existing refinery pipe track. The pipeline would then run north along the existing refinery pipe track to an existing laydown area where the treatment facility would be located.

The treatment facility would be located within an existing laydown area in the refinery site and cover an area of approximately 80m x 120m. Construction of the treatment facility would take approximately 6 months and would be undertaken by specialist crews across distinct phases of work. These would include initial earthworks and civil construction, mechanical installation and electrical and instrumentation works.

The 4km underground pipeline would be installed in stages over an approximate 4 month period within a corridor which has been selected so as to avoid watercourses or other environmental sensitivities, where possible. Firstly, a construction right of way (ROW) would be established, clearly identified and fenced off where required. Typically, this would be between 15 and 20m wide, and minimised where possible to reduce disturbance. Once the construction ROW is established, vegetation would be removed, and a trench excavated to a maximum depth of 2m and a maximum width of 1m for the pipeline to be placed. Following the placement of the pipeline, the construction ROW would be rehabilitated to its pre-existing condition as far as practicable for the purposes for which it was used immediately before the construction of that part of the pipeline.

Trenchless construction (including boring or horizontal directional drilling (HDD)) would be used to install the underground pipeline in areas that are not suited to open trenching techniques, such as at intersections with major roads, which would be confirmed during detailed design. Trenchless construction would involve boring or drilling a hole beneath the ground surface at a shallow angle and then pushing or pulling a welded length of pipe through the hole without disturbing the surface. It is anticipated that the maximum depth of the trenchless section would be 25m.

The anticipated trenching, HDD and thrust bore locations are presented in. It is possible that along the northern section of Macgregor Court the pipeline would also be constructed using HDD, however, this would be confirmed during detailed design.

Construction at the tie-in point to the SWP at Lara would be undertaken by specialist crews across the distinct phases of works, as with the treatment facility.

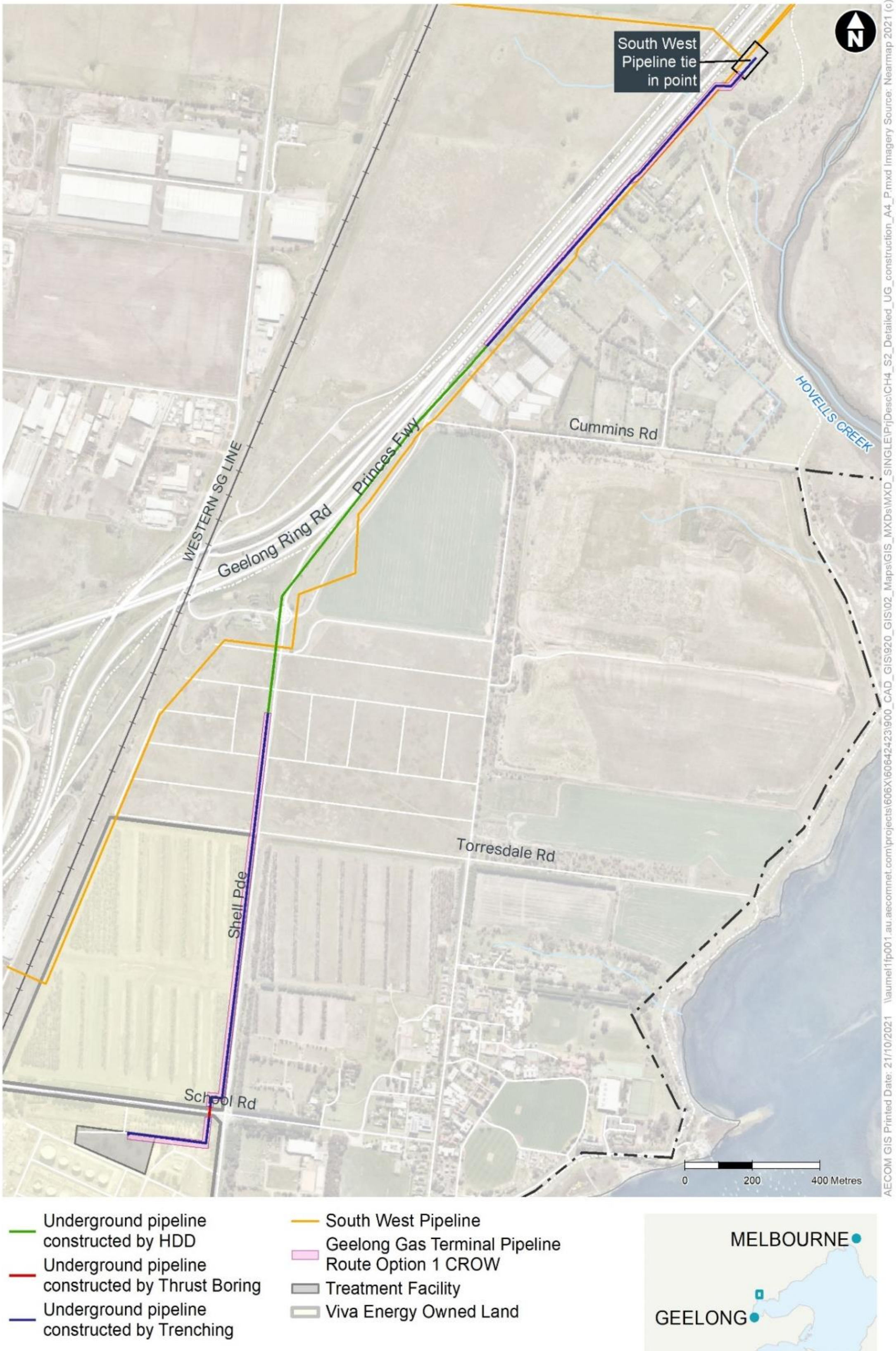


Figure 1-2: Proposed location of trenching construction techniques for the underground pipeline including open trenching, HDD and thrust boring

1.4.2. Key operation activities

The project is expected to be in operation for approximately 20 years. Key activities relating to project operation include:

- receipt of up to 45 LNG carriers each year at Refinery Pier – the number and frequency of LNG carriers arriving each year would depend on their storage capacity and gas demand
- regasification of LNG onboard the FSRU using seawater as a heat source, which would then be reused within the refinery as cooling water
- injection of nitrogen and odorant into the gas prior to distribution via the VTS
- monitoring and maintenance of the pipeline easement.

1.4.3. Key decommissioning activities

The FSRU, which continues to be an ocean-going vessel throughout the operation of the project, would leave Corio Bay on completion of the project life to be used elsewhere.

It is anticipated that the Refinery Pier berth and facilities would be retained for other port related uses. The underground pipeline would likely remain in situ subject to landholder agreements and either decommissioned completely or placed into care and maintenance arrangements. Decommissioning activities may be subject to change, subject to legislative requirements at the time and potential repurposing of the infrastructure at the end of the project.

2. Scoping requirements

The scoping requirements for the EES set out the specific environmental matters to be investigated in the EES. The scoping requirements include a set of evaluation objectives. These objectives identify the desired outcomes to be achieved in managing the potential impacts of constructing and operating the project.

The following evaluation objective is relevant to the safety, hazard and risk assessment:

- **Energy efficiency, security, affordability and safety -** To provide for safe and cost-effective augmentation of Victoria's natural gas supply having regard to projected demand and supply in context of the State's energy needs and climate policy.

The scoping requirements of relevance to the assessment of safety, hazard and risk and where they are addressed in the report are shown in Table 2-1.

Table 2-1 Scoping requirements relevant to safety, hazard and risk

Aspect	Scoping requirement	Section addressed
Key issues	Workforce, nearby operations and public safety risks associated with the construction operation of the project, including risks associated with or compounded by potential external threats.	Refer Section 5
Existing environment	Characterise the human environment near the project relative to safety buffer standards for surrounding current land uses and reasonably foreseeable future land uses.	Refer to Technical Report: M: *Land use impact assessment*
Likely effects	Assess the project's compliance with safety standards, including the FSRU.	Refer Sections 6 to 9 and 12
	Assess the potential for safety impacts to occur during operations on nearby residents (including North Shore residents) as well as workforce and nearby operations within Corio Bay and surrounds.	Refer Sections 6 to 9 and 12
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.	Refer Sections 5 to 9 and 11
Performance criteria	Describe the monitoring program to form part of the EMF to identify any potential hazards in time for corrective action to be taken.	Refer Section 11
	Describe the framework for emergency response, including contingency planning for foreseeable possible public safety or environmental emergencies.	Refer Section 10

3. Legislation, policy and guidelines

3.1. Legislative overview and project implications

Table 3-1 summarises the key legislation and policy that apply to the project in the context of this safety, hazard and risk impact assessment, as well as the implications for the project and the required approvals (if any).

Table 3-1: Primary health safety and risk legislation and associated information

Legislation / policy	Description	Project implications	Approval required
Commonwealth			
Legislation			
Navigation Act 2012 (Cth)	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 and LNG carrier are safe. AMSA is the responsible authority regarding international conventions giving responsibility to Australia to control ships in Australian waters so that they do not threaten safety or the environment.	No approval required Compliance required
Marine Order 17 (Chemical tankers and gas carriers)	Sets the certification requirements for vessels carrying liquefied gases in bulk, and safe operation of gas carriers.	The FSRU and LNG carriers must have the required certificates and comply with international convention standards about construction and equipment.	FSRU and LNG carrier vessel certification
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.	No approval required Compliance required
Marine Order 41 (Carriage of dangerous goods)	Applies to the carriage of dangerous goods (notifications and proper precautions) on a regulated Australian vessel and a foreign vessel.	AMSA may intervene if loading, stowage, carriage and unloading of dangerous goods is likely to be unsafe and may impose conditions to ensure safety.	No approval required Compliance required
Marine Order 58 (Safe management of vessels)	Implements the International Safety Management (ISM) Code governing the safe operation of ships and pollution prevention.	Enables AMSA to confirm that required safety management system certificates are in place, and system is in accordance with the ISM Code.	No approval required Compliance required

Legislation / policy	Description	Project implications	Approval required
Maritime Transport and Offshore Facilities Security Act 2003 (Cth)	Safeguards against unlawful interference with maritime transport, ports and ships including by reducing the risk of terrorist or other unlawful activities.	A maritime security plan must be approved by the Aviation and Maritime Security (AMS) Division. Maritime industry participants are required to maintain and comply with maritime security plans.	No approval required by project Compliance required
Occupational Health and Safety (Maritime Industry) Act 1993 (Cth)	Protection of maritime industry employees from risks to health and safety in their occupational environment.	This legislation will apply in the event that the FSRU is considered a "prescribed ship".	No approval required Compliance will be required in the event the FSRU is deemed a "prescribed ship".
Protection of the Sea (Civil Liability for Bunker Oil Pollution Damage) Act 2008 (Cth)	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.	No approval required Compliance required
Policy			
N/A			
State			
Legislation			
Port Management Act 1995 (Vic)	Provides 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.	Project will need to engage with GeelongPort to identify any changes required to the port Safety and Environment Management Plan as a result of the project. A marine operations risk assessment covering the LNG carrier transit through the entire shipping channel from entry into Port Phillip Bay through to mooring alongside the FSRU and return transit needs to be completed.	No approval required Compliance required
Marine Safety Act 2010 (Vic)	Provides for safe marine operations in Victoria by imposing safety duties on a	The FSRU's continuously moored operations, other operations at port and the arrival and departure of	No approval required

Legislation / policy	Description	Project implications	Approval required
	range of participants in marine activities, for navigation in State waters, mandating the office and functions of harbour masters and regulating pilotage.	LNG carriers must be conducted within the safety framework.	Compliance required
Occupational Health and Safety Act 2004 (Vic) and Occupational Health and Safety Regulations 2017	Primary 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 objectives of these regulations are to promote occupational health and safety, protecting workers and other persons present at workplaces from work-related risks to their health, safety and well-being.	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. 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. FSRU will require a MHF Licence for ongoing operation.	MHF Licence based on FSRU safety case Revision to existing refinery MFH safety case to include odorant storage, and if required for possible boil-off gas line to refinery fuel gas system.
Dangerous Goods Act 1985 (Vic) and Dangerous Goods Act (Storage and Handling) Regulations 2012	Promotion of the safety of workers, site visitors, general public and property in relation to the manufacture, storage, transport, transfer, sale and use of dangerous goods and the import of explosives into Victoria. Require facilities meeting threshold to have a Dangerous Goods Licence. Ensure that adequate precautions are taken against dangerous goods incidents. Allocate responsibilities to occupiers and owners of premises.	Obligations are typically captured under the MHF safety case, however any specific provisions will need to be addressed. LIN storage at the treatment facility will be covered by this legislation.	No approval required Compliance required

Legislation / policy	Description	Project implications	Approval required
Pipelines Act 2005 (Vic) and Pipelines Regulations 2017	This is the primary act governing the construction and operation of pipelines in Victoria. The Pipelines Act covers 'high transmission' pipelines for the conveyance of gas, oil and other substances. The Department of Environment, Land, Water and Planning (DELWP) and Energy Safe Victoria (ESV) are responsible for administering the Act and Regulations	The project requires a Pipeline Licence(s) under the *Pipelines Act 2005* for the construction and operation of the pipeline. Consultation and engagement with relevant stakeholders (e.g. land owners) is required. A Gas Safety Case (which covers the requirement for a pipeline Safety Management Plan) and an Environment Management Plan are required to enable a Pipeline Licence to be granted. Additional requirements are covered below under Gas Safety legislation.	Pipeline Licence(s) required
Gas Safety Act 1997 (Vic) and Gas Safety (Safety Case) Regulations 2018	The primary aim 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 Geelong Gas Terminal Pipeline and treatment facility will be subject to regulation by ESV under the Gas Safety Act 1997 subject to the owner or operator being declared to be a "gas company" under the Act. Gas companies must comply with general safety duties including to minimise as far as practicable • hazards and risks to the public and customers and their property from gas through effective risk control measures, • interruptions to the conveyance or supply of gas and the reinstatement of an interrupted gas supply. A safety case (including a formal safety assessment to identify credible threats) will be prepared for the	Gas Safety Case covering gas pipeline and nitrogen and odorant injection facilities at the treatment facility. This covers the Safety Management Plan for the pipeline.

Legislation / policy	Description	Project implications	Approval required
		pipeline and the injection equipment at the treatment 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.	
Planning and Environment Act 1987 (Vic) ('P&E Act')	The P&E Act establishes a framework for planning the use, development and protection of land in Victoria. The P&E Act provides for the preparation of planning schemes in each municipality consistent with the Victorian Planning Provisions (VPPs) and procedures by which planning schemes may be amended and planning permits obtained to govern land use and development. It also provides the context for the land use impact assessment.	The Pipelines Act 2005 (the Pipelines Act) provides that a permit is not required under the P&E Act for the use or development of land, or the doing or carrying out of any matter or thing, for the purpose of a licenced pipeline. The pier extension, FSRU and treatment facility will not be subject to the provisions of the Pipelines Act and will therefore require planning approval under the Scheme. Ministerial Direction No. 20 for Major Hazard Facilities would apply when preparing the planning scheme amendment and the applicability of Planning Policy Framework for Major Hazard Facilities - Clause 13.07 of the Planning Scheme would be considered.	Planning Scheme Amendment
Policy			
Harbour Master's Directions	Section 232 of the *Marine Safety Act 2010* provides a Harbour Master with the power to give written and/or oral directions for or with respect to vessels entering or within waters for which the Harbour Master has been engaged.	The Harbour Master's Directions for the Port of Melbourne and Harbour master's Directions for the Port of Geelong apply to all vessels operating in those respective port waters e.g., the FSRU and LNG carriers.	No approval required. Compliance required.

3.2. Application of legislation to project components

Detailed consideration of the *Gas Safety Act 1997 (Vic), Pipelines Act 2005 (Vic),* and associated regulations are captured below in Table 3-2.

Table 3-2: Key Sections of the Acts

Gas Safety Act 1997 (Vic)	Pipelines Act 2005 (Vic)
Sect 37 Safety case 2) A safety case for a facility must— b) in accordance with the regulations, specify the safety management system being followed or to be followed by the gas company— i. to comply with the gas company's duties under Division 1 {Sects 32-36}; and in relation to any other matters relating to the safe conveyance, supply, sale, measurement or control of gas that are prescribed.	**Definitions (Sect 5)** **Pipeline:** *means a pipe or system of pipes for the conveyance of anything through the pipe or system of pipes* *A Marine Loading Arm is a "system of pipes"*
Sect 33 Gas Quality 1) A gas company must ensure that, as far as practicable, the gas which it conveys— a) meets the prescribed standards of quality; and b) complies with any other prescribed requirements.	**Pipe or system of pipes** *include* a) *all apparatus and works associated with the pipe or system of pipes; and* b) *a part of the pipe or system of pipes;* *The in-line heating equipment, custody transfer measurement equipment, and in-line analysers form part of the system of pipes associated with the pipeline.*
Apparatus and works* *include* e) *storage, loading and all ancillary facilities and installations required for the pipeline or used in connection with, or incidental to, the pipeline* *Both the storage and injection of nitrogen and odorant into the natural gas stream from the FSRU are integral to the obligation under Gas Safety (Safety Case) Regulations 31 to "… ensure … the operation … (e) is adequate to ensuring the quality of gas conveyed or supplied" [per Regs 45 & 46 which prescribe the gas quality standards]* * *Definition is from referenced Gas Industry Act 2001*	**Apparatus and works** *include* c) *apparatus for transmitting information or instruction with regard to the operation of the pipe or system of pipes;* e) *apparatus or facilities permitting the addition of anything to or removal of anything from the pipe or system of pipes to facilitate flow* *"facilitate" – to make an action or a process possible or easier (Oxford dictionary)*

The inclusion of both the nitrogen and odorant injection facilities (piping and process equipment) as part of the gas safety case is consistent with the requirement under the *Gas Safety Act 1997 (Vic)* that the gas company must ensure that it meets the prescribed quality standards, which cannot be achieved without the ability to inject nitrogen (for Wobbe Index) and odorant (gas safety) into the gas pipeline. These conclusions are presented in Figure 3-1 highlighting the jurisdictional boundaries, the licence holder / operator under the legislation, and other pertinent information.

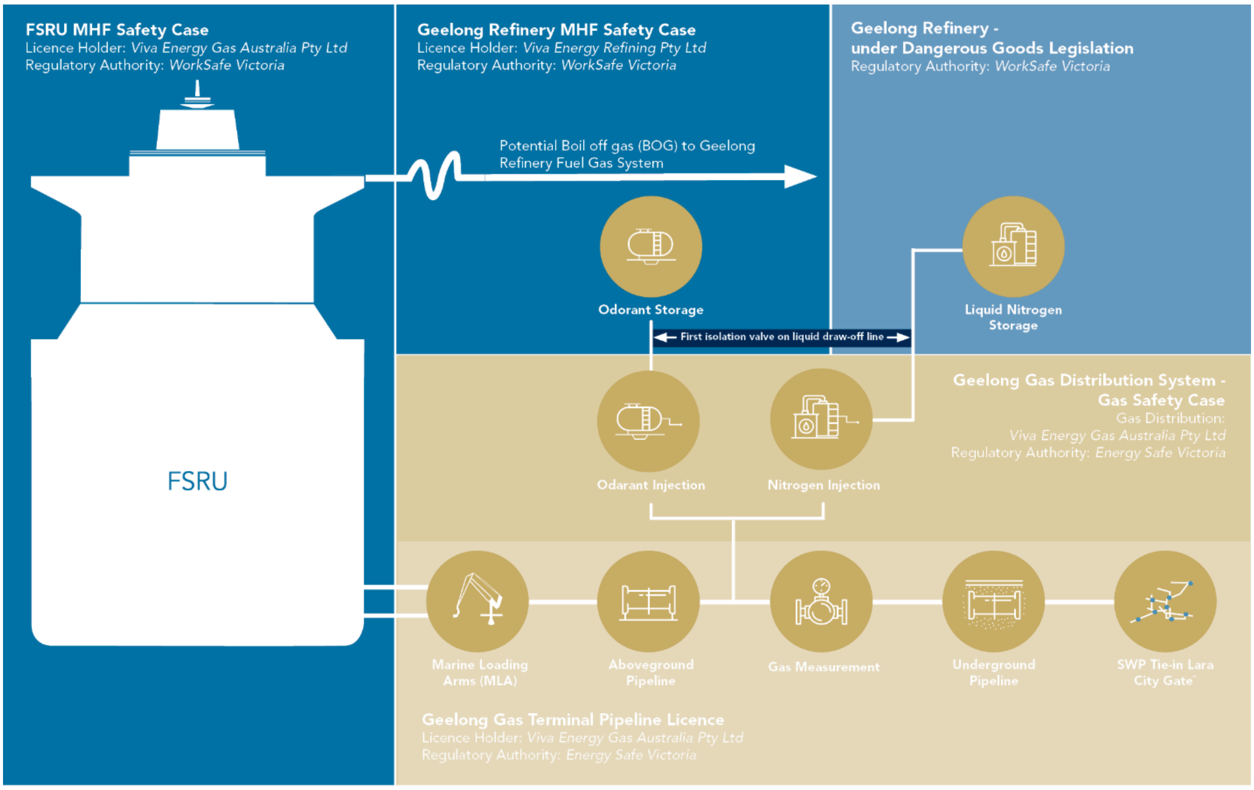


Figure 3-1: Jurisdictional boundaries (to be confirmed) for project components / facilities

3.3. Operational control

Consistent with Figure 3-1 above, with the exception of the LNG carrier delivering the LNG to the FSRU, Viva Energy would be the responsible entity and licence holder / gas distributor (under the applicable legislation) for the FSRU, pipeline and treatment facility operations. A service agreement would be established with the FSRU service provider who would be operating under Viva Energy direction to regasify LNG to meet Viva Energy's supply requirements.

Viva Energy would provide the personnel for operation, inspection and maintenance of the pipeline and treatment facility with specialist service providers (e.g. pipeline intelligent pigging and data acquisition) used on an as-needed basis. The FSRU would have an operation crew provided by the FSRU service provider to execute the regasification process. The operational management of the FSRU would have ongoing active engagement by an experienced senior operations representative in addition to the contractor oversight program under Viva Energy's Third Party Services Management System to ensure the effectiveness of the risk control measures is maintained, or addressed in an appropriate and timely manner should there be diminution of control measure effectiveness.

With a single entity having responsibility for, and control over, the entire process from receiving the LNG from the LNG carrier, to supply into the VTS at Lara City Gate there would be consistent understanding and clear accountability for the operation for all stakeholders. As Viva Energy is one of the existing users of Refinery Pier, this arrangement would minimise any increase in coordination activities required between pier users.

4. Methodology

An overall Safety Philosophy for the project covering both the construction and operational phases' health and safety exposures provides the structure and minimum expectations for effective safety management. The safety philosophy addresses:

- Reference Codes, Standards, and Guidelines,
- Hazard Management Process
- Occupational Health and Safety
- Safety Equipment
- Inherent Safety
- Emergency Control Systems
- Fire and Gas System
- Escape, Muster, Evacuation and Rescue

During project development a systematic, risk-based approach has been applied to understand the potential impacts of the project and how to eliminate, minimise or manage the risk of an impact to the workforce, nearby operations and the adjacent land users. During the project FEED stage, this included a series of safety, hazard and risk workshops, studies, and assessments either been completed, or scheduled that will ultimately result in a design that at the time of commitment will have risk reduced So Far As Is Reasonably Practicable (SFAIRP). These preliminary workshops, studies, and assessments (detailed below) will be refined as required as the project progresses through detailed design, consistent with an iterative risk-based approach ensuring continuous improvement in risk mitigation and risk management.

Hazard Identification Focused

- Hazard Identification and Assessment (HAZID) workshops
- Hazard and Operability (HAZOP) workshops

Consequence Focused

- Fire and Explosion Analysis
- Nitrogen Release Modelling
- Vent Dispersion and Radiation Study
- Fire Safety Study (pier)
- Addendum to Refinery Fire Safety Study
- Hazardous Area Classification Report

SFAIRP / Risk Reduction Focused

- Process Design Review
- Quantitative Risk Assessment (QRA)
- Safety Management Study and workshop for the pipeline
- SFAIRP Workshop
- Safety Integrity Level (SIL) studies
- Fire and Gas Detection requirements
- Safety Layouts (escape routes, safety equipment etc)
- Escape, muster, evacuation and rescue analysis (pier)
- Safety Studies Action Close-Out Report

*

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 project area including the refinery workforce and proposed operational workforce. These aspects are described in further detail in Technical Report M: *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 project, Viva Energy has 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 and assists in further developing mitigating factors.

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 suitable risk criteria is discussed further in the following sections.

4.2. LNG Properties

Reference to Safety Data Sheets will yield the following information on the properties of LNG and natural gas respectively.

Table 4-1: Properties of LNG and natural gas

Property	LNG – Liquefied Natural Gas	NG – Natural Gas
Appearance	Liquid	Gas
HAZCHEM Code	2WE	2SE
Initial Boiling Point	-162 °C	-162 °C
Flammability	Flammable Gas	Flammable Gas
Upper Flammability Limit	Typically 15% (by volume)	Typically 15% (by volume)
Lower Flammability Limit	Typically 5% (by volume)	Typically 5% (by volume)
Density	Typical 450 kg/m^3 (15.0 °C)	Typically 0.8 kg/m^3 SG = 0.615 (relative to air)
Auto-ignition temperature	537 °C	537 °C
Hazards	H220: Extremely flammable gas. H281: Contains refrigerated gas; Release of LNG into water may cause explosive boiling due to rapid phase transition (liquid to gas)	H220: Extremely flammable gas.

4.3. Demonstration that risks have been reduced so far as is reasonably practicable (SFAIRP)

Managing risk is an important component of managing Major Hazard Facilities. Industrial activities can never be entirely free from risk, 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, March 2020, 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, the overarching principles relating to demonstrating that risks have been identified and mitigated SFAIRP 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 4.9.7 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.

4.4. Inherently safe design

Consistent with Viva Energy's approach to safety, the philosophy and principles providing the foundation for inherently safe design (ISD) is to effectively use the opportunity at all phases of a project to eliminate hazards, and when not possible to eliminate the hazard to then consider the most effective strategies from the hierarchy of controls to minimise the consequences of each hazard within the project. ISD recognises that not all hazards can be eliminated, and that with some controls, there may be some changes in the risk profile for other hazards (e.g. reducing a hazardous consumable chemical inventory onsite will result in an increase in transportation risks due to higher delivery frequency).

The early design phase of a project provides the best opportunity to make maximum risk reduction impact through thoughtful and structured application of ISD – location, layout, process selection, required inventories, material choices among many risk management decisions that flow through into detailed design, construction, and ultimately operations.

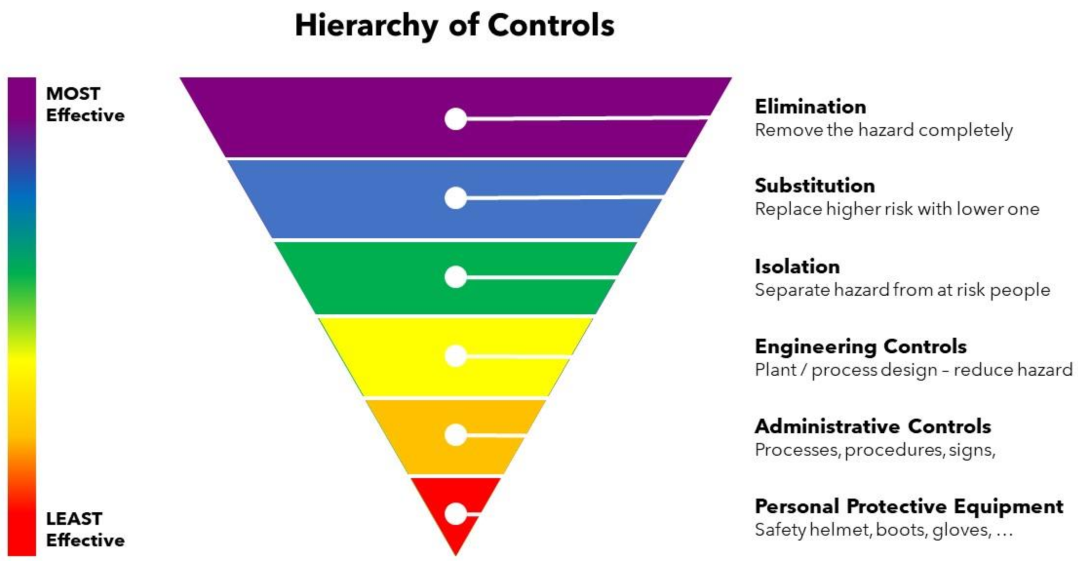


Figure 4-1: Hierarchy of controls

Structured assessments, workshops, and studies as outlined above in the Methodology section provide a framework to ensure knowledgeable participants from a range of technical, construction, and operation disciplines are given the opportunity to review preliminary design and provide their experienced input. With this input, the final project design represents the outcome where the overall risk from all hazards and potential consequences has been appropriately considered and reduced SFARP.

4.5. Process Design Review

The Process Design Review is conducted primarily to ensure that the selected design will meet the business premise, including throughput and cost objectives. It also serves to align stakeholders on the selected design. In addition to meeting the primary objective above, the review process will also highlight any significant potential safety and risks concerns that may be addressed through early design changes where practicable.

Process Design Reviews are performed to:

1 Ensure that the process design meets the functional objective, including production and cost targets.
2 Identify design issues in order to enable resolution of these issues early in the project, ahead of the HAZOP study. A successful Design Review should ensure there are no design changes raised at HAZOP.
3 Ensure that stakeholders are aligned. Involvement of stakeholders to get agreement on the selected design is also important to ensure that no changes are raised late in the project or change process.

The composition of the design review team includes an independent design review leader, project owner and relevant project team members, an experienced operations representative familiar with planned process, process engineer, as well as technical and process safety specialists. The team then follows an established review process where the overall project is reviewed by system by system using a Viva Energy project checklist to ensure consistent methodology is applied for the review.

Recommendations captured during the review are documented and tracked to closure, with each action formally signed as closed following resolution.

4.6. Hazard Identification (HAZID) workshops

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 multidisciplinary 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.

4.6.1. Objectives

A HAZID review is to identify all significant hazards associated with a proposed activity, with a view to eliminating or reducing the hazards through the application of inherent safety at an early stage of the design, thus reducing impacts on cost and schedule.

The objectives of a HAZID review are to:

1 Identify all potential hazardous events and their significance to safe operations;
2 Identify the potential impact/s on personnel, the asset, or the environment;
3 Identify existing safeguards (also termed barriers); and
4 If existing safeguards are considered inadequate, propose actions to undertake further hazard assessment and identify additional risk reduction measures by eliminating hazards, or by putting barriers in place to prevent the realisation of the hazards, or to control or mitigate the effects of the hazards. Safeguards considered but rejected and the basis for rejection, will also be documented.

4.6.2. FEED HAZID studies

The scope of the HAZID studies for the project Front End Engineering Design (FEED) phase primarily focused on the following facilities:

- FSRU Operation Interfaces
- Pier facilities
- Chilled water (FSRU seawater discharge) distribution
- Refinery Interfaces
- Treatment Facility (nitrogen and odorant injection, metering, analyser, pigging, and trim heater)

- Boil-off gas tie-in to refinery fuel gas system

The review of the following facilities and activities was conducted at a broad high-level approach:

- Existing Marine Operations (i.e. berthing, emergency response, vessel movements for bunkering etc.)
- FSRU and LNG carrier vessels
- Construction activities

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, additional HAZID studies will be undertaken as necessary to ensure all risks are identified.

4.6.3. Construction HAZIDs

Should statutory approvals be obtained following the EES process, the project will progress to a Final Investment Decision (FID) and then the construction phase. Construction Contractors will be appointed to construct various components of the project works. The appointed Contractors will 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.

4.7. Hazard and Operability (HAZOP)

The Hazard and Operability (HAZOP) study methodology involves a systematic and structured process which uses a guideword-based approach, as explained below, to prompt brainstorming of potential hazards by a multi-disciplinary team. The scope of review can be broken down into nodes to focus analysis, as required.

The primary objective of the FEED HAZOP review was to identify possible hazards during the design stage, including hazards to health, safety, environment, and quality of both the project design and operation. This ensures that proposed modifications can be appropriately made to the design and/or operating procedures. A secondary objective was to de-risk scope growth in Execute Phase.

The FEED HAZOP is a preliminary HAZOP (conducted with guidance from the Geelong Refinery HAZOP procedure [1]). Another HAZOP will be completed during the Execute Phase of the project. Given this approach, some low hazard systems (e.g. basic utilities such as air, water and sewage) will be deferred to the Execute Phase.

The scope of the preliminary HAZOP included:

- MLAs
- Aboveground pipeline from pier head through to Nerita Gardens
- Nitrogen injection and odorant injection pipeline tie-in points and trim heaters
- Nitrogen injection system (i.e. unloading, storage, pumps, vapourisers and boil-off gas (BOG))
- Odorant storage and injection system
- Custody transfer metering,
- Underground pipeline and Lara City Gate tie-in
- FSRU boil-off gas (BOG) supply to refinery
- Chilled water (FSRU seawater discharge) distribution to refinery

4.7.1. HAZOP Methodology

The detail of the HAZOP methodology followed is consistent with standard industry practice using a standard set of guidewords, which are then considered for sections of the process following an explanation of the design intent and main features of the system. For each guideword the multidisciplinary team (including a qualified independent HAZOP facilitator with knowledgeable Viva Energy operations and technical employees, specialist consultants supporting the process design and experienced with LNG design and operations) will identify causes and potential consequences associated with deviations from normal conditions associated with the guideword. Existing and planned safeguards are identified, and the adequacy of these safeguards discussed. If safeguards are not considered sufficient possible mitigation measures / further actions would be recommended. This process is repeated firstly for all guidewords, and then for all sections (nodes) of the system.

The HAZOP methodology is one of many comprehensive hazard identification tools, however as a tool it is reliant on the skills and knowledge and experience of the multidisciplinary team participants to identify the hazards, causes and potential consequences, so a HAZOP alone cannot provide complete assurance that all hazards (major and minor) will be identified. To ensure the hazard identification process is thorough, the HAZOP is used in conjunction with the other hazard identification processes, as well as subsequent workshops which reconsider the HAZOP findings and will flag any hazards or controls which may have been overlooked.

4.8. Consequence Modelling

The objective behind consequence modelling is to determine the extent (severity, impact distance) resulting from a specific potential incident without consideration of the likelihood (or probability) of that incident occurring. This information can be used to determine whether it is possible for a given event to have an impact on various receptors (people, environment, property).

4.8.1. Fire and Explosion Analysis

The objective of the fire and explosion analysis (FEA) is to identify and assess the impact of accidental releases of hazardous material with the potential to pose major accident risk at the site location. FEA determines the potential impacts associated with release of flammable gas and/or liquid and potential ignition leading to:

- Flash fires;
- Explosion;
- Jet fires; and/or
- Pool fires.

Findings from this FEA study will feed into the Pre Incident Emergency Response Plans (PIPs) at a later stage of the project.

For the project the FEA covers all equipment within the following locations:

- FSRU;

  Note: as FSRU process conditions are higher pressure and temperature than LNG carrier conditions, the FSRU consequences also cover the consequences from a similar release from an LNG carrier
- Pier facilities;
- Treatment facility; and
- Pipeline from pier head through to Lara City Gate SWP tie-in point.

This study excludes the following equipment and assessments:

- LNG carriers including unloading operation (FSRU operating conditions considered worst case);
- Geelong Refinery and other (non-FSRU related) Refinery Pier operations;
- Non-normal operating conditions (e.g. process upset, purging, blowby etc.) as these are covered by the maximum pressure shown in Table 4-2 used for all consequence calculations above; and
- Impacts on the FSRU vessel itself are not included in the FEA. It is expected that once the FSRU has been selected, a separate FEA would be provided by the vendor. The process conditions used for Scenarios 1-3 in Table 4-1 were provided by an FSRU vendor.

A description of the release scenarios used in the FEA is provided in Table 4-2.

Table 4-2: Release Scenarios

Scenario	Location	Isolatable Inventory (m^3)	Pressure (kPag)	Temperature (°C)
1	FSRU / LNG carrier LNG liquid pumped up from cargo tanks to suction drum module to regasification booster pump	Unlimited	550	-160
2	FSRU LNG discharge from regasification booster pump	Unlimited	12,340	-152
3	FSRU BOG compressed by cargo room low pressure compressors, through header to BOG cooler in regasification unit	Unlimited	500	0
4	FSRU LNG vapour from regasification heaters to MLA	Unlimited	10,210	0
5	LNG vapour from MLA to pier pipework	690	10,210	0
6	Pier pipework to pipe trench to the north of Road 16	690	10,210	0
7	Treatment facility gas pipework, pig receiver, pig launcher & gas metering	690	10,210	0
8	Buried pipeline	1,331	10,210	11
9	Pig receiver at SWP tie-in	1,331	10,210	11
10	Odorant storage & pipework	24	10,210	2

4.8.2. Nitrogen Release Modelling

The objective for modelling the nitrogen release is to determine the potential consequences associated with a release for onsite and offsite impacts, including on site evacuation and mustering.

In addition to a potential leak leading to a release of nitrogen, a cold vent will also be provided in the system to allow for a controlled release of nitrogen from the facility equipment.

The scope of work will be limited to the nitrogen unloading, storage and vapourisation facilities including:

- LIN tanker unloading gantry
- LIN storage vessels
- High Pressure (HP) LIN pumps
- Nitrogen air vapourisers
- Nitrogen trim heater and boil-off heaters and
- Nitrogen boil-off compressor package

Additionally, the minimum safety distances requirement of for LIN storage with other areas of the facility against the guidelines of European Industrial Gases Association (IEGA) Doc 224/20 has been considered.

4.8.3. Vent Dispersion and Radiation Study

The objective is to determine the thermal radiation and gas dispersion from atmospheric vents associated with the project located at the new pier head and the treatment facility. The study deliverables are as follows:

- Extent of flammable gas dispersion from unignited vents to support hazardous area classification and ignition control; and
- Extent of thermal radiation impacts from vents (if ignited) to specify vent height and location requirements.

Information regarding gas dispersion and thermal radiation modelling for the cold vents located on the FSRU and/or any existing vents within Lara City Gate SWP tie-in facilities are to be supplied by the FSRU vendor and APA, respectively. Additionally, the study excludes any vents within existing facilities not in scope of the project.

4.8.4. Fire Safety Studies (Pier and Refinery Addendum)

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 project.

A preliminary fire safety study has been completed for the pier extension and for the Geelong Refinery (which would supply some of the required firewater through existing firewater systems on Refinery Pier). The fire safety study will be updated as required consistent with project design developments and in consultation with the Country Fire Authority and Fire Rescue Victoria.

4.8.5. Hazardous Area Classification Report

Hazardous area classifications have been determined in accordance with AS/AZS 60079.10.1. The Model Code of Safe Practice, EI15 (previously known as IP15) was applied only in situations which were inadequately covered by the Australian Standard.

Classifications were determined with reference to Annex ZA (Examples of hazardous area classification) in the Australian Standard, whilst noting that Annex ZB (Generalised Method) in the Australian Standard was not applied.

Where applicable at the APA operated Lara City Gate Tie In facility hazard area classification will need to be re-classified in accordance with APA standards and procedures.

4.9. Quantitative Risk Assessment (QRA)

The use of QRA enables consistent and systematic calculation of the risks from hazardous events. It involves predicting the severity of consequences associated with a hazard, the frequency (or likelihood) at which a potential Major Incident (MI) may be expected to occur and the distribution of onsite personnel. Quantitative approaches allow for a more precise and consistent approach to defining the likelihood, consequence and resultant severity of a major incident – typically the risk of fatality. It is recognised by regulators across jurisdictions that the results from a QRA may be used with 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. Whilst these types of assessments are typically 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, the QRA results can be used in assessing the benefit of a range of risk reduction options to minimise risk SFAIRP. These types of assessments are undertaken early in the design to determine whether the development can occur in the proposed location.

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. 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.

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.

Quantitative Risk Assessments (QRAs) have been completed for the FSRU, the above and below ground sections of the pipeline, the Treatment Plant, as well as to evaluate the risk profile for an LNG carrier.

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.

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.

Given the specificity of the offsite risk to the general population broken down by different land use, the project has used the Hazardous Industry Planning Advisory Paper (HIPAP) 4 “Risk Criteria for Land Use Safety Planning” Table 2 “Individual Fatality Risk Criteria”, which is referenced in Worksafe Victoria’s Guidance Note MHD GN-16. The HIPAP 4 criteria are consistently used in QRA work for land use planning purposes. Worksafe Victoria no longer references the criteria from the “Interim Victorian Risk Criteria – Risk Assessment Guidelines” which were primarily developed for Altona Petrochemical Complex in 1987 and used on an interim basis until the first edition of Worksafe Victoria’s Guidance Note MHD GN-16 “The requirements for demonstration under the Occupational Health and Safety (Major Hazard Facilities) Regulations”.

Recommendations can then be made for risk reduction measures if the resulting risk levels exceed the tolerable risk criteria.

The results from the preliminary QRAs covering the FSRU, pier infrastructure, and Treatment Facility have been combined to provide the cumulative effects from facilities over the project area against the QRA risk criteria for the project, i.e. the recommendations and guidance within HIPAP 4.

4.9.1. Major incident (MI) events

The MIs identified and included in the QRA study include the loss of containment (LOC) scenarios 1-10 located as shown in Table 4-1 and listed below, plus other accidental LOC scenarios from the LNG carrier:

- LNG carrier / LNG Cargo Tank Puncture from collision with transiting or moored ship, or grounding
- FSRU / LNG carrier LNG liquid pumped up from cargo tanks to suction drum module to regasification booster pump
- FSRU LNG discharge from regasification booster pump
- FSRU BOG compressed by cargo room low pressure compressors, through header to BOG cooler in regasification unit
- FSRU LNG vapour from regasification heaters to MLA
- LNG vapour from MLA to pier pipework
- Pier pipework to pipe trench to the north of Road 16
- Treatment facility gas pipework, pig receiver, pig launcher & gas metering
- Buried pipeline
- Pig receiver at SWP tie-in point
- Odorant storage & pipework

Acknowledging the potential public safety impact as well as workforce safety and property damage consequences from an LNG release from the LNG carrier transiting past residential areas, the project has considered both the potential impact from an accidental release using accepted QRA methodology, and additionally considered international research on the potential consequences from a large LNG spill to water. Whilst acknowledging the large potential impact distances reported in international research (e.g. Sandia Laboratory Reports [2004, 2008] and US Department of Energy Report to Congress [2012]) these studies reinforce the need to consider specific local factors to determine the credibility of such events happening. Likelihood of a large accidental release (due to grounding or ship collision) is $<5\times10^{-7}$pa using recognised port logistics quantitative methodology. The larger releases referenced in the international reports would require successful adversarial threat of which there is no supporting history during the 60 years of LNG carrier operations globally. Comprehensive security assessments for the Port of Geelong have been, and will continue to be, conducted with the security management plans to ensure a safe and secure operation reviewed and approved federally. Security management includes enhancing countermeasures based on changing threat levels. The adversarial threats are considered to be extremely remote, and have not been incorporated directly into the project QRA (due to lack of a supportable basis to assign a probability to the event occurring).

4.9.2. QRA Model inputs and thresholds

The project specific input for modelling uses both location and project specific information, as well as a set of recognized and standardised industry failure frequency data for hydrocarbon process equipment. These parameters and data assumptions used in the model are key to the risk results.

Project specific inputs include:

- Release source and conditions *(phase, temperature, pressure, elevation, orientation and duration)*
- Environmental conditions *(atmospheric stability, wind speed and direction, ambient air and water temperature)*
- Elevation and location for project facilities

- Parts count *(taken from preliminary process drawings)*
- Traffic movement in relation to facilities *(volume, speed, direction)*
- LNG carrier movements and proximity to shore land users

Other model inputs that rely on suitable adoption of industry frequency data and thresholds for the project are:

- Leak size distribution *(based on UK Health and Safety Executive Offshore Hydrocarbon Release and Population Data)*
- Ignition probability *(based on United Kingdom Offshore Operators Association IP Models, recognising surrounding land use, location specific sources, immediate / delayed)*
- Impairment criteria *(Hazardous Industry Planning Advisory Paper [HIPAP] No 4, TNO Green Book)*

The meteorological data, ignition data and population data assumptions used in the model are critical to the risk results.

Inputs to the model included:

- release conditions (e.g. phase, temperature, pressure, leak size distribution and duration)
- release source characteristics (e.g. elevation, orientation)
- physical properties of the released material (e.g. heat of vaporisation)
- ignition probabilities (e.g. surrounding land use, specific location sources, immediate / delayed)
- atmospheric conditions (e.g. wind speed, atmospheric stability).

4.9.3. Consequence assessment

Risk modelling software, DNV SAFETI version 8.4 was used to carry out the QRA and model the identified consequences from releases of hazardous inventories by using a wide range of models for discharge and dispersion as well as toxic, flammable, heat radiation and explosion overpressure effects. Following the consequence analysis to determine the effect zones, the software is used to model complex probabilistic risk analysis including weather conditions, operational conditions, ignition probabilities etc.

The hazard consequences listed below were identified during the HAZID process and have been modelled:

- heat radiation from jet fires
- heat radiation from pool fires
- heat radiation from flash fires
- overpressures from vapour cloud explosions.
- toxic exposure from odorant dispersion

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: 100% Lower Flammable Limit (LFL)
- Thermal radiation: 35, 23, 12.6, 6.31, 4.7, 3.0, kW/m^2
- Overpressure: 70, 35, 21, 14, 7, 3.5 kPa

Due to a lack of published odorant concentrations for human health impacts, the following concentrations were calculated using the composition information and available animal toxicity data. The determination followed the process for calculating Probit Constants from the TNO Green Book, which resulted in the following fatality probabilities for a 30 minute exposure.

Table 4-3: Fatality probability used for toxic odorant exposure

Concentration (ppm)	Fatality Probability
5,450	0.1%
8,000	1%

Concentration (ppm)	Fatality Probability
13,500	10%
25,600	50%
58,100	95%

4.9.4. 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.

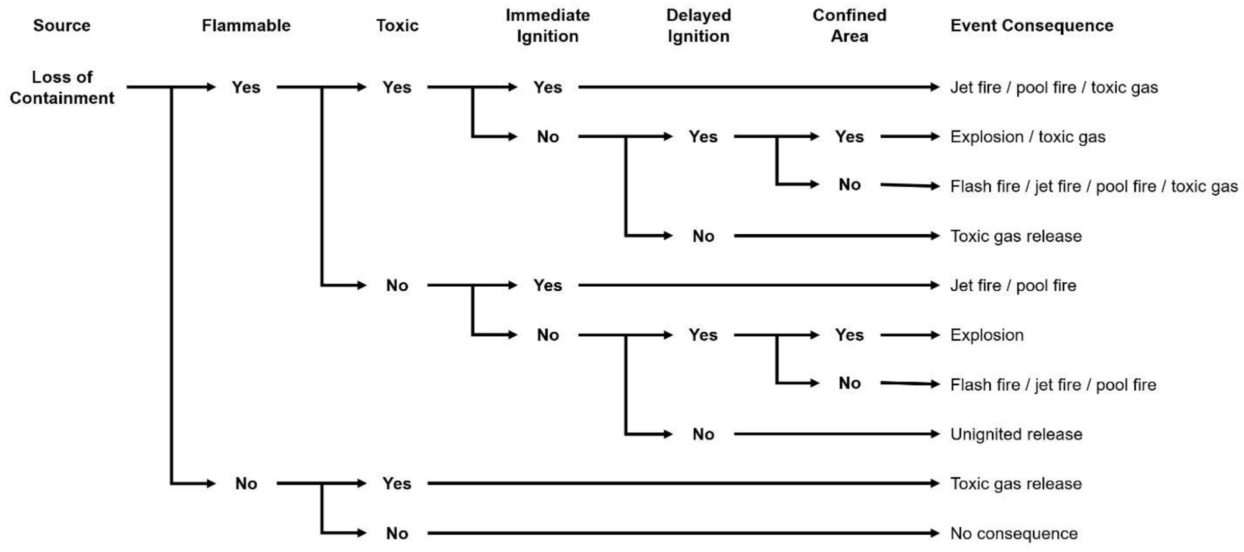


Figure 4-2: QRA event tree modelling framework

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).

4.9.5. 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 Location Specific Individual Risk for fatality.

4.9.6. Risk criteria

The risk criteria adopted by the project for use in the Quantitative Risk Assessments have been adopted from HIPAP #4 (see Table 4-4). 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 measurement used in determining the risk criteria are “probability of fatality per annum”, and “individual fatality risk”.

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.

4.9.6.1. 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 well as toxic exposure from odorant.

A key focus of the location specific individual risk (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 whether the level of risk is or isn’t tolerable.

Table 4-4 Location specific fatality risk tolerability criteria adopted for the project (per HIPAP 4)

Land Use	Probability of Fatality	Probability of Fatality (per year)
Hospitals, schools, child-care facilities, old age housing	Once in 2,000,000 years	5×10^{-7}
Residential, hotels, motels, tourist resorts	Once in 1,000,000 years	1×10^{-6}
Commercial developments, retail centres, offices, entertainment spaces	Once in 200,000 years	5×10^{-6}
Sporting complexes and active open spaces	Once in 100,000 years	1×10^{-5}
Industrial	Once in 20,000 years	5×10^{-5}

4.9.6.2. 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.

Table 4-5 Individual injury risk criteria adopted for the project (per HIPAP 4)

Personal Injury / Impairment	Threshold	Maximum Acceptable Frequency (per year)	Land use area(s)
Thermal Radiation	$\leq 4.7 kW/m^2$	5×10^{-5}	Residential / sensitive use
Overpressure	$\leq 7 kPa$	5×10^{-5}	Residential / sensitive use

Personal Injury / Impairment	Threshold	Maximum Acceptable Frequency (per year)	Land use area(s)
Toxic concentration to not cause irritation (eyes / throat) or acute physiological response to sensitive community members	No toxic threshold of odorant (or components) *	5×10^{-5}	Residential / sensitive use
Toxic concentration to not cause serious injury after short exposure to sensitive community members	No toxic threshold of odorant (or components)	1×10^{-5}	Residential / sensitive use

* *Injury criteria for toxic exposure unable to be assessed*.

Heat radiation 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 highlighted 4.7kW/m^2 radiation level is the threshold value referred to by HIPAP #4 for the individual injury risk criteria in Table 4-6 below.

Table 4-6 Effects of thermal radiation

Radiation (kW/m^2)	Effect
2.1	Minimum to cause pain after 1 minute
3.0	Criterion to determine approach distances for fire response team. Radiant heat threshold for operators and/or first intervention team dressed in "standard" inherently fire resisting PPE (e.g. coveralls).
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds of exposure (at least second degree burns will occur)
12.6	Significant chance of fatality for extended exposure. High chance of injury. Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
23	Likely fatality for extended exposure and chance of fatality for instantaneous exposure. Spontaneous ignition of wood after long exposure Unprotected steel will reach thermal stress temperatures which can cause failure Pressure vessel needs to be relieved or failure would occur
35	Cellulosic material will pilot ignite within one minute's exposure Significant chance of immediate fatality for people exposed

Overpressure 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 a 7kPa threshold (highlighted in Table 4-7) has been adopted by the project.

Table 4-7 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

4.9.7. 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:

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

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

4.10. Safety Management Study for the pipeline

The approximately 7km long Geelong Gas Terminal Pipeline will be a licensed pipeline and shall meet the requirements of AS 2885.6.

The key hazard and risk process detailed in AS 2885.6 is the Safety Management Study (SMS) which ensures the following objectives are met:

- All threats to the integrity of the pipeline system are identified,
- Multiple independent controls are identified for each threat to the pipeline integrity
- Threats not considered to be fully controlled are subjected to risk assessment, with residual risk shown to be reduce to a level that is As Low As Reasonably Practicable (ALARP).

A requirement of the process is that the SMS be validated in a properly constituted workshop, that shall review each aspect of the SMS.

Consistent with AS2885.6 part 1.5.2 (Safety management studies), the process safety of the pipeline system is to be assessed through a hazard and operability study (HAZOP) per section 4.6 above. Non-process threats were separately validated in a separately convened workshop consistent with the safety management process in accordance with the standard.

Additionally the SMS covered:

- Basic Pipeline Design Parameters (e.g. wall thickness, depth of cover)
- The energy release rate and the contour radius for a radiation intensity of 4.7 kW/m^2 and 12.6 kW/m^2 in the event of a full-bore rupture.
- Location-specific Threats, in high consequence locations
- Verification of allocated Location Classes, in particular High Consequence Location Classes for allocation of No-Rupture Pipe Type
- Pipeline Isolation Valve spacing and automation requirement established.
- Minimum offset to adjacent pipelines

4.11. 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 was conducted to determine whether the current preliminary design is SFAIRP, or whether more can be done to reduce risk. This workshop took the format of questioning the design and each potential MI event and brainstorming if further controls can be identified.

The definition set out by the Court of Appeal (in its judgement in Edwards versus National Coal Board, 1949) is as follows:

> *"Reasonably practicable is a narrower term than 'physically possible' and implies that a computation must be made... in which the quantum of risk is placed in one scale and the sacrifice involved in the measures necessary for averting the risk (whether in time, trouble or money) is placed in the other and that, if it be shown that there is a great disproportion between them – the risk being insignificant in relation to the sacrifice – the person upon whom the obligation is imposed discharges the onus which is upon him."*

Per the OHS Act, in determining what is reasonably practicable in relation to ensuring health and safety, regard must be had for the following matters:

- The likelihood of the hazard or risk concerned eventuating.
- The degree of harm that would result if the hazard or risk eventuated.

- What the person concerned knows, or ought reasonably to know, about the hazard or risk, and ways of eliminating or reducing the hazard or risk.
- The availability and suitability of ways to eliminate or reduce the hazard or risk.
- The resources required (e.g. cost) of eliminating or reducing the hazard or risk.

Review Methodology

During the SFAIRP workshop, each potential MI was reviewed, and additional controls for consideration nominated. For each control the following questions were addressed by the project team:

- Is the control a standard / common way of controlling the hazard?
- Is there a demonstrable risk reduction associated with the control?
- Are there risk trade-offs / new risks introduced associated with the control measure?
- Are operations supportive of the proposed measure?
- Is the cost likely to be grossly disproportionate to the benefit gained?

In some instances the above considerations were sufficient for the project to move ahead with an agreement regarding implementation. In others, the SFAIRP workshop could serve to narrow the options available for consideration, with additional analysis required to provide a definitive outcome. Typically this relates to more detailed analysis of likely risk reduction, and cost of implementation.

4.12. Other Studies

4.12.1. Safety Integrity Level (SIL) studies

The main objective of a Safety Integrity Level (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.

SIL Assignment workshops are to be undertaken to assess the requirements for instrumented protective functions for the operation of the pier infrastructure, treatment facility and Geelong Gas Terminal Pipeline. The outcomes from the SIL assessment will be included in the detailed 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.

4.12.2. Marine vessel simulation studies

Vessel simulation analysis was utilised to determine the layout and appropriate spacing configuration of the new berth at Refinery Pier No. 5 relative to the existing Refinery Pier berths. This analysis considered:

- Vessel dimensions (particularly width)
- Fendering distance(s)
- Allowances for tug operations
  - Operation zone
  - Tow line allowances
- Existing facilities operations and maximum vessel size using existing berth(s)
- Hazardous area separation distance from vessels
- Specific considerations that may apply during vessel arrival or departure

A review of relevant industry (SIGGTO) standards for LNG terminal layout confirmed there is no prescribed separation distance applied to ship movements in the standard, hence it is determined through simulation studies.

The results from these analyses provide the minimum separation distance(s) input to the design process for the berth layout and configuration to allow for vessel movements.

4.13. Forward safety, hazard, and risk assessment activity

With only front-end engineering design complete and the specific FSRU vessel not yet finalised, there will be ongoing work to ensure the safety, hazard, and risk assessments remain current as the project moves into detailed design.

The HAZOP, QRA, and SFARP assessments and workshops will be revisited and updated to incorporate detailed design where that results in changes to the front end engineering design.

Consistent with the regulatory obligations for both an MHF safety case (FSRU) and gas safety case (pipeline and treatment facility), a full review of the requirements will be completed, and a formal safety (and property) assessment plan will be developed.

4.13.1. FSRU – MHF Safety Case

Whilst no formal commercial agreement is in place with the FSRU service provider, requests for relevant safety, hazard and risk assessments have been made. The initial material provided has included a HAZID and HAZOP report which has not highlighted any discrepancies from earlier assessments.

The MHF regulations require that appropriate safety, hazard, and risk assessments are conducted specific to the vessel that will be operating, and that there will be appropriate engagement with operations employees in the following areas:

- Identification of major incident hazards and possible major incidents
- Adoption and/or review of risk control measures
- Conduct and documentation of the safety assessment
- Establishment and/or implementation of a safety management system

The safety assessment will comprehensively and systematically identify all potential major incidents, and the hazards that may lead to those major incidents. The risks captured will address both the severity of consequences on-site and off-site and the probability associated with those consequences, including the cumulative consideration of hazards and incidents. As part of the safety assessment, existing and proposed risk control measures will be documented, and through consideration of the control measures both adopted and rejected, will be used to demonstrate that the risk of major incidents and associated hazards has been reduced so far as is reasonably practicable (SFAIRP). As a minimum, the following studies / workshops will conducted for the FSRU:

- Hazard Identification (HAZID)
- Hazard and Operability study (HAZOP)
- Consequence modelling – Fire and Explosion Analysis (FEA)

- Layers of Protection Analysis (LOPA) / Safety Integrity Level assessment (SIL)

Contents and details of the FSRU service provider's safety management system will be reviewed once available to ensure all aspects are consistent with safety case expectations.

4.13.2. Pipeline and treatment facility – Gas Safety Case

The Gas Safety (Safety Case) Regulations require that appropriate formal safety, hazard, and risk assessments are conducted for the licensed pipeline and associated treatment facility:

- Identification of hazards with the potential to cause a gas incident
- Adoption and/or review of risk control measures
- Conduct and documentation of the safety assessment
- Establishment and/or implementation of a safety management system, including
  - Processes (and facilities) to ensure safety, reliability and quality of gas
  - Suitable permit to work process, clarifying all work covered
  - Personnel competency and training to ensure minimum levels of qualifications and skills necessary for carrying out work
  - Emergency response preparedness to cover all foreseeable emergencies and gas incidents
  - Incident reporting and investigation
  - Internal monitoring, auditing and reviewing of performance indicators to ensure effective implementation of the safety management system

The formal safety assessment will utilise the existing safety, hazard and risk assessments conducted for the project, including any updates and revisions as detailed design, construction and commissioning progresses. The risks captured will address both the consequences on-site and off-site (to the public) and the probability associated with those consequences, including the cumulative consideration of hazards and incidents given the proximity to an existing Major Hazard Facility. As part of the safety assessment, existing and proposed risk control measures will be documented, and through consideration of the control measures both adopted and rejected, will be used to demonstrate that the risk of major incidents and associated hazards has been reduced as far as practicable (AFAP).

4.13.3. Marine Operations – LNGC Transit

Completion of a marine operations risk assessment for LNGC entry into Port Phillip Bay, transit through the port waters of the Port of Melbourne into Port of Geelong, and berthing and de-berthing at Refinery Pier, and departure will occur in early 2022. Relevant stakeholders, including; Ports Victoria, pilotage providers, Fire Rescue Victoria, Hoegh (FSRU and LNGC operator), GeelongPort and tug providers will continue to be consulted and engaged to ensure thorough consideration of all risks.

Findings and any associated actions arising from the risk assessment will be addressed by the relevant stakeholders to ensure the safe and secure transit of LNGCs to / from Refinery Pier.

5. 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 hazards relevant to each element of the project are identified further in Sections 6.0, 7.0, 8.0 and 9.0.

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 liquefied natural gas (LNG), natural gas (NG); propane (heat transfer medium), odorant (stanching agent) and liquid nitrogen (LIN). The dangerous goods 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 flammable materials are discussed under each of the respective project elements.

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

Table 5-1 Dangerous Goods introduced by project

Material	DG Class	HAZCHEM Code	Hazard	Location	Estimated Quantity
LNG (Liquefied Natural Gas)	2.1	2WE	Flammable Cryogenic	FSRU Storage	170,000 m^3
NG (Natural Gas)	2.1	2SE	Flammable	Pier Infrastructure Pipeline Treatment Facility (Nerita Gardens)	1,400 m^3
Propane	2.1	2YE	Flammable	FSRU Process	~50 m^3
Acetylene *	2.1	2SE	Flammable	FSRU Workshops	0.16 m^3 (4×40ℓ cylinders)
Oxygen *	2.2 5.1	2S	Oxidising gas	FSRU Workshops	0.32 m^3 (8×40ℓ cylinders)
Paint Thinner *	3	3YE	Flammable	FSRU Stores	~0.5 m^3
Odorant	3	3WE	Flammable Toxic exposure	Treatment Facility (Nerita Gardens)	5 m^3

Material	DG Class	HAZCHEM Code	Hazard	Location	Estimated Quantity
LIN (Liquid Nitrogen)	2.2	2T	Asphyxiant Cryogenic	Treatment Facility (Nerita Gardens)	~1,500 m^3 (1,200 tonnes)

* *Material present in isolated quantity <2% of individual Schedule 14 threshold quantity.*

The operational hazards and risks and the safe handling and storage practices associated with both liquefied 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.
- toxic release

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 -162°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 liquefied gases and electrical risks from contact with exposed live conductors.

5.1.2. Fire and explosion risks

A release of liquefied 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 to be injected into the pipeline at the treatment facility is anticipated to consist of 67-73% tetrahydrothiophene (CAS No. 110-01-0) and 27-33% tertiary-butyl mercaptan (CAS No. 75-66-1).

5.1.2.1. 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/NZS 2885.6, 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.

5.1.2.2. 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.

5.1.2.3. 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) – 50% probability fatality.

5.1.2.4. Rapid Phase Transition

When a cryogen such as LNG mixes with another liquid with a large temperature difference it will result in the violent boiling of the cryogen. This may cause a physical explosion known as rapid phase transition (RPT) caused by the vapour occupying 200-600 times as much space as the liquid. The risk of its occurrence is difficult to estimate given the interplay between multiple physical phenomena.

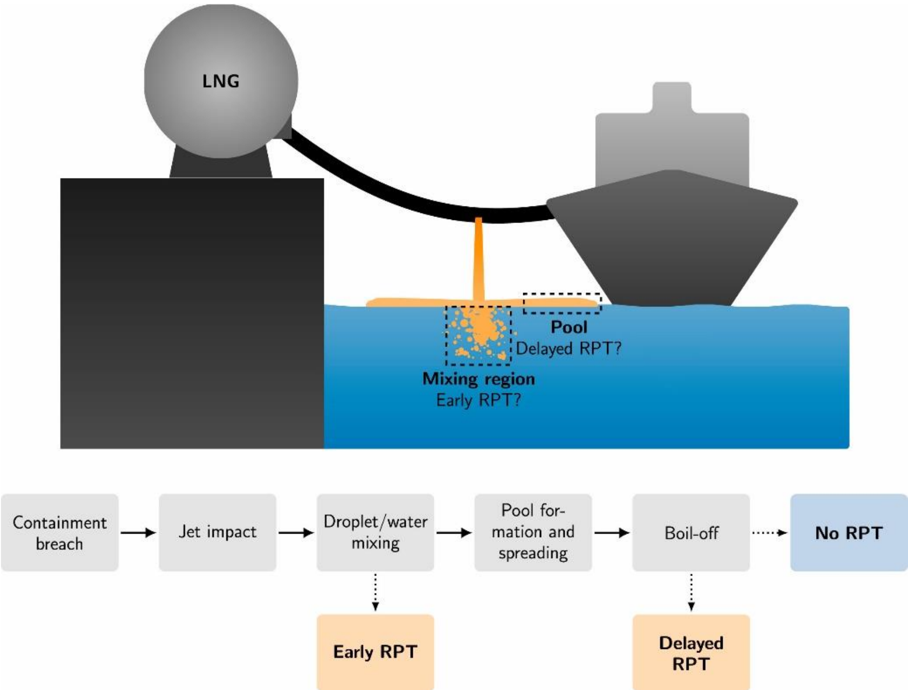


Figure 5-1: Illustration of an accidental spill event during loading or unloading of LNG

RPT can occur early typically at the spill point where the momentum of the spill forces the mixing of the two liquids which is likely to cause overpressure in the water which will quickly dissipate, although can result in localised damage near the spill point.

When the LNG pools on sea water, the LNG typically undergoes film boiling, which is characterised by a vapour layer between the LNG and water limiting the heat transfer to support evaporation only. A collapse of the film boiling quasi-equilibrium state can occur triggering a sudden increase in the heat transfer rate by orders of magnitude causing the LNG to superheat and rapidly evaporate. Aside from the impact of waves on the water surface (which may cause small localised RPTs), the changing composition of the LNG on the water due to evaporation of the methane may result in the Leidenfrost temperature of the LNG spill reaching the water temperature and the film boiling state to collapse.

5.1.2.5. Toxic release

A loss of containment from the odorant system, or during the delivery and exchange of the 2.5m^3 containers would result in a release of a low toxicity vapour which is detectable as an unpleasant odour at a concentration of 1ppb (part per billion). The odorant is classified as a Category 4 toxic substance under the Global Harmonised System and can cause headaches and nausea at low concentrations. It is also noted as both a reversible eye and respiratory tract irritant.

Toxicity impairment information (STEL, IDLH, etc) for the odorant and its two primary components of tert-butyl mercaptan and tetrahydrothiophene were not published / available, so estimates for fatality probit thresholds were estimated from animal toxicity data using established methods.

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.

The risk from contact with live exposed electrical conductors during operation of the pier infrastructure, pipeline and treatment facility would be managed through compliance to the requirements from Energy Safe Victoria under the *Electrical Safety Act 1998 (Vic).*

The design, installation and operation of the pier infrastructure, Treatment Facility and the Geelong Gas Terminal Pipeline will be in accordance with *Electrical Safety Act 1998 (Vic)*, the Electrical Safety (General) Regulations 2019 and AS/NZS3000 Wiring rules.

The FSRU would not fall under the purview of the *Electrical Safety Act 1998 (Vic).* 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.

Both LNG and LIN are cryogens. The risk of cryogenic burns and asphyxiation from large releases has been assessed as part of the HAZID studies 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 LIN at the Treatment Facility would meet the requirements under the Dangerous Goods Act (Storage and Handling) Regulations 2012, with inclusion in the Dangerous Goods manifest, and addressed as part of the emergency response plan. The key hazards associated with cryogens are listed below.

5.1.4.1. 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.

5.1.4.2. 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 Treatment Facility.

Both nitrogen and natural gas can act as an asphyxiant by displacing oxygen in air to levels below that required to support life. Inhalation of either gas 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.

5.1.4.3. Mitigation Measures

Personnel would be competency based trained to ensure understanding and familiarity with the properties and safety considerations of LIN before being allowed to handle LIN and/or its associated equipment.

Handling of LIN would only be carried out by suitable competent personnel wearing appropriate PPE 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 LIN containers.

The LNG is stored and regasified on board the FSRU and there is no handling of LNG to the extent there is for LIN.   Personnel on board the FSRU would be thoroughly familiar with the properties and safety considerations as well as the regasification process and associated process safeguards for the operation. Emergency response procedures will be available, and in the event of a release, personnel will wear appropriate PPE to deal with the incident.

Gas detection with local alarm will provide personnel working in areas with cryogens early warning to leave the area to an upwind location.

- Oxygen analysers will be installed at the LIN facility
- Hydrocarbon / gas detectors on Refinery Pier

5.2. Construction hazards

Viva Energy's 'Commitment to Health, Safety, Security and Environment (HSSE)' provides for "pursuing the goal of no harm to people and protecting the environment" by "ensur[ing] that our business plans consider associated HSSE risks including potential impact". The HSSE governance processes include a qualitative analysis of construction contractors' performance capabilities which includes evaluation of the contractor's safe systems of work to manage risk.

As part of contract requirements, HSSE performance expectations are set with contractors, including requirements to undertake HSSE 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 construction phase of the pipeline will be managed under a Construction Safety Management Plan (SMP) to ensure a structured safety management system is implemented to achieve a consistently high standard of safety performance. This CSMP is a requirement of the *Pipelines Act 2005 (Vic)* and addresses Viva Energy's general duty, as pipeline licensee, to minimise the risks to public safety that arise from pipeline construction.

5.2.1. Identified 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. These include, but are not 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
  - construction barge and other vessel movements in the vicinity of Refinery Pier
  - modified road access and crossings
  - noise and dust
- Workforce safety:
  - working in the vicinity of moving equipment and vehicles
  - construction barge and other vessel movements in the vicinity of Refinery Pier

- working at heights
- falling objects from elevated workers or crane assisted lifts
- exposure to electrical hazards
- excavation hazards
- hazards associated with horizontal directional drilling
- hazards associated with welding activities, such as fumes
- noise and dust
- confined spaces
- working overwater during pier extension and infrastructure, and pipeline construction.

5.2.2. Mitigation Measures

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

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 H: *Air quality impact assessment*) and noise (EES Technical Report I: *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 Geelong and other nearby towns. They may travel independently, share vehicles or be transported via bus where possible.

The pipeline construction work 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 would be stockpiled at nominated locations to be finalised as part of the Construction Management Plan. If required, Viva Energy 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.

The pipeline and its construction would be subject to regulation by DELWP and ESV. Other construction activity would be regulated by WSV.

6. Floating Storage and Regasification Unit (FSRU)

6.1. Overview

This section specifically covers the floating storage and regasification unit (FSRU) component of the project. Key aspects of the FSRU are:

- The FSRU is a registered sea-going vessel that includes cryogenic storage tanks and a topside regasification processing unit that is used for LNG vaporisation and gas export.
- The vessel will be assigned a class notation by DNV GL (or equivalent Classification Agency) 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 Treatment Facility via a ship manifold; MLAs and an approximately 2.5 km long section of licenced aboveground pipeline.

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 the new Refinery Pier berth 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 MHF safety case would be developed and approved prior to commencement of operation (Refer Section 6.4.1)
- Regulatory oversight would be provided by WSV and AMSA (Refer Section 6.4)
- Safety studies including a preliminary QRA have been carried out relevant to the FSRU (Section 6.5 and Section 4.0)
- The FSRU would be owned and operated by an experienced FSRU operating organisation consistent with the MHF Licence Holder's direction.

The details that are included in this section reflect a typical FSRU (similar in size, capacity, and regasification process to the vessel to be contracted) to provide an understanding of risk profile and to highlight risk controls that are in place for typical FSRU vessels.

As the detailed safety, hazard, and risk documents for the specific FSRU vessel are unavailable, the detailed assessments required both as part of the project safety and risk assessment plan, and to meet regulatory obligations as a future Major Hazard Facility will be reviewed and/or conducted during detailed design and through the safety assessment process. Those will be determined after a review of the existing assessment, and will be documented in the safety case outline for the FSRU.

6.2. Design and operation

The FSRU options proposed would be issued a Class notation (classification) by DNV GL (or equivalent Classification Agency). 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 ultimately selected for the project will have been built and tested under the survey of DNV GL (or equivalent Classification Agency) and would be routinely inspected by DNV GL (or equivalent Classification Agency) 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 (or equivalent Classification Agency) rules and engineering standards. Classification covers both the ship and the topside LNG regasification unit. Any modifications or changes to the vessel would require recertification from DNV GL (or equivalent Classification Agency).

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 and is applicable for the FSRU vessels under consideration. 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.

As an independent and accredited inspection process, the classification society’s inspections, certification and related records (including design basis) will provide relevant information for consideration in the safety assessment and subsequent demonstration of adequacy of the control measures. These records will be used by WSV as part of the initial and ongoing verification of the safety case to confirm risks have been reduced SFAIRP.

Initial Dynamic Mooring Analysis (DMA) and ship simulations have been completed with input from experienced pilots operating in the Port of Geelong. 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 to be managed by the FSRU operator. The FSRU operator has comprehensive and detailed operational procedures 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. Whilst there have been isolated incidents resulting in minor releases / spills, none of the spills resulted from a failure or breach of a containment system. LNG carrier spills have never resulted in loss of life (refer Appendix B: Significant LNG-Related Incidents)

Specific to marine vessels in LNG service, Figure 6-1 below provides a breakdown of shipping incidents (by number of casualties, including both injuries and fatalities) from the OCIMF (under the umbrella of the International Marine Organisation (IMO)) from 1995 to 2021 based on over 20,000 global incidents reported and included in their database. Whilst acknowledging LNG carriers constitute a small proportion of international marine vessel movements, no significant incidents involving release of LNG have been reported.

Note that the number of casualties includes both injuries and fatalities. However there have been no fatalities as a result of an LNG carrier release.

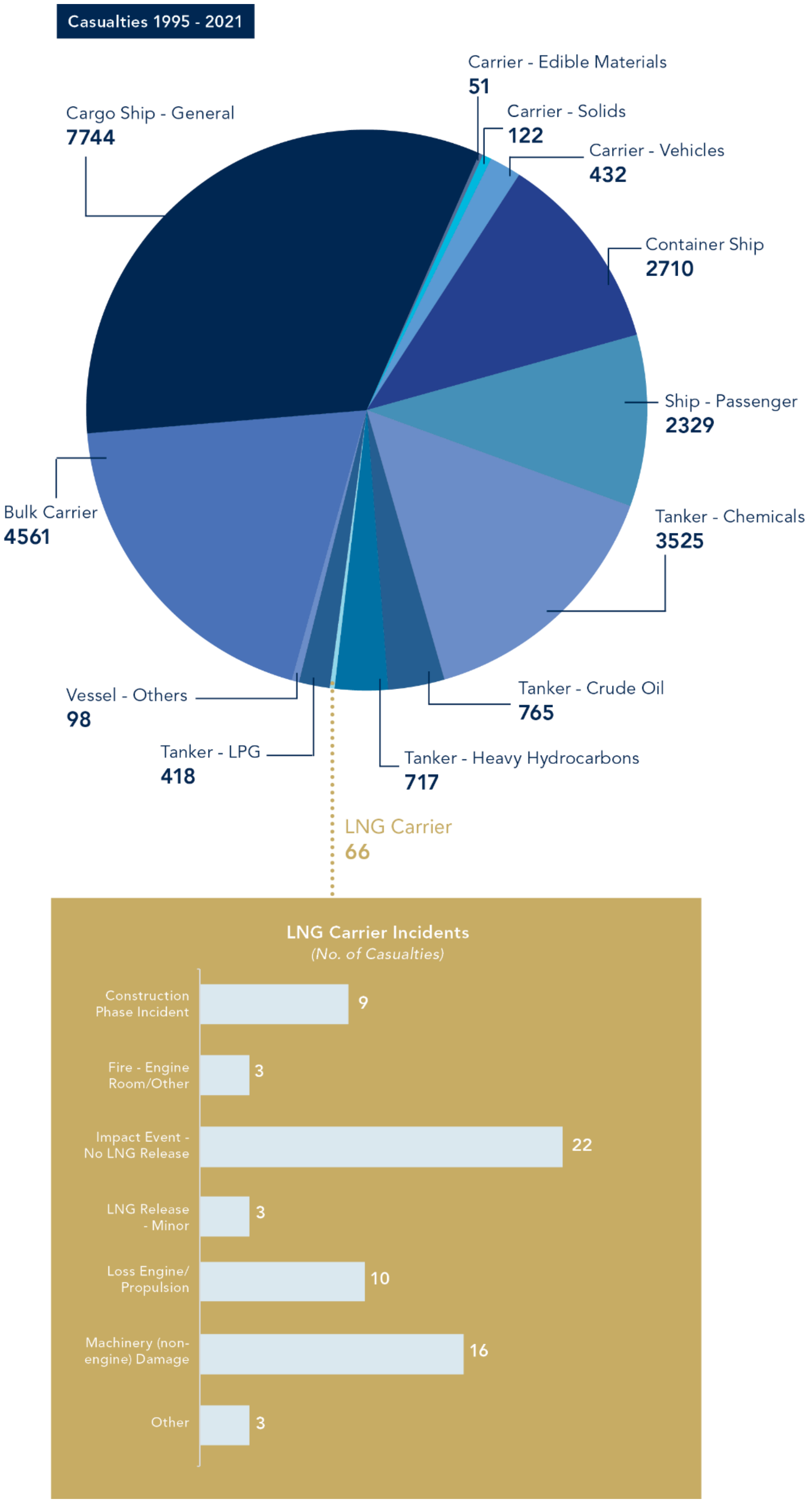


Figure 6-1: Breakdown of marine vessel incidents by number of casualties (1995-2021) OCIMF Incident Database

6.4. Regulatory Framework for FSRU

6.4.1. Overview

The safety requirements that apply to vessels will 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 as it will be a registered Major Hazard Facility (MHF). AMSA would also be involved 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 FSRU will be assessed as an MHF under Section 5.2 of the OHS Regulations 2017 (OHS Regulations), and
- the existing Memorandum of Understanding (MoU) between WSV and Australian Maritime Safety Authority (AMSA) be varied to expressly contemplate regulation of the FSRU

Consistent with the obligation to reduce the risk of a Major Incident so far as is reasonably practicable, the project has undertaken a range of safety studies, assessments and workshops (refer Section 5.0) that have considered a number of operational factors:

- marine operations (approach and mooring) for the FSRU, LNG carrier and other vessels within the port, and
- gas operations at Refinery Pier No. 5 including gas export from the FSRU, MLAs and interaction with Geelong Refinery operations, existing pipelines, and other nearby facilities

Consistent with the requirements as an MHF, following registration the FSRU MHF Licence Holder (Operator) will need to complete:

- a Formal Safety Assessment including hazard identification (which will draw on existing, planned and updated project safety assessments)
- demonstration that the identified Major Incidents have appropriate control measures that the risks reduce so far as is reasonable practicable, including the consideration of property damage
- consideration of the impacts and other factors of nearby and connected MHFs
- appropriate emergency planning in conjunction with emergency services providers, port operator, Greater Geelong City Council, and adjacent facilities (Geelong Refinery, Quantem)
- engagement with the Operator’s workforce
- demonstration that the Safety Management System provides the appropriate oversight of the operation including the monitoring of the control measures effectiveness relative to their performance standards

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)* (‘Navigation Act’) 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 International Safety Management (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.

These regulatory requirements would also apply to the LNG carriers. All vessels visiting Refinery Pier would be subject to Viva Energy's thorough Ship Assessment Vetting Process. This screening is carried out in accordance with the Viva Energy Ship Quality Assurance Standard and includes:

- Meeting the relevant laws, regulations, rules and standards for vessels entering Australian ports
- Having a SIRE (Ship Inspection Report Program) inspection conducted, by independent surveyors that have fulfilled the training and experience requirements of the Oil Company International Marine Forum (OCIMF), within the 6 months preceding the voyage completion date, with zero outstanding high-risk observations. Note: For an LNG carrier, this inspection covers over 300 items including international regulatory compliance and operations as per industry best practice
- Having not had serious Port State Control Inspection deficiencies observed within the preceding 12 months
- Being classed by a member of the International Association of Classification Societies (IACS)
- Holding protection and indemnity (P&I) insurance with a member of the International Group of P&I Clubs, with US$1bn of pollution cover
- Being crewed by qualified officers with minimum experience requirements across the junior and senior deck and engineering officers
- Paying wages not less than those described in the ITF/ILO Minimum Wage Scale 2021.

During the vessel screening, any observation considered to be high risk will be referred back to the vessel's Operator. A vessel will only be accepted for use when Viva Energy is satisfied that the issue has been successfully closed-out, which must be documented in evidence provided by the Operator. It is intended that existing Viva Energy requirements for shipping will be included in any agreements with project partners or 3rd parties who have access to Refinery Pier. These vetting protocols are well established, and Viva Energy has experience over a long period of time in ensuring that shipping associated with its operations are managed in accordance with all company and regulatory requirements.

In the Port of Geelong, there are two private-sector companies that own and manage the land assets of the port. These are GeelongPort and GrainCorp. There is also a statutory corporation, Ports Victoria, which is the port manager for the port waters of Geelong.

Ports Victoria and their appointed 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 continuously 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.

GeelongPort, GrainCorp and Ports Victoria as port managers must have a Safety and Environment Management Plan (SEMP) 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 managers' measures.

A maritime security plan must also be approved by the Aviation and Maritime Security (AMS) Division (Commonwealth Department of Home Affairs) under the *Maritime Transport and Offshore Facilities Security Act 2003 (Cth)*. The maritime security plan for the Port of Geelong was prepared by GeelongPort.

Emergency Management Planning and response plans will also be developed. GeelongPort manages the Port of Geelong Emergency Management Plan and with Ports Victoria are signatories to this plan. 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 Refinery Pier No.5 and in gas producing operation.

GeelongPort has primary responsibility for safety and hazard management at Refinery Pier through the preparation of the SEMP as required by Part 6A of the *Port Management Act 1995 (Vic)* and Safety, Health, Environment and Quality (SHEQ) management system for "whole of port risks". The SEMP and SHEQ management system will ultimately be revised to address operations at the new Refinery Pier berth and associated infrastructure.

Ship safety in port waters of the Port of Melbourne including during passage through the Port Phillip Heads and transit through Port Phillip Bay is the responsibility of the Port of Melbourne Harbour Master. Safety during approach and at berth in the Port of Geelong is the responsibility of the Port of Geelong Harbour Master under *the Marine Safety Act 2010*. A full description of the Harbour Master's responsibilities and functions are contained in Part 6.4 of the *Marine Safety Act 2010*. The Harbour Master's Directions, together with the Port Operating Handbook, provides a set of rules to govern port user activities including navigation of vessels in port.

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 - Maritime Safety
- Aviation and Maritime Security (AMS) Division (Commonwealth Department of Home Affairs)
- WorkSafe Victoria (WSV)
- Ports Victoria (PV)
- Australian Maritime Safety Authority (AMSA).

6.4.4. LNG storage, regasification and handling on the vessels

The FSRU will be classified as a Major Hazard Facility (MHF) under Part 5.2 of the *Occupational Health and Safety Regulations 2017* (OHS Regulations) when in port and will require preparation of a safety case, safety management system and emergency management plan. The MHF Licence once issued will be for the specific FSRU vessel, and is not transferable to another FSRU. Further, the requirements and recommendations for the handling and transport of dangerous goods in port areas (including facilities, berths and operations) are covered by AS 3846-2005. 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.

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 and Schedule 15, which provides a comprehensive and integrated management system for all risk measures adopted under Part 5.2.

The safety management system shall incorporate the structure and processes to ensure the risk control measures are effectively managed to maintain reduced so far as is reasonably practicable. This will address, but is not limited to:

- Organisation structure, staffing levels along with required competencies and training,
- Operational and maintenance procedures and work management instructions
  - Project management processes to ensure effective transition from construction completion through to commissioning, and then to full operation. Engagement of and communication and training to operational workforce
- Management of change

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.

AMSA will also be involved for certain operational activities, including the LNG carriers. In September 2018, WSV and AMSA entered into a 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, Viva Energy 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).

6.4.5. Legislation applicable to maritime activities

The legislation identified as being applicable to safe operation of the FSRU both covering maritime activities and when berthed is detailed in Table 3-1, with a listing below:

- *Navigation Act 2012* (Cth), and Marine Orders 17, 32, 41, and 58
- *Maritime Transport and Offshore Facilities Security Act 2003* (Cth)
- *Occupational Health and Safety (Maritime Industry) Act 1993* (Cth)
- *Protection of the Sea (Civil Liability for Bunker Oil Pollution Damage) Act 2008* (Cth)
- *Port Management Act 1995* (Vic)
- *Marine Safety Act 2010* (Vic)
- *Occupational Health and Safety Act 2004* (Vic), and Occupational Health and Safety Regulations 2017
- *Dangerous Goods Act 1985 (Vic),* and Dangerous Goods Act (Storage and Handling) Regulations 2012

6.4.6. Approval requirements for Licence to Operate

As a new facility which is designed but not constructed, the FSRU operator would apply to WSV for a 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 6-2.

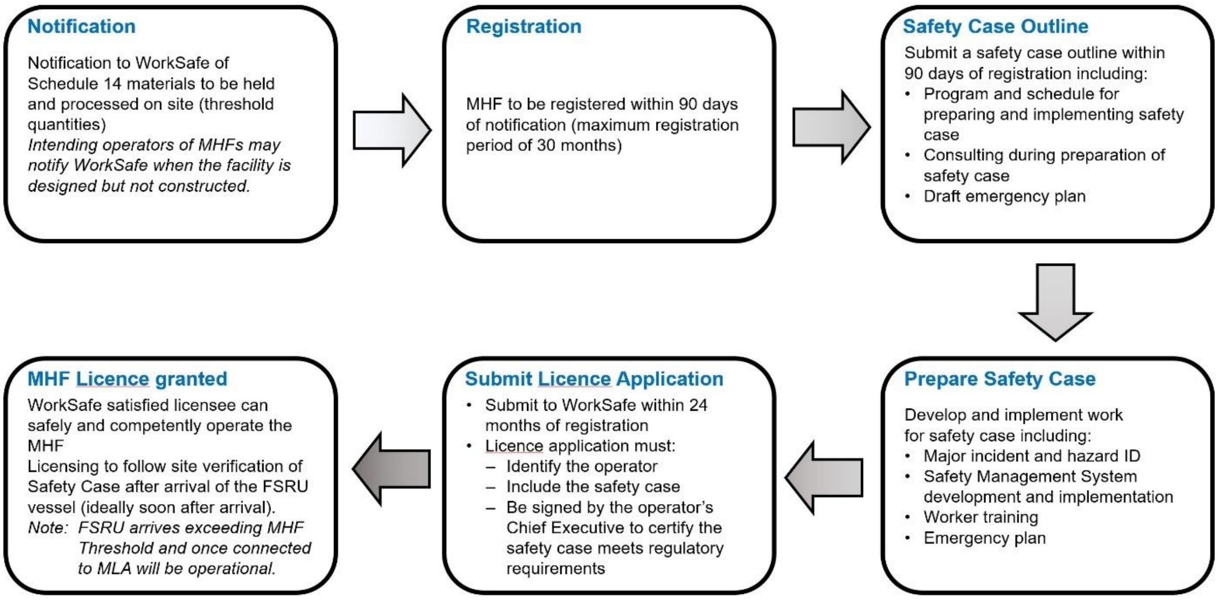


Figure 6-2: Steps to an MHF Licence

When granting a 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.

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

6.5. Studies completed

The FSRU Service Provider has provided a number of safety and risk studies on the design of the FSRU. The assessments were conducted on a sister vessel, the design of which has been shared for four FSRU vessels with the only changes being regeneration gas train capacity. The safety and risk studies form part of the consideration for the requirements on DNV GL (or equivalent Classification Agency) Classification. The following key studies related to the safety, hazard and risk for the FSRU component of the project have been provided for the FSRU berthed at Refinery Pier No. 5:

- Hazard Identification (HAZID)
- Hazard and Operability Study (HAZOP)

Additional studies have been completed for the planned FSRU which take into account the specific location where the FSRU is operating, however clarification is being sought as to whether these can be provided given they were conducted in conjunction with the current lessor of the FSRU. The additional studies include:

- Fire and Explosion Analysis (FEA)
- Quantitative Risk Assessment (QRA).

In order to appropriately consider the safety hazards and risks associated with the leased FSRU, as a minimum, the following studies / workshops will be conducted to confirm or update the existing results using a typical FSRU and to have vessel specific records as required under the legislation for an MHF Safety Case:

- Hazard Identification (HAZID)
- Hazard and Operability study (HAZOP)
- Consequence modelling – Fire and Explosion Analysis (FEA)
- Layers of Protection Analysis (LOPA) / Safety Integrity Level assessment (SIL)

6.6. Hazards 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 A provides a discussion of potential LNG release behaviours and associated risks.

6.6.2. Consequence modelling and impact distances

As highlighted in Section 4.8 Consequence modelling, a number of studies were completed which looked at the potential impact distances for the range of major incident scenarios in Table 4-1. Additionally, reviews were conducted of published research papers in consequences of significant releases of LNG in order to understand the potential impact distances associated with this type of release. In particular, the Sandia Laboratory reports published in 2004 and 2008, along with the US Department of Energy's Report to Congress that summarised the additional work performed by Sandia Laboratory from 2008 through 2011 were reviewed.

Table 6-1 Impact distances from Fire and Explosion Analysis

Scenario	Hole Size (mm)	Maximum Impact Distance (m)		
		Flash Fire (100% LFL)	Jet Fire 4.7kW/m^2	Pool Fire 4.7kW/m^2
1. LNG liquid pumped up from cargo tanks to surface equipment (FSRU) / loading hose (LNG carrier)	5	13	Not Reached	Not Reached
	25	51	66	38
	50	150	129	84
	100	450	237	156
2. FSRU LNG discharge from regasification booster pump	5	Not Reached	15	Not Reached
	25	109	113	88

Scenario	Hole Size (mm)	Maximum Impact Distance (m)		
		Flash Fire (100% LFL)	Jet Fire 4.7kW/m^2	Pool Fire 4.7kW/m^2
	50	284	214	164
	100	528	260	189
3. FSRU BOG compressed by cargo room low pressure compressors, through header to BOG cooler in regasification unit	5	Not Reached	Not Reached	Not Applicable (vapour)
	25	Not Reached	Not Reached	
	50	Not Reached	Not Reached	
	100	Not Reached	50	
4. FSRU LNG vapour from regasification heaters to MLA	5	Not Reached	Not Reached	Not Applicable (vapour)
	25	Not Reached	59	
	50	Not Reached	111	
	100	Not Reached	213	
5. LNG vapour from MLA to pier pipework	5	3	16	Not Applicable (vapour)
	25	169	65	
	50	477	121	
	100	1076	234	
6. Pier pipework to pipe trench to the north of Road 16	5	51	16	Not Applicable (vapour)
	25	232	65	
	50	443	121	
	100	793	234	
7. Treatment Facility gas pipework, pig receiver, pig launcher & gas metering	5	51	16	Not Applicable (vapour)
	25	225	65	
	50	415	121	
	100	691	224	
8. Buried pipeline	5	3	15	Not Applicable (vapour)
	25	3	60	
	50	3	113	
	100	4	213	
9. Pig receiver at SWP tie-in	5	45	16	Not Applicable (vapour)
	25	245	65	
	50	493	121	
	100	897	234	
10. Odorant storage & pipework	5	15	30	23
	25	114	127	57

Six confined domains (five on / around the FSRU) were assessed for vapour cloud explosion overpressure, with the largest impact distance being 210 metres for an overpressure of 7kPa (threshold for residential / sensitive land use) which does not reach the shoreline.

The QRA considered accidental release of LNG due to credible collision and grounding scenarios whilst in the port area based on work done for the Barcelona port and presented in a paper "*A Quantitative Analysis Approach to Port Hydrocarbon Logistics*" published in the Journal of Hazardous Materials in

January 2006. Two credible spill sizes were modelled – $32m^3$ released in 30 minutes (minor) and $126m^3$ released in 30 minutes (large).

The consequences of more significant breaches were considered in the original Sandia Report (2004) and subsequent reports with hole sizes ranging from 1-2 m^2 (accidental breaches) to 5-12m^2 (intentional breaches) with a total spill volume of 12,500m^3 of LNG. The consideration of potential incidents for LNG carriers followed the incidents surrounding 11 September 2001 in the United States with recommendations made within the context of credible threats under the US security environment.

Whilst the report considers the potential consequences associated with accidental collision and grounding, the report also acknowledges the excellent safety record "without major accidents or safety problems, either in port or on the high seas" of the LNG carrier operations.

For accidental breaches, the conclusions that can be drawn from the report are summarised as follows:

- Credible breaching scenario arises from a collision with a large vessel moving at high speed
- Breaching of the hull and cargo tank will likely provide a breach area for LNG release of 0.5 – 1.5m^2
- Public safety impact is limited to exposure only from inbound LNG carriers and is considered to potentially result in injury and property damage beyond the shoreline (>250m from breached LNG carrier)

Table 6-2 Impact distances from 2004 Sandia Report for Accidental Breaches

Hole Size (m^2)	Tanks Breached	LNG Pool Diameter (m) *Assumes single pool fire*	Burn Time (mins)	Distance from point of release to LFL (m)	Distance from centre of pool to 37.5 kW/m^2 (m)	Distance from centre of pool to 5 kW/m^2 (m)
1	1	148	40	1536	177	554
2	1	209	20	1710	250	784

For intentional breaches, the conclusions that can be drawn from the report are summarised as follows:

- The intentional nature of such breaches, which have a safety impact to both the public and workforce, present as security threats and need to be considered in that context.
- Consequences of these events may include structural damage to the ship from cryogenic exposure
- The potential for a large vapor dispersion from an intentional breach is highly unlikely. This is due to the high probability that an ignition source will be available for many of the initiating events identified,

Table 6-3 Impact distances from 2004 Sandia Report for Intentional Breaches

Hole Size (m^2)	Tanks Breached	LNG Pool Diameter (m) *Assumes single pool fire*	Burn Time (mins)	Distance from point of release to LFL (m)	Distance from centre of pool to 37.5 kW/m^2 (m)	Distance from centre of pool to 5 kW/m^2 (m)
5	1	330	8.1	2450	391	1305
5	3	572	8.1	3614	630	2118
12	1	512	3.4	Not Reported	602	1920

The report notes that the assumption of a single pool fire for larger releases is based on sufficient air being able to mix with the vapourising LNG in the interior of the fire to support combustion, which for a large fire may not be sustainable. Should this occur, the flame envelope would likely break up into a number of smaller flamelets which would see a reduction in the heat flux. The modelling indicated that for a single 500m diameter fire would have a flame height of 600m, with a distance of 1800m to the 5kW/m^2

radiation level. However, if this broke down into a number of 100m pools as flamelets, the flame height would be reduced to 150m (-75%) with the distance to the 5kW/m^2 radiation level reduced to 1000m (-44%).

An overall qualitative assessment was prepared to summarise the public safety and property impacts and Table 16 from the 2004 Sandia Report has been reproduced below in Table 6-4. These impacts also need to be considered from a risk perspective taking into account that at a transit speed of 6 knots in Corio Bay, it will take an LNG carrier less than 30 minutes to move past a shoreline point whilst it is within 1600 metres of that point, which represents 20hrs per year (0.23% of a year). Given the lack of incidents globally, it is not be possible to assign and substantiate a probability to a successful intentional breach event, Australian history for LNG carriers shows no incidents, and globally there have only been two incidents (Iran and Yemen) neither of which lead to any significant release. Australia has more robust controls around access to many of the means and resources to undertake an intentional attack when compared to the US, and in keeping with one of the key conclusions of the Sandia report, “risk management processes should be conducted in cooperation with appropriate stakeholders, including public safety officials and elected public officials. Considerations should include site-specific conditions, available intelligence, threat assessments, safety and security operations, and available resources”.

Table 6-4 Estimated Impact of Intentional LNG Breaches & Spills on Public Safety & Property (Sandia Report Table 16)

Event	Potential Ship Damage and Spill	Potential Hazard(s)	Potential Impact on Public Safety		
			< ~500m	~500 – 1600m	> 1600m
Insider Threat and/or Hijacking	Intentional, 2-7 m^2 breach and medium to large spill	• Large fire	High	Medium	Low
		• Damage to ship	High	Medium	Low
		• Fireball	Medium	Low	Very Low
	Intentional, large release of LNG	• Large fire	High	Medium	Low
		• Damage to ship	High	Medium	Low
		• Vapour cloud fire	High	High – Medium	Medium
Attack on Ship	Intentional, 2-12 m^2 breach and medium to large spill	• Large fire	High	Medium	Low
		• Damage to ship	High	Medium	Low
		• Fireball	Medium	Low	Very Low

Very low – little or no property damage or injuries
Low – minor property damage and minor injuries
Medium – potential for injuries and property damage
High – major injuries and significant damage to structures

6.6.3. Quantitative Risk Assessment

Whilst the specific FSRU vessel is yet to be finalised a typical FSRU design based on vessels from proposed suppliers has been used to conduct a preliminary QRA for hazards and risks associated with the FSRU operation including but not limited to:

- ship to ship transfer of LNG from the LNG carrier to FSRU
- gas operations at Refinery Pier No.5 including gas export from the FSRU, MLAs, ship to ship transfer and interaction with refinery operations

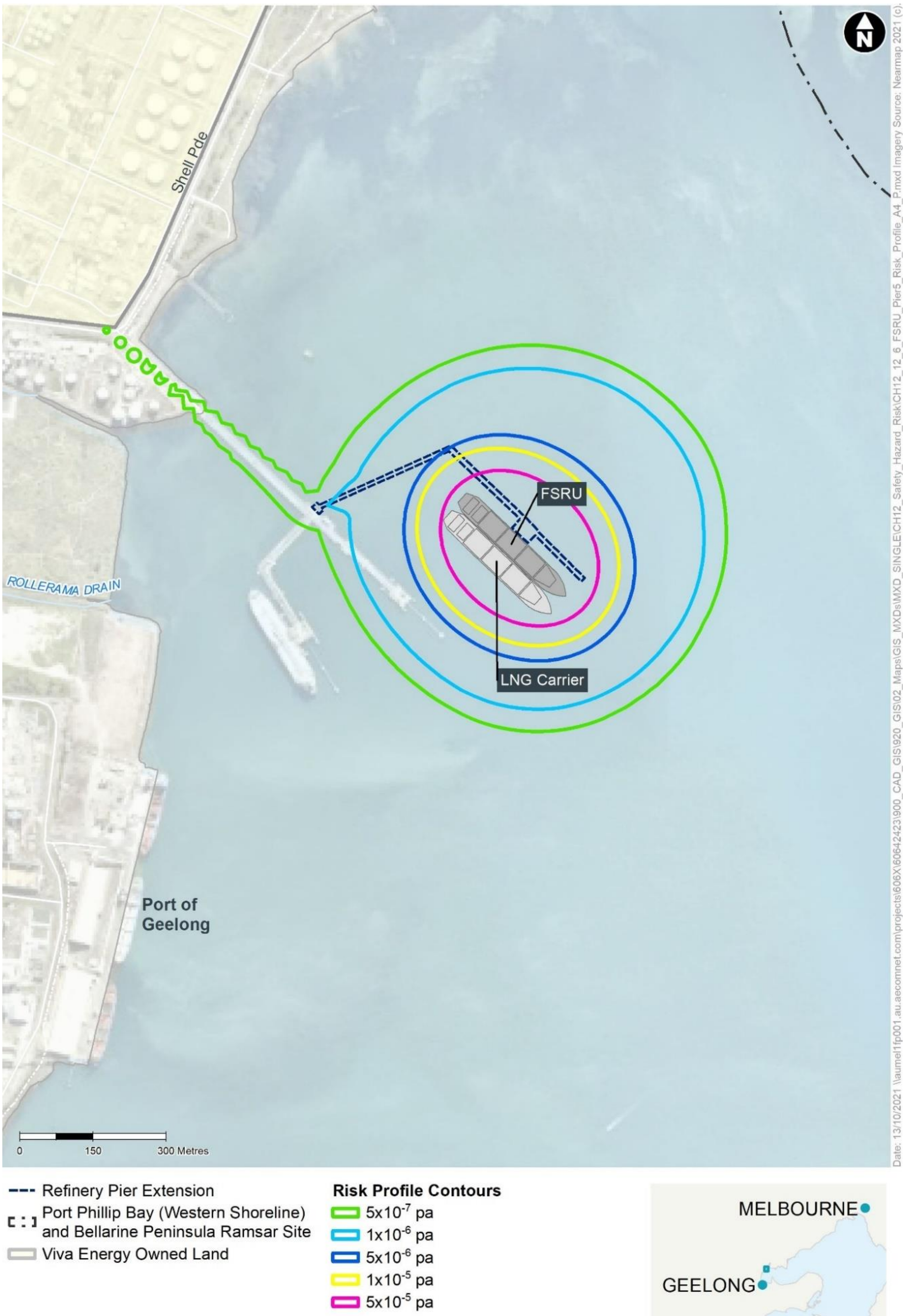


Figure 6-3: LSIR contours for FSRU, LNG carrier and pier infrastructure

6.6.3.1. *Results*

The individual fatality risk contours for the FSRU, LNG carrier and pier infrastructure are represented in Figure 6-3.

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

- The ‘once in 20,000 years likelihood of fatality’ represented by the 5×10^{-5} risk contour (pink), considered tolerable for industrial land use, is restricted to the immediate area around the FSRU and Refinery Pier No.5. This contour is limited to close in areas around the FSRU and LNG carrier but does not reach other Refinery Pier berths, nor reach the shoreline.
- The ’once in 100,000 years likelihood of fatality’, represented by the 1×10^{-5} risk contour (yellow), considered tolerable for active open spaces is restricted to the immediate area around the FSRU and Refinery Pier No.5. This contour is limited to close in areas around the FSRU and LNG carrier but does not reach other Refinery Pier berths, nor reach 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 LNG carriers mooring adjacent to the FSRU and Port of Geelong tugboats, there are not expected to be any ship or boat movements in this area.
- The ’once in 200,000 years likelihood of fatality’, represented by the 5×10^{-6} risk contour (blue), considered tolerable for commercial developments is restricted to the area around the FSRU and Refinery Pier No.5, and port waters. The area inside this risk contour is a controlled area and does not extend to the shoreline. It is not expected to be a highly trafficable area in terms of people or vehicle movements. With the exception of tankers berthing at Refinery Pier No. 4, LNG carriers mooring adjacent to the FSRU and Port of Geelong tugboats, there are not expected to be any ship or boat movements in this area.
- The ‘’once in 1,000,000 years likelihood of fatality’, represented by the 1×10^{-6} risk contour (aqua), considered tolerable for residential uses is restricted to the area around the FSRU and Refinery Pier No.5, and port waters. The area inside this risk contour is a controlled area and does not extend to the shoreline. With the exception of tankers berthing at Refinery Pier No.4, LNG carriers mooring adjacent to the FSRU and Port of Geelong tugboats, there are not expected to be any ship or boat movements in this area.
- The ’once in 2,000,000 years likelihood of fatality’, represented by the 5×10^{-7} risk contour (green), considered tolerable for sensitive land uses remains on Refinery Pier, extending along the Refinery Pier access route and reaching the shore. Access to the Pier is restricted however the risk contour extends to the publicly accessible area immediately in front of Refinery Pier gatehouse. There are no hospitals, schools or other sensitive receptors impacted by this contour.
- All the HIPAP 4 criteria have been met for the FSRU, LNG carrier and pier infrastructure elements of the project.

6.6.3.2. *Incremental risk to existing Geelong Refinery risk profile*

The individual fatality risk contours for the FSRU, LNG carrier and pier infrastructure have been superimposed on the existing risk profile in Figure 6-4.

Whilst a cumulative risk profile has not been able to be determined due to the Geelong Refinery QRA being undertaken using different software, the following observations are made:

- The FSRU and LNG carrier (when moored) would result in localised incremental risk in and around where it is located.
- The incremental risk near the shoreline, to the North Shore residential land use (approx. 1.6 km from the FSRU) and other adjacent land uses would be negligible as the existing risk is 1 to 2 orders of magnitude higher than the LSIR due to the FSRU and LNG carrier.

- The ’once in 2,000,000 years likelihood of fatality’, represented by the 5×10^{-7} risk contour would extend by some distance, likely in the range of 50-100 metres in the south east quadrant where the existing facility 5×10^{-7} pa risk contour (purple) and the project 5×10^{-7} pa risk contour (green) overlap.
- Overall the FSRU and gas operation on Refinery Pier No.5 provides a very limited incremental risk increase over port waters (Corio Channel), with negligible impact on land use.

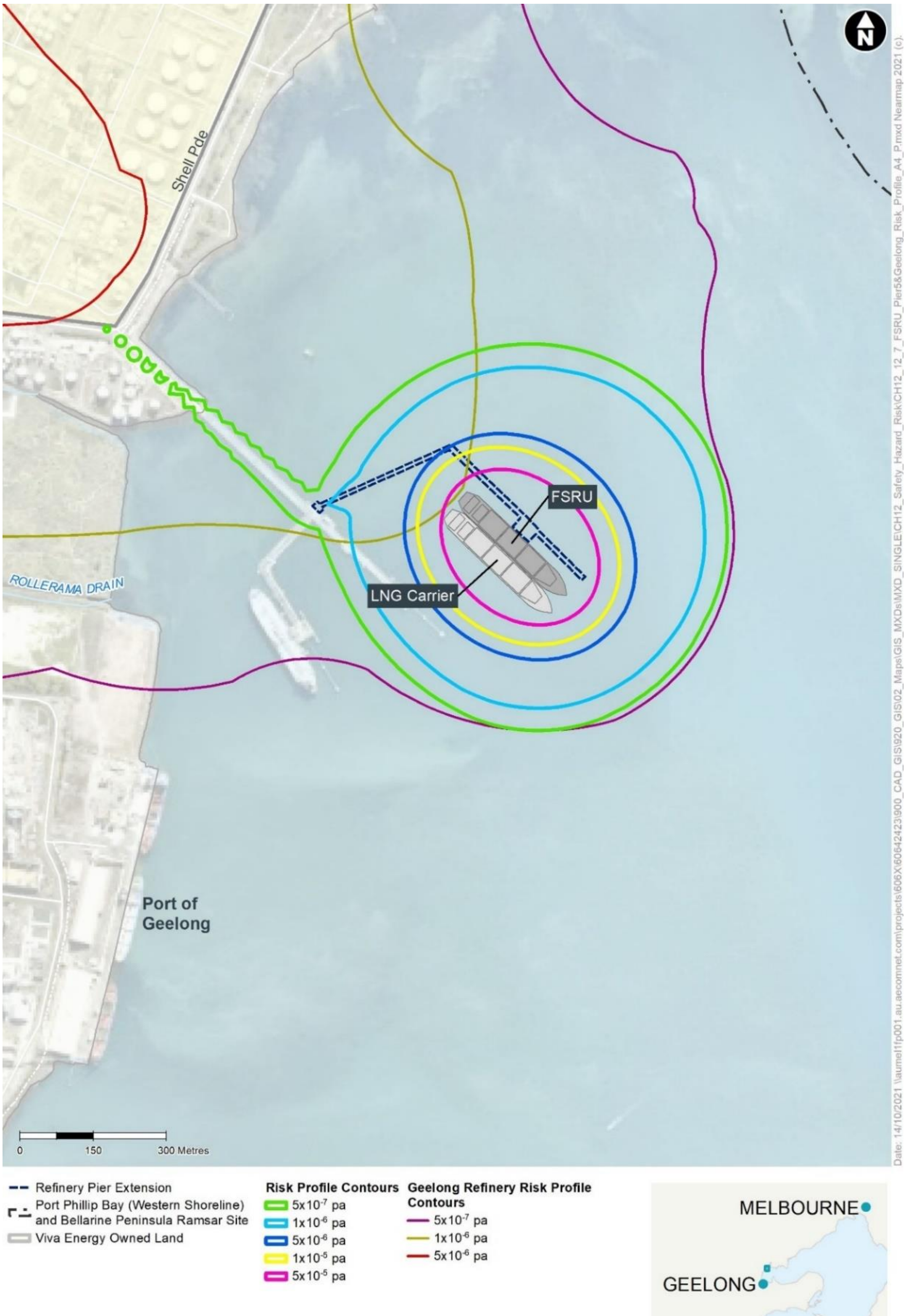


Figure 6-4: Existing Geelong Refinery risk profile and FSRU, LNG carrier and pier infrastructure risk profile

6.6.4. Fire prevention and mitigation

The following fire prevention and mitigation strategies will be incorporated in the FSRU, although details for the FSRU will not be available until the specific vessel is chartered.

Minimisation of leak sources and inventory

The FSRU includes the minimum process equipment necessary to provide reliable supply of natural gas to Viva Energy utilising a range of operational modes. Equipment will only be in service when required.

As a purpose-built LNG storage and regasification vessel, there are significant volumes stored in the LNG cargo tanks which are all isolatable. The consequence analysis has assumed that releases would be detected and isolated with a probability of failure on demand of 1% (typical for a SIL 2 rated system).

Control of ignition sources

Hazardous area standards and codes have been applied in detailed design and subsequently equipment would be appropriately certified for used in the hazardous zone. The hazardous zone represents the area where a potentially flammable atmosphere may exist and would be determined in detailed design through the application of relevant international standards applicable for explosive atmospheres.

Fire protection and suppression

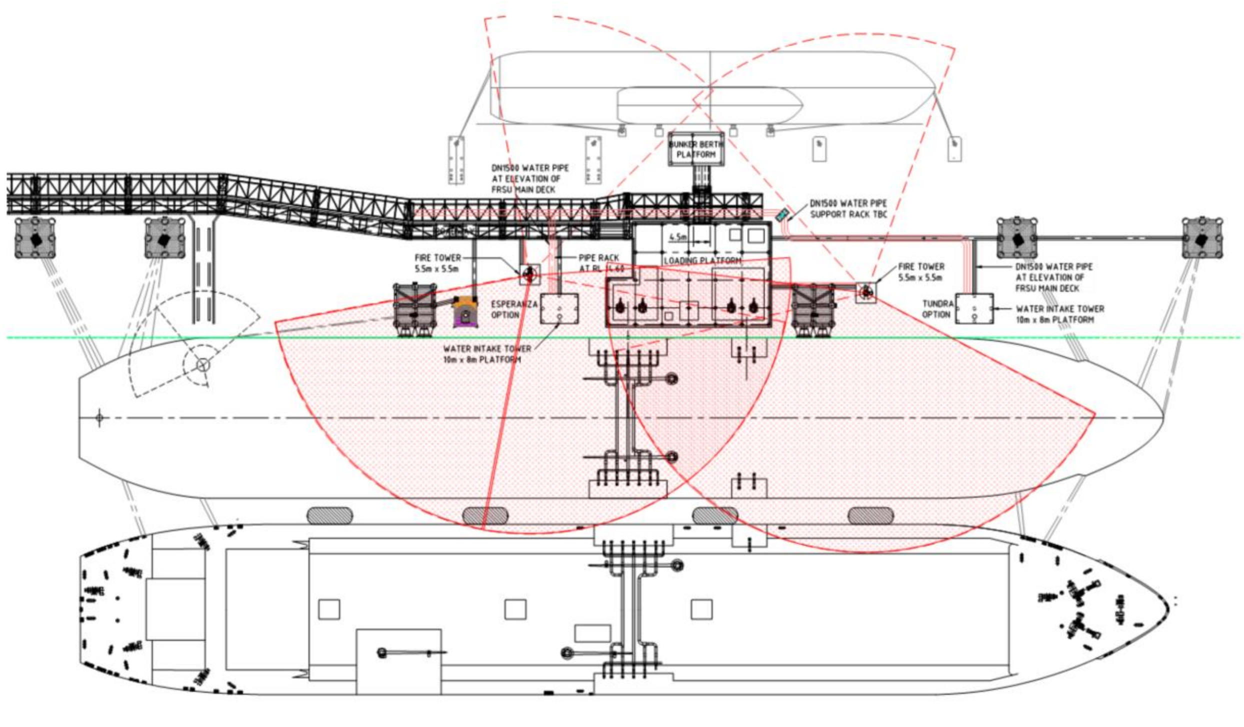
Active fire protection and suppression would be provided for liquid fires and gas fires at the FSRU and pier in compliance with relevant Australian Standards, including AS 3846-2005 *The Handling and Transport of Dangerous Cargoes in Port Areas*.

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.

For the assumed 82,000 tonne dead weight of a typical FSRU, it is assessed that a total fire water demand of $41m^3$/min to meet requirements at the pier manifold (AS 3846-2005 Table G4) and for a flammable gas tanker fire (AS 3846-2005 Table G5) plus a 50% allowance for losses.

The refinery fire water system will meet the manifold and vessel shielding requirements with requirement for full tanker fire achieved through use of both refinery firewater system and supplied firefighting tugs.



70m THROW RANGE PLAN

Figure 6-5: Refinery Pier Berth No. 5 Tower Mounted Fire Water Monitor Coverage

6.7. Additional safety, hazard, and risk assessments

Once the FSRU vessel is confirmed with all commercial details finalised and agreed between Viva Energy and the FSRU Service Provider, a forward plan will be developed to ensure an appropriate level of additional assessments are conducted. These assessments will address the following considerations:

- Location specific factors – environment, proximity to other facilities, land users, and residents
- Interaction with other users of Refinery Pier
- Process interaction with Geelong Refinery fuel gas system, cooling water system
- Escalation events to/from FSRU from nearby marine operations and other MHF operations
- Requirement for a comprehensive and systematic safety and property protection assessment under Occupational Health and Safety Regulations 2017, Part 5.2 – Major hazard facilities (refer Section 4.13.1)

7. Pier Infrastructure

7.1. Overview

The new berth, Refinery Pier No. 5, would be constructed on a new pier arm extending to the north from the existing Refinery Pier. The existing Refinery Pier is located on Crown land leased by Ports Pty Ltd. Viva Energy has lodged an application for a Crown lease over the seabed area on which the pier extension and new berth is proposed to be constructed.

The pier infrastructure on Refinery Pier No.5 would include FSRU seawater diffuser, non-gas piping, a fire protection system, an electrical substation and possible FSRU excess boil-off gas piping, if required. The licensed Geelong Gas Terminal Pipeline (see Section 8.0) commences from the seaward flange of the quick release coupling on the MLAs and runs along the new pier extension and then along the existing Refinery Pier pipe track.

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 pier infrastructure 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
- Approvals for the boil-off gas piping, if determined to be required during detailed design, would be regulated by WSV under safety case legislation (as a revision to the existing Geelong Refinery Safety Case which includes the existing Refinery Pier).
- Safety studies relevant to the pier infrastructure and a preliminary QRA (included with FSRU analysis in Section 6.0) have been completed.

7.2. Regulatory Framework

The legislation identified as being applicable to safe operation of the boil-off gas line, along with the implications for the project, is detailed in Table 3-1, with a brief listing below:

- *Occupational Health and Safety Act 2004* (Vic), and Occupational Health and Safety Regulations 2017
- *Dangerous Goods Act 1985* (Vic), and Dangerous Goods Act (Storage and Handling) Regulations 2012

7.2.1. Regulatory bodies

If it is determined to be required, the boil-off gas piping would be regulated by WSV under safety case legislation (incorporated as part of the scope for the Geelong Refinery MHF Safety Case).

7.3. Studies completed

As part of the overall safety and risk assessment program both the layout and configuration of the new berth Refinery Pier No.5, and the possible BOG piping from the FSRU to Geelong Refinery was included in a:

- Hazard Identification (HAZID)
- Hazard and Operability Study (HAZOP)
- Ship simulation studies (including manoeuvrability assessment)
- Quantitative Risk Assessment (QRA) - possible boil-off gas line included in Section 6.0 QRA modelling above.

7.4. Hazard and risks identified

7.4.1. Major risks

The specific operational hazards (Refer Section 5.0) associated with routine activities at the berth, and with the possible boil-off gas line, are the following:

- fire and explosion
- liquid hydrocarbon (fuel, flammable solvents) pool fire
- asphyxiation

The consequence of a release of natural gas is dependent upon process operating conditions, local weather conditions, the surrounding location of the release, and whether ignition occurs or not.

As for any liquid hydrocarbon pool fire near the FSRU (or back along the pier access route) radiant heat impacts are significantly smaller than for hydrocarbon jet fires. Fires along the main access to the Refinery Pier would be extinguished by emergency responders who would provide the required combatting facilities such as regularly installed hydrants and access to portable foam appliances.

7.4.2. Berth No.5 layout and configuration

The specific operational hazards (Refer Section 5.0) associated with the layout and configuration of Refinery Pier berth No. 5 include the following:

- Ship collision leading to hydrocarbon spill (and associated potential consequences)

The ship simulation studies were used to determine appropriate separation distances based on vessel manoeuvrability requirements.

The separation distances incorporated in the layout are based on the summation of relevant operational constraints and considerations as follows:

1. Vessel distance due to navigation requirements requiring 245m from existing Berth No.1 to Berth No.5
    a. Berth No.5 - Both vessels 50m in width
    b. Fenders between FSRU and LNG carrier 5m
    c. Berth No.1 - medium range tanker (MR) width is typically 35m
    d. Additional allowance between Berth No.5 and Berth No.1 for the removal of the LNG carrier from the FSRU for departure.
        i. 25m hazardous area separation from LNG carrier to tug
        ii. 30m tug operation zone
        iii. 25m tow line allowance
        iv. 25m hazardous area zone from MR to above operations

    In reviewing the SIGTTO standards there is no prescribed separation distance applied to ship movements or minimum separation distances between berths, hence the layout and spacing is determined through simulation studies.

2. Vessel movement sequencing.
    a. LNG carrier Arrival:
    The navigation studies determined that there should be no vessel on Berth No.1 when an LNG carrier is arriving - not due to separation distances, but rather due the propeller wash force from the tugs when pushing the LNG carrier into place.
    b. LNG carrier Departure:
    On departure a MR could sit on Berth No.1 but should not be completing cargo loading or unloading operations - as the tugs would be pulling the LNG carrier away, the propeller wash would not be a constraint for the MR. This would be a weather dependent exercise

as in strong northerly winds this may not be the case. But as per normal port operations this is an existing managed risk and activities are well planned and coordinated.

8. Geelong Gas Terminal Pipeline

8.1. Overview

Natural gas would be delivered from the FSRU to the Lara City Gate tie-in facility via a new gas pipeline as shown in Figure 1-2. The pipeline would be approximately 7 kilometres long with a proposed nominal diameter of 600 millimetres (mm): 3 kilometres (km) aboveground from Refinery Pier No. 5 to the treatment facility (situated in an area known as Nerita Gardens at the northern boundary of the Geelong Refinery), then approximately 4km belowground from the treatment facility to the VTS tie-in point at Lara City Gate.

The licensed pipeline also includes:

- Marine loading arms (from seaward side of the quick release coupling)
- Interconnecting piping on the Refinery Pier extension pier head from the MLAs to the DN600 pipeline, including depressurisation lines leading to a cold vent
- A temporary pig launcher tie-in assembly (for the aboveground pipeline) on the Refinery Pier extension pier head
- A temporary pig receiver tie-in assembly (for the aboveground pipeline) situated in the treatment facility
- A gas conditioning station situated in the treatment facility including odorant injection tie-in and inline mixer (nitrogen injection tie-in)
- A gas metering station situated in the treatment facility including gas analyser package and gas metering package
- Cold vent (to enable depressurisation of both above and below ground sections of the pipeline) situated in the treatment facility
- A temporary pig launcher tie-in assembly (for the belowground pipeline) situated in the treatment facility

A temporary pig receiver tie-in assembly (for the belowground pipeline) situated at the Lara City Gate station. A Safety Management Study (SMS) has been completed for the proposed pipeline alignment in accordance with the requirements of the *Pipelines Act 2005 (Vic)* and the Pipeline Regulations 2017. As the project moves into detailed design, there will be review and resolution to ensure all risks have been reduced to ALARP. Further, consistent with the requirements of the *Gas Safety Act 1997 (Vic)* and Gas Safety (Safety Case) Regulations 2018 there will be a formal safety assessment (FSA) which will use existing safety studies as the basis to develop the gas safety case (covering the pipeline safety management plan). The FSA will include identification of risks having the potential to cause a gas incident, a systematic assessment of risk, including the likelihood and consequences of a gas incident; and a description of technical and other measures undertaken, or to be undertaken, to minimise that risk as far as practicable.

8.2. Design and operation

8.2.1. Geelong Gas Terminal Pipeline

The key aspects associated with the pipeline are:

- The Geelong Gas Terminal 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 which includes controls to prevent reverse flow in an abnormal operational event, whilst providing the ability to pressurise the pipeline for commissioning and start-up purposes from the VTS.

- 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, 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.
- The pipeline easement would be inspected for any operational or maintenance issues on a routine basis.
- 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 5 years after the pipeline is put into initial service and then at a frequency determined by the results and findings of the first inspection.

Table 8-1 Key pipeline design parameters

Description / Parameter	Specification / Design
Nominal Diameter DN600	DN600 (609.6mm)
Length	Approximately 7km (3km A/G, 4km B/G)
Minimum Depth of Cover (all location classes) - for buried section	1 200mm
Wall Thickness	20.62mm – above ground 12.70mm – below ground
Corrosion Allowance - for above ground section only	3.0mm – above ground 0.0mm – below ground
Maximum Allowable Operating Pressure (MAOP)	10,210 kPag
Design Temperature range	-10C to +65C
Transient Low Temperature Excursions, min	-29C
Operating temperature range (deg. C)	-7C to +40C
Line Pipe Manufacturer Specification and Type	API 5L PSL-2, HFW
Pipeline material grade	Grade X65
External Coating	Below ground pipeline • Two layer Fusion Bonded Epoxy (FBE) – 600micron dry film thickness – for bored sections an additional abrasive overwrap Above ground pipeline • Fusion Bonded Epoxy (FBE) + UV protective overcoat
Cathodic Protection	Impressed current

The additional facilities and equipment which form part of the licensed pipeline are covered in section 8.2.2 Marine Loading Arms and section 9 Treatment Facility (which addresses the overall safety and risk as it will be included in the Gas Safety Case).

8.2.1.1. Pipeline alignment

The alignment of the pipeline (shown on Figure 1-2) has been selected to minimise impacts on sensitive land uses and, where possible, it would run parallel to existing pipeline easements and would be within existing infrastructure corridors. The pipeline would be constructed on land currently used for a variety of purposes, including port, industrial, conservation, rural-residential living, road and recreation.

The majority of 4km underground section would be buried using the cut and cover method, approximately 1.2 km would be constructed using HDD and thrust boring would be used for one road crossing.

The underground pipeline section 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.

8.2.2. Marine Loading Arms

The MLAs would be 12” (300 mm) diameter and each capable of transferring the full design flowrate of gas from the FSRU. Each of the MLAs would be fitted with a quick release coupling enabling rapid isolation in the event the vessel moves out of range from the pier. The MLA would vent to a safe location via a cold vent located on the pier head, and the MLA would be safely disconnected from the vessel. Additional isolation valves on the FSRU would also close to further isolate gas.

The pipeline on Refinery Pier can be isolated from the MLAs using the emergency shutdown (ESD) valve located upstream of the temporary pig launcher tie-in facility situated on the pier head (included as part of the licensed pipeline). Note the MLA piping and cold vent is also included in the licensed pipeline.

There is provision for blowdown of the MLAs and piping between the FSRU and the isolation valve downstream of the MLA piping to a cold vent on the pier head to enable safe depressurisation. The blowdown is controlled remotely from the refinery control room to ensure there are no automated releases of natural gas to the environment (to minimise emissions).

8.2.3. Victorian Transmission System Connection

The connection into the VTS at the Lara City Gate includes the following:

- a new DN500 tie-in valve to be installed to an existing unused tee connection on the DN500 Lara-Iona Pipeline
- a station isolation valve automatically operated remotely
- a temporary pig receiver tie-in assembly for pipeline internal inspections.

8.3. Regulatory Framework

The legislation identified as being applicable to safe operation of the Geelong Gas Terminal Pipeline is detailed in Table 3-1, with a brief listing below:

- *Pipelines Act 2005* (Vic) and Pipelines Regulations 2017
- *Gas Safety Act 1997* (Vic), and Gas Safety (Safety Case) Regulations 2018

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 (Vic)* 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 (Vic)*.

8.3.2. Approvals

The *Pipelines Act 2005 (Vic)* 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 (Vic)

Pursuant to Section 14 & 15 of the *Pipelines Act 2005 (Vic)*, 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.

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

8.3.2.3. Gas Safety Act 1997 (Vic)

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

In 2018 the Gas Safety (Safety Case) Regulations 2018 came into effect under the *Gas Safety Act 1997 (Vic)* which 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.

Key steps to acquiring a Pipeline Licence are outlined below.

Consultation Plan

Viva Energy's pipeline consultation plan was approved prior to giving notice to each landowner and occupier of their intention to enter land or giving notice of a pipeline corridor, consistent with the information outlined in the plan to provide to owners and occupiers affected by the proposed pipeline.

Viva Energy representatives 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, Viva Energy may apply to the Minister for consent under the *Pipelines Act 2005 (Vic)* to enter the land.

Details associated with the overall stakeholder and community engagement program undertaken during the EES including the requirements under the consultation plan required under the *Pipelines Act 2005 (Vic)* are presented in EES Chapter 6: *Stakeholder and community engagement*. The chapter provides details on the breakdown of stakeholders and the engagement activities undertaken, as well as the feedback received and the actions / responses that taken to address concerns raised.

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.

The pipeline application must include details of alternative pipeline alignments considered by the applicant 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 (Vic)* 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 (Vic)* 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.

Section 208 of the *Pipelines Act 2005 (Vic)* states that the safety case accepted by ESV under section 40 of the *Gas Safety Act 1997 (Vic)* is deemed f to be a Safety Management Plan. *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 1997 (Vic)*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.

Environmental Management Plan

Part 9 Division 3 Section 133 of the *Pipelines Act 2005 (Vic)* 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.

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.

8.3.3. Application of AS/NZS 2885 series

The *Pipelines Act 2005 (Vic)* provides for the licencing requirements of high-pressure gas transmission pipelines in Victoria and makes extensive reference to the requirements of the gas and liquid pipeline standard AS/NZS 2885 to design, construct and operate the pipeline.

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 multistorey 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 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: 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 locations 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.
- Design criteria consistent with a T1 environment has been adopted for the entire pipeline 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. 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 (Vic)*. A Licence to Construct is required before pipeline construction can commence.

A SMP is required prior to construction of the pipeline. 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. 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 (pressure) testing, commissioning manuals and procedures will be undertaken prior to the work occurring for approval by ESV in its role as responsible Regulator.

An EMP will be prepared for the pipeline construction. The EMP will form part of the tender documents for prospective tenderers. The selected Contractor must comply with the requirements of the EMP.

8.4. Risk study results

8.4.1. Major risks

The principal studies completed for the pipeline in the context of safety, hazard and risk were:

- Safety Management Study (SMS) for the pipeline
- Hazard and Operability Study (HAZOP) for the pipeline and facilities
- Quantitative Risk Assessment for the facilities.
- SIL Assignment Workshop 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 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 a 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.

8.4.2. Safety Management Study (SMS)

In accordance with AS/NZS2885.6, a SMS was completed for the pipeline - with separate workshops and reports for the aboveground and underground sections of the pipeline, then subsequently 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 will be shown to be As Low As Reasonably Practicable (ALARP) consistent with the requirements of AS/NZS2885.6.

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 (shown in Figure 8-1) for a full-bore rupture of the proposed Geelong Gas Terminal Pipeline operating at a pressure of 10,200 kPag, for the purposes of the determining the land use adjacent to the pipeline, has been calculated at 640 metres for the aboveground section from Refinery Pier No.5 to the Treatment Facility, and 560 metres for the below ground section from the treatment facility to Lara City Gate. The difference in measurement length is because the belowground pipeline is modelled as a hole in the 1:30 or 10:30 o’clock position while the aboveground pipeline is modelled as a hole in the 3:00 or 9:00 o’clock position.

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.

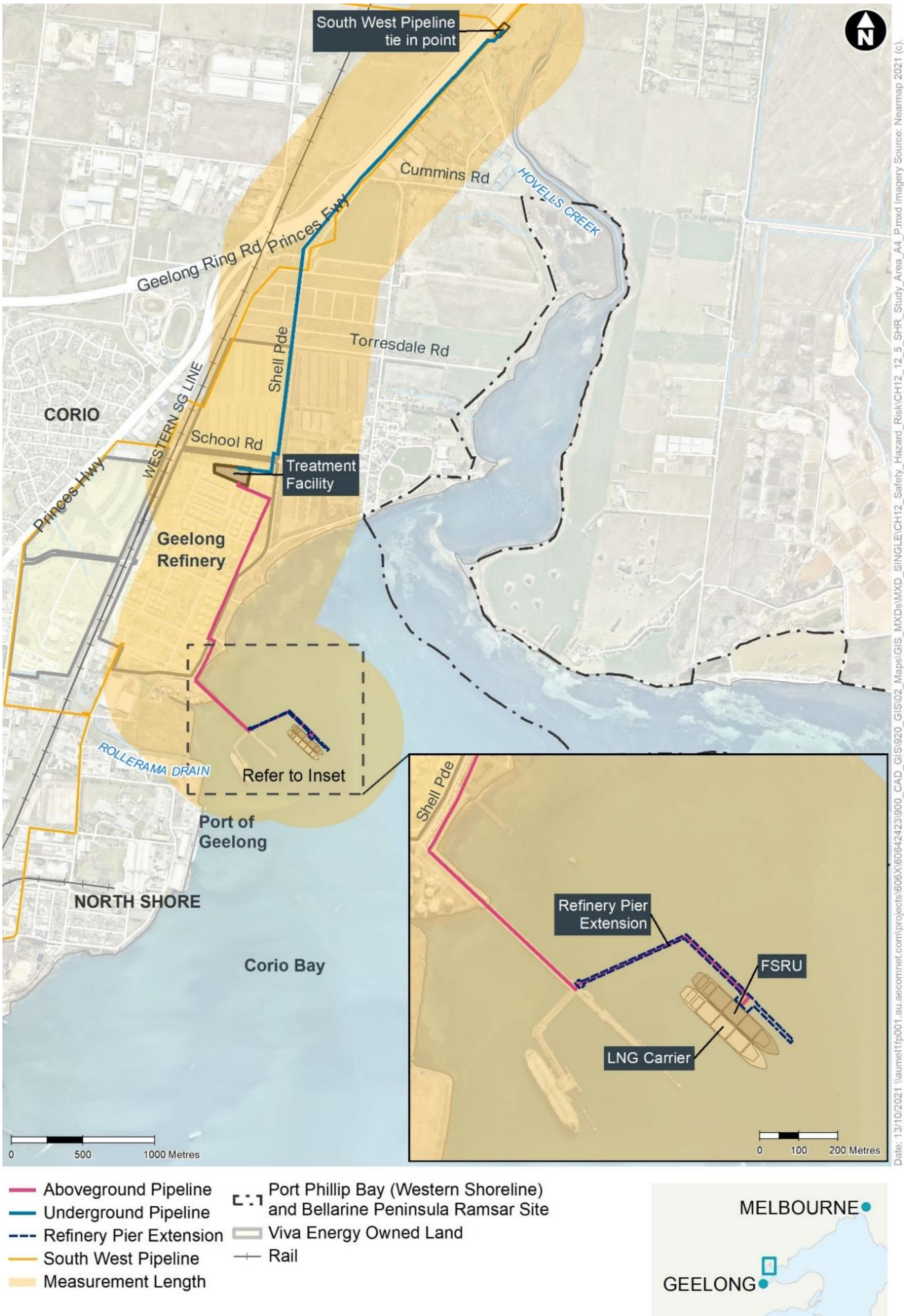


Figure 8-1: Measurement Length – For determining land use adjacent to the pipeline (per AS 2885.6)

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. For each of these sections, a *primary location class* based population density and land use within the measurement length (640m or 560m) 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 if there is the potential for any 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.

Table 8-2 Location classification along pipeline alignment

Start (m)	End (m)	Length (m)	Location Class	
			Primary	Secondary
Refinery Pier (includes Marine Loading Arms [14m])				
0	565	565	T1	HI
565	2 090	1 525	T1	HI / CIC
2 090	2 950	860	T1	S / HI / CIC
2 950	3 012	62	T1	S / HI
Treatment Facility (includes station piping [97m])				
3 012	3 640	638	T1	S / HI
3 640	4 040	400	T1	S
4 040	4 595	555	T1	CIC
4 595	5 550	955	T1	I / CIC
5 550	6 340	790	T1	CIC
6 340	6 750	410	T1	HI / CIC
6 750	6 942	192	T1	HI
Lara City Gate (includes station piping [58m])				

Pipeline design

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

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 tabulated below in Table 8-3. 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.

Table 8-4 shows the calculated radiation distances and energy released for various hole sizes on the proposed DN600 gas pipeline operating at 10.2 MPa while Table 8-3 shows the calculated hole sizes corresponding to 1 GJ/s and 10 GJ/s energy release rates.

Table 8-3 Heat Radiation Distance

Potential Hole Size (mm)	Distance to Radiation Level (above ground section) (m)		Distance to Radiation Level (below ground section) (m)		Energy Release Rate (GJ/s)
	4.7 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	12.6 kW/m^2	
5	9.8	9.2	10.7	8.4	0.02
25	54.0	47.1	46.6	31.5	0.5
50	105.9	88.8	88.4	57.2	2.1
100	200.8	156.8	167.6	107.4	8.3

Table 8-4 Heat Radiation Distance at 1 & 10 GJ/s

Potential Hole Size (mm)	Distance to Radiation Level (above ground section) (m)		Distance to Radiation Level (below ground section) (m)		Energy Release Rate (GJ/s)
	4.7 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	12.6 kW/m^2	
34	73.3	63.1	61.9	40.7	1 (T1)
109	216.3	167.9	181.4	116.1	10 (S)

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 Study workshop report.

Summary of threats

The threat identification process carried out as part of the Safety Management Study yielded the following outputs (Figure 8-2):

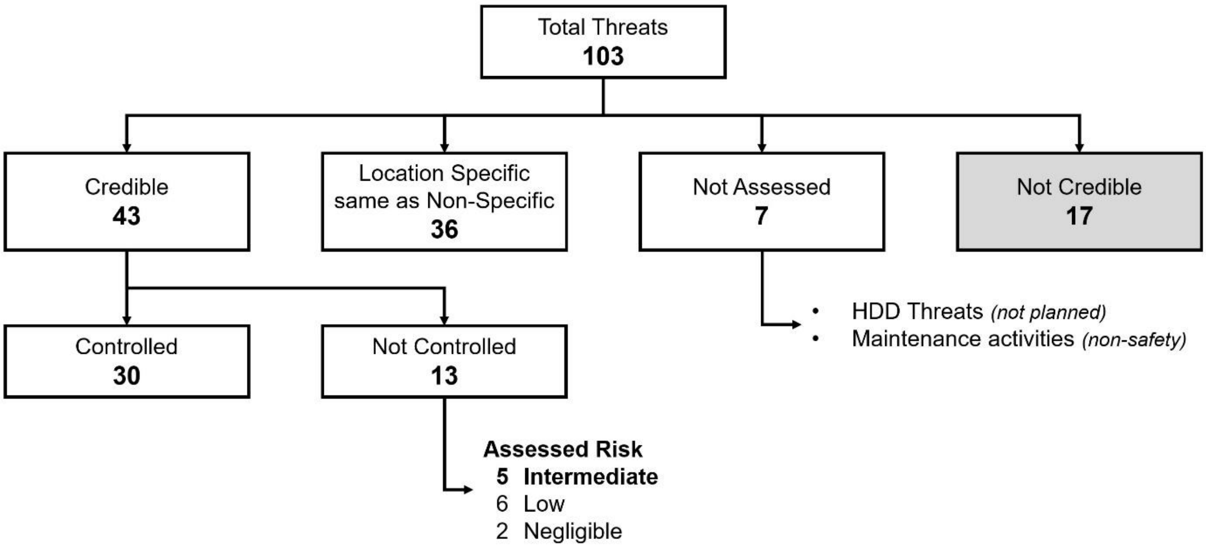


Figure 8-2: Total number of identified threats

- A total of 103 potential threats to the pipeline and facilities were identified.
  - 17 of the 103 potential threats were considered non-credible. Non-credible threats do not require controls.
  - 7 of the 103 potential threats were not assessed as they did not give rise to a safety exposure.
  - 79 of the 103 potential threats have been considered credible with 36 of the location specific threats considered to be covered by the non-location specific threat analysis.
- The consolidated 43 identified credible threats required further risk evaluation to arrive at a ‘risk ranking’.
  - There were no high or extreme risks identified.
  - 30 of the 43 consolidated credible threats required no further risk evaluation.
  - 8 of the 43 consolidated credible threats have been evaluated as presenting a low or negligible risk. These low and negligible risks are considered to be ALARP with existing controls.

- Of the 43 consolidated credible threats five have been evaluated as presenting an intermediate risk. These five threats will require a formal ALARP assessment that includes the application of additional control measures. These threats were defined as:
    i. Loss of containment in parallel fuel service within refinery (e.g. gasoline) leading to ignited pool fire engulfing pipeline.
    ii. Adversarial threat against pipeline (above-ground)
    iii. Adversarial threat against pipeline (below ground)
    iv. Possible pipeline impact from boring or exploratory drilling activities
    v. Offsite vehicle impact at aboveground valve stations (Nerita Gardens and Lara City Gate).

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).

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.

Demonstration of ALARP

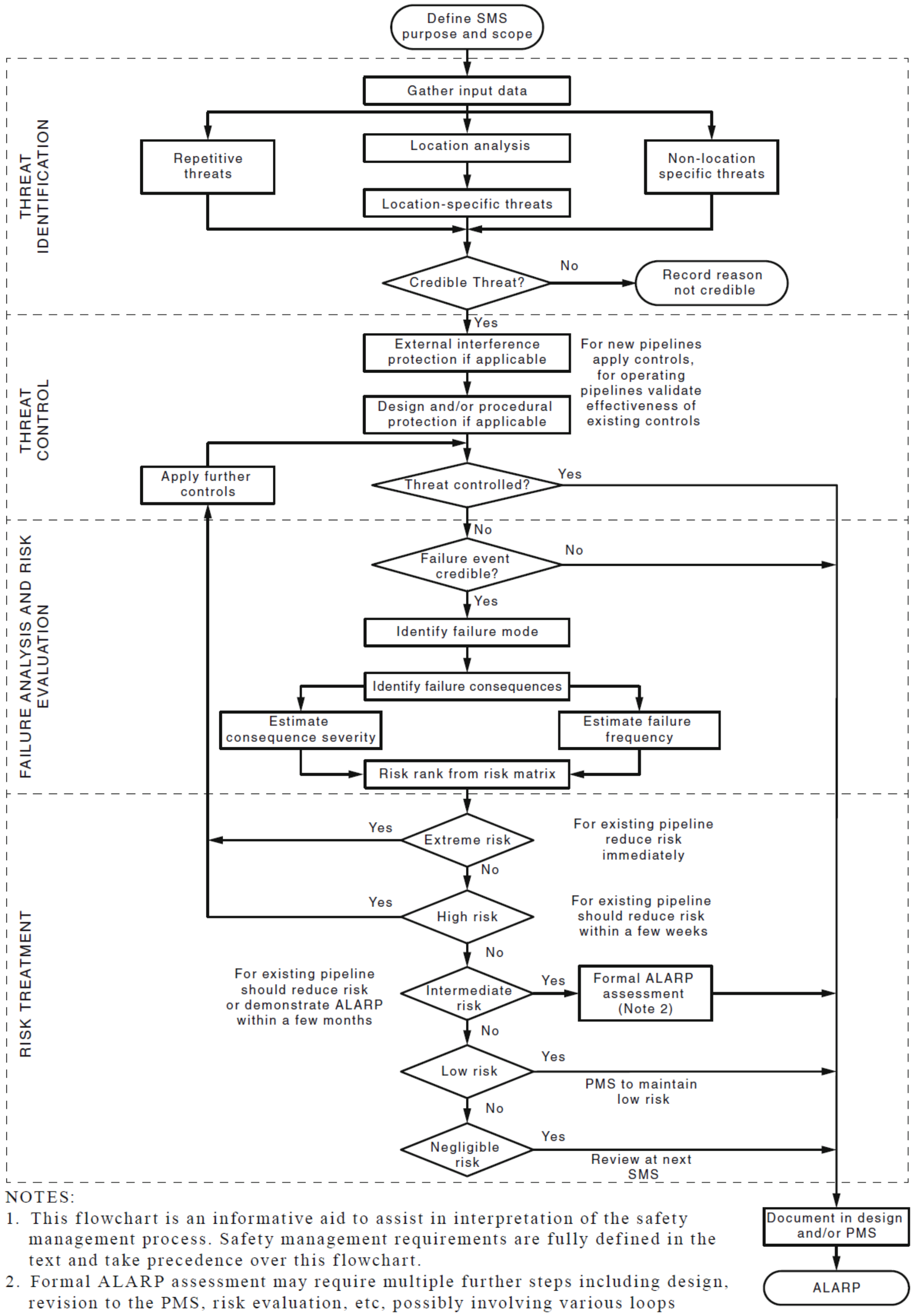
AS/NZS2885.6 requires that risks be reduced As Low As Reasonably Practicable (ALARP).

For the purposes of 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.

Within this framework and the definition of ALARP / AFAP in ESV's Gas Safety Case Preparation and Submission for Facilities and Pipelines, the Pipeline SMS followed the AS2885.6 Process Flowchart shown in Figure 8-3 below.

AS/NZS 2885.6:2018



NOTES:

1. This flowchart is an informative aid to assist in interpretation of the safety management process. Safety management requirements are fully defined in the text and take precedence over this flowchart.
2. Formal ALARP assessment may require multiple further steps including design, revision to the PMS, risk evaluation, etc, possibly involving various loops through the flowchart which have been omitted for simplicity.

Figure 8-3: Pipeline Safety Management Study Process Flowchart (per AS2885.6-2018, Appendix A)

Consistent with the risk treatment section shown in Figure 8-3, the following sections detail the different risks identified and how they were treated.

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 actions nor additional risk control measures are 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 and no further actions nor additional risk control measures are considered necessary. Measures have been taken to ensure that these risks are being managed as part of the gas safety case (and hence pipeline safety management system) 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

The SMS study and workshop assessment were recently completed, with further analysis and refinement of mitigation measures currently in progress to address the two remaining threats that of the five threats identified during the SMS workshop that had not been considered ALARP.

The other 3 of the 5 intermediate risks have been assessed and approved as ALARP

ii and iii 2× Adversarial threat against pipeline (1× above-ground, 1× below-ground)

- Security assessment has been completed, and with established counter-measures including security access control to areas where the pipeline is above ground, this threat should be re-assessed as ALARP given that the nature of threat leads to a credible "catastrophic" consequence (multiple fatalities, supply interruption for an extended period) and all reasonable security counter-measures and design considerations have been incorporated.
  Note: per AS2885.6 C6.6 "threats involving [adversarial threats] are often addressed by means which involve confidential national security aspects. In such cases it can be sufficient to note that the threat has been addressed outside the SMS and the details are confidential."

v. Offsite vehicle impact at aboveground valve stations (Nerita Gardens and Lara City Gate)

- Following the SMS assessment, the treatment facility within Nerita Gardens (where the above ground valve station may be potentially impacted) has been relocated~200 metres to the west away from Shell Parade, significantly reducing the probability of vehicle impact which would be re-assessed as "hypothetical" leading to a revised risk severity of "Low".

As indicated above, the remaining two intermediate threats undergoing additional analysis will be addressed during the project's detailed design phase where appropriate control measures will be considered based on the results of the analysis.

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.
- Corrosion protection through cathodic protection (for below ground section) and a two layer FBE coating applied for the full pipeline length
- 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.

- External loading from traffic (roadways and patrol easement) and earthquake have been assessed with no additional protection required other than incorporating in the earthquake loading inclusion in the aboveground pipe stressing.
- The regular operational patrol regime (including weekly aerial patrols, and daily ROW), as implemented across Viva Energy's existing pipeline network, will be adopted for the Geelong Gas Terminal Pipeline area to monitor whether there are activities occurring which could represent a threat to the pipeline.
- An inline gauging tool (pig) data acquisition run will be completed prior to pipeline hydrotest to provide the "as installed" pipeline physical condition (identification of previously unidentified mechanical irregularities)
- Managing latent dents or defects will be via inline inspection. In-line inspection (internal) of the pipeline will be carried out 5 years post construction and then on a frequency determined by the results of the previous inspection.
- 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. Marker tape will be laid in trenched areas.
- 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 along the pipeline alignment.
- For the sections for which installation would be 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.
- The pipeline meets the 'no rupture' requirements against a threat from a 40T excavator with a penetration tooth / 55T excavator with a tiger tooth. Use of larger than 30T 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.

This section will be updated following release of the final SMS Report.

Co-Located Liquid Hydrocarbon Pipelines

For the co-located piping / pipelines within the refinery, the Fire Safety Study considered the potential exposure of the Geelong Gas Terminal Pipeline from a range of equipment fires in tanks and other nearby equipment to the route through the refinery. The analysis determined that there would be insufficient radiation from these events to cause damage to the gas pipeline leading to escalation.

Release of Gas – MLA piping on the pier head and pipeline on the new pier arm

The catastrophic failure of an MLA could occur if the FSRU suddenly moved away from the Refinery Pier No.5 berth; this is considered to be a very short duration release due to the presence of quick disconnect closure systems on the MLA, and the proximity of fail closed emergency isolation valves.

Releases from the MLA piping may be sustained for a sufficient duration to cause extensive damage and may prevent escape along the pier. The releases from the MLA 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 and pressure blown down through the cold vent stack.

The Service Platform which would house the electrical substation and proposed muster point, is potentially within a high radiant heat zone. If confirmed during detailed design, heat shielding or other mitigation measures will be incorporated to ensure personnel are able to evacuate to a safe location.

The gas pipeline would travel adjacent to the Service Platform so any pipeline fire between Refinery Pier No. 5 and the connection of the new pier arm to Refinery Pier can expose the Service Platform to high radiant heat levels so shielding for the electrical substation should be considered.

8.4.3. Quantitative Risk Assessment

To provide an overview of the contribution of the pipeline risk as part of the overall project Figure 8-4 provides the combined LSIR contours for the project. The narrow band of risk (1×10^{-7}pa shown in white) is below the lowest HIPAP 4 criteria (5×10^{-7}pa) for the most sensitive land uses, and is remote (except for along Macgregor Court into Lara City Gate tie-in to the South West Pipeline) from existing residential land users.

Figure 8-4: Combined LSIR Contours for Gas Terminal Project

8.4.3.1. Results

The individual fatality risk contours for the Geelong Gas Terminal Pipeline and Lara City Gate Tie-in Facility are represented in Figure 8-4.

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

- The ‘once in 20,000 years likelihood of fatality’ represented by the 5×10^{-5} risk contour, considered tolerable for industrial land use, and the ’once in 100,000 years likelihood of fatality’, represented by the 1×10^{-5} risk contour considered tolerable for active open space have not been reached at Lara City Gate.
- The ’once in 200,000 years likelihood of fatality’, represented by the 5×10^{-6} risk contour (blue), considered tolerable for commercial developments is restricted to the immediate area around the Lara City Gate Tie-in Facility. Access to the facility is restricted by security fencing and is visited as part of daily patrols, and maintenance activities by workforce. This level of risk is also considered acceptable for users of the recreational open space (Hovells Creek Reserve) surrounding the facility.
- The ‘’once in 1,000,000 years likelihood of fatality’, represented by the 1×10^{-6} risk contour (aqua), considered tolerable for residential uses extends approximately 250 metres around the facility crossing the Princes Freeway (where the contour extends due to the higher ignition probability from vehicles). There is an existing residential property situated north of the freeway inside this risk contour, however this property has been present during the existing operation at the Lara City Gate facility and the pipeline tie-in represents an incremental increase to the existing risk profile.
- The ’once in 2,000,000 years likelihood of fatality’, represented by the 5×10^{-7} risk contour (green), considered tolerable for sensitive land uses extends approximately 400 metres around the facility crossing the Princes Freeway (where the contour extends due to the higher ignition probability from vehicles). There is an existing residential property situated north of the freeway inside this risk contour, however this property has been present during the existing operation at the Lara City Gate facility and the pipeline tie-in represents an incremental increase to the existing risk profile. There are no hospitals, schools or other sensitive receptors impacted by this contour.
- The ’once in 10,000,000 years likelihood of fatality’, represented by the 1×10^{-7} risk contour (white) has been included to highlight the lower risk associated with the Geelong Gas Terminal Pipeline and the narrow corridor of approximately 120 metres either side of the pipeline route that it covers.

The pipeline risk profile meets the Hazardous Industry Planning Advisory Paper (HIPAP) No.4 tolerable individual fatality risk thresholds based on land use zoning, both on a standalone basis, and when considered cumulatively with the existing refinery operation.

- The existing property off Rennie Street, approximately 200 metres NNE of the Lara City Gate Station is already exposed to a LSIR that exceeds 1×10-6pa from the existing facilities in operation.

9. Treatment Facility

9.1. Overview

The proposed treatment facility is situated at the northern boundary of the Geelong Refinery on an existing laydown area known as Nerita Gardens. The facility will receive unodorised natural gas from the FSRU via the above ground section of the Geelong Terminal Gas Pipeline. The main functions of the facility are to provide:

- odorant injection (a safety requirement which enables the normally odourless gas to be smelt), and
- nitrogen injection (to treat gas when required to meet Wobbe Index specification).
- gas metering to custody transfer standard,
- measurement of gas composition.

After measurement, odorisation, and addition of nitrogen (when required), the natural gas would be sent through the underground section of the Geelong Gas Terminal Pipeline to the Lara City Gate to tie into the South West Pipeline as part of the Victorian Designated [Gas] Transmission System.

The treatment facility's process and equipment are consistent with other similar facilities in Australia and present no unique risks nor hazards that are not encountered within other facilities. It is reasonable to state that the treatment 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
- It is anticipated that approval for the injection equipment at the treatment facility would be provided by ESV as part of the Gas Safety Case which also includes the pipeline as indicated by the jurisdictional boundaries described in Section 3.2.
- The storage facilities would be regulated by WSV for the odorant storage (under modified MHF Safety Case for the Geelong Refinery) and the LIN storage administered under the Dangerous Goods legislation.
- Safety studies relevant to the treatment facility and QRA have been completed and risk reduced so far as is reasonably practicable (SFAIRP).

9.2. Design and operation

Within the treatment facility would be situated:

- A temporary pig receiver tie-in assembly (included as part of the licensed pipeline)
- A gas conditioning station including odorant injection tie-in and inline mixer (nitrogen injection tie-in) (included as part of the licenced pipeline)
- A temporary pig launcher tie-in assembly (included as part of the licensed pipeline)
- A gas metering station including gas analyser package and gas metering package (included as part of the licenced pipeline)
- Cold vent (included as part of the licensed pipeline)
- Odorant storage
- Odorant injection package
- Liquid nitrogen storage
- Nitrogen facility and injection package

The odourised gas from the treatment facility would be the sent to the Lara City Gate tie-in point in via the new 4-kilometre-long underground section of gas pipeline.

9.2.1. Odorant Package

The treatment facility includes an odorant system (inventory of approximately $5m^3$) that would be designed to inject odorant into the gas pipeline to assist in detection of natural gas in the event of a leak.

The odorant package consists of two transportable odorant iso-storage tanks (~2½m^3), with a third dedicated iso-storage tank held offsite by the supplier to enable timely changeout, with the injection package, transfer pump, and associated piping and instrumentation housed in a building with an activated carbon filter system to remove any odorant venting should there be a minor leak. Gas detection and external alarms on the building are included to warn of any leak. Odorant would be delivered to the facility by road tanker and off-loaded to the dedicated storage area for connection to the process using flexible hoses.

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.

9.2.2. Nitrogen Facility

The treatment facility would include a nitrogen offload, storage and vaporisation (OSV) facility to ensure gas supplied to the Victorian distribution system is within specification. The plant would monitor gas composition and dilute rich gas with nitrogen such that natural gas provided by the facility into the gas network is within AS4564 specifications & AEMO Victoria guidelines. This is done by simply injecting the inert nitrogen into the gas pipeline 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 1200 net tonnes ($2120m^3$) of liquid nitrogen (LIN) would be required to be stored onsite. This would be stored in 4× $530m^3$ horizontal vessels (4.8m internal diameter × 29.4m length) each with a capacity of approximately 350 tonnes. Vessels would have a design pressure of 9 barg, with a normal operating pressure of 3 barg. 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, semitrailers, and B-doubles. The gantries would accommodate B-double trailers.

9.3. Regulatory Framework

The legislation identified as being applicable to safe operation of the treatment facility is detailed in Table 3-1, with a brief listing below :

- *Dangerous Goods Act 1985* (Vic), and Dangerous Goods Act (Storage and Handling) Regulations 2012
- *Pipelines Act 2005* (Vic) and Pipelines Regulations 2017
- *Gas Safety Act 1997* (Vic) and Gas Safety (Safety Case) Regulations 2018
- *Occupational Health and Safety Act 2004 (Vic)* and Occupational Health and Safety Regulations 2017

9.3.1. Regulatory bodies

The key regulatory bodies for the Treatment Facility are anticipated to be:

- ESV for the section of the licensed pipeline which is situated within the treatment facility (detailed in Section 8.0 above)

- ESV for all injection equipment and operation of the treatment facility (included in the Gas Safety Case).
- WSV for the storage facilities.

9.4. Studies completed

The following key studies have been completed related to the safety, hazard and risk for Treatment Facility component of the project:

- HAZID Workshop Report
- HAZOP Workshop – covering process, metering station, odorant injection, and nitrogen injection
- FEA Study
- QRA Report – including treatment facility.
- SIL Determination

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.

9.5. Hazards and risks identified

9.5.1. Major risks

The predominant risk associated with the treatment facility is the loss of containment from the process and associated equipment/plant as potential sources of fire events. Hazards associated with the storage of liquid nitrogen and odorant at the treatment facility are discussed in Section 5. The following specific issues were raised for assessment.

9.5.1.1. Release of Gas – Gas piping

For the purposes of the risk studies, hazard assessments and fire safety study the gas (predominantly methane) has been assumed to be 2°C and 10,000 kPag which provides the greatest combination of gas release rate and density. For the QRA a conservative pressure profile based on the system operating pressure history in the Victorian Transmission System (VTS) has been assumed to provide risk results that better reflect operating conditions since pressure in the treatment facility will closely match the VTS pressure given there is no pressure letdown prior to entering the VTS. 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.

9.5.1.2. Release of liquid hydrocarbon

Project-related

The following potential liquid hydrocarbon sources have been identified:

- Spotleak 1005 odorant.

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 2 liquids include Spotleak 1005 which is classified as a flammable liquid according to AS1940 and Australian WHS regulations.

For uncontained 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.

Bushfire risk

The treatment facility is located on cleared land currently in use as a laydown area within the refinery, but some planted vegetation is present in surrounding areas. In particular, there are areas of undeveloped ‘paddock’ to the north of the refinery which are owned by Viva Energy, who is responsible for its management, including managing fire risk.

The safety case for the treatment facility would include bushfire mitigation strategies.

9.5.2. Cryogenic hazards

The storage of liquid nitrogen at the treatment facility introduces 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.

9.5.3. Summary of hazard and risk studies

9.5.3.1 Quantitative Risk Assessment (QRA)

An initial QRA for hazards and risks associated with the treatment facility has been completed with the following equipment located at the treatment facility included:

- gas treatment to meet gas quality requirements for distribution within Victoria
- gas measurement sections of the Geelong Gas Terminal Pipeline

Figure 9-1: LSIR contours for Treatment Facility

9.5.3.1. Results

The individual fatality risk contours for the Treatment Facility are represented in Figure 9-1.

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

- The 'once in 20,000 years likelihood of fatality' represented by the 5×10^{-5} risk contour (pink), considered tolerable for industrial land use, is restricted to the immediate area around the treatment facility and land at Nerita Gardens used by the refinery for waste management and equipment laydown. This contour does not impact on any other land other than the industrial zoned land owned by Viva Energy.
- The 'once in 100,000 years likelihood of fatality', represented by the 1×10^{-5} risk contour (yellow), tolerable for active open spaces is restricted to the immediate area around the treatment facility and land at Nerita Gardens used by the refinery for waste management and equipment laydown. This contour does not impact on any other land other than the industrial zoned land owned by Viva Energy.
- The 'once in 200,000 years likelihood of fatality', represented by the 5×10^{-6} risk contour (blue), considered tolerable for commercial developments is restricted to the immediate area around the treatment facility and land at Nerita Gardens used by the refinery for waste management and equipment laydown. This contour does cross the currently fenced boundary at Road 16 between the tank farm and the Nerita Gardens laydown area but does not impact on any other land other than the industrial zoned land owned by Viva Energy.
- The ''once in 1,000,000 years likelihood of fatality', represented by the 1×10^{-6} risk contour (aqua), considered tolerable for residential uses is restricted to the area around the treatment facility and land at Nerita Gardens used for waste management and equipment laydown. This contour does however extend further south into the refinery crossing the currently fenced boundary at Road 16 between the tank farm and the Nerita Gardens laydown area. The contour reaches to (but does not cross) School Road to the north, this is the location where the public could have the closest access to the treatment facility. With the exception of land used for School Road the risk contour does not impact on any other land other than the industrial zoned land owned by Viva Energy. The contour does not reach any residential land use areas.
- The 'once in 2,000,000 years likelihood of fatality', represented by the 5×10^{-7} risk contour (green), considered tolerable for sensitive land uses extends outside the area around the treatment facility and land at Nerita Gardens used for waste management and equipment laydown. This contour extends to the following areas outside of Nerita Gardens:
  - crosses School Road to the north into the paddocks owned and managed by Viva Energy (note there is no public access to this area).
  - crosses Shell Parade to the east for approximately 150 metres running in a southerly direction from the roundabout with School Road and extends a maximum 25 metres beyond the eastern edge of Shell Parade onto a treed area on land owned by Geelong Grammar School. It does not extend into the open spaces used by the school for outdoor equestrian activities nor reach the school's Equestrian Centre building located in the northeast corner of the paddocks. The equestrian centre land use is consistent with the "active open areas" descriptor in HIPAP 4 and hence the LSIR criterion of 1×10^{-5}pa risk contour.
  - crosses the currently fenced boundary at Road 16 between the tank farm and Nerita Gardens. The contour does not reach beyond the northern tank farm area.
- All the HIPAP 4 criteria have been met for the treatment facility elements of the project.

9.5.3.2. Incremental risk to existing Geelong Refinery risk profile

Figure 9-2: Estimated combined LSIR contours for the Treatment Facility with existing Geelong Refinery HFA risk contours

The individual fatality risk contours for the treatment facility have been combined with the existing refinery risk profile and shown in Figure 9-2.

The following observations are made:

- The project will result in localised incremental risk in and around where it is located.
- The incremental risk to the west towards the train line beyond the project's 5×10^{-7} risk contour (green) will be negligible with the existing refinery risk profile being at least an order of magnitude higher than that of the Treatment Facility.
- The 'once in 2,000,000 years likelihood of fatality', represented by the 5×10^{-7} risk contour will extend by some distance to the north, likely in the range of 50 -150 metres, into the Viva Energy owned paddocks where there is negligible impact on the public.
- The 'once in 2,000,000 years likelihood of fatality', represented by the 5×10^{-7} risk contour extends by approximately 50 metres to the east. The contour extends into open space utilised by Geelong

Grammar School for outdoor equestrian activity however it does not extend to the school's Equestrian Centre building.

- In consideration of the cumulative risk, all the HIPAP 4 criteria continue to be met for the treatment facility elements of the project on the basis that the Geelong Grammar School land (currently zoned as Farming Zone) which is used for equestrian activities is considered as "sporting complexes and active open space" per HIPAP 4.

9.5.4. Fire prevention and mitigation

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

Minimisation of leak sources and inventory

The Treatment Facility includes the minimum process equipment necessary to provide reliable supply of natural gas meeting the specification required for Victorian Transmission System distribution and custody transfer measurement.

The largest gas inventory is the Geelong Gas Terminal Pipeline which can be remotely isolated at the head of the pier, and at the Lara City Gate station. With the short pipeline length, manual and remote isolation can be effected at the Treatment Facility. The consequence analysis has assumed that releases would be detected and isolated with a probability of failure on demand of 1% (typical for a SIL 2 rated system).

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

Active fire protection and suppression would be provided for liquid fires and gas fires at the Treatment Facility in compliance with relevant Australian Standards, including 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 pier and the safe evacuation of personnel. This demand scenario exceeds firewater demand requirements for the Treatment Facility.

The existing refinery firewater system will be extended as required· 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 requires review of the existing refinery fire pump capacity for 2×100% or change to 3×50% design basis. The system will remain as a jockeyed system where a small pump maintains pressure, and be designed for saltwater service, providing an indefinite supply of water.

Fire water must be able to be provided for six hours. Due to the large volume of water for fire-fighting sea water will continue to be used for firewater cooling as required by AS 3846.

Foam use 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.

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.

10. Emergency Response

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 (Vic)*, 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 Refinery Pier under the umbrella of the GeelongPort Emergency Management Plan.

The GeelongPort Emergency Management Plan identifies the requirement that the Facility Operators shall develop an emergency plan that is consistent with the GeelongPort 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 Ports Victoria, WSV, Victoria Police, the Country Fire Authority and Fire Rescue Victoria.
- Consultation on and coordination with GeelongPort and Quantem on the Refinery Pier emergency response.
- Consultation with Greater Geelong City 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 Ports Victoria.
- Consultation with relevant neighbouring facilities and the community.

The number of stakeholders present at Refinery Pier can change 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 Terminal Project.

10.1. ERP structure and content

The ERP will be developed specifically for use at the Gas Terminal Project, and be based on the design, equipment, operations and environment in which the import operation would be undertaken. Given the support from the Geelong Refinery emergency response resources, the structure and content will be aligned with the existing refinery practices to enable ease of implementation under emergency response conditions.

Both the Gas Safety (Safety Case) Regulations (Reg 34) and the Occupational Health and Safety Regulations (Regs 375-378 plus Schedule 16) require emergency response plans to be developed.

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

- what defines an emergency
- the hazards related to constructing and operating the FSRU and pier infrastructure

- 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; pier pipeline 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 Geelong; 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.

10.2. Construction phase emergency response

The emergency response during the construction phase will be based on the capabilities planned and implemented by the construction contractor. The Construction Emergency Response Plan will be aligned with the requirements of the GeelongPort Emergency Management Plan and existing Geelong Refinery emergency management plans.

As the Refinery Pier is an operating site for other organisations, the Construction Emergency Response Plan would be developed in consultation with:

- Viva Energy
- Ports Victoria
- GeelongPort
- Quantem
- Construction contractor
- Emergency Response Service Providers – as required

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 GeelongPort emergency management framework for the Port of Geelong. This framework is supported by the GeelongPort Emergency Management Plan.

All works on water or when a vessel is berthed at Refinery Pier will be subject to the directions of the Port of Geelong Harbour Master or delegate acting in the role of incident controller in accordance with the GeelongPort Emergency Management Plan.

During the construction phase there will be up to three ERPs at Refinery Pier. These plans sit within the Victorian Emergency Management framework for support and offsite emergency impact management.

10.3. 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 the new Refinery Pier No.5.

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

The operations phase emergency response stakeholders include:

- Viva Energy
- Ports Victoria
- GeelongPort
- Quantem
- Operator of the FSRU
- VTS various LNG carriers: the operators of the LNG carriers transporting LNG to Refinery Pier and involved in the STS transfer of LNG to the FSRU.
- Emergency Response Service Providers (Ambulance, Fire Rescue Victoria, Country Fire Authority)

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 Ports Victoria/GeelongPort Emergency Management Framework as required. 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 GeelongPort EMP. The Incident Controller for both plans is fulfilled by the Harbour Master or delegate. The emergency response capability for the LNG carriers will be integrated in the early stages of an LNG carrier arriving at Refinery Pier. This process will occur each time an LNG carrier arrives at Refinery Pier and prior to STS.

The impact on the FSRU at berth arising from an incident during unloading operations at the other Refinery Pier berths will be considered in the ERP.

Emergency support to an LNG carrier in the Port of Geelong prior to mooring at Refinery Pier is managed by the Harbour Master and GeelongPort Emergency Management Plan.

The emergency response plan(s) will cover all the major incidents identified as part of the FSRU safety and the treatment facility gas safety case, plus any other foreseeable scenarios requiring emergency response including, but not limited to) environmental incidents. In addition, the Geelong Refinery emergency response plan will be updated to reflect the gas pipeline running through the refinery process area. The emergency response plan(s) would cover:

- Unignited LNG spill
- LNG pool fire (including spill to water)
- Unignited gas release
- Gas jet fire (FSRU / pipeline / treatment facility)
- Liquid nitrogen release (potential asphyxiation)
- Unignited toxic odorant release / spill
- Toxic odorant pool fire
- Medical emergency
- Chemical / oil spill.

11. Mitigation measures

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

Viva Energy design contractors and other specialists have been consulted to ensure that the recommended mitigation measures would be achievable and compatible with those proposed by other specialists.

These recommended mitigation measures shown in Table 11-1 have been refined as a result of these discussions and should be incorporated into the EMF, which will be implemented through the Project approvals to effectively manage the environmental performance of the Project.

Additional mitigation measures recommended to eliminate, minimise and mitigate potential safety, hazard, and risk consequences are listed in Table 11-2.

Table 11-1 Recommended risk reduction measures

ID	Mitigation measure	Project Area	Project Phase
1	**FSRU safety standards** The Floating Storage and Regasification Unit (FSRU) 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 (or equivalent classification agency). 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.	FSRU	Design Construction Operation
2	**Pipeline standards** The pipeline 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.	Geelong Gas Terminal Pipeline	Design Construction Operation
3	**Facility standards** The Refinery Pier No. 5 extension, the equipment installed on Refinery Pier No. 5, and the Treatment Facility will be designed, operated and maintained in accordance with relevant Australian and international standards	Refinery Pier No. 5 Pier Infrastructure Treatment Facility	Design Construction Operation
4	**Automated systems – safety and process control** The operation of the FSRU, pipeline and Treatment Facility will be monitored using appropriately SIL rated process automation and shutdown systems. Abnormal conditions will alarm 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 with	FSRU Geelong Gas Terminal Pipeline Treatment Facility	Design Construction Operation

ID	Mitigation measure	Project Area	Project Phase
	de-pressuring of inventory through vent stacks to be initiated remotely. The control, monitoring and shutdown systems will be fail-safe and be designed to best industry practices with redundancy.		
5	**Dangerous Goods – storage and handling** Dangerous goods, as defined by the Australian Dangerous Goods Code, and flammable and combustible liquids will be stored and handled in accordance regulatory requirements (refer Table 3-1), 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.	FSRU Geelong Gas Terminal Pipeline Treatment Facility	Design Construction Operation
6	**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.	FSRU Geelong Gas Terminal Pipeline Treatment Facility	Construction Operation
7	**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.	FSRU Geelong Gas Terminal Pipeline Treatment Facility	Construction Operation
8	**Fire and gas protection** 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 (or other equivalent classification society) class notation. Active fire protection and suppression will be provided for liquid fires and gas fires on Refinery Pier in compliance with Australian Standards. The design fire case for 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	FSRU Geelong Gas Terminal Pipeline Treatment Facility	Design Construction Operation

ID	Mitigation measure	Project Area	Project Phase
	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 existing refinery system design will provide part of the required firewater with the remaining firewater to be provided by fire fighting tugs located with the Port of Geelong. Fire and gas detection will be provided in key locations piping on Refinery Pier and within the Gas Treatment Facility.		
9	**Separation distance** The location of the FSRU provides sufficient separation distance from sensitive receptors (North Shore, Geelong Grammar School) to be outside impact zones for significant breach events. The refinery process area is located over 600m from the FSRU to minimise the potential for escalation of an incident from one facility to the other.	FSRU Geelong Gas Terminal Pipeline Treatment Facility	Design Operation
10	**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.	FSRU Geelong Gas Terminal Pipeline Treatment Facility	Construction

Table 11-2 Recommended risk reduction measures since concept and pre-FEED

ID	Recommended mitigation measure	Project Area	Project Phase
1	**Minimise dangerous goods inventory** Reduced site inventory of odorant as Gas Treatment Facility by removing 20m^3 storage tank and replace with 2×2.5m^3 transportable tanks.	Treatment Facility	Design
2	**Reduce leak frequency** Maximise welding in of valves on pipeline (replacing flanged connections) where appropriate from an overall reliability and maintenance perspective	Geelong Gas Terminal Pipeline Treatment Facility	Design
3	**Increased safety factors** Increased wall thickness with additional corrosion allowance for the above ground pipeline Increasing flange ratings to 900# (vs 600# required) Lowering the setpoint on the High Integrity Pressure Protection System (HIPPS) from the standards (allowing 107% of MAWP) to the MAWP	Geelong Gas Terminal Pipeline Treatment Facility	Design

ID	Recommended mitigation measure	Project Area	Project Phase
4	**Increase separation from sensitive receptors** Relocated Treatment Facility from selected base location option to optimised location approximately 190m to the west to minimise risk exposure to Geelong Grammar School.	Treatment Facility	Design

11.1. Performance monitoring

Ongoing performance monitoring of key risk controls is a critical operations activity as well as being a clear requirement under MHF Safety Case, Gas Safety Case, and Pipeline Licence regulatory obligations.

Each safety critical control will have established performance standards (e.g. a pressure relief valve should activate at its set pressure with a reliability >95%) with an established test frequency based on industry and site specific experience. Key performance indicators can track both the overall fleet of similar equipment as well as flagging poor performers requiring corrective action.

The FSRU will be operating under its own safety management system, and the FSRU Operator will be required to ensure effective ongoing management of the key safety critical equipment on board the FSRU. The MHF Licence Holder for the FSRU operation will require strong oversight of the FSRU operation and the performance of the safety critical controls.

Performance monitoring overseen by Viva Energy is anticipated to follow established practices (including regular periodic review of relevant performance indicators) by the Geelong Refinery to ensure a consistent approach providing responsible operations management with a well understood line of sight to the effectiveness of the safety critical controls. Specifically for the FSRU service provider, as the MHF Licence Holder, Viva Energy will be actively engaged as part of the operation in the performance monitoring of the safety critical control measures, as well as oversight of the service provider complying with the safety management system processes and procedures.

Typical Performance Indicators and Standards for Pressure Safety Valve

Performance Indicator	Performance standard
Relief Capacity	"X" kg / sec
In-situ "pop" pressure of relief valve	Standard is +/– 3% of set pressure as for a new valve supplied to AS 1271. If pop pressure exceeds +/– 3% from set pressure then overhaul as per AS 1271. If pop pressure exceeds 110% of set pressure then reduce test interval
Test interval	Five years (max. interval as per AS 3788).
Reliability	98%

Taken from WorkSafe Victoria "Control measures for a major hazard facility", Example 9

Typical Performance Indicators and Standards for the effectiveness of the safety management processes for Pressure Safety Valves or Pressure Safety Valve (PSV)

Performance indicator	**Performance standard**
Percentage of relief valves tested within scheduled time	95%
% Reliability	98%
Number of PSV exceeding inspection interval by three months	“Y”: valves, or “Z”% of total PSVs

Taken from WorkSafe Victoria “Control measures for a major hazard facility”, Example 10

12. Conclusion

The safety, hazard and risk 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 1997 (Vic) 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 Occupational Health and Safety Regulations require the operator of the FSRU to identify, assess and mitigate all risks having the potential to cause a major incident. The treatment of the risks identified, the assessment of risks so far as is reasonably practicable, safety management system and emergency plans to WSV for approval prior to operations 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 (or equivalent Classification Agency) classification for the FSRU
- the design basis for the pipeline including the design parameters and the functional description for the Treatment Facility facilities
- the emergency shutdown system design basis; operation philosophy and function description for the pipeline and facilities
- the Process Engineering Flow Scheme (also known as Piping and Instrument Diagrams);
- SIL verification studies and Operating Philosophy pipeline and facilities
- Location Specific Individual Risk (IRPA) 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. referenced in the 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 following observations from the QRA are highlighted given their significance in light of the project's development in an area with existing Major Hazard Facilities and their associated risk profile:

- The Location Specific Individual Risk (LSRI) 5×10^{-7}pa contours for the both the FSRU and the Treatment Facility at Nerita Gardens, are within the existing 5×10^{-7}pa contour for the Geelong Refinery.

The FSRU poses negligible incremental risk within the port waters

With the location of the Treatment Facility approximately 200 metres to the west of the refinery site boundary within the Nerita Gardens area, the 5×10^{-7}pa contour for the Treatment Facility extends just beyond Shell Parade, and results in a minor increase of the existing refinery 5×10^{-7}pa contour when considered cumulatively. It does not reach the Geelong Grammar School Equestrian Centre building.

The exposure to North Shore residents from the FSRU operation and from credible scenarios during LNG carrier transit is below the 5×10^{-7}pa criterion for sensitive land use, and the QRA results indicate the risk for North Shore residents is below 1×10^{-7}pa.

Both the Treatment Facility specific and cumulative 5×10^{-7}pa contour do not extend beyond the WSV proposed 300 metre distance for the land planning use Inner Safety Area, measured from the Geelong Refinery facility boundary.

- The worst-case pipeline rupture scenario results in an impact zone radius of 640 metres (above ground section) and 560 metres (below ground section) distance to the 4.7kW/m^2 radiation exposure (per AS 2885.1 requirement), which is consistent with gas distribution pipelines with a maximum operating pressure throughout Victoria given the maximum pressure for all is 102.1 barg. This short 7km section of pipeline benefits from having a low isolatable inventory of 1,331m^3 limiting the duration of any release event and being run through predominantly non-residential areas.

Wall thickness has been increased ~25% of minimum requirements for residential T1 land use areas to 12.7mm, and further increased to 20.62mm thickness for the above ground section from the pierhead though the refinery to the treatment facility.

- Toxic exposure from the odorant (Spotleak 1005) would not extend beyond the Treatment Facility boundary for any loss of containment event.

Any unplanned release of odorant would likely cause a widespread and distinctive odour beyond the Treatment Facility boundary which may result in short term reversible impacts of nausea, irritation of eyes, respiratory tract and mucus membranes.

- The potential for asphyxiation from a liquid nitrogen loss of containment event is limited to within the Treatment Facility boundary.
- The separation distance of >400 metres between the FSRU and land-based industrial facilities (including the refinery) ensures that no radiation, or potential jet fire from the FSRU will impact these facilities. The potential for a flash fire from the FSRU impacting these facilities is $<5 \times 10^{-5}$pa which is consistent with guidelines for industrial land use.

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 Terminal Project operations are expected to be limited and not disproportionate to those already experienced by the current operations of product movements across Refinery Pier, as well as the operation of the Geelong Refinery.

The results from the initial QRA, in conjunction with Fire and Explosion Analysis, and dispersion modelling for nitrogen and odorant confirm that the level of risk at Refinery Pier, Nerita Gardens, along the pipeline route and nearby public land use resulting from a major incident is within the suggested acceptable thresholds as defined by HIPAP 4. As the project transitions into detailed design, construction, and operational phases further safety and risk analysis will be completed to ensure that these risks continue to be reduced so far as is reasonably practicable.

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Appendix A: Potential Effects of LNG Hazards

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

A.1. Release of LNG

At atmospheric pressure, LNG will boil off at approximately -162°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.

A.2. Pressurised LNG Release

A.2.1. 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.

A.2.2. 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.

A.2.3. 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 (or equivalent Classification Agency) 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.

A.2.4. 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.

A.2.5. 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. This is a very different situation to marine LNG tanks.

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 a BLEVE cannot occur.

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.

A.2.6. 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 unlikely to damage a ship's large structural elements (2004 Sandia Report).

A.2.7. 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.

A.3. Non-Pressurised LNG Releases

A.3.1. 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 -162°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.

Appendix B: Stakeholder Safety, Hazard & Risk Issues

This appendix captures all the safety, hazard and risk related issues raised during the stakeholder engagement process, and how these have been addressed throughout project development.

Table B-1 Viva Energy responses to stakeholder and community feedback

Issue raised	Response to issue
1. General concern around safety of gas terminal operation and transportation of LNG	• Extensive consultation with WorkSafe Victoria, Energy Safe Victoria, DELWP Pipelines Regulation and Ports Victoria • Suite of safety studies conducted including HAZID, HAZOP, pipeline Safety Management Study and Quantitative Risk Assessment (QRA) • Pipeline design specification exceeds the requirements of Australian standards • Development of varied collateral to assist in responding to the questions that have been raised regarding the safe operations of the gas terminal and LNG transportation. This has included: - LNG safety fact sheet - Safe and secure operations fact sheet - information in Refinery Update newsletters, and - E-news updates This information was shared on communications channels including Facebook, advertorial in local newspapers and the project website • In response to the frequency of the issue being raised a community information session was held in July 2021 to provide safety study results to date – recognising that further work was underway. The session focused on the LNG carriers and FSRU and provided an opportunity to answer questions. This meeting was recorded and made available online. Further follow up occurred after the session to respond to additional areas of concern • A second community information session focused on safety was held in October 2021 • Developed a Study Summary for the safety, hazard and risk assessments technical report
2. Impact on maritime and port operations safety with increased ship visits to Refinery Pier	• Berthing simulations and modelling of LNG carrier movements undertaken in conjunction with Ports Victoria and pilotage providers • Highlighting that LNG shipping movements will only be a small increase in total shipping visits to the Port of Geelong
3. Concern around increased security and terrorism risk	• An independent vulnerability and security risk assessment was completed by an industry risk management specialist with consideration of the presence of the FSRU and LNG carrier • Security content added to safe and secure operations fact sheet • A security expert was present at the community information sessions in July 2021 and October 2021 and answered direct questions about this topic

Issue raised	Response to issue
4. Concerns around a major incident given proximity to North Shore residents of transiting LNG carriers	• Engagement with Ports Victoria has been occurring on an ongoing basis since project inception • Independent vulnerability and security risk assessment was completed for the project • QRA undertaken for LNG carriers in transit through the shipping channel and past North Shore • Results of risk assessments presented at the July 2021 community information session • Safety was also the focus of the October 2021 community information session • Direct responses to concerns raised and videos posted on Facebook and through Geelong Advertiser 'Letters to the Editor' • Offers to meet and discuss safety with the North Shore Residents Group • In line with Viva Energy processes and regulatory standards, prior to visiting the gas terminal all LNG carriers would be assessed and vetted • Strong safety track record of LNG shipping industry • Ships in transit required to follow Ports Victoria direction
5. Confusion about jurisdictional coverage of exclusion zones and 'buffer zones' around LNG carriers	• Engagement with Ports Victoria has been occurring on an ongoing basis since project inception • Maps developed of current and future maritime exclusion zones • Exclusion zones available on project website clarifying use around LNG carriers in transit • Information provided at July 2021 community information session
6. Understanding the outcomes of risk assessments (QRA analysis) and relevance to residents	• QRA was used in an iterative process to inform additional design measures to minimise risk based on results and stakeholder feedback • Cumulative QRA risk profiles developed for project and the refinery • Met with stakeholders to discuss the safety, hazard and risk assessment tools, methodology and outputs • Shared current status of risk assessments for FSRU; treatment facility and cumulative impact assessment • Safety information was posted on project website • Community information sessions held in July 2021 and October 2021 focused on the issue of safety. Meeting materials made available on-line

Issue raised	Response to issue
7. Potential for major incident / explosion on the FSRU	• The FSRU would be classified as a Major Hazard Facility (MHF) and would require an accepted MHF safety case and licence issued by WorkSafe Victoria. Multiple studies and assessments have been completed to ensure safety in design and operation • Partnered with reputable FSRU provider Hoegh with strong track record around the world • Engaged FSRU specialist consultants to provide input into design and operational requirements including exclusion zones. • Community information session held July 2021 with content showing QRA for FSRU. Meeting materials made available on-line. This was also discussed at the October 2021 community information session • Facilitated a meeting with Worksafe and Geelong Grammar School to ensure stringent regulatory requirements for a MHF were well understood.
8. Concern about trucks running off the road and damaging the aboveground pipeline resulting in a major incident. Particular areas of concern are at the Wharf Road / Shell Parade bend (near the Refinery Pier Gatehouse), and at the culvert where the aboveground pipeline crosses underneath Shell Parade from the foreshore.	• Measures proposed following pipeline SMS workshop to address this 'threat' to pipeline integrity include installation of additional "armco" roadside barriers at these two locations. The exact positioning of the additional roadside barriers is to be further investigated as detailed design proceeds

Appendix C: Significant LNG-Related Incidents

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1944 - October	East Ohio Gas LNG Tank	Cleveland, Ohio, USA	N/A	128 deaths	N/A	N/A	LNG peakshaving facility. Tank failure and no earthen berm. Vapour cloud formed and filled the surrounding streets and storm sewer system. Natural gas in the vaporizing LNG pool ignited. Stainless steel alloys were scarce because of World War II; tank was made of a low-nickel content (3.5%) alloy steel.
1964 and 1965	Methane Progress	Arzew, Algeria	Loading (1964); Shortly after leaving port (1965)	None	None		In 1964, a lightning strike to the forward vent riser of the Methane Progress ignited vapour which was being routinely vented through the venting system at the time. A similar occurrence also occurred in early 1965. Both times, the flame was quickly extinguished by purging with nitrogen through a connection in the riser.
1965	LNG import facility	Canvey Island, UK	Transfer Operation	1 Injury (serious burn)		Yes	During LNG transfer from tank during maintenance, an error resulted in the small release of LNG. The release became ignited, causing one person to be seriously burned.
1965	Methane Princess		Disconnecting after discharge	None	Yes	Yes	Valve leakage. Deck fractures.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1965 - May	Jules Verne	Arzew, Algeria	Loading	None	Yes	Yes	Overflowing of a cargo tank. Resulted in a tank cover and adjacent deck fracture.
1966	Methane Progress		N/A	N/A	N/A	Yes	Cargo leakage reported.
1968	Aristotle	Mexico	N/A	N/A	Yes	No	Ran aground and the bottom was damaged, possibly during LPG service.
1968	LNG peak shaving facility	Portland, Oregon, US	N/A	4 deaths	N/A	No	Unfinished LNG storage tank. Natural gas from a pipeline being pressure tested inadvertently entered the tank as a result of improper isolation, and then ignited causing an explosion. Neither the LNG tank nor the process facility had been commissioned at the time the accident occurred; thus, the tank had never contained any LNG.
1969	Polar Alaska		N/A	N/A	No	No	Sloshing of the LNG heel in No. 1 tank caused part of the supports for the cargo pump electric cable tray to break loose, resulting in several perforations of the primary barrier. LNG leaked into interbarrier space.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1969		Portland, Oregon, USA	Under construction	N/A	Yes	Yes	An explosion occurred in an LNG tank under construction. No LNG had ever been introduced into the tank. The cause of the accident was the accidental removal of blinds from natural gas pipelines which were connected to the tank. This led to the flow of natural gas into the tank while it was being constructed.
1970	Arctic Tokyo		N/A	No	Yes	No	Sloshing of the LNG heel in No. 1 tank during bad weather caused local deformation of the primary barrier and supporting insulating boxes. LNG leaked into the interbarrier space at one location.
1971	Descartes		N/A	N/A	No	No	A minor fault in the connection between the primary barrier and tank dome allowed gas into the interbarrier space.
1971	LNG ship Esso Brega, La Spezia LNG Import Terminal	La Spezia, Italy	Unloading LNG into the storage tank	N/A	Yes	Yes	First documented LNG “rollover” incident, where two differing temperatures and densities of LNG mix. Tank developed a sudden increase in pressure, causing LNG vapour to discharge safely from the tank safety valves and vents. Tank roof slightly damaged. No ignition.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1972	Gaz Métropolitain LNG peakshaving facility	Montreal East, Quebec, Canada	N/A	N/A	N/A	No Although an LNG facility, LNG was not involved	The accident occurred in the control room due to a backflow of natural gas from the compressor to the nitrogen line. Nitrogen was supplied to the recycle compressor as a seal gas during defrosting operations. The valves on the nitrogen line were not closed after completing the operation. This resulted in the overpressurisation of the nitrogen header, and the instruments vented their contents into the control room where operators were allowed to smoke. The explosion occurred while an operator was trying to light a cigarette.
1972 - January	Montreal East	Montreal, Canada	Defrosting operations	N/A	N/A	N/A	During defrosting, a back flow of natural gas from the compressor to the nitrogen valve when the valve remained unclosed caused over-pressurization of the compressor. This led to a leak and subsequent ignition.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1973 - February 10 (1:00pm)	Texas Eastern Transmission, LNG Tank	Staten Island, NY, USA	N/A	40 deaths	Yes	No	Industrial incident unrelated to the presence of LNG (construction incident). During the repairs, vapours associated with the cleaning process apparently ignited the mylar liner. Fire caused temperature in the tank to rise, generating enough pressure to dislodge a 6-inch thick concrete roof, which then fell on the workers in the tank. While repairing the interior of an empty storage tank, a fire started. The increase in pressure inside the tank occurred so quickly that the concrete dome collapsed down inside the tank. 40 workers inside the tank were killed.
1973		Canvey Island, UK	N/A	None	Yes	Yes	Glass breakage. Small amount of LNG spilled upon a puddle of rainwater, and the resulting flameless vapour explosion, called a rapid phase transition (RPT), caused the loud "booms." No injuries resulted.
1974	Euclildes		In port	No	Yes	No	Ran aground and damaged bottom and propeller. In another incident, minor damage occurred due to contact with another vessel.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1974	Methane Princess			No	Yes	No	While moored, rammed by freighter Tower Princess resulting in 3-foot gash in hull.
1974	Methane Progress	Arzew, Algeria	In port	None	Yes	No	Touched bottom at Arzew.
1974 - July	5,000 m3 Barge Massachusetts	Massachusetts	Loading	No	Yes	Yes	Valve leakage after power failure. USCG found that a pressure surge caused the leakage of about 40 gallons of LNG. Deck fractures. 40 gallons of LNG leaked during loading, as a result of a power failure and the resulting automatic closure of the safety valves. The leak resulted in several fractures to the deck plates.
1975	Philadelphia Gas Works		N/A	None	Yes	N/A	Not caused by LNG. An iso-pentane intermediate heat transfer fluid leak caught fire and burned the entire vaporizer area.
1977	LNG export facility at Arzew	Arzew, Algeria	N/A	1 death (frozen)	N/A	Yes	Aluminium valve failure on contact with cryogenic temperatures. Wrong aluminium alloy on replacement valve. LNG released, but no vapour ignition (LNG liquefaction facility). *Note: the current practice is to provide valves in LNG service that are made with stainless steel.*

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1977 - September	LNG Aquarius	Boatang, Indonesia	Loading	None	None	Yes	Tank overfilled. During filling, LNG overflowed through the vent mast. Possible cause was difficulties in the liquid level gauge system.
1978	Khannur	Strait of Singapore	N/A	No	Yes	No	Collision with cargo ship Hong Hwa.
1978	LNG export facility	Das Island, United Arab Emirates	N/A	No	No	Yes	A bottom pipe connection of an LNG tank failed resulting in a spill inside the tank containment. The liquid flow was stopped by closing the internal valve, and a large vapour cloud resulted and dissipated without ignition.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1979	Columbia Gas LNG import terminal	Cove Point, Maryland, US	N/A	1 death 1 injury (serious)	Yes	Yes	An explosion occurred within an electrical substation. LNG leaked through LNG pump electrical penetration seal, vaporized, passed through 200 feet of underground electrical conduit, and entered the substation. Since natural gas was never expected in this building, there were no gas detectors installed in the building. The normal arcing contacts of a circuit breaker ignited the natural gas-air mixture, resulting in an explosion. Building codes pertaining to the equipment and systems downstream of the pump seal were subsequently changed.
1979	Columbia Gas LNG Terminal	Cove Point, Maryland	N/A	1 death 1 injury (serious)	Yes	Yes	LNG leaked through the LNG pump electrical penetration seal and entered the substation. A circuit breaker ignited the natural gas-air mixture, resulting in an explosion.
1979	El Paso Paul Kayser Ship	Strait of Gibraltar	At sea	No	Yes	No	Stranded. Severe damage to bottom, ballast tanks, motors water damaged, bottom of containment system set up.
1979	El Paso Paul Kayser Ship		At sea	No	Yes	No	Stranded. Severe damage to bottom, ballast tanks, motor was water damaged, bottom of containment system set up.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1979	Mostefa Ben-Boulaid Ship	Cove Point, Maryland, US	Unloading	No	Yes	Yes	Valve leakage. Deck fractures.
1979	Pollenger Ship	Distrigas terminal, Everett, Massachusetts	Unloading	No	Yes	Yes	Valve leakage. Tank cover plate fractures.
1979 - April	Mostefa Ben-Boulaid Ship		Unloading	None	Yes	Yes	Valve leakage. Deck fractures.
1979 - April	Pollenger Ship		Unloading	None	Yes	Yes	Valve leakage. Tank cover plate fractures.
1980	LNG Libra		At sea	No	Yes	No	Shaft moved against rudder. Tail shaft fractured.
1980	LNG Libra		At sea	No	Yes	No	Shaft moved against rudder. Tail shaft fractured.
1980	LNG Taurus	Ran aground near Tobata, Japan	In port	No	Yes	No	Stranded. Ballast tanks all flooded and listing. Extensive bottom damage.
1980s - early	El Paso Consolidated		N/A	N/A	Yes	Yes	Minor release of LNG from a flange. Deck plating fractured due to low temperature embrittlement.
1980s - early	Larbi Ben M'Hidi		N/A	N/A	No	No	Vapour released during transfer arm disconnection.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1983	LNG export facility	Bontang, Indonesia	N/A	3 workers	Yes	No	Liquefaction column (large vertical, spiral wound heat exchanger) ruptured due to overpressurisation caused by a blind flange left in a flare line during startup. Debris and coil sections were projected.
1983	Norman Lady	Sodegaura, Japan	Prior to unloading	Not reported	Not reported	Yes	During cooldown of the cargo transfer arms, the ship moved astern under its own power. All cargo transfer arms sheared and LNG spilled. No ignition.
1984	Melrose		At sea	No	Yes	No	Fire in engine room. No structural damage sustained – limited to engine room.
1985	Annabella		N/A	N/A	N/A	Yes	Reported as “pressurized cargo tank.” Presumably, LNG released from the tank or piping.
1985	Gradinia		In port	No	Not Reported	No	Steering gear failure. No details of damage reported.
1985	Isabella		Unloading	No	Yes	Yes	Cargo valve failure. Cargo overflow. Deck fractures.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1985	LNG peakshaving facility	Pinson, Alabama US	Unloading	6 injuries	Yes	Yes	The welds on a "patch plate" on an aluminium vessel failed as the vessel was receiving LNG which was being drained from the liquefaction cold box. The plate was propelled into a building that contained the control room, boiler room, and offices. Some of the windows were blown inward and natural gas escaping from the vessel entered the building and ignited, injuring six employees.
1985	Ramdane Abane		N/A	N/A	Yes	No	Collision while loaded. Port bow affected.
1989	LNG peakshaving facility	Thurley, United Kingdom	Unloading	2 injuries (burns)	Yes	Yes	While cooling down vaporizers in preparation for sending out natural gas, low-point drain valves were opened. One of these valves was not closed when pumps were started and LNG entered the vaporizers. LNG was released into the atmosphere and the resulting vapour cloud ignited, causing a flash fire that burned two operators.
1989	Tellier		Loading	No	Yes	Yes	Broke moorings. Hull and deck fractures.
1990	Bachir Chihani		At sea	No	Yes	No	Sustained structural cracks allegedly caused by stressing and fatigue in inner hull.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
1992	LNG peakshaving facility	Baltimore, MD, US	N/A	No	Yes	Yes	A relief valve on LNG piping failed to open and released LNG into the LNG tank containment for over 10 hours, resulting in loss of over 25,000 gallons into the LNG tank containment. The LNG also caused embrittlement fractures on the outer shell of the LNG tank. The tank was taken out of service and repaired.
1993	Indonesian Liquefaction facility	Indonesia	N/A	No	N/A	N/A	LNG leak from open run-down line during a pipe modification project. LNG entered an underground concrete storm sewer system and underwent a rapid vapour expansion that overpressured and ruptured the sewer pipes. Storm sewer system substantially damaged.
1997	LNG Capricorn	Japan	N/A	N/A	Yes	No	Struck a mooring dolphin and sustained damage to hull but no ingress of water.
1997	Northwest Swift	400 km from Japan	N/A	N/A	Yes	No	Collided with a fishing vessel and sustained damage to hull, but no ingress of water.
1999	Methane Polar		N/A	No	Yes	No	Engine failure during approach to Atlantic LNG jetty. Struck and damaged Petrotrin pier.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
2000	LNG import terminal	Savannah, Georgia, US	N/A	No	Yes	No	In September 2000, a 580-foot ship, the Sun Sapphire, lost control in the Savannah River and crashed into the LNG unloading pier at Elba Island. The Elba Island facility was undergoing reactivation but had no LNG in the plant. The Sun Sapphire suffered a 40-foot gash in her hull. The point of impact at the terminal was the LNG unloading platform. The LNG facility experienced significant damage, including the need to replace five 16" unloading arms.
2002	Norman Lady	East of the Strait of Gibraltar	At sea	No	Yes	No	Collision with a U.S. Navy nuclear-powered attack submarine, the U.S.S Oklahoma City. In ballast condition. Ship suffered a leakage of seawater into the double bottom dry tank area.

2004 - January 19	Skikda I	Skikda, Algeria	N/A	27 deaths 72 injuries (the casualities are mainly due to the blast, few casualties due to fire)	Yes	No	A leak in the hydrocarbon refrigerant system formed a vapour cloud that was drawn into the inlet of a steam boiler. The increased fuel to the boiler caused rapidly rising pressure within a steam drum. The rapidly rising pressure exceeded the capacity of the boiler's safety valve and the steam drum ruptured. The boiler rupture was close enough to the gas leak to ignite the vapor cloud and produce an explosion due the confined nature of the gas leak and an ensuing fireball. The fire took eight hours to extinguish. The explosions and fire destroyed a portion to the LNG plant and caused 27 deaths, and injury to 72 more. On January 19, 2004: No wind, semiconfined area (cold boxes, boiler, control room on 3 sides). The fire completely destroyed the train 40, 30, and 20, although it did not damage the loading facilities or three large LNG storage tanks also located at the terminal. Explosion due to a confined gas leak and ensuing fireball. FERC and DOE joint report indicated that there were local ignition sources, a lack of 'typical' automatic equipment shutdown devices, and a lack of hazard detection devices.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
2004		Trinidad, & Tobago	N/A	No	Yes	N/A	Workers were evacuated after a gas turbine at Atlantic LNG’s Train 3 facility exploded.
2006	Train 2 Facility	Port Fortin, Trinidad, Caracas	N/A	1 injury	Yes	No	Atlantic LNG reported that an accident occurred at its Train 2 facility at Point Fortin, Trinidad when a temporary eight inch isolation plug was blown by built-up pressure. The Train 2 facility had been shut down due to the detection of a gas release from a two-inch pipeline. The release of natural gas was brought under control, and personnel returned. While the company was carrying out repairs the plug blew injuring one worker. It had been filled with inert gas to facilitate repairs.
2009	South Hook LNG Terminal	UK	N/A	No	No	Yes	A maximum of ten litres of LNG was spilled and “immediately vaporized”, because of the unintended activation of the emergency shutdown system, which caused powered emergency release couplings to separate, discharging LNG.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
2010	Montoir de Bretagne terminal	France	Unloading	No	Yes	No	The incident occurred when liquid passed into the gas take-off line during discharge operations. The damage sustained extended to part of the ship's manifold and its feed lines.
2010	Withnell Bay facility	Australia	Loading	No	Yes	Yes	The ship suffered cryogenic burns when 2,000 to 4,000 litres of LNG were spilt
2011	Pyeongtaek LNG terminal	South Korea	Unloading	No	Yes	Yes	The ship disconnected from the berth after what was described as a very small leak of LNG was reported around the top of one emergency release coupler shortly after a scheduled overhaul of the unloading arms had been completed. Seals and ball valves were replaced on the unloading arms and discharge recommenced using the remaining two arms.
2011	Yung An LNG Terminal	Taiwan	Unloading	No	Yes	Yes	The vessel's master decided to suspend the discharge and move the ship off the berth but the problems were eventually rectified and the vessel returned to complete the discharge of its cargo.

Date	Ship / Facility Name	Location	Ship Status	Injuries / Fatalities	Ship / Property Damage	LNG Release	Incident Summary
2015	Al Oraiq	Off Zeebrugge, Belgium	At sea	1 injury	Yes		Al Oraiq involved in a collision with the Dutch freighter, Flinterstar. Flinterstar sank with all survivors rescued and one injury. The Al Oraiq suffered a slight gash and there was some water ingress, however, the vessel was able to return to port with the assistance of a tug.
2021-July - 30	Esperanza	Punta Indio Canal, River Plate, Argentina	River transit	No	No structural damage	No	The ship ran aground enroute to Escobar in the shallow waters of the River Plate and needed to be towed out of its predicament so that navigation could resume. The ship had a machine problem and to that was added the river is at a very low level.